Preventing Illness and Injury in the Workplace

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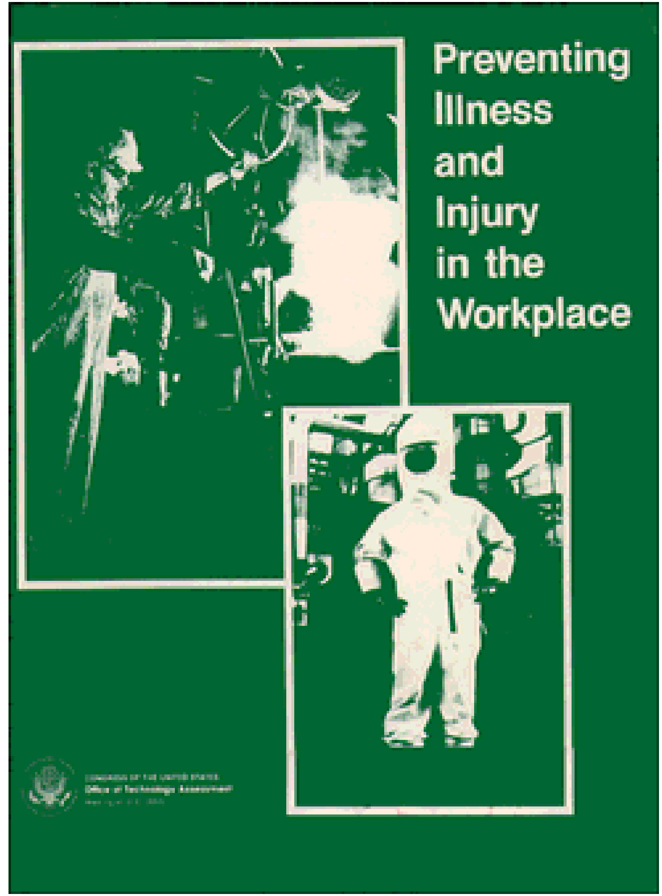

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Foreword

Congressional interest in work-related disease and injury led to the passage of the Occupational Safety and Health Act in 1970. The Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health were created to administer that Act, which stated an ambitious goal: "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions."

This report responds to a request from the Chairman of the House Committee on Energy and Commerce and a supporting letter from the Chairman of the Senate Committee on Labor and Human Resources. In this report, OTA examines three main topics: identification of occupational hazards, including the available data on injuries and illnesses; development of control technologies for reducing or eliminating workplace hazards; and the incentives and imperatives that influence decisions to control hazards.

Workers, employers, health and safety professionals, and government officials have all contributed to progress in this field. But improvements can still be made. More concerted effort and better use of existing methods would enhance hazard identification. Further research could improve health and safety control technologies and contribute to their incorporation in U.S. workplaces. Employers' decisions to control hazards might be fostered by changing the incentives and imperatives that affect those decisions.

In preparing this report, OTA staff drew upon the expertise of members of the assessment advisory panel and contractors, as well as other experts in the field of occupational health and safety. Contractors' reports are available from the National Technical Information Service. In some cases, contractors' opinions and viewpoints differ from those in this report. Drafts of the final report were reviewed by the advisory panel, chaired by Dr. Morton Corn; executive branch agencies, congressional staff, and other knowledgeable individuals and groups. We are grateful for their assistance. Key OTA staff involved in this assessment were Michael Gough, Karl Kronebusch, Hellen Gelband, Gwenn Sewell, and Beth Bergman. Denny Dobbin worked on this report while on detail from the National Institute for Occupational Safety and Health.

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Summary and Options

Occupational hazards are not spread evenly: Some workplaces, such as banks and offices, have few hazards; manufacturing is more dangerous; and mining and construction are comparatively the most hazardous, Certain hazards—some chemicals and forms of radiation—are concentrated in particular places of work; others—powerful machines and fast-moving machinery—are found predominantly in manufacturing and construction. Each uncontrolled hazard is an opportunity for preventing illness or injury.

The exact numbers of workplace-related deaths and injuries are disputed, but OTA estimates that there are about 6,000 deaths annually—about 25 per working day—due to injuries. Depending on how injuries are counted, between 2.5 million and 11.3 million nonfatal occupational injuries occur each year. Each working day there are about 10,000 injuries that result in lost work time and about 45,000 that result in restricted activity or require medical attention. There is so little agreement about the number of workplace-related illnesses that OTA does not take a position on the controversy about the "correct" number. Most deaths and injuries occur one at a time or in small numbers in the Nation's more than 4..5 million workplaces.

OTA finds that controls for health and safety are often developed for specific workplaces and not disseminated to others. This results in duplication of effort as employers faced with the same or similar problems are unaware of successful controls and thus do their own research and development. As well as being economically inefficient, the unshared knowledge about controls may contribute to injuries and deaths.

Occupational hazards accompanied the industrial development of the Nation. In the 19th century, for instance, advances in manufacturing and transportation exposed workers to new hazards, including boilers, train couplings, and powered saws, Scaldings, burns, missing fingers, hands, and arms, and other injuries were the unplanned consequences of work.

Because the relationship between these hazards and injuries is usually immediate and direct, recognition of the hazards is relatively straightforward. The connection between occupational hazards and illness is more difficult to pin down. Although a number of skin and respiratory diseases and some kinds of poisoning caused by metals are definitely associated with work, deciding whether other illnesses stem from workplace exposures is difficult.

This century has seen some examination of the role of the workplace in injury, illness, and death. Motor vehicles used in work are involved in thousands of accidents, resulting in many injuries and deaths. Construction remains a relatively dangerous trade: Powerful earth-moving and erection machines, high scaffolding, and falling objects are hazards continually faced by construction workers. Painful and sometimes incapacitating repetitive-motion disorders are associated with assembly-line work. Chronic diseases, respiratory conditions, and cancers have been linked with exposures to hazards in a variety of workplaces.

The control of workplace health and safety hazards can be divided into three steps: hazard identification, development of controls, and the decision to control, The first two steps are largely technical and require specialists. The third step involves generalists, managers, and employers, and may actually occur before hazards are fully identified and controls are developed.

The control of illnesses and injuries is not the sole purview of any particular sector of society. Employers and employers' associations, workers and trade unions, universities, and the Federal and State governments have initiated research directed at identifying and controlling hazards, and all have participated in decisions to control dangers that have been identified. Federal involvement has increased over the years, and in 1970 Congress mandated a direct Federal role in all aspects of occupational safety and health, including the setting of mandatory nationwide standards for safe and healthful workplaces.

The Chairman of the House Committee on Energy and Commerce requested that the Office of Technology Assessment undertake a study of technologies to control occupational illnesses and injuries. Both his letter and a supporting letter from the Chairman of the Senate Committee on Labor and Human Resources, called for a broad-based study. In addition to requesting examination of the general subject of control technologies, the chairmen asked for evaluation of the available data and systems for collecting data about work-related deaths, injuries, and illnesses; analysis of incentives and imperatives that influence the decision to control hazards; and a discussion of the opportunities for bettering occupational health and safety as the country enters a period of reindustrialization. Because of the many roles given to Federal agencies by the Occupational Safety and Health (OSH) Act, the activities of the Federal Government are important to understanding developments and problems in designing, developing, and disseminating control technologies, in collecting and analyzing data concerning occupational health and safety, and in providing incentives and imperatives for the adoption of controls.

The report is organized in five parts:

- This chapter summarizes the findings of the report and presents the options for improving occupational health and safety that have been developed during this assessment.
- Chapters 2, 3, and 4 describe the data available on workplace deaths, injuries, and illnesses and discuss methods for identifying health and safety hazards.
- Chapters 5 through 10 consider various control technologies and current efforts to train and educate employers, managers, employees, and health and safety professionals.
- Chapters 11 through 16 discuss the factors that are involved in the decision to control hazards. They review the activities of Federal agencies, the role of economic analysis in decisionmaking, the influence of various incentives and imperatives on decisionmaking, and the opportunities for installing controls during a period of reindustrialization.
- Chapter 17 looks at opportunities for preventing occupational injury and illness in the future.

(The contractors' reports and OTA working papers prepared for this assessment are available through the National Technical Information Service of the U.S. Department of Commerce.)

FINDINGS

Occupationally Associated Deaths, Injuries, and Illnesses

Currently available data are sufficiently accurate and comprehensive to describe the approximate number of occupational injuries and deaths due to such injuries, although these data are still limited and, in particular, offer little guidance for prevention. Data about occupational illnesses are far less accurate and comprehensive.

Deaths

The National Safety Council (NSC, a private organization) and the U.S. Bureau of Labor Statistics (BLS) of the Department of Labor compile data about occupationally related deaths. The most reliable estimates are derived from the BLS Annual Survey, although the survey data do not include the Nation's entire work force. *OTAs adjustment of the BLS figures yields an estimate* of *about 6,000 deaths annually from occupational injuries, or about 25 deaths each working day.* Occupational fatalities usually occur as isolated events that kill only one or, at most, a few workers and attract little publicity.

Currently collected data can be used to identify the most hazardous industries and the types of accidents that most commonly result in death. The most dangerous industry is mining, which had 44 fatalities per 100,000 full-time workers in

1982. It was followed by the construction, agriculture, and transportation industries (29, 28, and 22 fatalities per 100,000 workers, respectively). Falling below the all-industry average of 7.4 per 100,000 are manufacturing, wholesale and retail trade, and the service industries, all of which had about 4 fatalities per 100,000 workers. The finance, insurance, and real estate industries had the lowest rate of about 2 fatalities per 100,000 workers.

BLS data show that about half of the fatal occupational injuries involve motor vehicles, off-the-road industrial vehicles, and falls. Complementing those findings, an examination of every on-the-job fatality in the State of Maryland during 1 year found that transportation vehicles, nonroad vehicles, and gunshots were the leading causes of fatal injuries. Truck drivers were the most frequent victims of transportation vehicle accidents; most gunshot deaths occurred during holdups.

Injuries

The OSH Act requires employers to keep records of: 1) injuries that caused 1 day or more's absence from work or "restricted activity" at work, and 2) injuries that required medical attention but caused less than a day of missed work. *BLS estimates that in 1983 there were 2.1 million "lost-workday" injuries and 2.6 million "medical treatment" injuries in the private sector, which covers about three-fourths of the work force. Injuries to Federal, State, and local government employees may add another 0.4 million lost workday injuries and 0.5 million medical treatment cases.* Adding those numbers, there were approximately 5.6 million occupationally related injuries. The National Center for Health Statistics (NCHS), which uses different definitions for injuries and prepares estimates for the entire work force, estimates a total of 11.3 million occupationally related injuries in 1981.

BLS and NCHS have separately estimated that workplace-related injuries lead to the loss of, respectively, 36.4 million and 60 million to 70 million days of work annually. Projections from NCHS data are that workers spend about 44 million days in bed because of disability and have over 200 million days of restricted activity. *The NSC has estimated that for 1980 the total costs of work injuries amounted to $30.2 billion.*

The leading types of disabling, nonfatal injuries are overexertions (largely injuries to the back), which occur in many industries. Injuries in manufacturing and construction often involve moving machinery and falls.

Illnesses

Three factors generally contribute to incomplete recording of occupational illnesses: 1) many occupational diseases are indistinguishable from nonoccupational illnesses, 2) the occupational causes of diseases are often not recognized by employers and employees, and 3) diseases with long latencies often occur after employment or exposure has ceased. Thus the BLS Annual Survey estimate of 106,000 such illnesses in 1983 consists mostly of diseases, such as acute dermatitis, that are easily diagnosed and readily connected with workplace exposures. Serious diseases—respiratory and necrologic disorders and cancers—are not generally captured in the BLS records of workplace-related illnesses.

Arguments about the number of occupationally related diseases may obscure the important fact that occupational illness is preventable. For instance, a decade-long debate about the number of occupational cancers has been resolved to most people's satisfaction, and it is generally accepted that occupational cancers represent something like 5 percent (20,000 annual deaths) or less of all cancer deaths. The more important considerations are that workers in some industries have borne and still bear a disproportionate amount of risk and that, once causes of occupational disease are identified, controls can be adopted to reduce risks.

Some Caveats on Available Data

Accurate data are necessary to know the magnitude of the workplace health and safety problem, to target prevention programs, and to assess the progress in controlling illnesses and injuries. Many factors other than control programs, however, can influence the number of illnesses and injuries. For instance, it has been known for some time that injury rates fall during periods of high unemployment because younger, less skilled workers are laid off first and there is more time for maintenance of plant and machinery. OTA finds that the slowdown in business activity between 1980 and 1983 was the most important factor in the decrease in injury rates during that period. Moreover, national injury rates are related to the level of business activity, going up as business expands, down as it contracts. The Occupational Safety and Health Administration (OSHA), on the other hand, points to these declines as a measure of the success of its new programs that emphasize a cooperative approach between the agency and employers.

Over the last decade the identification and control of health hazards, especially of substances suspected of causing cancer, has received much attention. *Yet the available data about workplace diseases, even if accurate, would not yet reveal any* effects from *a recent reduction in exposures to* carcinogens, Given the long time between exposure to cancer-causing substances and development of the disease, years or decades may pass before cancer rates are affected. An even greater problem in relying on figures in this area, however, is the inaccuracy of occupational illness data. In 1981, only 234 occupational cancers were reported to workers' compensation systems in 29 States, which contain about half the Nation's work force. That number can be compared to the 4,000 to 12,000 cancers that are estimated to occur from asbestos exposure alone.

Identification of Occupational Hazards

Health

Toxicology, occupational medicine, and epidemiology provide the means for identifying the chemical, physical, or biological causes of occupational illnesses. Identifying an association or possible association between an exposure and disease often ignites a dispute. Employers, who have investments to protect and are perhaps reluctant to accept the idea that employees have been harmed, will require more evidence than workers seeking an explanation for disease among them. It is clear from these controversies that the results of toxicologic texts often lead to further study rather than efforts to control a hazard; that physicians' reports of associations, depending on the disease and exposure, may or may not be accepted as convincing; and that epidemiologic evidence linking exposures and disease is most convincing.

The traditional role of toxicology has been to provide information about the mechanisms of disease causation. *Especially since the late 1960s, however, toxicology has been used to investigate chemicals in an attempt to predict their effects in humans.* The bulk of the effort has been directed toward identifying chemical carcinogens, but some attention is now being directed toward necrologic and reproductive health hazards.

Physicians, *both* those *who specialize in occupational medicine and those in private practice, have identified many health hazards.* As an example, reports of asbestos-associated lung cancer cases in the 1930s were an early clue about that occupational hazard. More recently, a physician noticed an excess of liver cancers in vinyl chloride workers. His observation led to a very successful effort to reduce exposures to that substance. Importantly, physicians speak to workers, and it is workers who are often the first to be aware of hazards.

Epidemiology, the systematic investigation of possible associations between exposures and diseases, has confirmed important suspicions about work-related illnesses. The now universally acknowledged case against asbestos, for example, rests on epidemiologic studies. *Positive epidemiologic results showing that an exposure is associated with a disease are the most convincing evidence of a substances toxic effect.* Unfortunately, the power of epidemiology to detect small risks is limited, and evidence obtained from toxicology that a substance is toxic can often be neither confirmed nor denied by epidemiologic studies.

The National Institute for Occupational Safety and Health (NIOSH) conducts various epidemiologic investigations and also makes Health Hazard Evaluations (HHEs), short-term studies conducted in response to private and public sector employee or employer requests. HHEs are designed to "determine the toxic effects of chemical, biological, or physical agents . . . in the workplace through medical, epidemiologic, and industrial hygiene investigations." HHEs, which become public reports, have identified and verified the workplace origins of some illnesses.

Information that could be useful for generating and examining hypotheses about relations between exposures and health effects is currently collected by some industries, but it is not clear that the data are often analyzed and the conclusions used to decide upon controls. Even data collected by the Federal Government are not used as much as they could be. Useful data are collected by different agencies, but concerns about individual privacy have restricted linking data from different sources. Although several committees of government scientists have explored ways to remove the restrictions, little has been done.

Safety

The idea that "unsafe workers" are a major contributor to injuries has hampered efforts in injury prevention. In the 1920s, a researcher concluded that nearly 90 percent of injuries were due to workers' "unsafe acts" and 10 percent to "unsafe conditions." Although this ratio of "unsafe acts" to "unsafe conditions" is often referred to, it is not supported by other research. Unfortunately, efforts are still made to separate injury causes into "unsafe acts" and "unsafe conditions," while neglecting the often complex interactions between workers and machines that can lead to injuries. *Additional efforts to apply epidemiologic techniques to injury analysis should be encouraged.*

Technologies to Control Hazards

A generalized model of occupational injury and illness is derived from the public health model of infectious disease transmission. The model has three parts: sources of hazard, transmission of the hazard, and workers. Methods for controlling workplace illnesses and injuries are intuitively simple. Health and safety professionals generally follow a "hierarchy of controls" approach that is related to this general model:

- first, containing the hazard—whether it is a substance or some physical, electrical, or mechanical energy —at its source;
- second, interfering with transmission of the hazard to the worker; and
- third, providing the worker with protective clothing and equipment.

The first two types of controls, controlling at the source and controlling transmission, are commonly called "engineering controls."

Controlling Health Hazards

Control at the source can be accomplished by design or modification of process or equipment or by substitution of less hazardous materials. This approach offers the greatest opportunist y for prevention, especially when incorporated in the initial installation of equipment into a plant. For example, redesigned dry-cleaning equipment eliminates the need for someone to transfer chemically treated clothes from one machine to another and thus prevents worker exposure to that particular chemical. Similarly, the very successful control of vinyl chloride exposures involved process changes that reduced the number of times workers' had to clean reaction vessels, thus lowering exposures during maintenance operations. An illustration of control by substitution is the use of steel shot instead of sand in abrasive blasting operations. This eliminates worker exposure to silica dust, which can lead to silicosis.

Ventilation is the method most often used to control transmission of health hazards. Local exhaust ventilation uses an air stream to remove contaminants from work areas. Familiar examples of this include laboratory fume hoods and the local exhausts above many kitchen ranges. Similar devices are installed for many types of workplace hazards. General dilution ventilation reduces worker exposure by supplying "fresh" air to the workplace and usually involves the heating/air-conditioning systems of a plant. These systems can be modified to increase the amount of airflow and thus dilute airborne hazards. Recent changes in building ventilation aimed at conserving energy use air recirculation techniques. If not done properly, some of these altered systems may increase worker exposures.

Other ways to control transmission include isolating the source and preventing toxic materials from becoming airborne. Worker exposures to asbestos and cotton textile dust were reduced by enclosing dusty carding machines. More generally, automating processes and locating equipment in rooms or buildings away from workers reduces exposures. A common technique for preventing dust from becoming airborne is to spray water on the material.

Finally, control at the worker may include administrative procedures, work practices, and the use of personal protective equipment. Administrative procedures include worker rotation among jobs to reduce the number of people exposed full-time, as well as the scheduling of jobs and processes that generate hazards at times when few workers are present. Work practices are simply job procedures and methods that are designed to reduce hazards. Personal protective equipment, such as hard hats and respirators, are described in more detail below.

Controlling Injury Hazards

Workplace injuries generally involve transfers of energy, and thus controlling them could be approached as a task of preventing the transmission of energy. For example, mechanical energy can be transmitted to stationary workers by falling objects, such as bricks on a construction site. Controls could involve securing the bricks so they do not fall, setting up overhead barriers to prevent any falling bricks from striking workers, and issuing hard hats to the workers.

However, the terminology, analytical methods, and procedures of safety professionals have usually differed from those used in controlling health hazards. Safety engineers have tended to use codes, standards, and models of "good practice" that are oriented around particular topics: fire prevention, electrical safety, machinery design, plant layout, etc.

Recommended "good practice" often involves common sense and the personal experience of safety engineers, with relatively little scientific analysis, systematic data collection, epidemiology, or experimental research. In addition, as mentioned, the view that many or most injuries are due to so-called unsafe acts has interfered with the incorporation of injury controls into the design of plant and equipment.

Nevertheless, injury prevention can be incorporated into the design of workplaces. Controls can be introduced to prevent electrical shocks, falling objects, the collapse of buildings and trenchs, and workers falling or being crushed by machinery and equipment.

Manufacturing involves the application of energy to materials to shape them into usable products. Woodworking, hot metalworking, and cold metalworking are three processes with significant hazards. A number of traditional control techniques are available to reduce these hazards. These include the installation of guards to prevent hands and fingers from getting caught in machinery and material from flying out and striking workers. Machinery and processes can also be redesigned to minimize the need for workers to place their arms or legs near moving machinery parts. Interlocks and two-hand controls are available to prevent machine operation when guards have been removed or when a worker's hands are inside the machine. Finally, personal protective equipment, such as face shields and goggles, are available to reduce the risk of injury from flying objects.

Fires and explosions cause deaths and injuries as well as large economic losses. For both those reasons, efforts to prevent them have resulted in careful attention to good plant design, control of the ignition sources of fires, installation of warning alarms and systems to extinguish fires at early stages, and plans for quick evacuation of burning buildings.

Finally, employers often set up formal injury prevention programs. Because management has the primary responsibility for prevention of work-related injury and illness, a successful program must start with a strong commitment from management. The stronger the commitment at the top, the greater the likelihood of success. Typical management efforts to prevent work-related injury include establishing company policies, incorporating injury prevention into plant design, carefully investigating reported injuries to identify hazards, keeping accurate and comprehensive records, placing workers in appropriate jobs, and conducting safety training for workers and supervisors.

Personal Protective Equipment

Hard hats, safety shoes, and protective eyewear are examples of personal protective equipment.

In many cases, especially construction, there are no practical engineering substitutes for such devices. Respirators and hearing protectors guard against hazardous dusts, fumes, vapors, and loud noises.

Obviously, personal protective devices must be worn to be effective, and their successful use requires both that equipment and instruction be made available and that use be properly supervised. There is evidence that safety equipment, such as hard hats and safety toe shoes, is worn when required by employers. Because of the clear connection between those devices and injury prevention, it is reasonably easy to argue that safety equipment will provide immediate benefits. On the other hand, the value of wearing a respirator to protect against a disease that may not manifest itself for several years or a few decades may not be as immediately clear. In addition, most respirators and hearing protectors are uncomfortable and hamper communication, and respirators make breathing more labored. Finally, there is a body of engineering knowledge that can be applied to reducing or eliminating the need to use respirators and hearing protectors.

Unlike engineering controls that are often tailored to a particular workplace, personal protective equipment is manufactured and sold for use at many diverse sites. Some Federal regulations require the use of personal protective equipment. There are, however, no Federal standards for its performance (with the exception of respirators); instead, the Government relies on manufacturers to produce and sell equipment that meets standards adopted by voluntary standards organizations, The American National Standards Institute (ANSI) is the source of most such standards.

In the mid-1970s, NIOSH purchased samples of personal protective equipment and tested them against ANSI standards. Many items failed. For instance, the lenses on 11 of 24 models of a type of protective eyewear splintered or shattered when subjected to the ANSI test for impact resistance; only 4 of 19 models of hard hats passed all the ANSI-specified tests. These results are especially discouraging because the employer who purchases the equipment and the workers who depend on it must rely on the manufacturer to produce a good product.

The standards, often not met, are themselves limited. Plastic lenses are tested for resistance to penetration, whereas glass lenses are not; NIOSH commented that it would expect most glass lenses to fail the test if it were required. Similarly, hard hats are tested for resistance only to vertical impacts. No tests are required for off-center impacts.

The only type of personal protective equipment that is tested and certified by the Federal Government is respirators. NIOSH certifies respirators using laboratory test methods that, in some cases, were developed years ago. Efforts to update the certification requirements have progressed slowly and may take years to complete.

The few tests carried out in the workplace under conditions of normal use show that respirators often do not provide the level of protection expected from the laboratory measurements. The poorer performance may be due to inappropriate use or maintenance or overestimation of performance based on laboratory tests.

The Environmental Protection Agency (EPA) formerly required that hearing protectors be rated for effectiveness. The effectiveness of probably all hearing protectors is overrated because of systematic errors in tests conducted to comply with the EPA requirements.

Hierarchy of Controls

Using engineering solutions to control hazards at their source or in the pathway of transmission is more reliable and less burdensome to the worker than personal protective equipment, Once installed, these controls work day after day with minimum routine intervention beyond maintenance and monitoring.

In keeping with the tenets of professional organizations such as the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists (ACGIH), OSHA had permitted use of personal protective equipment only when engineering controls were not feasible, not capable of reducing exposures to the required levels, or in the process of being designed and installed. This approach has been criticized by some employers who argue that they should be able to substitute personal protective equipment more freely for other types of controls.

In 1983, OSHA announced its intention to reconsider its policy of relying first on engineering controls for airborne health hazards. In a more specific action, OSHA in 1984 proposed a reduction in permissible exposure to asbestos. The agency proposes to allow the use of respirators to attain the new standard. If this regulation becomes final, it will almost certainly provide an argument for primary reliance on respirators in meeting other standards. Such a change must consider the poor results attained with those devices. OTA's analysis of the literature indicates that respirators provide the protection that is claimed for them only in workplaces that provide scrupulous supervision of maintenance and use. Those conditions are rare. To *turn away from the hierarchy of control without careful verification* of the levels of *protection afforded by personal protective devices is likely* to increase *exposures to health hazards.*

Training and Education

OTA finds that programs to educate workers and *health* and safety *professionals have* rarely *been evaluated, and that evaluation is necessary to know about their effect. Although not supported by evaluation, there appears to be general agreement that they succeed.* Evaluation is difficult because of the difficulty in determining what causes changes in illness and injury rates. Nevertheless, such efforts should be encouraged.

NIOSH funds Educational Resource Centers (ERCs). The centers are to educate occupational health and safety professionals, to offer continuing education programs, to conduct research, and to provide regional consultation services. They are required to provide interdisciplinary education with contributions from occupational medicine and nursing, industrial hygiene, and safety engineering. These requirements set ERCs apart from other health and safety professional education programs.

In 1981, with $12,1 million funding, the ERCs graduated over 780 professionals from degree programs and trained over 12,000 professionals in continuing education programs. Since then the President's budget has proposed cutting the ERC funding to zero, and Congress partially restored funding to $5.8 million in both fiscal year 1982 and 1983. Decreases in Federal funding will probably result in fewer degree and training programs.

Large companies with *successful* programs em*phasize that commitment to control of* work-*related injury and illness must begin with top* management. Despite that widely held opinion, little attention is given to injury and illness prevention in the education of business administration students. One attempt at building manager awareness, the NIOSH and OSHA Project Minerva, is sponsoring a series of meetings for business education teachers to introduce them to the concepts of occupational health and safety and to find ways of bringing those concepts into their courses.

The Nation's *engineering schools* annually train nearly 400,000 students. The accrediting organization for engineering schools requires, in theory, that engineering design courses consider health and safety. These courses, in which students learn the fundamentals of designing plants and processes, would appear to be especially appropriate for learning about the control of hazards. The topic apparently receives little attention, however. At one major engineering school, for example, most faculty interviewed agreed that safety was important, but few hours were devoted to teaching it,

The engineering curriculum, which prepares students for a professional license at the baccalaureate level, is acknowledged as one of the most course-laden programs at a university. *Although adding instruction in health and safety is attractive, it is difficult to fit this instruction into the existing engineering curriculum.*

Educating physicians about occupational medicine falls into two categories: general education about occupational disease and injury, and specialized training for practitioners of occupational medicine. Improvements can be made in both areas. It is generally accepted that physicians in general practice fail to recognize the impact of occupational factors on the health of their patients. This poor recognition stems from an orientation toward occupational health that is minimal at best and often nonexistent in U.S. medical schools. To accommodate classes on occupational medicine in the crowded medical curriculum would require that other subjects be dropped, a difficult task.

Postgraduate, specialty training in occupational medicine has traditionally been subsumed under preventive medicine, centered in schools of public health, and sometimes criticized for providing too little clinical experience. The criticism is being muted by the requirement of clinical experience for board certification of physicians in occupational medicine.

Dissemination of Health and Safety Information

Much information about hazards and controls is available from NIOSH, OSHA, health and safety professionals' associations, and the trade literature. The volume and unorganized state of this information impede its use. As a start in making information more accessible, NIOSH *and the National Library* of *Medicine have established computerized data systems that provide useful information for evaluating workplace hazards.*

OSHA has a consultation program that is designed to provide assistance in hazard identification and control to employers, especially those who run small *businesses.* It is a potentially valuable tool for the dissemination of information and may be a way to improve job conditions that is less adversarial than the enforcement of regulations through inspections. In fiscal year *1983,* OSHA funded consultations in more than *30,000* workplaces.

To date, OSHA has not evaluated the effects of the consultation program on injuries and exposures. Although OSHA urges that employers share the consultants' information with employees, this step is not required, and it is probable that workers are sometimes not informed. Some observers have expressed concern that funding for consultative visits diverts resources from OSHA inspection activities.

Letting workers know about occupational hazards is now facilitated and required by State and local "right-to-know" laws and the recently issued OSHA rule concerning the labeling of containers of hazardous chemical substances. Such information is valuable not only to workers but also to owners and managers who purchase chemicals for their businesses and to doctors and other health professionals,

Incentives and Imperatives That Influence the Decision to Control Hazards

Increased knowledge of hazards and improved controls provide the means for protecting health and safety, but a decision to adopt the controls is necessary for *them to have any impact at* all. In fact, the first and most important act in workplace health and safety may be the decision to control hazards. At least seven factors may motivate the decision to control:

- employers' enlightened self-interest,
- information on hazards and controls,
- financial and tax incentives,
- workers' compensation and insurance,
- tort liability,
- employees' rights and collective bargaining, and
- regulation.

The first six factors can be viewed as incentives; the last, regulation, is an imperative. OTA finds that while each of these may motivate a decision to control, the influence of all the incentives and the imperative is limited.

Employers' Enlightened Self-Interest

An important motivating factor behind voluntary employer actions concerning health and safe*ty is enlightened self-interest and concern for other humans,* Reinforcing such voluntary efforts are reductions in the costs of absenteeism, workers' compensation, or medical care when the decision to control hazards results in fewer injuries and illnesses.

OSHA has recently instituted several programs to encourage voluntary hazard control. In several States, employers are exempt from programed inspections if they receive an OSHA consultation and thereafter correct all serious hazards. OSHA's Voluntary Protection Program also encourages voluntary actions.

Some employers also participate in cooperative efforts to develop voluntary standards that draw upon the collective information and expertise of companies in a particular industry, trade association, or standard-setting organization. *Voluntary standards are an important source* of *information for employers, workers, and Government agen-*

cies, and they may move all companies that agree to them to a common performance level.

However, voluntary standards are also criticized for being insufficiently protective. Suggested remedies include having additional input from labor unions and the public when standards are drafted. Yet unions and public interest organizations frequently lack the staff and other resources to participate in voluntary standard-setting. Furthermore, they often do not want to participate because of a history of industry domination and the unenforceable nature of voluntary standards

The pressures of the competitive marketplace substantially limit the ability of individual employers to improve employee health and safety through voluntary actions. If a company devotes its resources to improving workplace conditions but its competitors do not, the firm can find itself at a disadvantage.

Information on Hazards and Controls

Timely and accurate data are necessary for making decisions, and both Government and private organizations provide information about hazards and controls. Although necessary, information alone may have little influence on decisions to control.

Financial and Tax Incentives

Reducing the costs of purchasing needed equipment and technology can encourage employers to improve health and safety. Four kinds of tax and assistance programs might be useful for occupational health and safety: investment tax credits, accelerated depreciation allowances, direct subsidies, and Government loan programs. Funds from a Government loan program for small businesses have been used for occupational health and safety investments, but that program was abolished in 1981. The other three mechanisms have been used to encourage investments in equipment for environmental protection, but not for health and safety controls.

Workers' Compensation and Insurance

The primary goal of workers' compensation programs is to pay injured workers' medical expenses and to compensate for lost wages. Prevention of injuries and illnesses is a secondary goal. Although workers' compensation programs have probably had a positive effect on injury experience, empirical evidence for this has been difficult to gather.

Four factors limit the incentives that workers compensation can provide for control of hazards. First, all insurance schemes spread losses; therefore, the insurance function of workers' compensation means that employers who cause injuries do not bear their full costs, unless they are self-insured or pay premiums that are directly tied to their injury and illness experience. Second, benefit levels represent less than the full social costs of injuries and illnesses. Third, some injuries and most illnesses are not compensated because a claim is never filed, or they are inadequately compensated because the claim is delayed or denied. To the extent that these factors reduce the fraction of the costs of injuries and illnesses that are borne by employers, they reduce incentives for prevention. Changes in the system that lead to a greater proportion of the costs of illnesses and injuries being paid by employers would enhance the prevention incentives of workers' compensation,

Tort Liability

The last decade has seen spectacular growth in the number of cases in which workers sued firms that manufactured machinery and other products purchased by employers for workers' use, Such suits are generally filed against "third parties, " manufacturers and suppliers, because workers' compensation programs bar suits against employers.

Tort liability has received special attention because of the number of third-party lawsuits against suppliers of asbestos. If the number of third-party suits increases, and if they are successful for hazards other than asbestos, they may become an important incentive for prevention. Even so, the number of cases may be limited because it is difficult to produce the degree of proof required by courts in cases of occupational disease.

Employees' Rights and Collective Bargaining

The OSH Act created opportunities for worker participation in health and safety activities. The act provided that workers can:

- request OSHA inspections,
- participate in the conduct of an OSHA inspection,
- participate in any of the stages of a proceeding before the Occupational Safety and Health Review Commission,
- contest the “reasonableness” of the abatement date set by OSHA,
- participate in standards development and the issuance of variances, and
- request a Health Hazard Evaluation from NIOSH.

In addition, the act established a mechanism to protect employees from job discrimination for having exercised any of these rights. This provision prevents discrimination against employees who refuse work that presents an imminent danger of injury, although it probably does not extend to employees who refuse work that the worker thinks presents a health hazard.

Collective bargaining is particularly useful for establishment-specific implementation of controls and for monitoring employer actions. It is severely limited because only about 20 percent of the work force is unionized and because not all unions have sufficient staff expertise in industrial hygiene, injury prevention, or occupational medicine. Moreover, health and safety provisions must compete with other bargaining issues for attention and resources. Some people object to collective bargaining for injury and illness prevention because they believe that health and safety on the job ought to be an employee right, not subject to negotiation.

At least 82 percent of union contracts contain at least one clause related to health and safety according to data collected by the Bureau of Na*tional* Affairs, Unions can encourage members' participation in health and safety activities, participate in worker education in hazard recognition, provide or have access to technical expertise, and establish mechanisms for dispute resolution between employer and union,

OSHA Regulation

Mandatory Federal regulations are an imperative for the adoption of controls. *Labor representatives insist on mandatory standards and employer representatives, especially health* and safety *professionals, accept the need for them.* Most of the standards set by OSHA, however, have been criticized by nearly all parties, but for different reasons. Labor groups judge the standards as insufficient to protect health. Business groups see them as nit-picking, excessively stringent, unnecessary, inflexible, and too costly. The criticisms from both sides in part reflect fundamental differences concerning the desirable level and type of Federal intervention in this area.

OSHA's Standard-setting Criteria.–Since 1981, OSHA has used four criteria for decisions on health standards. First, it determines if the hazard in question poses a “significant risk” and warrants regulatory intervention. Second, the agency determines whether regulatory action can reduce the risk. If so, OSHA develops a standard to reduce the risk “to the extent feasible, ” considering both technological and economic feasibility. Finally, OSHA analyzes the cost effectiveness of various options to determine which will achieve its chosen goal most efficiently.

All OSHA regulatory actions are now reviewed by the Office of Management and Budget (OMB) under Executive Order 12291, which, to the extent permitted by law, requires regulatory agencies to demonstrate that their proposed and final regulations pass a cost-benefit test. Generally speaking, the results of the OMB review and agency responses have not been made public, making it difficult to determine if OSHA decisions have been altered by OMB's cost-benefit review.

OSHA's Record of Standard Setting.—There is dissatisfaction about the length of time OSHA takes to develop, propose, and promulgate new standards or revisions of existing standards. In its first 13 years, through December 1984, OSHA issued only 11 new or revised health standards concerning 24 specific chemical substances and one standard covering exposure to noise. Standards for two of the substances and noise were overturned by the courts. Twenty-six new or revised safety standards were completed. In addition, broader regulations concerning employee access to records, a “generic” policy concerning the regulation of carcinogens (under which no substance has been regulated), and the labeling standard were issued.

In part because of the slowness of OSHA standard writing, *many OSHA standards seriously lag behind recommendations and voluntary standards issued by professional societies and voluntary standards organizations.*

Most current OSHA health standards are based on the exposure limits published by the American Conference of Governmental Industrial Hygienists in 1968, and most safety *standards rely on American National Standards Institute publications of the 1960s.* Those standards were adopted in *1971* under a section of the OSH Act which gave OSHA authority to adopt established Federal standards and national consensus standards. ACGIH annually updates its limits, including standards for additional chemicals, and often recommends stricter exposure limits. OSHA often does not follow suit.

OTA finds that ACGIH exposure limits and NIOSH recommendations, overall, are stricter than the OSHA standards. In addition, the *1968* ACGIH list covered nearly 400 substances. The current ACGIH list covers over *600* substances, but OSHA'S list—with a handful of additions—remains essentially the same as ACGIH's 1968 list. A mechanism for timely and efficient OSHA consideration of new ACGIH exposure limits and NIOSH recommendations might prevent OSHA from lagging behind professional recommendations.

OSHA Inspection and Enforcement.—A *regulatory* strategy will *succeed* only if the *agency's enforcement efforts have adequate resources.* For most establishments the probability of a routine OSHA inspection is very low (there are about 160,000 inspections annually in a total of 4,600,000 workplaces). Most inspections take place in manufacturing or construction. But even in those industries, on average, a plant or site will be inspected only rarely. For example, the typical manufacturing establishment can expect to be inspected once every *6* years. In addition, even if an employer is found not to be in compliance, the fines issued by OSHA are small, especially when compared with the costs of many types of controls. For example, the average proposed penalty for employer violations that threaten "death or serious physical harm" is less than $200,

The current administration has implemented a number of changes in inspection and enforcement. A new type of inspection examines only the employer-maintained injury records if the firm's injury rate is below the national average for manufacturing. In addition, the number and percentage of inspections with "serious" and "willful" violations has fallen, and the total dollar amount of proposed penalties has been reduced substantially.

Other new OSHA policies encourage area directors and employers to "settle" citations by reducing or eliminating penalties in return for an employer's promise to abate the hazard and to comply with OSHA regulations. These changes may decrease the contentiousness of some OSHA proceedings. On the other hand, they may have further reduced an already weak regulatory effort.

OSHA's Effects.—The impact OSHA can have on injury rates is constrained by the small size of the OSHA regulatory effort, which can inspect less than 4 percent of the Nation's workplaces annually. Most evaluations have searched for OSHA's effects on total injury rates, which could be masking the success of the agency in preventing certain specific types of injuries as well as possible differences in the effectiveness of each area office of OSHA and of the 25 jurisdictions operating "State programs. "

The research results are mixed. *Several researchers have found favorable, but generally* small, *changes, implying that OSHA activities have reduced injury rates. Other researchers have not found any significant correlation between OSHA activity and workplace injuries.*

Currently, OSHA points to decreasing injury rates for 1980 through 1983 as evidence that the agency's new regulatory approaches are paying off. However, changes at OSHA could not fully account for the declines, for they were not instituted until 1981, more than a year after the drop in rates began. Moreover, as indicated earlier, the economic recession, including increased unemployment and a shift away from "smokestack industries, " is the most important factor behind this decline.

There is some evidence that several OSHA regulations have had a positive effect on *exposures to health hazards.* The best known case is vinyl chloride. Exposures declined dramatically after the issuance of a more stringent OSHA standard. Substantial declines have taken place in asbestos exposure levels, perhaps due to OSHA efforts, but more likely due to fears of tort liability suits.

A study commissioned for this assessment found substantial decreases in lead levels in workplace air and even more marked reductions in lead levels in employees' blood in the years since OSHA's new lead standard was promulgated. Another study commissioned by OTA found substantial decreases in exposures to cotton dust following the introduction of a new agency standard. The number of workers exposed to levels above the new, tighter exposure limit for cotton dust has been halved in the short time since the standard came into effect. Several textile mills appear to be in complete compliance, while others expect to be in the near future.

Measuring OSHA's impact is difficult. To detect the impact of a small Federal program on something as large as the Nation's entire work force might be asking too much, Regarding workplace-related illnesses, even if the data were reliable, it is too early to expect that OSHA regulations would have much impact on occupational disease. On the positive side, however, *OSHA standards for vinyl chloride, cotton dust, and lead have clearly reduced workplace exposures. Furthermore, increased productivity accompanied compliance with both the vinyl chloride and cotton dust regulations.*

Reindustrialization and Workplace Health and Safety

Over the years, the process of industrial change and renewal has led to improvements in occupational health and safety. *Although quantitative estimates are lacking, to some extent the reported declines in injury rates dating from early in this century may be due to the installation of* mod*ern, safer plants and equipment. A second factor may be general shifts in employment away from industries and operations with greater hazards.* Similarly, in some particular cases, exposures to health hazards have declined because of increased mechanization, but it is not clear whether exposures to health hazards overall have decreased, remained the same, or increased.

Thus, through the process of industrial change health and safety can improve without anyone's explicitly "intending" it. In addition, some changes in the workplace have taken place because of employers' desires to minimize the threat of fire and explosion or to reduce the downtime of plant or equipment. Some changes that lower the threat of property damage or "down time" also reduce exposures to toxic agents or the risk of injury.

If this country is entering a period of reindustrialization, many opportunities will be available to improve health and safety. As new plants are built, employers may take advantage of opportunities to install controls as part of initial construction, when they can be put in at lowest cost. If the Government provides economic incentives or financial assistance to firms as they modernize, it can consider methods to encourage the installation of controls. Some of the incentives already mentioned—including tax breaks and direct financial subsidies, as well as possibly timing new OSHA regulations to coincide with industrywide changes—might be useful during a period of reindustrialization.

OPTIONS FOR CONTROLLING WORKPLACE HAZARDS

Data and Hazard Identification

Increasing the Usefulness of Current Data Systems

Identifying workplace health and safety hazards is the first step in reducing occupational morbidity and mortality. Certain changes in Federal data collection efforts can make epidemiologic investigations.

Mortality Surveys.--One nationwide study of death certificates to examine associations between industry and occupation and mortality was done in the 1950s. Since then, epidemiologists in the States of Washington and Rhode Island have conducted statewide studies. These are valuable not only for identifying high risks associated with some types of work but also for indicating occupations and industries that do not present high risks. Yet statewide mortality analyses cannot be representative of the Nation as a whole and lack the statistical power that would be present in an analysis of data for the whole country. Nationwide mortality analyses would provide important leads for further study to pin down associations between work and various causes of death, as well as valuable information about hazards in occupations that are scattered across the country, e.g., carpenters or butchers.

Currently, NIOSH and the National Center for Health Statistics provide instruction and assistance to a few States that are conducting mortality surveys. A collaborative effort between NCHS and NIOSH would probably best accomplish the task of carrying out *nationwide* mortality surveys.

Option I: Congress could provide funds and personnel for an NCHS/NIOSH collaborative effort *to produce accurate coding of industry and occupation information on death certificates. That information could then be used to produce mortality analyses for occupations and industries either in:*

- *the few States that are establishing mortality surveys or*
- *nationally*.

The National Death Index. -Information on death certificates is essential to any epidemiologic study investigating causes of death. When supplied with someone's name and date of birth or Social Security number, the National Death Index (NDI), a service of the NCHS, can tell epidemiologists whether that person has died and where the death certificate is located. Until NDI was established, epidemiologists had to contact every department of vital statistics to locate the death certificate. Quite simply, the NDI reduces the number of such inquiries from more than so to 1, although each certificate must still be obtained from the office of vital statistics that holds it.

The NDI would be more useful if it supplied all the information encoded upon death certificates. Were it to be modified to do that, epidemiologists could obtain all vital information for mortality studies from a single inquiry. The benefits of such a change would be to speed up studies and reduce their costs. Such a change would increase the work load at NCHS associated with the NDI and require some system whereby State departments of vital statistics could still receive revenue for supplying information.

Option 2: The National Death Index could be modified so that all information collected on death certificates can be made available from it.

Addresses From Internal Revenue Service Records.—Epidemiologic studies frequently require investigators to interview subjects of the study or their families. One impediment to such efforts is the difficulty of locating people. Internal Revenue Service (IRS) records are a reasonably complete source of recent addresses, but only NIOSH and some other Federal agency scientists and persons working on contract to NIOSH can obtain addresses from IRS.

There is some confusion about who can use this "NIOSH window" and clarifications about this are needed. In addition, it may be desirable to allow a wider spectrum of researchers to obtain addresses from IRS. Any expansion of the window would require safeguards so that addresses received this way are used only for epidemiologic studies.

Option 3: Congress could direct the Federal agencies to define clearly who can obtain IRS-held addresses and create procedures to allow a wider spectrum of researchers to obtain addresses from the IRS for use in locating persons for epidemiologic studies.

Linking Federal Data Systems to Facilitate Epidemiologic Studies.–The records systems of the Census Bureau, Social Security Administration, Veterans' Administration, OSHA, and NIOSH could be linked together to provide information about medical conditions, work history and exposures, and the current address in a single file. Such a link could improve epidemiologic studies; but it increases also the possibility of invasion of a person's privacy. The option suggested here is intentionally vague because of the delicate balance between improving our capacity to understand disease and protecting citizens' privacy.

Although epidemiologists are convinced of the value of linking together data systems, few efforts to do so have been approved. "On Occupational Cancer Estimation, " the recent report of the Department of Health and Human Services' Committee to Coordinate Environmental and Related Programs, suggests some options for linking data systems.

Option 4: Congress could encourage consideration of *various proposals to link together Federal data systems* for *use in epidemiology.*

Injury Investigation

OSHA investigates 1,500 *to 2,000* accidents involving fatalities or five or more hospitalizations each year. Unfortunately, little attention has been paid to using the collected information to prevent future accidents, and for many years it had only gathered dust in OSHA's files. The agency has conducted some limited analyses of these investigations, has initiated a small effort to distribute summaries of construction accidents to labor unions, trade associations, and other organizations, and is developing a new data system to provide information collected during accident investigations. Complementing these activities, NIOSH has begun detailed investigations of a small number of fatal injuries. In addition, the BLS has obtained information on some types of nonfatal injuries through questionnaires completed by injured workers.

Option 5: Congress might direct OSHA, N1OSH, and BLS to devote additional resources to investigating fatal and nonfatal injuries, with *the* objective of *developing information useful for preventive efforts.*

BLS Annual Survey

The BLS Annual Survey, which collects information from employer-maintained logs of injuries and illnesses, is the best source of information about occupational fatalities and nonfatal injuries. Since 1981, employer-maintained injury records and the results of the BLS Annual Survey have been used to grant exemptions from OSHA inspections. Because of this reliance on the data, assessing the reliability of the responses would be prudent.

In the early 1970s, BLS conducted onsite evaluations of a sample of employer responses to the Annual Survey to verify their accuracy. This "Quality Assurance Program" has not been repeated since 1976.

Option 6: Congress could direct OSHA and BLS to conduct a new "Quality Assurance Program" to determine the accuracy of employer-maintained injury records.

Toxicology

The Federal Government, especially through the National Toxicology Program and the National Center for Toxicological Research, is supporting large-scale efforts to improve toxicology so that results will be more predictive of human effects and more readily accepted in the setting of standards. The Toxic Substances Control Act mandates the submission to EPA of information about "substantial risks" to human health that are identified by companies. This section of the statute and the act's requirement that companies notify EPA of available toxicologic information before new chemicals are introduced into commerce are important in protecting workers' health. This assessment suggests no particular options regarding toxicology, but it draws attention to the importance of those programs.

Improved Control Technologies

NIOSH-Supported Research on Controls

Provided with sufficient resources, NIOSH, through vigorous grant and contract programs, could encourage the application of the techniques of engineering, epidemiology, ergonomics (human-factors engineering), industrial hygiene, and other disciplines to the development of innovative hazard control methods. Increasing NOSH'S research in control technologies even five- or tenfold need not require a proportional increase in NIOSH staff. Most of the research could be done in private sector and university laboratories.

Increased research and development of control technologies would enable the Federal Government to provide new information to improve safety and health. It might also improve cooperation between the Federal Government and occupational health and safety professionals in the private sector. Research in control technologies represented only 12.8 percent or about $7.4 million of the NIOSH budget in fiscal year 1983. Three general research areas could benefit from additional funding: engineering controls, personal protective equipment, and new production techniques.

Workplaces built some years ago with little attention to occupational health and safety often incorporated few injury and illness controls when they were constructed. Instead, controls—if they are used at all—are added later as retrofits. Additional work is needed to develop general principles for designing controls into plant and equipment in order to increase effectiveness and minimize interference with production. Another goal could be improved control at reduced cost. Lower costs might reduce employer and manufacturer resistance to the installation of controls and the burdens of regulatory standard setting and enforcement.

Research on personal protective equipment should develop reliable and comfortable devices and methods to assess efficacy in "real-world" conditions. Research on respirators is particularly needed, but investigations of other kinds of personal protective equipment are also important.

A third priority area for research in worker health and safety is new technologies. The hazard potential of new processes, procedures, equip ment, and techniques needs to be evaluated, and attention paid to the development of controls. Early attention to hazards will provide health benefits to workers; moreover, lower costs are associated with building hazard control into the technologies at first rather than having to retrofit later.

Option 7: Congress could expand support of NIOSH research and demonstrations in control technologies, using both NIOSH staff and resources as well as grants, cooperative agreements, and contracts. This expanded research and demonstration effort could be directed at four different areas:

- *fundamental engineering research, directed at finding generalizable principles for health and safety controls;*
- *applied research and demonstration projects concerning improved engineering control techniques;*
- *research in improved personal protective equipment;*
- *efforts to track emerging industries and new plants, evaluate hazards, and offer advice to firms engaged in new technologies,*

Private Sector Research

Much research, especially that oriented towards the development of controls for particular installations, is conducted by employers, equipment manufacturers, and the insurance industry. Their efforts have produced successful solutions for many occupational health and safety problems, To the extent that they have the appropriate expertise, employers and manufacturers should be eligible for NIOSH research grants and contracts.

Certification and Regulation of Personal Protective Equipment

All types of personal protective equipment pose similar questions: What kinds of tests for effectiveness should be required? When should the tests be done—before or after marketing? Who should conduct the tests? How should test results be used?

Option 8: N1OSH could be given resources *to establish procedures to test and certify some or* *all types of personal protective equipment; the* agency might:

Option 8A: establish a program of *premarket testing that includes, at a minimum, appropriate laboratory evaluation of personal protective equipment, and, as soon as possible, testing and certification to reflect real workplace situations;*

Option 8B: conduct postmarked surveillance to collect reports of equipment failure and defects, and to investigate those reports; or

Option 8C: explore alternative arrangements for both premarket testing and postmarked surveillance of *persona! protective equipment.*

These arrangements could include different combinations of self-testing and certification by manufacturers, testing and certification by independent parties, "spot-check" testing by NIOSH, and full-scale *testing by NIOSH.*

Although employers and employees rely on effectiveness labeling to select equipment, those figures often overstate actual effectiveness. For example, OSHA instructs its compliance officers to assume that hearing protectors provide only so percent of the laboratory-measured protection.

Option 9: Congress could provide OSHA and NIOSH with resources to develop, collect, and disseminate information on *"real-world" effectiveness of currently available personal protective equipment.*

Education, Training, and Information Dissemination

The Federal Government provides in-house training to its own and other employees and grant support for various education and training programs. One example of an in-house activity is the OSHA Training Institute, which provides continuing education to Federal and State OSHA staff (principally inspectors) and, to a limited extent, to individuals from the private sector. Grant-supported activities are split: OSHA has concentrated on employee and employer training, whereas NIOSH has general responsibility for the education of professionals.

Workers and Supervisors

Since 1978, the OSHA New Directions Program has awarded grants to labor unions, trade associations, universities, and nonprofit institutions for developing and conducting training and education programs. The focus has been worker training, although a number of New Directions grantees have also trained supervisors and produced educational materials useful to supervisors, managers, and workers.

The New Directions Program, although not so well evaluated as it could be, is seen as a success by many health and safety professionals. Currently the grants that were supported by transfer of money from the National Cancer Institute to OSHA are being evaluated, and other assessments could be encouraged. The characteristics of good and poor projects should be publicized and the funding level of the New Directions Program, which has been decreased, could be reconsidered. Aiding local or industry-centered organizations to find solutions to local problems provides a direct approach to health and safety problems,

Option 10: Congress might increase Federal support for occupational health and safety education and training, possibly through the New Directions Program, by:

- *involving unions, workers' organizations, and trade and educational associations in education and training through the provision of grants to develop informational and educational materials and to hire professional health and safety staff;*
- *supporting education of supervisors and managers in occupational health and safety through programs directed at providing educational materials to employees.*

The Federal Mine Safety and Health Act of 1977 requires mine operators to provide certain specified amounts of safety training to workers. Some OSHA standards require employers to provide worker training concerning specific hazards, but there are no requirements for instruction or training in most occupations. However, in the absence of any requirement, some employers provide health and safety training. Furthermore, some collective bargaining agreements specify that all workers receive some training and that advanced instruction be provided to worker members of health and safety committees.

Option 11: Employers might be required to provide a certain minimum level of health and safety training to their entire work force.

Health and Safety Professionals

NIOSH training grants to universities support two activities: academic programs that train individuals in a single specialty, and Educational Resource Centers, which provide complete programs. Many health and safety experts believe that these funds have been well spent, increasing the number of graduated professionals and enhancing the abilities of professionals through continuing education. On the other hand, there has been only limited evaluation of these programs or the actual impact that the increased number of professionals has had on worker health and safety.

Funding for these programs has been reduced in recent years and the current administration has proposed complete elimination of the ERCs. Cutbacks in Federal funding in this area are likely to reduce the number of trained professionals.

Option 12: Congress could continue to fund training of occupational health and safety specialists, including the Educational Resource Centers, through the NIOSH training grants program.

Engineers, Physicians, and Managers

The disciplines of engineering and medicine have a marked impact on occupational health and safety even though most practitioners in these disciplines are not specialists in workplace health and safety. Neither general-practice physicians nor engineers receive significant instruction about occupational hazards and controls. For physicians, the prime need is training to recognize the impact of occupational exposures on health. Engineers need to understand the nature of occupational hazards and to learn the fundamental design techniques useful for prevention of work-related illness and injury. In addition, managers play an important continuing role in decisionmaking about health and safety.

Some starts have been made (and some abandoned) to extend information about safety and health to physicians, engineers, and business administration educators and students. The Department of Health and Human Services supported some efforts to educate physicians in environmental and occupational health in several medical schools in the late 1970s, but funds are no longer available. NIOSH has sponsored a series of workshops on the topic of engineering education concerning health and safety,

Option 13: Congress could provide support for and encourage:

- *introducing occupational medicine in medical school course work;*
- *introducing or expanding occupational safety and health into engineering school curricula;*
- *introducing or expanding classes about occupational health and safety in business administration courses,*

For example, grants through NIOSH or the National Science Foundation might be used to develop training modules for integration into existing courses.

Expanded Information Services

The OSHA consultation program, which was instituted to provide health and safety evaluations to businesses, especially small firms, is a relatively popular program. One possibility is to expand the program to provide consultation to a greater number of employers as well as to employees and unions. This would require funding, as well as the creation of procedures for providing these services.

Option 14: Congress could expand the OSHA consultation program by:

- *providing increased funding for OSHA consultation;*
- *directing OSHA to explore methods to encourage employers to share this information with employees and their representatives;*
- *expanding the consultation program to provide this service to employees and unions.*

Insurance Industry Research

Representatives of insurance companies visit more plants than OSHA is able to inspect, and many employers, especially small firms that lack full-time health and safety personnel, rely on the advice of their insurers' loss-control specialists. The establishment of an institute similar to the Insurance Institute for Highway Safety might facilitate the dissemination of industry-collected information on occupational health and safety. No option is proposed because there would be no Federal role in such an institute,

Computerized Information Systems

There are many useful collections of data. For instance, NIOSH produces and collects information about toxicity, assessment of control technologies, and product testing; OSHA collects information about hazards and controls during inspections, consultations, and courses. Combining information from some or all of these sources would produce a data system for use by designers, engineers, workers, employers, and health and safety specialists. Users could be charged for services to defray expenses and possibly to make the service self-supporting.

Option 15: The Federal Government could provide grant or contract money to apply computer technology to the collection and dissemination of occupational health and safety information.

Incentives and Imperatives

Voluntary Implementation of Controls

Voluntary employer efforts to improve health and safety are very important. OSHA has initiated a program to encourage such efforts, and NIOSH has often persuaded employers to control hazards that are not currently subject to OSHA regulations. Attempts to encourage "voluntary protection" must be kept in balance, however, with the standard-setting and enforcement required by the OSH Act.

Option 16: Congress could direct OSHA and NIOSH to increase the attention devoted to encouraging voluntary efforts and to publicize the firms that have exemplary programs in health and safety,

Workers' Compensation Programs and Tort Liability

Workers' compensation programs, administered by the States, have been credited with contributing to the prevention of injuries and illnesses. There is reason to believe that this may be true for occupational injuries, although data *to* support this conclusion are limited. For illnesses, data are even more sparse, and the programs offer fewer incentives for prevention of illness than for injuries.

Most potential lawsuits by employees against their employers for occupational injuries and illnesses are barred by the statutes that created the State workers' compensation systems. It has been suggested that this prohibition be eliminated in some circumstances, but this would involve major changes in workers' compensation laws.

Congress is considering legislation to provide compensation for the victims of asbestos-related disease. This proposal is a response to perceived problems in both the workers' compensation and tort liability systems.

Prevention should be considered in any changes in compensation. In general, a compensation system should be designed to encourage prevention. If Federal revenues are used to supplement occupational disease compensation funds, the Federal contribution might be accompanied by a requirement that companies take concrete steps to prevent future cases of disease—a suggestion that is admittedly hard to implement, Since OSHA would almost certainly already be regulating any hazard important enough to require a Federal contribution to compensation, it is not clear what additional requirements might be imposed on companies that benefit from compensation legislation. But it is also important to consider carefully any changes in either compensation or tort liability to guard against changes that might weaken incentives for prevention.

Labor-Management Committees

Labor-management health and safety committees exist in many U.S. workplaces, in both union and nonunion shops. They offer an avenue for sharing and conveying information about hazards and controls. OSHA currently supports the formation of joint committees in companies that participate in the OSHA Voluntary Protection Programs.

Option 17: Congress could encourage the formation of labor-management committees by:

- *directing that OSHA expand its* Voluntary *Protection Program;*
- *increasing OSHA funding for training, consultation, and other technical assistance to workplaces with labor-management committees.*

The Role of OSHA

Updating OSHA Regulations

It is well known that OSHA lags behind professional health and safety organizations and consensus standards in responding to new information about health hazards. The agency upgrades its regulations through the same time-consuming rulemaking procedure it uses to promulgate new regulations, and changes are often opposed.

OSHA considers NIOSH recommendations about exposure limits, but has taken few regulatory actions based on NIOSH criteria documents. Requiring an OSHA response to NIOSH recommendations would ensure that the regulatory agency considered the research agency's findings, but making it mandatory for OSHA to regulate on the basis of NIOSH recommendations might not be useful. The Mine Safety and Health Administration (MSHA) is currently required to respond to certain NIOSH recommendations. However, NIOSH has sent no such recommendations to MSHA, perhaps because of the direct tie between recommendation and regulation.

Option 18: Congress might direct OSHA to develop methods to respond to changes in national consensus standards and other professional recommendations.

Option 19: Congress might require OSHA to consider NIOSH recommendations for new or more stringent controls within a fixed period of time—say, 2 or 3 years. At the end of that time, OSHA *could adopt,* modify, or *decide against adopting the recommendations, but it would have to respond or be subject to suit.*

Without changing the current system of standard setting, OSHA inspectors could provide information to both employers and workers concerning professional recommendations. Although it would not be legally binding, employers might take actions based on this information.

Option 20: OSHA inspectors could be directed to provide information (to employers and employees) on current NIOSH recommendations, professional organizations' recommended exposure limits (such as ACGIH's, which are updated annually), and voluntary standards whenever these recommendations and standards would affect the hazards found in particular workplaces,

Standard Setting

Despite the fact that it did not succeed, a recent effort to negotiate a standard for benzene should provide much valuable information about the feasibility of using negotiations in standard setting.

Option 21: *Congress might encourage OSHA to study possible procedures* for *negotiation during standards development and implementation. These procedures will have to assure the adequate representation of* all *affected parties.*

In the setting of health standards, OSHA has generally moved substance-by-substance, Each proposed health standard can be, and most have been, opposed. OSHA has made three attempts to establish "generic standards. " The agency promulgated a "cancer policy" in 1980 that defined what data would be necessary and sufficient to make a decision about a substance being a carcinogen and the nature of the standard that would then be issued. The "access to records regulation, " a generic standard applying to all employer-held health and safety records, guaranteed workers the right to inspect records and required that employers retain them. The recently promulgated labeling, or "hazard communication" standard also has generic aspects.

Generic standards offer greater efficiency in that matters of a general nature can be settled once rather than being renewed for every specific case. There are, however, difficulties in issuing broad regulations that are to apply in many situations. Moreover, there is no guarantee that generic standards will be used. For example, no carcinogens have been regulated under the agency's "cancer policy. "

Possible areas for generic standards include exposure monitoring and employee training. It may also be possible to issue standards that deal with groups of, rather than single, substances.

Option 22: OSHA could be encouraged to issue generic standards to supplement substance or hazard-specific rules.

OSHA Enforcement Activity

No other OSHA activity stirs up so much emotional fervor as its inspection and enforcement activities. Many businesses object to inspections as being nit-picking and unrelated to employee health and safety, Employees and unions, on the other hand, believe that inspections are essential to worker protection and are concerned that OSHA devotes insufficient resources to them and that inspectors are not vigorous enough in enforcing legal requirements.

Whatever the number of inspections, some violations are found and punished by fines, In most cases, the fines levied by OSHA are less than the costs of controlling hazards. One possibility would be to increase fines to levels equal to the actual costs of implementing controls. Or fines might be based on a calculation of the amount necessary to have a deterrent effect.

In some cases, fines equal to the costs of control would exceed the maximum levels established in the OSH Act. Therefore, the law may have to be changed to allow higher penalties. Of course, higher penalties will raise the number of contested OSHA actions and the general level of controversy in this field.

Option 23: Congress could consider what the appropriate level of OSHA enforcement activ*ity should be; it could then either:*

- *continue the current levels of personnel and funding for inspection activity and the new policies concerning inspection targeting and citation settlement;* or
- *increase the number of inspectors, and the level* of *fines, and change the targeting and settlement policies to increase incentives for compliance.*

Other Federal Actions Affecting Hazard Control

Various tax and financial assistance programs—investment tax credits, accelerated depreciation, government loan programs, and direct subsidies—might encourage employers to install control technologies. However, all these programs have disadvantages. First, they would reduce Federal tax revenues or increase budget outlays. Second, depending on their design, tax-based incentives can be relatively inefficient mechanisms because firms that would have installed controls, even *in* the absence of the program, would now receive a tax subsidy, Third, there will be difficulties in dividing the purchase price of equipment between features that are health and safety controls and those that are part of the equipment for purely productive reasons.

Option 24: Congress might enact a tax and financial assistance program to assist businesses in improving occupational safety and health.

As the United States considers its economic and industrial policies, it is unclear what balance is to be struck between updating old-line industries and focusing on new industries. In the future, the Federal Government may play an active role in the "reindustrialization" or "deindustrialization" of America.

If explicit Federal policies are created, they may include discussions and agreements among interested businesses, unions, communities, and others, as well as Federal loans and financial assistance. Information could be developed concerning the health, safety, investment, and productivity needs of *various* industries. One possibility would be to provide financial assistance for health and safety, as well as for productivity investments.

The general disadvantages of these approaches include the concern that health and safety will "take second place" to the push for productivity. In addition, many object to any Federal role in coordinating or financing industrial investments.

Option 25: If the United States makes available funds or tax incentives for the building or rebuilding of industry:

- *controls for health and safety hazards could be* eligible for the same *funds* or tax *breaks as other construction costs;*
- *companies receiving reindustrialization* assistance *might be* required *to design health and safety into their new plant and equipment, either to meet existing standards or to achieve lower exposure levels or safer processes.*

It has been suggested that regulatory requirements have diverted resources from "productive" uses and contributed to economic slowdowns. However, in at least two cases (standards concerning vinyl chloride and cotton dust), new production processes were developed that both benefited worker health and improved productivity. Fitting regulatory activities to productivity concerns can be achieved in two ways: either delaying regulatory requirements until they coincide with planned modernization or using health and safety regulations to "spur" productivity improvements.

Option 26: Congress could direct OSHA to:

- *delay the required use of engineering controls, so that the installation* of *these controls coincides with modernization of an industry;*
- *use health and safety regulations to encourage plant and equipment modernization.*

Creation of an Occupational Safety and Health Fund

OTA is aware of concern about recent large swings in occupational safety and health policy. Two areas—education and training programs, and research on workplace controls—have had funding reduced in the past few years. The creation of an Occupational Safety and Health Fund might provide more stable and enhanced funding.

Recent U.S. research concerning the use of "washed cotton" to control the hazards of cotton dust also provides a model for cooperative research. This project was funded by Government and industry, with oversight and direction provided by a group of labor, management, and Government officials. Jointly administered research efforts and training programs have also emerged from collective bargaining.

A fund could be established with or without a Government contribution. For example, interested citizens, employers, workers, foundations, and other groups could make voluntary contributions. Or Congress could create a fund. If it becomes a Federal activity, financing could be through a payroll tax on employers or, although this would be more difficult, through a tax or surcharge based on workers' compensation premiums (with some adjustments for the presence of health hazards in various industries). For example, a 0.1 percent employer tax on the total U.S. payroll of $1.6 trillion (in 1982) would result in annual revenues of about $1.6 billion; a 0.01 percent tax would produce $160 million. A 1.0 percent surcharge on workers' compensation premiums (about $25 billion in 1980) would produce annual revenues of $250 million. Another possibility would be to allocate fines collected for violations of OSHA standards to this fund. This would produce less money; in 1983, OH-IA'S proposed fines totaled $6.4 million.

Several different administrative arrangements for such a fund are available, Congress could follow the model of the Work Environment Fund of Sweden by creating a tripartite board of employers, employees, and Government representatives, or it could delegate administrative responsibilities to NIOSH, since this would be a research and information dissemination activity. The fund and its research and training projects could exist alongside existing projects and arrangements at OSHA and NIOSH, or Congress could consolidate existing research and training activities (including NIOSH extramural research grants and training grants, OSHA New Directions grants and OSHA-funded consultations) under one umbrella group.

Although such a fund would enhance the commitment to research and training, there are disadvantages to consider—primarily that this represents a new venture, with all the problems that such undertakings incur. Moreover, a new tax or surcharge, even though of modest size, runs against the desire embodied in recent legislation to reduce business taxes.

Option 27: Congress could create an Occupational Safety and Health Fund to *finance research in control technology, training and education, and information dissemination.*

The Needs of Small Businesses

Loans for Compliance With OSHA Standards

Small businesses are often disproportionately burdened by investments required for health and safety protection. Congress recognized this when it passed the OSH Act by also amending the Small Business Act to allow the Small Business Administration (SBA) to make loans for OSHA compliance. Between 1971 and 1981, when Congress eliminated authorization for this program, SBA processed 261 such loans. Now may be a good time to study this program to learn what effect these loans had and why so few were processed. Following such a study, Congress could consider reauthorizing the loan program.

Option 28: Congress might direct OSHA and/or SBA to study the results of SBA loans made for compliance with OSHA standards.

Shared Resources

It is inefficient and impractical to require each small business to provide a full range of health and safety services. Instead, organizations and programs to serve the needs of a number of small businesses in a given area or industrial specialty might be cost effective. Initial funding could come from OSHA or NIOSH, with the hope that these programs would ultimately be self-supporting.

The most difficult part of this option is to design a method to sustain the program after the startup period. Even though shared programs should cost less than if a company were to purchase the services entirely on its own, some small businesses might find the price beyond their means. It is unclear how to aid those companies.

Option 29: Congress might direct NIOSH and OSHA to encourage the development of shared programs to provide industrial hygiene, safety engineering, medical surveillance, and worker health and safety training for small businesses,

Changed Regulatory Approaches

Providing protection against occupational injuries and illnesses in small business establishments presents its own set of problems. It may be cost effective to treat occupational health and safety in such firms in a fashion similar to current regulation of consumer products—by regulating machines and products that small businesses purchase.

Of course, many products purchased by small businesses are also used in larger businesses, whose employees would also benefit from such regulation. An important limitation of this approach is that some occupational hazards are created in the improper installation, use, and maintenance of machines and products. This regulatory approach would have only limited impact on those hazards.

Option 30: *Congress could take actions to improve the safety* of *products used by small business. This might include:*

- *directing NIOSH to conduct tests of products used by small businesses and to publish the results in a form easily available to such establishments;*
- *encouraging OSHA, Consumer Product Safety* Commission, *and EPA regulatory actions concerning the products used by small businesses.*

Establishment of Occupational Medicine Clinics

In the United States, most occupational medicine is practiced in the workplace by physicians employed by industry, especially by large companies.

Changes are apparent, however, as small-and medium-sized companies are making choices between contracting with hospital-based clinics for medical care or maintaining a company medical department. The clinics may grow to fill current voids—servicing industries, regions, and employers where such services are unavailable or deficient. Clinics might, because of a larger patient load and a staff that consequently sees more patients, be able to provide more-knowledgeable care and improved physician training.

The staff of these clinics emphasize that they will provide advice about prevention as well as medical care. The combination of staff physicians, industrial hygienists, and engineers could provide a critical mass for a great deal of important activity in hazard identification and control.

Programs concerned with occupational medicine and prevention should consider and study the choices. They may alter industrial medical care and responsibilities of industry and labor, as well as the relationships between such clinics and the private practice of medicine.

Assessing Health and Safety Programs

A key final component in improving occupational health and safety is evaluating which programs to identify hazards, develop control technologies, disseminate information, and implement controls work and which programs can be improved. Assessing or evaluating efforts in occupational safety is difficult because of the many factors that influence injury rates over time. Some of these may also stymie the evaluation of occupational health activities; more importantly, because of latent periods and difficulties in recognition, it is hard to measure improvements in occupational health.

Congress in the last few years has already indicated a desire for more systematic assessment of Government activities. The Regulatory Flexibility Act of 1980, for example, requires that regulatory agencies, including OSHA, review over a 10-year period all regulations that have a significant impact on small businesses.

This principle of reviewing and analyzing existing programs might be extended to nonregulatory programs. For example, the OSHA New Directions grants program, and the NIOSH training grants programs could be assessed. In addition, periodic assessment could be specified when new programs are established. The principal disadvantage of such a requirement would be the diversion of resources from other important areas, such as hazard identification and research on control techniques.

Option 31: Congress could require periodic assessment of all occupational safety and health programs and provide funds to conduct such assessments.

2.

Data on Occupational Injuries and Illnesses

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Data on Occupation; Injuries and Illnesses

In this chapter, OTA presents a summary of the available statistical information concerning the number and distribution of occupational injuries and illnesses. In general, currently available data describe, with reasonable accuracy, the total number of occupational injuries in U.S. workplaces. For occupational illnesses, however, the data are extremely limited. (A fuller discussion of these topics is found in Working Paper #l of this report.)

SOURCES OF INFORMATION

Prior to the passage of the Occupational Safety and Health (OSH) Act in 1970, occupational injury data collection efforts were limited. One source was a series of surveys by the Bureau of Labor Statistics (BLS). This information was limited by its dependence on voluntary reports from employers, by the particular standard most commonly used for recording occupational injuries, and by incomplete industry coverage by the BLS surveys. One study of data from 1967 and 1968 indicated substantial underreporting of injuries by employers (186), In addition, some limited data were available from the National Safety Council (NSC), state workers' compensation agencies, and employer records. In the OSH Act, Congress called for the creation of a new, mandatory system of data collection.

The system created by the Occupational Safety and Health Administration (OSHA) and BLS requires employees to keep records using a specified format. In addition, BLS conducts annual surveys of a sample of employers. These survey results are used to compute injury and, to a limited extent, illness rates by industry, as well as estimates of the total numbers of fatalities, lost-workday cases, and cases without lost worktime but that involved medical treatment.

The BLS Annual Surveys (604,606-608) are the best source of statistical information concerning work-related injuries. The published data are based on large survey samples, and, within the limitations of the survey methods, appear to be reliable. These estimates, however, are subject to several limitations:

- they are available only since 1972,
- depending on the type of case, they cover only two-thirds to three-fourths of the U.S. work force,
- they are based on a survey that is administered only once a year, and
- they provide very little detail concerning the nature and causes of occupational injuries.

A possible fifth limitation is that these estimates are ultimately based on employer records of injuries and illnesses. (The extent of this possible bias is discussed below and in Working Paper #l.)

Nothing can now be done about the first limitation. The second and third could be improved, but these would involve changes in methods and perhaps require greater resources. To address the fourth limitation, BLS has initiated two additional data collection efforts. Since 1976, the Bureau has compiled information provided by 26 to 36 state workers' compensation agencies, in a data base known as the Supplementary Data System (SDS) (397). And since 1978, BLS has conducted a series of surveys of injured workers concerning specific types of occupational injuries, published as Work Injury Reports (599-601,603,605).

Two other Federal systems provide injury data. The National Health Interview Survey (NHIS) of the National Center for Health Statistics (NCHS) collects information during household interviews. A system recently developed by the National Institute for Occupational Safety and Health (NIOSH) uses information from hospital emergency room admissions to produce information on occupational injuries. Finally, OSHA has published analyses of several different types of fatal injuries using information collected during accident investigations.

OCCUPATIONAL INJURIES

Fatal Injuries

As discussed in Working Paper #l, for the last five years, data from the BLS Annual Surveys indicate that between 3,000 and 5,000 occupational fatalities occurred each year in private sector establishments with 11 or more employees. About 1,000 deaths occur in private sector establishments with fewer than 11 employees. The NSC figures range between 11,000 and 13,500 for the entire workforce. Applying a variety of assumptions to data derived from death certificates yields a range of estimates from 5,500 to 11,000 for the entire workforce for 1977. OSHA inspection data suggest that at least 4,500 occupational fatalities occurred in the private sector workforce in fiscal year 1982.

The Annual Surveys conducted by BLS are the best source of statistical information on occupational injuries. They use a large survey sample that is capable of directly measuring the occurrence of injuries. However, because this sample covers only private sector employment (the self-employed and public sector employees are excluded), an adjustment must be made to generate an estimate for the entire workforce.

OTA used two similar methods, both based on the BLS data, to develop its estimate of the number of occupational fatalities due to injuries. The first estimate uses the five-year average of the number of fatalities in establishments with 11 or more employees. For 1979 to 1983, this equals about 4,180. Approximately 11 percent of these are due to heart attacks. Subtracting these yields a total of 3,720 deaths due to injury (see table 2-1). To this should be added the five-year average from the BLS Annual Survey of deaths in establishments with fewer than 11 employees. For 1979 to 1983, after adjusting for heart attacks, this was 930. Thus, the total from the BLS Annual Survey is 4,650.

To this should be added the deaths among the self-employed and public employees. Applying the death rates for private sector workers, adjusted for heart attacks, to these workers yields a five-year average of 1,640. Adding this to the 4,650 generated directly by the Annual Survey yields a total of about 6,300 deaths.

Table 2-1.—Annual Occupational Fatalities From Injuries, Summary of Estimates

Universe	Years	Average annual total	Source of estimate or data
All employment	1979-83	12,200	NSC
All employment	1979-83	6,000	OTA[a]
Private sector workplaces with 11 + employees	1979-83	3,720	BLS
Private sector workplaces with 1-10 employees	1979-83	930[c]	BLS

[a]Estimate is based on BLS and OSHA data and is described in the text
[b]4,180 minus 11 percent of deaths reported as heart attacks (460).
[c]1,040 minus 11 percent of deaths reported as heart attacks. (110).
NOTE: Because of differing methods and definitions, some of these estimates are, strictly speaking, not directly comparable with each other.

SOURCE: Office of Technology Assessment.

Alternatively, the BLS figures for establishments with 11 or more employees for each individual year can be adjusted by applying the private-sector death rate (for injuries in establishments with 11 or more employees) to the workers excluded completely (self-employed and public employees) or for which *annual* estimates are not available (small, private sector establishments). Using this method, the total ranges from 7,265 in *1979* to *4,600* in 1983, with an average of 6,180 deaths per year.

Rounding either of these estimates to the nearest thousand yields OTA's estimate that about 6,000 deaths due to occupational injuries occur each year. The National Safety Council average of 12,200 is considerably higher. It is difficult if not impossible, to reconcile the estimates from the BLS and the NSC. The published data from state vital statistics are insufficient to do so (see Working Paper #l). Moreover, the NSC estimates have been criticized in the past for including duplicate reports and deaths from previous years and for not being based on the results of a probability survey. Instead they are developed using the results of special studies in combination with a variety of statistics from several sources. These methods may not generate reliable estimates, either for a particular year or over time.

OTA's estimate of **6,000** injury deaths per year translates into about 25 occupation] fatalities each working day. Rarely, however, does this daily toll occur at the same time, in the same workplace. Usually, occupational deaths occur one or two at a time in widely scattered workplaces. Because of this, occupational fatalities only rarely receive significant publicity.

Motor vehicles *(30* to *40* percent), off-the-road industrial vehicles (10 percent), and falls *(10* percent) are associated with over half of the fatal occupational injuries. In addition, occupational fatalities are unevenly spread among industries. Table 2-2 presents fatality rates for the major industry divisions in the private sector. Mining, with a fatality rate of 44.3 per 100,000 full-time workers, is the most hazardous industry. Construction; agriculture, forestry, and fishing; and the transportation and public utility industries also present above-average risks of deaths due to injury. Manufacturing has a death rate below the average for the private sector, although it has a nonfatal injury rate substantially above the average. Wholesale and retail trade; services; and finance, insurance, and real estate are safer industries, with fatality rates between *2.5* and *3.8* deaths per 100,000 workers.

Table 2.2.—Occupational Fatality Rates[a] By Industry for 1982

Industry division	Rate[b]
Mining	44.3
Construction	28.7
Agriculture, forestry, and fishing	28.4
Transportation and public utilities	21.9
Average of private sector	7.4
Manufacturing	4.5
Wholesale and retail trade	3.8
Services	3.5
Finance, insurance, and real estate	2.5

[a]For establishments with 11 or more employees Includes fatal injuries and reported deaths due to illness.
[b]Fatalities per 100,000 full-time workers

SOURCE: (608)

Nonfatal Injuries

Table 2-3 summarizes the estimates of the numbers of occupational injuries. These estimates vary partly because of differences in the definitions of injuries, the population universes, and methods of estimation.

NSC defines a disabling injury as one that involves one or more days away from work, some form of permanent impairment, or death. For BLS and OSHA, a lost-workday injury is one that involves the employee either not working at all for one or more days beyond the day of the injury or reporting to work and being assigned to a "lighter duty" job (restricted work activity).

Combining the BLS estimate of lost-workday injuries (2.1 million in both 1982 and 1983) in the private sector with the estimates for Federal, State, and local employees (0.1 and *0.3* million) yields a total of 2.5 million lost-workday injuries. This compares to the NSC estimate of 1.9 million "disabling" injuries. Using the total of 2.5 million injuries, it appears that each working day results in about 10,000 injuries that are serious enough to lead to loss of worktime.

Table 2-3.—Annual Nonfatal Occupational Injuries, Summary of Estimates

Definition	Universe	Year	Estimate (millions)	Source of estimate or data
Lost-workday cases	All private sector workplaces	1983	2.1	BLS
Lost-workday cases	U.S. Government—civilian and personnel	1982	0.1	OSHA
Lost-workday cases	State and local government	1982	0.3	SDS[a]
"Disabling"	All employment	1983	1.9	NSC
Total "recordable"	All private sector workplaces	1983	4.7	BLS
Total "recordable"	U.S. Government—civilian and personnel	1982	0.2	OSHA
Total "recordable"	State and local government	1982	0.7	SDS[a]
Medically attended or activity restricted	All employment	1981	11.3	NHIS
Treated in emergency rooms	All employment	1982	3.2	NIOSH

[a]Estimate Is based on data from SDS and Annual Survey and Is described in Working Paper #1.
NOTE: Because of differing methods and definitions, some of these estimates are, strictly speaking, not directly comparable with each other
SOURCE' Office of Technology Assessment

The BLS/OSHA definition of "recordable" injury includes all lost-workday injuries plus all those that involve medical treatment beyond first aid. The National Health Interview Survey includes all injuries that are "medically attended" (which may involve only a consultation with a doctor) or cause "restricted activity," whether or not that also involves lost worktime. Data developed by NIOSH through the National Electronic Injury Surveillance System (NEISS) include all cases treated in hospital emergency rooms.

These various sources again yield differing estimates. The sum of BLS data and the Federal, State, and local government estimates is 5.7 million recordable cases in 1982. The number of private sector injuries went down slightly in 1983, Assuming that the number of public sector injuries stayed the same (0.9 million), the sum of the BLS and public sector estimates would be 5.6 million in 1983. The NHIS estimates 11.3 million cases. This translates into a range of between 22,000 and 45,000 injuries each working day. And the NIOSH estimate of the number of emergency room cases, based on the NIESS data, is 3.2 million cases or about 12,000 cases per day.

The largest difference in these figures is between the combined BLS and public sector estimate (5.6 million cases) and the National Health Interview Survey (11.3 million). Most of this difference remains even when data from the same year are used. The 1981 BLS and public sector estimate is a total of about 6 million cases.

The NHIS includes self-employed persons, but it is unlikely that approximately 8.7 million self-employed workers can account for the remaining 5.3 million injuries. It could be that the slightly different definitions of the BLS Annual Survey and the NHIS contribute to this discrepancy. It is also possible that employees and their families are reporting to the NHIS injuries that are not recorded by employers. A number of reasons could account for employers not recording an injury: an employee may not have reported it to the employer; the employer judged the injury to be a "'first aid only" case that is not required to be recorded; or the employer's records are not accurate and comprehensive.

The NEISS estimate of emergency room cases could be consistent with either the BLS estimate or the NHIS figure. The 3.2 million emergency room cases (in 1982) would constitute about 55 percent of the 5.7 million cases in the private and public sectors from (the 1982) BLS and government reports or about 30 percent of the 11.3 million cases estimated by the NHIS. The figure of 30 percent is roughly consistent with a special study of data from 1975, which estimated that about 36 percent of all injuries occurring "at job or business" were medically attended at emergency rooms (388).

Table 2-4 summarizes various estimates of the amount of time lost due to nonfatal occupational injuries, including lost worktime, bed disability, and restrictions on daily activity. The BLS esti-

Table 2-4.—Days Lost Annually From Occupational Injuries, Summary of Estimates

Definition	Universe	Year	Estimate (millions)	Source of estimate or data
Lost workdays	All private sector workplaces	1983	36.4	BLS
Lost workdays	U.S. Government—civilian and personnel	1982	1,2	OSHA
Lost workdays	All employment	1981	60-70'	OTA
Bed disability days	All employment	1981	**44.0**	**NHIS**
Restricted activity days	**All employment**	**1981**	**214.9**	**NHIS**

[a]OTA estimate is based on data from NHIS and is described in Working Paper #1
NOTE Because of differing methods and definitions, some of these estimates are, strictly speaking, not directly comparable with each other
SOURCE Off Ice of Technology Assessment

mate of days away from work and of restricted work activity ("light duty") equals *36.4* million days—the equivalent of over 140,000 people working full-time for a year. Time lost by Federal civilian employees adds about 1.2 million days to this total. No estimates for State and local employees or for the self-employed are directly available.

A higher total of about *60-70* million "'lost workdays" can be indirectly estimated using the results of a special NCHS analysis of injuries. Part of the reason for the higher figure is that this estimate should cover the entire work force. In addition, the varying definitions and survey methods between the BLS and the NHIS may contribute to the difference. The NHIS also provides data on bed disability (44 million days) and of days of restricted daily activity (close to 215 million days).

The BLS figures imply that about 1 in 13 U.S. workers suffered an occupational injury in *1982.* Nearly half of these were serious enough to result in the employee missing one or more days of work beyond the day of the injury, On average each lost-workday injury results in 17 days lost from work. The NSC has estimated that the direct and indirect costs of work injuries totaled *$30.2* billion in 1980 (324),

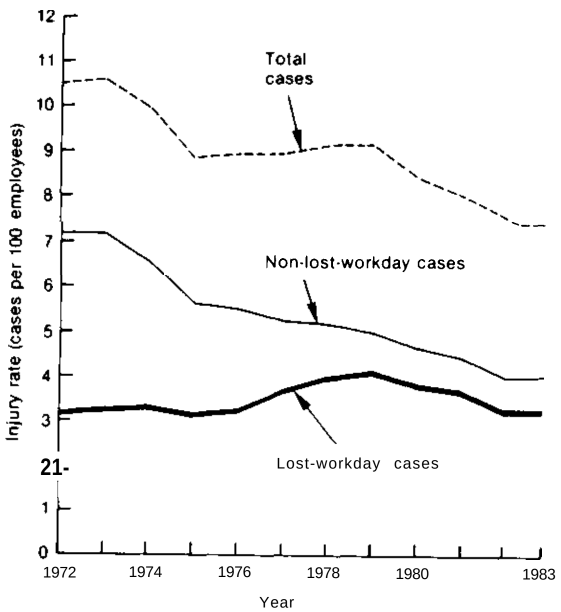
Trends in Injury Rates

It is probable that occupational injury rates have fallen since the turn of this century. The data published by the NSC support this, but these data may not be accurate or reliable. In particular, recent trends in the NSC data are inconsistent with data collected from other sources. However, accounts of working conditions earlier in this century reveal many instances of job hazards that are considered appalling by today's standards. Many of these have been improved, and injury rates have fallen. (Of course, this decline in injury rates may not apply to occupational *illness* rates.)

Trends over the last two decades have not been constant from year to year and measures of different types of injuries sometimes go in different directions. During the 1960s, the BLS surveys of manufacturing showed rising injury rates. The BLS Annual Surveys from the 1970s show a relatively large drop in *non-lost-workday injuries* from 1972 to 1975, and then a continuing decline from 1975 to 1983. The BLS *lost-workday case* rate rose during most of the 1970s, falling only between 1974 and 1975 and for the three years after 1979 (fig. 2-1). The BLS *total case* rate, which combines the non-lost-workday and lost-workday cases, shows a slight rise from 1972 to 1973, and then a decline from 1973 to 1975. This rate then began a slight rising trend until its peak in 1979. By 1982, the total case rate had declined to 7.7 per 100 workers. This decline continued in 1983, **when the total case rate** was 7.6 per 100 workers. This is the lowest level reported since 1972, when these data were first collected. *Fatality* rates calculated from the BLS estimates show a general decline through the 1970s. *Injury* rates calculated from the National Health Interview Study show no readily apparent trend from 1962 to 1981, possibly because of the relatively larger sampling error for this survey.

Injury and fatality rates are affected by a number of factors. These include the effects of the busi-

Figure 2.1.-Occupational Injury Rates, 1972.83



ness cycle, various changes in the administration of workers' compensation, the practice of occupational medicine, 'and other socioeconomic factors. In addition, OSHA and NIOSH and other safety and health programs may have contributed to changes in rates. But the effects of OSHA activities, in particular, may be difficult to discern in national injury trends because of the low probabilities of OSHA inspections, the relatively low penalties for violations of standards, and the possibility of differential effects on various types of hazards. There may also be variations in the effectiveness among the *24* separate State programs and Federal OSHA operations, which cannot be detected using national data.

Injury Rate Trends, the Business Cycle, and OSHA Policies

The lack of any dramatic improvements in injury rates during the 1970s has been cited to support the belief that OSHA has been ineffective. More recently, it has been claimed that the recent declines in the injury rates resulted from the current administration's "cooperative, non-adversary approach to job safety and health" *(643,644,650).* Although it is possible that some of the decline can be explained by these changes, several other features must also be considered.

First, as figure 2-1 shows, the decline in injury rates started in 1980—before the changes in OSHA policies that were instituted in *1981.* Moreover, the installation of controls, changes in employee training, etc., often take place over several years. Thus it is possible that the observed changes from 1979 to 1983 represent the effects of some combination of the policies of the "old" and the "'new" OSHA. Second, the new policy that targets inspections on the basis of injury records may influence employer recordkeeping toward undercounting. Independent verification of employer injury records is necessary to assess the possible impact on changes in employer recordkeeping. Third, as mentioned above, a number of factors besides the effectiveness of OSHA can influence injury-rate trends.

Foremost among the factors influencing injury statistics is the business cycle. Since the 1930s researchers have noted that, other things being equal, increased business activity leads to higher injury rates while decreased activity lowers rates. The general explanation for this phenomenon is that as business picks up, employers hire more young and inexperienced workers. Both younger workers and inexperienced workers of all ages tend to have higher injury rates than older, more experienced workers. Moreover, as production expands, businesses open new plants and bring new machinery on-line. For both of these cases there may be a period of adjustment as management and workers learn how to use the machinery safely. In addition, during a business upturn there will be increases in the pace of production, increases in the amount of overtime worked, less down time, and less time devoted to repair and maintenance, all of which lead to increases in accidents. During business downturns, all of these elements are reversed-younger and less experienced workers are laid off while older and more experienced employees are retained, plant operations slow down, and more effort is devoted to repair and maintenance (254,444).

OTA has compared injury rates with several measures of the business cycle. Figure 2-2 shows data for the BLS total recordable injury rate and

Figure 2.2.—Injury Rates and Unemployment—Private Sector: 1972.83

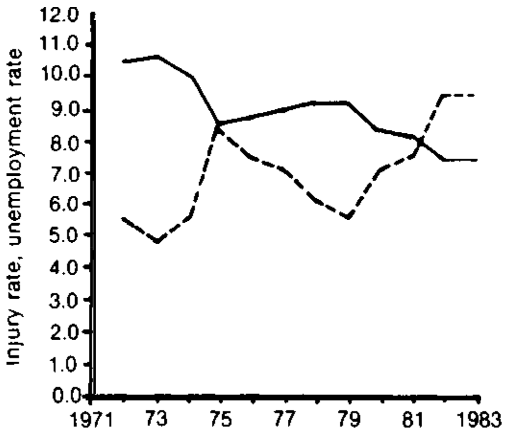


Figure 2-3.–Injury Rates and Unemployment-Private Sector: 1972-83

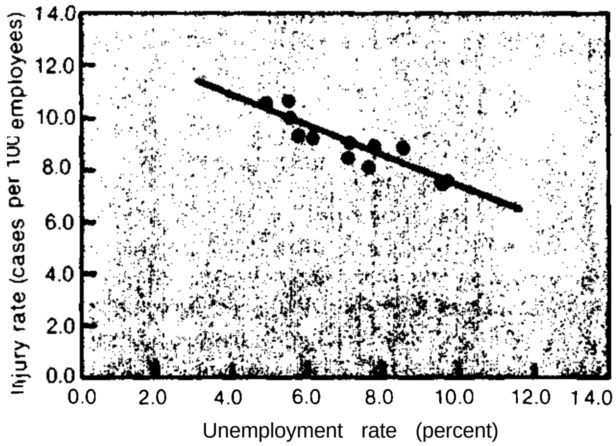
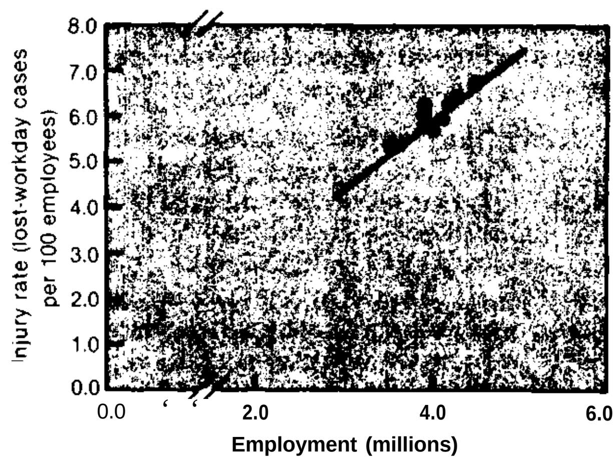


Figure 2.4.—Lost-Workday Rate and Employment—Construction: 1972.83



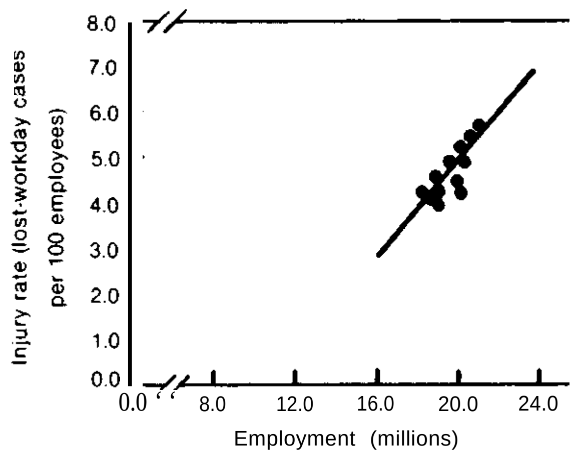
the unemployment rate for 1972 to 1983. The total recordable injury rate declined from 1973 to 1975 and again from 1979 to 1982, simultaneously with rising unemployment rates. In addition, the rising injury rates from 1975 to 1979 coincided with declining unemployment rates. From 1982 to 1983, the total injury rate and unemployment went down slightly, while the lost workday rate stayed the same.

In figure 2-3, these two variables have been plotted against each other, with the unemployment rate on the horizontal (or x-axis) and the injury rate on the vertical (or y-axis). Examination of this figure reveals an apparent inverse relationship between injury rates and unemployment. That is, as unemployment rises in a recession, injury rates decline.

Another possible measure of the business cycle is to examine the level of employment, as opposed to the unemployment rate. This must be done carefully because in the last few years, the changes in the level of employment have not been the same in all industries. In fact, from 1979 to 1982, employment in the more hazardous manufacturing and construction industries declined, while employment in the other major private sector industry groups has stayed the same or increased. Figures 2-4 and *2-5* show the relationship between employment and lost-workday injury rates in construction and manufacturing alone. Again there appears to be a close relationship. As employment rises, so do injury rates.

OSHA has suggested to OTA that the recent injury rate declines are not the result of the current recession because "BLS has estimated that only 16 percent of the decline in injury rates in 1982 can be attributed to a disproportionate drop in hours worked in high-risk industries" (34). BLS, however, noted that the procedure they used for this calculation, "does not take into account . . . other factors which may also affect the rate, but

Figure 2.5. -Lost. Workday Rate and Employment—
Manufacturing: 1972-83



which have not been measured, such as the demographic composition of the workforce, worker education, improved safety measures, the role of State and Federal agency compliance programs, technological change, etc" (607).

But the "demographic composition of the workforce" and "technological change" are two variables that are particularly affected by the business cycle. In addition, the amount of overtime worked, the pace of production, and the rate of new hires are affected by the business cycle. The BLS procedure for calculating the effects of the decline in hours worked may not fully capture the effects of these other variables on injury rates.

Additional analysis using variables that directly measure the new hire rate, the number of overtime hours, the rate of production, and capacity utilization in specific industries may clarify this relationship further. (Examination of the influence of new hires is, however, made more difficult because BLS no longer publishes statistics on labor turnover, which included the new hire rate.) But at present, it appears that the effect of the recent recession, especially in construction and manufacturing, is the most important factor behind the injury rate declines from *1979* to 1983. In addition, it appears that national injury rates since 1972 have been largely related to the level of business activity.

When the OSH Act was enacted in *1970,* Congress placed the legal responsibility for preventing occupational injuries and illnesses with employers and created several agencies, including NIOSH and OSHA, to conduct research and administer regulations. Employees, of course, also have a personal stake in preventing disease and injury in the workplace. Some detailed studies on the effectiveness of OSHA in improving the efforts of employers and employees have found a favorable but small impact, while other studies have not found any effect (see ch, 13 for a summary). Even the favorable effects detected in several studies may not be large enough to be discerned in national injury statistics, while shifts in the nature of the injury rate-business cycle relationship may be difficult to detect. However, it is clear that if any improvements have been made they have not been large.

Accuracy of Occupation Injury Estimates

Questions raised about the accuracy of estimates based on employer-maintained injury records have intensified with the current administration's inspection targeting system. OTA has conducted a limited comparison of data from the BLS Annual Survey and from the BLS Supplementary Data System (SDS) to see if they are consistent. Data were available only for years *before* the implementation of the new inspection targeting system and the conclusions of this analysis, therefore, apply just to that period.

Some States participating in the SDS report only lost-workday cases while others report all cases involving either lost workdays or medical treatment. OTA found that for States reporting only lost-workday cases to the SDS, the numbers of cases were not consistently higher or lower from either SDS or the Annual Survey, after adjusting for the minimum waiting periods (as defined by State workers' compensation). Although there were some differences between these two data sources, these differences were not consistent from one State to the next. In States that report all cases involving either lost workdays or medical treatment to the SDS, consistently more cases were reported to the SDS than would be expected from the Annual Survey data.

In another analysis, OTA compared BLS Annual Survey injury rates with rates calculated from the estimates of the NHIS. This analysis compared information derived from employer records (BLS) with that from workers and their families (NHIS). This comparison showed that, in recent years, overall injury rates based on the NHIS are about one-third higher than those from the BLS Annual Survey.

Differences among the various sources could arise from different methodologies and, as such, may not be worrisome. Or it could be that employers do not report certain types of injuries to the BLS Annual Survey even though they do submit reports to workers' compensation. As discussed above, the differences between the BLS Annual Survey and the NHIS may also stem from employers labeling some injuries as cases involving only first-aid treatment, even though employees and other family members consider them serious enough to report to the NHIS.

OCCUPATIONAL ILLNESSES

There is substantially less quantitative information on occupational illnesses than on injuries. Although employers are required to include occupational illnesses in their records, it is well accepted that employer records and the BLS Annual Survey estimates, which are based on employer records, underestimate the magnitude of the occupational disease problem. This *is* because many occupational diseases are indistinguishable from non-occupational diseases, because they often become manifest only after a latent period, and because of a general lack of recognition of the occupational causes of many diseases. For 1983, the BLS Annual Survey estimate is about 106,000 occupational illnesses, but that is almost certainly an underestimate.

The most commonly quoted estimates are that up to 100,000 deaths due to illness and 390,000 illness cases occur each year as a result of workplace conditions. Although the estimate of 390,000 cases was cited during the Congressional debates about the Occupational Safety and Health Act, OTA has not been able to determine the exact methods for deriving this estimate.

The estimate of 100,000 deaths was derived first by a crude technique using the results of three epidemiologic studies and later by an analysis of information in a 1951 British death registry. As a result, the 100, 000-deaths figure can only be considered an estimate, but it is unclear to what extent the figure is biased. Peter Barth and Allen Hunt (46) have reported other estimates that range from 10,000 deaths to 210,000 deaths. More accurate estimates are difficult because of a general lack of information on both historical and current worker exposures, incomplete knowledge of the deleterious effects of workplace exposures, and the general problems of assigning single "causes" to diseases created by multiple factors.

Although it is well accepted that employer records understate the magnitude of the occupational illness problem, it is very difficult to quantify the extent of this understatement. One pilot study, conducted by David Discher and colleagues (143), explored the usefulness of medical examinations and industrial hygiene surveys for identifying the extent of occupational illness in several industries. The researchers administered medical exams to workers in four industries, conducted industrial hygiene surveys, and classified a total of 451 medical conditions among the surveyed workers as probably linked to occupational exposures. Eighty-nine percent of these 451 conditions were not noted in either the workers' compensation claims or the employers' logs. Although this percentage of non-reporting may not be applicable to all workplaces, this study did reveal a large number of cases that were not being recognized by employers and were thus not recorded.

It is also interesting to note that the BLS Supplementary Data System reported only 234 workers' compensation cases for all cancers in 1980. This can be compared to the range of estimates for occupational cancer caused by asbestos alone, which is between 4,000 and 12,000 cases annually. Even if the SDS total is adjusted for all the states that do not currently report to the SDS, there appears to be substantial underreporting of cancer cases to workers' compensation programs.

The absence of an accurate accounting of the occupational disease toll highlights the need for accurate and comprehensive information on employee exposures, both to provide a basis for more accurate disease estimates and to measure the effectiveness of current occupational health efforts. The NIOSH National Occupational Hazard Survey (564,565,566) and National Occupational Exposure Survey can provide information on the number of employees potentially exposed to hazardous substances, but they do not provide any information on the level of exposure and only limited information on the duration of exposure. Although it may be possible to use the data collected by OSHA during inspections to develop estimates of worker exposures, such analysis depends on further research.

CONCLUSION

OTA estimates that about *6,000* U.S. workers die each year from occupational injuries, or about *25* each working day. In addition, each working day there are at least 10,000 injuries that result in lost worktime, and about 45,000 that result in restricted activity or that require medical attention. Estimates of the number of nonfatal injuries vary partly because of differences in the definitions of injuries, the population universes, and methods of estimation. Some discrepancies may also be due to differences in how employers and employees interpret the severity of an injury.

Injury and fatality rates are affected by a number of factors. These include the effects of the business cycle, and various changes in the administration of workers' compensation, the practice of occupational medicine, and other socioeconomic factors, as well as the possible effectiveness of OSHA in reducing injury frequency and severity.

OTA finds that the effect of the recent recession, especially in construction and manufacturing, is the most important factor behind the injury rate declines from 1979 to 1983, In addition, it appears that most of the changes in national injury rates since 1972 are associated with changes in business activity.

Compared with occupational injuries, there is substantially less quantitative information on occupational illnesses, Although employers are required to include occupational illnesses in their records, it is well accepted that employer records underestimate the magnitude of the occupational disease problem. However, it is difficult to quantify the extent of this understatement.

3.

Health Hazard Identification

Contents

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3. Health Hazard Identification

Since work occupies a central place in most lives, it is not surprising that it is related to many afflictions, nor that in one form or another it contributes to diseases of every system of the body.

Some diseases are relatively easily linked to workplace conditions, either because the diseases themselves are distinct or relatively rare, or because the particular workplace conditions differ greatly from ordinary conditions of daily life. Other diseases are associated with either the workplace or other activities, or with both; pinning down causes and preventive strategies of those diseases is more complicated.

Occupational diseases have been recognized for centuries, although definitions of disease and ill health have changed over time. Society—less willing to accept adverse effects of any kind and knowing that much disease is preventable—no longer believes poor health to be a necessary concomitant of work.

While attention often focuses on new hazards, and in identifying and preventing more subtle, previously unnoticed effects, professionals in occupational safety and health also continue to deal with many cases of well-known occupational diseases. The still-frequent occurrence of many of these older diseases represents a failure to use already available knowledge.

Health hazards include those identified as present in the workplace, those present but unidentified, and new hazards, not yet introduced there. The identified hazards include exposures to physical agents such as radiation and noise, and exposures to some substances, including chemicals, metals, minerals, and vegetable dusts. Present, unidentified hazards may be many or few. Continued observation of workers and testing of substances are necessary to determine what exposures are hazardous. Testing of new substances should reduce the number of hazards introduced unknowingly into the workplace.

Traditionally, physicians and groups of workers have been the sources of information leading to the association of particular hazards with disease. "Factory fever" (typhus), "mad hatters" (victims of mercury poisoning), and "wrist drop" (lead poisoning) were related to workplace exposures through observation. Recent years have seen increasing importance being given to epidemiology—the study of the distribution of diseases—and toxicology— the study of the dangerous properties of substances—in identifying workplace hazards.

Case reports from doctors, workers, and employers can be valuable sources of information on hazards and serve to generate hypotheses for larger studies. But inadequacies in the training of physicians, both those who practice occupational medicine and those in general practice, limit identification hazards through case reports.

Epidemiology relies on observations or suggestions of possible associations between exposures or behaviors and disease for hypothesis generation. It has limitations in the kinds and magnitudes of effects it can detect, but it can provide the most convincing evidence of associations between exposures and behaviors and health. The strengths of epidemiology still remain to be exploited, and much remains to be learned about diseases and syndromes that are widespread in the population.

Toxicology can garner useful information about the possible effects of substances, but large toxicologic studies are expensive, require years to complete, and produce information that is sometimes difficult to apply to human exposures. Making risk assessments from animal data involves both technical problems and assumptions. Although continued attention to toxicology and risk assessment may reduce technical controversies, the assumptions about the predictive value of various tests are likely to remain in dispute.

Epidemiology and toxicology have not been the panacea for solving workplace health problems that some envisioned. The limitations of both argue for a continuing role for occupational medicine in hazard recognition as well as treating workers. That role can be enhanced during the education of physicians.

Computerized information about workplace exposures and workers' health forms the basis for surveillance systems that aim to identify health hazards. Occupational health surveillance is the source of both great promise and great controversy. It can be used to identify the causes of occupational illness, setting the stage for preventing further illness. But there are practical difficulties in implementing systems that will be statistically useful, concerns about company liabilities after discovering a possible relationship, and concerns that efforts will be made to substitute surveillance activities for preventive efforts and installation of appropriate controls.

OCCUPATIONAL DISEASE

Some diseases are always or nearly always caused by conditions at work. These diseases represent relatively easy cases for health and safety professionals because they can be readily linked to particular working conditions. In general, identification of workplace hazards is facilitated by:

- conditions at work that differ greatly from the normal conditions of daily life, and
- the presence of distinctive or very rare diseases in these exposed workers.

Examples from the early part of this century are the occurrence of "phossy jaw" among phosphorus match workers, the diseases of radium dial painters, and "wrist drop" caused by lead poisoning among adult workers. More recently, mesothelioma and liver angiosarcoma both occur so rarely in the nonexposed population that when cases were observed among asbestos and vinyl chloride workers, respectively, questions of occupational causation were immediately raised and relatively quickly answered.

But relationships between work and diseases are not always so clear-cut. In fact, it is probably more frequent that working conditions directly cause or contribute to diseases that are also related to other human activities. In other words, workplace exposures c ause workers to suffer an *increased incidence* of disease, even though these diseases also regu arly occur in the general population.

For example, most lung cancer occurs in smokers, and it is accepted that there is a causal relationship between cigarettes and lung cancer. Some substances encountered in the workplace are also known lung carcinogens because they increase the occurrence of lung cancer in nonsmokers as well as in smokers. In addition, smoking and other carcinogens may also act together to cause cancer. However, deciding which exposure(s) caused lung cancer in a particular smoking worker is a difficult task.

Hazards that increase the incidence of common diseases can be best identified using the techniques of epidemiology. But even after studies have shown a link between exposures and increased disease incidence for a *group* of workers, it often remains impossible to determine, for any *individual* worker, that his or her disease was caused by occupational exposures.

MAJOR CLASSES OF OCCUPATIONAL DISEASES

Occupational diseases have been recognized as such for centuries. References to almost all classes and types of diseases appear in the works of Ramazzini, the 18th-century physician often called the father of occupational medicine. Since then, the definition of disease in general has changed, as has the perception of work-relatedness. Society is less willing to accept adverse effects of any kind. Because so much disease is known to be preventable, poor health is no longer taken as a concomitant of certain occupations. Our increasing ability to detect subtle effects allows us to broaden our efforts in prevention.

There is something seductive about new risks, and a tendency to focus on new hazards. Although in one sense occupational health is dealing with new and ever-subtler effects, the old diseases are still around, in greater numbers than is generally perceived. In **1979,** an estimated **84,000** active workers suffered from acute byssinosis and at least 35,000 employed or retired workers were disabled from cotton dust-related disease. In 1978, an estimated 59,000 workers were thought to suffer from silicosis. Even as new and perhaps scientifically and medically more intriguing conditions become issues in occupational health, the old problems require continued vigilance.

To guide its research priorities, the National Institute for Occupational Safety and Health (NIOSH) has developed a list of 10 groups of occupational diseases (table 3-1). Although termed the "Ten Leading" work-related diseases, the list includes nearly all categories of health effects that have ever been linked to workplace conditions.

Six of the categories of diseases listed by NIOSH are discussed in this chapter. Traumatic injuries are the subject of the next chapter, and noise-induced hearing loss is discussed in chapter 8. The reader is referred to the recent textbooks by Levy and Wegman **(269)** and Rem, et al. **(396),** for details of disease and hazard identification.

Respiratory Disorders

The lungs and other parts of the respiratory tract come in contact with all manner of airborne materials in the workplace. Gases, vapors, fumes, fibers, and particles all may be inhaled, Of all health effects, occupationally related cancers of the respiratory tract receive the greatest attention, but they are not the only serious respiratory conditions associated with the workplace, and certainly not the most widespread. Other responses of the respiratory system may be acute irritation, immunologic or allergic reactions, or chronic changes in the tissues that line the respiratory

Table 3.1 .—The Ten Leading Work-Related Diseases and Injuries: United States, 1982[a]

Type of disorder/inju"~	Exam Dies
1 Occupational lung diseases	asbestos is, byssinosis, silicosis, coal workers' pneumoconiosis, lung cancer, occupational asthma
2 Musculosketal injuries	disorders of the back, trunk, upper extremity, neck, lower extremity; traumatically induced Raynaud's phenomenon
3, Occupational cancers (other than lung)	leukemia, mesothelioma; cancers of the bladder, nose, and liver
4. Amputations, fractures, eye loss, lacerations, and traumatic deaths	—
5. Cardiovascular diseases	hypertension, coronary artery disease, acute myocardial infarction
6 Disorders of reproduction	infertility, spontaneous abortion, teratogenesis
7, Neurotoxic disorders	peripheral neuropathy, toxic encephalitis, psychoses, extreme personality changes (exposure-related)
8, Notse-induced loss of hearing	—
9. Dermatologic conditions	dermatosis, burns (scaldings), chemical burns, contusions (abrasions)
10, Psychologic disorders	neuroses, personality disorders, alcoholism, drug dependency

'The conditions l isted u rider each category are to be viewed as *selected* examples, not comprehensive defin It lons of the category

SOURCE (563)

tract. Some conditions that begin as acute problems progress to chronic states, perhaps the best known being byssinosis–or "brown lung" disease.

NIOSH has made formal recommendations for maximum exposure levels to 60 substances, based on their effects on the respiratory system. That number is greater than the substances cited for any other organ system.

Chronic Conditions

The most serious conditions are pneumoconioses, chronic conditions occurring generally after years of exposure to very fine dusts. The tissue reacts by thickening, producing a condition called "pulmonary fibrosis. " The best known pneumoconioses are asbestosis, silicosis, and coal workers' pneumoconiosis ("black lung"), but similar conditions may be produced by a number of different materials, such as talc and kaolin. Pneumoconioses are characterized by coughing and shortness of breath, which grow worse over time, followed in the later stages by signs of heart failure and eventually ending in death.

Chronic bronchitis can be caused by a number of occupational hazards but, as the commonest chronic response of the respiratory tract, is also brought on by nonoccupational causes. It may also be multicausal, as many diseases are, with nonoccupational factors (particularly cigarette smoking) interacting with occupational exposures to cause disease.

Emphysema is another chronic condition in response to many different stimuli. Though there are undoubtedly cases of occupational origin, few convincing, direct correlations between workplace exposures and this disease are known.

Beryllium disease (berylliosis) is an example of granuloma formation in response to foreign bodies in the lungs. Granulomas form when body cells responding to an "inciting agent" become surrounded by bundles of collagen (a type of connective tissue).

Acute Conditions

Inflammations and irritations of the tissues lining the respiratory tract occur in response to many inhaled substances. The upper respiratory tract—the nose, throat, and larynx-is the most frequent site of irritation, It is susceptible to highly soluble irritants, such as ammonia, hydrogen chloride, and hydrogen fluoride-gases commonly encountered in industry.

Irritants that are less soluble tend to travel farther down the respiratory tract before they are absorbed entirely, causing irritation in the middle as well as the upper respiratory tract. Chlorine, fluorine, and sulfur dioxide, all commonly used chemicals, have such properties, The major effect on the lungs is bronchoconstriction.

Irritants of low volubility may cause only minor upper respiratory tract problems, but their delayed reaction deep in the lungs, which may occur as much **as** a day later, can be very serious. Ozone, oxides of nitrogen, and phosgene—again, commonly encountered in workplaces—are the most important hazards in this class.

Asthma and "hypersensitivity pneumonitis" are two manifestations of immunologic or allergic type reactions. Bronchial asthma, a condition affecting perhaps 4 percent of the U.S. population, is also prevalent among certain occupational groups. Asthma is a generalized obstruction of the airways in an allergic type of response to some substance. Causes can be of bacterial or animal (e.g., animal dander, small insects, bee toxin) or plant (e.g., flour, grain dust, fungi, cotton, flax, tea fluff, wood dusts) or chemical (e.g., formaldehyde, certain pesticides, some metals, some acids) origin. Often the condition develops only after a period of sensitization, and for some agents, very high percentages of those exposed become sensitized. It has been reported that nearly all workers in power plants along the Mississippi River become sensitized to river flies *(396).*

The causes of hypersensitivity pneumonitis include a variety of organic materials, commonly fungi or bacteria. Beginning with coughing, but without the wheezing associated with asthma, these disorders can become chronic and disabling. Such conditions as "farmer's lung, " "mushroom picker's lung, " "cheese washer's lung, " and "paprika splitter's lung" fall into this category.

Byssinosis deserves particular recognition. (For further discussion of this disease, see ch. 5.) Though it has been known in some sense as a disease associated with cotton and other textile fibers for hundreds of years, it was ignored as an occupational disease in this country until fairly recently. The disease begins with tightness in the chest and a decrease in lung capacity upon exposure. The condition is most severe on Monday mornings. Over a period of years, chronic obstructive lung disease may develop, partially or totally disabling the worker. The earlier stages of the disease are thought to be reversible, but the later stages are not. The exact etiologic agent of byssinosis is not known, but various chemicals and organic substances have been suggested.

Musculoskeletal Disorders

Low back pain is responsible for more lost work-time than any other medical condition except upper respiratory tract ailments. In terms of treatment and workers' compensation, low back pain is the costliest occupational ailment. More than half of all workers will experience low back pain of some kind sometime in their working lives, but the percentage of those cases associated with the workplace is unclear.

Low back pain may develop progressively and insidiously, or it may come on with immediacy. Pain may be dull and aching, with fatigue and stiffness, or sharp and crippling. Surprisingly little is known about the physiologic and physical causes underlying back pain. Circumstantial evidence implicates intervertebral discs in many cases. (Discs are cartilaginous structures separating the vertebrae of the spine.) In extreme cases, a disc may rupture, but physical signs that would explain the pain are usually absent. Episodes of pain, which last usually from a few days to a few weeks, generally resolve with rest. Months or years may pass without another attack.

Muscles, tendons, ligaments, and bones can also be damaged by traumatic events or by repeated strains over a long period. Although muscle pulls and tears have been recognized for years, the "repetitive motion disorders"—those caused by repeated, often forceful motions, mainly of parts of the arm—have come to attention more recently (see "Carpal Tunnel Syndrome, " ch. 7), Much assembly-line work and food processing, for example, is characterized by repetitive, strenuous, awkward tasks. The prevalence of repetitive motion disorders is unknown, but more and more industries are recognizing that they have such problems.

Cancer

Table **3-2** is a list of recognized occupational cancer hazards. In most cases, there is convincing or very strong evidence that the listed substances have caused cancer in humans. Inspection of the table shows that many of these substances cause common cancers, for instance, of the lung and skin. Except for a few specific and infrequent cancers, there is no way to tell, from examining a cancer patient, what agent(s), exposure(s), or behavior(s) caused the tumor.

The most detailed information about an occupational cancer hazard involves asbestos. The unfolding of that story illustrates the time necessary for association to be accepted and some controversies about occupational illness. Individual case studies and reviews of case series relating exposures to asbestos with cancer began to appear in the literature in the 1930s (161). According to Selikoff (430), however, the establishment of an association between occupational exposure to asbestos and lung cancer depended on a classic study by Doll in 1955 (147).

Although asbestos **was** positively identified as a cause of lung cancer in the 1950s, and exposure to it **was** known to be widespread, no published estimate of its impact on nationwide mortality was available until 1978, when two estimates were made. Selikoff (555) estimated that the annual number of asbestos-related cancer deaths was about 50,000. His estimate elicited little public attention.

The other 1978 estimate (555), entitled "Estimates of the Fraction of Cancer in the United States Related to Occupational Factors, " was prepared by the National Cancer Institute, the National Institute for Environmental Health Sciences, and NIOSH. Ten employees of those institutions were listed as contributors to the "estimates paper, " which was placed in an Occupational Safety and Health Administration (OSHA) hearing record about that agency's proposed generic cancer

Table 3=2.—Some Occupational Cancer Hazards

Agent	Cancer site or type	Type of workers exposed
Acrylonitrile	Lung, colon	Manufacturers of apparel, carpeting, blankets, draperies, synthetic furs and wigs
4-aminobiphenyl	Bladder	Chemical workers
Arsenic and certain arsenic compounds	Lung, skin, scrotum, lymphatic system, hemangiosarcoma of the liver	Workers in the metallurgical industries, sheep-dip workers, pesticide production workers, copper smelter workers, vineyard workers, insecticide makers and sprayers, tanners, miners (gold miners)
Asbestos	Lung, larynx, GI tract, pleural and peritoneal mesothelioma	Asbestos factory workers, textile workers, rubber-tire manufacturing industry workers, miners, insulation workers, shipyard workers
Auramine and the manufacture of auramine	Bladder	Dyestuffs manufacturers, rubber workers, textile dyers, paint manufacturers
Benzene. . . . . , . .	Leukemia	Rubber-tire manufacturing industry workers, painters, shoe manufacturing workers, rubber cement workers, glue and varnish workers, distillers, shoemakers, plastics workers, chemical workers
Benzidine.	Bladder, pancreas	Dyeworkers, chemical workers
Beryllium and certain beryllium compounds	Lung	Beryllium workers, electronics workers, missile parts producers
Bis(chloromethy l)ether (BCME)	Lung	Workers in plants producing anion-exchange resins (chemical workers)
Cadmium and certain cadmium compounds	Lung, prostate	Cadmium production workers, metallurgical workers, electroplating industry workers, chemical workers, jewelry workers, nuclear workers, pigment workers, battery workers
Carbon tetrachloride	Liver	Plastic workers, dry cleaners
Chloromethyl methyl ether (CMME)	Lung	Chemical workers, workers in plants producing ion-exchange resin
Chromium and certain chromium compounds. . . .	Lung, nasal sinuses	Chromate-producing industry workers, acetylene and aniline workers, bleachers, glass, pottery, pigment, and linoleum workers
Coal tar pitch volatiles	Lung, scrotum	Steel industry workers, aluminum potroom workers, foundry workers
Coke oven emissions	Lung, kidney, prostate	Steel industry workers, coke plant workers
Dimethyl sulphate	Lung	Chemical workers, drug makers, dyemakers
Epichlorohydrin . . . .,.	Lung, leukemia	Chemical workers
Ethylene oxide	Leukemia, stomach	Hospital workers, research lab workers, beekeepers, fumigators
Hematite and underground hematite mining	Lung	Miners
Isopropyl oils and the manufacture of isopropyl oils	Paranasal sinuses	isopropyl oil workers
Mustard gas	Respiratory tract	Production workers
2-naphthyiamine	Bladder, pancreas	Dyeworkers, rubber-tire manufacturing industry workers, chemical workers, manufacturers of coal gas, nickel refiners, copper smelters, electrolysis workers
Nickel (certain compounds) and nickel refining	Nasal cavity, lung, larynx	Nickel refiners
Polychlorinated biphenyls (PCBs)	Melanoma	PCBS workers

Table 3-2.—continued

Agent	Cancer site or type	Type of workers exposed
Radiation, ionizing	**Skin, pancreas, brain, stomach, breast, salivary glands, thyroid, GI tract, bronchus, lymphoid tissue, leukemia, multiple myeloma**	Uranium miners, radiologists, radiographers, luminous dial painters
Radiation, ultraviolet	**Skin**	Farmers, sailors, arc welders
Soots, tars, mineral oils	Skin, lung, bladder, GI **tract**	Construction workers, roofers, chimney sweeps, machinists
Thorium dioxide	**Liver, kidney, larynx, leukemia**	Chemical workers, steelworkers, ceramic makers, incandescent lamp makers, nuclear reactor workers, gas mantle makers, metal refiners, vacuum tube makers
Vinyl chloride	Liver, brain, lung, hematolymphopoietic system, breast	Plastics factory workers, vinyl chloride polymerization plant workers
Agent(s) not identified	Pancreas	Chemists
	Stomach	Coal miners
	Brain, stomach	Petrochemical industry
	Hematolymphopoietic system	Rubber industry workers
	Bladder	Printing pressmen
	Eye, kidney, lung	Chemical workers
	Leukemia, brain	Farmers
	Colon, brain	Pattern and model makers
	Esophagus, stomach, lung	Oil refinerv workers

SOURCE (542)

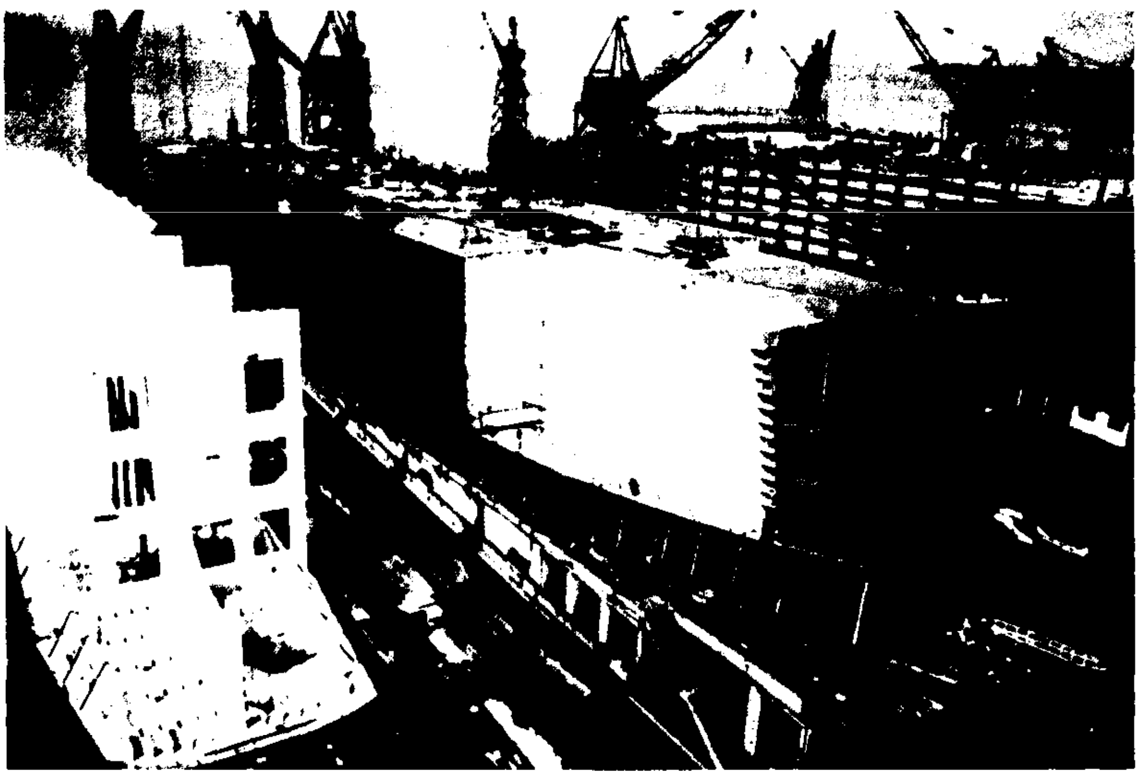

Photo credit OSHA, Office of Inforrnation and Consumer Affalrs

Shipbuilding operations present a variety of both safety and health hazards. During World War 11, many workers were exposed to asbestos in naval shipyards policy (the "estimates paper" is available as an ap pendix in Peto and Schneiderman (371)).

Had the paper been only deposited in the hearing record it might have passed largely unnoticed. Its findings, however, were widely publicized when then-Secretary of Health, Education, and Welfare Joseph Califano cited them in a speech. Based on the "estimates paper, " he stated that workplace exposures caused at least 20 percent of all cancer in this country-with exposure to asbestos alone responsible for 13 to 18 percent. These projections were controversial as soon as they were publicized, and they attracted many critics. They also resulted in a spate of articles presenting other estimates of the cancer risk associated with occupational exposure to asbestos.

The subsequent papers can be divided into two general groups. One group used methods similar to the "estimates paper" to project numbers of cancer deaths based on estimates of workers exposed, exposure rates, and mortality observed among insulation workers highly exposed to asbestos. A second type of paper measured the number of deaths from mesotheliomas, which are closely associated with asbestos exposure, and then multiplied that number by some factor to estimate all asbestos-caused cancer deaths.

Methods similar to those employed in the 1978 paper generated three estimates of total asbestos cancer mortality. Those estimates, lower than the 13 percent figure in the "estimates paper, " were 1 percent (162), 2 percent (216) and 3 percent (331). The different numbers reflect the authors' different estimates about the numbers of heavily exposed workers—estimates that can be criticized because they were not made on the basis of actual measurements. As that sort of information does not exist, however, documented assumptions are the best that can be provided.

In the case of asbestos, scientists interested in extrapolating from study-generated data to estimates of national cancer mortality are aided by the fact that asbestos causes asbestosis and mesotheliomas. Both those diseases are reasonably rare and reasonably diagnostic for asbestos exposure. Although both are subject to undercounting that limits the accuracy of estimates based on them, the estimates from them are congruent with those based on the method used originally in the "estimates paper. " Calculations based on numbers of mesotheliomas and asbestosis produced estimates of between 1 and 2 percent of all cancer deaths being due to asbestos (148,212,294,370).

The consistency of the projections that asbestos causes between 1 and 3 percent of current cancer deaths (190) has a pronounced effect on estimates of total occupationally related cancers. Most, but not all, participants at an international conference about occupational cancer agreed that workplace exposures cause less than 5 percent *(20,000* annual deaths) of U.S. cancer mortality (371).

Although this number is not as frightening as saying asbestos causes 13 percent of cancer and that workplace exposures cause at least 20 percent, and perhaps twice that figure, it is still a large number of deaths. Furthermore, as representatives from all sides—academe, labor, and management—agree, those cancers are preventable.

The amount of cancer that is associated with workplace exposures is a significant part of the current debate about the relative importance of various factors in cancer causation (see (18), the exchange of facts and opinions in 'letters" Science 224:659 et seq., especially (154) and (19)).

Reproductive Disorders

The possibility that people's occupations are leading to problems for an unborn generation is frightening. It is increasingly a concern among workers, and attention to reproductive disorders on the part of scientists is intensifying. Few facts are available to either support or quell the fears that a great many reproductive hazards are present in the workplace. Relatively few instances of harm are known when compared with the known effects of workplace hazards on workers themselves.

Initial concerns about reproductive health focused almost exclusively on women. Exposure to the high levels of lead common at the beginning of this century were known to cause menstrual disorders, sterility, miscarriages, and stillbirths.

Much more recently, concern has been extended to males. One episode provided the catalyst. In the late 1970s, a number of men working in the manufacture of dibromochloropropane (DBCP), a pesticide, were unable to father children, Investigation revealed severely depressed sperm production.

Damage can occur in males and females in a number of **ways.** In men, successful reproduction depends on proper functioning of the prostate, on libido, and on erection and ejaculation. The production and viability of sperm can be affected by damage to the sperm-producing cells or to the sperm as they develop.

In women, damage can occur in the reproductive cells, the oviducts, the endometrium, or to ovarian function. During fetal development in the uterus, humans are most vulnerable to environmental insults. Death, irreversible structural changes (teratogenesis), and growth retardation are the main classes of effects. More difficult to measure or prove are subtle deficits in intellectual capacity and functioning.

The effects of lead have been mentioned. At least one form of another heavy metal, mercury, is a known teratogen. Certain pesticides—DBCP and Kepone for instance-affect sperm production. Ionizing radiation has a variety of effects, particularly on fetuses—causing growth retardation, for instance, or microcephaly, or having latent effects, such as leukemias that develop during childhood. A few organic solvents and pharmaceuticals also are known to affect reproductive health. In all, relatively little is known about the extent of workplace-induced reproductive damage, but efforts to find out more are under way. A current OTA assessment scheduled for completion in 1985, “Reproductive Health Hazards in the Workplace, ” addresses this issue.

Necrologic Disorders

A wide variety of metals and organic compounds act on the nervous system to cause physical and behavioral problems. Since many bodily functions require the participation of nerves, nerve impairment affects not only sensory abilities, but motor (muscular) ability as well as the functioning of organs.

Lead is the best-known neurotoxin in the workplace. More than a million American workers are exposed currently. Mercury, manganese, and other metals, **as well** as organic solvents and organophosphate insecticides, also pose neurotoxic risks. Table 3-3 lists some known neurotoxins and their effects.

Neurotoxins can damage the myelin sheath surrounding the nerve fiber or the nerve cell itself. Toxins can also interfere with the production and functioning of “neurotransmitters,” chemicals produced in the body that are necessary for proper functioning of the nerves. ’some necrologic impairment is reversible, but damaged nerve cells have limited capacity for regeneration and repair.

Neurotoxins affect the parts of the nervous system to different degrees. The most commonly affected are peripheral nerves-those of the extremities. Hands and feet are often the first symptomatic zones, and numbness and tingling the first signs. Weakness in the hands and feet follows, and then difficulty walking and an inability to grasp heavy objects. Other symptoms include impaired vibratory sense, loss of touch perception, and tremors of the hand and other parts of the body.

A host of behavioral changes can also result from necrologic insults: Slow response time, impaired hand-eye coordination, irritability, lack of concentration, continual emotional instability, and impairment of recent memory area few such signs. (Lewis Carroll’s “Mad Hatter” may have been a victim of the necrologic effects of mercury used in making felt hats.)

Most neurotoxins act through common pathways, though some have more specific effects: Carbon disulfide, for instance, acts at all levels on the central nervous system, but also causes conditions as extreme as acute psychosis.

Skin Disorders

The skin, the largest organ of the body, provides the first line of defense between workers and their environment. Because it is readily observable, recognition of a problem is relatively easy. For

Table 3-3.—Neurologic Effects of Occupational Toxins

Peripheral Effects

Effect	Toxin	Comments
Motor neuropathy	Lead	Primarily wrist extensors; wrist drop and ankle drop rare
Mixed sensorimotor neuropathy	Acrylamide	Ataxia common; desquamation of hands and soles; sweating of palms
	Arsenic	Distal parethesias earliest symptom; painful limbs, especially in calves; hyperpathia of feet; weakness prominent in legs
	Carbon disulfide	Peripheral neuropathy rather mild; CNS effects more important
	Carbon monoxide	Seen only after severe intoxication
	DDT	Only seen with ingestions
	N-hexane and methyl n-butyl ketone (MBK)	Distal paresthesia and motor weakness; weight loss, fatigue, and muscle cramps common
	Mercury	Predominantly distal sensory involvement

Other Manifestatlons

Manifestation	Agent	Manifestation	Agent
Ataxic gait	Acrylamide	Increased intracranial pressure	Lead
	Chlordane		Organotin compounds
	Chlordecone (Kepone)	Myoclonus	Benzene hexachloride
	DDT		Mercury
	N-hexane	Nystagmus	Mercury
	Manganese	Opsoclonus	Chlordecone (Kepone)
	Mercury (especially with methyl mercury)	Paraplegia	Organotin compounds
	Methyl n-butyl ketone (MBK)	Parkinsonism	Carbon disulfide
	Methyl chloride		Carbon monoxide
	Toluene		Manganese
Bladder neuropathy	Dimethylaminopro pionit ri te (DMAPN)	Seizures	Lead
Constricted visual fields	Mercury		Organic mercurial
Cranial neuropathy	Carbon disulfide		Organochlorine insecticides
	Trichloroethylene		Organotin compounds
Headache	Lead	Tremor	Carbon disulfide
	Nickel		Chlordecone (Kepone)
Impaired visual acuity	N-hexane		DDT
	Mercury		Manganese
	Methanol		Mercury

NOTE: This table Includes most, but not all, of the neurotoxic substances associated with llsted conditions.

SOURCE: (39a)

both these reasons, skin disorders account for nearly half of all reported occupationally related illnesses in the United States. NIOSH has recommended maximum exposure levels for about *40* agents based on their effects on the skin (see table *3-4).*

Chemical, physical, and biological agents, mechanical factors, and plant and wood substances are known to cause occupationally related skin disorders (see table 3-5). There is probably no industry without some potential for exposure to one or more of these agents. The industries with the highest risk for skin disorders are listed in table 3-6. Although caused by a large number of agents, both biological and chemical, skin diseases are manifested in a relatively limited number of clinical symptoms: contact dermatitis, infection, pilosebaceous follicle abnormalities, pigment disorders, and cancers.

Contact dermatitis accounts for 90 percent of all occupational skin disorders. The most common manifestations of contact dermatitis are redness and swelling, and vesiculation (e.g., a poison ivy rash) in more severe cases. Contact dermatitis may be an allergic reaction or simply due to an irritant.

Bacterial, fungal, and viral infections may be contracted from customers or clients by such pro-

Table 3-4.—Substances for Which NIOSH Has Recommended Exposure Limits to Prevent Skin Disorders

Acrylamide
Alkanes:
Pentane
Hexane
Heptane
Octane
Arsenic, inorganic compounds
Benzoyl peroxide
Benzyl chloride
Carbon black
Chromium (Vi)
Coal tar products
Cresol
Epichlorohydrin
Ethylene dibromide
Fibrous glass (dust)
Glycidyl ethers:
Allylglycidyl ether (AGE)
n-Butyl glycidyl ether (BGE)
Di-2-,3-epoxypropyl ether (DGE)
Isopropyl glycidyl ether (IGE)
Phenyl glycidyl ether (PGE)
Hydrazines:
Hydrazine
1,1-dimethyl hydrazine
Phenyl hydrazine
Methyl hydrazine
Hydrogen fluoride
Hydroquinone
Nickel, inorganic and compounds
Phenol
Polychlorinated biphenyls:
Chlorodiphenyl (42°/0)
Chlorodiphenyl (54°/0)
Refined petroleum solvent
Thiols:
Butyl mercaptan (1-butanethiol)
Methyl mercaptan (1-methanethiol)
Ethyl mercaptan (1-ethanethiol)
Tin, organic compounds
Tungsten:
insoluble compounds
soluble compounds
Vanadium

SOURCE Adapted from (128a)

Table 3-5.—Workpiace Agents That induce Skin Disorders

Chemical **agents**
Rhus oleoresin (poison ivy and oak)
Acids
Alkalis
Solvents
oils
Soaps and detergents
Plastics
Resins
Paraphenylenediamine
Chromates
Acrylates
Nickel compounds
Rubber chemicals
Petroleum products not used as solvents
Glass dust
Plant and Wood Substances
Pink rot celery
Citrus fruit
Physical Agents
Ionizing and nonionizing radiation
Wind
Sunlight
Temperature extremes
Humidity
Biological Agents
Bacteria
Viruses
Fungi
Ectoparasites (mites, ticks, fleas, etc.)
Biting animals
Mechanical factors
Pressure
Friction
Vibration

SOURCE: (23a).

fessionals as barbers and hairdressers and by hospital workers. Staphylococcus and streptococcus bacteria may cause a range of skin conditions from superficial to those of deep skin layers. More serious bacterial infections, such as anthrax in sheep handlers and animal hide workers, are rarer.

Fungal infections often arise in moist, warm environments. Ringworm and *Candida albicans* infections are common examples. Candida infection is common in workers, such **as** dishwashers, who are frequently exposed to water, because moist conditions favor the fungus' growth. Viral infections are acquired by contact with other people and are a particular hazard for workers exposed intimately to other individuals in the course of their work, such as health care workers.

Pilosebaceous follicle abnormalities, generally acne-like lesions, occur after exposures to heavy oils and certain chemicals, particularly chlorinated aromatic hydrocarbons. The example currently most discussed is chloracne after exposure to chlorinated dioxins, either in the manufacturing process, or, most dramatically, after industrial accidents involving the generation and release of large amounts of the chemical. Chloracne may persist for **10** yearn or more after exposure ceases.

Table 3-6.—industries at Highest Risk for Occupational Skin Diseases

Industry	Annual reported incidence rate (per 1,000 workers)	x	Target population (rounded to nearest 1 ,000)	x	Severity[a]	x	Duration[b]	=	Incidence of lost workdays per industry per year
Poultry dressing plants	16,4		89,800		030		10.0		4,405
Meat packing plants	72		164,300		0.31		4,3		1,561
Fabricated rubber products	55		103,200		0.22		11,5		1,424
Leather tanning and finishing	21,2		22,900		0.34		8.3		1,392
Ophthalmic goods	8.5		38,000		0.52		8.3		1,390
Plating and polishing	8.3		61,400		0.28		9.0		1,270
Frozen fruits and vegetables	7,2		43,200		0.31		12,1		1,153
Internal combustion engines	5.5		75,700		027		8.8		999
Canned and cured seafoods	5.6		19,700		0,36		23,7		934
Carburetors, pistons, rings, valves	70		29,400		024		17.9		895
Chemical preparations	8.3		36,700		0.23		12.3		855
Boat building and repairing	11.1		48,000		0.22		7,4		854

[a]Severity is defined by number of lost-workday cases divided by total number of cases in that industry

[b]Duration is the number of lost workdays per lost workday case

SOURCE (23a)

Pigment disorders occur when melanin production is either increased or decreased through exposures to chemicals or from a traumatic event—a burn, for instance. Loss of pigment may be reversible or not, depending on the causative agent and on the severity of the insult. Other changes in skin color are due to staining of various layers by such substances as heavy metals.

KNOWN AND UNKNOWN HEALTH HAZARDS

Health hazards are agents that can cause disease in people exposed to them. In terms of occupational health, there are three kinds:

- identified hazards known to be present in the workplace;
- hazards that are present in the workplace but that have not been identified as causes of disease; and
- new substances or processes not yet introduced into the workplace, that will be hazardous to human health.

This section reviews the findings that led to some associations being made between particular diseases and workplace hazards, as well as the methods currently employed to identify hazards.

Identified Hazards

Diseases associated with mining and metalworking have been recognized for many years, to some extent because of the antiquity of those trades. Some industrial chemicals are known to cause a variety of diseases, and energy from all parts of the electromagnetic spectrum is a hazard under particular circumstances. As the following examples show, associations between agents and diseases have been made by people from all sectors of society based on laboratory information as well as observations of human illness.

Physical Agents

Sources of ionizing radiation are increasingly common in the workplace. X-ray apparatus and radioisotopes are widely used, and nuclear powerplants and scientific research also involve potential exposures to ionizing radiation. Very high doses of radiation can kill workers within a few days, but of greater concern, because the events are more likely, is low-level exposures, which may last for several years and may cause cancer. The deleterious effects of radiation were discovered from observations of disease among early workers in the field and confirmed by analyses of the survivors of Nagasaki and Hiroshima.

Nonionizing radiations include ultraviolet, infrared, microwave, and laser. All present hazards for workers' eyes, and there is continued interest in and study about other effects from microwave radiation. Ultraviolet and infrared radiation as well as intense visible light are generated in welding, and welders' goggles and helmets are designed to protect against such hazards.

Also in the category of physical agents is noise, which, especially if it is loud and continuous, causes progressive hearing loss. The impact of occupational noise is difficult to separate from the effects of aging, but many studies have shown workplace noise is a hazard to hearing. (See ch. 8 for a discussion of the role of personal protective equipment in preventing hearing loss.)

Vibration, often experienced as a result of the use of handtools, causes a number of musculoskeletal disorders (see ch. 7).

Heat, cold, and pressure encountered in underwater work are also hazards. These have been associated with particular jobs for a very long time, and many of their effects are visible during or soon after exposure.

Metals

Hunter (218) divides hazardous metals into three groups. Those known since ancient times, such as lead and mercury, were long ago associated with disease. According to Hamilton (1922, quoted in 218), the first legislation directed against an occupational hazard was drafted in 1665 in Idria, now part of Yugoslavia. The workday for cinnebar (mercury ore) miners was restricted to 6 hours as a preventive measure to reduce the occurrence of tremors. Mercury continues to cause concern today as an environmental contaminant, and it is especially dangerous in the organic (methylmercury) form.

Hunter's second group, the "other metals, " are arsenic, phosphorus, and zinc. He points out that the grouping is arbitrary in that arsenic is a metalloid and phosphorus a nonmetal. These three elements have been in common industrial use for a few centuries, and all have caused illness and death. The recognition of phosphorus as the cause of "phossy jaw" among matchmakers (see box A) led to the substitution of a safe form of phosphorus in matches. These three metals still occupy important places in industry and in agricultural products.

The third group of metals are those recently introduced into commerce, including some important in advanced metallurgic technologies and the nuclear industry. Toxic effects are definitely associated with some—beryllium, cadmium, chromium, manganese, nickel, osmium, platinum, radium, ruthenium, selenium, tellurium, thallium, thorium, uranium, and vanadium. In some measure, because these substances were introduced into the workplace when industrial hygiene measures were more common, exposure to many of them

Box A.—"Phossy Jaw"

Phossy jaw was a disease that resulted from inhaling yellow or white phosphorus fumes that penetrated any defective tooth and killed cells in the jaw and surrounding tissues. Invasion of the dead areas by germs from the mouth led to suppurating infection, swelling, and intense pain. Death could result from blood poisoning; surgical treatment, which often included removal of the jaw, was incapacitating and disfiguring. The **disease was** first diagnosed in workers in European match factories in the middle of the 19th century.

Up through 1908, there was no recognition of phossy jaw as an occupational health problem in the United States. A Bureau of Labor study that year of the wages of women and children in the match industry revealed 150 cases of phossy jaw. Two years later, the Bureau issued "Phosphorus Poisoning in the Match Industry in the United States."

One of the surest forms of controlling exposures to hazardous substances is to substitute a less hazardous chemical. Phossy jaw was conquered by substituting a different form of phosphorus for the "white phosphorus" commonly used in matches. The Diamond Match Co., which held the American patent for the safe form (sesquisulphide), waived its patent rights and made the safe substitute available to the entire industry (199). In 1912, Congress passed the "Esch Act," which levied a tax on white phosphorus matches, driving them from the market.

has been well controlled (218). Also important to controlling exposures to some of these metals is their great expense; uncontrolled losses through spills or into the atmosphere as vapors, fumes, or dusts entail financial losses as well as health hazards.

Many metals are worked in industry with no reported toxic effects. Cesium, cerium, columbium, gallium, germanium, hafnium, iridium, lanthanum, molybdenum, rhenium, rhodium, rubidium, strontium, tantalum, titanium, tungsten, and zirconium, for example, have not been associated with illness in workers (218). Exposures to many such metals are controlled by standard industrial hygiene practices, and the fact that some of these metals are very expensive also encourages reduced exposures.

Hunter (218) is a good source of historical information about the uses and effects of the various metals and about British approaches to controlling exposures. Rem, et al. (396), discusses clinical symptoms and treatments as well as U.S. approaches to control, and Levy and Wegman *(269)* provide a lively introduction to the occupational health and industrial hygiene problems associated with the metals, with less emphasis on clinical detail than Rem. Tyrer and Lee (483) summarize information about acute and chronic health effects of the metals and list recommended and regulatory limits to exposure.

Dusts and Fibers

The hazards of mineral dusts have been known since mining began. Both silica dust and coal dust cause lung diseases. The widespread use of silica as an abrasive for "sand blasting" and other polishing results in many thousands of American workers being exposed to mineral dusts that are associated with lung diseases. In addition, cotton dust and asbestos are important as causes of byssinosis and asbestosis, respectively.

Chemicals

Because of the explosion of organic chemistry (chemistry that involves carbon) in the last 100 years, thousands of new chemical substances have been introduced into the workplace. Currently there are more than 55,000 chemicals listed in the Environmental Protection Agency's (EPA) *inventory of Chemical Substances,* which is a compilation of chemicals in commerce. About 100 new chemicals are introduced to commerce each month (547a). Many of these substances–pesticides of various kinds and drugs-are designed to alter normal biological functions, and it is no surprise that some have been found to cause cancer and other diseases, and that these substances are of special concern **(542).**

Some of the now-known hazards, such as vinyl chloride monomer, have been discovered as a result of workers who have become sick. (See ch. 5 for a fuller discussion.) Several years before an alert physician noted an excess of rare liver tumors in vinyl chloride workers, the results of an animal test of the same chemical were announced at a scientific meeting. The animal tests also showed the chemical to be a liver carcinogen. It can be argued that had the animal results been taken seriously, exposure to vinyl chloride would have been reduced sooner. As it happened, the existence of the animal studies may have been a factor in the rapid regulatory process that led to significant reductions in vinyl chloride exposures.

Acrylonitrile is a commonly used plastic that, like vinyl chloride, presents little hazard after it is polymerized. However, animal studies showed that acrylonitrile monomers are carcinogenic, and a follow-on epidemiologic study showed an excess of cancer among acrylonitrile production workers. Regulations restricting exposures to the substance were drafted by OSHA; unlike most other OSHA health regulations, the final standard for acrylonitrile was not challenged in court. There must have been a number of reasons for that success, and included in them were probably the congruence between the results of the animal and human studies and the fact that the methods developed to control vinyl chloride exposures were directly applicable to the control of acrylonitrile.

Methods for Detection of Present, Unidentified Hazards

Epidemiology, toxicology, and occupational medicine provide the means for identifying the causes of occupational illnesses. In the traditional, idealized view of the process, physicians generate hypotheses about possible associations between workplace exposures and subsequent disease. Hypotheses are tested in epidemiologic studies so that the associations can be characterized in statements of statistical probability.

The traditional role of toxicology has been to provide information about the mechanisms of disease causation, the end results of which are detected by physicians and studied by epidemiologists. Toxicology today is generally thought of in different terms. Since the late 1960s and particularly through the 1970s, toxicology has been seen as a way to identify chemical hazards before their effects appear in humans. The most visible toxicologic activities are the testing of chemicals for carcinogenic properties in laboratory animals, mainly rats and mice **(542).** The Federal Government, through the National Toxicology Program, spent $31.6 million in 1983 on bioassays for that purpose.

There is also a certain amount of research now going on in development of short-term tests (so named because they require significantly less than the 2 to 5 years for an animal bioassay) as eventual replacements for and supplements to bioassays,

One of the most powerful methods of identifying associations between workplaces and diseases is through workers themselves. For instance, the pesticide dibromochloropropane was identified as a cause of male sterility by workers talking to each other. A possible relationship between office work involving video display terminals and fetal malformations that is now being actively investigated similarly derives from workers' observations. In many cases, workers' comments to their physicians lead to epidemiologic and toxicologic investigations and to medical surveys to decide whether a suspected association is real.

Toxicology

Toxicology is the testing of chemicals in animals, plants, or lower forms of life to detect biological effects. In addition to questioning what kinds of effects are produced and under what exposure conditions, toxicologists also investigate the mechanisms by which substances cause damage. That information is especially important in efforts to predict the likely toxic effects of substances that have not yet been tested. Toxicology can be subdivided in a number of ways. Here, testing for acute toxicities is discussed first, followed by a section on methods for investigating chronic toxicities—carcinogenesis, mutagenesis, and teratogenesis.

Acute Toxicity Testing. —Chemical burns and immediate difficulty in breathing as a result of inhalation of a substance are examples of acute toxic effects. Animal testing of chemicals for toxicity has produced a voluminous data set.

Increasing concern about animal welfare is causing reconsideration of animal testing methods. For instance, one of the most venerable acute toxicity tests is the LD_{50} test. Designed in the 1920s, the test involves the use of 50 to 100 animals to decide what amount of substance will cause the death of 50 percent of the animals. This method is coming under increased attack, however, as being imprecise and causing more animal suffering than is necessary. OTA is studying the use of alternatives to animals in research and testing. The report from that project, expected in 1985, will discuss the pros and cons of various animal tests and alternatives to animal tests.

NIOSH's 1980 Registry of Toxic Effects of Chemical Substances lists 45,156 substances. Included for most of the substances is the LD_{50} estimate of the amount that will kill half of a population of test animals. In addition, information about the toxic effects of the substance on animal skin and eyes is also commonly reported.

Dosages of ingested or injected substances necessary to cause effects in animals are expressed as the weight of the substance administered divided by the animal's body weight, i.e., milligrams of substance/body weight in grams or kilograms. When the substance is inhaled, the dangerous concentrations are expressed as parts per million in air or as the weight of the substance per cubic meter of air. These values provide data for making estimates of the biological effects of the substance in humans. Almost always, safety factors of 10 or 100 are used in setting acceptable limits for workers. That is, if 100 parts per million of **a** substance causes breathing difficulties in animals, a prudent policy would be to limit worker exposures to 10 or 1 part per million.

Chronic Toxicity Testing.—Structural activity relationship (SAR) analysis, chronic animal bioassays, and short-term tests are the main tools of toxicology (see table 3-7) as it relates to carcinogens, and, in general, chronic health hazard identification (542,547a). Finding a toxic effect in humans is far more convincing evidence about the seriousness of a hazard than detecting a toxic effect in animals, which, in turn, is more convincing than results from short-term tests. The weakest evidence is that derived from projections from structural activity relationships. Although the Federal effort devoted to chronic toxicities-mutagenicity and teratogenicity as well as carcinogenicity—is largely directed toward identifying carcinogens, there are some minor stirrings of effort to broaden beyond cancer (595).

Carcinogenicity has received the lion's share of OSHA's attention to health hazards. Of the fewer than two dozen chemicals regulated through new, permanent OSHA standards, all but two—lead and cotton dust—have been carcinogens.

Extrapolation problems—that is, how knowledge of effects in animals are projected to make predictions for people and how exposure levels in test animals are related to human exposure levels–bedevil the use of animal test data. OTA (542) has already discussed those problems and various approaches to reconciling them.

1) Structural activity relationship analysis, SAR uses known information about the properties of a substance to gain insight into the possible and probable effects of the substance on human beings. It is a new and still uncertain technique. Substances whose molecular structures resemble those of known toxic substances come under greater suspicion than those whose structures do not. No firm conclusions can be made based on these analyses except in the rare cases where all previously known members of an entire class of chemicals are known to be hazardous. In general, positive results are taken to indicate a need for further testing,

SAR has found most use in making estimates of the toxicity of "new" chemicals, when no test data are available. However, even there the scientific underpinnings of SAR are considered by some to be very weak, and the conclusions based on it are hotly argued (547a).

2) *Short-term tests.* Short-term tests encompass a large collection of methods for measuring toxicity in lower life forms-viruses, bacteria, and lower plants and animals, such as fruit flies-in cultured cells, or, in a few cases, in specific organ systems of laboratory rodents (542). Since their introduction about 15 years ago, they have been characterized as holding great promise for toxicology. A cynic might say that they always will.

Table 3-7.–General Classification of Tests Available to Determine Properties Related to Carcinogenicity

Method	System	Time required	Basis for test	Result	Conclusion, if result is positive
Structural activity relationship(SAR) analysis	"Paper chemistry" Basic laboratory tests	Days Weeks	Chemicals with like structures interact similarly with DNA	Structure resembles (positive) or does not resemble (negative) structure of known carcinogen	Chemical may be hazardous; that determination requires further testing
Short-term tests	Bacteria, yeast, cultured cells, intact animals	Generally few weeks (range 1 day to 8 months)	Chemical interaction with DNA can be measured m biological systems	Chemical causes (positive) or does not cause (negative) a response known to be caused by carcinogens	Chemical is a potential carcinogen
Bioassay	Intact animals (rats, mice)	2 to 5 years	Chemicals that cause tumors m animals may cause tumors in humans	Chemical causes (positive) or does not cause (negative) Increased incidence of tumors	Chemical is recognized as a carcinogen in that species and as a potential human carcinogen
Epidemiology	Humans	Months to lifetimes	Chemicals that cause cancer can be detected m studies of human populations	Chemical is associated (positive) or is not associated (negative) with an increased incidence of cancer	Chemical is recognized as a human carcinogen

SOURCE Adapted from (542)

Running counter to that lack of enthusiasm, recent spectacular advances in molecular biology suggest that short-term tests will grow in importance. As more and more insight into the molecular basis of carcinogenesis accumulates, along with rapid advances in methods to manipulate DNA and other cellular components **(542,548),** improved short-term tests should follow. The limitations and uncertainties of testing substances in whole-animal bioassays are built into the method itself. No such limits bound potential short-term tests for discerning interactions between chemical and cellular components. Of course, it will always be possible to argue that the short-term test system is not sufficiently parallel to human biology to serve as a guide to human risk estimation.

The critical issue for development of short-term tests is defining their current and ultimate value in policymaking. The first step is to find out how well the results of a test represent the “truth,” a process referred to as validation. Truth is usually relative, and in the case of the carcinogenic potential of chemicals, the convenient measuring stick for truth is the bioassay, with its attendant limitations **(542).** The acceptability of bioassay results as a guide to making decisions about health hazards appears, sometimes at least, to be tied to the financial interest or disinterest of individuals and organizations in the substances identified as carcinogens.

There is little hope that a single short-term test will ever suffice as a reliable predictor of toxicity in human beings, and hope is pinned on the development of a battery of tests. Years of discussion and argument will undoubtedly precede the acceptance by scientists and regulators of any set of tests. And even then, a “generally accepted” test battery will be challenged in specifics, much as evidence from bioassays currently is.

The development of reliable short-term tests may actually enhance the value of bioassays, which will always find a place in toxicologic testing. Short-term tests can increase the knowledge base for deciding which chemicals should be tested in animals, and can shed light on the probable mechanisms of action of each chemical.

3) Bioassays. The bioassay is the mainstay of toxicology today. For some questions, answers involving the biology of whole animals are essential. The technique involves exposing a population of laboratory animals, usually rats and mice, to a suspect toxic agent. After an appropriate time, about 2 years for carcinogenicity, the disease incidence in the the treated population is compared with the disease incidence in a population of untreated controls. The premise underlying the mammoth effort in bioassays is that evidence of disease in animals is applicable to predictions for people; in fact, substances known to be carcinogens in humans also cause cancer in animals.

An entire branch of risk assessment has grown up around the quantitative predictions of effects in human beings based on animal evidence, In the combination of bioassay and risk assessment has lain the hope of perfectly protecting workers and the public from chemical carcinogenesis before effects appear. On general principles, this appealingly simple system may still hold promise for setting and defending regulatory goals, but its systematic failure to guide regulatory efforts in specific instances has led to disillusionment.

The technical problems encountered in conducting bioassays--including questions about high doses, and the impossibility of knowing which extrapolation model is most appropriate—plague risk assessment. Equally or more important are the assumptions involved. For instance, apparently endless arguments have gone on about whether liver tumors in mice mean anything in terms of human risk; the argument has not been settled by experimentation but is silenced by convention **(542).**

Formaldehyde is a case in point. There is general agreement that formaldehyde is an animal carcinogen. The bioassay was carried out by industry’s own toxicology laboratory. But in the final analysis, industry objected to regulating formaldehyde on the basis of the bioassay, and assessments produced by different organizations varied in the amounts of human risk they predicted.

Epidemiology

The importance accorded epidemiology reflects a trend toward more systematic, scientific study of disease. The desire to base conclusions about causality on something more than individual observation and intuition-the two most valuable tools of the clinician—calls for describing associations quantitatively, both in terms of strength of association and in terms of the probability that the association is not simply one of chance. Careful epidemiologic investigations have confirmed important suspicions about work-related illnesses. The now universally acknowledged case against asbestos is built on epidemiologic studies.

The strengths of epidemiology still remain to be exploited. A great deal needs to be learned about diseases and **syndromes that are widespread in the population. Certain chronic conditions (cancers in particular) and heart disease are known** to be associated with various occupations. The means exists, through the Surveillance, Epidemiology, and End Results Program of the National Cancer Institute *(542,683)*, to enter about one-tenth of all U.S. cancer cases on tumor registries as they are diagnosed. This system provides the ability to set up large case-control studies with relative ease. (See box B.)

Cohort studies of large industrial populations—which can be assembled by corporations and/or unions and facilitated by workplace surveillance systems that have been installed by many companies to track and store various sorts of data—also yield valuable information. (These surveillance systems are discussed further in the "Occupational Medicine" section.)

Government Records. —An important and frustrating feature of epidemiology in the United States is the difficulty of locating and tracking people. In a cohort study, it is critical that the maximum number of cohort members be located. If the cohort contains workers employed at a particular site s, 10, or 20 years ago, many will have moved. In a case-control study, members of either population may be identified through hospital records, and the recorded addresses may no longer be current. In either type of study, the epidemiologist often needs to locate people for interview and examination.

There are standard methods for locating people in this mobile society. Asking at places of employment and using telephone and city directories are common. Mail sent to the last known address frequently reaches the person. In difficult cases, the epidemiologists can hire private detectives or credit bureaus to locate persons. The so-called NIOSH-window facilitates some occupational epidemiology studies. Investigators who are allowed to use it can supply a name and some other identifying information (such as the Social Security number) to the Internal Revenue Service, and the agency provides the person's current address. Members of the OTA Advisory Panel for this assessment reported that there is some confusion about who can and cannot use the NIOSH window and under what conditions.

The Federal Government collects information about places of employment and about what hazards or substances are present in them. Such records have obvious usefulness for epidemiology, providing a quick method for identifying persons who may have been exposed to a substance. However, all the record systems have flaws that restrict their usefulness **(542,557).** The recommendations made by the Committee to Coordinate Environmental and Related Programs (CCERP) of the Department of Health and Human Services provide an excellent grounding for questions about the current systems and suggestions for changes.

The National Death Index (NDI) can tell epidemiologists that a person is dead and which State (or other) department of vital statistics holds the death certificate. This speeds up the retrieval of information for studies, but the NDI does not actually provide information on the cause of death and underlying causes.

Section 8(e) of the Toxic Substances Control Act (TSCA) requires that manufacturers report to EPA on chemical substances that pose significant risks to human health or the environment. Some companies voluntarily report these results to NIOSH and OSHA. In practice, this reporting requirement means that an employer that carries out a short-term test, a bioassay, or an epidemiologic study that shows a health risk must report it to the EPA. EPA prepares a report on each 8(e)

Box B.—Epidemiology

Cohort Studies

A cohort study starts with a group of people—a cohort, considered free of the disease under study and whose exposure to a risk factor is known. Usually the risk factor is an exposure to a suspect toxic substance or a personal attribute or behavior. The group is then studied over time and the health status of individual members observed. This type of study is sometimes referred to as "prospective" because it looks forward from exposure to the possible development of the disease characteristic. Cohort studies can be either concurrent or nonconcurrent in design. Concurrent ones count only cases of disease or other outcomes that occur after the start of the study. Nonconcurrent cohort studies also count any cases or other outcomes for which there are records.

Case-Control Studies

In a case-control study, persons with the disease under study (cases) are compared with individuals without the disease (controls) with respect to risk factors that are judged relevant. Some authors label this study design "retrospective" because the presence or absence of the predisposing risk factor is determined for a time in the past. However, in some cases the presence of the factor and the disease are ascertained simultaneously.

The choice of appropriate controls is rarely without problems. Often, for practical reasons, controls are chosen from hospital records. But they may not be representative of the general population, and they therefore may introduct "selection bias" (2$2).

General Considerations

In case-control and cohort studies, the groups selected should be comparable in all characteristics except the factor under investigation. In case-control studies, the groups should resemble each other except for the presence of the disease; in cohort studies, the study and comparison groups should be similar except for exposure to the suspect factor. Since this rarely is possible in practice, comparability between groups can be improved by either matching individual cases and controls (in case-control studies) or by standard statistical adjustment procedures (in either case-control or cohort studies). Demographic variables such as age, sex, race, or socioeconomic status are most commonly used for adjustment or matching.

There are advantages and disadvantages in both types of study (see table 3-8). Case-control studies tend to be less expensive to conduct, require relatively fewer individuals, and often have been especially

Table 3-8.-Advantages and Disadvantages of Case-Control and Cohort Studies

Type of study	Advantages	Disadvantages
Case-control	Relatively inexpensive	Complete information about past exposures often unavailable
	Smaller number of subjects	Biased recall
	Relatively quick results	Problems of selecting control group and matching variables
	Suitable for rare diseaes	Only relative risk is yielded
Cohort	Lack of bias in ascertainment of risk factor status	Possible bias in ascertainment of disease
	incidence rates as well as relative risk are yieided	Large numbers of subjects required
	Associations with other diseases as by-product can be discovered	Long follow-up period
		Problem of attrition
		Changes over time in criteria and methods
		Very costly
		Difficulties in assigning people to correct cohort

SOURCE: (542).

[illegible]

notification and circulates it within the Agency and to other Federal agencies, including OSHA and NIOSH. In addition, periodically the reports received over a period of time are bound together for distribution to libraries. The 8(e) activities, therefore, provide a way to disseminate health hazard information rapidly.

Occupational Medicine

The field of occupational medicine has gone through a series of changes during this century. Not long ago, the clinician not only tended the sick but also filled a number of other roles, investigating possible disease relationships and fostering changes in the workplace. To a certain extent, the role of the occupational physician was altered by the rise of epidemiology and toxicology as separate professions.

Epidemiology and toxicology have not been the panacea for solving workplace health problems that some envisioned. Toxicology is limited to testing under conditions that cannot mimic complex human exposures and behaviors. Epidemiology cannot begin until it finds subjects for study, and it relies on outside input—in particular, clinical observations of possible associations between exposures or behaviors and disease—for hypothesis generation. It has limitations in the kinds and magnitudes of effects it can detect. The limitations of both toxicology and epidemiology argue for a continuing role for occupational medicine in hazard recognition as well as in treating workers.

Better use of physicians' experience and insights will depend on education. There are two categories: general education of physicians about occupational disease and injury, and specialized education and training for practitioners of occupational medicine. An orientation toward occupational health is minimal at best, in most U.S. medical schools. Levy (269a) reports that only 50 percent of U.S. medical schools provided some class time to occupational health during the 1977-78 academic year. This has risen to 66 percent in the 1982-83 academic year. However, the median number of required class hours devoted to occupational health remained at 4 hours. Postgraduate, specialty training in this country has traditionally been subsumed under preventive medicine, and centered in schools of public health. Recently increased emphasis has been placed on clinical experience in medical schools. The location of the specialty courses is less important than making sure the programs are well-taught and attractive and that they provide clinical experience. The NIOSH-supported Educational Resource Centers (discussed in ch. 10) provide postgraduate education for physicians.

In the United States, the occupational medical services are usually provided by physicians who are directly employed by or under contract to employers. Large companies frequently have onsite medical departments, staffed by physicians and nurses. Medium-sized companies might have the full-time services of an occupational health nurse, and possibly, the part-time services of a local physician. Small companies have only rarely provided occupational medical services.

An alternative organizational model is found in occupational medicine clinics, which have been growing in the last few years. These clinics are usually associated with a hospital or university and provide examinations and treatment to workers. Clinics might, because of a larger patient load and a staff that consequently sees more patients, be able to to provide more knowledgeable care, as well as improved physician training. In some cases, the clinics' staffs include not only doctors and nurses, but also industrial hygienists and safety engineers. The combination of staff from different disciplines can provide a critical mass for a great deal of important activity in hazard identification and control.

These clinics also provide advantages to employers, especially small to medium-sized companies, that previously were not able to provide occupational medical services to their workers. In the words of the director of an occupational health department at one hospital:

> The larger corporations will undoubtedly continue to have in-plant occupational health services. But medium and smaller companies will be forced to make an economic decision on whether it is more advantageous to do it themselves or farm the occupational health service to others *(Daniel Conrad,* quoted in 338a).

Some hospitals are apparently establishing these clinics in order to develop new sources of revenue. The staff of these clinics expect to be able to conduct some research, as well as to provide advice about prevention and medical care to employees (338a).

Medical Surveillance Systems. —Computerized information systems have made it possible to store massive amounts of data. Information about exposures in the workplace and the health records of workers can form the basis for surveillance systems that aim to identify health hazards. Surveillance is defined as the "collection, collation, and analysis of data and its dissemination to those who need to know" (474). Public health surveillance techniques were developed in the last century to identify foci of pestilential diseases such as cholera, smallpox, plague, and yellow fever, so that appropriate control measures could be instituted. In the workplace, the value of surveillance is to alert workers and employers to unusual patterns of morbidity or mortality.

Concerns today center on chronic rather than acute diseases; the technical problems of linking cause and effect are heightened by the remoteness of disease from exposure. Computerized information systems in industry, including their *use* for medical and exposure records, have enabled massive amounts of information to be stored and correlations to be produced.

In the occupational setting, the necessary components of surveillance are:

- exposure information of some type;
- records of health outcomes, which may include causes of death; and
- background information about characteristics of each individual that might influence susceptibility to disease.

Variations in epidemiologic surveillance systems have to do mainly with the quantity and type of data in each category. "Exposure" can be quite basic: for instance, knowing the plant within a company, or the department within a plant, in which a worker is employed, and updating it perhaps yearly. At the more comprehensive end of the spectrum, exposure might contain continuous records of personal and area monitors measuring chemicals and other agents in the industrial environment.

Health outcomes may be ascertained from industrial health and accident insurance reports, which record only the most serious events, These can be supplemented by information gathered in preemployment examinations and nonroutine visits to physicians, as an intermediate approach. At the extreme, to the above information could be added the results of periodic medical screening for many diseases or other abnormalities. Basically, the simpler systems are considered passive, using data collected for other purposes (personnel records, insurance data); systems can be progressively more active in seeking data expressly for health surveillance **(312).**

Routine analyses of data collected in surveillance systems are seldom sufficiently rigorous to evaluate possible instances of occupational disease. Their broad, sweeping monitoring of health events is more of a hypothesis-generating device. It provides the means to make epidemiologic studies as targeted and as timely as possible.

A sign of growing interest and activity in occupational health surveillance, and medical information systems in general, was a meeting of the American Occupational Medical Association's Medical Information Systems Committee in 1981. Papers presented at that meeting, which described

19 such systems, were published as a supplement in the October 1982 issue of the Journal of *Occupational Medicine (238).*

In the same issue of that journal, computer software companies advertised their ready-made programs for instituting surveillance systems. The literature packets behind those systems, which appeared to be directed at smaller companies, describe convenient ways to classify and store large amounts of information about workplace exposures and employee health, What is missing, at least in the prospecti, are discussions about the ultimate value and potential contribution of such information to detecting problems in the workplace. Although the systems may facilitate record keeping that already goes on, they may fail to have a serious impact on safety and health, as they are promoted to do.

Occupational health surveillance remains a source of both great promise and great controversy. If it could be used just to identify the causes of occupational illness, setting the stage for preventing further illness, there would be little to say against the idea. As a purely scientific concept, it is unassailable. In practice, from the point of view of companies, the collection and particularly the analysis of data about exposures and health outcomes raises legal issues of responsibility and liability. From the employees' point of view, there is a fear that surveillance will be adopted as an alternative to installation of controls.

There is anecdotal evidence that some companies that had maintained surveillance systems have now dismantled them. Although the same data may still be collected for administrative reasons, they are not being assembled in a form for analysis of possible relationships between exposures and disease. This step may at least in part stem from the unknown consequences of finding the suggestion of a health problem—for instance, a slight excess of some particular cancer. Further study would certainly be necessary to confirm the association, yet the liability associated with even suspecting that a problem exists cannot be known at this time.

Some employers are concerned that discovering a possible association may make them liable in tort actions. In addition, section 8(e) of TSCA requires reporting of such findings, making them public and available to potential litigants. On the other hand, some companies expect that acting responsibly will provide some defense against tort action. The problem of deciding how to use suspicions that may be generated by routine matching of health and surveillance information is a very real one.

A second policy issue in this field concerns the proliferation of data collection systems for health and exposure information that are accompanying the microcomputer age. There appears to be little thought given to the ultimate value of these systems in improving workplace safety and health. Certainly for small companies, the targets of much advertising, the number of workers will be too small ever to detect all but the most obvious excesses of disease. There may be scope for using computer networks to pool data, but these activities bring their own problems. (See ch. 10.)

Another pertinent issue is the substitution of surveillance for prevention, particularly prevention in the form of controls on workplace exposures. Union officials and many health professionals fear that the creation of surveillance systems will lead to the impression that "something is being done" to improve health, resulting in less emphasis on controls and paralyzing action against hazards until large numbers of people become sick or die.

New Hazards

In some measure, "familiarity breeds contempt"-even when the subject is hazards-and there may be a human tendency to fear new hazards more than old ones. The emphasis placed on identifying and understanding "new" hazards grows partly from that psychology and partly from the realization that it is easier to control hazards before they become established in commerce and economically important.

Epidemiologic studies and occupational medicine are of no value in learning whether a new agent is hazardous before people are exposed to it. The introduction of a new substance or process into the workplace that is subsequently shown to be a hazard must be regarded as a failure of preventive health measures. Analysis of the chemical structure of a new substance can be used to estimate what toxic properties are associated with it, but many people consider that technique to be unreliable. Toxicologic techniques can be used to learn about the hazards of new substances, but the associated costs place some restrictions on their use.

Toxicology costs money, and manufacturers will not spend great sums on testing a newly developed chemical before they know there is a market for it. Some manufacturers argued during the debate when the Toxic Substances Control Act was passed that they did enough toxicologic testing to be assured that new chemicals would not pose unreasonable risks. TSCA set up two programs to gather information about new chemicals.

The Premanufacture Notification Program

The Toxic Substances Control Act requires that manufacturers prepare a Premanufacture Notice (PMN) and submit it to EPA at least 90 days before starting manufacture of a chemical substance for use in commerce. The PMN is to contain any information available to the manufacturer about the toxicity of the chemical, Some PMNs contain many items of information bearing on the properties of the new chemical, while others contain none or only a few, and there are disputes about how useful the reporting has been to date (547a).

It is clear from EPA's experience with the PMN program that a common plain for potentially hazardous exposures to newly introduced substances is in their manufacture. EPA has used formal and informal regulatory procedures to reduce occupational exposures to chemicals described on PMNs (547a), and it has established informal communications with OSHA and NIOSH staff about controls. For instance, EPA has required the use of respirators in the manufacture of some new chemicals described on PMNs. According to EPA officials, the Agency consulted with NIOSH about appropriate respirators.

The PMN program provides an important opportunity to identify hazards before they become established in the workplace. Although EPA regulated pesticides under a licensing law before TSCA, its regulatory concern about other chemicals was restricted to those that became pollutants. Under the PMN program, it has authority to regulate chemical substances before they get into the workplace.

Significant New Uses

TSCA anticipated that the uses of a chemical described on the PMN might not be associated with an unreasonable risk, but that a different use, called a "significant new use, " might. TSCA directs EPA to write a significant new use order about new chemicals that fall into this category. In practice, EPA has restricted some chemicals to particular uses and required submission of more data about the chemical before it could be more widely used. One example of this process concerns a surfactant for cleaning. Concerned about possible dermatologic effects, EPA did not object to its use by professional cleaners, because those workers could be instructed in the proper use. However, if the surfactant is considered for use in consumer products-a significant new use—more information must be provided to EPA.

SUMMARY

Preventing workplace-related disease requires that associations between activities and exposures and diseases be identified. The known health hazards-extremes of heat and cold, radiation of various kinds, noise, and some dusts, fumes, and vapors from manufactured and naturally occurring substances—illustrate the diversity of exposures. In addition to identified hazards, present but so-far-unidentified hazards are also a concern. Finally, increasing attention is being focused on assessing the possible hazards of new substances and processes before they are introduced into the workplace.

Some health hazards that have been known for centuries were obvious because of the particular nature of the diseases; for instance, lead poisoning symptoms were sufficiently distinctive to make the association between exposure to lead and disease apparent. Three disciplines—occupational medicine, epidemiology, and toxicology—have been important in describing associations. All three are currently used in investigations of current exposures that may be hazardous. Toxicology is especially important to learning about "new," possibly hazardous substances before they are introduced into the workplace.

Some of the most successful efforts at prevention, such as the marked reductions in exposure to vinyl chloride, began with a physician noting an unusual cluster of diseases. The importance of this source of information draws attention to medical school teaching about the role of work in health and disease. Unless medical students learn the value of taking an occupational history as part of the medical examination, associations may be missed. Occupational physicians, familiar with working conditions and exposures and often interacting with industrial hygienists and safety engineers, can be especially important in hazard identification. Workers' own observations and complaints, brought to the physician, are often the first indication of a hazard.

Epidemiology is important less in initial identification of hazards than in providing evidence for or against an association. In making decisions about which hazards are "real," positive epidemiologic studies are the most convincing evidence, but there are often protracted arguments about the appropriateness of study methods and the conclusions drawn. Companies, trade associations, unions, and government agencies all commission epidemiologic studies and comment on studies done by others. Government records, which contain information about vital statistics and locations, are especially useful in epidemiologic studies.

Toxicology provides information about the potential hazards of substances by testing them in animals or other systems. With the passage of the Toxic Substances Control Act, which requires that companies notify the Environmental Protection Agency of their intention to manufacture new chemicals, the government is in a position to obtain information about chemicals before they enter commerce. Although there are conflicts about how much information EPA needs to protect human health, it is clear that workplace exposures are being identified as concerns in the case of some new chemicals. Toxicology plays the central role in identifying hazards from new chemicals.

TSCA also requires that companies notify EPA about substances present in commerce that are substantial risks, and the Agency then disseminates that information. All three disciplines—occupational medicine, epidemiology, and toxicology—have contributed to the identification of substantial risks. The NIOSH Health Hazard Evaluation program investigates possible associations between exposures and illness at the request of employers or employees or on its own initiative (see ch. 10). It, too, relies on all three disciplines.

Hazard identification is not a smooth path; arguments and conflicts abound. Evidence that convinces some people leaves others unmoved. The methods that were used in the past, improved by better training and techniques, continue to be of value today. More attention during the education of physicians and other medical personnel to the influence of work on health, better use of Federal records, where appropriate, to facilitate epidemiology, and continual research to make toxicology more predictive all offer opportunities to improve hazard identification. However, as is made clear in other parts of this assessment, hazard identification alone is not sufficient. Making a decision to control a hazard requires that the hazard be identified, but identification, by itself, is not sufficient for control.

4.

Safety Hazard Identification

LIST OF TABLES

4
Safety Hazard Identification;

Many safety hazards are obvious: a punch press ram that descends every five seconds, a wet floor, an unstable ladder. This is true at least for the causes of acute injuries, though it is not necessarily true for cumulative injuries. In either case, what is often unclear is the complex of events through which the potential of the hazard is realized and an injury occurs. During this century the theory of the cause of injuries has evolved, and is still evolving, from attributing most injuries to "unsafe acts" of workers, to identifying conditions that increase the probability of an injury occurring. Under the first approach, the preventive remedy is to install perfect workers in jobs. Under the second—by identifying all possible contributing factors—preventive strategies can be applied, or at least considered, in different ways.

The causes of work-related injuries can be examined at two levels. The "macro" approach uses aggregate statistics, such as those produced in the Bureau of Labor Statistics' Annual Survey, to examine the distribution of various types of injuries according to several variables: industry, occupation, size of establishment, sex of worker, and others (see ch. 2, Working Paper #l). These distributions provide general clues to injury causes. The "'micro" level identifies specific injury causes. An epidemiological approach analyzes sets of similar injury-related incidents to find common circumstances contributing to their cause. At the most specific level, individual injury-related incidents are examined to determine cause; several methods have been developed at this level.

The nearly 4,100 work-related fatalities (including heart attacks) that occurred in private sector workplaces with 11 or more employees during **1982 were not evenly distributed over all industries (see table 4-1). Mining, accounting for 2 percent of employment, had 11 percent of the fatalities, Construction, 5 percent of employment, accounted for 18 percent of reported on-the-job deaths.** The wholesale and retail trades represent **25** percent of employment, but recorded only 12 percent of the fatalities. Finance, insurance, and real estate, along with the service industries, accounted for 31 percent of employment, but only 12 percent of fatalities.

A further breakdown reveals the injuries that resulted in death by industry categories, both by the distribution of causes within an industry category (see table 4-2), and by the distribution of each cause across all categories (see table 4-3). Overall, motor vehicle accidents account for 27

Table 4.1.–On-the-Job Fatalities by Industry Division, in Private-Sector Units with 11 Employees or More, 1982

	Annual average employment		Fatalities	
Industry division	Number	Percent	Number	Percent
Private sector (total)	62,629,000	100	4,090	100
Agriculture, forestry, and fishing	729,000	1	180	4
Mining	1,070,000	2	440	11
Construction	2,898,000	5	720	18
Manufacturing	18,267,000	29	770	19
Transportation and public utilities	4,629,000	7	970	24
Wholesale and retail trade	15,603,000	25	490	12
Finance, insurance, and real estate	4,252,000	7	100	2
Services	15,181,000	24	420	10

NOTE Because of rounding, components may not add to totals

SOURCE (608)

Table 4-2.—Causes of On-the-Job Fatalities in Private-Sector Units with 11 Employees or More, by Industry Division, with Distribution by Industry, 1981 and 1982[a]

Cause[b]	Total[c]	Agriculture, forestry, and fishing	Mining—oil and gas extraction only	Construction	Manufacturing	Transportation and public utilities[d]	Wholesale and retail trade	Finance, insurance, and real estate	Services
Total—all causes	100	100	100	100	100	100	100	100	100
Over-the-road motor vehicles	27	18	26	15	20	52	20	35	29
Falls	12	12	9	31	10	6	5	9	10
Heart attacks	10	6	8	8	10	6	12	23	16
Industrial vehicles or equipment	10	27	21	17	9	3	4	0	9
Nonaccidental injuries	7	3	<1	<1	2	2	30	8	15
Struck by objects other than vehicles or equipment	6	1	9	5	8	3	12	0	2
Electrocutions	6	16	4	11	5	6	1	0	5
Caught in, under, or between objects other than vehicles or equipment	6	1	3	4	5	9	8	17	2
Aircraft crashes	4	2	5	1	3	6	1	7	7
Fires	3	8	7	1	6	2	< 1	1	<1
Plant machinery operation	3	1	1	2	10	< 1	1	0	<1
Explosions	2	0	2	2	4	2	1	0	1
Gas inhalations	2	1	3	1	4	1	1	0	1
Another	3	4	3	3	4	2	3	<1	3

[a]It is impossible to estimate year-to-year changes precisely because at the industry division level sampling errors are large Therefore, the results are for both Years rather than a comparison between them.
[b]Cause is defined as the object or event associated with the fatality.
[c]Excludes coal metal, and nonmetal mining, and railroads for which data are not available
'Excludes railroads
NOTE: Because of rounding, percentages may not add to 100
SOURCE (608)

Table 4-3.—Causes of On-the-Job Fatalities in Private-Sector Units with 11 Employees or More, by industry Division, with Distribution by Cause, 1981 and 1982"

Cause[b]	Total[c]	Agriculture, forestry, and fishing	Mining—oil and gas extraction only	Construction	Manufacturing	Transportation and public utilities[d]	Wholesale and retail trade	Finance, insurance, and real estate	Services
Over-the-road motor vehicles	100	3	6	10	18	37	11	4	11
Falls	100	4	4	47	20	8	6	2	8
Heart attacks	100	3	5	16	24	11	18	7	16
Industrial vehicles or equipment	100	12	14	32	23	5	6	0	9
Nonaccidental injuries	100	2	<1	<1	6	5	63	3	20
Struck by objects other than vehicles or equipment	100	<1	10	16	33	8	31	0	3
Electrocutions	100	12	4	34	21	18	3	0	8
Caught in, under, or between objects other than vehicles or equipment	100	1	4	12	21	30	20	9	3
Aircraft crashes	100	2	9	6	22	32	6	5	19
Fires	100	12	15	8	46	14	1	2	2
Plant machinery operations	100	1	2	11	78	2	7	0	<1
Explosions	100	0	5	14	47	20	8	0	6
Gas inhalations	100	2	9	10	48	14	12	0	5
All other	100	6	5	18	33	13	16	1	8

[a]It is impossible to estimate year-to-year changes precisely because at the industry division level sampling errors are large Therefore, the results are for both Years rather than a comparison between them
[b]Cause Is defined as the object or event associated with the fatality
[c]Excludes coal metal, and nonmetal mining, and railroads for which data are not available
'Excludes railroads
NOTE Because of rounding, percentages may not add to 100.
SOURCE (608)

percent of fatalities, but in transportation and public utilities the figure is 52 percent. In construction, falls were responsible for a greater proportion of deaths (31 percent) than were over-the-road motor vehicles (15 percent), although *industrial* vehicles and equipment were associated with 17 percent of deaths.

Nearly half of all fatalities (47 percent) resulting from falls occurred in the construction industry (see table 4-3). Most fire- and explosion-related deaths in the work force (46 percent) and deaths from plant machinery (78 percent) occur in manufacturing. Additional sources of aggregate injury statistics are described in Working Paper #l.

Aggregate statistics can guide injury prevention by highlighting general hazard categories in specific industries. Immediate or underlying conditions related to an individual injury can only be determined through case study.

BASIC THEORIES OF INJURY CAUSATION

Traditional Approach—Unsafe Conditions or Unsafe Acts

In the 1920s, Heinrich proposed a theory of injury causation that many safety professionals have followed ever since. Simplified, the theory states a domino sequence:

- Injuries are caused by accidents.
- Accidents are caused by unsafe acts of persons or by exposure to unsafe mechanical conditions.
- Unsafe acts and conditions are caused by faults of persons.
- Faults of persons are created by the environment *or* acquired through inheritance.

Using this approach, Heinrich analyzed 12,000 cases of injury from insurance claim records plus 63,000 cases from the records of plant owners, for a total of 75,000 cases. Seventy-three percent of the injuries were classified as due to "unsafe acts" by workers. Heinrich noted that 25 percent of the cases examined would, according to the usual methods employed at the time, have been charged to defective or dangerous physical or mechanical conditions. However, he concluded that many cases in this group of 25 percent were caused either wholly or chiefly by worker failure, and only partly by physical or mechanical conditions. He decided to classify as "unsafe conditions" only those cases that were *wholly caused* by physical or mechanical failure. The injuries not wholly due to physical or mechanical failure (15 percent) were grouped with the 73 percent of cases that involved only "'unsafe acts." Thus he produced a well-known and often cited figure that 88 percent of injuries are due to "unsafe acts" by workers (380). Heinrich attributed only 10 percent of injuries to unsafe conditions and considered the remaining 2 percent of injuries to be unpreventable (207).

Critique of Traditional Approach

Arndt (24) has noted that, although there has been little research published to support Heinrich's theory of injury causation, Heinrich's ratio of 88 percent unsafe acts to 10 percent unsafe conditions is commonly cited. In fact, the published research on this topic uniformly refutes Heinrich's theory.

Heinrich himself pointed out two other studies. The first, by the National Safety Council (NSC), concluded that unsafe acts contributed to 87 percent of the cases examined, while mechanical causes contributed to 78 percent. The total of 165 percent is due to NSC's considering multiple causes of accidents. An analysis in 1940 by the State of Pennsylvania showed that an "equal number" of injuries resulted from unsafe acts and mechanical causes. Heinrich recognizes the discrepancy, which he attributed largely to the fact that the NSC and Pennsylvania studies allowed both an unsafe act and an unsafe condition to contribute to a single injury. Heinrich's methodology did not permit such multiple assignment of cause (207),

Table 4-4 presents a summary of other research aimed at apportioning injury causes between unsafe acts and unsafe conditions. Heinrich's study is the only one to attribute more than 35 percent of injuries primarily to unsafe acts by workers. The other research has generally categorized most injuries as resulting from a combination of unsafe acts and unsafe conditions.

Arndt **(24)** examined nearly 1,000 injuries associated with mechanical punch presses. He developed eight mutually exclusive categories to describe the circumstances of the injury. These included operator timing errors, inadvertent tripping of the press, other operator errors, tripping of the press by a second person, and machine malfunctions. He found that 53 percent of the injuries resulted from something other than machine malfunctions. All of that 53 percent would be attributed to "unsafe acts" in a dichotomous system, like Heinrich's, for recording causes of accidents. The machine malfunctions, including broken parts and accidental recycling of the press, which would generally be labeled "unsafe conditions, " amounted to 18 percent of cases. Arndt was unable to classify **29** percent of the cases because of a lack of information.

Thus, under the traditional breakdown between unsafe acts and unsafe conditions, about three times as many injuries in Arndt's study would be classified as due to unsafe acts rather than unsafe conditions. But Arndt observes that a very large number of those classified as "unsafe acts" occurred on presses activated by a foot pedal, by a one-hand control, or automatically. These presses allow operators to insert their hands inside the "point of operation" of the press. It is not surprising, then, that someday someone places a hand or arm inside such a press to adjust the piece being worked on or to clear a jam, and then is unable to remove it quickly enough. For example, if a press operator produces 5,000 pieces a day, then the operator's hands are placed in front of the press ram every 5 seconds, which means about **25,000** times per week or 1.2 million times a year (24). It may be only a matter of time before an operator commits an "error" and loses a finger in the press.

There are, however, machine designs that can reduce and nearly eliminate this particular hazard. Machines can be designed to operate with two-handed controls, so that the operator must have both hands on the controls. In Arndt's analysis, 60 to 70 percent of the injuries from presses activated by foot pedals, by one-handed controls, or automatically were related to "unsafe acts, " and only 10 to 20 percent related to "unsafe conditions. " For presses with two-handed controls, the fraction due to "unsafe acts" was only 35 percent. "Unsafe conditions" were cited in about 54 percent of these cases. Arndt's paper does not present any information on the injury rates associated with the various kinds of presses because data on the total numbers of each control type are not available. But it is clear that the design of the press has a dramatic affect on the number and percentage of cases attributed to "unsafe acts. "

The traditional partition between unsafe acts and unsafe conditions unfortunately often draws

Table 4-4.—Estimated Percentages of Accidents Due to Unsafe Acts versus Unsafe Conditions

Study	Percent due to unsafe acts	Percent due to unsafe conditions	Percent due to combination	Percent unknown
Furniss	—	16	84	—
Pennsylvania Department of Labor	2	3	95	—
National Safety Council	19	18	63	—
Mintz and Blum	21	—	79	—
Hagglund [a]	26	58	2	13
Hagglund [b]	35	54	4	7
Henrich [c]	88	10	—	—

[a] Investigations of reported fatalities.
[b] Random sample of accident reports
[c] Henrich classified 2 percent as 'unpreventable "

SOURCES (30,37,207,316)

attention away from the job or equipment redesigns that can remove or minimize hazards. In the 1959 edition of his textbook, Heinrich himself cautioned safety professionals not to neglect workplace conditions. He expressed confidence that safety professionals would not "ignore the very first common-sense step. . . of safeguarding [the] mechanical environment" (quoted in 462).

The catchall category of "unsafe act" or "human error" has greatly restricted advances in injury research and the application of control techniques in workplaces (380). The label "unsafe act" has, unfortunately, often led to a failure to recognize how the design of workplace equipment can minimize the occurence of "unsafe acts" or reduce the probability and severity of human injury.

The seriousness of this limitation is clear from one commonly used system for recording information about injuries. The American National Standards Institute (ANSI) Standard Z16.2, *Method of Recording Basic Facts Relating to the Nature and Occurrence of Work Injuries*, used widely for employer injury investigation and recordkeeping. ANSI itself sees inadequacies in its method, as the text of Z16.2 indicates:

> It is recognized that the occurrence of an injury frequently is the culmination of a sequence of related events, and that a variety of conditions or circumstances may contribute to the occurrence of a single accident. A record of all these items unquestionably would be useful to the accident preventionist.
>
> Any attempt to include all subsidiary or related facts about each accident in the statistical record, however, would complicate the procedure to the point of impracticability. The procedure, therefore, *provides* ***for*** *recording* ***of one pertinent fact about*** *each* ***accident in each of*** *the* ***specific categories or classifications.*** To insure uniformity in the selection of items to be recorded in each category, the items are specifically defined in terms which eliminate any necessity for decision as to the relative importance of multiple items falling in the same category (emphasis added).

Instead of collecting information on all the circumstances leading to the accident, the ANSI Standard Z16 allows "only one pertinent fact" to be recorded concerning the nature of the injury, the source of the injury, the type of accident, the hazardous condition present, and any unsafe act. This standard facilitates the administration of injury data collection because of its simplicity, but it is inadequate for research on causation. Unfortunately, the most common entry under this system is simply to attribute the injury to "worker error."

According to Purswell and Stephens (380), attributing responsibility for accidents to human error, with no significant information as to why the error **was** committed, is not limited to the ANSI system. It is found in other workplace-injury data collection systems as well as those for collecting data on non-workplace injuries. For example, researchers in the field of highway safety have noted that there is no place on standard police forms to record many items that relate to features of the vehicle or the road that contributed to the injury. For the most part, these forms are oriented around recording information on the driver (41).

OTHER MODELS OF INJURY CAUSATION

Purswell and Stephens (380) describe a number of other models of injury causation and investigation. These include behavioral models, management models, epidemiological models, and ergonomic or human factors **models.**

Behavioral Models

The underlying concept of behavioral models is that of the "accident proneness" of individuals. Some safety specialists believe that a disproportionate number of injuries are incurred by a handful of individuals who are especially prone to accidents. Accident proneness has been, at one time or another, ascribed to recent immigrants to the United States, to certain ethnic/racial groups, or to certain personality traits (380). Thus efforts were made to identify these workers and either fire them or not hire them in the first place. Later researchers have been unable to find similar traits that will reliably predict which workers will be injured. Unfortunately, the belief that there are "injury-prone" workers is still commonly held. According to a Bureau of National Affairs (78) report, 65 percent of the businesses surveyed stated that their safety programs attempted to identify "accident-prone" individuals.

Other behavioral models have considered motivational factors, the rewards of working safely, and the level of satisfaction received from working safely *(368)*. It has been observed that many workers perceive little positive reward for working safely.

Management Models

Bird (58) revised Heinrich's domino theory to emphasize management's responsibility for injury causation. His revised domino theory is:

- Injuries are caused by accidents.
- For each accident there are immediate causes that are symptomatic of problems in the overall system.
- There are basic causes in the overall management of the system that produce the immediate causes of the accident.
- The lack of management control permits the basic causes of accidents to exist in the system.

Bird's approach therefore shifted the emphasis from the worker as the cause of injuries to the management system in which the worker exists.

Zabetakis (684) of the Mine Safety and Health Administration Academy added the idea that injuries are due to an unplanned release or flow of energy, again following the approach of the domino theory. Energy release is considered in the general sense—mechanical, electrical, chemical, thermal, or ionizing radiation. Since unwanted energy flow is a fundamental source of injuries, Zabetakis claimed, a system maybe evaluated and improved by studying:

- the sources of energy existing in a system,
- the means available to reduce the energy levels,
- the means of controlling the flow of the energy, and
- the methods available for absorbing the energy should loss of control or improper flow occur.

The next major outgrowth of the domino theory was based on the idea that multiple factors can combine in a random manner to produce accidents and injuries. Such causation models focus not only on unsafe acts of the injured person, but also on unsafe acts of coworkers and unsafe conditions that existed at the time. Attention is ultimately drawn to failures in management systems that permit the multiple factors to converge and produce an injury.

One of the best known management-oriented approaches to accident causation is called the Management Oversight and Risk Tree (MORT), developed by Johnson (235) for use in the analysis of complex systems related to atomic energy. It could also be called a systems model (discussed later in this section). MORT employs a large schematic to inductively trace events of a work-related injury back in time, to identify the sequence of unwanted energy flow, and to evaluate the adequacy of barriers to unwanted energy transfer to persons or equipment. Along the route, hazards arising from specific accident circumstances, from risks acknowledged or assumed by management, and from general management systems and policy weaknesses are identified.

Still, several difficulties exist in adopting MORT to general injury investigation or applying it to most industrial workplaces. Its use as an industrial injury investigation procedure is limited by its complexity. The method is more suitable for investigating large-scale incidents, especially situations holding the potential for public disaster, such as nuclear powerplants. While it is an excellent approach for these situations, in its present form it is much less useful for explaining most work-related injuries. But it may be useful as a blueprint for the optimal allocation of resources for building a safety program (380).

Epidemiologic Models

Epidemiology has been described as the search for causal association between diseases or other biologic processes and specific environmental experiences or exposures. The epidemiologic model applied to injury research seeks to explain the occurrence of injuries within the system of host (injured victim), agent (means of injury), and the environment (physical, psychological, and social factors related to the event).

Using such a model, it should be possible to identify features common to a set of injuries or accidents, and either identify causes directly or find clues to causation. This approach has advantages over investigating each incident separately, Looking at a group of off-the-road industrial vehicle accidents, for instance, it might become apparent that one company's products are involved in a disproportionate number of incidents **(40).**

Gordon **(187)** and McFarland **(295)** were two early proponents of epidemiologic models of injury causation. Haddon (197) was successful in implementing an epidemiologic approach to transportation accidents while directing the National Highway Traffic Safety Administration. Baker and her coworkers (40) have successfully used epidemiologic techniques to describe work-related deaths in Maryland.

The epidemiologic method requires the collection and study of far more information about the host, the environment, and their interactions than the behavioral and management models do. This approach, which recognizes the interactive nature of the injury process, is a significant advance over earlier models. In fact, it has provided a framework for the application of many systems approaches that incorporate human operator variables, environmental factors, and task demands. The National Institute for Occupational Safety and Health is currently conducting two epidemiologic studies to evaluate the role of personal, managerial, and work environment factors in the etiologies of fall-from-ladder accidents and accidents that result in fatal injuries. Both are case-comparison studies that should produce a scientific assessment of these causal factors.

Systems Models

The emergence of systems engineering as a discipline in the 1960s gave rise to many new applications of systems theory, including systems safety. The various models that have been used include "failure mode and effects analysis" and "criticality analysis." Both these are largely oriented towards assessing the reliability of hardware and equipment. Another systems model, "fault tree analysis," involves building a logical "tree" of events that can lead to undesirable outcomes. The analyst examines component failures, which can include both hardware and human errors, and attempts to learn what might cause these failures and what effects on system safety they might have.

The systems-safety models have been applied most extensively in military and aerospace endeavors with the focus on potential failure points in system hardware. Few quantitative data exist about human error rates, so including the human component of this system is frequently precluded.

Ergonomic/Human Factors Models

The injury causation models developed by human-factors engineers or ergonomists attempt to provide insights into the problems of "unsafe acts" or human error that are lacking in other injury causation models.

Ergonomists generally analyze the interactions between workers and their machines for the sources of injury causation. The limits of human beings to perform consistently and without errors are important issues to the ergonomists. Rather than viewing operators' errors as merely "unsafe acts" that can only be addressed through training and motivation, the ergonomic approach looks to see if various features of the machine or the design of the work might themselves be inducing worker errors. These features can include the presentation of information to workers through displays, the design of machine controls, and the relationships between displays and controls. In addition, ergonomists analyze the physical capacities of workers, such as lifting or reaching ability, to determine whether the task places undue stress on specified parts of the body or leads to excessive fatigue.

Because of the importance of this discipline for the prevention of both acute trauma and cumulative trauma, as well as its potential usefulness in the field of general workplace and equipment design, ergonomics is discussed in greater detail in chapter 7.

CRITIQUE OF INJURY CAUSATION THEORIES AND MODELS

The inherent simplicity of Heinrich's domino theory and its historical availability no doubt account for its widespread acceptance. A minimum amount of training is required to understand its application and it does provide an answer to the question of "cause," even if it is a superficial one. Since most injuries are classified as resulting from "unsafe acts," it unfortunately allows more fundamental features of workplace design that lead to injuries to be ignored.

Behavioral models initially contributed to our understanding of the human component of injury causation, although approaches based on studying "accident proneness" have contributed little or no useful information for prevention. It is unfortunate that many firms still expend resources trying to identify "accident-prone" individuals, rather than pinpointing features of workplace design that lead to injuries.

The adaptations of Heinrich's theory that place the responsibility for unsafe acts and unsafe conditions on the management system of the enterprise represent a major step forward in preventing occupational injuries, The causal explanations are still too simplistic, although these approaches do provide a limited ability to predict the occurrence of hazards in the workplace.

The chain-of-events or multiple events models (MORT is an example) recognize that many factors influence injury causation and thus represent progress over single-event models. However, the current models do not have a sufficiently simple organizing structure to make them useful across a wide range of industries.

The epidemiologic model has value as an organizing framework for the systematic study of the factors related to various types of injuries. It is limited in that, in general, it cannot adequately explain why injuries happen or how corrective measures can be identified and applied.

The systems models have been developed primarily to evaluate system, subsystem, and component failures. The primary focus has been on nonhuman or hardware failures. Although the potential exists for incorporating human error rates into these analyses, the data to do so are currently very limited.

The human factors/ergonomics models focus on the human/machine interface and thus provide a much-needed emphasis on understanding the interaction of worker and machine in order to achieve a safe working environment. The thrust of the practice of ergonomics is designing the ***work tusk,*** rather than merely installing machinery and letting the worker find a way to adapt. Thus injury prevention can bean integral part of job design. The principal shortcoming of this model is the absence of any analysis of hardware failures beyond the human/machine interface. However, compared with the injuries that occur at that interface, hardware failures are relatively rare.

Purswell and Stephens (380) conclude that no single model provides a wholly satisfactory approach to explaining the various facets of injury causation. They suggest that, for the present, the epidemiologic model is useful for identifying major categories of causal factors in the workplace, and that these major categories should be studied in-depth using the human factors/ergonomics model.

The quest for causal models should not be the sole object of research on injury prevention. What is even more important is the design of interventions to eliminate or reduce the injury hazards faced by workers. In fact, one distinguished researcher has concluded that the search for causal models for injuries may ultimately be fruitless. Singleton has recently stated that "there can never be a theory which will predict an accident and even accident rates are subject to too many variables for prediction to be meaningful. " But he adds:

> It does not follow that we must abandon hope of controlling accidents. The same problem occurs in other complex practical situations. The physician, for example, is often faced with a patient with a disease which he cannot readily identify. . . However, this does not mean that nothing can be done, The physician has certain general principles; the temperature must not be allowed to get too high, the body must not get dehydrated and so on. He can take action on the basis of these principles without waiting to identify the cause of the symptoms. Similarly in accident prevention we can take action to increase safety without waiting for a theory of accident causation (442).

5.
Technologies for Controlling Work-Related Illness

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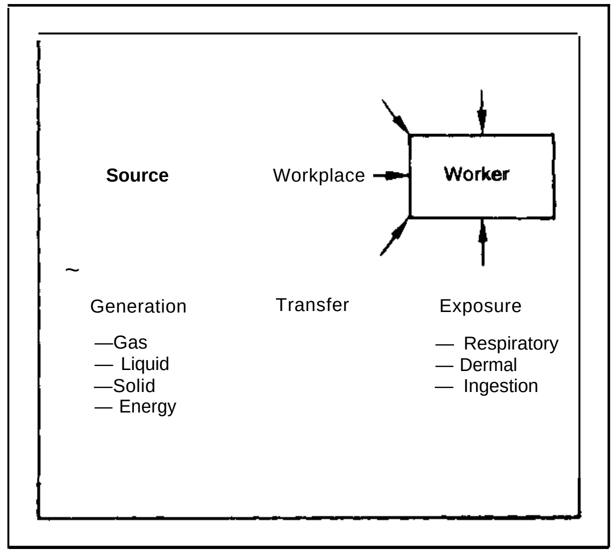
5. Technologies for Controlling Work-Related Illness

This chapter describes the principles and technologies for controlling workplace health hazards—toxic substances and harmful physical agents found in the workplace. For clarity and since the control principles are similar for both toxic substances and harmful physical agents, discussion focuses on control of the former. Emphasis is given to technologies proven to be the most effective for protecting workers' health—those that prevent hazard generation or that prevent worker contact with the hazard. Three case studies commissioned by OTA illustrate these principles and technologies as applied in controlling work-related exposure to cotton dust, silica, and lead. In addition, the extent of the use of control technologies in United States workplaces is discussed.

Health hazards, as defined by public health science, cause disease by an agent (hazard source) transmitted through the environment by a vector (transmission of hazard) to a host or a receptor (worker) who is affected. This model includes workplace hazards to which workers are exposed (see fig. 5-1). For workplace hazards, the source– the point at which the hazard is generated—may be a gas, a liquid, or a solid if it is a substance, or a form of energy if it is a physical agent. Transmission or dispersion of the toxic substance or harmful physical agent is generally through workplace air or by direct contact. The worker at risk may receive (absorb) the hazard through ingestion, the skin, or by inhalation (see fig. 5-2).

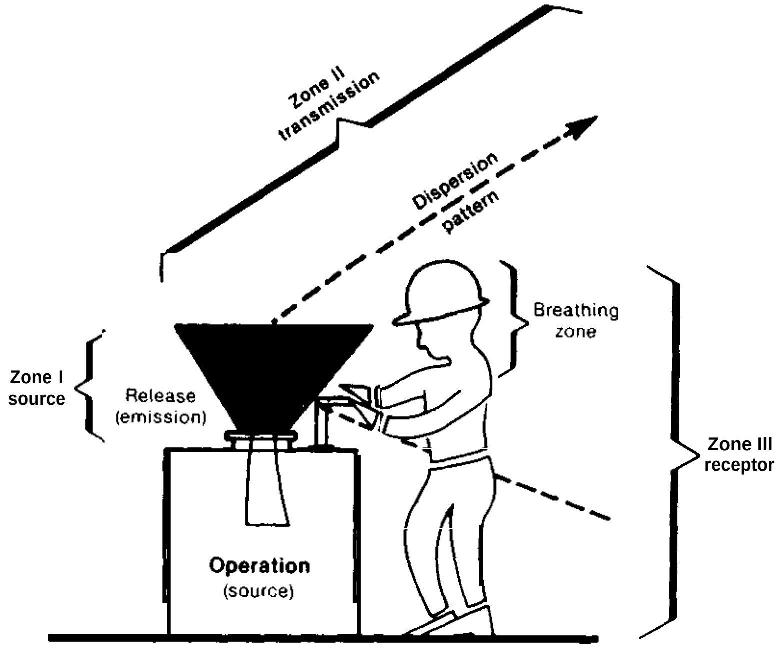
A control technology system can include hazard control at any or all of these three points—source, transmission, or worker. Hazard controls applied at the source, such as isolation of a process, or in the transmission or dispersion path, such as local exhaust ventilation, are generally called "engineering controls. " Those worn by the worker, such as protective clothing or a respirator, are generally called "personal protective equipment."

Figure 5-1 .—Generalized Occupational Exposure



A hierarchy of control methods is commonly used. The first choice is control at the source, which can be done by design or modification of a process or equipment or by substitution of less hazardous materials. If the source is unalterable through design or substitution, the next choice is to control or contain the dispersion of the contaminant by isolation of the source, preventing the toxic substance from becoming airborne, or by removing the contaminant through local exhaust or general dilution ventilation. Finally, control at the worker may include administrative controls, personal protective equipment, and work practices. (Personal protective equipment is discussed in ch. 8, and the hierarchy of controls is discussed in ch. 9.)

Figure 5-2.—Generalized Model for Control of Workplace Hazards



CONTROL SYSTEMS

There have been many attempts to define control technology. Brandt (71) described it as a system designed to control contaminant emission and dispersion along the pathway to the worker. Bloomfield (61) cited ventilation to reduce levels of airborne contaminants as the primary means of engineering control. The International Labour Office (229) includes several techniques in control technology: ventilation; process changes; substitution of process, equipment, or material; isolation of stored material, equipment, process, and workers; and education of management, engineers, supervisors, and workers. Caplan (96) defined engineering controls for industrial hygiene purposes as "installation of equipment, or other physical facilities, including if necessary selection and arrangement of process equipment, that significantly reduces personal exposure to occupational hazards." Smith (450) defined control technology as substituting less dangerous substances, equipment, or processes; limiting releases or preventing buildup of environmental contamination; limiting contacts between worker and toxic materials by personal protective equipment; and introducing administrative changes.

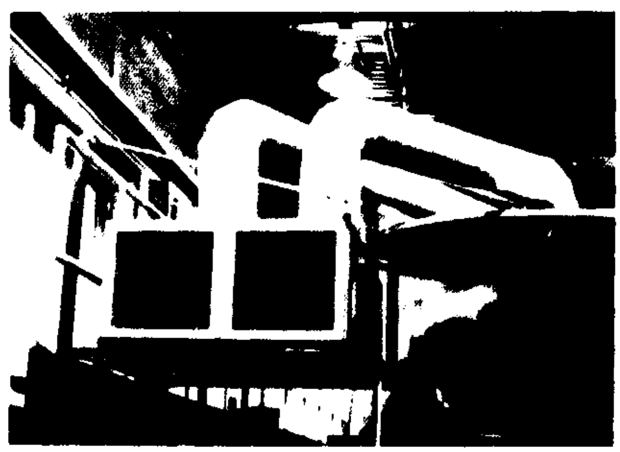


Photo credit: NIOSH

This electrostatic precipitator is used to remove oil mists from the atmosphere of a machine shop

For this assessment, a hazard control system includes:

1. control at the emission source by substitution of materials, change of process or equipment, or other engineering means,
2. control of the transmission or dispersion of the contaminant by isolation, enclosure, ventilation, or other engineering means, and
3. control at the worker by personal protective equipment, work practices, administrative control, training, or other means.

The controls in No, 1 and No. 2 are commonly called "engineering controls."

Training workers, supervisors, managers, engineers, and other concerned persons about a hazard and its control underlies the effectiveness of control solutions. Hazard-free operation requires rigorous maintenance of controls, and good housekeeping is essential to control secondary sources of contamination. Work practices (e.g., instructions that liquids should be poured away from the worker) and administrative procedures (e.g., that workers spend limited time in the presence of hazards) are also important parts of a control system. Table 5-1 is a compilation of hazard control principles and includes examples of control measures.

One tenet of effective hazard control is that a system should be designed in a way that the controls are automated or inherent in the operation of the system. Thus, hazard controls should function even in the absence of continuous worker and manager attention. For instance, enclosing a process to prevent emission of toxic substances to workplace air is a more reliable, and likely less expensive, control than respirators, where effectiveness is difficult to measure, protective fit is difficult to achieve. Although systematic design will consider a variety of control methods and combinations, engineering solutions are preferred because they depend less on routine human involvement for effectiveness. For example, grounding home electrical appliances provides greater protection against electrical shock than instructions to remember not to simultaneously touch an ungrounded appliance and a metal surface.

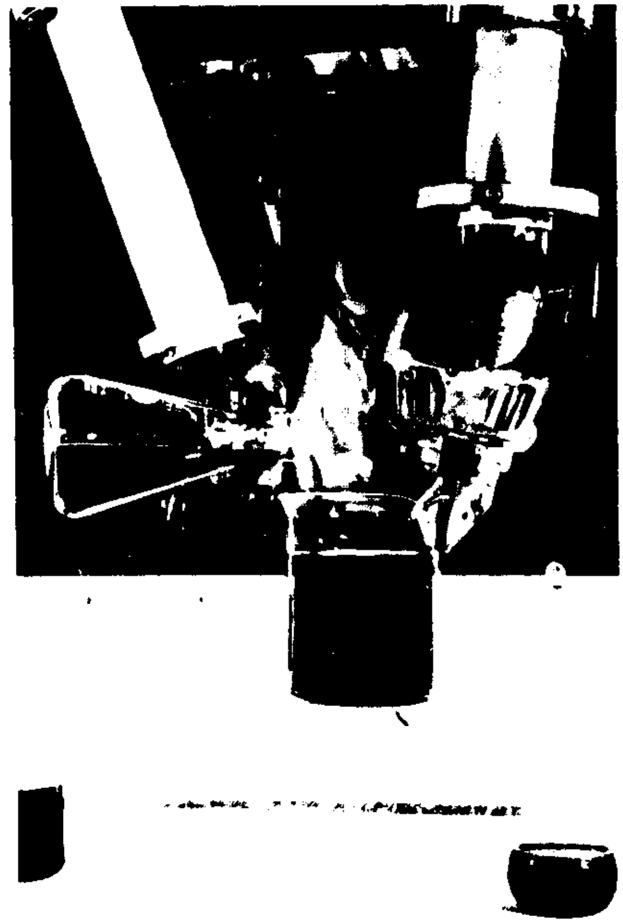


Photo credif: OSHA, Office of Information and Consumer Affairs

Engineering controls include the enclosure of operations and using remote controls. This photo illustrates equipment designed to handle very toxic radioactive materials

Because of the continuing need for human intervention and attention in the use of personal protective equipment, practicing industrial hygienists employed by business, government, and unions have long recognized that such equipment should be turned to only after other means of protection have been exhausted (see ch. 9). Occupational Safety and Health Administration (OSHA) standards require the use of engineering and work practice controls except for the time period necessary to install such controls, when engineering and work practice controls are infeasible (including many repair and maintenance activities),

Table 5=1 .–Principles of Controlling the Occupational Environment

Point of application of the control measure	Control measure
At or near the hazard zone.	Substitution of nonhazardous or less hazardous material Process modification Equipment modification Isolation of the source Local exhaust ventilation Work practices (housekeeping)
To the general workplace environment	General dilution ventilation Local room air cleaning device Work practices (housekeeping)
At or near the worker	Work practices (housekeeping) Isolation of workers Personal protective equipment
Adjuncts to the above controls	Process monitoring systems Workplace monitoring systems Education of workers and management Surveillance and maintenance of controls Effective process-people interaction and feedback

SOURCE (576)

when they are insufficient, and in emergencies (see ch. 9). For instance, engineering solutions to reduce airborne lead concentrations to the OSHA standard are difficult to apply in lead smelters, and OSHA allows respirator programs while the solutions are engineered.

Of course, the nature of some jobs requires reliance on personal protective equipment. For instance, firefighters depend on self-contained breathing apparatus when fighting fires.

Control at the Source

Control at the source can be achieved by design of new or modification of existing processes or equipment, or by the substitution of less hazardous materials-all done, preferably, before the process or equipment is installed and operated. The industrial hygiene literature repeatedly points to source control as the most effective means of preventing work-related illness.

Designing Controls

Designing equipment to eliminate contact between hazard and worker is the most effective way to control exposure (71). The control of vinyl chloride monomer (VCM) provides an example of successful design eliminating a health hazard (see also box N in ch. 12). In the 1960s, before VCM was recognized as a carcinogen, it was identified as a cause of acro-osteolysis (bone deterioration, especially in the finger tips). This finding led the American Conference of Governmental Industrial Hygienists (ACGIH) to revise the Threshold Limit Value (TLV) exposure limit from 500 parts per million (ppm) to 200 ppm in 1970 (5).

Revision of the exposure limit meant that the firms that followed ACGIH recommendations had to find ways to reduce worker exposure. Analysis by design engineers identified two methods by which the high exposures associated with cleaning the VC reactor vessel could be reduced: elimination of reactor fouling or mechanical or chemical removal of the polymer buildup. Hydraulic reactor cleaning technology was adopted that reduced the frequency of worker cleaning from once per several reactor charges (loading the reactor) to once per 25 to 30 charges and thereby reduced worker exposure (256).

When VCM exposure was recognized in 1974 as strongly related to angiosarcoma of the liver (a rare and deadly cancer) by health professionals, OSHA mandated a permissible exposure limit of 1 ppm. Feasible engineering and work practice controls were required to reduce exposure below this level (617).

Again, industrial hygiene analysis determined that exposure to gases during reactor cleaning was a major problem. Re-investigation led the design engineers back to earlier considerations, of either eliminating the fouling or finding an automated cleaning method. But this time the design criterion was to reduce drastically exposure from over 200 ppm down to 1 ppm, and mechanical cleaning alone was found to be inadequate. However, spraying a simple coating solution on interior reactor walls before mixing each batch prevented polymer buildup, Automating and enclosing the reactor cleaning process by installing a permanently mounted nozzle inside the reactor (see fig. s-3) very effectively contained the VCM gases and greatly reduced worker exposure (256).

Commercial use of this design demonstrated that the new reaction vessels needed cleaning only once every 500+ polymerization batches, greatly improving the productivity of the process. The developer, B.F. Goodrich, now uses the innovative process in its vinyl chloride monomer plants both here and abroad and also licenses it worldwide to other chemical manufacturers. Table 5-2 shows the benefits of this control technology (256).

This example illustrates the advantages of applying engineering controls to the prevention of work-related illness. Engineers sought solutions to a recognized health problem by first considering methods that would eliminate exposure such as by automating cleaning or by preventing buildup of materials that require removal. This example also shows that production costs can be reduced and productivity increased, as Brandt postulated some 35 years ago in his book on occupational health engineering (71).

Health hazards can also be eliminated or controlled by changing an industrial process. For example, the National Institute for Occupational Safety and Health (NIOSH) recently conducted a study of dry cleaning machine operators exposed to perchloroethylene, a widely used solvent, known to cause contact dermatitis, central nervous system depression, liver damage, and anesthetic death. NIOSH investigators found higher exposure levels of perchloroethylene vapors in processes involving separate washing and drying machines than in processes that combined these two steps in one machine. The two-step process requires manual transfer of clothes, resulting in unnecessary worker exposure, which is avoided in the combined process.

Substitution

Substitution of a less toxic agent for a more toxic one is an important means of control, but care must be taken that the substitute does not itself harbor toxic properties. For example, asbestos, an excellent insulator, is found widely in buildings, ships, and other places requiring thermal insulation. However, as its toxic properties, especially its carcinogenicity, were recognized, other materials were considered as a replacement. Several materials are suitable, depending on the application and the temperature range to be insulated. These include insulating concrete, vermiculite, fiberglass, and rockwool. While none of these is yet known to cause cancer, precautions

Figure 5-3.-Vinyl Chloride Reactor System

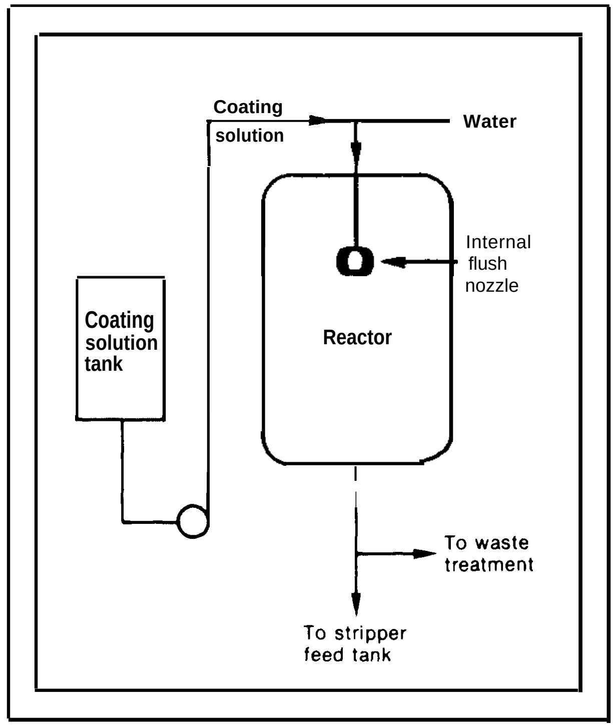


Table 5-2.—Benefits of New Technologies for Controlling Worker Exposure to Vinyl Chloride Monomer (VCM)

Reduction in worker exposure to VCM.
Reduction in VCM emissions to the atmosphere.
Closed reactor operation—entry only for normal maintenance.
Savings in labor.
Reduction in reactor downtime due to cleaning and, as a result, increase in productivity.
Polymer buildup lost as scrap is eliminated.
Reduction of rupture disc changes due to polymer buildup.
Constant and maximum process side heat transfer coefficient in the reactor.

SOURCE: (25S).

should be taken to control exposure to these materials during installation (80).

Silica dust, which can cause lung disease, is one of the oldest known occupational health hazards, and its control well illustrates the principle of substitution (see case study, later in this chapter). Silica dust is a problem in "sand blasting," in cleaning and polishing moldings and metals, and in mining and quarrying, where it is generated by explosives and mining machinery.

In foundries, silica dust is generated during cleaning, during chipping and grinding of castings because some sand from the cores and molds remains on the castings, and during abrasive cleaning, which generates airborne silica dust. If abrasive cleaning is performed by sand blasting, silica dust may be generated from both the blast sand and the mold and core sand.

The most direct method of eliminating silica dust is to make substitutions for silica-containing material. A number of silica-sand substitutes are available for abrasive blasting, including metallic shot and grit, garnet, nut shells, cereal husks, and sawdust, and have been widely used in abrasive blasting operations and to some extent in foundries *(560).*

In some cases, silica dust can be eliminated by substitution of a nonabrasive process—by cleaning castings by the salt bath process, acid pickling, or ultrasonic cleaning. Water jetting and laser cutting to remove excess metal from castings have been considered as alternatives to chipping and grinding (435).

Controlling Dispersion

If a source cannot be altered through design or substitution, the next choice is to control or contain the dispersion of the contaminant. This may be done by isolating the source, preventing the toxic material from becoming airborne, or by ventilation.

Isolation

Isolation of a process involves the placement of a barrier between the process and the worker. In dusty operations for example, there are three basic means of isolation: enclosure of an operation (to prevent dust, fumes, or vapors from escaping into occupied areas); *automation,* through the use of unattended machines; and *distance,* to place operations away from workers.

Isolation by enclosure has been used effectively to reduce silica exposure in foundries (359,569, 577). Abrasive blasting operations maybe located in enclosed, ventilated booths. Enclosure is also used to reduce worker exposure in the asbestos textile industry. Card machines, among the dustiest parts of the asbestos textile manufacture process, can be completely enclosed and asbestos dust filtered from the air exhausted (80). Enclosure has been applied successfully in containing contamination from radioisotopes since the beginning of the nuclear industry. A variation is to protect workers from physical and chemical hazards by locating their work stations in ventilated control booths.

Many jobs with risk of exposure to toxic substances can be automated. For instance shakeout (a method for removing foundry sand from molds or parts) in a foundry can be done by ventilated machines rather than by hand. Automobiles may be spray painted or welded by automated machines to remove workers from exposure to spray paint and solvent and welding fumes, respectively.

Finally, explosive or extremely toxic materials can be stored in remote and inaccessible areas and hazard-generating operations may be removed from areas where workers are concentrated. Open-air sand blasting can be done at a distance from other work sites to reduce the number of workers at potential risk. Persistently leaky pumps and piping for the transport of toxic substances can be isolated by placing them in areas remote from workers.

Wetting

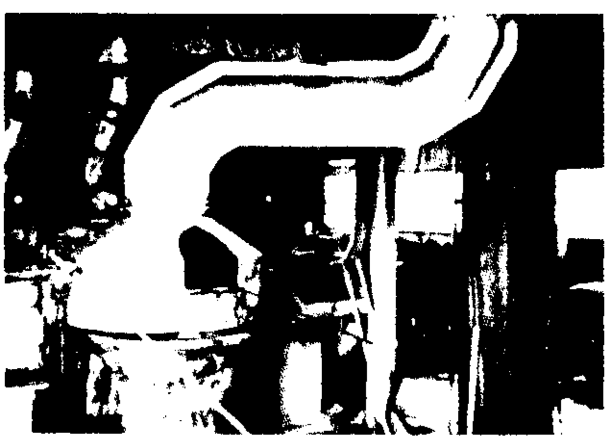
Wetting dust to prevent it from becoming airborne is used to reduce worker exposure. Spraying is a primary means of dust control in mining, but it is considered to be inadequate alone and is usually used in conjunction with ventilation (230,394). Substitution of wet processing and spraying for dry operations has been widely used to control silica dust. In foundries, adding moisture to sand has been found to reduce dust concentrations substantially (435,569). By contrast, wet processing in the manufacture of portland cement appeared to have no effect on respirable dust levels (419).

Local Exhaust Ventilation

Local exhaust ventilation is one of the most commonly used engineering controls. It aims to protect the worker by capturing generated gases, vapors, fumes, or particles in an exhaust air stream and discharging them away from workers. Examples are laboratory fume and kitchen-range hoods, both of which use fans to exhaust contaminated air, Industrial operations are often placed in hoods to obtain maximum contaminant control with minimal exhaust air volume.

For example, local exhaust can be applied in aluminum reduction operations to reduce worker exposure to carcinogenic particulate, in spray paint booths to control paint mist and solvent vapors, in garages to control carbon monoxide from auto exhaust, and in foundries to control silica exposure from abrasive blasting and grinding.

NIOSH is currently investigating "push-pull" ventilation. Generally, local exhaust ventilation depends on "pulling" air away from the operation and exhausting it at some distance from the worker, If the emission source is over two feet from the exhaust, a great quantity of room air must be pulled into the exhaust, significantly reducing control effectiveness. Furthermore, energy costs are increased to heat the air that replaces the exhausted air.



This hood in a secondary lead smelter illustrates the use of local exhaust ventilation

Using a jet of air "upwind" from the exhaust pushs the emissions toward the exhaust. This is commonly referred to as push-pull ventilation. NIOSH showed that push-pull ventilation controlled emissions from chrome plating tanks with just 25 percent of the exhaust needed if only pull was used. The system thus controlled emissions and reduced energy costs (582).

A successful local exhaust ventilation system.—As already indicated, controlling exposures is best done by considering design of the health hazard control at the time a process is established and carefully monitoring performance of the system. Anderson *(20)* describes the effective design of a control system in a large electronics plant.

The process begins when a manufacturing engineer asks to add or change a chemical process. The request is submitted to the facilities engineering department and an engineer is assigned responsibility for installing the equipment to satisfy process, safety, health, and other requirements. Part of the facilities engineer's responsibility is to review the need for local exhaust ventilation with the industrial hygienist, who is responsible for providing health protection information including details about hood design and air volume requirements. The preliminary design is then reviewed by the environmental engineering department to determine the need for air cleaning devices and emission permits. After the process design is completed, it is given a final review by the industrial hygiene, environmental engineering, safety, maintenance, and manufacturing engineering departments.

Installation is supervised by a coordinator who ensures that contract specifications are followed, Changes must be approved by the facilities engineer. The contract coordinator informs the facilities engineer when the job is done and puts a warning tag on each completed hood.

Before the hood can be used it must be adjusted to meet design specifications by the facilities engineer and the maintenance ventilation technician, who enters information about the system in a data

base for scheduling preventive maintenance and who also tags the hood to indicate that this has been done. After this the hood is inspected by the industrial hygienist, who reviews its use with the workers and ensures that the proper chemical identification labels are placed at each station.

Hood effectiveness is measured periodically and data entered into a computer. Each week the computer system generates a card for each hood performing below specified levels for review by the industrial hygienist. If the hood is in need of attention, the card is forwarded to building maintenance. If that department is unable to fix the hood, the facilities engineering department treats the failure as a unique project, and then follows the same procedure that is used in designing a new hood,

If a hood is found to be dangerously deficient by the ventilation technician, it is tagged "Do Not Operate" and immediately reported to the department manager, facilities engineering department, and industrial hygiene department.

The main features of this well-thought-out system for designing and managing controls are:

- coordination among all concerned parties,
- integration of occupational health **concerns** at the beginning and throughout the design process,
- integration of occupational health concerns following installation, and
- execution of a well-planned preventive maintenance program.

The company has found that this approach greatly lowers costs by reducing the need to retrofit processes. Before this method was adopted, newly installed exhaust systems frequently failed because of improper design or installation. Post-installation approval guarantees all concerned parties that the system works from the start as it was designed. A well-planned, computer-based, preventive maintenance program assures continued effectiveness.

General Dilution Ventilation

While local exhaust systems are applied at a particular point to remove contaminants at relatively high rates, general dilution ventilation is the gradual introduction and mixing of fresh air with, and exhausting of, workplace air. Continuous air exchange in buildings reduces nontaminants that resist other control means while contributing to maintenance of a comfortable environment. General dilution ventilation is defined as "the process of supplying or removing air by natural or mechanical means, to or from any space" (71). The air circulation systems found in most buildings are examples of general dilution ventilation.

This technique requires careful planning, and it can fail if inadequate consideration is paid to contaminant generation rates. Furthermore, provision must by made for adequate fresh "makeup" or "replacement" air, for heating or cooling the makeup air, and for avoiding contamination of makeup air.

Recent interest in energy conservation has added new considerations. Increased building insulation has greatly reduced the flow of air from "leaks," which requires more makeup air. Chapter 16 describes particular problems among office workers in new "tighter" buildings, Office workers report health effects from microorganisms, organic chemicals, asbestos, tobacco smoke, and other sources in buildings with inadequate ventilation **(25).**

Control by general ventilation is aided by removing sources, such as smoking, and by cleaning air. Since most building ventilation systems now recirculate air, cleaning the air becomes especially important. This is a relatively new problem; before energy conservation was given emphasis, accepted engineering practice was to completely exchange building air to avoid contamination buildup. Now, building air is often cleaned and then recirculated to reduce energy cost. Systems are available for cleaning both gas and particulate, but care must be taken to ensure that the system is reliable and the cleaning complete *(563).*

Neither local nor general ventilation acts to prevent generation of hazards; it can only capture or dilute contaminated air and take it to another location. The air may still have to be cleaned before discharge to the ambient environment, to meet Environmental Protection Agency or other ambient-air standards **(6,562,563).**

Control at the Worker

Control at the worker may include certain work practices, personal protective equipment, and administrative procedures. (Personal protective equipment is discussed in ch. 8.) For example, work practices important in preventing generation of airborne silica dust include using vacuum instead of compressed air cleaning, keeping enclosed operations tightly closed, and housekeeping to reduce dust accumulation.

Other administrative procedures include rotation of workers in hazardous areas so that no one person is exposed full-time, and scheduling procedures such as cleaning or maintenance to take place on weekends or at other times when few workers are present.

An underlying factor in the success of administrative controls is the adoption and enforcement of exposure control policies. Company policies directed at control of chronic health hazards are often enforced less vigorously than are policies that require workers to wear hard hats or that prohibit tobacco smoking where flammable substances are used. This is probably because it is easier to relate cause and effect to an immediate explosion ignited by a burning cigarette than it is to relate severe respiratory problems to 10 years spent in a job with high exposure to a health hazard (210).

Integration of Health Hazard Controls into Workplace Management

Workplace decisionmakers—including managers, supervisors, workers, engineers, architects, equipment manufacturers, and installers—all contribute to effective disease prevention. For instance, Peterson (369) points out that engineers should know the concepts of hazard control and that they should

> . . . open their eyes to the consequences of decisions they may make in their professional capacity. Undergraduate engineers (and most graduate engineers for that matter) simply are not aware that it is perfectly possible to write noise specifications for much equipment: that carbon tetrachloride and benzene have excellent, much less hazardous, substitutes; that LPG fueled lift trucks generate much less carbon monoxide than do gasoline-powered lift trucks, that electric lift trucks are available and entirely suitable for most lift-truck tasks; or when and where to install fire doors.

Effective control programs need supervisors who are trained in hazard recognition and know about control systems. They must be responsible for maintenance of controls as part of the process and process equipment, and must understand the consequence of its failure (154,369).

Peterson (369) points out the direct benefits of workers being informed about and involved in controlling the hazards of their work. Since they are directly knowledgeable about the materials, equipment, and processes with which they are working, workers often spot health exposure problems in early stages and may have the best ideas about how to eliminate or control the hazard. (The need for training is discussed in greater detail in ch. 10.)

CASE STUDY: CONTROLLING WORKER EXPOSURE TO COTTON DUST

Byssinosis

> In many cases . . . the disease induced has appeared to me to differ from ordinary chronic bronchitis. In the commencement of the complaint, the patient suffers a distressing pulmonary irritation . . . . Entrance into the atmosphere of a mill immediately occasions a short, dry cough, which harasses him considerably in the day, but ceases immediately after he leaves the mill and inspires an atmosphere free from foreign molecules. These symptoms become generally more severe, the cough is at length very frequent during the day, and continuous . . ., disturbing the sleep, and exhausting the strength of the patient. . . . he seeks medical aid (Kay (241). Quoted in 124).

The quote was made in reference to a respiratory disease suffered by workers in English textile mills **150** years ago. That disease—byssinosis, or "brown lung''—was recognized in this country much later than in Europe. The reasons for the late recognition are complex. Many occupational health authorities suggest ignorance or refusal to recognize particular respiratory diseases that were common to mill workers to spare employers the costs of installing controls. In addition, social conditions inhibited workers from making their complaints known and prevented actions on those complaints. Also, local and State Governments were reluctant to act because they feared the loss of textile industry jobs as a result of requiring prevention of work-related injury and illness. Finally, a lack of scientific studies showing an association between cotton dust and illness in the United States contributed to the tardy recognition of the disease and inhibited action to prevent it until OSHA came into being **(124).**

The OSHA Cotton Dust Standard

Although the exact disease-causing agent within cotton dust has eluded identification, it is known that the dusts from the early stages of processing are more hazardous than those from later stages. Opening cotton bales and sorting, picking, and blending raw cotton present greater risks than do weaving and finishing.

In **1964,** the American Conference of Governmental Industrial Hygienists considered the evidence for establishing a recommended limit for cotton dust exposures. Two years later, the Conference agreed on a Threshold Limit Value of 1,000 micrograms/m3 as the maximum exposure that was consistent with maintaining workers' health. In 1969, the Secretary of Labor incorporated ACGIH's recommended TLV into Federal standards for employers with Government contracts (see ch. 11 for a discussion of the Walsh-Healey Act).

The Occupational Safety and Health Act of **1970** required that the newly established OSHA adopt the Walsh-Healey Act standards and apply them to all the Nation's workplaces. Thus, the cotton dust standard of 1,000 micrograms/m^3 was adopted as a startup standard by OSHA in 1971 (see Ch. 12).

In 1974, ACGIH revised its TLV downward to 200 micrograms/m^3 (the method of measurement changed also, and the "new" 200 micrograms/m^3 is not directly comparable to the ' old" 1,000 micrograms/m^3). That same year, the Director of NIOSH recommended that exposure to cotton dust should be reduced to the lowest feasible level, and that it should in no case exceed **200** micrograms/m^3.

In 1976 OSHA proposed a 200 micrograms/m^3 standard. The final standard, issued in 1978, set three different exposure limits—200 micrograms/m^3 for cotton yarn manufacturing, 750 micrograms/m^3 for "slashing and weaving" operations, and 500 micrograms/m^3 for exposures in other operations. This standard was contested by the textile industry through legal suits. While the Supreme Court upheld the standard for the textile industry in 1981, in the same year the current administration moved to reconsider it. This action is pending. Table 5-3 shows how the suggested and recommended levels for cotton dust came downward after the substance was regulated as a health hazard in the United States.

Changes in Cotton Dust Levels

Table 5-4 presents North Carolina Department of Labor measurements of the percentage of textile plant departments that were in compliance with the OSHA cotton dust standard i n **1981.** As can be seen, just two years after promulgation of the new standard and during the period the standard was being challenged in the courts, over half the departments complied with the standard. Some problems remain, as higher frequencies of noncompliance were found in the early stages of the process-opening, picking, carding, drawing, and combing. In these stages, workers are exposed to the more hazardous dusts associated with unprocessed cotton. overall, however, the cotton industry is coming into compliance with the new standard.

The industry trade association, the American Textile Manufacturers Institute, estimates that about 75 percent of the industry was in compli-

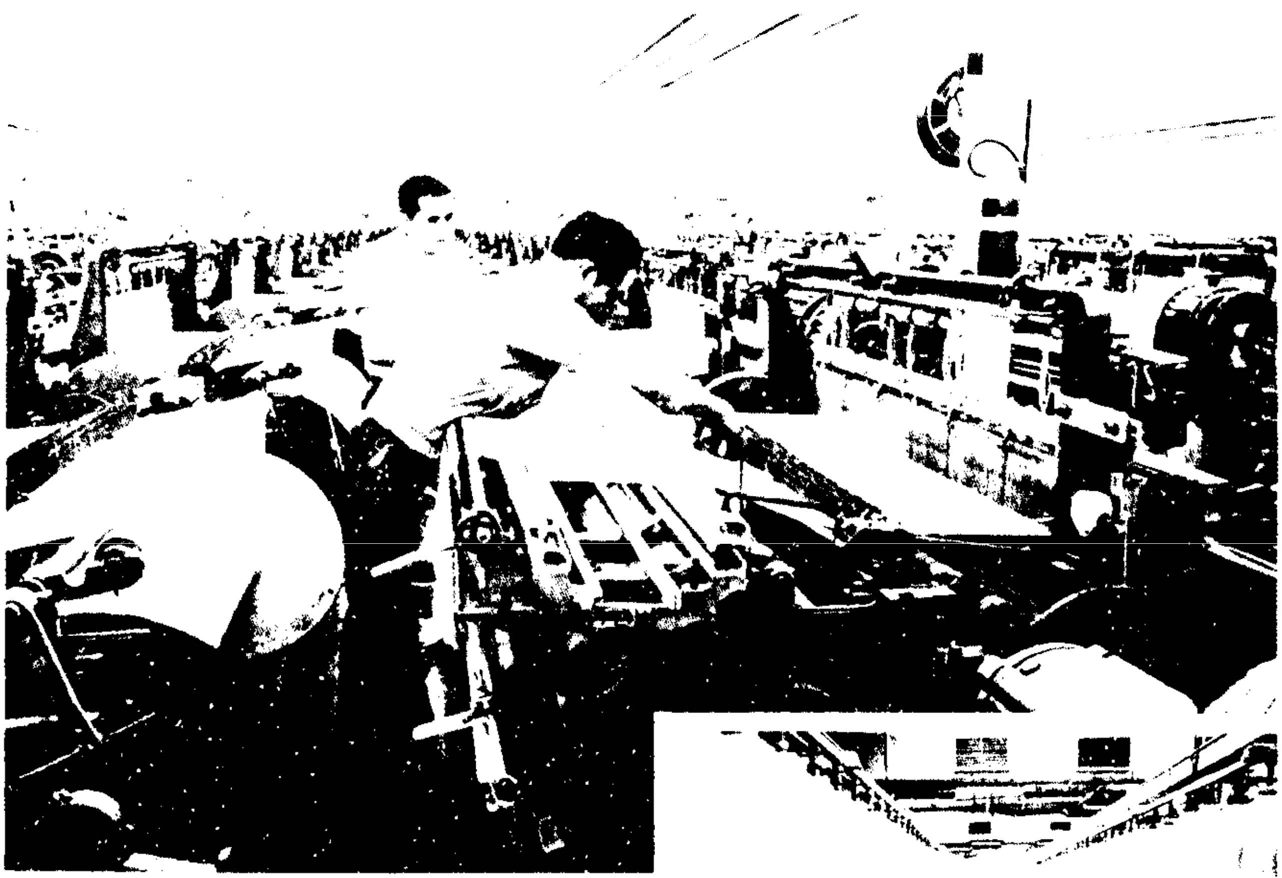


Photo credit O. SF/A, Office of Information and Consumer Affairs

The spinning of cotton fibers into yarn and weaving yarn into fabric are two of the operations regulated by the OSHA cotton dust standard. In recent years, the textile industry has invested heavily in modernized equipment in order to comply with the standard and to improve productivity

ance within two years of the standard being introduced. Some plants that have been completely modernized **are in full compliance** (413).

In 1981, the U.S. textile industry purchased $1.6 billion worth of new machinery. About 70 percent of those purchases were for the purposes of modernization to increase productivity (413) in the face of increased foreign competition and, to some extent, to comply with the OSHA standard for reduced cotton dust levels.

Ruttenberg (413) concludes that it is impossible to decide the relative importance of increasing productivity and compliance with OSHA regulations in the modernization of the American textile industry', but that both have made a contribution.

> The U.S. Occupational Safety and Health Administration dust regulations have had a dramatic effect on . . . processing equipment design and purchasing. Machine suppliers modified equipment to comply with OSHA regulations and this equipment has been accepted on a worldwide basis as well as in the USA. The dust controls have also contributed to much better operating results. . . (U.S. Department of Commerce (551). Quoted in 413).

Table 5-3.-Suggested and Recommended Levels for Cotton Dust Exposure

Organization	Year	Level[a] (micrograms/m³)	
American Conference of Governmental industrial Hygienists (ACGIH)	**1964**	1,000	tentative recommendation
ACGIH recommendation	**1968**	1,000	formal
Secretary of Labor	**1968**	1,000	Walsh-Healey Act standard
Occupational Safety and Health Administration (OSHA).	**1971**	**1,000**	OSHA standard
British Occupational Hygiene Society	**1972**	500	recommended standard for **Britain**
ACGIH recommendation	**1974**	00	**formal**
National Institute for Occupational Safety and Health (NIOSH)	**1974**	200	recommendation
OSHA	**1976**	200[b]	proposed standard
OSHA	**1978**	200	**final standard**

[a]The levels from 1964 through 1972 were based on techniques that measured the concentration of total dust in the workplace atmosphere. From 1974 on, the levels are based on the use of the vertical elutriator—a device that measures the quantity of small, respirable dust particles. Levels based on the these two methods are not directly comparable

[b]The 200 limit is for yard manufacturing, 750 for slashing and weaving, and 500 for all other processes The limit goes up as the cotton dust becomes cleaner

SOURCE Adapted from (413).

Table 5-4.—Cotton Dust Measurements Before Promulgation of the OSHA Cotton Dust Standard and Percentage of Companies Claiming Compliance with the Standard in North Carolina

Area of plant	Range of measurements before OSHA standard (micrograms/m³)	Limit under OSHA standard (micrograms/m³)	Companies claiming compliance in North Carolina (percent)
Opening	300-3,000	200	53
Picking	700-1,700	200	61
Carding	300-1,800	200	52
Drawing	400-800	200	63
Combing	NA	200	61
Roving	NA	200	81
Spinning	200-300	200	83
Winding	1,200	200	76
Twisting	1,200	200	80
Slashing	NA	750	100
Weaving	400-1,000	750	96
Knitting	NA	500	100
Waste Processing	NA	500	85
Other	NA	500	97

SOURCE: (413).

Tougher government regulations on workers' health have, unexpectedly, given the [U. S.] industry a leg up. Tighter dust-control rules for cotton plants caused firms to throw out tonnes of old inefficient machinery and to replace it with the latest available from the world's leading textile machinery firms. (The Economist (160). Quoted in 413).

Costs of Compliance with the Cotton Dust Standard

OSHA contracted for an economic analysis of the expected costs of compliance with the cotton dust standard, and the contractor assumed that compliance would be accomplished by "add-on" ventilation equipment. However, the availability of newer production equipment, which increased productivity and reduced cotton dust exposures, resulted in much lower costs than those estimated at the time the standard was considered. As table s-5 indicates, the initial 1974 estimates of capital costs for compliance were nearly $2 billion **(in** 1982 dollars). At the time of promulgation in 1978, **OSHA estimated costs of just under $1 billion** (in 1982 dollars). Thus, while cost estimates plummeted more than 50 percent by the time the standard was issued, the reduced estimate was still almost four times higher than the actual costs reported in 1982 in a poststandard contract report.

Table 5-5.—Estimated and Realized Costs of Compliance with the OSHA Cotton Dust Standard

	Millions of 1982 dollars
Preregulatory estimates	
OSHA contractor, 1974	1,941
Revised OSHA contractor, 1974	1,388
ATMI[a] contractor, 1977	875
OSHA, 1978	970
Postregulatory estimate	
OSHA contractor, 1982	245

[a]American Textile Manufacturers Institute

SOURCE (413)

Although most of the more productive, less dusty machinery now in use in U.S. textile mills was available in the mid-1970s, its potential use was ignored in the early estimates of compliance costs. Even if purchase of new technology had been anticipated, it would have been difficult to assign the proper fraction of its costs to dust control. In the event, new technologies greatly reduced the costs.

CASE STUDY: CONTROLLING WORKER EXPOSURE TO SILICA DUST

Silica is a major component of the earth's crust; it is the sand covering the beaches, the sand sprinkled on icy winter streets, the grit in the dust on windy days—it is everywhere. It is also widely used in industry. Over 402 million tons of silica-containing sand were produced in the United States in 1980. Of this total, nearly 300 million tons were used for glassmaking, as molding sand in foundries, and as industrial abrasives. Since it is ubiquitous, silica is frequently found as an unwanted constituent of ores mined for other minerals. In those cases, it must be removed and discarded.

Silicosis is a disabling lung disease resulting from the inhalation, deposition, and retention in the lungs of respirable crystalline silica dust. Acute silicosis can occur within six months following exposure to extremely high silica dust concentrations. Silicosis victims appear to suffer more episodes of chest illness than workers without the disease. The mortality for nonmalignant respiratory disease is significantly higher among workers receiving compensation benefits for silicosis than in the general population. A complication of silicosis, progressive massive fibrosis, results in significant impairment in lung function and may result in respiratory failure and secondary heart disease. Tuberculosis and other pulmonary infections may complicate acute or chronic silicosis and significantly shorten life expectancy. Hickey, et al. (210) discuss these silica-related health problems and reported associations between worker exposure to silica dust and an increased risk of lung cancer.

Since diagnostic procedures do not detect silicosis at a reversible stage, and since medical treatment will not alter the course of the disease after it is found, emphasis on exposure control is imperative. Yet, even though the cause of the disease has been well understood and technologies for controlling exposure have been available for decades, silicosis continues to occur in the United States at an alarming rate. A minimum of 59,000 cases of silicosis may be expected based on knowledge about current exposure levels and numbers of exposed workers at risk in 1980 **in** U.S. **industry** (210).

Hickey, et al. (210) estimate that there are 1.3 million production workers with potential exposure to silica dust—40 percent of whom are in workplaces lacking exposure control. Historically the most severe exposures to silica have occurred in granite and stone working, foundries, mining, and abrasive blasting. Workers producing and using silica flour (silica ground so fine that it appears to be refined grain flour) have recently been recognized to be at high risk for silicosis, because of the extremely fine size of the particles produced.

Regulatory Activities for Silicosis Control

The current OSHA standard for silica is based on an equation that limits the total amount of free silica to 100 micrograms per cubic meter. This standard was adopted as a start-up standard in 1971 (see ch. 11). Evaluation of the silica standard shows that it may be inadequate at its present level. In 1974, NIOSH recommended limiting silica exposure to 50 micrograms per cubic meter—half the current level. The studies on which NIOSH based its recommendation used pulmonary function performance as the measure of health effect—a more sensitive indicator of silicosis than X-ray methods.

In certain circumstances, such as in abrasive blasting where alternatives to silica are available, substitution may be the most appropriate method of control. The United Kingdom banned the use of silica sand for abrasive blasting in 1948, and NIOSH has recommended a similar prohibition in this country (560). Sweden banned silica as an abrasive in manual abrasive blasting in 1981 (210). A California standard requires that prior to use, not more than 1 percent, by weight, of abrasive sand must pass a No. 70 U.S. standard sieve (0.3 mm). After use, the sand must have no more than 1.8 percent of its weight as particles 5 micrometers or less in diameter (211). These restrictions on size reduce the number of respirable particles.

In 1978, OSHA conducted a technological feasibility assessment and economic impact analysis for a specific standard addressing use of silica sand in abrasive blasting (211). The study considered three alternatives: banning use of silica sand in abrasive blasting, setting minimum criteria on size and hardness of blasting sand, and controlling exposure through work practices. To date no revised standard has been issued.

However, due to the serious silicosis problem, OSHA has made a special effort to enforce the existing silica standard. In 1972, silica was one of five major health hazards selected for special enforcement efforts in the 'Target Health Hazard Program" (414). Silica was again given priority in the 1975 National Emphasis Program, as one of the major worker health hazards in foundries (339). In both cases OSHA industrial hygienists focused health inspections on plants where silica was likely to be found.

Control Technologies: Engineering Methods

Silicosis is an entirely preventable disease. Exposure occurs whenever materials containing crystalline-free silica are processed and dust is generated. Processes include abrasion (sand blasting, grinding, milling, etc.) that creates dusts of particularly small particle size (less than 5 micrometers in diameter). These dusts are too small to be easily seen as a "cloud." Too small to settle, they remain airborne and "respirable"—that is, they may readily pass through the upper respiratory passages and be deposited in the alveolar spaces of the lung (the small air sacs deep in the lung where gas is exchanged with the blood).

The most direct method of eliminating silica dust is to substitute less hazardous materials for the silica-containing material. This control has been widely used in abrasive blasting operations and to some extent in foundries. Silica-sand substitutes include metallic shot and grit, garnet, nut shells, cereal husks, and sawdust. Olivine (magnesium iron silicate) has been used for mold making in foundries to reduce silica dust exposure, but it is not clear how effective this method will be *(210).*

Process change may also be used to control silica dust exposure. For instance, water may be added to foundry molding sand or sprayed on at the point of dust generation in granite sawing and processing of portland cement. In some situations, dust-producing abrasive processes may be replaced by other types of cleaning such as salt baths, acid pickling, or ultrasonic cleaning. Water jetting and laser cutting for removal of excess metal from castings have been considered as alter-substitutes that are suitable for replacing silica. Also, for those situations where engineering control maybe infeasible, further improvement in respirator effectiveness is **necessary.** Medical procedures for detection of the early stages of silicosis should be refined to provide a better way of worker protection. Information about the toxicity of silica and technologies for controlling exposure could be provided to workers and employers using it.

CASE STUDY: CONTROLLING WORKER EXPOSURE TO LEAD

Early efforts against industrial lead intoxication in this country were championed by Alice Hamilton. Her autobiography, *Exploring the Dangerous Trades (199),* presents many examples of terrible exposures that were corrected when managers and owners were convinced that lead was causing the "colic, " "lead fits, " and blindness that occurred in lead workers. Until they were convinced, owners and managers preferred to believe that the illnesses resulted from bad personal habits—drinking, smoking, or the consumption of coffee.

Some firms refused to act voluntarily, and states began passing "lead laws" in the 1910s that set limits on occupational exposures. These early efforts were the forerunners of the revised OSHA lead standard, which was issued in 1978.

The current standard regulates exposure to lead in over 40 different industries. With only few exceptions, most industries comply with the **sO** micrograms/m^3 permissible exposure limit for workplace air concentration. The exceptions include primary and secondary lead smelting and lead-acid battery manufacture, where controls are most difficult and economic conditions have been unfavorable. (Primary smelters purify lead from lead concentrate, which is lead ore enriched by milling. Secondary smelters recover lead from discarded lead-containing products—in particular, worn-out batteries. Battery plants make lead-acid batteries.) Although the standard was contested by both union and management and it is impossible to be certain of the future of these industries or of the burdens placed on them by the standard, it is clear that workers' health has been improved as measured by reduced lead levels in their blood.

Some Features of the OSHA Lead Standard

The lead standard sets limits on ambient concentrations of the metal in workplace air, requires engineering controls and work practices to reach those limits, and requires that workers be informed about lead, its effects, and the methods used to protect against them. Two features—Medical Removal Protection (MRP) and the extended time periods granted to selected industries before engineering controls are required—distinguish the lead standard from other OSHA health standards.

MRP requires employers to measure workers' blood lead levels regularly. If the measured concentration of lead in the blood exceeds certain limits, the worker must be removed from lead exposure until the level drops to an acceptable value. For up to 18 months, the employer must maintain the worker's wages and seniority status even if the person cannot perform his or her regular job.

OSHA requires that air lead levels be reduced to an effective concentration of **50** micrograms/m^3. Since reported exposures have ranged above 2,000 micrograms/m^3, reaching the regulatory limit poses many problems for employers. The regulation gives companies 3 to 10 years to attain the so micrograms/m^3 limit through engineering controls; in the meantime, employers can require the

natives to chipping and grinding in foundries. Vacuum cleaning may be substituted for dusty compressed air cleaning and screw conveyors used instead of dust-producing pneumatic conveyors. However, care must **be taken to assure that** such treatment, while suppressing visible dust, also controls the smaller, more hazardous, respirable silica dust particles.

Where silica remains in use and worker exposure is possible, local exhaust ventilation may be used to capture and carry dust away. Environmental Protection Agency or other ambient-air standard regulations may require that ventilated air be cleaned before discharge to the outside.

Control Technologies: Personal Protection and Administrative Controls

Respiratory protection and face, eye, and body protection against physical injury are also required by OSHA in specific regulations for abrasive blasting. NIOSH has specified the respirator types required for protection from various air concentrations of silica, but these often prove to be inadequate in practice *(210)*. Employer-provided and -maintained protective clothing and facilities for changing at work plus training about personal hygiene prevent exposed workers from exposing family members to silica dust when taking work clothing home.

NIOSH (and others) recommend: administrative measures that help reduce risk of silicosis; training managers and workers about the hazards of silica dust; the effective use of personal protection equipment; and work practices that prevent the generation of silica dust, Dust-reducing practices include vacuum cleaning, regular maintenance of dust-producing and dust-controlling systems, and good housekeeping. Dusty work may be scheduled or located to reduce the number of workers at risk. However, Hickey, et al. **(210)** report that company dust-control policies are often unenforced.

Strategies for Silica Dust Control

One might ask why a well-recognized, entirely preventable, work-related illness, for which the etiology is understood and for which engineering and other controls are available, remains a problem. Hickey, et al. *(210)* note some possible reasons:

- the current OSHA standard is inadequate and based on outdated information,
- compliance with the inadequate standard is insufficiently monitored,
- accurately measuring silica concentrations in respirable dust samples is difficult and costly, and
- there is too much reliance on after-the-fact control methods that control the dust after it is generated rather than on methods that eliminate silica dust.

An underlying reason for failure of worker protection against silicosis is the cost of controlling exposures.

To attack this problem, Hickey, et al. *(210)* suggest promulgating a protective standard based on the latest medical knowledge and streamlining enforcement by developing an accurate, inexpensive, and rapid measurement method. These initial steps will provide the basis for developing more effective technology to prevent generation of silica dust. Greater emphasis should be placed on preventing generation than on refinement of measures for control after the dust is generated. Research should be conducted to find nontoxic

Photo credit OSHA, Office of Information and Consumer Affairs

Abrasive blasting workers are frequently exposed to high levels of silica dust

use of respirators to reduce workers' exposures to airborne lead.

Control Methods: Engineering and Respirators

Table 5-6 lists categories of control measures that can be employed to reduce lead exposures. In general, major changes in processes will be introduced only when a plant is rebuilt for other reasons. (An example of the costs involved in substituting a new process in primary smelters compared with adding on controls is presented inch. 16.) Add-on controls, in particular better ventilation, are probably the most common form of engineering controls, although far simpler controls—such as covering stockpiles and putting tops on reaction vessels—are an important part of engineering controls.

A number of process innovations are being made in the secondary smelting industry and in battery manufacture that reduce worker exposure to lead. A major source of lead exposure here has been the breaking open of old lead storage batteries. Goble, et al. (184) mention two new processes that significantly reduce the liberation of lead in that process. In addition, technological changes recently introduced in the manufacture of new lead storage batteries reduce worker exposure while increasing productivity.

Table *5-6* includes personal protective equipment as well as business cycle factors that influence the number of workers exposed. The role of respirators in providing protection until engineering controls are installed is clearly recognized in the OSHA standard. The standard does require that ultimately compliance shall be achieved through the use of feasible engineering controls.

Table 5-6.—Measures To Reduce Air Lead and Blood Lead Levels

A. Measures that affect air lead levels in the plant
   1. Changes in production processes (direct smelting processes, more automated battery production lines)
   2. Add-on controls (ventilation systems)
   3. Changes in operating practice (keeping floors cleaner)
   4. Greater or lesser use of lead-emitting equipment
B. Measures that do not affect air lead levels but limit times workers spend in lead-contaminated atmospheres
   1. Isolation booths with filtered air supply
   2. Changes in work practices to limit time in high lead areas
c. Measures that do not affect air lead levels but limit workers' lead absorption
   1. Respirators
   2. Showers, changing clothes before and after entering work areas
   3. Business cycle factors: layoffs, overtime
D. Measures that do not necessarily affect exposure of the work force as a whole but affect the distribution of exposures among the work force
   1. Monitoring of workers and removing those with biological indicators of exposure to areas with lower lead contamination
   2. Rotation of workers
   3. Firing of highly exposed workers
E. External measures that impact on lead exposure
   1. Changes of lead level in out-of-plant environment
   2. Changes of lead content in food and water

SOURCE (164)

Medical Removal Protection

The OSHA lead standard provides that when the amount of lead in a worker's blood exceeds a trigger level, he or she is to be removed from exposure or placed in an area of lower exposure until the blood lead level drops (see table 5-7). When the amount falls to a specified reinstatement level, the worker can return to his or her regular job.

When the OSHA standard was being considered, employers pointed at MRP as a source of high costs. They argued that older, more experienced workers who were paid a premium for their knowledge would be removed to less skilled jobs, causing losses in productivity. In addition, since MRP requires that the worker's wages be main-

Table 5-7.—Blood Lead Levels That Trigger Medical Removal From and Return to Lead-Contaminated Atmospheres

Date	Blood lead levels[a] (micrograms/100g blood) for: Removal	Return
March 1979	80	60
March 1980	70	50
September 1981[b]	60	40
March 1983[b]	50	40

[a]Workers' blood levels are to be monitored quarterly except workers with levels greater than *40* micrograms/100g are to be monitored monthly.
[b]Many firms have been given extensions of the time for the 60/40 and 50/40 triggers

SOURCE (164)

tained, experienced workers doing less skilled jobs would still receive the pay associated with their previous positions.

Table 5-8 summarizes three years' data about medical removal from companies seeking relief from the lead standard. These data represent a worst-case group and may not be representative of the industry. In both the primary smelter and the battery industries reported, the percentage of workers on MRP transfer and the share of work-time spent on transfer peaked in the second year. The data for primary smelters is reasonably complete, based on 5 of 7 smelters and about 2,120 workers each year, compared with a total of about 2,500 workers; it is less complete for the battery industry, based on only *8* plants and about 1,300 workers in an industry that employs about 30,000 people. In the secondary smelting industry, the percentage of workers on MRP and the proportion of worktime on MRP transfer increased each year. The data in this case are certainly incomplete, and the facilities reported may not be representative of the entire industry; the data in table 5-8 are based on about 640 workers out of a total of some 3,000 workers in the industry. If the data are representative, the secondary smelters are encountering greater problems complying with the OSHA standard.

Goble, et al. (184) compared the percentage of total worktime on MRP transfer to projections of transfers that had been made based on assumptions of *so* or 100 micrograms/m^3 air lead levels in the industries. They found that the reported percentages of transfer worktime agree reasonably well with achievement of 100 micro~grams/m^3 air lead levels, supporting the conclusion that effective air lead levels are between 50 and 100 micrograms/m^3. Given that blood lead levels are related to worker health, these changes are evidence that lead-related diseases and disorders should be declining.

The number of terminations of workers because blood lead levels remained above the reinstatement values even after removal to lower exposure situations is apparently small. An examination of the new-hire and termination rates before and after imposition of the OSHA lead standard did not show an increase. That observation is inconsistent with the idea that employers would terminate "leaded-up" workers and replace them with new hires.

Changes in Air Lead Levels

Although some data about air arid blood lead levels are available, they are often unsuitable for making precise estimates of levels, of high exposure. For instance, although 67 percent of secondary smelter workers in 1977 were exposed to greater than 200 micrograms/m^3 airborne lead, neither the maximum exposure level nor the average exposures of the highly exposed workers in this group were reported. Goble, et al. (184) made a number of assumptions and then calculated approximate average air lead exposure levels in the three industries in *1977-78* and in 1981-82 (see table s-9). Air lead levels dropped by about one-quarter in primary and secondary smelting and

Table 5-8.—Medical Removal Protection Transfers in a Sample of Lead Industry Plants

		Plants		Average number per plant		Percent
Industry	Year	In survey	In industry	Lead exposed workers	Workers on MRP[a] transfer	worktime on MRP
Primary lead smelting	1979	5	7	465	21	1.0
	1980	5	7	419	31	2.1
	1981	5	7	492	18	1.3
Secondary lead smelting	1979	6	36	120	4	1.0
	1980	6	36	104	9	4.6
	1981	6	36	96	11	6.9
Battery manufacture	1979	8	136	176	2	0.4
	1980	8	136	140	8	1.9
	1981	8	136	162	6	1.5

[a]MRP, Medical Removal Protection.

SOURCE: (1S4 from data available in 103).

Table 5-9.— Reductions in Average Air Lead Levels, 1977-78 and 1981-82

Industry	Average air lead levels (micrograms/m') 1977-78	1981-82	Percent reduction
Primary lead smelting.	740	565	24
Secondary lead smelting . .	285	205	28
Battery manufacture . . .	160	80	50
Seven battery plants	160	90	50

SOURCE (184)

by half in battery plants. Confidence about the validity of these estimates, especially for battery plants, is increased by the access Goble, et al. had to detailed, company-collected exposure data from seven battery plants. The percentage reduction observed in those plants is the same as the calculated reduction for the industry overall.

The data in table 5-9 show what are probably minimal estimates of reductions in air lead levels because of systematic errors in the calculations. Clearly, however, levels are coming down. Equally clearly, there is some distance to go before the eventual goal of *50* micrograms/m^3 is reached. OSHA recognized that engineering control of air lead levels would take time, up to **10** years in some industries. The decreases shown in table *s-9* were achieved in less than 5 years and during the period when the standard was still being challenged in the courts.

Changes in Blood Lead Levels

Data on blood lead levels for the period before promulgation of the lead standard are not so plentiful as air lead data. The estimates shown in table 5-10 for 1977-78 are from information presented in OSHA hearings. The data shown for 1981-82 are from measurements reported in a Charles

Table 5-10.—Average Blood Levels Before and After Promulgation of the OSHA Lead Standard

Industry	Approximate average blood lead levels (micrograms/100g blood) 1977-78	1981-82	Difference
Primary lead smelting.	**49.4**	**41.6**	**7.8**
Secondary lead smelting . .	**56.5**	**44.2**	**12.3**
Battery manufacture	**53.2**	**42.4**	**10.8**
Seven battery plants	**53.0**	**38.3**	**14.7**

SOURCE (184)

River Associates *(103)* report prepared for OSHA, and those are probably more reliable.

A satisfying drop in blood lead levels was seen in less than **5** years between 1977 and 1982. Not shown on the table is the finding that the number of workers with blood lead levels greater than 80 micrograms/100g blood dropped from l,553 (2 percent of 2,200 primary smelter workers plus 16 percent of 3,170 secondary smelter workers plus 6 percent of 16,700 battery workers) to about 20 (0.1 percent of 2,470 primary smelter workers plus 0.6 percent of 3,000 secondary smelter workers and no battery workers).

Furthermore, the number of workers with blood lead levels above 40 micrograms/100g dropped from 17,217 to 6,738. This significant decrease is especially important because that is the lowest action level required at any stage of MRP. In other words, the almost 9,000 workers who have moved from the over-40 to under-40 micrograms/100g category are now at a level that means they would not have to be removed from their current jobs even as the threshold level for medical removal drops.

In 1978, OSHA had estimates prepared of the blood lead levels to be expected if the statutory limits for lead were set and realized at 50, 100, or 200 micrograms/m^3. The levels were expected to fall as exposures decreased and workers eliminated some of the lead accumulated during their previous high exposures.

Measured blood lead levels two-and-a-half years after the introduction of the standard were consistent with projections made on the basis of achieving a level near so micrograms/m^3 in the battery industry and 100 micrograms/m^3 in the other two industries **(184). These measurements are somewhat surprising because the air lead levels** in the industries **are above so or 100** micrograms/m^3. Effective respirator programs and attention to personal hygiene **have** probably contributed to the lowering of blood lead levels.

Although no blood lead level has been established below which symptoms are never found, and there is no level at which symptoms will necessarily occur, there is agreement that lower blood lead levels are associated with lower risks (174).

OSHA has established 40 micrograms/100g as an action level; when the lead standard is fully implemented, workers with blood levels above 50 micrograms/100g must be removed from lead exposure until their blood lead levels drop below 40. The Centers for Disease Control (558) have concentrated on 30 micrograms/100g as a level at which concern should be raised.

costs

Capital expenditures for current controls run at about $1,000 to $1,500 per worker each year. To that must be added the expense of respirators, clothing, and facilities for personal hygiene (showers, changing rooms, etc.)–between $1,000 and $1,700 per worker per year. Monitoring and medical surveillance cost about $500 per worker annually, and the tranfer costs under MRP are expected to run between $300 and $600 per worker yearly. Taken altogether, complying with the lead standard is estimated by Goble, et al. to cost between $2,800 and $4,300 per worker yearly.

In addition to the current costs, Goble, et al. (184) project that future conventional industrial hygiene controls will cost between $8,000 and $9,000 per worker per year in secondary smelters and battery plants. Future costs in primary smelters are expected to be lower, about $5,200.

Table 5-11 presents estimates of the engineering cost of reducing air lead levels to 50 or 150 micrograms/m^3. The costs are quite close. One reason is that (according to engineers employed by Charles River Associates (184)) the best conventional engineering controls will not reduce exposure to 150 micrograms/m^3. Another reason is that isolation booths, if installed, could reduce exposures to less than 50 micrograms/^{3} for about the same as it would cost to reach 150 micrograms/m^3.

Table 5-1 l.—Projected Industry-Wide Annual Costs of Compliance With Air Lead Levels of 50 and 150 micrograms/m^3

Industry	Millions of 1962 dollars: 50 micrograms/m^3	150 micrograms/m^3
Primary lead smelting . .	15.5	16.0
Secondary lead smelting	24.5	26.4
Battery manufacture . . .	97.4	not done

SOURCE: (1S4).

Major process changes, although costing more in capital expenditures, are expected to result in operating savings. In general, the capital costs of process change may be appropriate if a new plant is to be built, but they outweigh the costs of add-ons in an existing plant unless significant tax savings or credits accompany installation of the new process.

Summary of Improvements

The data about workplace air lead and blood lead levels show that both have decreased since the issuance of the OSHA lead standard. While the air lead levels have dropped about 25 percent in primary and secondary smelters and about so percent in battery plants, they still remain much higher than 50 micrograms/m^3 that is the goal of the standard. At the same time, however, blood lead levels have dropped appreciably, and in general are close to the levels predicted for reaching air lead levels between 50 and 100 micrograms/m^3. A number of factors—including decreases in lead uptake from the environment in general, changes in the methods for measuring lead, errors in the model that is used to project blood leads based on air leads, and greater-than-expected impacts of respirator programs and hygiene practices—have contributed to the apparent better realization of reductions in blood levels than was predicted. Whatever combination of factors is responsible, the falls in blood lead levels are gratifying and bode well for better health among lead workers.

EXTENT OF CONTROL TECHNOLOGY USAGE IN THE UNITED STATES

The National Occupational Exposure Survey (NOES) (see chs. 2 and 12) includes data that describe the extent of the usage of control technologies for the prevention of work-related illness. NOES, conducted from 1980-82, estimates the extent of worker exposure to potentially hazardous workplace agents. This survey was conducted as a followup to a similar survey, the National Occupational Hazard Survey, conducted in 1972-74.

The sample of businesses in the NOES survey consists of approximately 4,000 establishments in 67 metropolitan areas throughout the United States. The sample represents all nonagricultural businesses covered under the Occupational Safety and Health Act. Data were collected onsite by teams of engineers and industrial hygienists specially trained for the survey.

NOES was conceived for the purpose of recording specific worker exposures to potential workplace health hazards. Among the questions that the survey attempted to answer were:

- What occupational groups are exposed to what types of potential health hazards in the United States?
- In what types of industries are these hazards found?
- What control technologies are present to prevent work-related disease in terms of plant operation and occupational safety and health practice?
- What are the exposures by intensity, duration, type of control?
- What trade name products were present?

Both surveys included questions about demography and occupational safety and health practice, followed by a walk-through survey of the plant work area to inventory potential exposures. A series of questions specifically aimed at the practice of using controls was asked in NOES.

With the control questions asked in NOES it is possible to analyze the extent of engineering control usage in the manufacturing sector of the country. Areas include practices of material substitution, process change, and the management of personal protective equipment programs. These data are unique in that there are no other comprehensive assessments of work-related exposure control practice. Control technology usage may be classified by plant size and by industry, allowing distributions to be done for comparison.

These data may be used to pinpoint patterns of control technology use within and among industry groupings, giving insight about areas where improvement is needed. This analysis may also be used to assist in setting priorities for control technology research.

Information About Controls and Areas for Research

The vinyl chloride, industrial solvent, lead, cotton dust, and silica examples show that control technologies for workplace exposures can be engineered once commitment to control is made. Commitment, however, is often difficult to achieve. For example, in the regulatory proceedings concerning new health standards, arguments are often raised about the harmful health effects of existing exposure levels, and the costs and feasibility of controls (see ch. 14 and box 12-1 in ch. 12). In addition, opposition to some governmental regulation may result simply from employers' concern that an outside authority is telling them what they must do to protect workers.

However, as shown by the vinyl chloride and cotton dust examples, the installation of technologies to control workplace hazards can be accompanied by greater productivity. As seen in the case of the ventilation control system in the electronics industry, there are advantages to planning, installing, and maintaining control technologies in a systematic way. Anticipation of work-related health problems very often reduces the cost of their control.

Access to information about control technologies for workplace health and safety could be improved. Perhaps the greatest current need is for published information about controls in the occupational safety and health literature. While there are journals dedicated to toxicology and epidemiology, there are none specific to industrial hygiene engineering. Industrial hygiene journals infrequently and engineering technical journals only rarely include articles about technologies for controlling worker exposure to hazardous materials. Yet it has been suggested that such information should be part of every engineer's training and be readily available as reference material to the practicing engineer *(587).*

Published information about specifics of workplace control is sparse for several reasons. First, and probably most significantly, companies that develop controls simply do not take the time to publish details since it is not their business. On the other hand, it is likely that some consider the information proprietary and keep it unpublished for competitive reasons.

In some cases, such as for the control of exposures to vinyl chloride, a few companies market new technology for preventing work-related injury and illness. This, however, appears to be infrequent and be limited to very large companies such as B.F. Goodrich and Dupont. Probably most companies that have found and use innovative control technologies in their plants simply have yet to explore workplace control technologies as a market.

University and government researchers have published some practical information that can be used by design engineers but the volume of this material is limited. One widely used handbook specific to ventilation is the ACGIH Ventilation Manual that is published annually *(6).* Programs such as the NIOSH Control Technology Assessments have produced useful information for hazard control in some specific and some generic manufacturing processes (see ch. 12).

There is also a dearth of new approaches in this area. For instance, First (173) pointed out that little has been added to the theory of ventilation since two Ph.D. theses done at Harvard in the 1930s. The tendency has been to retrofit control solutions after problems appear rather than to anticipate them. Yet there is promise of new methods on the horizon.

Brief and colleagues (74), recognizing the limitations of retrofit solutions in preventing work-related injury and illness, have explored techniques for designing new plants with new control systems built in. They have found that in the past

> retrofit control procedures were recommended without being able to judge the effectiveness of controls, until after installation and operation. This retrofit approach is probably not as cost effective as designed-in controls, although cost effectiveness was rarely tested. In many cases additional administrative and personal protective programs were used to achieve desired worker protection.
>
> We have embarked on a new era involving some major companies and government agencies investigating the impact of engineering design on the workplace environment. The objective is simple. It states that we will attempt to design into our plants and operating facilities the necessary engineered controls to meet occupational health standards. Intuitively, we believe that it is more cost-effective to install engineering controls in new plant designs than to retrofit later. Equally as important is the practicality of having an environmentally sound plant at the start, rather than one which requires modifications later. Retrofitting controls may be difficult to implement due to physical factors and the time to implement the changes after the plant is running.

In this innovative approach, design is based on selection of process equipment controls appropriate to the process. The key is to determine emission rates of contaminants from each type of process equipment used. These data may then be used to build a near-field dispersion model (a mathematical expression of the release and buildup of contaminant in workers' breathing zones) to calculate collective concentrations to which workers could be exposed. By trying various combinations of equipment and controls in the model and testing them against recommended health standards, engineers can predict potential worker exposure and thus design processes with optimum worker protection *and* production. These investigators stress the need for interaction between engineers and occupational safety and health professionals at the design stage for this to succeed.

Thus, control technology for work-related illness prevention is possible but insufficiently applied, particularly in plant design stages. Technologies are available but information about specific solutions is difficult to find because it is seldom published. Retrofit is the dominant mode even though there is recognition that solutions should be designed into new processes.

SUMMARY

Workplace exposures to toxic substances can be controlled at their source, during transmission, and at the worker. Control at the source includes changes in the design of a process and substitution of nontoxic or less toxic materials. Controlling the transmission of a toxic substance can be done by isolating or enclosing hazard sources, wetting toxic dusts to prevent dispersion, installing local exhaust ventilation to capture and carry toxic substances away, or reducing toxic concentration through the use of general dilution ventilation. Control at the worker includes the use of personal protective equipment (see ch. 8), work practices, and administrative procedures. Engineering controls that can be designed into a work process to control hazard sources and dispersion of contaminants are preferred to other measures that may provide less reliable protection. Training (see ch. 10) of supervisors and workers is required to make sure control programs are effective.

Three case studies prepared for this assessment provide information on controls for health hazards. Exposures to cotton dust cause a debilitating respiratory disease known as byssinosis. In the years following the issuance of a revised OSHA health standard concerning cotton dust, the U.S. textile industry has invested heavily in modernizzing its operations. The new equipment has led to improved productivity in this industry, as well as reduced worker exposures.

Data about workplace air lead and blood lead levels show that both have decreased since the issuance of the revised OSHA lead standard in 1978. The possible factors to explain the improvements in blood lead levels include changes in exposures to lead in the workplace air, the use of medical removal protection, decreases in the amount of lead absorbed from the environment, changes in lead measuring methods, and improvements in respirator programs and hygiene practices.

Silicosis—a disabling lung disease-is caused by silica dust. Control measures include substitution with safe abrasives, ventilation, wetting, as well as the use of respirators, work practices, maintenance of ventilation systems, and good housekeeping practices.

A considerable amount of information about how to design and implement control technology for worker protection is available but is not widely disseminated. Research on improved control technology design and implementation is also needed. For example, little has been added to the basic theory about ventilation since the 1930s. The National Occupational Exposure Survey conducted by NIOSH collected information which will give estimates of the extent of worker exposure to potential hazards and the current practice of control technology use. These data can potentially assist in setting priorities for research on improved controls.

6.

Technologies for Controlling Work-Related Injuries

LIST OF TABLES

6. Technologies for Controlling Work-Related Injury

Injuries are caused by "abnormal energy transfers or interferences with energy transfer" (198). One analytical method breaks the injury-causing event into three parts: 1) the source of hazard, 2) its transmission, 3) and the worker; this method is patterned after the traditional public health model of disease transmission ("agent," "vector," and "host").

Control technologies suggested by this approach consider: control at the source of energy, control of transmission of energy, and control at the worker. Although there are many similarities between safety engineers' approach to injury control and the public health approach, their terminology and methods have usually been quite different. Safety engineers have tended to use codes, standards, and models of "good practice" that are oriented around particular topics: fire prevention, electrical safety, design of machinery, plant layout, etc.

This chapter describes how designers and engineers can plan sites, plant layout, and equipment design in order to prevent work-related injury. "Safe" design presents particular difficulties in the construction industry where constantly changing conditions create constantly changing workplace hazards against which workers must be protected. In manufacturing, the worksite is relatively more stable but there is still a great deal of worker exposure to hazardous releases of energy. Fire and explosion prevention is an area that not only can prevent human deaths and injuries, but also can prevent very large economic losses. Probably for that reason, fire and explosion prevention has received a great deal of attention from the safety profession.

Finally, this chapter discusses injury prevention programs. Because management has the primary responsibility for prevention of work-related injury and illness, a successful injury prevention program must start with a strong commitment from management. The stronger the commitment at the top, the greater the likelihood of success. The success of one such program is illustrated by a discussion of the injury prevention program of one large company—Du Pont.

Workplace injuries can be prevented by proper design of structures, machines, and operations (see table 6-l). Proper design considers the stresses to be placed on the building structure, the arrangement of spaces for the work to be accomplished, and specific safety requirements. For example, falls on working surfaces, the single most common cause of workplace injuries (13.5 percent of all nonfatal injuries), can be largely prevented by designing proper walking and working surfaces.

Appropriate design, including safe construction plans, can prevent work-related injuries as buildings go up and equipment is installed. Structure collapse during concrete pouring may kill or injure a number of workers at once. Such catastrophes get media attention whereas the bulk of work-related injuries and fatalities that occur singly do not. One disaster at Willow Island, WV,

Photo credit: Office of Technology Assessment

The rear of this construction site shows the use of shoring to prevent the collapse of surrounding soil

Table 6-1.-Princlples of Preventing Work-Related Injury

Injury-prevention objective	Examples	Relevant control principle
1. To prevent the creation of the hazard.	One-story buildings reducing need for ladders	Elimination, substitution
2. To reduce the amount of hazard.	Reducing speeds of vehicles.	Process design
3. To prevent release of the hazard.	Bolting or timbering mine roofs.	Enclosure
4. To modify the rate or spatial distribution of release of the hazard.	Brakes, shutoff valves, reactor control rods.	Ventilation
5. To separate, in time or space, the hazard and that which is to be protected.	Walkways over or around hazards, evacuation.	Isolation Administrative controls
6. To separate the hazard from workers by interposition of a material barrier.	Operator control booths.	Isolation, Personal protective equipment
7. To modify relevant basic qualities of the hazard.	Using breakaway roadside poles, making crib slat spacing too narrow to strangle a child.	Process design
8, To make what is to be protected more resistant to damage from the hazard.	Making structures more fire- and earthquake-resistant.	Process design
9, To counter the damage already done.	Rescuing the shipwrecked, reattaching severed limbs, extricating trapped miners.	NA
10. To stabilize, repair, and rehabilitate the object of the damage.	Posttraumatic cosmetic surgery, physical rehabilitation, rebuilding after fires and earthquakes.	NA

SOURCE: (71,197).

in 1979 was found by the Occupational Safety and Health Administration (OSHA) and National Bureau of Standards investigators to be related to concrete failure from improper pouring and from insufficient allowance of curing time. The National Institute for Occupational Safety and Health (NIOSH) (584) is refining equations to predict more accurately concrete's curing time as an aid to preventing similar disasters.

In 1981, 11 workers were killed and 23 injured in Cocoa Beach, FL, when a five-story building collapsed during placement of a concrete roof slab. Analysis of this catastrophe showed two factors caused the failure:

- A design error: a check for punching shear (the stress or force around holes cut in beams) was omitted.
- A construction error: supports for reinforcing steel other than those-specified by the design were used and proved to be inadequate.

A failure at one column precipitated a progressive failure of the slab, which, when it fell, caused successive collapse of all lower floors (271). Tragically, this disaster closely resembled a collapse of similar construction in Jackson, MI, in 1956.

Information about these and other failures is now available in a data base maintained by the University of Maryland's Architecture and Engineering Performance Information Center. This computer compilation of analyses of design errors enables designers and engineers to search for and compare information on failures of similar designs.

Checklists have been developed for engineers, architects, and designers to guide their attention to methods of reducing injury risks. An abbreviated example of such a list is given in table 6-2.

Codes and standards for building structure, for steam, heating, and electrical systems, and for fire and injury prevention are also used as design criteria. The sources for these codes include the American National Standards Institute, the National Electrical Codes, the National Fire Protection Association (NFPA) Codes, OSHA regulations, and recommendations made by NIOSH.

Site planning and plant layout for location of buildings, facilities, and processes and other design practices can be done in ways to prevent work-related injury. Table 6-3 provides examples of injury control practices that are possible

Table 6-2.—Prevention Checklist To Be Used Before Starting a Production Plant

Section I—Boiler and machinery review
- A. Boilers
- B. Pressure vessels
- C. Piping and valves
- D. Machinery

Section n-Electrical safety review

Section Ill—Fire protection review

Section IV—Personnel safety review
- A. Project site location
- B. Building and structures
- C. Operating areas
- D. Yard

Section V—Process safety review
- A. Materials
- B. Reactions
- C. Equipment

Section Vi—Environment control audit
- A. Atmospheric discharges
- B. Liquid discharges
- C. Solid discharges

Section VII—Periodic plant loss prevention review (manufacturing) to:
- A. Keep operating personnel alerted to the hazards.
- B. Determine whether operating procedures require revision.
- C. Carefully screen the operation for changes that may have introduced new hazards, or changes that should be made to reduce existing hazards.
- D. Reevaluate property and business interruption loss exposures.
- E. Uncover potential hazards not previously recognized, especially in the light of experience or new information.

SOURCE (172)

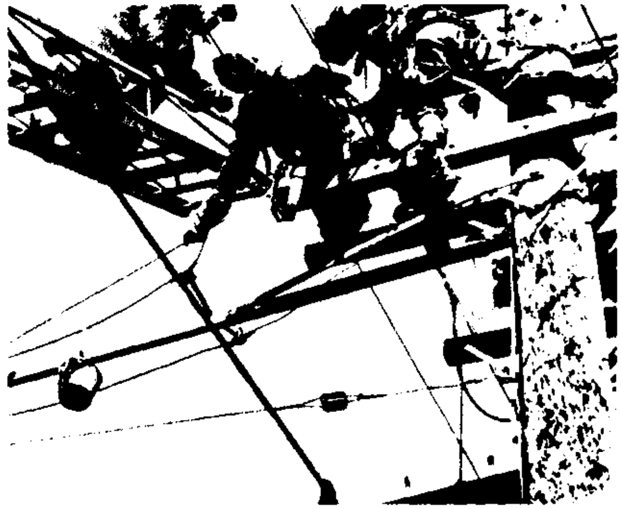


Photo credit: Department of Labor, Historical Office

Electrocutions account for about 6 percent of reported work-related fatalities

through plant layout. The isolation of hazardous materials and machinery, for instance, can be achieved through building special rooms or buildings. Falls can be prevented by providing adequate walkways and lighting. Again, specific codes are available to guide designers and planners in these areas.

Many vehicular-related injuries and fatalities in and around factories maybe prevented through

Table 6-3.—Examples of Injury Control In Plant Layout

Source of injury	Design solutions
Contact with moving machinery	Adequate space between and around machines
Potentially explosive or inflammable processes and substances	Remote siting; separate buildings to contain explosion or fire; isolated storage areas
Crane loads striking worker	Site cranes away from work areas
Building fire	Adequate space between buildings to prevent spread of fire
Chemical burns	Use corrosive-resistant containers, remote siting, and special handling procedures
Falls from trestles	Provide adequately wide walkways along trestles, and adequate lighting
Falls in pits or bins	Provide grating screens and covers, and adequate lighting
Falls on stairs and from ladders	Design stairs with non-slip tread; provide adequate lighting
Electrocution and electrical burns	Adequate grounding; wiring inaccessible to inadvertent insulation wear
Being caught in machinery during maintenance	Interlocks and tag-out procedures to prevent inadvertent start-up
Being caught in machinery during operation	Adequate illumination
Explosion related to broken light bulbs	Special lamps and enclosures where physical conditions may shatter ordinary bulbs

SOURCE (322)

careful planning of transportation facilities, including shipping and receiving departments, railroad sidings, parking lots, and roadways. Worksite roadways and walkways can be laid out and designed according to safe engineering practices to prevent traffic-related injuries. Adequate anticipation of traffic to, from, and during work and landscape design to eliminate blind spots can also reduce risk. Railings on stairs and walking inclines prevent falls.

Shipping and receiving, whether by truck, train, ship, or airplane, pose special potential for work-related injury. Facilities can be designed to reduce overexertion and back injury by providing working surfaces at correct height and allowing room for mechanical lifting devices. Shipping and receiving docks can be isolated to prevent harm from mishap when loading or unloading inflammable, explosive, or extremely toxic substances and from falling objects.

Sensible plant layout, including consideration of headroom, aisle width, and access for maintenance can both lower injury risk and increase productivity (322). Clearly, the risk of injury is reduced by designing work stations that are located away from hazardous areas.

PREVENTING MOTOR VEHICLE= RELATED INJURIES AND FATALITIES

Analysis of injury statistics shows that motor vehicle-related fatalities account for 30 to *40* percent of work-related fatalities and are among the 5 leading causes of work-related injuries (see Working Paper #l). While a good deal of public attention is given to "defensive driving, " speed limits, collision protection through passive and active restraints, and reducing the number of drunk drivers, little of the industrial injury-prevention literature relates to the occupational use of motor vehicles (40).

An insurance company has prepared a handbook that describes both routine and particular precautions. For example, braking systems on earth-moving equipment, large trucks, and long distance tractor-trailers should be maintained with emphasis on safety rather than mere schedules. Drivers should be properly trained to operate equipment safely under different road and weather conditions. Vehicles used for employee transport should meet appropriate requirements for both driver and passenger safety; for example, proper emergency exits should be available to allow escape.

PREVENTING CONSTRUCTION= RELATED INJURIES

The lost-workday rate from job-related injuries is much higher in the construction sector than the all-industry average. The constantly changing conditions of construction sites create a variety of workplace hazards against which workers must be protected.

Specialized, often large, machines that come and go to construction sites bring their own mechanical energy-related hazards. The "beep-beep-beep" of backing earth-moving equipment alerts workers on the ground; the cages around drivers' seats protect against falling and swinging objects and from being crushed if the machine tips over. Seat belts or other restraining devices protect vehicle operators from harm during collisions.

A frequently reported cause of injury is falls from heights—31 percent of construction fatalities. These may occur from inappropriate ladders, improperly erected scaffolds, poorly designed temporary stairs, or inadequately protected openings in floors, elevator shafts, and roofs under construction. Yet available equipment and procedures can protect against each of these hazards. Manufactured ladders that meet codes and ladders constructed on the job that meet minimum requirements will reduce the number of falls. Rail-

Photo credit Department of Labor. Hisforlcal Office

Earthmoving equipment is now built to include protection from falling objects and accidental rollovers

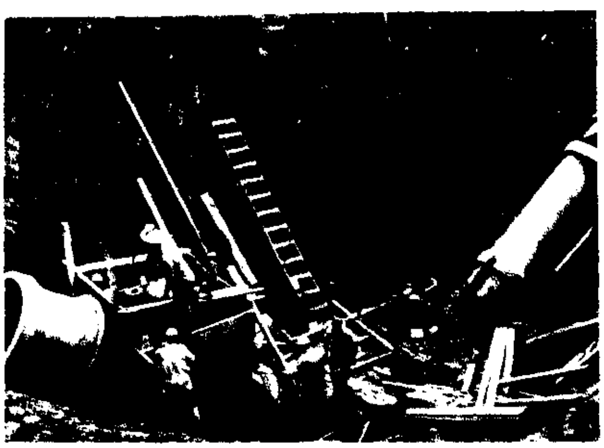


Photo credit OSHA, Office of Information and Consumer Affairs

Improperly shored trenches can be a source of serious injury when laying pipes and pipelines

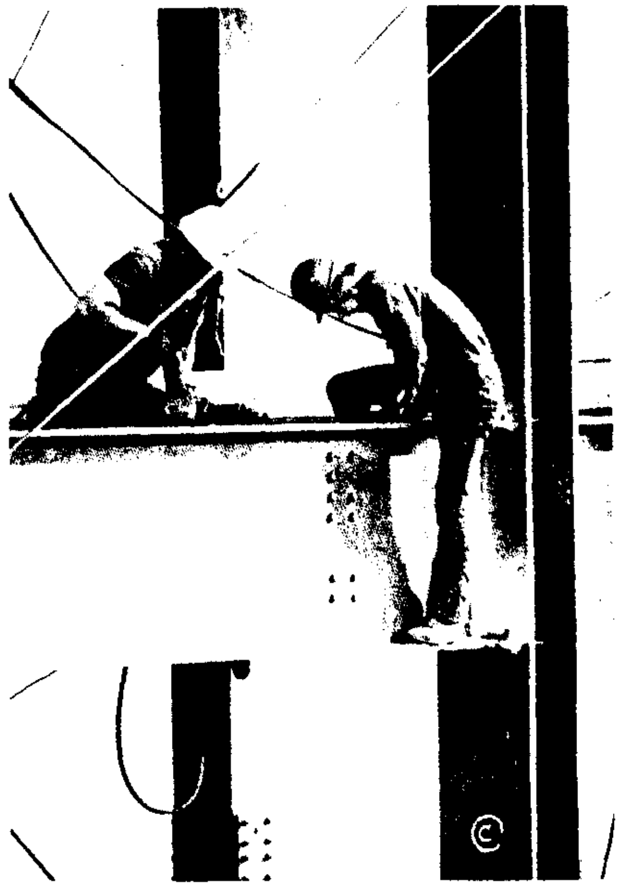


Photo credit: OSHA, Office of Information and Consumer Affairs

Falls from heights are a frequent source of fatal injuries in the construction industry

ings that are sufficiently strong and high will prevent a worker from slipping through openings inadvertently. Adequate scaffolds have been described for particular construction tasks; bricklaying and stonework require sturdier scaffolding than light carpentry.

Another source of injuries and fatalities is trenching. Collapsing trenches can bury workers **alive. This can be prevented by shoring trenches or by sloping trench sides as they are dug to prevent collapse.**

Scaffolding, railings, and blocked holes in floors under construction are day-to-day steps taken to prevent injury. These temporary measures must be put up, taken down, and supervised each day or as each floor in a new building is completed.

Construction workers depend on personal protective equipment—hard hats, gloves, and steel-toed shoes-for immediate protection but consideration of worksite layout to prevent workers entering areas likely to be filled with **flying objects plays an important role in preventing construction-related injuries and death.**

Photo credit: OSHA, Office of Information and Consumer Affairs

Mechanical power presses are an important safety hazard in many manufacturing plants

In all these cases, the persons responsible for safety must be given authority to require that precautions be taken. The urgency to finish a job and the false confidence that comes with "I've done it a thousand times this way" lead both workers and management to ignore hazards. These human tendencies are among the reasons that involvement of management from the top down is necessary for injury control.

PREVENTING MANUFACTURING= RELATED INJURIES

Though the rates are not as high as the construction industry, the manufacturing sector still has injury and illness rates higher than the all-industry average (see ch. 4 and Working Paper #l). It also offers many opportunities for injury prevention because it is a relatively stable work environment. Workers make products generally using the same methods day after day, while management closely controls the entire operation.

Manufacturing involves applying energy to wood, metals, or other materials to shape them into usable products. Even handtools multiply human muscle forces greatly; the cautionary instructions about hammers, screwdrivers, saws, and snips delivered from parent to child or from teacher to student often include gory descriptions of injuries known first or second hand. Power tools move faster, generate greater energy, and, hence, involve a greater degree of hazard.

The following selected examples of dangerous operations among the wide variety found in manufacturing operations illustrate injuries that may be related to manufacturing and provide a summary of control strategies.

Woodworking Processes

Table 6-4 lists woodworking processes, possible injuries, and preventive technologies. Devices used to cut, shape, and join wood—including a variety of power saws, planers, shapers, lathes, and routers—are capable of causing serious injury, especially to the hand or eye. Preventing such injuries depends on design of special guards, on work practice, and on personal protective equipment. For instance, a guard would prevent contact with a power saw, a lock would prevent the saw from being turned on while maintenance work is in progress, and gloves and goggles would protect the worker's hands and eyes from flying chips.

Many items of equipment can be purchased with built-in guards *(322)*. There is general agreement that built-in guards are less expensive, more

Photo credit OSHA, Office of Information **and Consumer** Affairs

Improper use of powered woodworking tools, such as this saw, can lead to serious injuries, including cuts and amputations

effective, and less likely to interfere with production than "bolt-ons." Unfortunately, the extra cost—coming at a time managers are spending money on new machinery-may inhibit purchase of the safer equipment.

Metalworking— Cutting, Welding, and Cold Forming

The most casual sidewalk superintendent can appreciate the hazards inherent in welding and cutting metals. These involve high temperatures, hot metal, and intense visible and ultraviolet light. Table 6-5 shows a summary of the potential hazards of each process and gives examples of the types of control technologies that can be used to prevent injury.

The hazards of welding and cutting are similar. Skin may be injured by infrared, visible, or ultraviolet radiation or by fire, hot metal parts, explosions, or electrical shock. Eye injury or burns may result from flying sparks, hot metals, or the immensely strong light emitted in the infrared, visible, and ultraviolet spectrum. Gases including oxygen, acetylene, hydrogen, and others, usually stored under pressure in special cylinders, may explode, or injury may result from physical handling of the cylinders. Shielding can protect adjacent workers, and face masks can protect the welder (322). One type of welding—resistance welding— is usually done by a special machine that eliminates many sources of injury.

Table 6-4.—Technologies for Preventing Work-Related Injury From Woodworking Machinery

Process, device, or tool	Injury potential	Examples of prevention technology available
Saws	Cuts, amputation, eye damage, projectile wounds, hearing loss	Kickback and hood guards, jigs[a], operating methods, push sticks, maintenance goggles, hearing protectors
Jointers, planers	Hand and finger cuts	Swing guards, hold down clamps, maintenance
Shapers	Hand and finger cuts, projectile wounds	Use of solid cutters instead of knives, maintenance, safety collars, brakes, operating methods, holding jigs[a], goggles
Power-feed planers	Hearing loss, projectile wounds	Isolation, goggles, maintenance, hearing protectors
Sanders	Abrasions, projectile wounds	Guards, goggles
Lathes	Eye and projectile wounds	Goggles, face shields
Routers	Hand cuts	Jigs[a] with handles

a Jig—a device for mechanically holding a piece of work in the correct position while working on it

SOURCE (322)

Photo credit Department of Labor, Historical Office

Lack of attention to prevention can result in equipment collapse

Photo credit" OSHA, Off/cc of Information and Consumer Affairs

The hazards of welding include heat, flying sparks, and fumes, as well as infrared, visible, and ultraviolet radiation

Cold forming involves applying great cutting and punching forces to metal. The power of the machines for turning, boring, milling, planing, grinding, and power pressing is a obvious hazard. Table 6-5 also includes a summary of the types of injuries associated with these machines. Cuts, eye injuries, injuries from being caught in the machine, and foot injuries from dropping heavy chucks (devices that hold the cutting tool in place during machine work) are the main problems. Control technology ranges from careful design that considers safety to personal protective equipment.

OSHA and NIOSH studied self-tripping power presses that use presence-sensing devices such as photoelectric detectors and light beams to prevent hands from entering the presses. Use of these devices to activate power presses could increase productivity as compared with the use of two-handed switch activators. Although photoelectric devices for these purposes are ordinarily prohibited by an OSHA regulation, a variance was granted to one company to evaluate the relative degree of injury control among workers using self-tripping devices and those using two-handed switches. Investigations found no significant difference in observed injuries or stress as measured by heart rate, blood pressure, and subjective responses to a questionnaire among the two groups of workers tested (588).

Although the photoelectric devices provide protection equal to traditional methods, and at the same time increase productivity, NIOSH studies have found other innovations less positive. For instance, presence-sensing devices that halt machine operation when a worker's hand interrupts a radiofrequency field in the danger zone proved inadequate for reliable injury prevention. These studies have also shown that the current standards for two-handed activator switches for power presses may be inadequate. Under some condi-

Table 6-5.–Technologies for Preventing Work. Related injury From Metalworking Machinery

Process, device, or tool	Injury or illness potential	Examples of prevention technology available
Welding and cutting	Shock trauma; eye injury; back injury from handling heavy gas cylinders; cuts from sharp edges on finished work; hearing loss	Careful layout of equipment, process, and job; arc and spark-shielding; proper insulation of electrical cable; goggles; welding hoods; welders' helmets; gloves; ultraviolet-energy-resistant clothing
Metalworking machinery; turning machines; boring machines (drills, boring mills); milling machines (saws, gear cutters, electrical discharge—EDM[a]); planing machines	Eye injury (flying chips), scalping (hair caught in machinery), foot injury from dropped chucks; hand, finger, or limb injury; skin irritation (cutting fluids), electrical shock (EDM[a])	Machine design, including shielding, proper electrical insulation, local exhaust ventilation for grinding wheel discharge and for discharge gases from EDM[a] machines, provision of emergency stop buttons Safe working practices, including keeping tools sharp, never leaving machine unattended, using handtools instead of hands to work metal
Grinding machines		Inspection of grinding wheels for integrity and balance; good maintenance; shields to prevent flying chips; use of personal protective devices, including goggles, hearing protectors, closely fitted clothing, haircaps, safety shoes
Power presses; hand- or foot-operated presses; metal shears; press brakes	Finger or hand amputation or injury; finger punctures; fatigue; eye injury, foot injury; lacerations	Enclosure of the die during operation; adjustable, fixed, or interlock press barrier guards; point-of-operation safe-guarding with movable barriers, two-handed tripping devices, presence-sensing devices; semiautomatic feed systems to avoid use of hands; electrical controls such as interlocks, emergency stop switches, and ground fault protection; apparatus for transferring dies; anti-repeat clutches and magnetic brakes to prevent inadvertent triggering of power press or shear; frequent machine inspection; careful maintenance; special handtools for feeding pieces into the machine

[a] Milling by electric arc
b Systems for Preventing inadvertant machine operation during maintenance

SOURCE (322)

tions workers could activate the power press and have time to reach into the press before the press ram completes its cycle (588).

Metalworking—Hot Working

Hot metal work is done primarily in foundries. It is characterized by massive, often older, machinery. The size of the operations and the weight and heat of the materials being worked result in many injuries. The processes range from handling raw material—ore concentrates, coal, coke—to working with heating and shaping ovens and production equipment, to non-destructive testing of finished products. Injury risk is high to the eye, head, foot, trunk, and limbs.

Injury prevention depends on proper design of the job, good work practices, and personal protective equipment (table 6-6). Bums are prevented by spark shielding, special clothing, and insulation of electrical cables. Electric shock prevention methods include shielding, guarding, good work practices, proper electrical insulation, and maintenance. Eye protection is needed where sparks and hot metal particles may fly. Fire and ultra-

Photo credit: Department of Labor, Historical Offlce

This machine will not operate unless both of the operator's hands are on the control switches. The use of "two-handed controls" represents one method of preventing injuries associated with power presses and shears

violet-energy-resistant clothing is important for worker protection. Gloves are needed to protect hands from bums. Welders' helmets are required for electric-arc welding.

Preventive Maintenance

Careful attention to the plant, its operations, and workers is necessary to maintain controls. Table 6-7 shows a range of maintenance operations required to prevent injury in manufacturing operations. Maintenance of everything from foundations and footing to electric bulbs can prevent injuries.

Table 6-6.—Technologies for Preventing Work. Related Injury During Work with Hot Metal In Foundries

Process, device, or tool	Injury potential	Examples of prevention technology available
Handling of materials such as sand, coke, and coal	Injury from electrical shock, heat, being struck by or against, or being caught between; explosions, vibration, noise; injury to hand and foot, eye, trunk, limbs, or other body parts; death from trauma or asphyxiation	Ladles equipped with automatic safety locks or brakes; devices to warn when ladles are being moved; appropriately guarded conveyors for transport of sand and molds
Cupolas, crucibles, ovens		Mechanical devices for charging cupolas; blast gates to prevent injury from gas explosion
Production equipment		Venting molds to prevent explosions; two-hand controls for molding and core-blowing machine operators; dust-tight sandblast rooms; guards, two-handed tripping controls for forging hammers, presses, and upsetters; careful and frequent equipment inspection Personal protective equipment, as required, including hard hats, gloves, leather aprons, steel-toed shoes, metatarsal guards, safety glasses, goggles, flame-retardant clothing; devices to prevent doors and other movable parts from hitting workers; material-handling devices to eliminate heavy lifting and possible spills or splashes of solids and liquids

SOURCE (322)

Table 6-7.—Technologies for Preventing Work-Related Injury Through Maintenance of Structures

Process, device, or tool	Injury or illness potential	Examples of prevention technology available
Foundations	Injuries and fatalities from building collapse	Check for and repair settling footings and columns, cracked foundations
Structural members, walls, floors, roofs, and canopies	Injuries and fatalities from plant building collapse	Check for and repair settling walls, defective columns, joists, beams, and girders; cracked building materials such as steel, concrete, wood; cracked walls and windows; sagging or rotted roofs and ceilings; rotted, sagging, cracked floors
Stacks, tanks, and towers	Injuries and fatalities from structural collapse; asphyxiation and acute poisoning from tank gases; injuries from explosions during tank cleaning or repair	Place railing around edges of platforms; check structural integrity; use proper procedures for maintenance work
Platforms and loading docks	Injuries from slips and falls	Use metal protectors on edges of concrete platforming; check surfaces for rotting, holes, or other hazards
Sidewalks and driveways	Injuries from slips, falls, or collision with moving vehicles	Repair damaged sidewalks and motorways; install and maintain warning signs and markings
Underground utility repair and maintenance	Injuries and fatalities related to sewer gas explosion; asphyxiation from oxygen depletion; injuries or fatalities from collapsed trenches; drowning or injury from failure of underground pipelines	Test for gases and oxygen deficiency before attempting maintenance work in underground tunnels and sewers; provide contaminant-free ventilation during maintenance work; slope trenches at angles to prevent collapse
Lighting systems	Cuts from broken bulbs; injury from electric shock, fails, or poor illumination	Provide proper equipment for disposal of burned-out lamps; use properly designed ladders and platforms; clean and replace burned-out bulbs on a regular schedule
Stairs and exits	Injuries from slips and falls; injuries from crowding in emergency situations	Install and maintain adequate handrails, illumination, and walking surfaces on stairs; keep passageways and stairs free for exit; install unobstructed exit doors for fire and emergencies
Grounds maintenance	Injury from grounds maintenance; cuts from mower blades and snow throwers; eye injury from frying objects; collapse from quick-acting pesticides	Maintain tools and equipment; provide guards for belts, chains, and other moving parts

SOURCE: (322)

FIRE AND EXPLOSION PREVENTION

Fire and explosions levy an enormous cost on industry and continue to cause many deaths and injuries among workers and the general public. Of fire-related deaths, 75 percent are due to inhalation of smoke and toxic gases and the other 25 percent to direct flame. Injury and death from fires can be prevented by proper design and construction of buildings, vigilant inspection, early detection and warning, and appropriate control methods.

Building designers play an important role in fire prevention. Engineers and architects can anticipate fire problems in the design of buildings and facilities and thereby protect workers and the public from injury. A study of over 25,000 fires between 1968 to 1977 resulted in a listing of ignition sources ranging from the most common—electrical ignition and arson—to the least common—lightning (table *6-8).* These findings point to areas where controls are most needed and on

Photo credit OSHA, Office of Information and Consumer Affairs

The hazards of hot metalworking are found in steel mills and foundries

Table 6-8.—Common Ignition Sources of Industrial Fires

Source	Frequency (percent)	Means of prevention
Electrical	22	Design and maintenance
Incendiarism (arson)	10	Security
Smoking	9	Supervision, substitution
Hot surfaces	9	Design and maintenance
Friction	7	Design and maintenance
Overheated materials	7	Work practice and control
Cutting and welding	7	Work practice
Burner flames	6	Design and maintenance
Spontaneous ignition	5	Housekeeping
Exposure (fire from adjacent property)	4	Design
Combustion sparks	3	Design
Miscellaneous	3	Design and other
Mechanical sparks	2	Housekeeping
Molten substances	2	Work practice and maintenance
Static sparks	2	Design (grounding)
Chemical action	1	Work practice
Lightning	1	Design (grounding)

a Removal of chemicals that cause cigarettes to burn for longer times would reduce the number Of cigarette-caused fires that kill 3,000 Americans annually.

SOURCE: (322).

Photo **credit** *OSHA Office of Information and Consumer Affairs*

An explosion at this oil refinery killed 3 workers and injured 14 others

which building codes and standards tend to concentrate for prevention.

Local building codes and OSHA standards, generally based on National Fire Protection Association Codes, provide the minimum basis for fire-safe construction design. The NFPA Life Safety Code is an appropriate design guide for warning and exit requirements.

Since electrically started fires are the most frequent type, appropriate sections of the OSHA standards and the National Electrical Code of the NFPA are to be followed for proper installation and maintenance of electrical equipment. Sparking can occur when unwanted metal objects enter machinery. Particular attention should be given to preventing heat-generating short circuits and arcs, two of the leading causes of electrical fires. Temporary and makeshift wiring when existing electrical outlets are overextended to accommodate a growing office computer system, for example, is one potential source of fire. Improperly insulated portable electric tools and extension cords should be avoided. Proper grounding is essential for preventing electrical shock and fire-causing arcing.

Smoking, friction, and open flame devices are other sources of work-related fires that can be controlled. Smoking should be prohibited in all but approved areas to prevent fire. Friction from improperly maintained machinery can cause fires. These can occur in workplaces where organic dust may accumulate, such as grain elevators, textile mills, and woodworking mills. Open flame devices used in industry are frequent causes of fire, These include heating torches and welding and cutting equipment. Many fires occur in plants where housekeeping is lax. Accumulations of oily rags, waste, and other combustible refuse can ignite unless kept in air-tight noncombustible containers. Compliance with local ordinances concerning incineration, sewage, and other means of waste disposal provides a minimum of safety.

A designer, engineer, manager, *or worker* who knows the identity of combustible hazards can choose the proper emergency equipment to deal with fires. Table 6-9 is the fire classification developed by the National Fire Protection Association that relates to the decal identifying most fire extinguishers. Clearly, placing the appropriate extinguisher in the right place is necessary.

Giving early warning of fires, extinguishing a fire at early stages, and quickly clearing buildings are also obviously essential to prevent injury. Design should include early warning and alarm sys-

Table 6.9.—National Fire Protection Association Fire Classification

Class	Description	Means of control
A.	Fires occurring in ordinary material such as wood, paper, etc.	Cooling and quenching by water to reduce heat is recommended. Special dry chemicals may be used to control flame.
B.	Fires that occur in the vapor-air mixture over **the surface of flammable liquids** such as gasoline, oil, etc.	Since water tends to spread such **fires, dry chemicals, carbon** dioxide, foam, or halogenated agents are preferred.
c.	Fires that occur in or near equipment using electrical energy.	Non-conducting agents such as dry chemical or carbon dioxide must be used to extinguish to prevent electric shock.
D.	Fires that occur in combustible metals such as magnesium, lithium, potassium, etc.	Since ordinary means of control such **as** water may increase the intensity of such **fires, special equipment and materials are required to control this tvpe of fire.**

SOURCE (322)

terns. Both manual and automatic fire extinguishing systems should be strategically located to limit fires in their early stages. Fire-safe stairwells, adequate aisle space, and appropriate stairwell width are essential for safe and rapid exit. Emergency stairwell lighting should be provided.

The use of fire-resistant materials, the design and construction of building frameworks, ventilation systems, concealed spaces, storage areas, exteriors, fuel sources, and building uses—all part of the designer's functions—make a difference. Widespread use of masonry in the interiors of European dwellings is thought to be a factor in their superior fire record. Plastic interiors used in this country, on the other hand, are the source of deadly toxic gases during fires.

Explosions are a special preventive concern of designers. Explosive atmospheres result from the accumulation of organic dusts and from gases and vapors. The U.S. Department of Agriculture lists 133 dusts by degree of explosibility (322). Dusts produced from phenolic, urea, vinyl, and other synthetic resins and powders used in the plastics industry also explode under certain conditions. The Explosion Venting Guide of the NFPA provides specifications for buildings where the risk of explosion is high.

Explosion prevention can be accomplished by inert gas systems that displace oxygen so that gases and dusts are incombustible and by adequate ventilation, proper process operation, and vigilant maintenance. Gas lines and valves should be inspected frequently for leaks.

Since three-fourths of fire-related deaths are from toxic fumes and since industrial fires may involve extremely toxic materials, it is important for firefighters to be able to identify chemical and material inventories in establishments under their jurisdiction. Several municipalities and States have developed systems for this. The OSHA hazard communication (labeling) standard may also be useful for this purpose.

INJURY CONTROL PROGRAMS IN INDUSTRY

Effective control of work-related injury depends in part on how well a company is organized to deal with it. Management has the primary responsibility for prevention. Relevant programs include training workers, supervisors, and managers to recognize workplace hazards and take steps to control them (see ch. 10).

Successful injury prevention must start with a strong commitment from management. The stronger the commitment at the top the greater the likelihood of success. Typical management programs for preventing work-related injury (and illness) include:

- establishing clearly stated company policies for prevention;
- avoiding work-related injury and illness by planning ahead when designing new plant or modifying existing processes;

- analyzing each hazardous operation to determine the steps required to do the job without causing injury or illness;
- identifying hazards through workplace surveys and investigating the factors surrounding an event that caused or nearly caused injuries or illnesses;
- maintaining accurate and complete records of the causes of injuries and illnesses;
- training workers, supervisors, and managers to identify hazards and prevent injury and illness that could result from them; and
- placing and maintaining people in jobs suitable to their physical status.

THE DU PONT INJURY CONTROL PROGRAM

Perhaps the best source of information about how to run an injury-control program is available from the successful companies. Determining one best program is impossible, of course, for hazards vary from industry to industry, plant to plant, and department to department, making comparisons of overall rates difficult. This section focuses on the Du Pont Company not because its program is best, but because it is good enough that Du Pont sells it to other companies and much information is available about it. Du Pont plants have very low injury rates, which have dropped dramatically since 1912, falling even more than the all-industry average according to National Safety Council data. A key to the company's success in preventing injuries at work is its commitment in this area. Its program consists of four main parts:

- establishing injury prevention as a top management objective;
- establishing injury prevention as a line-management responsibility;
- adopting an injury-control philosophy to guide management action; and
- establishing an organization for injury control.

Du Pent's success in preventing injuries may largely be attributed to strong commitment of top management. The founder of the company was personally committed to preventing injury among his workers, often family or friends, who were in the high-risk business of manufacturing gunpowder.

Commitment to injury prevention still permeates this *Fortune 500* corporation from the top down. For example, performance rating at all levels of management is partly dependent on success in preventing injury. Du Pont lists the following as incentives for making injury control a management objective:

- protect workers,
- improve profits,
- improve product quality,
- improve productivity,
- improve employee-management relations, and
- comply with OSHA regulations.

Du Pont finds that injury control increases profits. Using National Safety Council statistics for 1976, Du Pont estimated the average cost of each disabling injury to be $7,182. The company then compared its estimated costs for 1977 (based on their rate of 0.2 disabling injuries per million hours worked) with the projected cost if the rate had been at the all-industry level of 10.87. Table 6-10 shows Du Pont's estimated savings were greater than $15 million, based on the all-industry injury rate; a more representative comparison, however, would be with large chemical companies, which as a group have lower injury rates than the all-industry average. Nevertheless, Du Pont's own comparisons were impressive enough to be featured in a ***Fortune*** article about savings from preventing work-related injury (284).

Line-management emphasis on preventing injury is another critical element of success. Responsibility for preventing injury is as much a condition of employment in Du Pont as getting the job done, High-level staff meetings often begin with reports of job injuries, and any fatality has first priority at any management meeting, including the presidents.

Table 6-10.–Du Pent Calculations of Cost Savings From Injury Control

	Du Pont U.S.A. actual (1977)	Totals if at all industry rate (1976)
Disabling injuries/million worker-hours	0.20	10.87
Disabling injuries/year		2,174
Average cost/injury	$7,182	$7,182
Cost/year (total injuries)	$287,280	$15,613,668

SOURCE: (156)

Five basic beliefs underlie Du Pont's program:

- **all personal injuries can be prevented,**
- **managers and supervisors must personally accept their responsibilities to prevent personal injuries,**
- **reasonable safeguards are possible for all construction and operating exposures that may result** in injury,
- efficiency and economy are enhanced when personal injuries are prevented, and
- all employees must be trained to understand the advantages to them, as well as to the company, of taking responsibility to prevent personal injuries.

Du Pont's Safety Training Observation Program (STOP) uses programed self-study courses to enhance injury prevention. It is one of more than 200 vocational courses developed for industrial craft skill training. The objective of STOP is to train line managers to notice workplace conditions that might lead to an injury or illness.

STOP presents seven broad categories that are suggested for observation rather than having detailed checklists of hazardous working conditions. The manager looks for injury potential associated with procedures, tools, equipment, orderliness, personal protective equipment, positions of people, and actions of people. **A** training unit divided into eight parts is used for instruction and includes pocket-size cards to record workplace observations as practice between teaching units.

The administrator of the course is key to its effectiveness. To show management commitment to the course and to motivate supervisors to be equally committed, the administrator must be highly placed in the management structure.

The desired outcome of the training, which should take only 12 to 16 hours away from work, is supervisors who are able to recognize hazardous conditions, to assign responsibility for correcting it, and to ensure the elimination of the hazard. The success of the program has been measured through reduced injury rates in firms that have purchased and used the training program from Du Pont.

SUMMARY

Perhaps because of the more obvious sources of injury as compared to illness, safety engineering appears to be more pragmatic than industrial hygiene. Engineers have, to some extent, directed their attention to sources of hazard such as electricity, falls, and fires, and produced codes and standards for good practice.

These codes and guides to good practice appear often to be based on the personal experience and judgment of the practitioners who happen to write safety textbooks or are members of the committees who write the codes. This field has relied on experience and judgment instead of scientific analysis, systematic data collection, the application of epidemiologic techniques, and experimental research. It is probably fair to say that up to the present there has been little that might be called a "science" of safety. In addition, as described in chapter 4 on the identification of injury hazards, the attempt to attribute most injuries to so-called unsafe acts has often diverted attention away from the design of plant and equipment that can prevent "unsafe acts" or minimize the adverse consequences of "unsafe acts. " However, it is unclear what differences a more theory-based rather than the pragmatic approach would have made.

Several specific areas where injury control can be applied were discussed in this chapter. A number of different methods and technologies are available for preventing injuries related to motor vehicles, construction activities, manufacturing processes, and fire and explosion hazards. These include the proper planning of plant sites and the design of equipment, as well as the use of guards, personal protective equipment, and appropriate work practices. Adequate attention to preventive maintenance, and the training of workers and managers, also play roles in injury prevention. Successful injury *control* programs start with a strong commitment *to* injury prevention at all levels of management.

Controls are known for many hazards. However, they are not always used because they were not built into a plant, are not available at a particular worksite, or are pushed aside to get the job done. All of these reasons for not using controls emphasize the important role of management in providing controls and seeing that they are used.

7.
Ergonomics and Human Factors

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Ergonomics and Human Factors

Neither workers, nor machines, nor workplaces exist apart from each other. To accomplish work, all come together, and injuries and illnesses sometimes result from their interactions. The study of these interactions is called "ergonomics," or "human factors engineering."

The term ergonomics was coined in the United Kingdom after World War II to describe a discipline created during the war. It had been noted that "bombs and bullets often missed their mark, planes crashed, friendly ships fired upon and sunk, and whales were depth charged" (471). In response to this situation, research on designing military equipment to match more closely the capacities of the users began on both sides of the Atlantic. Attention was thus devoted to the interaction between the human operators and their machines.

One name for this new discipline, ergonomics, is derived from two Greek words, ergo, meaning work, and nomos, meaning laws. Ergonomics is the science devoted to understanding the laws or principles that govern the design of work systems. A British professional group—the Ergonomics Research Society—was formed by the practitioners of this new discipline. An organization with similar aims, the Human Factors Society, was founded in the United States in 1957. The work of the original members was termed "human factors engineering," or engineering psychology. Whether they are called human factors engineers or ergonomists, the scientists who practice this discipline draw on a number of other disciplines, including medicine, physiology, psychology, sociology, engineering, and physics.

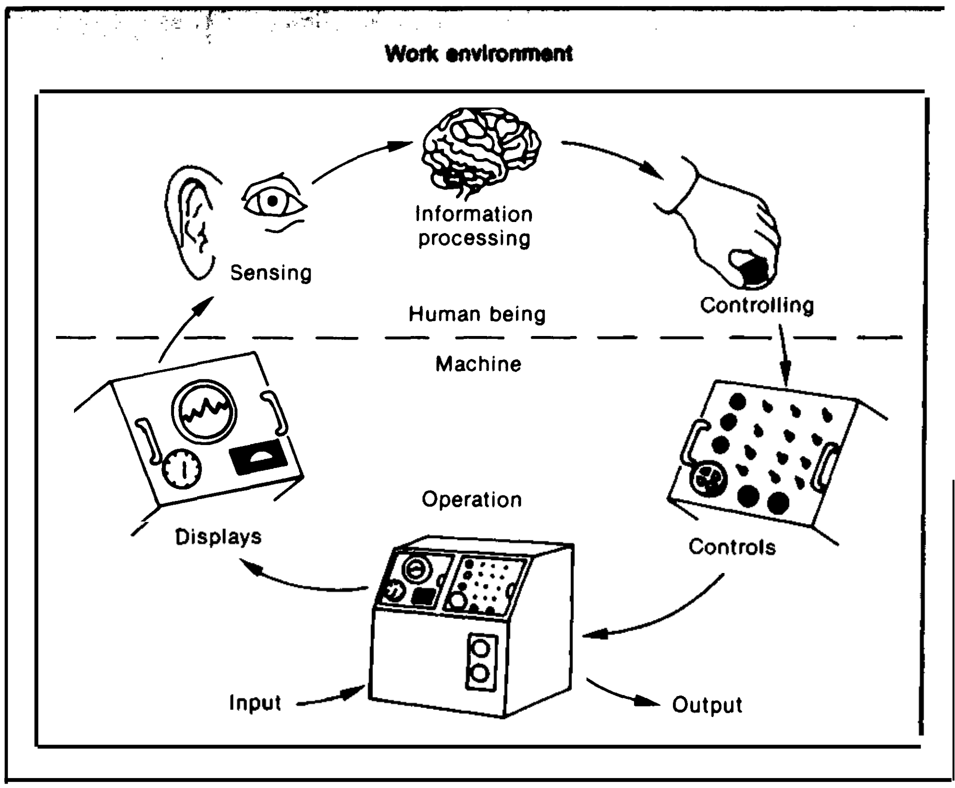
Ergonomists are concerned with safety, effectiveness, and efficiency wherever people are part of a system (380). The discipline is "an applied science concerned with the design of facilities, equipment, tools, and tasks that are compatible with the anatomical, physiological, biomechanical, perceptual, and. behavioral characteristics of humans" (250). The principle behind ergonomic design is that the machine should fit the worker, rather than forcing the worker to fit the machine. To quote from one ergonomics guide (655):

> Man's physical limits for bending, stretching, and/or compressing are such that the machine must be made to adapt to the man rather than the converse. Behavior characteristics are somewhat more flexible. Man can adjust his sensory-motor behavior to some degree, and . . . can utilize alternate procedures and make up for certain equipment inadequacies. However . . . as operator load increases due to task complexity, fatigue may reduce operator reliability; system performance could degrade at a critical time . . . Workplace layout should favor the man's physical and behavioral capability in all cases in which a likely error in human performance could affect . . . safety . . , The designer cannot assume that personnel selection and training will be a panacea for improper workplace considerations.

Figure 7-1 is a schematic representation of a human-machine system. The person processes information about the environment and acts on it by using the machine's controls. The important features of the machine include the controls used by the worker, the operations of the machine, and the displays used to feed information back to the worker. The task of the ergonomist is to analyze how the worker obtains the information needed to operate the machine, how that information is processed to reach a decision concerning the appropriate way to control the machine, and what worker actions are appropriate to control the machine in a fashion that is safe and meets production criteria (380).

Other considerations, especially improving the productivity of workers, fit easily into the goals of ergonomics. Opportunities exist for workplace designs that simultaneously improve production output and reduce the risks of injury. For instance, C. G. Drury reported that new handtools in the component-assembly department of a large computer company and changes in seating, lighting, and workbenches led to improved production and the elimination of repetitive motion injuries. The costs of the redesign" were earned back *4.3* times within one year through increased productivity and savings, and the number of rejected components fell to half the previous level. The workers involved expressed increased satisfaction with their jobs *(340).*

Figure 7-1.—Schematic Representation of a Human-Machine System



SOURCE (292)

CLASSIFICATIONS OF ERGONOMICS

Ergonomists usually subdivide the field into information ergonomics and physical ergonomics. Information ergonomics is concerned with the collection, display, sensing, and processing of information. Physical ergonomics is concerned with worker size, strength, capabilities for motion, and working posture.

Ergonomists use a number of techniques that include the evaluation of the transmission of information between the machine and the worker (link analysis), discovery and evaluation of system failures (critical incidence analysis), detailed examination of the sequence of actions taken by workers (task analysis), and analysis of situations that may arise from unprogrammed events or human errors (contingency analysis) (380). Ergonomists also make extensive use of anthropometric data concerning the physical dimensions and capabilities of the human population. In addition, the techniques of biomechanical analysis are used to measure expected physical stresses encountered by parts of the body while performing; work tasks.

Information Ergonomics

Information ergonomics is generally concerned with what the worker senses in the workplace and how that information is processed by the worker, The two major sources of sensory information are visual and auditory.

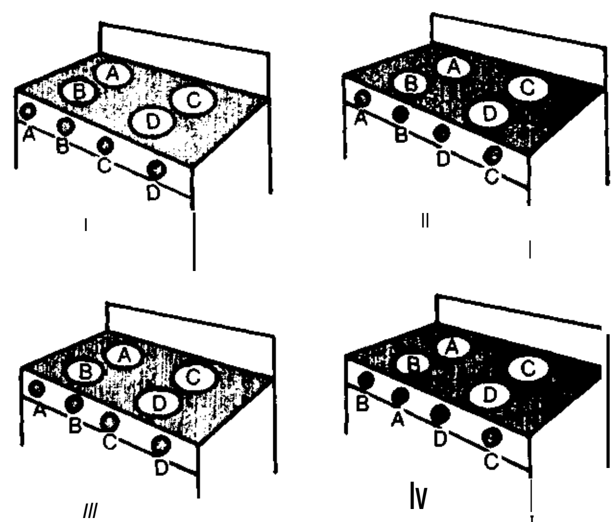
Visual displays in the workplace include meter scales, control labels, warning signs, cathode-ray tube (CRT) displays, and printed text. To this list can be added video display terminals (VDTs), which can be CRT displays, liquid crystal displays, or other technologies. Three factors important to the operator must be considered in designing a visual display: the size of the critical detail in the display, its brightness, and the contrast of the display against the background. There are a number of techniques available to achieve these goals in design and to evaluate existing equipment. There are also many guidelines for special applications, including the special needs of groups such as older workers (23).

Workers also receive information through sound. These can include tones (bells, whistles, beepers, etc.) as well as speech. Designers and ergonomists often face the question of whether to provide information through visual or auditory means. In general, if the message is simple, short, or calls for immediate action, if the worker is already overburdened with visual messages, or if the workplace is too dark or too bright for visual displays, an auditory presentation is recommended. If the message is complex, long, and does not necessitate immediate action, or the auditory system of the worker is already overburdened, or if the workplace is too noisy, a visual display may be preferred (23).

Finally, information ergonomics is concerned with the processing of information by the worker and the design of the workplace, including the design of controls. Research that has measured the abilities of humans to accurately process information has shown that people often will not be able to make quick, accurate responses in complex or unexpected situations, Second, the studies have also shown that "compatibility" in display-control design is very important. Compatibility refers to the relationships between stimuli and responses, and generally falls into three categories: spatial (the compatibility of physical features or spatial arrangement for displays and controls), movement (the direction of movement of displays and controls), and conceptual (the associations people hold concerning the meaning of signals, such as in the United States the association of the color green with "go") (292).

One example of an everyday problem in compatibility will perhaps clarify this notion. Figure 7-2 presents four possible arrangements of the burners and burner-controls for a stove. For several of these patterns, the relationships between burners and controls can be difficult to learn and hard to remember because the arrangements lack spatial compatibility. To examine this, researchers in the 1950s setup an experiment in which they told a group of subjects to turn on specific burners. The subjects' reaction times *were* measured and the number of errors was noted. Design I, asso-

Figure 7-2.–Control Burner Arrangements of Simulated Stove Used in Experiment About Logical Arrangements



Number of errors in 1,200 trials:
arrangement

1	0
II	76
III	116
IV	129

SOURCE: (292)

ciated with both the fewest errors (zero) and the best reaction time, was considered to be the most compatible (292).

Many workplaces have dozens of incompatible control configurations, which often lead to operator errors and subsequent serious injury (23). The cherry-picker accident discussed in box C illustrates the importance of controls layout.

Physical Ergonomics

Physical ergonomics, concerned with the worker as a physical component of the work process,

Box C.—Cherry Picker Accident

Design as Related to the Accident.—The worker was painting the inside of a large industrial plant that was under construction. He was using a large mobile work platform—a cherry picker.

The worker stood in the "bucket" of the cherry picker. The control knobs for moving the bucket left or right and raising or lowering the bucket were identical. The painter, who did not use the equipment regularly, was found with a severe head injury adjacent to a beam with which he had apparently collided.

Application of Heinrich's Approach.—According to the dichotomous classification of accidents provided by Heinrich (see ch. 4), the injury would have been reported as resulting from an unsafe act, i.e., the painter operated the controls in such a mannner as to produce his collision with the I-beam. (In fact, this was the classification used when the injury was reported under the workers' compensation system.)

Using the *ergonomics model,* the investigator would focus on the following questions:

1. What was the worker's experience in using the lift?
2. What was the worker's physical size? (Did he have limitations in his upper limb movement? What was the strength in his upper limbs?)
3. What was the placement of the operating controls? Were they labeled to indicate method of operation? What protection was provided against inadvertent operation?
4. What was the relationship between the method of control operation and movement direction and placement of the lift?
5. How much strength was needed to operate the controls?

It was found that the worker had no problems with upper limb movement or strength, but he had [illegible] experience and training in using the lift. No protection was provided against inadvertent operation (a wire mesh cage over the upper perimeter of the two control levers would have [illegible] inadvertent operation).

A major problem was found in the absence of compatability of control movement versus lift movement. Pushing the lever forward, away from the body, caused the "bucket" to rotate to the left, counterclockwise, while pulling it toward the body caused the "bucket" to move to the right, clockwise.

The ergonomist would therefore have concluded that two possible causes existed for the accident:

1. Since the controls were not protected from inadvertent operation, one of the hoses of the spray painting system had become entangled with the control for rotary movement and had caused the bucket to collide with the beam, or
2. Since the worker was inexperienced in using the equipment and control movement was not compatible with the lift movement, he could have operated the control in the wrong direction and thrown himself against the beam.

often uses the techniques and equipment of anthropometry and biomechanics. Anthropometry is the measurement of the physical dimensions of the human body, including both the structure of the body in fixed positions and the extent of movement possible, such as reach or lifting capacity.

Biomechanics is the study of the mechanical operations of the human body. The muscles, bones, and connective tissue can be analyzed as **a** mechanical system using the fundamental laws of Newtonian mechanics. The forces acting on the muscles, bones, joints, and spine can be determined for the lifting of an object, for instance. Through such analysis, it is possible to calculate the size and direction of forces acting on the body. These can be compared with expected human tolerances to judge whether the activity in question will cause harm.

ERGONOMICS AND PREVENTION OF MUSCULOSKELETAL INJURIES

Ergonomic principles can be applied to prevent both overt and cumulative traumas. An example in the overt category is the risk of falling from a ladder, which can be reduced by considering the sizes and mobility of people when deciding how far apart to place a ladder's rungs **(250).** Cumulative traumas are not the result of single events or stresses; they stem from the repeated performance of certain tasks. Back problems are by far the most common cumulative trauma injuries. Evaluation and redesign of tasks to prevent back injuries is discussed later in this chapter.

Repetitive motion disorders are a type of cumulative trauma associated with repeated, often forceful movements, usually involving the wrist or elbow. Some 20 million workers on assembly lines and in other jobs that require repetitive, strain-producing motions are at increased risk of developing such disorders. Redesigning work stations, equipment, and handtools can significantly reduce the awkward, forceful movements common to many jobs on assembly lines, in food processing, in the garment industry, and in offices. Carpal tunnel syndrome, one of this class of disorders, illustrates the potential for prevention offered by the integration of ergonomics, medical surveillance, and treatment.

Carpal Tunnel Syndrome

A wide variety of workers (see table 7-I), from aircraft assemblers to upholsterers, are among those at risk for carpal tunnel syndrome (CTS), a progressively disabling and painful condition of the hand. Because the musculoskeletal strain from repeatedly flexing the wrist or applying arm-wrist-finger force does not cause observable injuries, it often takes months or years for workers to detect damage.

Table 7.1.—Occupations and Activities Associated With Carpal Tunnel Syndrome

Aircraft assembly	Inspecting
Automobile assembly	Meat processing
Buffing	Metal fabricating
Coke making	Musicians
Electronic assembly	Packaging
Fabric cutting/sewing	Postal workers
Fruit packing	Textile workers
Gardening	Tire and rubber workers
Hay making	Typing
Waitressing	Upholstering
Housekeeping	

SOURCE (60)

The incidence and prevalence of CTS in the work force is not known. The National Institute for Occupational Safety and Health **(567)** reports that 15 to 20 percent of workers employed in construction, food preparation, clerical work, production fabrication, and mining are at risk for cumulative trauma disorders. The Bureau of Labor Statistics (603) reports 23,000 occupationally related repetitive motion disorders in 1980, although the number of CTS cases is not specified.

CTS is undoubtedly underreported in aggregate statistics. Research in particular high-risk plants provides some insight into the extent of the problem. In a study at an athletic products plant, **35,8** percent of workers had a compensable repetitive trauma disorder. In some jobs within the plant,

Photo credit: OSHA, Office of Information and Consumer Affairs

Work on an automobile assembly line can involve cramped working positions. A Volvo assembly plant in Kalmar, Sweden, uses "tipper trolley s." These trolleys hold the automobile bodies and can be tipped 90 degrees to allow work on the underside of the car

the rate was as high as 44.1 percent, and carpal tunnel syndrome occurred in 3.4 percent of the workers (21,23). Many industries claim that the incidence of CTS is increasing and is one of their most disabling and costly medical problems (60).

Symptoms

The onset of symptoms of CTS is usually insidious. Frequently, the first complaint is of attacks of painful tingling in one or both hands at night, sufficient to wake the sufferer after a few hours of sleep. Accompanying this is a subjective feeling of uselessness in the fingers, which are sometimes described as feeling swollen. Yet little or no swelling is apparent. **As** symptoms increase, attacks of tingling may develop during the day, but the associated pain in the arm is much less common than at night. Patients may detect changes in sensation and power to squeeze things but some people suffer severe attacks of pain for many years without developing abnormal neurological signs. Ultimately, in advanced cases, the thenar muscle at the base of the thumb atrophies, and strength is lost.

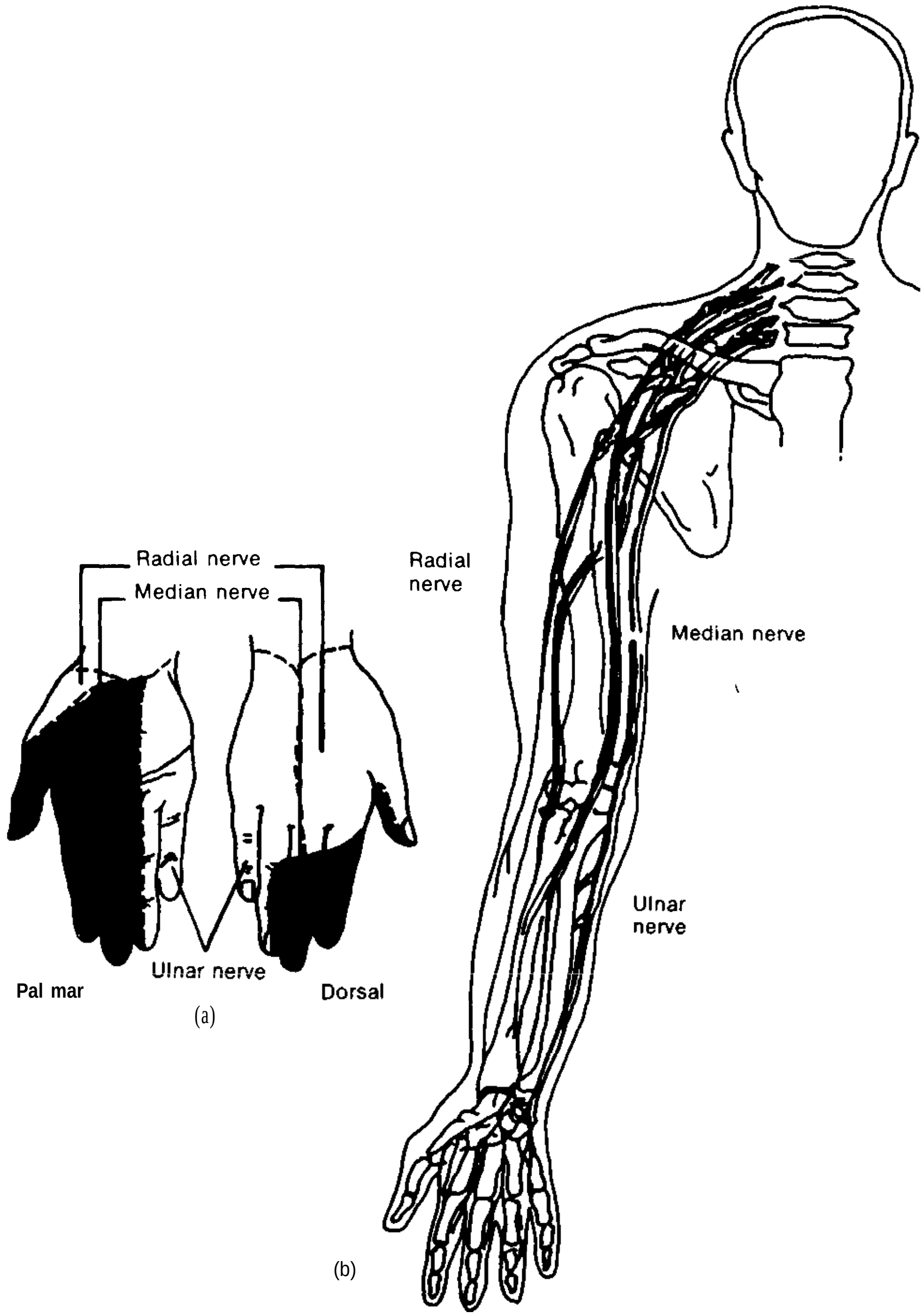
Compression of the median nerve is the immediate cause of CTS. The median nerve comes down the **arm,** through the wrist, then branches in the hand, supplying the thumb, forefinger, middle finger, and half the ring finger with nerves (fig. 7-3). The carpal tunnel itself, located in the wrist, is formed by the concave arch of the carpal bones and is roofed by the transverse carpal ligament (fig. 7-4). These structures form a rigid compartment through which nine finger tendons and the median nerve must pass. Any compromise of this unyielding space usually compresses the median nerve.

Risk Factors

Repetitive motions, such as those required in many jobs, is one of a number of risk factors for CTS. It is probably the most readily controllable cause, however. Certain diseases, acute trauma, congenital defects, wrist size, pregnancy, oral contraceptive use, and gynecological surgery all may contribute to the likelihood of developing CTS. Overall, the incidence of CTS is higher in women than in men, perhaps because of some of these risk factors.

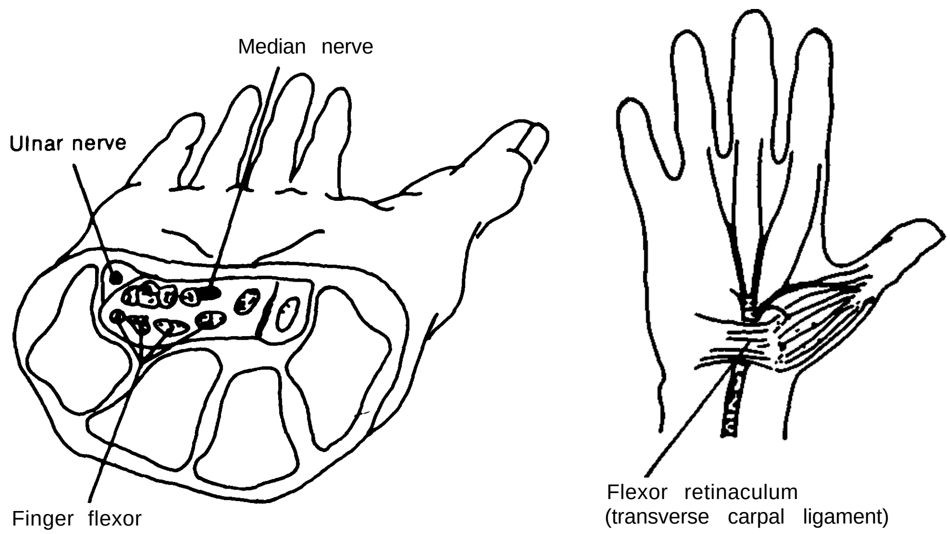
Occupational tasks responsible for the development of CTS include physical exertions with certain hand postures or against certain objects, and exposures to vibration or cold temperatures. Repeated and forceful up-and-down motions of the wrist (flexion and extension) (fig. 7-5), cause the finger tendons to rub on the structures forming the carpal tunnel. This constant rubbing can cause the tendons to swell (tenosynovitis), eventually putting pressure on the median nerve inside the carpal tunnel. The nerve itself is stretched

Figure 7-3.—Major Nerves in the Arm and Hand



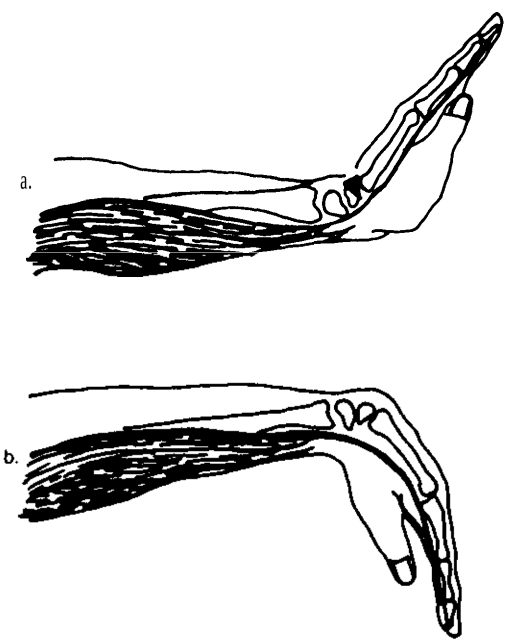
SOURCE (60)

Figure 7-4.--The Carpal Tunnel



SOURCE (60)

Figure 7-5.—Flexion and Extension of the Wrist



Bending the wrist causes the finger flexor tendons to rub on adjacent surfaces of the carpal tunnel.

SOURCE' (60)

by repeated exertions, and compressed between the walls of the carpal tunnel.

Forceful movements and the direction of the movement are only two of the underlying causes of tenosynovitis that can lead to CTS. The speed of movements and incorrect posture while working also are important (275). Median nerve compression also can be caused by tasks that require a sustained or repeated stress over the base of the palm (247). Examples include the use of screwdrivers, scrapers, paint brushes, and buffers.

Although the mechanism is not yet understood, low frequency vibration is a recognized risk factor for CTS (405). Vibration exposure may result from air- or motor-powered drills, drivers, saws, sanders, or buffers. Cannon (95) examined medical records at an aircraft company and found a strong association between CTS and use of vibrating tools.

Control of CTS

Control of CTS requires a two-pronged approach. The primary strategy to prevent cases is the use of ergonomic principles to modify handtools and to improve work-station design and work practices. Even a successful ergonomic program will not prevent all cases of CTS, however. The second important element, therefore, is a medical surveillance program. This is particularly important now when so little is known about the individual factors that cause some people to develop CTS. Thus far, no programs focusing on the medical evaluation of CTS seem to exist (60).

Ways are needed to identify the earliest sign of CTS, to evaluate progression of the disease, and to examine the role of predisposing risk factors. The purpose of such a medical surveillance program is prevention of advanced disease by instituting therapy at early stages.

Although medical surveillance for CTS is still in very early stages, ergonomic interventions have been remarkably successful where they have been instituted. Armstrong (21) describes the steps involved in developing appropriate controls. First, plants and specific departments within plants in which there is a documented high rate of CTS should be identified. Then each job should be systematically analyzed. Traditional time-and-motion studies, in which each movement or act is recorded, can be used. Each element of the job can then be checked against factors known to be associated with CTS development. These include posture of the hand and wrist, strength, stress concentrations over the palm, vibration, cold temperature, and the presence of gloves.

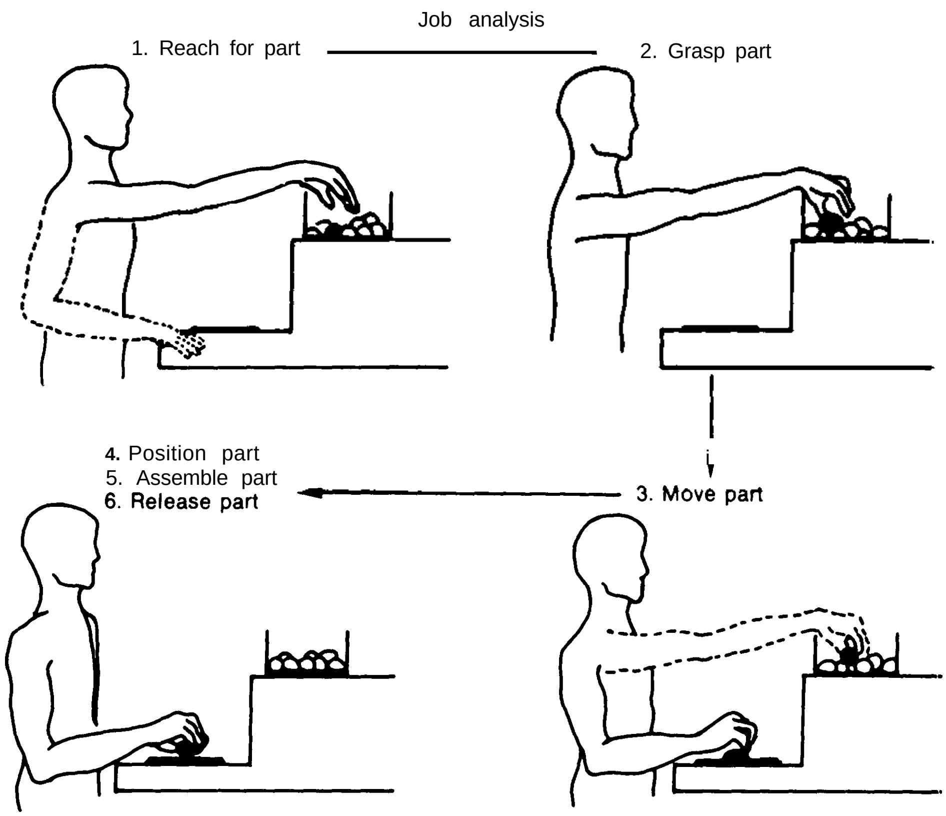
Armstrong presents a typical work task as an example. Figure 7-6 shows a worker taking parts out of a container and placing them on a conveyor. The six elements involved in this task are reach, grasp, move, position, assemble, and release. Reaching into the container involves wrist flexion and pinching, during which the worker's wrist is likely to rub on the edge of the box. The forearm is also likely to rub on the edge of the work bench while the part is positioned. The redesigned work station should reduce stress on the hand and wrist, and eliminate sharp edges. Good and bad designs for the container and the workbench with jig in this hypothetical case are illustrated in figure 7-7.

Powered handtools can also be designed and used to minimize stress. As illustrated in figure 7-8, good designs allow the work to be done with little or no flexion or extension of the wrist.

Armstrong and his colleagues have investigated cumulative trauma disorders in a poultry processing plant using the procedures described above. They discovered that workers in the "thigh boning" section had the highest incidence of cumulative trauma disorders of all departments. Thigh boning involves grabbing the thigh with one hand on a moving overhead conveyor, then making four cuts with the other to separate the meat from the bone. Each worker makes an estimated 15,120 cuts per shift. Ergonomic improvements to the process recommended by Armstrong and colleagues include training workers in the "proper work methods and knife maintenance to minimize the time and, hence, the distance that must be reached and force that must be exerted on the thigh." The work station could be modified to minimize the distance to be reached. The workers wear wire mesh gloves with rubber gloves underneath, which increase the force necessary to grasp the thigh and pull the meat away. Gloves should fit well, and the addition of barbs on the palm of the wire mesh glove might facilitate the hand actions. A new knife handle design, to reduce the force required to hold the knife and make the cuts—e.g., that pictured in figure 7-9—is suggested (22). Such a design would also minimize wrist flexion.

A high incidence of repetitive trauma disorders, including carpal tunnel syndrome, in a telephone assembly plant prompted management to consider how to prevent future cases. McKenzie and colleagues (299) noted the highest rates in areas using vibratory air screwdrivers, and in jobs requiring repetitive grasping, squeezing, or clipping motions. Ergonomic changes recommended included modifying the screwdrivers with sleeve guards and changing work positions to minimize hand and wrist stress. The changes were instituted with almost immediate results: from 2.2 percent annual incidence of repetitive trauma disorders in 1979

Figure 7-6.-Job Analysis: Assembly Tasks



• **Assembling parts on a moving conveyor can be described by a series of six elements,**

SOURCE (21)

to 0.79 in 1981. Lost and restricted workdays fell from 5,471 in 1979 to 1,111 in 1981, and further reductions were expected in subsequent years.

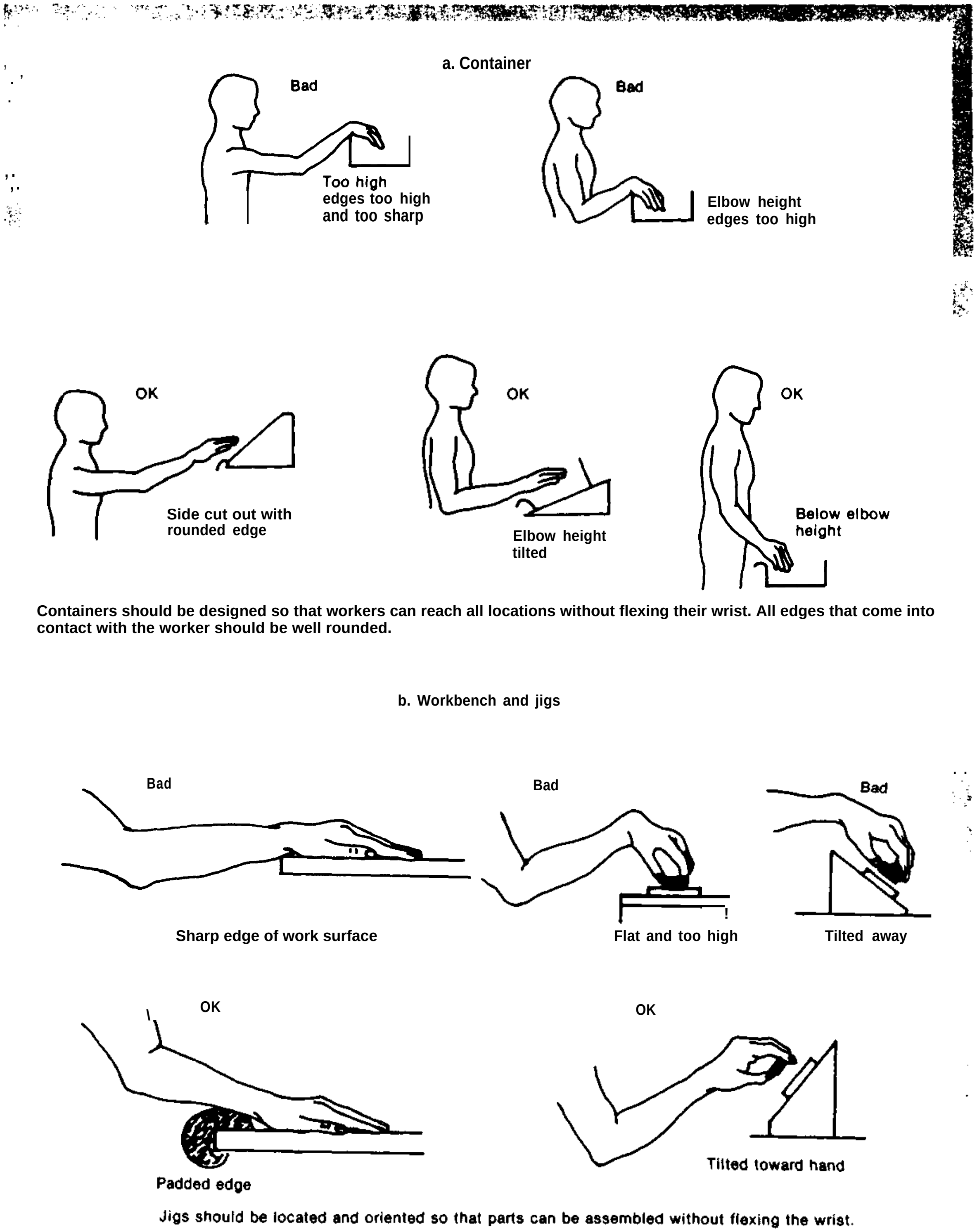
Back Disorders

The Bureau of Labor Statistics completed a survey of workers who had incurred back injuries while lifting, placing, carrying, holding, or lowering objects (605). Of the 900 workers included in the tabulated results, more than 75 percent were lifting at the time of the injury, Surprisingly, the back injuries were concentrated in younger workers; almost 75 percent occurred in 20- to 44-year-olds. Both the weight and the bulkiness of the lifted objects were often associated with injuries. About half the injured workers had received some instruction about proper lifting.

Manual lifting presents a risk of overexertion injuries and cumulative damage to the soft tissues around the spine. Overexertion injuries to the back constitute the largest single category of workers' compensation claims, amounting to 25 to 30 percent of all disability cases Lower-back injuries are often extremely painful and significantly diminish the quality of life of the afflicted workers. Many of these can be prevented by job and equipment redesign.

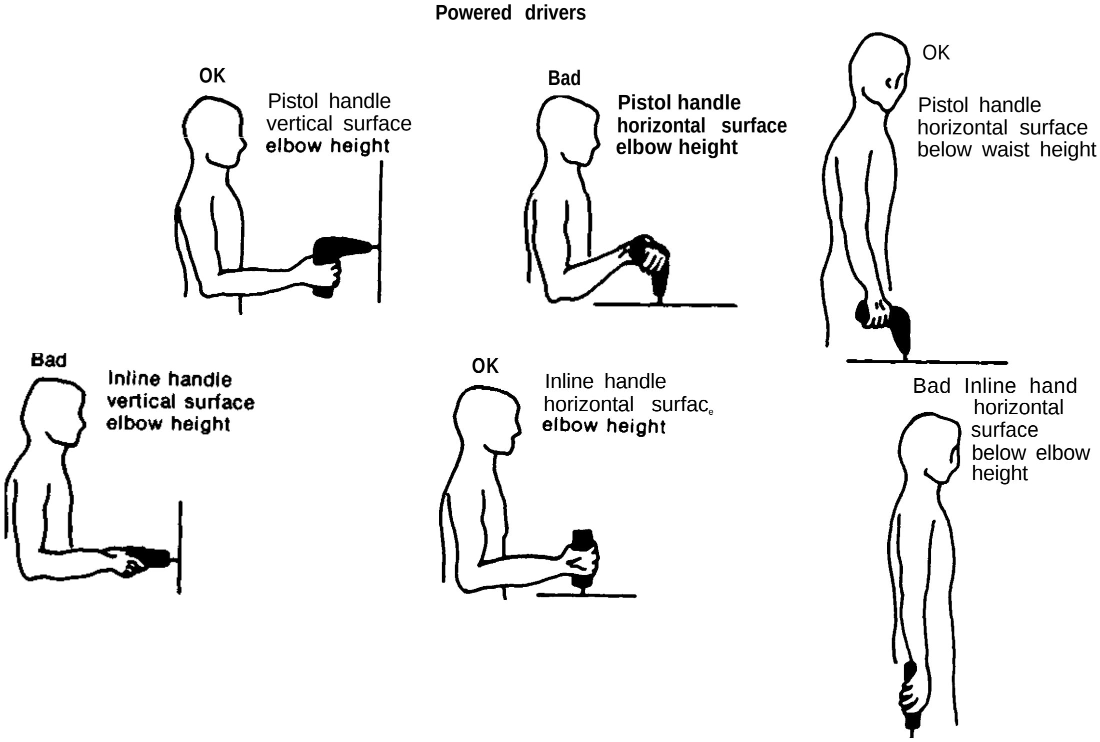
The conventional wisdom about how to lift something is to squat, pick up the object, and, while keeping the back straight, lift straight up

Figure 7-7.—Good and Bad Designs for Containers and Workbenches



SOURCE: (21)

Figure 7-8.—Good and Bad Designs for Powered Drivers



Wrist posture is determined by the elevation and orientation of the work surface with respect to the workers and the shape of the tool.

SOURCE: (21)

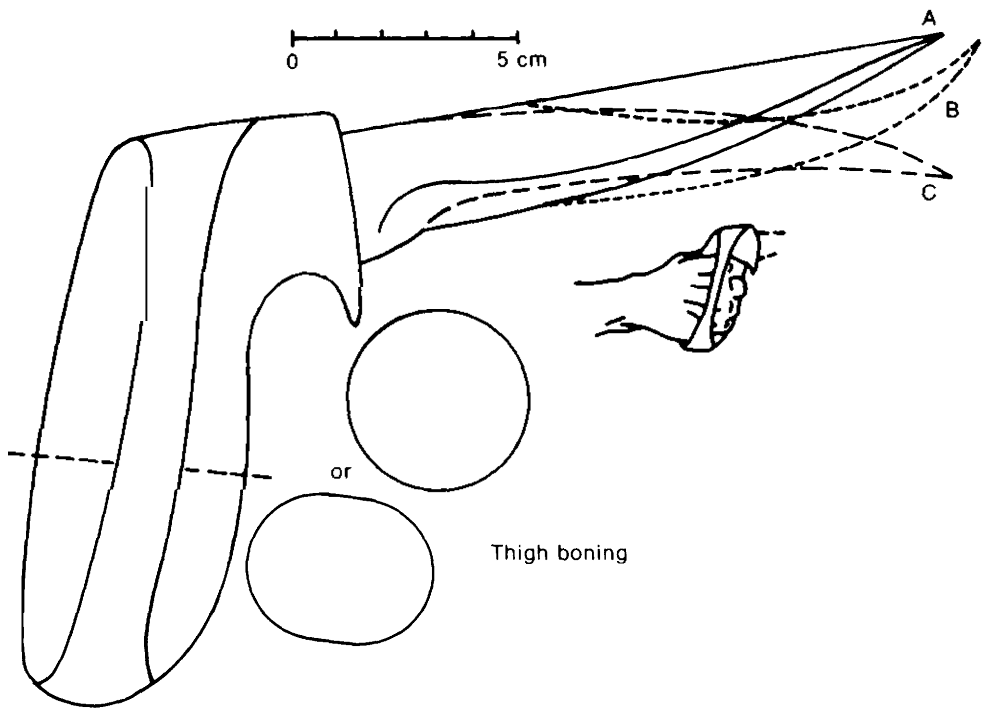
with the legs. This procedure is thought to prevent injury to the back. In many cases this procedure is justified, but there are many other situations where it is not.

Work-Load Evaluation

There are at least four basic sets of criteria for determining acceptable work loads: biomechanical, physiological, psychophysical, and epidemiological (453). Biomechanical criteria are based on pressures and stress exerted on the body, particularly on the spinal column. Limits of tolerance have been developed by observing damage to cadavers when pressure is applied. Physiological criteria are primarily metabolic, e.g. oxygen consumption and heart rate. The psychophysical method incorporates workers' perceptions and sensations into the assessment of work load for both static and dynamic strength. Epidemiologic criteria are derived from aggregate data concerning the incidence, severity, and distribution of low back pain. These four approaches can be integrated and guidelines established with input from each. The National Institute for Occupational Safety and Health has developed recommendations in this way.

Maximum acceptable work loads are often expressed in terms of the weight and frequency of lifting. For instance, 75 percent of the industrial male population can lift a 13-kilogram box of fixed proportions every 5 seconds, and a 34-kilogram box every 30 minutes without triggering or aggravating low-back injury symptoms.

Figure 7-9.—A Knife Designed to Reduce Cumulative Trauma Disorders in Poultry Processing



One possible knife handle with three blades for reduced wrist deviations. The handle is designed to reduce the tendency for the knife to fall out of the hand in thigh boning.

SOURCE (22)

There is great practical significance to having very specific work-load recommendations. They can be used both for determining that a task is unacceptable and as guidelines for redesigning the task. Recognition of a problem often occurs only after a number of compensation claims have been awarded, triggering investigation. Insurance companies have a direct incentive to cut down on compensable back problems. For **case** histories of task evaluation and redesign carried out by the Liberty Mutual Insurance Co., see boxes D and E. According to Snook (453), "most industrial tasks with unacceptable work loads can be modified for less than the average cost of a single low back compensation claim. "

APPLYING ERGONOMICS TO VDT DESIGN

The first reports from Europe concerning potential adverse health effects associated with video display terminals included accounts of many reported musculoskeletal and visual problems. Early U.S. studies of potential VDT hazards also concluded that there were no known radiation hazards and that the real hazards were ergonomic problems: musculoskeletal problems, visual problems, and fatigue. Poor design of equipment or poor job design may produce such problems.

Box D.—Ergonomics—Task Evaluation and Redesign

This case history involves back injuries sustained by employees of a drywall contractor. About eight employees work on an average job undertaken by this contractor. They are required to manually lift and carry Sheetrock (96″ x 4′) to the area where it is installed. There were five compensable back injuries reported during the year preceding the installation of control measures.

The task was evaluated at several job sites. From observation and weight measurements it was determined the exposure could be reduced through the use of carts to carry the drywall. For evaluation purposes a cart was fabricated, which would hold up to 20 sheets, with 2 fixed and 2 swivel wheels of 4-inch diameter. Measurements of initial and sustained forces were made, using 9, 15, and 20 sheets. This revealed that each load should be limited to 15 sheets, which could be handled by 85 percent of the male population without overexertion. Further study showed that by increasing the wheel diameter to 6 inches the population percentage would be increased to a point where employees could handle up to 20 sheets (fully loaded) on the cart. It was also determined that all wheels should be of the swivel type, which would allow the cart to turn corners much more easily.

Management, who actively participated in the [illegible], agreed to fabricate carts with 6-inch [illegible]. The exposure to back injury was [illegible] the efficiency of the task increased. [illegible] of the carts during October [illegible] back injuries have been reported.

[illegible] (675).

Box E.—Ergonomics-Task Evaluation and Redesign

This case history involves back injuries to material handlers in the packing department of a metal office equipment and desk accessory manufacturer. The six female material handlers are required to manually lift boxes of various sizes and weights from a conveyor and stack them on wooden pallets. There were six compensable back injuries reported between February 1980 and September 1982, with a cost of $131,415.

Boxed products are transported by belt conveyors to the position of the material handler, where they are taken off the line and lowered and/or lifted onto pallets. Due to the wide variety of Sire, shapes, and weights, the boxes handled vary in weight from a pound to large bulky boxes weighing 50 pounds. Full pallets are taken by forklift to a warehouse.

A task evaluation was completed. The product being handled at the time of the evaluation weighed 45 pounds, measured 5′ x 1′ x 2′, and was lowered a maximum of 31 inches or lifted 29 inches; the task was performed once every 1.2 minutes. It was determined that less than 10 percent of the female population could be expected to perform this task without overexertion.

The recommendation was to eliminate the manual handling task through the use of an automatic palletizer. The palletizer would automatically remove the boxed products from the conveyor belt and stack them on the wooden pallets.

Management agreed to this approach and installed automatic palletizers during December 1982. As the manual material handling task has been eliminated, there have been no compensable back injuries reported.

Source: (675}.

Musculoskeletal problems among office workers range from discomfort to pain and medical disability. The back, neck, and shoulders are the most frequent sites of problems. Table 7-2 summarizes the results from several studies of VDT workers. There is general agreement that musculoskeletal problems are associated with poor working positions, repetitive motions, and the length of work time without a break.

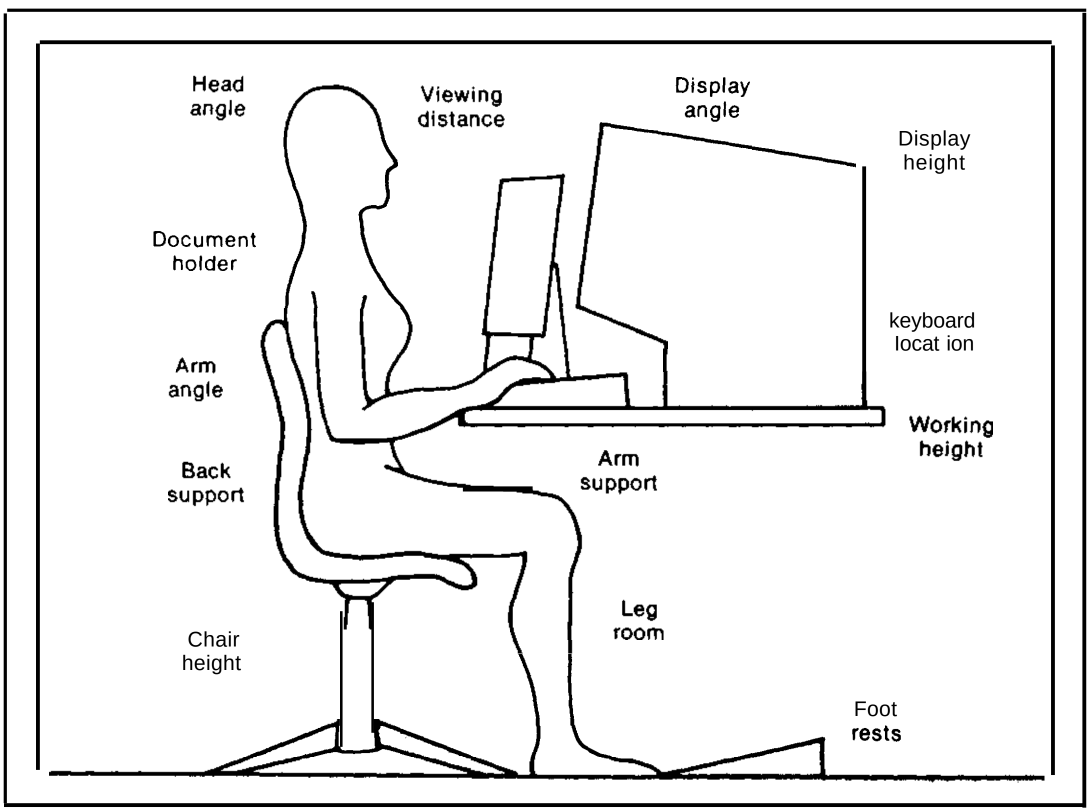
Figure 7-10 illustrates risk factors contributing to musculoskeletal problems associated with VDTs, including equipment design (VDTs, work stations, and chairs) and job design (constrained working positions, repetitive work, and inadequate rest breaks). Any of these can be changed. The keyboards and screens of many early VDT work stations were fixed relative to each other and the height of the work station was not adjustable.

Table 7-2.—Frequency of Reported Musculoskeletal Problems From Various Studies of VDT Workers

	Percent reporting frequent or daily problems[a]		
Study/type of worker	Neck-shoulder	Back	Arm-hand
Arndt, 1980:			
Telephone operator[b]	8-17	15	12
Service assistant	9-14	14	6
Accounting clerk[b]	7-1o	10	5
Laubli, et al., 1980:			
Data-entry VDT operator	11-15	N.A.	6-15
Accounting machine operator	3-4	N.A.	8
Conversational VDT operator	4-5	N.A.	7-11
Typist	5	N.A.	4-5
Traditional office worker	1	N.A.	1
Hunting, et al., 1981:			
VDT operator	6-12	6-10	6-12
Typist	6-12	6-10	6-10
Traditional office worker	2-5	2-5	2-5
Canadian Labour Congress, 1982:			
VDT operator	10-12	10-15	2-3
Non-VDT operator	7-8	9-14	4
Sauter, et al., 1983:			
VDT operator	24-34	27-35	3-4
Non-VDT operator	19-28	22-29	4-6

[a]Results include percent reporting almost daily, frequent, often constant Ranges represent multiple Questions
[b]Approximately 33 percent use VDT
N A = Not available
SOURCE (25)

Figure 7-10.— Potential Ergonomic Risk Factors Associated with VDT Design



SOURCE (25)

Equipment can be redesigned and made to fit the various sizes of people. Many manufacturers now offer, usually at a higher price, office furniture and equipment that has been "ergonomically designed. " Although this equipment has been advertised as being vastly superior to ordinary office equipment, its biggest advantage from an ergonomic perspective is the simplest—it is adjustable. Job redesign to reduce repetitiveness and to alleviate constrained postures is also possible. Finally, rest breaks can be instituted to reduce fatigue from working in one position for long periods of time. Rest breaks often result in increased productivity as well as fewer musculoskeletal complaints (25).

Visual problems reported among VDT users include eyestrain, burning/itching eyes, blurred vision, double vision, color fringes, and deterioration of acuity (table 7-3). A recent review by a National Research Council panel (321) concluded, however, that there was no evidence that the use of VDTs led to visual system problems different from symptoms reported by workers engaged in other tasks involving intensive close work.

The problems reported are related to the visual demands of VDT work. The intensity and duration of visual demands, the quality of the VDT image, and illumination are important. VDTs have often been manufactured and introduced in workplaces without sufficient attention to the these factors. The National Research Council (321) report notes that "[i]n many instances . . . VDTs have been designed without attention to existing scientific data on image quality, and many VDTs on the market do not provide the legibility of high-quality printed material." Snyder (454) has estimated that nearly half of all VDTs now in use are improperly designed for intensive office use.

VDTs have usually been placed into workplaces without consideration of the available lighting. There has been a tendency to believe that more light creates a better environment for office workers. The result is that many offices are overlit or too bright for certain activities. This is a particular problem in offices with VDTs, Increasing the light level, up to a point, improves contrast and visibility for most office tasks. VDTs, however, emit their own light and increasing illumination

Table 7-3.--Frequency of Reported Visual Problems From Various Studies of VDT Workers

Study/type of worker	Percent reporting frequent problems[a]: Eyestrain	Burning, itching, irritation	Blurring, double vision
Holler, et al., 1975:			
VDT user	21	N.A.	7
Arndt, 1980:			
Telephone operator[b]	8	N.A.	1-5
Service assistant	9	N.A.	1-4
Accounting clerk[b]	6	N.A.	1-3
Laubli, et al., 1980:			
Data-entry VDT operator	20	N.A.	N.A.
Conversational VDT operator	28	N.A.	N.A.
Typist	18	N.A.	N.A.
Traditional office worker	5	N.A.	N.A.
Canadian Labour Congress, 1982:			
VDT operator	N.A.	9-17	13-16
Non-VDT operator	N.A.	7-8	8-9
Sauter, et al., 1982:			
VDT newspaper editor	40	43-46	N.A.
Non-VDT newspaper editor	17	17-22	N.A.
Sauter, et al., 1983:			
VDT operator	24	19-27	5
Non-VDT operator	20	21-23	5

[a]Frequency of problems reported daily, constantly, often, very often, frequently.
[b]Approximately 33 percent used VDTs.

N.A. = Not available.

SOURCE: (25).

levels actually reduces the contrast and visibility of the screen image.

It is frequently suggested that the general lighting level in a room be somewhat reduced for screen-based work. An alternative recommendation is to provide even lower levels, with supplementary task lighting for reading text from paper and for other non-VDT work. Other illumination problems that must be addressed concern reflections off the VDT screen, glare, and contrast. There are techniques for reducing and eliminating most of these problems and for enhancing the ability of each worker to adjust the environment of the VDT to fit his or her needs. Unfortunately, these techniques have very often been ignored by manufacturers, vendors, and employers (25).

SUMMARY

Ergonomics —techniques for examining worker-machine interactions and design of machines to fit workers better—can be important in reducing injuries and discomfort from repetitive motions and other work activities. Information ergonomics involves workers' receipt of sensory information and how it is processed; physical ergonomics deals with worker body size, strength, and stresses while working. Generally, when faced with a problem in the workplace, ergonomists systematically analyze the job using biomechanical, physiological, psychophysical, and epidemiological analyses; each job element is compared with factors known to be associated with overt or repetitive trauma injuries. Changing work practices, tools, and machine design and redesigning plant layout are among the principal ergonomic solutions. There are many examples of the incidence of carpal tunnel syndrome and back disorders, two common repetitive trauma injuries among industrial and office workers, being reduced through the use of ergonomic designs. In addition to preventing overt and cumulative trauma injuries, ergonomic design has been shown to increase worker productivity and efficiency by making the machine or tool more closely fit the worker and the worker's capabilities.

8.
Personal Protective Equipment

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Personal Protective Equipment

Based on an analysis of the literature about personal protective equipment, OTA concludes that the effectiveness of many of these devices, especially under conditions of use in the workplace, has not been demonstrated. Instead, many devices have been tested only in laboratory situations that do not duplicate and may not even approximate workplace conditions. The overall impression is that test results tend to exaggerate the effectiveness of personal protective devices. Additionally, the few in-workplace evaluations reveal that continual maintenance and supervision, which are seldom provided, are necessary for acceptable performance.

This discussion is divided into three parts. Greater emphasis is placed on respirators and hearing protectors than on all other personal protective devices. Respirators and hearing protection devices are primarily intended to protect workers' health, while most other personal protective devices are important for safety. Furthermore, both respirators and hearing protectors are frequently mentioned in arguments about the costs of workplace health. They have been and continue to be suggested as less expensive and equally effective alternatives to engineering controls for health risks. Knowledge of the effectiveness of these devices is thus important for making comparisons of the costs and benefits of personal protective equipment versus engineering controls.

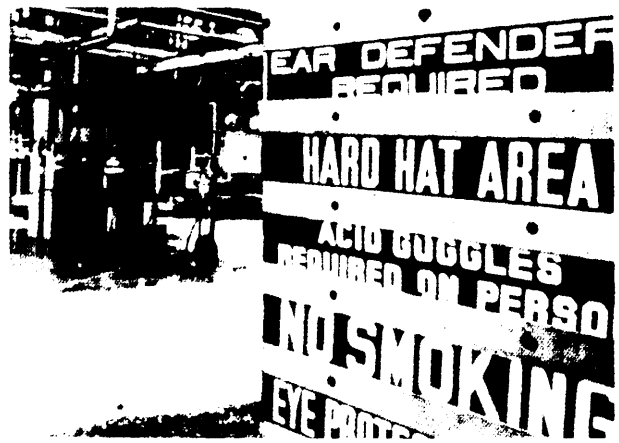


Photo *credit E.I. du Pont de Nemours & Co.*

Signs are frequently **used to indicate when the use of protective equipment is mandatory**

RESPIRATORS

Dust masks, gas masks, and devices that supply clean air to workers through hoses or from tanks are all called respirators. The most common are "dust masks" that employ fiber filters to prevent particles from being inhaled (see fig. 8-l). The second general class of respirators are "gas masks, " familiar to most veterans of the armed forces. They purify air contaminated with fumes and vapors by passing it through a chemical "sorbent. " Less common are air-supply devices. Figure 8-1 illustrates **a** variety of respirators. The disposable face mask "dust mask" and the "reusable air-purifying respirator" are negative-pressure respirators and rely on the wearer's breathing to pull "outside" air **across** the filter or sorbent. The other respirators shown in the figure, all air-supply devices, are positive-pressure respirators, which supply clean air to the wearer from a tank, from a hose that originates in an **area of clean air, or from a hose that supplies air that has been purified by passage through a filter or sorbent.**

Federal involvement in testing and certifying respirators originated in congressional and public concern about coal mine safety. Beginning in the Civil War period, **a** number of bills were introduced and passed by one or the other House of Congress to set up an agency with responsibility over mineral industries. In **1910, a** series of dramatic mine disasters led Congress to establish

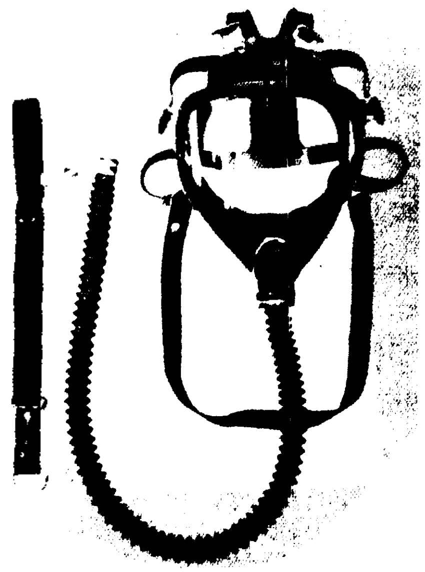
Figure 8-1 .- Respiratory Protection Devices

Abrasive bias.tlng helmet
by 3M

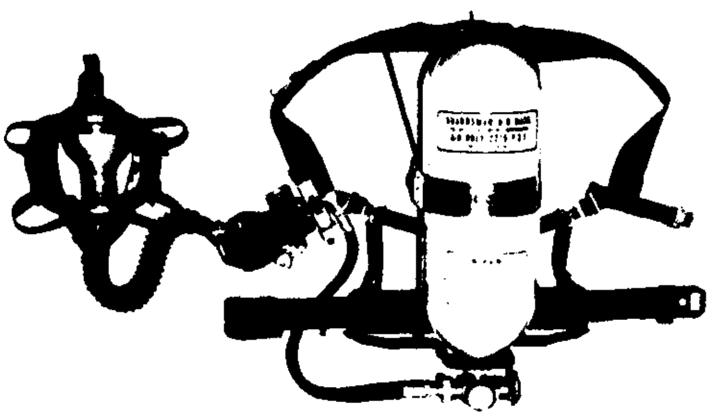
Disposable respirator
by 3M

Reusable air-purifying
respirator by Cesco

Powered **alr** purtfying helmet
by Racal



Airline respirator
by Willson



Self-contained breathing
apparatus by Globe

Photo credit Department of Labor, *Historical Office*

An example of a respirator from earlier in this century

the **Bureau of Mines** in the Department of the Interior. The Bureau was interested in techniques and equipment for use in mine rescue operations, and, because the air in mines following cave-ins and fires was often unfit to breathe, some effort was devoted to development of respiratory protection.

The use of poison gases during World War I spurred on the work of the Bureau of Mines, which cooperated with the military to develop masks for use by American soldiers in France. In 1919, following the war, the Bureau published procedures by which manufacturers could apply for certification of gas masks and breathing apparatus for use in mine rescues *(438)*.

In 1969, Congress brought the Department of Health, Education, and Welfare into respiratory protection certification. The Federal Coal Mine Health and Safety Act of that year included the Department's Bureau of Occupational Safety and Health in a joint certification and testing program with the Bureau of Mines. A year later, the Bureau of Occupational Safety and Health was replaced by the newly created National Institute for Occupational Safety and Health (NIOSH), and responsibility for testing and certifying respirators was assigned jointly to NIOSH and the Bureau of Mines by the Occupational Safety and Health (OSH) Act. (The mine safety function was moved to the Department of Labor in 1977 and *is* now **called the Mine Safety and Health Administration (MSHA).) More importantly, Federal regulations require that industrial users select federally approved** respirators, if they are available.

Under authority of the Federal Mine Safety and Health Act of *1977,* NIOSH established a laboratory to certify respiratory protective devices, Although the Occupational Safety and Health Administration (OSHA) can accept testing results for certification from any laboratory, it has chosen **to accept only NIOSH certifications. Therefore, there is one laboratory responsible for respiratory protection certification (68).**

Qualitative and Quantitative Fit Testing of Respirators

Most tests **of respirator effectiveness are conducted** in laboratories and usually maximize the apparent effectiveness of the devices. For instance, most air-purifying (negative-pressure) respirators depend on the user's inhalation to create a negative pressure inside the mask. In theory, the only source of air to equalize the pressure is air that passes through the air-purifying system (i.e., a filter or sorbent). The practical realization of the theory requires that the seal between the edges of the mask and the wearer's face be sufficiently tight to prevent contaminated air leaking in from the sides.

Many factors may reduce the security of the seal-changes in the tension of the headstraps that secure the mask, daily growth of facial hair or the presence or absence of a beard, perspiration, head movements, and talking. Although laboratory tests attempt to make allowances for such factors, no test duplicates "field situations." Two general methods are available to test whether the respirator is properly worn, and, indeed, if a particular respirator can protect an individual.

The "qualitative fit test" relies on the sensory perception of the worker wearing the mask. A chemical that has a distinctive smell or taste (isoamyl acetate, which smells like bananas, or saccharin) or that is an irritant (stannic chloride or titanium tetrachloride) is introduced into a chamber where someone is wearing a respirator. If the wearer detects the smell or irritation, the fit of the mask is judged to be inadequate. In a program designed to match appropriate respirators to people with different facial shapes, other masks would be tried until one was found that passed the qualitative fit test.

The "quantitative fit test," on the other hand, uses instruments to measure concentrations of the contaminant inside and outside the mask. For instance, the respirator-wearing worker can be subjected to an atmosphere containing dioctyl phthalate (DOP), and instruments can be used to measure concentrations of DOP. This method has two obvious advantages: It does not depend on human sensory perceptions, which may vary between workers and for a single worker depending on a number of factors, and it provides a quantitative measure of how well the respirator works.

The quantitative measure is generally expressed as a "protection factor" or "PF," the ratio of the concentration of the test substance outside and inside the mask. One disadvantage is cost. The testing requires highly trained personnel and the necessary equipment costs up to $10,000, according to a *1978* NIOSH estimate. Another disadvantage is that DOP, as is the case with many phthalates, is a suspect carcinogen. Substitution of another test agent is possible, and aerosols of sodium chloride (table salt) have been used in some tests.

Wilmes *(673,674)* provides a readable and informative discussion of the two types of fit tests. He maintains that quantitative measurements, although providing greater precision, are not worth the additional costs. Instead, the money saved from not doing the quantitative tests would be better spent by increasing efforts directed at instruction of workers and reinforcement of good respirator habits, careful maintenance, and education of workers, supervisors, and managers about the importance of respirators. Additionally, he states that provision of different models of respirators, which costs money, is a better investment because it allows workers to choose respirators on the basis of comfort. A respirator that is not worn provides no protection; having a single model of respirator that, in tests, provides excellent protection but is uncomfortable does not provide good workplace protection.

Wilmes's position is not shared by others. Both NIOSH and the Los Alamos Scientific Laboratory (LASL) endorse quantitative fit procedures. In their opinion, a worker's sense of smell and taste may be insensitive under certain conditions—allowing mistakes to be made. Mistakes may be especially common if the worker tries several masks and his or her senses become jaded to the test substance. A worker who is in a hurry may say that the respirator is "okay" too quickly. Alternatively, as demonstrated by a study discussed later in this chapter, the worker may "smell" the test substance even though it is not detectable by instruments. Finally, only a quantitative fit test provides information about the degree of protection.

Disagreements about the merits of quantitative fit tests have been going on for years, with OSHA, for instance, taking different positions at different times. The lead standard that became final in 1978 required quantitative fit testing. However, revisions made in 1982 allow qualitative testing. If, as is expected, NIOSH formally requires quantitative tests in its revised respirator testing regulations, the argument about certification tests will be settled. Arguments will probably continue about what methods employers should use to fit respirators.

Use of Qualitative and Quantitative Fit Tests in Certification Programs

Currently, under the provisions of 30 CFR Part 11, NIOSH certification of respirators employs the isoamyl acetate (IAA) fit test. A panel of people chosen to represent a cross section of facial sizes and shapes tests each mask. Each subject is first checked to ensure that he or she can smell IAA; in general, people chosen to participate in the tests can detect it at concentrations of 1 to 3 parts per million. A subject enters a chamber in which the concentration of isoamyl acetate is between 100 and 1,000 parts per million and is asked whether the respirator prevented him or her from smelling the chemical. The minimum requirement is

> six persons will each wear the apparatus in the test concentration. . . for 2 minutes and none shall detect the odor or taste of the test vapor (30 CFR 11.85-19).

Evidently, NIOSH is moving away from qualitative tests and toward requiring quantitative fit tests. According to Wilmes (673), NIOSH objected to the 1980 American National Standards Institute (ANSI) consensus standard on respirators that included reliance on the qualitative fit test because the agency concluded that such a test was unable to predict fit. The ANSI Board of Standard Review considered NIOSH's objection and decided that it was without merit, a decision NIOSH appealed to the ANSI Board of Directors. But in 1980 the agency agreed to the consensus standard with the provision that a statement be added to it saying that NIOSH takes the position that only quantitative fit tests should be used.

Comparing Results of Qualitative and Quantitative Fit Tests

A former Chairman of the ANSI Respiratory Practices Standard Subcommittee has reported a comparison of results obtained in the two types of fit tests (386). Four models of NIOSH/MSHA approved respirators were tested by 22 people (19 males and 3 females) using qualitative and quantitative methods.

Importantly, all respirator wearers who did not smell IAA in the qualitative fit test were protected to a PF of at least 10 (as measured by the quantitative fit test in the laboratory). Therefore, according to these study results and assuming that a PF of 10 is sufficient and that a test-measured PF of 10 is reflective of the protection to be expected on the shop floor, an employer can qualitatively test various respirators and select one that will provide adequate protection.

Unfortunately, 16 of the 22 workers, who—according to the quantitative fit test-were protected to a PF of at least 10, reported smelling MA. This suggests that an employer who relies upon qualitative fit tests might also have to provide other respirators for workers who detect with a particular mask IAA even though a quantitative test would show that they would be adequately protected. In other words, although the quantitative fit test costs more, for instruments and operators, its absence may also generate costs because workers' senses lead them to report a poorer fit than has been achieved.

The Los Alamos Scientific Laboratory Tests of Respirators

The Los Alamos Scientific Laboratory studies are the major work on respirator effectiveness, Begun in 1969, they are gererally regarded as thorough and definitive studies. Nevertheless, their importance does not appear to be based on their superiority to other studies. Rather, they appear to be the only studies available for many respirator types.

LASL used the DOP quantitative tests to measure and assign PFs to classes, or categories, of respirators. The standard for assigning a PF to a class was to determine the highest PF obtained by 95 percent of all subjects using each respirator in the category. In practice, that means the "class" PF was determined by the poorest performing respirator in the class. For instance, the testing of "full-facepiece air-purifying respirators" involved six different masks. The one that provided the lowest protection was shown to protect 97 percent of the tested men to a PF of *SO*, so that category was assigned a PF of sO. Other masks in the same class provided better protection; the best provided a PF of at least 2,000 for 97 percent of tested men.

At the end of the first phase of testing, LASL assigned PFs to the classes of respirators it tested and extrapolated PF values for other classes (219). As expected, positive-pressure masks provided higher PFs, from 1,000 to 10,000. Positive pressure tends to blow contaminants away from any leaks or ventings around the mask, minimizing the influence of differences in personal anatomy.

By contrast, negative-pressure respirators tend to suck contaminants into the protective mask through any openings, which makes proper fitting critical. The highest PF assigned to any class of negative-pressure respirator was 50, although some specific respirators in some classes achieved much higher PFs. The PF assigned to a class was judged to be applicable for all respirators of that class that are used in a respirator program that includes routine equipment maintenance and qualitative fit testing.

In a subsequent phase of testing, LASL measured PFs for other classes of respirators and compared them with the extrapolated PFs. In the examples of this work given in table *8-1*, measured PFs were found to be higher for positive-pressure respirators than the earlier extrapolated values, and the measured PFs for a class of negative-pressure masks was lower (196).

Also shown in table 8-1 is an exception to the general trend of extrapolated values for positive-pressure respirators underestimating their effectiveness. NIOSH (580), after a complaint,, earned out field studies of one model of "high-efficiency Powered Air-Purifying Respirator (PAPR)" and found that measured PFs in the workplace were significantly below the PF of 1,000 extrapolated from LASL tests.

Before 1969, when the LASL studies began, no one had conducted laboratory tests of respirators in a systematic fashion. Furthermore, the first field studies of respirator effectiveness were not published until 1973 (see section on field testing later in this chapter) and few have been reported. Two million workers who wear respirators rely on this limited research for assurance of protection.

"Dust Masks"

The progenitor of the most widely used type of respiratory protection was a defective bra cup that fell off an assembly line in 1972. "Someone with a bright idea at 3M Corporation clipped an elastic band to the fiber cup and produced the first disposable dust mask, which, with some modifications, now claims the largest share of the multi-

Table 8-1.—Comparison of Extrapolated and Measured Respirator Protection Factors

Class of respirator[a]	Pressure in mask	Extrapolated protection factor	Measured protection factor
Loose-fitting supplied air hood . .	positive	2,000[b,c]	2 tests <1,000 9 tests 1,000-10,000 36 tests >10,000 47 tests total[d]
Continuous-flow supplied air:			
Half-mask ., ...	positive	1,000	10,000 (combined results,
Full-facepiece ... , ...	positive	2,000	both half- and full-facepiece)[e]
Pressure demand:			
Half-mask	positive	1$300	20,000 (combined results,
Full-facepiece	positive	2,000	both half- and full-facepiece)[e]
Demand:			
Half-mask	negative	10	<5 (93 percent attained PF
Full-facepiece	negative	50	of 5)*
Powered air-purifying respirator (PAPR)	positive	1,000	<15 percent achieved PF of 1,000[f]

[a]The respirators are described in Working Paper #9.
[b]Protection factor (pF) reached by at least 95 percent of subjects wearing any respirator of that class
[c]Hyatt (219).
[d]Douglas, Hesch, and Lowry (152).
'Hack, .et al. (196)
[f]NIOSH (580)

SOURCE Office of Technology Assessment from cited references.

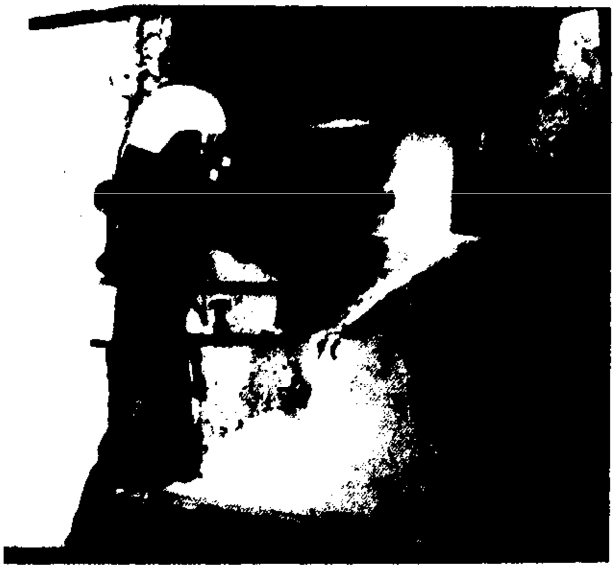


Photo credit: NIOSH

A worker wears a powered air-purifying respirator (PAPR) during a NIOSH field study

million dollar market for industrial respirators. . ." (178a).

Lowry, Hesch, and Revoir (272) tested six masks on a panel of 5 males and 5 females. Quantitative measurements of the leakage of sodium chloide aerosols into the masks showed that only two of the six masks provided a PF of at least 5 for all 10 subjects. These findings suggest that the LASL study (219), which had earlier assigned a PF of 5, overestimated the effectiveness of dust masks.

Interestingly, the dust masks failed to provide a PF of 5 far more often for females than for males. Gillen (181) pointed out that two models that, as tested, provided a PF of at least 5 for men would fail to provide that level of protection for 17 percent of women because of differences in face size. Another model that, as tested, provided a PF of at least 5 for 94 percent of men would fail to provide that level of protection for 56 percent of women. Given the large number of women employed in *some* dusty trades, such as the textile industry, and the increased participation in the labor force by women, the poor level of protection accorded women is especially noteworthy.

There is often little warning that a dust mask has failed to provide protection. In very dusty workplaces, the first indication may be streaks of dust on the worker's face. Short of such drastic failures, tasting or feeling the dusty material on the mouth or nose may alert the worker to the absence of sufficient protection. On the other hand, a person's senses may become acclimated to the dust, rendering the worker unable to detect the mask's failure.

Field Testing of Respirators

Duplicating a worker's movements and activities in a laboratory is difficult. In the course of a day, a worker walks or rides or runs from place to place, reaches and lifts, bends and stretches, gestures and converses, eats and drinks. Each of those actions may affect the fit of a respirator, and some of them require its removal. Even if the respirator, at the start of the workday, provided protection equivalent to that measured in the laboratory, it is unlikely that those conditions would prevail at the end of a shift.

A few reports describe field testing of respirators. The more sophisticated tests involve attaching one sampling device to the worker's clothing and one inside the respirator and measuring concentrations of airborne dusts, fumes, and vapors inside and outside the respirator. Other evaluations depend on collecting "pencil and paper" data about whether government-approved respirators are used in the workplace, whether the mask is the appropriate type for the hazard, whether respirators are worn correctly and at the right times, and whether the equipment is properly maintained.

Protective Factors Realized in Field Studies of Respirators

NIOSH (59) has reported on the use of respirators in the abrasive blasting industry during 1971-73. The results were not encouraging. PFs (which according to current NIOSH usage would be program protective factors; see box F) ranged from less than 2 to 3,750. Lower PFs were associated with poor maintenance, poor training, poor fit-

Box F.—[illegible]

A number of [illegible]

[illegible]

ting of respirators, and inadequate supervision of use. Although in many cases inappropriate respirators were used, low PFs (2 or less) were found in at least some cases with all types of respirators, pointing to problems of fit, maintenance, and use.

Similar findings of poor respiratory protection were also reported in NIOSH-contracted studies of paint-spraying operations (481) and coal mining (200,201,202). The coal mine study measured the effective protection factor (EPF) and the workplace protection factor (WPF).

The EPF was determined by measuring dust concentrations inside and outside the respirator during a complete workshift, whether the respirator was being used or was hanging from the wearer's neck. Twenty tests (11 percent) produced EPFs greater than 10; 54 (29 percent), less than 2.0; and 16(9 percent), less than 1.0. The EPFs of less than 1.0—which mean that the concentration inside the mask was higher than the concentration outside—are thought to have resulted from dust collecting in respirators while hanging around miners' necks. One general conclusion reached from the study was that miners did not wear their masks enough (201).

The WPF was measured during a half-shift timespan after the respirator was donned according to the manufacturer's instruction. As expected, WPFs tended to be higher because of the attention given to fitting the respirators. Two respirators produced mean average WPFs of greater than 11 on all nine of the miners who participated in the study; all five tested respirators produced WPFs greater than 5 on all nine men. Therefore, the observed WPFs show that PFs approaching those measured in the laboratory can be achieved, at least for relatively short periods of time under conditions of close observation and continuous use. However, the EPFs show that those high levels of protection were seldom reached under conditions of normal use.

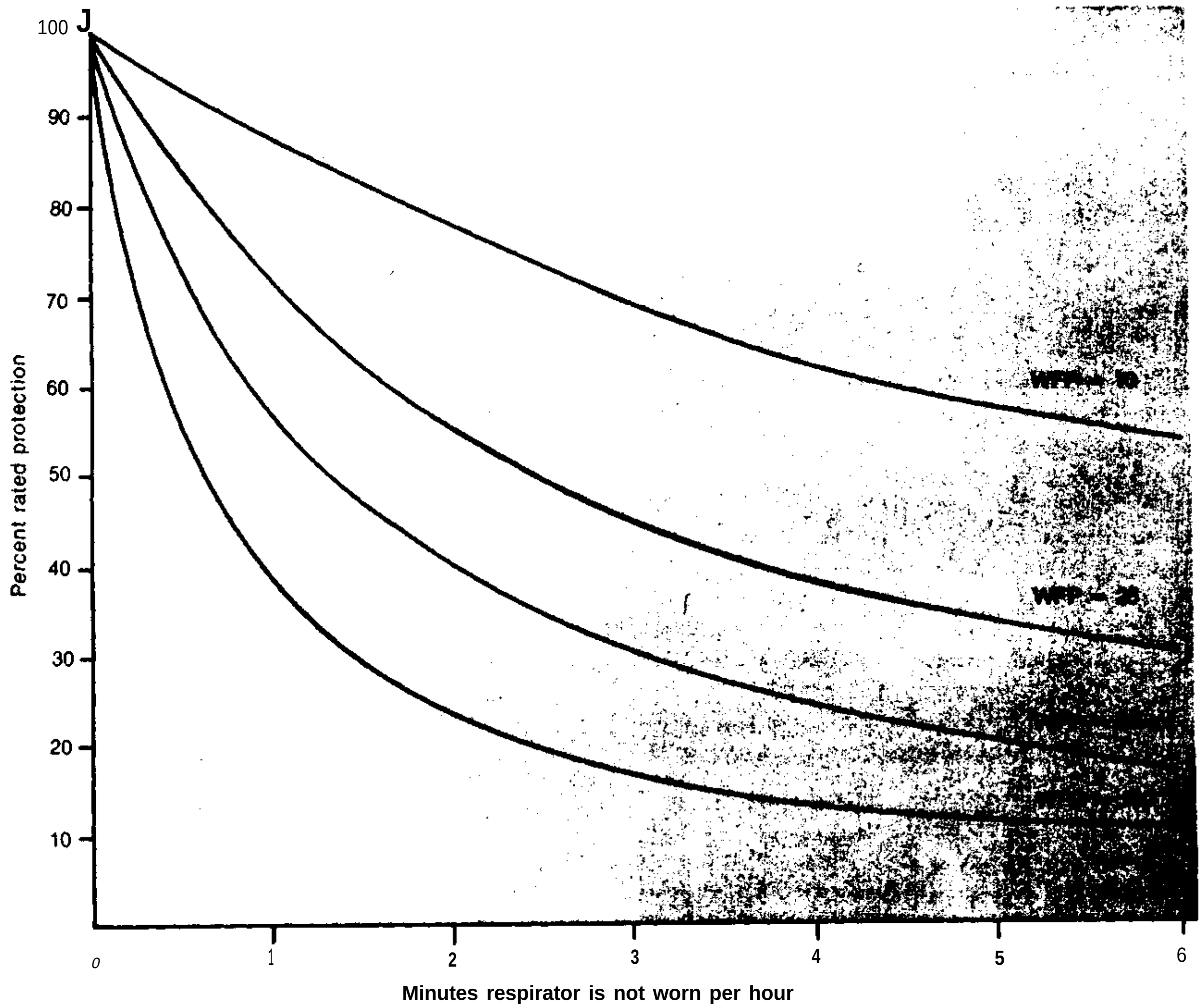
Smith, et al. (450) observed a wide range of EPFs (from 1.12 to 146) in a study of cadmium workers, which resulted partly from workers deciding whether or not to wear respirators in different situations.

The paucity of information on how effective respirators are in the workplace is well illustrated by the observation of these authors that "only one other published study was found on the effective protection provided by intermittent respirator usage."

The major—and, in retrospect, perhaps obvious—conclusions reached from the papers by Hams, et al. (201) and Smith, et al. (450) are that respirators do not afford protection unless they are worn and that the degree to which they afford protection depends on how well they fit and how well they are maintained.

Figure 8-2 illustrates the rapid decrease in EPF as the time the respirator is not worn increases. The uppermost curve shows that not wearing a respirator with a WPF of 10 for 1 minute each hour reduces the EPF to 90 percent of the WPF;

Figure 8-2.—Effect of “Non-wearing” on the Effectiveness of Respiratory Protection



SOURCE Adapted from (403)

for 6 minutes, it drops to less than 70 percent. The EPFs, then, if a respirator with a WPF of 10 is not worn for 1 minute or 6 minutes each hour become 9 and less than 7 respectively. The percentage decrease increases with higher WPFs; a respirator with a WPF of 100 that is not worn for 1 minute per hour provides an EPF of only about 40; if not worn for 6 minutes, the EPF is only about 10 (403).

Before turning from the limited information about effectiveness of respirators in the workplace, the protective factors assigned on the basis of laboratory tests can be compared with the results of field testing. The LASL studies (219) assigned a PF of 10 to half-mask, air-purifying respirators. In the coal miners’ study (201), an overall median EPF of 3.2 was observed; in the cadmium workers’ study (450), a geometric mean of 3.9 was noted, “which compares favorably with the median 3.2 found by Hams, et al.” Overall, then, the protection factors realized by workers in those two studies were about one-third those predicted in the laboratory.

The mean and median (or average) effective protective factors obscure the high and low EPFs obtained by some workers. In the study of coal miners, 11 percent of EPFs exceeded 10; some were as high as 20. In the cadmium workers' study, 22 percent of EPFs exceeded 10. Furthermore, in the latter study, one "fastidious worker," who was exposed to the highest levels of cadmium also achieved the highest EPF. On the other hand, about 9 percent of miners achieved EPFs of less than 1.0 and 29 percent had less than 2.0 (450). Miners who realized EPFs of less than 1.0 were worse off than if they had not worn a mask at all. Those achieving EPFs of less than 2.0 were little better off although they might have thought they were protected from airborne hazards.

Dixon and Nelson (145) and Myers (315) reported EPFs that stand in marked contrast to those reported above. The first authors found WPFs ranging from 40 to greater than 27,000 for workers who had been instructed in the proper use of respirators and who wore masks during the 30 minutes to 2 hours necessary to complete specific tasks. One reason offered for the greater efficiency was the use of a new model of respirator (146). Use of silicon rubber for the facepiece produces a much more comfortable fit with the face, and the mask can be worn for longer periods without causing discomfort that leads to easing the respirator off the face.

By another measure, Dixon and Nelson (145, 146) determined the Program Protection Factor (PPF) for a respirator program directed against lead. In six of seven groups of workers who wore respirators, the PPF was about 36. Technical problems prevented accurate measurement of the PPF in the seventh group, but those workers also achieved significant protection.

Myers (315) measured WPFs in a primary lead smelter and a blast furnace area. The median WPFs were 450 and 130, respectively, with ranges from 110 to 2,200 and from 10 to greater than 1,700. (The respirators that were used in those workplaces had rated protective factors of 10 based on the LASL studies.)

Dixon and Nelson (146) state that higher WPFs were seen in their own work and in Myers' studies because the research was carried out in workplaces with good respirator programs and "adequate fit testing."

Several reports of studies of respirator effectiveness in the workplace are soon to appear or have just been published (674a). The founding in 1982 of a new professional society, the International Society for Respiratory Protection, and its publication of an international journal are expected to increase the availability of information about testing.

Deficiencies in Respirator Programs

Nicas (329) prepared a working paper about respiratory protection programs for the use of unions affected by the cotton dust and lead standards. The paper drew attention to deficiencies in many respirator programs because of poor maintenance and supervision, to the limited testing of respirators in the workplace, and to the costs of maintaining an effective respirator program.

The sometimes high cost of a proper respiratory protection program (111) was suggested as a bargaining chip in labor-management negotiations about whether to install engineering controls or depend on respirator programs. The paper by Nicas (329) is especially interesting because it provides a concise, readable review of the respirator testing literature. As it is available only in a photocopied form, it has a limited distribution, however.

Dixon and Nelson (146) point out the importance of good respirator programs in achieving high protection factors. Rosenthal and Paull (402) examined OSHA inspection records to determine how frequently respirator programs were cited for falling below OSHA standards. From 1977 through 1982, at least one respirator program violation was found in about 10 percent of all OSHA health inspections. "All" health inspections includes those of establishments that have no respirator programs. They (402) estimate that 27 percent of all respirator programs were in violation of all OSHA respirator program standard. This percentage was constant over the 6 years from 1977 to 1982. The importance of respirator programs is underlined by their finding that respirator program deficiencies were found in 40 to 70 percent of inspections in which overexposure was documented.

Adequate respirator programs include providing, maintaining, and insisting on the proper wearing of respirators. Given that more than a quarter of all OSHA-inspected respirator programs are cited for noncompliance, simply providing good respirators in a workplace is not enough. Occupational health professionals insist that careful attention to the respirator program is essential, and they also point out that the costs of such a complete program must be figured into any comparison made between engineering controls and respirators (111).

NIOSH Certification of Respirators

NIOSH tests complete respirator systems consisting of the mask and any air-purifying filters, cartridges, and canisters or air-supply apparatus. The agency certifies the respirator for specified uses (for instance, against a particular chemical) and if the manufacturer subsequently decides that certification of the same respirator against another hazard is needed, the new use must be submitted for NIOSH approval.

As part of this program, NIOSH purchases respirators from suppliers and checks that they meet certification standards. Additionally, a program that was initiated to investigate complaints about inadequate respirator performance has been expanded to include field studies. The latter program has been under way since 1981, and reports from it are now appearing (315 and see below).

In large part, NIOSH's testing specifications (30 CFR Part 11) were developed, published, and revised by the Bureau of Mines from 1920 through 1970. Those somewhat dated specifications adopted by NIOSH in the early 1970s have been criticized by industry (305,393) and Government officials (360,572) because they are believed to restrict innovation in respirator design and to be inappropriate for testing devices that will be used in the workplace (360, 610). To date, however, opponents of the current regulation have been unsuccessful in getting a new version adopted.

Increasing emphasis on workplace health has been accompanied by a greatly increased work load; in 53 years, the Bureau of Mines approved 340 devices, or about 6 each year. In 1981, NIOSH issued 99 new approvals (67). This large number of approvals does not show that innovative respirators have been introduced, for each time an "old" design is cleared for a new use, it receives an additional approval.

In general, the resources of NIOSH are seen as being woefully inadequate to carry out all the desired activities in the area of respiratory protection research and development, testing, and certification *(305,393).*

OTA staff heard many complaints about NIOSH's testing and certification program—primarily that it was slow, bureaucratic, restricted innovation, and depended on outdated criteria for an acceptable respirator. While all those complaints evidently have some basis in fact, NIOSH is far from satisfied with all the companies in the respirator industry. For instance, the first test that NIOSH applies to a respirator when it arrives for testing, "the shake test, " reflects that quality control is not always good. In that test, a NIOSH employee takes the respirator out of the box in which it arrives, shakes it vigorously, and if some piece falls off, the mask is sent back to the manufacturer.

Possible Changes in NIOSH Certification Procedures

NIOSH is considering changes in its respirator testing regulations that would shift responsibility for testing from the NIOSH laboratory to the manufacturers *(344).* This approach follows suggestions by a group of five consultants to NIOSH (73) who concluded that routine testing consumed too many resources and that the current procedures lacked a feedback loop to alert NIOSH to failures in respirators that were already on the market. Evidently, the revisions forwarded to Dr. Donald Millar, the Director of NIOSH, in early summer 1983 would allow self-certification, but he was not satisfied that NIOSH retained enough authority to assure itself of the validity of the manufacturers' tests. The revisions are being redrafted.

These changes would significantly alter the process of testing respirators. NIOSH would no longer receive samples of respirators and evaluate them in its own laboratory. Instead, manufacturers would test respirators against standards to be developed by NIOSH, and, when they are satisfied that the devices meet the requirements, they would be allowed to represent the respirator as up to NIOSH standards. NIOSH's role would be essentially twofold: It would write the standards, and it would carry out "spot checks" of respirators on the market.

To play a more active role in self-certification, NIOSH may, as part of the revised 30 CFR Part 11, reserve the right to see any data produced by manufacturers in the self-certification process. In addition, it could require notification by manufacturers of any major modifications in their products.

The reported information (344) did not mention a feedback loop for manufacturers or users to alert NIOSH about failures in respirators. Such a process would seem to be necessary to ensure that NIOSH could alert users to possible difficulties.

Union representatives, while generally supporting changes in the regulations about testing and certification that would make the tests more predictive of workplace performance, favor NIOSH continuing its testing and certification. One area they single out for attention in any revision is changes in the recertification process, by which respirators are removed from commerce and use when NIOSH finds they are deficient (610).

There are many rather vague suggestions that the testing requirements of 30 CFR Part 11 be changed to encourage innovations in respirator design. John Moran, then chairman of the respirator Research Subcommittee and now director of Safety Research at NIOSH, made a specific suggestion *(310):* that a minimum standard be set for approval of all respirators of each class, as is now done, and that higher standards also be indicated. In this way, a manufacturer who produced a respirator that was significantly better than others on the market would be rewarded with a higher degree of certification, which would be useful in marketing.

Third= Party Testing of Respirators

An alternative both to NIOSH testing and certification and to self-certification would be to have the testing done by a third party, such as the Safety Equipment Institute (SEI), which springs from the Industrial Safety Equipment Association (334). SEI would undertake certification only if NIOSH leaves the field of routine respirator testing, for there is no future in being a competitor with Government testing and certification. (A description of SEI testing of other personal protective equipment is provided at the end of this chapter.)

SEI argues that a third-party laboratory would free the Government from routine testing and provide public assurance of higher quality testing than is possible under self-certification. If arrangements were made for a third-party certification program, SEI estimates that it could establish a program within a year by contracting with existing laboratories (672). Other estimates are that 2 to 3 years would be needed to equip and staff an adequate testing laboratory (610).

The idea of a third-party testing and certification program is supported by some manufacturers but not others. Those who support it see an opportunity to have a more timely and responsive program than NIOSH has been able to provide and, at the same time, to increase acceptance over what would be expected from self-certification. Supporters draw an analogy between the suggested function and the Underwriters Laboratory that certifies many electrical devices. Those who oppose third-party certification see it as essentially a self-certification program because safety equipment manufacturers are involved in SEI's direction; although these critics do not fault self-certification, they are uneasy about a third-party testing program that they see as under control of the manufacturers.

HEARING PROTECTORS

Exposure to continuous noise at levels greater than 80 decibels (dB), about the noise level of a garbage disposal at 3 feet or of a diesel truck traveling at *40* miles per hour *so* feet away, may be associated with progressive loss of hearing. Noise above 90 dB is definitely associated with hearing loss. Reduced noise exposures can be accomplished by engineering controls (redesigning, muffling, or enclosing machinery *or* providing workers with soundproof areas), by administrative controls (reducing the time workers spend in noisy areas), and by use of hearing protectors that reduce the level of noise reaching the workers' ears.

OSHA requires employers to reduce workpace noise levels to 90 dB (about the noise level encountered in a newspaper press room) by the use of engineering or administrative controls. When such controls are infeasible or cannot achieve 90 dB, employers must issue and require the use of hearing protectors to reduce the noise exposure to less than 90 dB (*29* CFR 1910.95). In addition, any worker who has lost a certain amount of hearing ability, as defined by OSHA, must wear hearing protectors if exposed to noise greater than *85* dB. The hearing protectors must work well enough to reduce the noise that reaches the workers' ears either to no more than 90 dB or, if some hearing loss has already occurred, to no more than *85* dB.

Hearing Conservation Programs

Programs designed to reduce hearing loss generally have three components: identification of noisy areas; implementation of engineering, administrative, and personal protection controls to reduce exposure to noise; and audiometric testing of workers to check that the controls are protecting hearing. Hearing protectors are an essential part of hearing-conservation programs.

> Economic considerations make it unlikely that noise can be reduced at the source to acceptable levels in the immediate future and isolation of workers in sound-attenuating enclosures or reduction of an individual's exposure time is not always practical (389).

The Du Pont Company has maintained a program to protect workers' hearing since the 1940s (364). A study was undertaken of the hearing acuity among workers in three different situations: quiet, office-like areas; work areas with noise levels in the general range of 85 to 94 dBs; and the noisiest work areas. Each of the men in the study worked in one of the three noise levels for 5 years. The ability of each to hear noise at various frequencies was established at the beginning of the 5-year exposure period and tested again at the end.

Evidently the hearing conservation program was quite successful *over* a period of at least 5 years. Changes in the hearing levels of workers in the three noise levels were essentially the same and did not vary depending on the hearing level observed in the first measurement. The latter point is important because there is the possibility that workers who are already hearing-impaired might be more sensitive to continued noise. Results from the Du Pont study (364) showed that hearing-impaired workers, as well as workers with normal hearing, were protected from further loss of hearing by a program that used hearing protectors in noisy areas.

Despite those results, some reservations must be attached to the conclusions drawn from the study. Hearing loss is known to increase with time of exposure, and studies conducted over periods longer than 5 years are necessary to be certain of the continued success of hearing conservation programs. The importance of longer-term studies is apparent when it is remembered that many people work 40 to 45 years, and their hearing should be conserved throughout that time.

Temporary Threshold Shift

Immediately following exposure to a sufficiently loud noise, the ability of a person to hear quiet noises is reduced. Over time, unless there has been permanent hearing impairment, the ability to hear quiet noises will return. Temporary loss of hearing acuity is called temporary [hearing] threshold shift (TTS).

In hearing conservation programs, hearing tests are administered 14 hours after the last exposure to loud noise so that TTS will not interfere in the person's ability to hear. Richman (387), however, argues that hearing loss involves a lengthening of the period of TTS. He suggests that audiometric testing within 4 or 6 hours after exposure would pick up cases of TTS, and altered TTS readings would alert the responsible authorities that hearing protection was insufficient. (Of course, in order to have a baseline for comparison, the initial hearing tests should be made 14 or more hours after the last noise exposure.)

By changing the time of routine audiometric testing to within 4 to 6 hours after exposure, Richman (387) believes the tests would be more useful for prevention of hearing loss. Testing only at 14 hours after exposure, he feels, leaves the tests unable to predict permanent hearing loss before it can be prevented.

Methods of Audiometric Testing

Riko and Alberti (389) briefly describe the three classes of audiometric testing, which differ in the amount of reliance they place on the human sense of hearing as opposed to the ability of instruments to detect noise.

Real-Ear Attenuation at Threshold.—This method depends on a person's report of being able to hear sounds. It resembles the classic "hearing test" of a nurse or doctor whispering across the room and asking the patient if the whisper can be heard. In the workplace and in clinics, the real-ear attenuation at threshold (REAL) test involves placing someone in an acoustically quiet room and using earphones to generate defined levels of noise at various frequencies. The worker then puts on hearing protection, and the machine generates noises at the same frequencies. The difference in the intensity of noise that is heard with and without the protectors is a measure of the protection afforded.

The REAL test is used more commonly than the other two tests ("semiobjective" and "objective") described here. The audiometric tests used in hearing conservation programs are similar; the lowest intensity of sound that a worker can hear is determined and recorded at the time of first employment. Subsequently—at the time of an annual physical examination, perhaps—another REAL test is administered.

Semiobjective. —This method eliminates the complete dependence of the REAL method on a person's hearing, which is, to some extent, subjective. In the semiobjective test, a tiny microphone is positioned in the ear and the noise energy is measured with and without a protector in place. The major drawback of this test is that it is virtually impossible to evaluate any protectors that are inserted into the ears.

Objective. —This method also uses microphones to detect noise levels, but it uses "an artificial head or ear" instead of a human subject. Although it is attractive to manufacture of hearing protection devices because it would be convenient for quality control, it has proved to be very difficult to simulate a human head.

Acceptance of Hearing Protectors

OSHA's noise standard and its Hearing Conservation Amendment (625, 640) require employers to provide hearing protection to their employees and ensure that the protectors are worn. Compliance with requirements to wear hearing protectors is undermined by dissatisfaction with the devices. Workers often object to wearing earmuffs in hot, humid conditions, and earplugs are so uncomfortable that some workers reject them. Additionally, earplugs can contribute to infections in dusty, dirty environments, and earmuffs cannot be worn with glasses.

Furthermore, although some hearing protectors are more comfortable than others, they all work by creating a physical barrier to the passage of sound, The seal between the protector and the worker's head or ear is of great importance to the effectiveness of the protector. In general the seal is created by pressure. The pressure creates discomfort and, for some workers, pain.

An interesting study (686) demonstrated that quick feedback about the value of hearing protectors promoted their use. Hearing tests were administered to some members of a metal fabrication department at the beginning and end of their workshifts on 2 days over a l-month period. Exposure to workplace noise reduced aural acuity sufficiently that pre- and post-work hearing tests differed when hearing protection was not worn. The people providing the tests discussed the implications of the results with workers, who congregated around the results that were posted in the department, until everyone understood the meaning of the test results.

According to the authors, workers' appreciation of the value of the protectors resulted in a change in accepted behavior; 5 months after the program began, 85 to 90 percent of the workers in the department wore their hearing protectors. In contrast, only 10 percent of workers in another, equally noisy, department who received a "standard lecture" about hearing conservation protection wore hearing protection. A subsequent attempt to discipline workers in that department who did not wear hearing protectors failed because of both union and management resistance. Union members objected because the disciplinary action (removing workers from the noisy department) reduced the workers' earnings, while management did not like losing the services of experienced workers.

Noise Reduction Ratings

As a result of the Noise Control Act of **1972,** the Environmental Protection Agency (EPA) beginning in 1979 required that all hearing protectors be labeled with a noise reduction rating (NRR). The NRR is a single number that describes the attenuation of noise that can be expected from wearing the protectors. NRRs are used in connection with measured noise levels in the workplace *(640)* to select appropriate hearing protectors.

As discussed in the beginning of this chapter, all models of each class of respirator receive the same protection factor, and only extrapolated PFs are available for some classes of respirators (219,580). In contrast, EPA required that each model of hearing protector be labeled with its own NRR.

Problems With Noise Reduction Ratings

The importance of accurately determining NRRs was recognized by EPA, and that agency conducted a study to determine if NRRs were in agreement by having four models of hearing protectors tested in seven laboratories. The NRRs reported on the labels of the four models tested had all been determined in a single laboratory, which was referred to as laboratory 8 in the study. Although EPA was unable to analyze the results because of budget cutbacks, three employees of two private-sector companies did analyze the study **(50).**

The various laboratories differed quite consistently in measuring NRRs. That is, each laboratory tended to report low, medium, or high NRRs, in comparison with the others, regardless of which device was being tested, The authors felt "this fact suggests the likelihood of a systematic bias in the testing procedure. " The paper explores the influence of proper or improper fitting of the hearing protector, subject selection and training, and data reduction techniques in producing the variability among the laboratory measurements.

Perhaps the most striking finding was that

> The labeled NRRs for all four devices were based upon data from Laboratory 8, and even though in some cases they were derated by the manufacturers, all devices would have failed an EPA compliance audit test conducted at any one of the other seven facilities. This would have required relabeling. Since there now will be no enforcement of the labeling regulation [because of EPA budget cutbacks], it is likely that manufacturer's data will continue to reflect the highest measurable values found today.

OSHA Use of Noise Reduction Ratings

One of the authors of the paper that compared NRRs measured in different laboratories presented similar evidence to **OSHA during a hearing on the Hearing Conservation Amendment (48).** In addition, he said that the laboratory that reported the highest NRRs was responsible for "85 percent of manufacturers' reported NRRs. " He also expressed the opinion of his company (E.A.R. Division of the Cabot Corp.) that the NRRs should be "de-rated" for two reasons: the generally high NRRs determined by laboratory 8, and the substantial difference between results of laboratory and field testing of hearing protectors.

OSHA mentions this testimony in its latest preamble to the Hearing Conservation Amendment (640), **and says that it will consider** it in any modification of the noise standard. In a *1983* directive, OSHA has instructed its inspectors not to cite exposures between 90 and 100 dB as violations of the hearing conservation standard provided that the employees are wearing adequate hearing protection. "Adequate" was described as the NRR de-rated by 50 percent.

The situation regarding noise reduction ratings needs correction, but there appears to be little chance of that happening. A published report has presented evidence that the NRRs that appear on package labels are higher than the NRRs determined in seven of the eight laboratories equipped to carry out the appropriate tests (so). A company that manufactures hearing protectors has written OSHA that the effectiveness of its product is overstated and that the protection offered by the protectors in the field is lower than that obtained in the laboratory. The Agency (EPA) responsible for ensuring that NRRs are assigned to hearing protectors and that they are accurate has discontinued its NRR program because of budget cutbacks and evidently will not change existing NRRs. OSHA has instructed inspectors that the NRRs are in error, but OSHA's instructions to employers about selecting appropriate hearing protection (640) continue to rely on NRRs that are almost certainly too high.

Field Testing of Hearing Protectors

Poor agreement between laboratory and field tests was demonstrated by a NIOSH test of 420 workers at 15 industrial plants (267). Fifty percent of the workers achieved considerably less than half the potential protection demonstrated in the laboratory (table 8-2). Also shown in the table is the level of protection achieved by the 10 percent of workers who received the least protection. At least 10 percent of the users of preformed types of hearing protectors received no protection; at least 10 percent of the users of the other types of "earplug" hearing protectors received only 3 dB protection.

These results are consistent with the findings of Riko and Alberti (389), who measured the attenuation of noise achieved by 400 workers using their own protective devices. Although they do not present numerical results, they state

> . . . for both muffs and plugs, the average attenuation was less than that expected from manufacturer specifications and was considerably less than their theoretical potential. Mean attenuation was not as revealing, however, as the scatter of attenuation scores, which was wide. For given frequencies, values ranging from O to 50 dB between individuals were obtained. The use of standard deviation measurement was avoided deliberately because the distribution of attenuation was not sufficiently uniform and was skewed in the direction of poorer attenuation values.

Riko and Alberti's comments about the scatter of attenuation are often repeated in discussing hearing protection. Although some workers obtain satisfactory protection, others obtain none or hardly any. In some cases, the hearing protection simply doesn't fit or doesn't work. The solution generally suggested for that problem is to offer the worker a variety of protectors so that comfortable ones can be selected; the worker's selection should be checked by an audiometric test to be certain that it provides hearing protection. Another solution is to reduce noise exposures through engineering controls.

Table 8-2.—Comparison of Noise Reduction Achieved by Insert-Type Hearing Protector In the Laboratory and in Field Use

Type of protector	Median noise reduction ratings[a] laboratory	field	Protection obtained by lowest 10°/0 in field[b]
All earplugs.	28	13	—
Preformed types.	29	7	0
Acoustic Wool	26	10	3
Custom-molded[c].	20	14	3
Acoustic foam	36	20	3

[a]Measurements in dB.
[b]Average noise reduction achieved by the 10 percent of workers who obtained the poorest noise protection.
[c]In one plant, the custom-molded earplugs wera fabricated by the plant nurse; In the other plant, thay were fabricated by the manufacturer.

SOURCE: (267).

OTHER TYPES OF PERSONAL PROTECTIVE EQUIPMENT

NIOSH tests and certifies respirators, but no other personal protective equipment. Formerly, NIOSH also tested and certified several types of measuring equipment, such as gas detector tubes, coal-mine-dust personal sampler units, and industrial sound-level meters, but these programs were discontinued in 1983.

According to NIOSH, some equipment is advertised as meeting "Federal" or "OSHA" standards. In fact, there are no general Federal or OSHA standards for personal protective equipment. In some regulations OSHA requires that safety equipment be worn and stipulates that the equipment meet certain requirements, generally ANSI standards. NIOSH concluded that the "Federal" or "OSHA" standard statements arise from those requirements.

Personal protective equipment other than respirators is "self-certified" by the manufacturers, who may test it to determine if it meets ANSI standards. Equipment that conforms to the standard can be so advertised. Since few purchasers have the facilities, professional staff, and other resources to test safety equipment, knowing that a device meets ANSI standards should provide assurance to the purchaser and user that the equipment will provide a specified level of protection.

NIOSH Tests

In the mid-1970s NIOSH purchased samples of personal protective equipment that was advertised and sold as meeting ANSI standards. NIOSH tested the samples to determine if they did, in fact, meet the appropriate standard.

In several cases NIOSH noted some ambiguity in the ANSI standards. Because of the possibility of various interpretations of some standards, NIOSH called together representatives of manufacturers, labor unions, and Federal agencies to discuss the test procedures to be used in evaluating the particular classes of equipment. In all cases, NIOSH tested equipment against the ANSI standard, sometimes including modifications made after the meeting; the agency did not draw up its own requirements.

The principal finding from the NIOSH tests was that many items of personal protective equipment did not function as expected, given the ANSI specifications (see table 8-3 for a summary of the data in this section).

Head Protection

Hard Hats.—Protective headwear, all of which is designed to protect against impacts, is classified as A, B, or C depending on its resistance to transmitting electricity. Class A requires limited electrical protection, Class B requires higher electrical protection, and Class C requires no electrical protection. (Reviewers of drafts of this report remarked on the classification that placed the most protective units in the middle of an A-B-C classification scheme.)

NIOSH tested Class B industrial helmets "because they, as a class, offer the most comprehensive head protection available to the industrial worker." The tests revealed a distressingly high failure rate. Only 4 of the 21 tested models passed all the ANSI performance tests. Only 7 passed the impact resistance test; 16, the electrical resistance test. Hats that failed the impact test were found to transmit too much force, and those that failed the electrical test did not insulate as well as claimed.

Photo credit OSHA, Office of Information and Consumer Affairs

Many employees are now required to wear hardhats during the workday

Table 8-3.--NIOSH Testing of Various Types of Personal Protection Equipment

Equipment type (reference)	Number of models tested	Number (percent) meeting ANSI performance standards
Head protection:		
Class B industrial helmets ("hard hats" with highest electrical resistance) (Cook and Groce (1 16))	21 ("randomly selected")	4 (19°/0) met all performance standards 7 (33%) passed impact resistance test 16 (76%) electrical resistance test 20 (95%) passed crown clearance test all passed penetration resistance test
Miners' safety caps (Cook and Love (120))	16 (all available models)	13 (81 °/0) met all performance standards 14 (88°/0) passed electrical resistance test 15 (94°/0) passed impact resistance test
Firefighters' helmets (Cook (117))	8 (6 advertised as meeting ANSI standard)	for the 6 advertised as meeting ANSI standard, 4 met all performance standards and passed penetration resistance, electrical resistance, and self-extinguishing tests
Eye protection:		
Glass piano safety spectacles (Campbell and Collins (92))	22 (1 model from each manufacturer)	21 (95°/0) passed Impact resistance test (only 1 of 24 samples fractured of the model that failed) 21 (95°/0) passed frame impact test 18 (82°/0) passed flammability tests (failures were by small margin, judged not to be major) all passed optical quality tests
Plastic piano safety spectacles (Collins and Wolfe (113))	17 (1 model from each manufacturer)	all passed impact resistance test (16 of 17 passed test at 5 times impact energy required by ANSI) all passed frame and lens penetration resistance tests 7 (41 ?/0) passed flammability tests (failures judged to present little danger in workplace) all passed optical quality tests
Flexible fitting safety goggles (Campbell and Collins (92))	50 (all available clear-lens models)	all passed impact resistance tests all passed penetration resistance tests 48 (96%) passed "design test" that estimated risk from particles entering inside goggles through ventilation opening 32 (64°/0) passed flammability test 33 (66%) did not meet ANSI optical standards
Eyecup goggles (Campbell, Collins, and Wolfe (93))	24 (1 model from each manufacturer)	13 (54%) passed impact resistance test 16 (67°/0) passed frame impact test all passed flammability test all passed optical transmittance test
Welding filter plates (Campbell (91))	94 (all available shade models)	19 (20%) met all performance standards more than 90% passed ultraviolet, infrared, and impact tests (when appropriate) 76 (80°/0) passed visible-light transmittance tests
Face protection:		
Industrial face shieids (Campbell (90))	37 ("representative sample")	36 (97°/0) passed impact resistance test 36 (97°/0) passed penetration resistance test ail passed flammability test
Hand protection:		
Linemen's rubber insulating gloves (Cook and Fletcher (119))	12 (randomly selected and representative of 155 available models)	11 (92%) passed electrical resistance test (model that failed electrical test was withdrawn from market by manufacturer) 10 (84%) passed tensile strength

Table 8-3.—NIOSH Testing of Various Types of Personal Protection Equipment—Continued

Equipment type (reference)	Number of models tested	Number (percent) meeting ANSI performance standards
Foot protection		
Men's safety-toe footwear (Cook (118))	76 (random samples of types in general use (71), plus styles not represented in general samples (5))	ANSI analysis:[a] 49 (55°/0) passed impact resistance tests 60 (79°/0) passed compression tests 43 (37°/0) passed overall tests Statistical analysis: 28 (37°/0) passed impact resistance tests 50 (60°/0) passed compression tests 36-50 (48°/0-600/0) passed overall tests

[a]95% confidence level that 9 out of 10 shoes would pass ANSI test (see text)

SOURCE Office of Technology Assessment from cited references

The impact resistance test is conducted for vertical impacts only. A member of the advisory panel to this OTA assessment reports that NIOSH also conducted nonvertical impact tests—with disastrous results. Those results were not reported by NIOSH.

Miners' Helmets.—Miners are *required* to wear helmets in underground mines and in surface mines where falling objects may create hazards. NIOSH characterized 15 of the 16 models of miners' helmets as industrial helmets to which a lamp and a cord bracket for mounting it have been added. Miners' helmets, like "hard hats, " can be Class A, B, or C, depending upon their resistance to electricity.

The miners' safety caps had better test results than the Class B hard hats: 15 of 16 models passed the impact resistance test; 14, the electrical resistance test. Manufacturers had drilled holes for use in attaching lamps to the 2 models that failed the electrical tests; electrical shorts across the holes caused those models to fail. Overall, 13 models met all the ANSI performance standards.

Oddly, of the five companies making both miners' helmets and Class B hard hats, four produced a miners' helmet that passed the the impact resistance test and at least one model of Class B hard hat that failed it. By contrast, the producer of the miners' helmet that failed the impact resistance test made a Class B hard hat that passed.

Firefighters' Helmets. -Firefighters' helmets differ in shape from hard hats and miners' helmets, and they have a broad brim to carry water away from the wearer's face and neck. In addition to

Photo credit: E. /. du Pont de Nemours & Co.

These firefighters are using protective clothing, firefighters' helmets, and self-contained breathing apparatus

providing protection against impacts and electricity, firefighters' helmets must also be self-extinguishing. NIOSH used two different methods to measure the transmission of impact forces in testing firefighters' helmets. An analysis showed that the method they favored produced more consistent results; using that test, four of the six models advertised as meeting the ANSI standard passed the impact resistance test. All six models passed the tests for electrical resistance and penetration resistance, and all were self-extinguishing. NIOSH concluded that the two helmets advertised as meeting ANSI standards that failed the impact resistance test suffered from poor quality control in the manufacture of the suspension systems.

The agency suggested that the tests for these devices would more accurately reflect firefighters' needs if an impact resistance test at 300° Centigrade (572 °Fahrenheit) were added to the ANSI standards. The severity of such a test reflects the conditions that firefighters and their equipment face.

Comments on Head Protection.—The tests showed significant performance variations from ANSI standards. The highest failure rates were found in Class B hard hats, which are used in the greatest numbers and manufactured by the largest number of firms. The miners' helmets, as a class, performed very well. The single failure in the impact resistance test was associated with quality control during manufacture, and the electrical test failures were related to holes being drilled in the helmets.

Overall, the performance of protective headwear in tests completed in 1976 and 1977 does not produce confidence that the devices work as claimed. Furthermore, NIOSH drew attention to the absence of tests of impact resistance for the front, sides, and rear of helmets, highlighting what appears to be a deficiency in the tests. In the report on miners' helmets, NIOSH noted that the present ANSI standards do not consider the effects of projections into the interior of some helmet models, which would tend to concentrate the force of any impact from the front, sides, or rear. After recommending that models with protrusions be avoided, NIOSH suggests a crude test to identify them:

> With the helmet in place, a cautious series of blows to the perimeter of the helmet is sufficient to identify models with these protrusions.

The report on Class B helmets acknowledged that "It should be recognized that many lives have been saved through use of industrial helmets and such devices are a valuable adjunct to the overall protection of workers. " However, apparently in recognition of the deficiencies found in those helmets, the agency added, "NIOSH intends to promulgate regulations in the immediate future to establish the legal basis for a testing and certification program for industrial helmets. " That was 8 years ago.

Protective Eyewear

Protective eyewear (fig. 8-3) is the most commonly used personal equipment. In the workplace, this equipment provides protection against particles, sparks, and chemicals that might hit the eye and/or protection against harmful ultraviolet, infrared, and too-intense visible light. ANSI specifies that protective eyewear must not affect visual acuity to the point where a worker's performance is impaired and certainly not to the point where the worker's safety is affected by reduced field or clarity of vision.

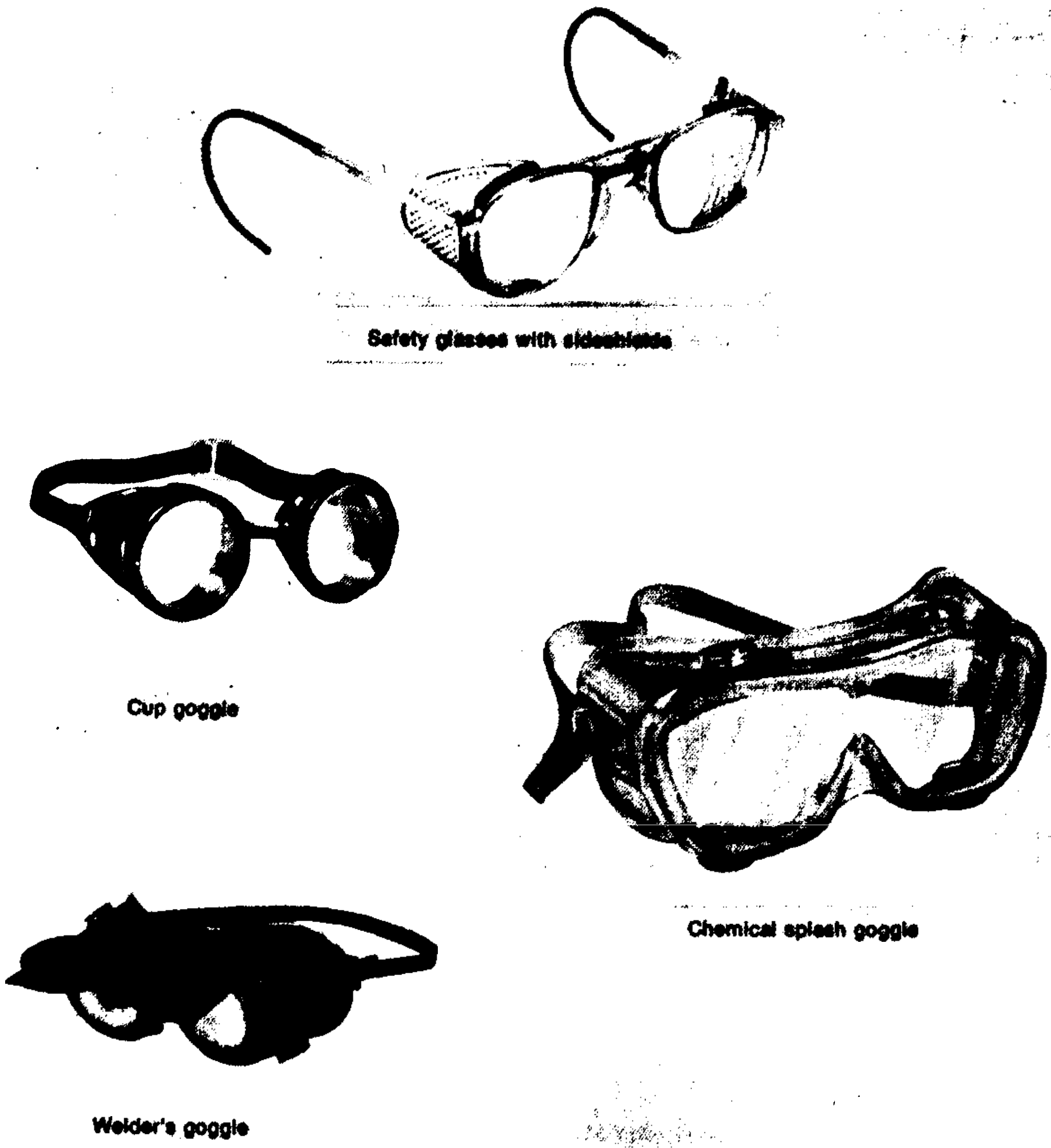
An obvious concern in safety eyewear is that the eyewear itself can present a hazard if it fails. A particle splintering the lens of spectacles may be the cause of an accident, but the injury may stem from fragments of the lens entering the eye. Since 1972, all spectacles sold in the United States must have impact-resistant lenses, but the level of impact resistance in "street-wear" spectacles is far below that required of safety eyewear used in the workplace. To facilitate making a distinction between lenses intended for street wear and those for industrial use, all the latter spectacles are marked with the manufacturer's name.

Piano Safety Spectacles.—Glass (or plastic) piano safety spectacles ("piano" means flat, noncorrective lens) are the "safety glasses" with which most people are familiar. They are intended to be a barrier between the eye and foreign objects and not to interfere with the wearer's vision.

NIOSH tested 22 models of glass safety spectacles, one from each manufacturer. All but one model passed the impact resistance test prescribed by ANSI. Twenty-four samples of each model were tested, and even in the model that failed only one lens of the 24 fractured. All the models passed the frame impact test, which requires the lens to remain in the frame after impacts on the side or top.

The spectacles were also tested for resistance to higher energy impacts, although the results of this test did not affect NIOSH'S decision on whether a lens passed or failed the basic impact test.

Figure 8.3.—Protective Eyewear



SOURCE: U.S Safety Service

NIOSH found that many lenses provided impact resistance in excess of the ANSI requirements. For 5 models, none of the tested samples fractured at impacts 2.5 times greater than the ANSI standard, and 467 of the 528 sample lenses exposed to that much impact survived.

All models passed the optical quality tests, and NIOSH considered overall optical quality to be above the ANSI requirements.

Sideshields, constructed of wire mesh or plastic, that cover the opening between the outside edge of the glasses and the wearer's face are necessary to prevent particles from reaching the eye from the side. NIOSH found that four models with plastic sideshields did not pass the ANSI flammability test, but they considered these failures to be of minor importance because they were barely outside the acceptable range.

The *plastic* piano safety spectacles tested also met ANSI standards. All 17 models, one from each manufacturer, passed the lens and frame impact tests. Sixteen of the 17 passed a lens impact test at 2.5 times the energy level specified by ANSI, and NIOSH reported that the manufacturer of the one other model planned to change its lenses to the more energy-resistant plastic. Overall, plastic lenses provided more impact resistance than glass ones.

The optical quality of plastic lenses was sufficient to pass the ANSI standard, but below that of glass lenses. An important tradeoff in selection of safety spectacles is that glass lenses are more resistant to abrasion, and they are generally chosen for use in situations where abrasion is a problem.

Ten models of plastic safety spectacles did not pass the flammability test because of sideshields burning at rates greater than allowed by ANSI. As with the glass models, however, the bum rate was so close to the ANSI limit that NIOSH did not consider these failures to be serious.

One difference between the ANSI tests for glass and plastic spectacles is that glass lenses are not tested for resistance to penetration. All plastic lenses passed the lens penetration test specified by ANSI. NIOSH commented that they would expect many glass lenses to fail that test, and that they are unaware of why it is not required of glass lenses.

Flexible Fitting Safety Goggles.—All the NIOSH-tested flexible fitting safety goggles passed the impact and penetration tests. Two of the 50 models suffered from design defects that would allow particles to enter the eye area from the side, and, as was found with the safety spectacles, the plastic used in some of the goggle frames burned at a rate slightly greater than allowed by ANSI. The excess burn rate was not considered to be a problem in most workplace situations. The optical quality of the goggles was poorer than that of spectacles.

Eyecup Goggles. —Eyecup goggles performed poorly. Eleven of the 24 models tested failed the impact test. All the models that failed used flat lenses, and no models with curved lenses failed. In addition, the frames of eight models failed (all the failures occurred in models that had also failed the lens impact test). NIOSH concluded that "many models of eyecup goggles were found to be seriously defective and are considered to represent a significant hazard to the user"; unfortunately, the defects in eyecup goggles "are not detectable by the user. " Overall, although some eyecup goggles offered good protection, NIOSH pointed out that safety spectacles and flexible fitting goggles provided better impact protection.

Welding Filter Plates. —The primary purpose of welding filter plates is to protect the welder's eyes from intense ultraviolet, visible, and infrared radiation. Different shades of plates are available, depending on the type of welding and the radiation encountered on the job. NIOSH tested a total of 94 different shade-models; only 20 percent met all ANSI performance standards.

Comments on Protective Eyewear. -Testing of protective eyewear showed that spectacles and flexible fitting goggles performed well. Eyecup goggles did not, as a class, provide the level of protection specified by ANSI. Few welding plates met all ANSI standards.

It is impossible to tell from the results reported by NIOSH whether the failures were due to design defects or poor quality control. An exception to that generalization is the two models of flexible fitting goggles with design defects that allowed particles to strike the eye from the side.

Face Protection

NIOSH tested faceshields that were attached to hard hats. All but 1 of 37 models (a "representative sample" of those available) passed both the impact and penetration tests. The same model failed both tests. NIOSH concluded that the other shields performed in accordance with ANSI standards, but warned, as do several manufacturers, that shields are not a substitute for eye protection. Particles can pass around or under the shield and cause injury if eye protection is not worn in conjunction with the face protection.

Photo credit OSHA, Office of /n format/on and Consumer Affairs

Faceshields and safety glasses protect these workers from flying particles

Linemen's Rubber Gloves

Only three manufacturers make the 155 models of rubber gloves worn by electrical linemen to provide protection against electrical shock. NIOSH tested 12 models considered to be representative of all those available. Eleven models passed the ANSI specified electrical resistance test. The model that failed was, according to ANSI, withdrawn from the market by the manufacturer.

One of the two models that failed the tensile strength test was advertised as meeting the ANSI standard; the other was not. These two are the only models not made from rubber and are intended for use in areas with very high voltages. NIOSH apparently sees the use of plastic in place of rubber in these gloves as acceptable because they offer superior service qualities in the specific uses for which they are sold.

Men's Safety-Toe Footwear

Safety-toe footwear (more generally called "steel-toed shoes") are subjected to two performance tests. The impact resistance test measures the deformation of the toe of the shoe when it is subjected to a single hit with a falling object. The compression test measures the deformation during the application of a steady squeezing force. Safety-toe shoes are rated by the manufacturers on the basis of the shoes being able to withstand an impact of 30, 50, or 75 foot-pounds and an average compressive force of 1,000, 1,750, or 2,500 pounds. The shoes are rated as Class 30, SO, and 75 respectively. NIOSH tested 76 different models, a random sample of those available.

The ANSI standard is based on a pass/fail test. NIOSH analyzed its results on this basis as well as on another statistical basis. The statistical analysis considered how close each model came to failing the test, and resulted in an estimate of the 95 percent probability that at least 90 percent of all shoes of that model would pass the test.

Using the ANSI standard, 49 of 76 models passed the impact tests; 60, the compression tests; only 43, both tests. The statistical test resulted in 28 of 76 models passing the impact tests; 50, the compression tests; 36-50 the overall tests.

Under both methods of analysis, a significant proportion of the tested shoes did not conform to the ANSI standard. NIOSH concluded that manufacturers overrate the shoes. For instance, a shoe marketed as Class 75 provided only the protection required of a Class 50 shoe. NIOSH also noted, however, that some cases of failure, in which the shoe deformed just past the fail mark, might not be associated with an injury in actual use, and that safety shoes have afforded a substantial degree of protection to workers.

Comments on NIOSH Testing of Personal Protective Equipment

Some types of safety equipment—notably spectacles, flexible goggles, miners' helmets, linemen's rubber gloves, and face protection—were found to conform to the ANSI standard against which they were manufactured. Others—safety-toe shoes, eyecup goggles, industrial safety helmets, firefighters' helmets, and welding filter plates—often did not measure up to the ANSI standards. Furthermore, some deficiencies were found in the ANSI test standards, which do not measure some important properties such as resistance of hard hats to off-center impacts or of glass safety glasses to penetration.

Photo credit: E.I. du Pont de Nemours & Co

Protective clothing is frequently required for exposures to toxic substances

NIOSH has not tested these safety devices since the publication of these reports in the mid-to late-1970s. Furthermore, several items of personal safety equipment, notably clothing and chemical-resistant gloves, were not tested in the NIOSH program. Whether design and quality control now are better, about the same, or worse than when NIOSH performed these tests is not known.

Tests of Gloves Against Chemical Hazards

Manufacturers, in their literature, rate various types of gloves as providing "excellent, good, fair, or poor" protection against workplace chemicals. There seems to be little reason for the general assignments of resistance to chemicals. As is shown on table 8-4, many chemicals penetrate "chemical-resistant" glove materials quite quickly.

Some workplace solvents, for instance halogenated ethanes (dichloroethanes and trichloroethanes) and polychlorinated biphenyls (PCBs), have presented special problems because they penetrate most gloves in minutes or seconds. A relatively new material, Vitron, developed by Du Pont, provides excellent resistance to the halogenated ethanes, however, and better resistance to PCBs than any other tested material. This example illustrates how new developments in technology find application in the protective devices industry. Yet Vitron gloves may not be used widely because of the high cost—10 times as much as any other glove.

Involvement of Personal Protective Equipment in Injuries

There are no field tests of personal protective equipment used for preventing injuries. It is probably impossible to design such tests, and only

Table 8-4.—Comparison of Various Protective Garment Materials' Capacity to Resist Penetration by Chlorinated Ethanes and PCB

	Number of minutes required for solvent to penetrate **1/1,000 inch of the protective material**			
Protective material	1,2-di-chloroethane	1,1,1-tri. chloroethane	1,1 ,2-tri - chloroethane	polychlorinated biphenyl (PCB)
Butyl rubber	**6.4**	**2.7**	**2.3**	**0.1**
Neoprene rubber latex	**0.9**	**2.0**	**0.3**	**0.02**
Nitrile rubber latex	**0.3**	**3.8**	**0.3**	**0.1**
Polyethylene	**1.2**	**1.5**	**1.8**	**0.4**
Surgical rubber latex.	**0.2**	**0.05**	**0.1**	**0.04**
Vitron	**82.0**	**>144.0**	**>144.0**	**6.0**

SOURCE Adapted from (456)

workers with a great deal of confidence in their equipment would submit to having their hard hats or safety-toe shoes struck by a heavy weight while their heads or feet were inside. In the absence of such data, it is useful to inspect the Bureau of Labor Statistics (BLS) reports of accidents involving different parts of the body.

BLS warns that its data do not allow any conclusions to be drawn about the incidence of injuries suffered by workers wearing and not wearing protective equipment, for no information about exposure is available. For instance, the BLS data do not reveal if workers wearing protective eyewear are exposed to more airborne particles with the potential of harming eyes than are workers who do not wear protective eyewear. Although the BLS data cannot reveal how many injuries personal protection devices prevented, they can be used to learn about conditions that caused failure of such devices and why personal protective devices were not worn.

The BLS data were collected over time periods ranging from 2 to 5 months in 19 or 20 States (depending on the injury studied). Employers' reports of injuries to State workers' compensation agencies were reviewed, and questionnaires were mailed to workers in selected occupations in all industries except mining. In general, the survey period ended when a certain number of questionnaires were returned, and the results cannot be taken as representative of all injuries affecting the specified part of the body.

Selected Data From the BLS Survey of Head Injuries

The head injuries suffered by workers wearing hard hats were divided about equally among impacts sustained on the hard hat, on an unprotected area, and both (600) (table 8-5). The shells of 37 percent of the helmets broke, and the suspensions of 17 percent failed as a result of the accident. An injury can result, of course, from an impact that does not damage the helmet. For instance, too much force can be transferred if the shell is pushed forcibly onto the worker's head. The high failure rate reflected in shell and suspension breakage parallels NIOSH's observations that only 33 percent of tested Class B industrial helmets passed the ANSI impact resistance test.

Table 8-5 presents data on the reasons that hard hats were not worn. The majority of workers who were unprotected were not supplied with protective equipment, not required to wear it, or thought it was unnecessary. Less than 20 percent of the injured workers who were not wearing head protection said that hard hats were uncomfortable, impossible to wear, or interfered with work.

The percentage of workers usually wearing hard hats in their work is very close to the percentage required to do so. Twenty-one percent of all workers who responded to the BLS questionnaire are required to wear hard hats; 20 percent wear hard hats all or most of the time. Ninety-five percent of the workers wearing hard hats at

Photo credit: Chemical Manufacturers Association

Worker dons full protective suit

the time of their accident were required to wear them.

Selected Data From BLS Survey of Eye Injuries

The most important information for assessing the effectiveness of eye protection would be to know how many injuries were prevented by them. As with head injuries, however, no data are available to calculate that.

Photo credit: Department of Labor, Historical Office

Although materials have changed since this photo was taken, the basic purpose of protective clothing is still to prevent worker contact with harmful substances

Table 8=5.—Selected Information From BLS Survey of Head injuries

	Number	Percent
Workers' reports of head Injuries while wearing hard hats:		
Total	169[a]	
Struck on hard hat area only	53	31
Struck on unprotected part of head only	60	36
Struck on hard hat area and unprotected part	55	33
Don't know	1	1
Helmet shell broken or damaged	40	37
Helmet suspension broken or damaged	18	17
Workers' reports of masons for not wearing hard hats: [a]		
Total	852	
Thought it was not needed	216	25
Not available from employer	176	21
Not normally used or not practical	471	55
Uncomfortable, did not fit with other equipment, hard to work with it on, or in bad condition	163	19
Other	42	5

[a]Some responses exceed total number of Injuries and sum of percentages exceeds 100 because multiple responses could be given by single individual.

SOURCE: (600).

Table 8-6 lists the reasons workers thought protective eyewear failed to protect them (598). The most frequently cited reason was that the object or chemical that caused the injury went around or under the protection. NIOSH (94,133) has drawn attention to this possibility in reports on piano safety spectacles (which should be equipped with side shields) and on face protection (which should not be used without eye protection).

Despite all the caveats that must be attached to conclusions about the effectiveness of protective eyewear, it can be concluded that few devices failed because of characteristics for which ANSI has testing standards. Only 4 percent of the injuries involved lens failures, and only 1 percent were related to frame breakage.

The reasons given by injured unprotected workers for not wearing eye protection are tabulated in table 8-6. Twenty-two percent reported that protective eyewear was unavailable at the work site. The other reasons given were either that the worker or the worker's supervisor did not think eye protection was necessary or that the eye protection interfered with the worker's vision.

Table 8-6.—Selected Information From BLS Survey of Eye injuries

	Number	Percent
Workers' reports of ***reasons*** *Injury occurred when eye protection was worn:*		
Total	401[a]	
Object or chemical went under or around protection	376	94
Object went through lens or the shattered lens hit eye; lens was knocked out of frame	15	4
Frame broke and injured worker	4	1
Eye or face protection slid or fell out of place	16	4
Other	28	7
Workers' reports of reasons for **not** *wearing eye protection:*		
Total	612	
Eye or face protection lifted up; not in place	37	6
None available, not required, or worker thought none needed or not normally used or	136	22
impractical	402	66
Protection device reduced vision or device fogged up, or device **was** uncomfortable or in bad condition	293	39
Other	63	10

[a]Some responses exceed total number of Injuries and sum Of Percentages exceeds 100 because multiple responses could be given by single individual

SOURCE (598)

There is no way to be certain that wearing eye protection would have reduced the number of injuries to unprotected workers, but it is a safe assumption that at least some injuries would have been prevented and that the severity of others would have been reduced. Apparently greater use of protective eyewear would result from greater supervisor attention and improved designs to reduce interference with workers' vision. Seventy-nine percent of those wearing eye protection were required to; only 52 percent of all workers were required to.

Just over half (56 percent) of the injured workers who were wearing eye protection thought that it reduced the severity of their injuries. Five percent thought that the protection contributed to the injury. The remaining 39 percent did not have an opinion about the effect of the eye protection or thought that it had had no effect.

Selected Data From the BLS Survey of Face Injuries

Only 9 of 770 workers who were included in the survey of face injuries reported that they had been wearing face shields when they were hurt (599). However, about a third of the injured workers had been wearing eye protection; about 20 percent of them thought the eye protection minimized their injuries, and about 10 percent reported facial injuries from broken frames or lenses.

Most workers who did not wear face protection reported that it was not required or was not considered necessary. Only about 10 percent reported that it was uncomfortable or interfered with vision.

The one face shield that failed was split by fragments of an exploding cutting wheel, which caused multiple fractures. In five cases, the object or chemical that caused injury went around or under the face shield.

Selected Data From the BLS Survey of Foot Injuries

Workers only infrequently wear safety footwear unless required by employers; "fewer than a tenth of those not required to use foot protection were wearing safety shoes" (601). Eighty-five percent of the workers wearing safety shoes were injured in an unprotected part of the foot. Importantly, given the ANSI emphasis on testing the strength of the safety toe, only 7 percent of foot injury accidents reported to BLS involved safety toe failures.

As noted earlier, NIOSH (117) observed that manufacturers sometimes exaggerated the impact or compression resistance of the safety toe. Evidently users of safety shoes are seldom aware that the shoes are rated on these features; 82 percent of workers wearing safety shoes did not know what class of protection the shoes provided. Fifty-seven percent of workers wearing safety shoes thought that the severity of their injuries had been reduced; only 1 percent thought that the shoes contributed to injury.

Possible Conclusions From the BLS Surveys

The results of the BLS Surveys are consistent with the conclusion that the equipment works-in that the failures the ANSI standards are to guard against occurred infrequently except in the case of hard hats, which failed relatively often. That conclusion is necessarily limited. For instance, if the 7 percent of safety-toe shoes that failed on the job did so because they received an impact of much greater force than the shoes were designed to withstand, then the shoes performed up to the standard. On the other hand, if some fraction of the 7 percent failed at an impact less than they were designed to resist, then the 7 percent failure rate is an underestimate.

Third= Party Laboratory Testing of Personal Protective Equipment

Manufacturers of personal protection devices are not required to test their products. They may do tests to assure themselves that the products meet ANSI standards. However, the results of the (now dated) NIOSH evaluation of personal protective equipment against ANSI standards provides no assurance that such tests are always done or that quality control is sufficient to guarantee that products coming off the assembly line meet the standards.

The Industrial Safety Equipment Association is the trade association of manufacturers of personal protective equipment. According to its president *(672),* the association had supported the extension of NIOSH certification programs from respirators to other personal protective equipment. In 1980, the association, upon deciding that NIOSH was unlikely to be able to expand its certification program, established as a separate entity the Safety Equipment Institute.

SEI is a testing and certification organization. It does not develop its own test standards; instead, as NIOSH did in the late 1970s, it tests equipment against the ANSI standards. The tests are carried out in laboratories under contract to SEI. The Institute so far has tested hard hats made by 95 percent of the manufacturers and eye and face protection made by 65 percent of the producers, and it makes available lists of hard hats and eye and face protection that passed the ANSI standards and were certified. Currently it is testing emergency eyewash and shower facilities.

Following the testing phase of the SEI certification procedure, the Institute, through an independent consulting firm, arranges for quality assurance audits of the manufactures of certified equipment on a biannual basis. In addition, at 6- or 12-month intervals, SEI retests a number of each certified model of personal protective equipment.

Upon retesting hard hats, SEI found that all the tested green-colored hats of one model made by one manufacturer did not meet the ANSI standards. Upon being notified of this fact, the manufacturer withdrew that lot of green hats from the market and informed all distributors that had purchased them that the hats were below ANSI standards.

SEI has not been greeted by everyone as an independent source of information about the effectiveness of personal protective equipment. Springing as it did from the trade association, it is seen by some as under the control of the manufacturers. The Institute has partially addressed this criticism by establishing a board of directors that has only one -member from the trade association. Its bylaws also separate it from the trade association.

Although time will have to pass before the success of SEI's program can be evaluated, the program is now well under way, and it offers third-party certification of personal protective equipment. SEI points out that it offers both an alternative to self-certification and assurance to the purchaser of certified personal protective equipment that the equipment meets national consensus standards for performance.

SUMMARY

The Federal Government does not certify that any types of personal protective equipment, except respirators, work. **In** the case of some other items of personal protective equipment, the American National Standards Institute has drawn up standards, and manufacturers advertise that their products meet those standards.

The procedures used by NIOSH to certify *respirators* are dated, and there is a great deal of dissatisfaction with them. Even devices that pass the tests may not work well **in the field, and since there is only a pass/fail evaluation, better respirators receive the same grade as ones that barely meet the standards.**

Few **studies have measured the effectiveness of respirators in the workplace. High effectiveness has been found only in workplaces that have well-developed respirator programs with careful maintenance, education, and supervision.**

NIOSH is currently drafting a revision of the certification regulations, which reportedly will require that manufacturers test and certify their own products. Not everyone supports self-certification. Labor unions are in favor of the government maintaining **a role in certification. An alternative offered by some manufacturers is the establishment of a testing laboratory, supported by industry fees, to carry out the certification tests. Industry is not uniformly behind the idea of a third-party laboratory, however, because the facility, as proposed, would have ties to some manufacturers. To opponents of the third-party laboratory, those ties mean that it too would be a method of self-certification, and they favor straightforward self-certification.**

Hearing **conservation programs depend on measuring the level of noise in the workplace, lowering it when possible by engineering controls, providing hearing protectors to workers exposed to noise above certain specified levels, and checking workers' hearing periodically to determine if hearing acuity has dropped below prescribed levels. All hearing protectors are labeled with a Noise Reduction Rating, which is supposed to give the purchaser information about the amount of protection provided by the protector.**

There is almost universal agreement, and no evidence to the contrary, that the NRRs overstate the amount of protection afforded by hearing protectors. NRRs are required by a law administered by the Environmental Protection Agency; because of budgetary cutbacks, however, EPA is no longer monitoring the accuracy of NRRs. Therefore, products bearing a Government-approved efficiency rating are known to be overrated, and that situation is unlikely to change.

Field testing of hearing protection has yielded evidence that noise attenuation achieved **in the workplace is much less than that expected from the NRRs. Some workers, even though they wore hearing protectors, received no benefit in terms of noise reduction. On the other hand, a limited study of hearing acuity in a major chemical company showed that hearing losses among its workers over a 5-year period were not related to noise levels. Additional, longer studies are necessary, however, before the success of these programs can be fairly judged.**

Analogous to the situation with respirators, the usefulness of hearing protectors depends on how they are chosen and used. A **continuous program of instruction, supervision, and maintenance is necessary.**

In the late 1970s, NIOSH tested several types of personal protection equipment against the ANSI standards. Since almost all the equipment was manufactured by companies that claimed adherence to ANSI standards, the NIOSH tests were a measure of the quality assurance programs of the manufacturers or of their ability to carry out the ANSI tests.

Some types of safety equipment, notably *spectacles, flexible goggles, miners' helmets,* linemen's *rubber gloves, and face protection,* were found to conform to the ANSI standard against which they were manufactured. Others—safety-toe *shoes, eyecup goggles, industrial* safety *helmets (hard hats), firefighters' helmets, and welding filter* plates—often did not measure up to the ANSI standards. Furthermore, some deficiencies were found in the ANSI test standards, which do not assess some important properties such as resistance of hard hats to off-center impacts or of glass safety glasses to penetration.

The Bureau of Labor Statistics has collected questionnaire data about some industrial accidents. Their survey data about *head injuries* showed that hard hats frequently failed in accidents, which fits with NIOSH's findings that many hard hats did not meet ANSI standards. Other Bureau reports found that other types of personal protective equipment also failed under certain, sometimes very severe, conditions. However, protective equipment was seldom identified as the cause of an accident. Although it is impossible to know how many injuries were prevented by personal protective equipment, it is clear that its use depends on good design and supervision of its use.

9
Hierarchy of Controls

Contents

9. Hierarchy of Controls

As explained in chapter 5, a generalized model of the workplace environment looks at sources of *hazards, transmission* of *the hazard,* and *workers (see fig. 5-2* in ch. 5). Health and safety hazards are controlled by interrupting the transmission of hazardous agents to workers. Controls can be introduced at several points: the source of the hazard, the workplace atmosphere (or transmission points), and the workers' location(s). For health hazards, control at the source can include substitution of less toxic agents or substances, as well as process and engineering changes to reduce emissions of the hazardous agents or substances. Control of transmission of the agent can be accomplished by ventilation, isolation, dilution, or enclosure. Control at the worker can include personal protective equipment, work practices, and administrative procedures (see discussions in chs. 5 and 8).

This model can also be applied to injury hazards, although much of the safety research published to date has followed other approaches. For example, control of electrical energy at the source might involve grounding to prevent the buildup and inappropriate release of hazardous amounts of energy. Control of transmission could include separating workers from the hazard by, for example, placing physical barriers or guards between the worker and the hazard, Personal protective equipment, such as insulated gloves, represents a control applied on the worker.

DESCRIPTION OF HIERARCHY OF CONTROLS

Health and safety professionals have traditionally ranked controls according to their reliability and efficacy in removing or controlling hazards. Put simply, the principle of the hierarchy of controls is to control the hazard as close to the source as possible. (This hierarchical approach is most commonly discussed in relation to health hazards and the methods of industrial hygiene. Although the principle can also be applied to safety hazards, most of the discussion in this chapter will focus on the control of health hazards.)

Expressed differently, the hierarchy of controls describes the *order* that either *should* be followed or *must be* followed when choosing among options for controlling health and safety hazards. In its simplest form, the hierarchy of controls specifies that engineering controls (including substitution, enclosure, isolation and ventilation) are preferred to the use of personal protective equipment. Work practices are frequently added to this list between engineering controls and personal protective equipment. Administrative controls, such as worker rotation, are also oftentimes included and generally constitute the "third" line of defense, falling after engineering controls and work practice controls and ahead of protective equipment. For some hazards, however, the Occupational Safety and Health Administration (OSHA) places administrative controls on an equal basis with engineering controls. In addition, OSHA now usually groups engineering controls and work practices together and assigns them the same priority. Nevertheless, in all cases, personal protective equipment is listed as the control of last resort.

Views of Health Professionals

The hierarchy of controls is widely supported in the professional community. Every current industrial hygiene textbook endorses the idea of such a hierarchy and lists engineering controls as the first priority and personal protective equipment as a last resort (455). It is often expressed in the context of controlling exposures to airborne contaminants-fumes, dusts, and vapors-that may enter the worker's respiratory system. Elimination of the contaminants by substitution of materials, enclosure of operations that generate fumes and vapors, dust suppression methods, or dilution of the contaminants by ventilation are all preferred over reliance on respirators. Leaders in this field and industrial hygiene texts all agree on this point (129,173,199,362,369,423).

Excerpts from a 1947 textbook on industrial hygiene and from a 1980s text underline the unchanging preference for engineering controls.

> Obviously, the most successful approach to the problem of industrial atmospheric sanitation lies in the design or *alteration of plant and equipment so* that the control features are engineered into the structure and machinery (71, emphasis in original).
>
> In many instances, however, the reduction of exposure [through engineering methods] is not sufficient to eliminate the hazard, and other control measures are needed.. , . Respiratory protective devices have a distinct place in the field of industrial health engineering. That they are a last ***Zinc of defense*** can hardly be denied (71, emphasis added).

The newer text states:

> If confinement or removal by adequate properly engineered and operated ventilation systems is not possible, personal protective equipment on a ***temporary*** basis should be considered. We stress the word "temporary" since respiratory protection can seldom be relied on for long periods of time in hazardous exposures, unless highly unusual control procedures are established and rigorously enforced *(172).*

In *1963,* the American Conference of Governmental Industrial Hygienists (ACGIH) and the American Industrial Hygiene Association jointly issued a comprehensive guide to respiratory protection in the United States. The opening paragraph is clear on the preferred methods of controlling occupational hazards:

> In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fumes, mists, gases, or vapors, the primary objective should be to prevent the air from becoming contaminated. This is accomplished as far **as** possible by accepted engineering control measures; . . . (9).

Consensus Standards

The hierarchy of controls is also found in the "consensus" standards written by committees meeting under the auspices of the American National Standards Institute (ANSI) and its predecessor, the American Standards Association. The Association's *1938* standard for protective equipment did not require any particular "hierarchy of controls, " but the attached commentary noted:

> It is obviously better to remove the hazard, when this is possible, than to protect the worker against it [using personal protective equipment]. Thus, in granite cutting it is preferable to remove the dust by an exhaust system rather than to allow it to contaminate the air, and then to protect the worker against breathing the dust. . . . This code does not attempt to specify how various industries shall be conducted, with respect to avoiding hazards, but points out the method of protecting the worker where the hazard has not been eliminated by other means (15).

In the 1959 revision of this consensus standard, respirators were assigned a ***supplemental*** function in the actual text of the standard:

> **General Considerations.** Respirators are used to supplement other methods of control of airborne contaminants rather than to substitute for them. Every effort should be made to prevent the dissemination of contaminants into the breathing zones of the workers. In some instances, it is necessary to use respirators only until these control measures have been taken; in others, such measures are impracticable, and the continued use of respirators is necessary *(16).*

In 1969, ANSI issued a separate standard for respiratory protection. The heading of the paragraph that describes the applicable principles was changed from "General Considerations" to "Permissible Practice," adding weight to the importance of the control hierarchy. In addition, emphasis was given to what was now viewed as the "primary objective" of workplace controls: preventing the contamination of the workplace atmosphere. In addition the word "feasible" was used in connection with controls.

> **Permissible Practice.** In the control of those occupational diseases caused by breathing air con-

taminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the *primary objective shall be to prevent atmospheric contamina*tion. This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used . . . (11, emphasis in original).

The 1980 revision of this ANSI standard is virtually identical in wording, although the phrase beginning with "the primary objective" is no longer underscored. In addition, respirators are now permitted "[w]hen effective engineering controls are not feasible, or while they are being instituted or *evaluated* . . . " (12, emphasis added).

Government Standards

The conclusions and practices of the professional community and the consensus standards organizations now have regulatory force. The startup standards adopted by OSHA in 1971 under the authority of section 6(a) of the Occupational Safety and Health (OSH) Act (see ch. 12) included three specific provisions concerning the hierarchy of controls.

The applicable paragraph in OSHA's standard concerning respiratory protection (29 CFR 1910.134 (a)(l)) was taken, word for word, from the paragraph in the 1969 ANSI standard quoted above, although the one phrase underscored in the ANSI standard is not underscored in the OSHA standard. Second, the OSHA noise standard requires employers to comply with the permissible exposure limit through the use of "feasible administrative or engineering controls" (29 CFR 1910.95(b)(l)).

Finally, OSHA's main requirement for limiting exposures to toxic substances (the Air Contaminants standard) reads:

To achieve *compliance with . . , this section, administrative or engineering control must first be determined and implemented whenever feasible.* When such controls are not feasible to achieve full compliance, protective equipment or any other protective measures shall be used to keep the exposure of employees to air contaminants within the limits prescribed . . . Any equipment and/or technical measures used for this purpose must be approved for each particular use by a competent industrial hygienist or other technically qualified person. Whenever respirators are used, their use shall comply with section 1910.134 [the OSHA respirator standard] (29 CFR 1910.1000 (e), emphasis added).

In addition, in all of its substance-specific proceedings that resulted in new or revised permissible exposure limits, OSHA has maintained a policy of first requiring employers to comply by implementing "feasible" engineering and work practice controls. Although the precise wording of these requirements has differed slightly among these health standards, the basic outline is clear:

First, an employer must institute feasible engineering and work practice controls to reduce emloyee exposures to or below the permissible exposure limit.

Second, even if the feasible engineering and work practice controls are insufficient to achieve compliance with the permissible limit, the employer is required to use them in order to reduce exposures as low as possible before issuing personal protective equipment.

Personal protective equipment, such as dust masks, gas masks, and other types of respirators, is to be used against airborne contaminants in only four circumstances:

- during the time period necessary to install feasible engineering and work practice controls,
- when engineering and work practice controls are not feasible (including many repair and maintenance activities),
- when engineering and work practice controls are not sufficient to achieve compliance with the permissible limits, and
- in emergencies.

Controls for Safety Hazards

A similar priority system has been suggested for the control of injury hazards. A clear exam-

Photo credit: NIOSH (photo provided by OSHA, *Office of Information and Consumer Affairs*

Because respirators increase the effort required for breathing and are uncomfortable, workers often do not wear them or wear them only intermittently. Engineering cent rots can often eliminate the need to use respirators

ple can be found in the National Safety Council's *Accident Prevention Manual (322),* which lists the following "hierarchy":

> The basic measures for preventing accidental injury, in order of effectiveness and preference are:
>
> 1. ***Eliminate*** the hazard from the machine, method, material, or plant structure.
> 2. Control the hazard by enclosing or guarding it at its source.
> 3. ***Train*** personnel to be aware of the hazard and to follow safe job procedures to avoid it.
> 4. Prescribe ***Personal protective equipment*** for personnel to shield-them against the hazard.

Discussions about the hierarchy of controls in these situations is often concerned with the relative priorities to be placed on workplace and machinery design as opposed to worker training. Employee training and education will always be an important adjunct to any control technique. But ergonomics and safety research now stress the importance of design over *primary* reliance on the inculcation of certain "safe" work routines through training. (See also discussions of safety hazard identification, injury controls, ergonomics, and worker training in chs. 4,6,7, and 10).

ADVANTAGES AND DISADVANTAGES OF THE HIERARCHY OF CONTROLS

The preference for engineering methods for controlling workplace hazards is sometimes questioned. Why are engineering controls preferred and why is personal protective equipment ranked lower than other methods? Why have nearly all professionals, the National Institute for Occupational Safety and Health (NIOSH), and OSHA assigned personal protective equipment to the position of being only a 'last line of defense"? The reasons can be divided into those that deal with specific, often technical, problems of currently available personal protective equipment and those that address more general advantages of engineering controls.

Problems with Personal Protective Equipment

Many types of existing personal protective equipment do not provide reliable, consistent, and adequate levels of protection. Indeed, research conducted on the real-world or workplace, as opposed to laboratory, effectiveness of such equipment shows that the protection provided by these devices is unequal, highly variable, and substantially lower than that predicted from laboratory measurements (see ch. 8). For example, it has been estimated that the mean real-world attenuation of hearing protectors is only about one-third their laboratory attenuation *(49).* These shortcomings often make personal protective equipment inadequate for worker protection.

Advantages of Engineering Controls

The problems specific to personal protective equipment are sufficient to cause professionals to rank engineering controls above them in the hierarchy of controls. Additionally, engineering controls have a number of advantages ranging from the relatively mundane and pragmatic to the more philosophical.

In brief, engineering controls are inherently more reliable and provide more effective protection than personal protective equipment and are more likely to result in successful hazard control (see box G). Once installed and adequately maintained, engineering controls provide reliable and consistent performance, and, if designed correctly, adequate levels of protection.

Engineering controls work day after day, hour after hour, without depending on human supervision or intervention. Because they do not depend on a "good fit" with workers, they provide the same protection to all, and monitoring devices can measure the protection afforded. Separated from contact with the worker, engineering controls do not create additional health or safety problems, Moreover, these controls, especially those at the source of a hazard, can simultaneously control several exposure routes, such as respiratory and dermal exposure, while protective equipment is generally limited to protecting only one exposure route.

Box G.—Essentials of Successful Control

Four essential characteristics of successful control solutions for any health or safety problem, according to NIOSH (585), are:

- The levels of protection afforded workers must be reliable, consistent, and adequate.
- The efficacy of the protection for each individual worker must be measurable during use thoughout the life span of the system.
- The solution must minimize dependence on human intervention for its efficacy in order to maximize its reliability.
- The solution must consider all routes of entry into workers' bodies and should not exacerbate existing health or safety problems or create additional problems of its own.

In addition, OTA has identified five other areas for which engineering controls have advantages over personal protective equipment. First, many employer-provided personal protective programs are currently inadequate. Most discussions of the relative merits of engineering controls and personal protective equipment center on respiratory hazards. For those hazards, it is argued that respirator programs can be designed and implemented to provide protection equal to that afforded by engineering controls. Successful control through the use of respirators has sometimes been achieved by a few, usually large, employers who have sophisticated health and safety programs. But not all employers have implemented such programs or are capable of doing so.

Indeed, failures in employer respirator programs are the most frequent cause of OSHA citations in health inspections, reinforcing the experience of many industrial hygienists and OSHA inspectors that most existing respirator programs are inadequate. More than one-third of all OSHA citations for violations of health standards involved the respirator program requirements, which were directly adopted from the 1969 ANSI consensus standard (180).

Former OSHA inspectors have written that, in their experience, for most cases of employee overexposure to air contaminants the employers' respirator programs were inadequate (329,363). This is supported by analysis of OSHA inspection data. OSHA inspectors cite violations of the respirator program requirements in 40 to 70 percent of the inspections in which employee overexposure was measured (402). A leading consultant in the field has summarized his experience:

> having reviewed the respirator programs of hundreds of private companies, I can state that I have not, with the exception of the nation's very largest corporations, ever observed a proper and adequate use of respirators in the occupational setting (309).

Second, it is generally impossible to make periodic measurements of respirator efficiency, and it is very difficult to monitor each individual employee as he/she cleans, dons, and uses his/her respirator. Moreover, it is probably human nature to be on one's "best behavior" when someone is "watching. " It is therefore difficult to be certain that the use of equipment observed by a respirator program manager is representative of regular use. Similarly, it is much more difficult for OSHA to monitor the use of masks and respirators during an inspection, which are conducted infrequently, and to be certain that the use observed then is representative of use on other days.

Third, in a hierarchical approach, with control achieved close to the source of the hazard, there is room for backup or supplemental controls. For example, if the primary control involves the use of process containment ("control at the source"), then this control can be supplemented by having personal protective equipment available ("control at the worker") for emergency use. If the primary control is protective equipment, the opportunity to provide for supplemental control is eliminated because the control selected is already "at the worker"; that is, the last line of defense has already been used.

Fourth, primary reliance on engineering controls can spur the advance of technology. The OSH Act allows the agency to mandate "technology-forcing" controls (see ch. 14). New control technology can be, and has been, accompanied by other changes in plant and equipment that improve productivity, as well as protecting worker health and safety (see ch. 16). Relying on personal protective equipment would reduce technological development—including the development of controls that may find application to other hazards, as well as improvements in equipment that reduce hazards and simultaneously raise productivity. For example, if OSHA had permitted the use of dust masks to comply with the cotton dust standard, the installation of new technology in the cotton textile industry would probably not have taken place as rapidly as it did. Modernized equipment has both dramatically improved productivity and lowered worker exposures to cotton dust (413).

Finally, personal protective equipment is burdensome on employees. It is usually uncomfortable, decreases mobility, and the weight of many types of personal protective equipment increases employees' physical work loads. Negative-pressure respirators, in addition to their discomfort, also significantly increase the effort needed for breathing. This can create special difficulties for workers who have already suffered lung impairments.

Moreover, this equipment often impairs productivity. In many cases workers are paid on a "piecework" basis or are evaluated on how well they meet employer-set productivity standards. If allowance is not made for the decrease in productivity due to the use of protective equipment, an economic burden may be borne by the employee.

The use of such equipment, especially respirators, also impairs communication and worker-to-worker contact. This may lead to additional safety problems because employees wearing respirators will be unable to warn each other of potential safety hazards, while those wearing hearing protection may be unable to hear instructions, warning signals, or changes in the operations of plant equipment. (However, one study has found decreases in accidents after implementation of a hearing conservation program (622).) In addition, reducing worker-to-worker communication can increase a person's sense of isolation and detract from the important social functions of work.

Lastly, workers required to use personal protective equipment may feel that they are no longer being treated as persons, especially if they are not allowed to participate in any decisions concerning the use of equipment. People in this position may feel that they are merely cogs in the workplace, similar to other machines that require hoods, filters, and masks.

Problems with Engineering Controls

Notwithstanding the advantages of engineering controls over personal protective equipment, there are some drawbacks. First, although they are less subject to human error and inherently more reliable, engineering controls can fail. No matter how well designed, a ventilation system will fail to remove an airborne contaminant if the fan stops. Although these failures can be kept to a minimum with adequate maintenance, respirators must be available for use in such emergencies.

Even substitution does not eliminate the possibility of a failure in hazard control. For example, carbon tetrachloride, which had been used as a substitute for petroleum naphtha, is now widely recognized as toxic itself. Some of the substitutes for carbon tetrachloride (tricholoroethylene, perchlorethylene) are now suspected of having various previously unrecognized toxic effects.

Second, there are a number of situations for which feasible control methods have not yet been fully developed. In these situations, the best that can be done is to require the use of personal protective equipment while attempting to develop feasible engineering controls. In addition, such equipment will always be needed when engineering controls are insufficient to reduce exposures to permissible levels and during the interim period while engineering controls are being designed and implemented.

These situations are widely recognized and are provided for in OSHA's hierarchy of controls. There are, and will be, however, disputes about what kinds of controls are "technologically feasible" in any given situation. This is particularly true when OSHA issues a regulation that "forces" technology, either by speeding development of control techniques or by facilitating dissemination of existing techniques.

Photo *credit OSHA Office of* **Information and** *Consumer Affairs*

Engineering controls for occupational noise exposures include the use of sound dampening enclosures

Cost is the principal objection to requiring engineering controls. Although a well-designed and well-conducted respirator program can be expensive, such programs are in many cases cheaper than engineering controls and certainly capital costs are lower. Sometimes the concern about the costs of engineering controls arises because of the belief that these costs would be infeasible for a particular firm (leading to a plant closing) or for an industry as a whole. Sometimes arguments are based on the relative "cost-effectiveness" of controls.

Some employers and economists have suggested that employers should be allowed the flexibility to choose among the available control methods, rather than being required first to install feasible engineering controls. This flexibility would allow employers to choose the least-costly control method.

For example, in its reconsideration of the lead standard, OSHA estimated the compliance costs for a group of industries. If these industries were required to use engineering controls, total annual Costs were estimated to be nearly $130 million. But if respirators were allowed, the costs would be about $78 million (626).

A second example concerns compliance costs for reducing asbestos exposures from 2 fibers/cubic centimeter to 0.5 fiber/cubic centimeter. The total annual costs for all industries, in 1982 dollars, are estimated to be about $134 million if engineering controls are required and $54 million if respirators are allowed. If the permissible limit is set still lower, at 0.2 fiber/cubic centimeter, the annual costs would be about $170 million for engineering controls and $56 million for compliance through the use of respirators (647).

For both examples, there are limitations to the accuracy of these estimates. Moreover, in neither case was OSHA able to estimate the potential reduction in worker productivity due to the interference caused by respirators. But, as estimated, the cost differences between these control methods appear, in many cases, to be substantial.

Many employers believe that the use of personal protective equipment can provide adequate employee protection at reduced cost. This argument is used with regard to both full 8-hour exposures and for brief and intermittent exposures. These industry representatives argue that if the degree of protection offered by the equipment is equivalent to that provided by engineering controls, it would be sensible to choose the least costly means. Unfortunately, as already noted, many kinds of protective equipment have not been demonstrated to be effective in actual workplace conditions. In addition, there may be additional benefits from requiring engineering controls, such as increases in productivity or relative decreases in absenteeism. These economic benefits need to be considered when judging the "cost-effectiveness" of different control techniques.

The cost-effectiveness argument is also raised in connection with the requirement that feasible engineering controls be installed even when engineering and work practice controls are insufficient to achieve compliance. In these situations personal protective equipment is needed for workers in order to meet permitted exposure levels. It is argued that in such cases expenditures for engineering controls are wasted because personal protective equipment will still be required. But because personal protective equipment often fails, reducing contaminant levels through the use of engineering controls minimizes the likely degree of worker overexposure.

OSHA'S POLICY TOWARD THE HIERARCHY OF CONTROLS

Since its creation in 1971, OSHA has enforced the provisions of the startup standards requiring the use of engineering controls. In addition, OSHA has developed, through rulemaking proceedings, new or revised standards covering a number of toxic substances or hazardous physical agents.

In these proceedings, nearly every health and safety professional, irrespective of whether the person worked for an employer, a trade association, a labor union, a public-interest group, a university, or the Government, agreed that engineering controls are preferable to the use of personal protective equipment. Many of these same professionals, and other representatives of employers' and trade associations, would then explain why this general policy did not apply to their own workplaces or industries. Representatives from labor unions, public-interest groups, and Government would carefully argue in reply that the preference for engineering controls was necessary to protect employee safety and health.

The requirement that regulatory agencies perform "economic impact assessments" (see ch. 14) has resulted in economists becoming directly in-

volved in discussions concerning health standards. The Council on Wage and Price Stability advised OSHA, on a number of occasions, to change its policy and allow the use of personal protective equipment **in place of engineering controls. In each proceeding on health standards before** 1981, **OSHA rejected that advice and continued to require engineering controls as the first line of de**fense for controlling exposures to air contaminants.

Actions by the Current Administration

In February *1983, OSHA* published an Advance Notice of Proposed Rulemaking announcing that it was conducting a review of the hierarchy of controls and requesting information and comments from the public. OSHA stated that its objectives were to:

- **Explore whether a revised policy will allow employers to institute more cost-effective compliance strategies.**
- **Investigate whether advances in respirator design, technology, and applications may permit increased reliance on respirators.**
- **Attempt to identify processes, operations, and circumstances appropriate for particular compliance strategies.**
- **Assess actual workplace conditions and em**ployee health in industries and operations employing different compliance strategies (639).

During the comment period that followed this announcement, OSHA received 132 separate comments from the public, including employers, trade associations, labor unions, and individuals. **Employers and their representatives supported a general change in OSHA's policy, and asked that the** agency **allow the use of respirators to substitute for engineering controls. There were some differences among employers and trade associations concerning the precise circumstances under which such a substitution should be permitted, but nearly all were in favor of allowing employers flexibility to choose between engineering controls and respirators. Labor unions, on the other hand, voiced support for the existing policy and objected strongly to any changes.**

NIOSH, in its comments, supported the hierarchy of controls:

> Each element of the hierarchy: 1) preventing emissions at their source, 2) removing the emissions from the pathway between the source and the worker, and 3) control at the recipient, should be applied in descending order to the extent feasible before the next lower element is applied **(585).**

Health and safety professionals working for universities and government agencies supported the preference for engineering controls. The two associations of professional industrial hygienists (the American Conference of Governmental Industrial Hygienists and the American Industrial Hygiene Association) supported the concept of first using engineering controls:

> The elected Board of Directors of the [ACGIH] . . . unanimously endorses continuation of the current [OSHA] policy to require employers to use feasible engineering controls, work practices, and administrative controls to prevent employee exposures above permissible levels. Personal protective equipment, including respirators, may be used as alternatives only when other methods are not adequate, are not feasible, or have not yet been installed. Furthermore, we endorse engineering controls as the preferred approach **(125).**

> The AIHA would like to go on record **as stating** that the elimination of workplace hazards is superior to the use of engineering controls, personal protective equipment, and other control strategies. Where elimination is not feasible, engineering and other control strategies should be the primary methods for reducing or eliminating exposures in the workplace. However, personal protective equipment may be necessary pending more long-term solutions, We recognize that there are times where personal protective equipment is ultimately the only feasible control. The decision to recommend engineering controls, personal protective equipment or other control strategies depends on the nature of the hazard in question and should be based upon the professional judgment of an industrial hygienist (375).

At this time, OSHA has not yet publicly announced what course it will follow concerning the general hierarchy of controls policy. ***in*** *light of OSHA's* ***reconsideration of the hierarchy*** of ***con-***

trols, the advisory panel for this OTA assessment asked to be recorded as endorsing the hierarchy of controls. To turn away from the hierarchy of controls without careful verification of the level of protection afforded by personal protective equipment is likely to increase exposures to health hazards.

In several substance-specific standards, the current administration has both continued the traditional policy and proposed changes. In its reconsideration of the cotton dust standard, OSHA decided to continue to require engineering controls, even in the face of objections from the Office of Management and Budget (OMB). This dispute between OSHA and OMB was, at least temporarily, resolved in OSHA's favor and the published proposal reiterates the hierarchy of controls (641).

However, in a proposal concerning a new standard for ethylene dibromide (EDB), OSHA proposed for the first time to make an important exception to the traditional hierarchy of controls, although this exception would be limited to cases of *intermittent* exposure. The agency's proposal would allow employers to use respirators as the *primary* means of control "where exposure to EDB . . . is intermittent [defined as an operation that results in exposures occurring for 1 or 2 days at any one time] and occurs less than a total of 30 days per year" (642).

In its 1984 proposal for a new asbestos standard, the agency proposed that employers be allowed to use respirators on a continuous basis as the primary means to comply with a new, reduced exposure limit. Employers would still be required to use feasible engineering and work practice controls to meet the current existing limit (2 fibers/cubic centimeter). But they would be allowed to use personal protective equipment on a *continuous* basis to reduce exposures from the 2 fibers/cubic centimeter limit to the new permissible exposure limit (either 0.5 or 0.2 fibers/cubic centimeter) (647).

In its 1984 final rule reducing the permissible exposure limit (measured as an 8-hour time-weighted average) for ethylene oxide exposures, OSHA requires employers to comply with the new permissible exposure limit through the use of feasible engineering and work practice controls. OSHA also concluded that most operations that generated *short-term* exposures to ethylene oxide could be controlled with the use of engineering controls. Thus, the agency did not, as it proposed for ethylene dibromide, allow the general use of respirators for all short-term operations with ethylene oxide exposures (649). (However, because of objections from OMB, the agency did not issue any short-term exposure limit for ethylene oxide, but requested public comments on the need for such a limit and the feasibility of a short-term exposure limit without the use of respirators.)

In addition, OSHA concluded that for some situations, engineering controls to meet the 8-hour time-weighted average for ethylene oxide were not feasible and, for the first time in any health standard, specifically lists those operations in the text of the regulation. For those situations, employers are allowed to issue respirators as the primary means of control (649).

Moreover, the current administration has also issued an administrative directive to OSHA inspectors, ordering that no citations concerning OSHA's permissible exposure limit for noise be issued to employers who had issued and required the use of hearing protectors by employees exposed to levels up to 10 decibels (dB) above the permissible limit (that is, exposures between 90 dB to 100 dB) (646). Because of the logarithmic nature of the decibel scale, this difference of 10 decibels is equal to a tenfold increase in permissible exposures. One researcher has estimated that using hearing protectors instead of engineering controls for noise exposures between 90 dB and 100 dB will double the probability that an exposed worker will incur an occupational hearing loss (165).

Finally, OSHA first granted and then withdrew an experimental variance from the medical removal protection provisions of the lead standard. The lead standard requires that employees whose blood lead levels exceed certain specified limits must be transferred to jobs with little or no exposure to lead. The variance would have allowed one employer to issue respirators to several employees with blood lead levels above the permitted limits, who would then continue in lead-exposed jobs instead of being transferred to positions without lead exposures (243,338,349).

CONCLUSION

In summary, OTA finds the hierarchy of controls to be a well-founded and protective concept. Applicable to both health and safety hazards, the hierarchy is derived from the experience of health and safety professionals and has been embodied for years in consensus standards, professional practice, and OSHA regulations. Engineering controls are more likely to meet the essential requirements for hazard control, and personal protective equipment is a last line of defense to be used when engineering controls are infeasible, insufficiently protective, or not yet installed. The problems of personal protective equipment arise out of 1) limitations in performance, 2) difficulties in evaluating their performance, 3) problems associated with their use, and 4) the physical and other burdens they create. Moreover, engineering controls are preferred on more general grounds because most personal protective equipment programs are inadequate and because engineering controls allow easier monitoring of performance by employers, employees, and OSHA. In addition, these controls are inherently more reliable and do not create employee burdens, and requiring them enhances the development of new controls and production technology.

OSHA's reevaluation of its longstanding policy favoring engineering controls for airborne contaminants may indicate a shift in the agency's approach to the hierarchy of controls. That policy has led to improvements in the health of U.S. workers and has spurred, at least to some extent, the development of control technologies. Policy changes that allow greater use of personal protective equipment may endanger the health and well-being of many American workers and reduce the regulatory imperative to develop new and better production and control technologies.

10.
Training and Education for Preventing Work-Related Injury and Illness

Contents

FIGURE

10. Training and Education for Preventing Work-Related Injury and Illness

Worker training in injury and illness prevention is provided by many employers; it can range from rudimentary instruction about "safety rules" to sophisticated instruction about potential hazards and technologies for their control. Training was at management's discretion until the Occupational Safety and Health Administration (OSHA) included training requirements as part of several regulations. Unions have rarely had the resources to train members in preventing work-related injury and illness. However, some unions now have (or had) training programs for their members supported by funds from the OSHA New Directions program (see ch. 12). OSHA is the Federal agency primarily responsible for worker training.

The National Institute for Occupational Safety and Health (NIOSH) is primarily responsible for educating occupational safety and health professionals. NIOSH, especially through its funding of Educational Resource Centers (ERCs), has emphasized interdisciplinary education of occupational physicians and *nurses*, industrial hygienists, and safety engineers,

Responsibilities of NIOSH and OSHA overlap. For instance, NIOSH publications are used in worker training and the OSHA Training Institute trains professionals in short courses about OSHA regulations.

The importance of managers and engineers in identifying and controlling workplace hazards has led some professional organizations to discuss educational needs of their members. Both NIOSH and OSHA are participating in developing short courses for these professionals.

It is difficult to measure the effects of training and education programs. Ideally, decreases in illness and injury rates would be associated with the programs, but the rates are influenced by so many factors that clear conclusions are difficult. Currently most measures of success are "process measures" that count the number of students taught or hours of instruction provided.

WORKER TRAINING AND EDUCATION

Workers trained to recognize and avoid hazards are an indispensable part of creating and sustaining an illness- and injury-free workplace. In this assessment, worker *training* is defined as instruction in recognizing known hazards and in using available methods of worker protection. Such training, for example, emphasizes physical procedures and skills, such as keeping a shop floor free of debris, proper attention to the locking of machinery during maintenance, or proper use and cleaning of respirators.

Worker education is defined as instruction in analyzing and responding to new circumstances **and unforeseen problems. It prepares the worker to identify potential hazards, to request and collect information about hazards, and to seek ways to eliminate or control hazards.**

Although the boundary between training and education programs is often vague, the various programs may be described in four major and logically related categories: fundamentals, recognition, enforcement, and empowerment (227). In general, the narrower the role the worker is expected to assume, the more instruction is "training." The broader the role, the more instruction is "education."

Since a comprehensive analysis of worker training and education programs, their effectiveness, and the resources devoted to them is lacking, OTA contracted with INFORM to survey 40 worker training and education programs. Respondents included 8 business firms and trade associations, 10 unions, 4 hospital-based programs, 8 university-based programs, 6 Committees (or Coalitions) for Occupational Safety and Health (COSH groups), and 4 miscellaneous educational programs.

Fundamentals Programs

"Fundamentals" worker training programs instruct about known hazards in order to prevent work-related illness and injury. Such training may instruct workers in:

- prevention of work-related injury and illness through the proper use and maintenance of potentially hazardous tools, equipment, and materials;
- emergency procedures;
- personal hygiene as related to use of hazardous materials;
- the need for medical checkups or examinations; and
- use of protective devices such as masks, respirators, safety goggles, or gloves during nonroutine maintenance, where protective engineering methods have not yet been implemented, or during emergencies (227 and see box H).

Of the five "fundamentals" programs in the INFORM survey, three were operated by business firms and two by trade associations. Four teach supervisors, occupational safety and health specialists, or other "keypersons" to convey information and skills to workers. In the fifth case, the health and safety staff of a company instructs both workers and supervisors. The program objective most frequently cited was to reduce costs of work-related injury and illness.

Recognition Programs

"Recognition" programs prepare workers to participate in a broader range of worksite safet y and health activities through:

- emphasizing awareness of the hazards present in the workplace;
- understanding different methods available for hazard elimination or control;
- understanding rights and responsibilities under the law, e.g. right-to-know laws;
- collecting information about workplace hazards, e.g. chemical identity of workplace substances, symptoms associated with exposures, exposure levels;
- observing or informally inspecting the workplace for potential hazards; and
- reporting hazards or potential hazards to appropriate individuals *or* committees (227 and see box I).

Of the 14 "recognition" programs in the survey, 3 are conducted by businesses, 5 by unions, 3 by universities, and 3 by hospitals; their major objective is to teach workers to recognize hazards.

Problem-Solving Programs

The general objective of "problem-solving" programs is to provide workers with the information and skills necessary to participate in hazard recognition and control. These programs prepare workers to:

- help solve problems that may arise on the shop floor, in an ongoing, regular way, by use of union and management resources and mechanisms; and
- exercise legal rights when necessary and practical, to bring outside agencies, especially OSHA and NIOSH, into the workplace to help address hazards (see box J).

In order to be effective, workers must learn to:

- question work processes and materials to assess whether hazards have been adequately identified; and
- judge the effectiveness of alternative methods of control (227).

Of the 14 "problem-solving programs" included in the survey, 5 are administered by unions, 5 by universities, 1 by a hospital, and 3 by independent educational programs. The major program objectives emphasize teaching workers to use particular mechanisms to address workplace problems.

Empowerment Programs

"Empowerment" programs aim to teach workers the broadest range of skills so as to involve them in defending and expanding their rights to an illness- and injury-free workplace. The major assumption underlying "empowerment" programs is that the goals of cleaning up hazardous worksites and ensuring the health and safety of workers requires a substantial transfer of political and economic power to workers and their unions. To help educate workers to play a broad social and political role, "empowerment" programs must either instruct workers in the entire range of skills and knowledge offered by "fundamentals," "recognition, " and "problem-solving programs"—or they must work to ensure that such training is provided to workers by unions and/or management (See box K).

Although INFORM (227) did not collect information about employers' responses to "empowerment" programs, it is expected that those programs would be opposed. The transfer of political and economic power from employers and managers in any area, including safety and health, would be a dramatic shift.

Six of the seven "empowerment" programs in the survey are conducted by Committees or Coalitions for Occupational Safety and Health. The other is conducted by a nonprofit educational program. The political focus of "empowerment" programs is apparent in the following descriptions of program objectives listed by four groups from the survey:

- empower workers to deal with problems at work;
- build on hazard recognition and problem-solving skills to give safety committee mem-

Box I.—Example of a Recognition Program: International Brotherhood of Painters and Allied Trades (IBPAT)

[illegible] 1982 the IBPAT instructed and equipped 126 field instructors (who reached about 25,000 union [illegible] through workshops, conferences and lectures) with information about specific hazards and [illegible] of preventing illness and injury among workers.

[illegible] IBPAT program is used by local unions and by vocational or trade schools that offer courses [illegible] and local union officials. The program is tailored to meet the needs of specific groups of [illegible] for instruction about specific hazards.

[illegible]structional materials prepared by IBPAT include videotape modules, a quiz book, and a course [illegible]. These materials are designed to complement lectures as well as to stimulate class discussion.

[illegible] major elements of the IBPAT program compare with the basic elements of a "recognition" pro- [illegible] follows.

[illegible] programs convey [illegible] and skills to [illegible], enabling them to:	The IBPAT program, for the use of local unions and trade schools, includes materials and course plans for instructing workers in:
[illegible] different workplace hazards	1. recognizing and understanding: —exposure to silica, lead, asbestos, and carbon monoxide —causes of accidents in the glazing trade —how harmful substances enter the body and their effects —symptoms of neurological, respiratory, digestive, and circulatory disorders, and what substances are believed to cause them
[illegible] methods to control [illegible] hazards	2. control methods for silica, lead, and toluene diisocyanate using personal protective equipment for abrasive blasters using engineering controls, administrative controls, and work-practice controls for asbestos selecting the proper respirator for different hazards, such as asbestos, and isocyanate vapors
[illegible] and companies' [illegible] under the [illegible]	3. worker and company rights and responsibilities under the law regarding monitoring, record keeping, medical examinations, OSHA complaints, NIOSH health hazard evaluation
[illegible] information about hazards	4. using: —charts to estimate a substance's toxicity —the IBPAT/OSH Dilution ventilation chart to determine ventilation requirements
[illegible] inspect the [illegible] for potential hazards	5. [locals provide instruction]
[illegible] hazards or potential hazards to [illegible] individuals or committees	6. [locals provide instruction]

IBPAT reports that its program has had a significant impact on collective bargaining. According to an IBPAT evaluation of its fiscal year 1982 activities, 5 out of 10 locals or district councils that completed the IBPAT program prior to negotiations of their contracts secured provisions for health and safety committees. Among affiliates that did not receive IBPAT instruction, only 3 out of 10 secured such committees.

The IBPAT program evaluation also showed that 27 percent of those affiliates that have completed the program won provisions for training programs in their new contracts. This compares with only 10 percent of affiliates that had not undertaken the program. (Both measures of success are complicated because the affiliates who participated in the program may have already made significant commitments to safety and health. If that were so, participation and *success* in negotiations might be better characterized as two successes stemming from overall commitment rather than any cause-effect relationship.)

Source: (227).

Box J.—Example of a Problem-Solving Program: Labor Occupational Health Program (LOHP) at the University of California, Berkeley

LOHP offers a variety of programs and services, including:

1. formal education and training courses;
2. workshops and conferences;
3. plant walk-throughs to assist in hazard identification;
4. off-site technical advice;
5. legal advice;
6. assistance in collective bargaining; and
7. maintenance of a resource center for public use.

In 1982, LOHP instructed more than 800 workers and union officials through courses, workshops, and conferences and provided educational and training materials to 4,000 workers and union officials.

In addition to providing instruction typical of "fundamentals" and "recognition" programs, LOHP places special emphasis on teaching the problem-solving skills listed in the chart below:

Problem-solving programs convey information and skills to workers that enable them to:	LOHP offers the following programs that instruct workers and union officials in problem-solving skills:
1. take an active role in seeking solutions to problems on the shop floor	1. training for participation in joint committees (such as an annual course for the Oil, Chemical and Atomic Workers International Union , and petrochemical companies in the Berkeley area) a conference on workers' compensation for workers and trade unionists workshops on "Collective Bargaining on Health and Safety" steward training sessions in health and safety ' for unions
z. exercise legal and contractual rights and ensure management compliance with laws and contractual agreements	2. a conference on California right-to-know law, attended by 150 union and management representatives, professionals, and students small workshops to aid in the implementation of the state right-to-know law

Source: (227).

Box K.—Example of an Empowerment Program: Unidentified COSH Group

[illegible] dozen local unions representing over [illegible] workers, and more than 150 individuals, including union officials, workers, health and safety professionals, lawyers, and doctors, are members of this COSH group. The following list of activities illustrates how this group puts the [illegible] of "empowerment" programs—to defend and expand workers' rights under the [illegible] into practice.

The COSH group provides services common [illegible] other programs. For instance, it:

- [illegible] and distributes materials about [illegible] and specific methods of haz[illegible] and worker protection;
- [illegible] and conducts workshops, confer[illegible] courses designed to train and [illegible] workers in a variety of subjects [illegible] hazard recognition to labor [illegible] such as building a strong safety [illegible] committee and winning good [illegible] language on safety and health;
- [illegible] technical assistance to workers [illegible] right to refuse dangerous work [illegible] to call in OSHA; and
- [illegible] technical assistance to workers [illegible] process of workers' compen[illegible]

[illegible] workers and unions in [illegible] to improve safety and [illegible]

[illegible]

bers and local union officials and stewards skills in observing and interpreting air monitoring and medical tests; track trade names of potentially hazardous chemicals; devise engineering control methods; negotiate effective health and safety contract language;

- empower workers and their unions to win illness- and injury-free working conditions; have more control over their working conditions; and
- empower workers with the skills and the confidences they need to prevent work-related illness and injury in their workplaces through collective action (227).

Evaluation of Worker Training and Education Programs

Ideally, effectiveness of worker education and training programs would be measured by reduced job-related injuries and illnesses. However, the data currently available are often limited, especially for illnesses (see ch. 2). In addition, even with the appropriate data, attribution of improvements to one factor requires knowledge of all other factors that might have an effect. In practice, effectiveness measures are generally indirect and include counting the number of workers trained or educated and surveying workers' and management's perceptions of the value of the programs.

OCCUPATIONAL SAFETY AND HEALTH PROFESSIONALS

Congress recognized the need for training a cadre of occupational safety and health professionals to reach the objectives of the Occupational Safety and Health (OSH) Act of 1970. Section 20 of the Act designates NIOSH as the agency to plan for and carry out programs to assure an adequate supply of professionals. NIOSH was given authorit y to conduct programs for this purpose directly, through grants, and through contracts.

Since 1971, NIOSH has conducted short-term training programs for occupational health and safety professionals, developed curricula and training materials, and provided grants to universities. Through a grant program, it has established Educational Resource Centers to train occupational safety and health professionals through interdisciplinary programs, to provide consultation and training for workers and employers, and to conduct research related to worker health and safety. NIOSH has also provided financial support to students through training grants to qualified universities (588).

In addition to NIOSH courses, large companies sometimes train their own professionals. A cooperative agreement between General Motors and the United Auto Workers to train union safety stewards is described in chapter 15.

Continuing Education

NIOSH conducts technical training courses for private-sector and Government professionals and technicians. The cost of the training courses is paid by reimbursements to NIOSH. Short-course topics include:

- industrial hygiene;
- occupational safety;
- industrial toxicology;
- occupational health nursing; and
- occupational medicine.

Special custom courses are produced to meet specific training needs identified by Government and private sector groups. For example, in fiscal year *1982,* courses were presented to the U.S. Navy about analyzing asbestos samples taken during ship refitting; to the Health Departments of New Jersey and Arizona to train state officials in the recognition of workplace hazards; to the Mine Safety and Health Administration Training Academy to provide information about industrial hygiene sampling and analysis for mine inspectors; and to Case Western University to train science department faculty in preventing injuries in laboratories.

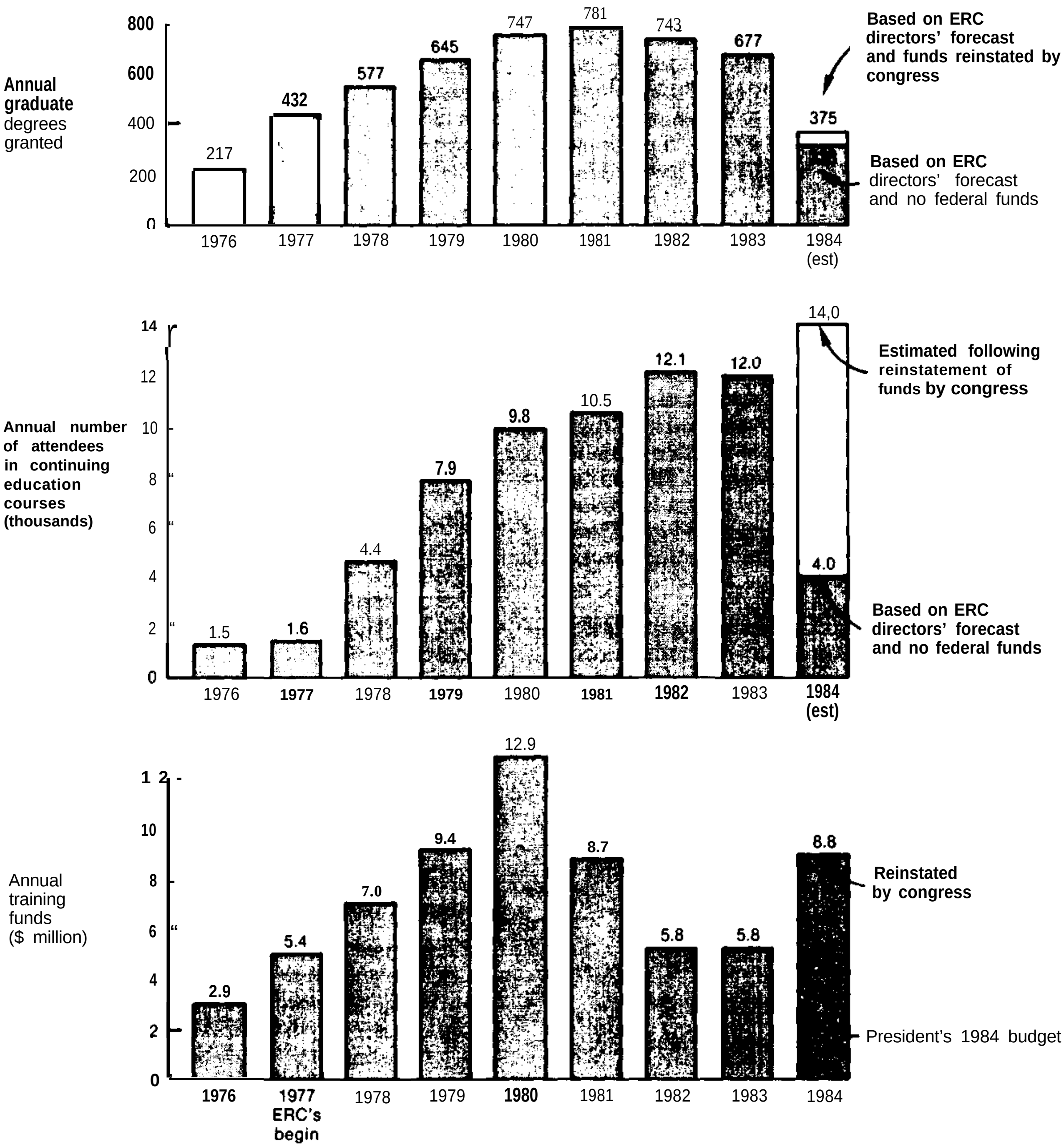
Between *1977* and 1981, continuing education enrollment increased from approximately 1,600 to over 10,000 per year (fig. 10-1). At this rate, enrollment could eventually increase to 50,000 per year if each specialist in the field attended one continuing education program at least every other year. As figure 10-1 illustrates, the number of attendees in continuing education courses increased with funding from 1976 to 1980.

However, a substantial reduction in the number of attendees was projected, based on an assumption of a lack of Federal funding of ERCs in the 1984 Presidential Budget (102). In fact, funding was continued by Congress and the number of trainees is now estimated to be 14,000 per year. The demand for continuing education increased dramatically as OSHA and NIOSH resources for disseminating information to professionals were cut. This is partially because graduated professionals sought to update their knowledge and skills. Funds have been available to meet this demand due to the flexibility of ERCs in rebudgeting funds intended for graduate training, where enrollment has been declining.

Curriculum Development and Dissemination

Refinement and modernization of curricula for short-term and continuing education can improve the effectiveness of occupational safety and health training. One way NIOSH disseminates recent research findings that may help prevent work-related illness and injury among high-risk groups is through the development of curricula. Generally this approach consists of identifying groups who have access to high-risk workers, developing materials that will train these target groups in recognition and means of prevention of harm, and conducting "training-the-trainer" programs so these groups can transfer the knowledge.

Figure 10.1 .—Effect of Funding Changes on Numbers of Graduate Degrees Granted and Continuing Education Courses Provided by Both NIOSH and Grant Supported Universities



An example of curriculum development is the joint NIOSH-OSHA program for instructing vocational education teachers how to teach skills in recognition and control of workplace hazards. Introducing such concepts to new workers before they are employed is especially important since young workers are at the highest risk of traumatic injury. Pilot programs were conducted with over 100 vocational education administrators and teachers in Ohio, California, Minnesota, Arizona, Florida, and New York. The program was designed for flexibility so that its 17 units can be taught over 3 days or over longer periods, depending on individual needs.

Another example of training-the-trainer was the NIOSH program to increase the awareness of high school science teachers about hazards in the working environment. In a three-year period, over 100,000 teachers were trained through this program at a cost of little more than $1 per trainee. This program also resulted in changes that described chemical hazards to workers in a recently published high school science text.

Specific teaching modules have also been developed and made available to appropriate groups. For example, audiovisual presentations on safe removal of asbestos from school buildings were developed jointly by NIOSH, OSHA, the Environmental Protection Agency, and the National Cancer Institute. Over 1,000 copies of these programs were distributed to train asbestos removal contractors. In another case, videotape programs were developed to instruct firefighters and other workers in the techniques of maintaining and donning self-contained breathing apparatus. These tapes featured the latest findings from the testing of these devices.

Planning

In 1977, NIOSH conducted a nationwide survey of governmental agencies and nonagricultural firms with more than 100 workers to determine the current number of employed occupational safety and health professionals and to predict future demand. Based on nearly 3,300 survey responses, NIOSH estimated the number of full-time professionals to be between 104,360 and 110,840 and forecast 3,100 new positions a year would be available by 1990. Growth in demand was concentrated in jobs that "inspect, interpret, investigate, and plan," such as industrial hygienists and safety engineers (570).

The future supply of occupational safety and health personnel was estimated in another NIOSH survey by asking 112 programs in occupational safety and health education how many graduates they expected in the future. These results, combined with estimated numbers of personnel trained by insurance companies and by the Federal Government, showed that in 1977 the demand exceeded supply of occupational safety specialists, occupational health nurses, and occupational health physicians, but that the demand equalled supply for industrial hygienists. Due to survey limitations, data collected at that time were insufficient to predict adequacy of supply of occupational safety and health personnel by 1990 (570). A report that updates work force supply and demand information has been completed (584); however, publication of the report awaits OMB approval.

The NIOSH surveys of demand and supply, like all such projections into the future, were based on assumptions about conditions in the years ahead. Because of the sagging economy in the early 1980s, and probably also because of a reduced Federal presence in occupational safety and health, there have been few positions available in this field. *The Advisory Panel to this assessment lamented the fact that occupational safety and health professionals are often among the first*

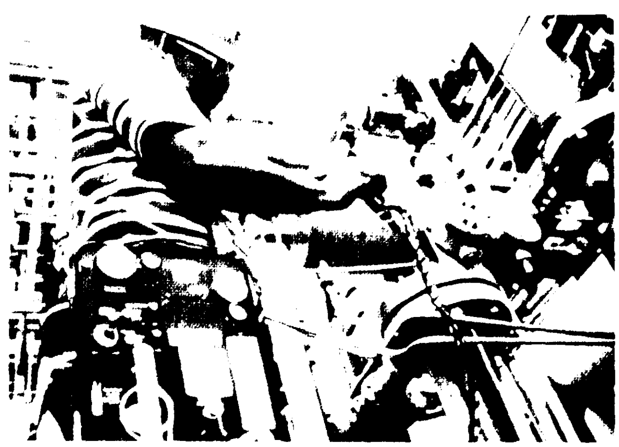


Photo credit E.I. du Pont de Nemours & Co

Measuring the concentration of potentially harmful gases is one aspect of an industrial hygienist's job

to be laid off from company and union jobs, but could offer no suggestions to alter that condition.

Training Grants

NIOSH's findings of shortages of trained occupational safety and health graduates were cited in successful efforts to expand training grants programs. One part of this expansion was to introduce the concept of multidisaplinary educational resource centers. The other part was growth of single-discipline training grants.

Single-discipline training project grants have been established in 28 universities, and over 100 different academic degree programs were in place in **1980. Because of budget cutbacks, the number of programs was reduced** to 60 in **1982.** The number of professionals graduating from these and ERC programs each year increased from 217 in 1976 to 747 in 1980. As shown in figure 10-1, the number of graduates increased as the funding increased.

Educational Resource Centers

Congress authorized creation of up to 20 Educational Resource Centers for occupational safety and health in **1976. Funding increased from $2.9 million** in 1977 to $12.9 million in 1980, and the ERCs now number 15. These centers: 1) provide continuing education to occupational health and **safety professionals; 2) combine medical, industrial** hygiene, safety, and nursing training so that graduates are better able to work effectively in complex and diverse conditions; 3) conduct research; and 4) conduct regional consultation services. All **ERCs but one are located in universities.**

The centers are distributed as far as possible to give regional representation and to meet training needs for all areas of the Nation. The Federal cost **of ERC education is approximately $7,000 for each degree graduate and $70 for each attendee at continuing education courses (102).**

Recent budget cuts have reduced the current level of funding for Educational Resource Centers to **$5.8 million,** 55 per cent below the level in fiscal year *1980.* According to projections by the Association of University Programs for Occupational Health and Safety, if Federal funding for ERCs had been eliminated as proposed in the President's fiscal year *1984* budget, the number of graduates completing their programs would have decreased to approximately 338 (compared with about **781** in 1981) and only about 25 degree programs of the 112 programs currently in existence could have been expected to survive. Furthermore, there was concern that without Federal funds, multidisciplinary programs would revert to more narrow and limited single-discipline programs.

While the President's 1984 budget for NIOSH contained no request for ERC funding, the Congress added $8.8 million for the centers.

Other Training Programs for OSH Professionals

Other Federal agencies and private companies train occupational safety and health professionals in special cases. OSHA maintains a training institute in Des Plaines, IL, primarily to give short-term training to State and Federal compliance officers, and the institute also provides short courses to some private sector groups **(636).** The Mine Safety and Health Administration maintains a Training Academy in Beckley, WV, to give short-term training to its inspectors **(452).**

Many short-term training courses for workers and occupational safety and health professionals are sponsored in the private sector. The courses, including a wide variety of specialized short-term training in both illness and injury prevention, are announced weekly in journals such as the *Occupational Safety and Health Reporter* published by the Bureau of National Affairs. The number of private sector courses has grown substantially since the passage of the OSH Act.

ENGINEERS AND MANAGERS

Although there appears to be a growing awareness in the business community of the costs of work-related illness and injury (284), little information is provided about prevention in business schools (579). Furthermore, there is little evidence that engineering schools treat the subject at any level, but there are some attempts to change this. Professional engineering societies and trade associations have formed committees on occupational safety and health, governmental agencies are conducting training and information programs, and educators are slowly becoming concerned.

Engineers and business managers are often unaware of the potential for reducing work-related injuries and illnesses either because the hazard remains to be identified or because information about it is new and inadequately disseminated. Even after a hazard is recognized, these business decisionmakers may lack access to information on which to base plans for prevention.

Educating Engineers

The engineering curriculum is one of the few that prepares baccalaureate degree holders for a professional license. Because it provides both an undergraduate and a professional education, the curriculum is a crowded one and under constant pressure to add new material. Occupational safety and health would be a useful addition *or* augmentation to currently scheduled lectures, but it is difficult to squeeze it in.

Few people more fully recognize the difficulties of the engineering curriculum than professional educators, yet they see some opportunities to increase safety and health instruction. For instance, industrial-hygiene-engineering educators recommend, in a recent report, presenting students with information on recognition and control of work-related injury and illness hazards and making such information available to practicing engineers (587). They single out design engineers as a particularly important group because the greatest opportunity for change is in the planning stages of industrial processes. "All undergraduate engineering curricula (particularly design courses) should include instruction on the responsibilities of engineers for occupational safety and health engineering problems and solutions" (587). The report also recommends that academic programs in occupational safety and health should be offered to practicing engineers as continuing education. The American Board of Engineering and Technology, which accredits programs in engineering, finds it "desirable" for engineering schools to teach safety (4).

Specific legal responsibilities require professional engineers to protect workers and the public as well as their employers. Professional engineers may be required to act according to the prevailing practice of the profession by State law, but they may lack knowledge about local or Federal regulations or penalties for noncompliance. Indeed, engineers have been held accountable for the actions of untrained subordinates in some cases. In the case of workplace health and safety regulations, training may be absent since few schools of engineering have courses bearing on responsibilities under the Occupational Safety and Health Act.

Complicating problems for engineering schools are current pressures to update curricula to meet rapidly changing technology, to respond to the sudden upsurge in enrollment, and to upgrade faculty and overcome critical staff shortages. Undergraduate enrollment exceeded 387,500 in the academic year 1981-82. This was an all-time high for the Nation's 286 engineering schools (419).

Training Business Managers

According to a national survey of 217 schools of business management accredited by the American Assembly of Collegiate Schools of Business (a group representing a majority of business management schools) that was conducted by the National Safety Management Society, few specify safety management studies as a degree requirement (311). It is not difficult to imagine that such studies would be of low priority in management schools, but some companies argue that commitment of top management is the single most necessary ingredient in safety and health programs (156).

NIOSH and OSHA have begun Project Minerva to develop occupational safety and health training programs in business schools. The project will be publicized through a series of briefings given to administrators and faculty at selected business schools. Audiovisual materials will be prepared and a case-study book assembled containing 50 related occupational safety and health articles. These materials will be designed so that they can be used in classwork by the business educators (584).

COMPUTER NETWORKS AS AN EDUCATIONAL TOOL

Improving the quality and quantity of information available about preventing work-related injury and illness depends upon finding solutions and communicating the solutions to people who will benefit from them. The traditional methods of information exchange are journal articles, presentations at professional meetings, and various kinds of consultation. Computer conferences—formed by people who share common interests and who "participate" in the conference by sending and receiving messages in a central computer—are an experimental method of information exchange. They have been tried on a limited scale for the exchange of information about occupational safety and health and on a larger scale within companies to exchange technical information. It is unclear what their eventual value will be, but they have been praised by some occupational safety and health professionals who have used them.

NIOSH Use of Computer Networks

One of the duties of the Technical Information Division of NIOSH is to draft responses to OSHA-proposed rules. NIOSH used computer conferences to respond to two 1982 Advance Notices of Proposed Rulemaking from OSHA. One notice concerned "Hazard Communication" (the "labeling standard"), which details what information is to be provided to workers about the chemicals to which they are exposed. The other dealt with OSHA's regulation concerning Access to Employee Medical Records, which stipulates what medical records are to be retained by employers, for how long, and who has access to them. In both cases, NIOSH arranged a conference that involved about 10 NIOSH employees in scattered locations; there was little overlap in the membership of the two groups.

NIOSH participants consider the exchanges to have been a success. The computer-time cost for the hazard communication exchange was $2,500, about two-thirds as much as a 2-day meeting at NIOSH in Cincinnati, which would be an alternative method of gathering needed responses.

A NIOSH-MIT exchange was organized differently. The Reader's Digest computer data base, the Source, has software called PARTICIPATE that permits its users to join in conferences. Three professionals with expertise in computers and video display terminals posted a message on the Source inviting comments and discussion. Over a dozen participants joined in; the discussions followed two paths—one concerning possible health effects from radiation and ergonomic considerations, the other stress and quality of work.

Priest (377) sees the NIOSH-MIT exchange as a limited success. It attracted participants, but because it did not have a goal, such as producing a document or answering a question, the exchange strayed, just as undirected conversations do.

Privacy and Trade Secret Concerns

In the late 1970s, a large United States-based pharmaceutical firm with over 60,000 employees worldwide developed its own system of computer exchanges and over 4,000 employees use it. The firm's Vice President for Research and Development considers it a "crucial and integral part" of the firm's development and management operations (377).

The system is used extensively by employees concerned about product safety. Although the firm's representatives stated that they used the system considerably for health and safety purposes, they would not disclose any details about the content or process (377). Concern about disclosing business secrets was partially responsible for the company's not discussing computer exchange of safety and health information. In addition, a company representative stated that sharing its health and safety information with other companies might make the company subject to antitrust actions. Only trade associations and public meetings were seen as acceptable for sharing information (377).

The firm in this situation has made an implicit tradeoff—between, on the one hand, deaths and injuries that might be reduced by disclosing information about their methods and, on the other hand, their proprietary business interests and desire for privacy. There is also the possibility that the firm was concerned about disclosing information about product safety discussions that might be "discoverable" in a legal proceeding (377).

The Future of Computer Exchanges

Computer exchanges are attractive because they provide fast and interactive communication. The information is "written down" and can be retrieved. However, a company inhibited by desires to protect its privacy will be reluctant to allow employees to participate in a medium as rapid, fluid, and uncontrollable as computer exchange.

The future of government-sponsored and business computer exchanges among occupational safety and health professionals is likely to increase as cost savings become more apparent, as hardware becomes more widely available, and as more people experience and grow accustomed to this communication medium. Information exchange in this manner can enhance face-to-face meetings. There appear to be few advantages of computer conferences that are peculiar to occupational safety and health.

SUMMARY

Traditionally, education and training programs have focused on workers and safety and health professionals. However, with recognition of the importance of designers, engineers, and managers in health and safety, some attention is now given to providing them with the principles of prevention and control.

Both OSHA and NIOSH are involved in education and training programs. OSHA has supported worker training and education; NIOSH grants are used primarily for education of occupational health and safety professionals. Both participate in Project Minerva, with the objective of introducing health and safety into business administration curricula. NIOSH has also sponsored workshops directed towards adding health and safety topics into the curricula of engineering schools.

OTA sponsored a survey of worker training programs. Not unexpectedly, the survey found that company programs, which are the majority of programs, emphasize fundamentals of safe working habits and recognition of hazards. Union, university-based, and Committee for Occupational Safety and Health programs prepare workers for a more active role in recognition and control. The company programs are the norm; the other programs, which would involve transfer of some power from management to labor, are more controversial and they do not represent the only way to go beyond the traditional programs. For instance, General Motors and the United Auto

Workers cooperate in the training of union safety stewards in General Motors' training programs.

NIOSH's 15 Educational Resource Centers, located across the Nation, represent a departure from disciplinary training for health and safety professionals. They emphasize interdisciplinary training of industrial physicians and nurses, industrial hygienists, and safety engineers. Unfortunately no solid evaluation of the programs has been carried out, but the ERCs are well regarded by most professionals.

The stability, if not the very existence, of ERCs is threatened by uncertain Federal funding. For each of the last four years, the President's budget has recommended no Fe&al funding. In each year, Congress restored funding. Nevertheless, the threat to the ERCs has seen parallel decreases in the number of graduate degrees awarded.

One of the surest ways to disseminate new information is to graduate new professionals and send them into the work force. As enrollment in graduate programs has declined, ERCs have increased attention to continuing education for practicing health and safety specialists. The flexibility of ERCs in providing both degree and continuing education programs is an argument for their continuation.

Evaluation of Federal education and training programs has consisted largely of counting numbers of graduates and hours of instruction. While those measures provide an indication of how much education is going on, they provide no details of the impact of the education. Careful evaluation would aid in making funding decisions.

11.

A Short History of Private and Public Activities

Contents

11. A Short History of Private and Public Activities

Accompanying new methods of factory production in the 18th and 19th centuries were exposures to new working conditions and new hazards. As some associations between hazards and injuries or illnesses were recognized, efforts were made to improve working conditions and to reduce or eliminate job hazards. Some of these originated in the private sector; others, in the Government. Many of these efforts concerning occupational conditions were intertwined with attempts to improve public health more generally. A number of programs were successful, resulting in improved working conditions, although progress has often been strikingly slow (see, e.g., 218).

VOLUNTARY EFFORTS

The importance of workplace safety was recognized by some large American firms around the turn of the century in the face of a rising number of injuries associated with the installation of new industrial machinery. One positive response was the creation of employer policies and practices directed at reducing the frequency of those injuries (box L). In addition to company-specific efforts, several voluntary organizations have been created to promote occupational health and safety.

National Safety Council

The first national organization devoted entirely to occupational safety, the National Safety Council (NSC), was established in 1912 as a response to the high industrial accident rate. It popularized the "Safety First" slogan that had been used by U.S. Steel. The council was governed by a business-dominated Board of Directors. It sought to achieve industry consensus for its recommendations, and favored nonmandatory standards, training and education, and voluntary safety programs (361) as the best method of improving safety records. The NSC thus epitomizes the voluntary safety movement.

Although the council has now shifted its emphasis to automobile and home accidents, its safety publications (and particularly *Accident Facts (324)*) *are well known* and widely disseminated. The council has worked extensively with the Department of Labor to provide safety training courses and materials to industry. Industrial firms that belong to the NSC have been reported to have "injury rates well below those of non-members" (249). The cause-and-effect relationship between low injury rates and membership in the NSC is not clear. It is at least as likely that companies with low rates join the NSC as it is that membership in the NSC results in lower injury rates.

American Occupational Medical Association

Industrial medicine originated in large companies that employed surgeons to treat traumatic injuries. By 1915, enough physicians and surgeons were engaged in industrial health to lead to the organization of the American Association of Industrial Physicians and Surgeons. Seventy-two physicians attended the association's first meeting in 1916. (In 1951, the association's name changed to Industrial Medical Association and later to American Occupational Medical Association.) Also in 1915, the American Medical Association held its first symposium devoted to industrial hygiene and medicine. The American Occupational Medical Association publishes a monthly journal, the *Journal of Occupational Medicine.*

American National Standards Institute

n 9 8 a g oup o a ge and med um ıze o po a on and ade a o a on ormed he Ame an Eng nee ng S anda ds Comm ee o de e op ndu rıa anda d h ough onsen u The name of h organıza on ha hanged on se e a o ca on and n e 969 ha been known a he Ame an Na ona S anda ds n u ANS A hough mo ANS andard a e d rected at technical specifications for manufacturing, such as having common thread pitches for screws, nuts, and bolts, some of the standards issued by ANSI are directed at improving occupational safety (249).

The membership of ANSI consists of companies (company members) and trade associations, government agencies, and private groups (member bodies). Several unions are also member bodies of the organization. The "consensus" method used by the institute is defined in its constitution as a position "achieved according to the judgment of a duly appointed authority. Consensus implies much more than the concept of a simple majority but not necessarily unanimity."

ANSI standards are developed by standards committees and are reviewed, since 1969, by a Board of Standards Review. The 15-person board has 9 industry members, 2 representatives from the Federal Government, 1 from municipal government, 2 academic representatives, and 1 member from a consumer organization. The board is authorized to decide when a standards committee has reached consensus; this decision includes counting and weighting the votes of the committee's members (249). The votes and weighting factors are not made public, although ANSI does circulate drafts to interested parties for comment throughout the final consensus process. (The ANSI standards concerning occupational health and safety that existed in early 1971 were adopted as regulations by the Occupational Safety and Health Administration (OSHA) using the authority granted in sec. 6(a) of the Occupational Safety and Health Act of 1970. See below and ch. 12.)

American Conference of Governmental Industrial Hygienists

The American Council of Governmental Industrial Hygienists (ACGIH) was founded in 1938 by a group of industrial hygienists from various levels of government. The ACGIH is a professional organization that issues "recommendations" that are developed by a straight membership vote.

By 1968, ACGIH had adopted nearly 400 Threshold Limit Values (TLVs) for hazardous substances. The TLVs are 8-hour time-weighted average values that are suggested limits for workday exposure; they are "guides for the control of health hazards" and were historically directed to the toxic rather than the carcinogenic, cytogenic, or mutagenic properties of chemical substances. In a special appendix to the 1968 publication, ACGIH recommended no exposure to a list of carcinogens. ACGIH standards have been adopted by several foreign governments and were incorporated in 1969 by the Bureau of Labor Standards of the U.S. Department of Labor using the authority of the Walsh-Healey Act (described below). Following its establishment in 1971, OSHA adopted the Walsh-Healey standards as its own, resulting in the TLVs published in 1968 by ACGIH becoming occupational health standards for all U.S. industry (249) (see also ch. 12).

GOVERNMENTAL EFFORTS

Workers' Compensation

The first workers' compensation program was established in Germany by Otto von Bismarck in 1884, and other European countries soon adopted their own programs (279), In the United States, the most important early-20th-century activity of State governments concerning occupational health and safety was the creation of workers' compensation programs. A limited program was established for Federal workers in 1908, and a number of States established commissions to study possible programs at about that time. Interest in workers' compensation derived from several sources.

The focus of these efforts was on the perceived deficiencies of the U.S. legal system concerning compensation for industrial injuries, Under Anglo-American common law, individuals can sue others for damages if a wrong has been committed that causes harm. The basic duty of employers was to act with due care for employee safety, as a reasonably prudent person would, and to furnish a sufficient number of safe tools and equipment, as well as a sufficient number of qualified employees to do the work. Employers were responsible for issuing and enforcing rules for workplace safety, rules that with ordinary care would prevent reasonably foreseeable accidents. Finally, there was a duty to warn workers of unusual hazards.

In theory, if the employer failed to live up to this standard of conduct, an injured employee could sue for damages under the common law. This was not always easy, however. The first difficulty was simply proving the employee's case. Other employees might be crucial witnesses, but in the 19th century, when there were few governmental or union job protections, anyone who testified against an employer would risk being fired. More importantly, the law also established three powerful defenses that employers could use against lawsuits brought by employees. These were:

- negligence of other servants or co-workers,
- knowledgeable assumption of risk by the employee, and
- contributory negligence by the injured worker.

Progressive Era Aims

In the early 1900s a number of Progressive Era humanitarian efforts underlined the plight of the injured worker and paved the way for workers' compensation programs. Crystal Eastman conducted the now-famous "Pittsburgh Survey" of 1907-08. She examined the economic conditions of the families of workers who had been killed or injured. In over half the cases, she found that "the employers assumed absolutely no share of the inevitable income loss. " The costs of work accidents fell "directly, almost wholly, and in likelihood finally, upon the injured workmen and their dependents. " She concluded that a *system* of compensation was necessary to achieve equity, social expediency, and prevention (274).

At about the same time, a State commission in Illinois reported that most court awards for industrial accidents were small, and that the families of the injured were often forced to live on charity. Moreover, for employers who had liability insurance, only 42 percent of payments went to medical care. The remaining 58 percent went for administration, claims investigation, and legal expenses (100).

Employer< Attitudes

The apparently small awards made to most workers was not the only reason for dissatisfaction with legal remedies. Employers, who as a group supported workers' compensation legislation before labor unions did, also found advantages in compensation programs. There is some evidence that just prior to the creation of workers' compensation laws, injured workers, at least in some circumstances, won a substantial portion of lawsuits against their employers (100,130,234, 316).

Moreover, workers' compensation substituted a regular, fixed, and predictable compensation payment for uncertain, potentially ruinous liability judgments (274). Employers also feared that without a workers' compensation system, the courts would start making more awards to injured employees, especially if a worker could show that his/her employer had violated one of the increasing number of State safety regulations (249).

Finally, employers advocated workers' compensation in order to remove one source of hostility from labor-management relations and possibly to prevent more fundamental changes in the worker-employer relationship. They specifically opposed the passage of liability law reforms that would have eliminated the common law defenses of employers. Some large companies had already established company benefit plans that provided payments for work injuries. Smaller manufacturers favored creation of such plans, but lacked the resources to do so privately (667). Larger manufacturers feared that if such plans were not created, legislators might act to change employer and employee rights. In the absence of changes, it was feared that the nascent unions would be given a boost (100,667).

For these reasons, some of the initial advocates of workers' compensation included groups like the National Association of Manufacturers, the National Civic Federation, the American Association for Labor Legislation, and a number of the leading industrialists of the day.

Labor Union Reactions

Unions, on the other hand, initially opposed workers' compensation. They generally wanted workers to retain the right to sue employers and advocated abolition of the three common law defenses. They held this position in part because they thought injured workers would receive larger payments under such a plan and because, at the time, they generally mistrusted the government and feared that governmental intervention would weaken unions (667).

Union opposition was also based on their perception that workers' compensation was "palliative and not preventive" (279). The belief that workers' compensation could provide an economic incentive for prevention was, according to MacLaury (279), important in changing labor's position; it "seemed to tip the scales. "

initial Legislation

The very first compensation acts, in Maryland, Montana, and New York, were ruled unconstitutional. The Federal Government enacted a law in 1908, which covered only certain Federal employees. The first State law to become effective and remain so was passed in Wisconsin in 1911. Following this breakthrough and aided by the combined support of reformers, business, and labor, laws were passed rapidly. Four other States passed laws in 1911. By 1925,24 jurisdictions had enacted compensation, although it wasn't until 1948 that all the States had such laws (249,316,667).

In some cases, workers' compensation was set up to supplement rather than to replace the legal liability system. Lubove states that "[w]here labor had a major voice in shaping compensation legislation, as in Arizona, injured workers were allowed a choice of remedy after injury." It appears that until that choice was removed under business pressure a decade later, most injured workers chose the liability route (274).

Extent of Coverage

The initial laws covered only accidental injuries. Some state legislatures had no intention of compensating occupational diseases and specifically excluded them from coverage. Three reasons for this have been suggested. First, workers' compensation laws were created to supplant common law liability. Under the common law, workers were consistently denied recovery for occupational diseases. Second, it was thought that compensation for disease would be so expensive that it would best be handled under a general health or disability insurance program. For example, it was believed that complete coverage of certain occupational diseases, such as silicosis in foundries, mines, or quarries, would be extremely expensive for the compensation system and those particular industries (261).

It has also been suggested that some of the writers of the early workers' compensation laws used language that would not alarm legislators, but would be flexible enough to allow the courts to extend coverage to occupational disease (46). Massachusetts was the first State to compensate disease when the courts acted in just this way. But by 1928, only 10 States covered diseases. From 1931-39, 14 States added coverage, while 18 States did so in the 1940s. The 7 remaining States added coverage between 1951 and 1967 (261). (See ch. 15 for a discussion of the current workers' compensation system.)

State Health and Safety Programs

Most early occupational health and safety efforts in the United States occurred at the State level. Occupational safety laws were enacted by various States during the 19th century. As seems to be often the case, there appears to have been a tendency to direct the laws at what were, at the time, new technologies. For instance, in 1852, Massachusetts passed a law regulating steam engines and permitting State inspectors the "power of closure" in situations of grave hazard (249). Twenty-five years later, in 1877, the same State passed the first factory-inspection law that required the installation of certain safety devices (guarding of belts, shafts, and gears), fire exits, and protection on elevators (279).

The early lead of Massachusetts in establishing regulations about workplace safety was followed elsewhere. By 1890, 22 States had passed regulations permitting safety inspectors in mines, and 14 had factory and workshop inspectors. However, these early laws were rarely enforced, partly because inspectors, who *were* often political appointees, were too untrained to recognize even the most obvious safety hazards.

In the first decades of this century, Alice Hamilton (box M) and other researchers actively pursued the work-relatedness of certain diseases. Their work was important in stimulating the interest of State governments in occupational health. By 1913, programs were organized in Connecticut, New York, and Ohio. The first important occupational disease laws, the "lead laws, " were passed in New Jersey, Ohio, and Pennsylvania (373).

Despite the establishment of these State occupational health and safety programs in the early part of this century, these programs were often deficient. A 1964 study reported that, on average, there was only one occupational health staff member for every 108,000 workers, and there were fewer than 1,600 safety inspectors in the various State programs combined (249).

A survey taken in 1968 found that occupational health programs were in place in only 20 States and jurisdictions and that most States had more game wardens than safety inspectors. State occupational safety programs, which were much more highly developed than occupational health programs, covered only the mining portion of the work force in 4 States, and 1 State had no safety legislation at all until 1967. State expenditures on occupational safety ranged from 1 cent per employee in Wyoming to $2.70 per worker in Oregon. In addition, as late as 1969, only 21 States gave safety inspectors the right to shut down a work area that presented an imminent hazard (249).

Moreover, even in the States with occupational health programs, the powers to develop and enforce occupational health laws and to inspect worksites were often diffused through several agencies. The resulting fragmentation of powers contributed to the difficulties of enforcing State occupational health laws.

Box M.—Alice Hamilton

Alice Hamilton is recognized as one of the founders of occupational health in the United States. She received her medical training at the University of Michigan, lived in Hull House in Chicago, was greatly influenced by Jane Addams, and later became the first female faculty member at Harvard University Medical School.

In 1910, the Governor of Illinois appointed her as a member of the State Commission on Occupational Diseases. In addition to Hamilton, the commission included four other physicians, a professor of sociology, an employer, and two members of the State Labor Department. The [illegible] directed to survey the effects of industrial exposure to lead, arsenic, brass, carbon monoxide, cyanides, and turpentine. It had no legal right to demand entry into a factory, and relied on persuasion to accumulate the information it needed to report one year later [illegible] from these exposures.

[illegible]

A final complication of separate State laws is illustrated by what happened when Pennsylvania banned the use, manufacture, storage, and handling of beta-naphthylamine, a carcinogen. Soon after the ban, another facility in another State began producing the chemical (249). This State-by-State approach was also criticized by business representatives. A keynote speaker at a trade association meeting in Washington in 1973 noted:

> When . . . [there is] a proliferation of different state plans and state enforcement . . . American business [has] great difficulty because most . . . companies . . . are multiproduct, multiplant companies. Having to live with . . . 40 or 50 different approaches . . . as distinguished from a single set of rules . . . concerns me greatly (277a).

Thus, by the time Congress considered Federal occupational health and safety legislation in the late 1960s, there was widespread agreement that, as one historian has summarized it, "safety and health laws, historically left to the States, were piecemeal, varied in quality, and often unenforced" (124).

Early Federal Government Programs

As early as 1790, the First Congress appeared to take an interest in the safety of merchant seamen by giving the crew of a ship at sea the right to order the vessel into the nearest port if a majority of the seamen plus the first mate believed it unseaworthy (279). In 1798, the Marine Hospital Service, which evolved into the Public Health Service, was established to provide care to seamen disabled on the job. The Hospital was paid for through the first system of health insurance in this country: a tax of 20 cents annually deducted from all seamen's wages (249). In the early 19th century, the Marine Hospital's physicians were primarily concerned with the control of epidemic diseases, such as cholera and yellow fever, which was more in the realm of public health than worker health.

Federal employees benefited from several measures passed in the 1800s: an 1833 law granted compensation to disabled seamen; an 1868 law limited the workday of Federal employees to 8 hours; in 1908 and 1916, workers' compensation was enacted for Federal railroad and other employees. Several early attempts (1796, 1852) at Federal intervention in matters of public health (such as enforcement of maritime quarantine and State grants to establish asylums for the insane) were rebuffed by the States, which considered public health their responsibility (249).

Federal Research and Assistance in Occupational Safety and Health

The Public Health Service (PHS) activities were extended to the workplace in 1914 when the Office of Industrial Hygiene and Sanitation was established in the Division of Scientific Research (249). During the next 20 years, the office engaged in research to identify occupational health hazards and their effects. It studied lead poisoning, looked at hazards in brass foundries and in the glass and chemical industries, and made sanitary surveys in war plants during World War I. It also conducted studies about the physiological effects of lighting, high temperature, fatigue, and other environmental conditions in the workplace.

A study in 1924 followed up the deaths of 20 people who had been employed in the painting of radium watch dials. Recommended control measures subsequently ended radium poisoning in the watch industry. Less spectacular, but bearing on the health of many more workers, was the Office of Industrial Hygiene and Sanitation's study of the dusty trades. Begun in 1923, this research showed the extent of health impairment associated with the granite, pottery, cement, cotton textile, and mining industries.

During this same early-20th-century period, the U.S. Bureau of Labor, and its successor, the Department of Labor, also sponsored research on occupational health and safety. Its reports included studies of lead poisoning, phosphorus-caused disease, the dusty trades, and industrial accidents (124). A 1910 report on "phossy jaw," published by the Bureau, was important in revealing the nature of that occupational health problem. In the second decade of this century, the Bureau employed Alice Hamilton to investigate occupational hazards especially in the "dusty trades" and published the results of her studies (279).

The passage of the Social Security Act in 1935 led to an expansion of PHS studies of occupational hazards and to the provision of grants to States for public health work, including industrial hygiene activities. During the 1930s, the Public Health Service studied the health effects of lead in gasoline and of fumes of chromic acid and mercury in the workplace.

A 1937 reorganization of the PHS resulted in the Scientific Research Division being consolidated with the National Institutes of Health (249). The Office of Industrial Hygiene and Sanitation along with the Office of Dermatoses Investigations became the Division of Industrial Hygiene of the National Institutes of Health. Seven years later, because of the marked increase in its work with States, the Division was transferred to the Bureau of State Services.

In World War II, as in World War I, the PHS was concerned with the protection of employee health in government-owned, privately operated munitions plants. A dramatic illustration of the success of these efforts is provided by mortality associated with TNT manufacture in both wars. During 7 months of World War I, 475 workers died and 17,000 were disabled by fumes; in World War II, there were 22 deaths in 35 months. In addition, studies were carried out in aviation medicine and on the health effects of new chemicals and metals, such as vanadium and beryllium, newly introduced into airplane manufacture.

Other reorganizations followed World War II. In 1953, the Federal Security Agency, which had included the Public Health Service, was abolished, and the Department of Health, Education, and Welfare (HEW) was established. The Division of Industrial Hygiene became the Occupational Health Program and remained in the Bureau of State Services until it was designated the Occupational Health Program in the Bureau of Disease Prevention and Control in 1966. Other organizational moves within the Department followed, and it was renamed the Bureau of Occupational Safety and Health (249).

The Occupational Safety and Health Act in 1970 established the National Institute of Occupational Safety and Health (NIOSH), and in 1973

NIOSH was transferred to the Centers for Disease Control of the PHS. During all the bureaucratic reorganizations since it began in the Public Health Service, the occupational health program has produced important studies about occupational health and, more recently, safety.

Federal Legislation and Regulatory Programs

Federal regulatory attention has historically focused on several high-hazard industries, such as mining, longshoring, railroading, and construction. The coal mining industry provides an example of Federal efforts to control occupational hazards in these industries.

Coal Mine Safety Legislation

In the wake of the Monongah, WV, coal mine disaster of 1907 that killed 362 miners and other accidents that caused the loss of many lives, the Bureau of Mines was established in 1910 within the Department of Interior to promote mine safety. Bureau personnel were specifically denied "any right or authority in connection with the inspection or supervision of mines." Although the powerlessness of Bureau personnel was widely deplored, it was not until 1941 that the Federal Coal Mine Health and Safety Act, which granted inspection authority to the Bureau, was passed. An excerpt from the House of Representatives report accompanying the bill captures the sense of Congress at the time:

> Investigation reveals no common standard of safety among the States, no common regulations, and, in addition to this, a lack of uniform enforcement of such [State] regulations as are in effect . . . . In order to supplement the work of the State agencies, the bill under consideration extends and enlarges the authority of the Federal Bureau of Mines. It is not regulatory in any sense. It merely authorizes the Bureau, through its representatives, to make inspections of the underground workings and publicize its findings and recommendations. These inspections , . . are to be made in conjunction with the local State agencies so that there is no assumption of the State authority (quoted in 249).

Later laws gradually increased Federal authority over coal mine hazards; in 1966, Bureau inspectors were permitted to close certain establishments operated by employers guilty of repeated serious violations.

A disastrous explosion in 1968 killed 78 miners in Farmington, WV. This crystallized public attention on mine safety. Citing the Federal Government's "fatalistic attitude" and failure . . . "to act vigorously to change [the prevailing bad practices], " the 91st Congress passed the Coal Mine Health and Safety Act of 1969 (the Coal Act) (249).

Despite the increase in authority given to the Federal Government by the 1969 Coal Act, safety and health conditions in the mines continued to be unacceptable to the Congress; in 1973, approximately one of every 1,500 miners, compared with one of every 12,400 workers in general industry, were reported to have been killed. In 1977, Congress passed the Federal Mine Safety and Health Amendments Act, the first Federal law to consolidate jurisdiction over both coal and metal mines and all safety and health matters (except training and research) in one executive department. The Department of Labor was empowered by this Act to inspect mines, and to develop, promulgate, and enforce safety and health standards applicable to mines (249).

Legislation for Other Industries

The New Deal.—Frances Perkins, selected by President Franklin D. Roosevelt in 1983 to be the Secretary of Labor, brought experience in occupational safety and health to that position. In 1934, she created within the Department the Bureau of Labor Standards, the first permanent Federal agency with a mandate to promote safety and health for the entire work force. To a major extent, the Bureau acted by aiding the States in the administration of their workplace health and safety laws and by promoting protective legislation.

Three New Deal-era laws contributed to a growing Federal involvement in occupational safety and health. As noted above, the Social Security Act of 1935 provided for the Public Health Service's funding of State industrial health programs. In addition, the Fair Labor Standards Act of 1938 (the "minimum wage law") allowed the Labor Department to bar employment of persons under 18 in dangerous jobs, while the Walsh-Healey Public Contracts Act of 1936 directed the Department to ensure standards for safe work by Federal Government contractors and to "blacklist" contractors who did not comply with the standards (279). This last act is of particular interest because it created a Federal regulatory role concerning job safety and health and located this function in the Department of Labor.

Walsh-Healey Act.–This legislation covered all employees working for employers who had contracts with the Federal Government that exceeded $10,000 in total value. The McNamara-O'Hara Act of 1966 and the Construction Safety Act of 1969 extended Federal regulation to service contract employers and Federally funded construction employers, respectively. Employers were required by the terms of their contracts to comply with Walsh-Healey safety and health standards, which were recommended by the Bureau of Labor Standards of the Department of Labor. The Bureau of Labor Standards was also given the authority to inspect workplaces covered by the Walsh-Healey Act and had the power to prohibit employers who violated the act from bidding on Federal contracts for a period of three years.

Federal involvement in setting safety and health standards intensified in the late 1950s. In 1958, an amendment to the Longshoremen's and Harbor Workers' Compensation Act extended the Federal role in protecting safety and health in the hazardous maritime trades. The amendment authorized the Labor Department to set standards in those trades and to seek penalties against employers who willfully violated safety and health standards, Compliance with the standards was good after enforcement began in 1960, and accident rates in the maritime trades declined (279).

Acting on its own in December 1960, the Labor Department issued a set of mandatory safety and health standards under the Walsh-Healey Act. However, objections were raised to the rigidity of the rules that the Federal Government required State occupational safety agencies to enforce when they inspected Federal-contract workplaces. The criticisms were heeded by the Department, and hearings about the Federal standards were held in March 1964.

The Federal Bureau of Labor Standards almost never used its inspection and enforcement powers; in 1969, only 5 percent of the 75,000 firms covered by Walsh-Healey were inspected. At the 3,750 worksites inspected by the Bureau in 1969, a total of 33,000 violations of safety regulations were recorded, while only 34 formal complaints were issued. Two companies were blacklisted (prohibited from bidding on Federal contracts) in 1969, and three had been similarly treated in 1968 (361).

The history of events under the Walsh-Healey and other acts exemplifies the sporadic efforts of the Federal Government to control occupational hazards in the years before OSHA. However, a pattern of increasing Federal involvement, such as the progression that occurred in mining, can be seen, particularly in the extra-hazardous trades—maritime, railroading, and construction. In each case, the first laws permitted Federal personnel to inspect specific aspects of hazardous operations, such as man-cages (personnel hoists) in mines, air brakes on trains, and shackles and other rigging components in longshoring. This first stage was gradually followed by Federal assumption of the responsibility for developing or recommending standards, helping employers to comply with them (and only rarely, in cases of grave danger, using the power of closure), and finally enforcing them. In all cases, the creation of Federal agencies with inspection and enforcement authorities required more than a half-century from the time of initial congressional action (249).

The Occupational Safety and Health Act of 1970.—One result of the strong criticisms voiced before and during the 1964 Department of Labor hearings was a decision of the Department to examine its safety and health policy. A study by an independent consultant characterized the Labor Department's safety laws and programs as fragmented (279). During this period of self-examination, the environmental movement was attracting public and congressional support in its bids for Federal laws to protect human health and the environment from the effects of pollution. The environmental movement spilled over into questions of occupational health because of the attention paid to chemicals as risks to health and the reasonable extension of “environment” to include the workplace.

The Public Health Service published Protecting the Health of Eighty Million ***Americans*** (the “Frye Report”) in 1965, which drew attention to threats to health from new technologies. Although it highlighted the evidence that some chemicals were associated with cancer causation, it also emphasized that many “old” occupational health problems had not been remedied. The report suggested an approach to improve occupational health that would require a major new effort from the PHS. The AFL-CIO urged President Lyndon Johnson to respond to the PHS report’s recommendations (279).

With the President expressing interest in occupational safety and health, both the Labor Department and the Department of Health, Education, and Welfare began development of legislation for a Federal program in occupational safety and health. The departments deadlocked on the issue of which one would control the national program in late 1966, and the effort stalled (279).

A dramatic bureaucratic action led the Bureau of the Budget to accept the Department of Labor’s recommendations for legislation rather than those of HEW. In 1967, it was learned that abnormally high numbers of uranium miners were dying of lung cancer. Later that year, the Federal Radiation Council, composed of representatives from a number of Federal agencies, met to consider protective measures for uranium miners. They came to an impasse concerning the standard proposed by the Atomic Energy Commission versus the more stringent standard proposed by the Department of Labor. Unhappy with their indecision, Secretary of Labor Willard Wirtz adopted the proposed Department of Labor standards under the provisions of the Walsh-Healey Act the very next day. This bold move was instrumental, according to MacLaury (279), in the Bureau of the Budget accepting the Department of Labor’s recommendations about legislation.

In January 1968, President Lyndon Johnson called on Congress to pass job safety and health legislation closely modeled on the recommendations of the Department of Labor. The proposal gave the Secretary of Labor the responsibility of setting and enforcing standards to protect 50 million workers. The bill also had a general duty clause requiring employers to “furnish employment and a place of employment which are safe and healthful. ” It gave inspectors legal authority to enter workplaces without management’s permission or prior notice. Violators could be punished with civil or criminal penalties. Interested states could develop their own occupational health and safety programs to replace the Federal one. The Department of HEW would provide the Labor Department with scientific information (279).

Although hearings were held, that bill did not reach the floor of either the House or the Senate. Part of the reason was the opposition of business, particularly the Chamber of Commerce, to bestowing so much power on the Secretary of Labor and to undermining the role of the States in occupational safety and health. Also important were other events of 1968: Riots in the inner cities, protests against the war in Vietnam, and President Johnson’s decision not to run for re-election competed with occupational safety and health for public and congressional attention.

In 1969, Congress passed the Coal Act (see above) and President Richard Nixon introduced a new version of an occupational safety and health law for all U.S. workers. His version skirted the issue of whether the Department of Labor or HEW was to have the lead in the Federal program. The duty of Labor was to inspect workplaces for compliance with standards. The role of HEW was to carry out research. The important function of issuing safety and health standards would be vested in an independent, five-person standards-setting board. The Nixon proposal also stressed the use of existing State government programs and private industry efforts (279).

Objections to the Nixon bill were raised by many Democratic and some Republican congressmen. Their concerns involved the independent standards-setting board, because of the administrative confusion it would cause and its lack of political accountability. Labor unions, in particular, opposed this board, preferring instead that the authority to set standards be given to the Secretary of Labor. In addition, objections were raised to the bill's enforcement scheme because it would penalize only willful, flagrant violators. Finally, the bill's reliance on industry-written "consensus" standards, exemptions for small employers, and a three-year delay in its effective date were also points of criticism (279).

In response, Democrats in the House and Senate had already introduced their own bills and both the House and Senate committees reported to the floor bills sponsored by Democratic members. In the Senate, Peter Dominick (R-CO) presented a substitute bill that would have established two independent boards—one to issue standards and one to decide enforcement appeals. This was rejected by a two-vote margin. Then Jacob Javits (R-NY) introduced an amendment that gave the Secretary of Labor the authority to set safety and health standards and established a separate commission to oversee Department of Labor enforcement of the standards. This amendment was adopted, although another amendment to restrict the authority of inspectors to close down hazardous operations was narrowly rejected. (In addition, there was some debate on the criteria for standards. This is discussed in ch. 14).

In the House, Congressman Steiger (R-WI) proposed as a substitute an amendment that represented a modification of the original Nixon proposal and this substitute was adopted. The conference committee had to resolve a large number of differences. They used the framework of the mom liberal Senate bill. The single most important change from the Senate version was the deletion of a provision that allowed the Secretary of Labor to close down a plant under conditions of "imminent danger. " Under the provisions of the bill that emerged from conference, the Secretary is required to obtain a court order before closing a plant that poses an imminent danger. President Nixon, through the Secretary of Labor, let it be known that he approved the bill, and both the House and Senate passed the Occupational Safety and Health Act of 1970 (279).

12.
Governmental Activities Concerning Worker Health and Safety

Contents

12
Governmental Activities Concerning Worker Health and Safety

This chapter has three major sections. The first describes the framework of U.S. Government activities created by the Occupational Safety and Health (OSH) Act, while the second discusses the main activities of the Occupational Safety and Health Administration (OSHA): setting standards, inspecting and enforcing regulations, provialing public education and services, and monitoring the performance of State programs. The third section describes the activities of the National Institute for Occupational Safety and Health (NIOSH) in hazard identification, research on controls, and information dissemination.

CURRENT FEDERAL/STATE FRAMEWORK

In the Occupational Safety and Health Act of 1970, Congress authorized the creation of three agencies to set and enforce mandatory health and safety standards; to conduct research on occupational hazards and their control; and to review contested enforcement actions. The three agencies are OSHA, NIOSH, and the Occupational Safety and Health Review Commission (OSHRC).

One other Federal agency, the Mine Safety and Health Administration (MSHA) of the U.S. Department of Labor, specializes in worker health and safety. It is responsible for the health and safety of workers in coal mines, as well as in other metal and nonmetal mines. It was created as a result of the Metal and Non-Metallic Mine Safety Act of 1966, the Coal Mine Health and Safety Act of 1969, and the Mine Safety and Health Act of 1977 (333). Its activities are not described in detail in this assessment.

OSHA is a regulatory agency that sets and enforces regulations concerning the control of health and safety hazards. It began its operations on April 28, 1971. Part of the Department of Labor, it is headed by a Presidentially appointed Assistant Secretary of Labor for Occupational Safety and Health, to whom the Secretary of Labor has delegated authority to administer the OSH Act. OSHA sets mandatory health and safety standards, inspects workplaces to ensure compliance, and proposes penalties and prescribes abatement plans for employers found violating the standards. In addition, OSHA provides for public, worker, and employer education and consultation, mostly through grant activities. Finally, OSHA partially finances the operations of State agencies operating "State plans" and monitors their performance.

NIOSH is a research agency that is part of the Centers for Disease Control (CDC) of the U.S. Public Health Service, which is part of the Department of Health and Human Services (HHS). NIOSH is headed by a Director appointed by the Secretary of HHS for a term of six years. It was created from what had been the Bureau of Occupational Safety and Health and started operations as NIOSH on June 30, 1971. Congress mandated that it conduct research and related activities on developing criteria or recommendations to be used by OSHA in setting standards, on identifying and evaluating workplace hazards, and on measurement techniques and control technologies, as well as provide professional education and disseminate health and safety information.

The OSHRC has three members appointed by the President, with the advice and consent of the Senate, for staggered terms of six years. Its duties are limited to reviewing and resolving disputes concerning OSHA citations and penalties. In doing so, the Review Commission interprets the meaning of OSHA standards and thus determines the nature and scope of many employer obligations concerning employee health and safety.

In addition, the act created a temporary commission to examine the workers' compensation system—the National Commission on State Workmen's Compensation Laws. It also created a permanent advisory body for OSHA, known as the National Advisory Committee on Occupational Safety and Health.

Both OSHA and NIOSH have been criticized since their creation in 1971. OSHA has been called to task by employers and their representatives for issuing standards that are excessively expensive, overly stringent, not based on scientific evidence, or unrelated to employee health and safety. Labor unions, on the other hand, have criticized OSHA for failing to devote adequate resources to enforcement, for delaying or failing to set new regulations, and for considering employers' costs as a basis for health and safety decisions.

NIOSH, too, has been accused of having failed to fulfill its mission. OSHA has complained about the inadequacy of NIOSH's criteria documents for OSHA standard-setting. NIOSH has been criticized by the General Accounting Office for the quality of its criteria document and Health Hazard Evaluation programs. Labor groups have criticized NIOSH for being unresponsive to worker requests. Management representatives have claimed that Health Hazard Evaluations were too aggressively pursued and that NIOSH research was of poor scientific quality.

Separation of Research and Regulation

The OSH Act separated occupational health and safety research activities from standard-setting and enforcement by placing these responsibilities into two different departments of the Federal Government. This may, in part, simply be the result of the history of Federal activities, which prior to the OSH Act had been found in both the Department of Labor and the Public Health Service of HHS and their predecessor agencies. During congressional consideration of the OSH Act (see ch. 11), labor unions strongly supported designation of the Labor Department as the lead regulatory agency. The congressional debate concerning research focused only on the need to enhance occupational safety and health research and to "elevate [its] status" (551).

Separating research from regulatory activity may also help ensure the quality and objectivity of the research. On the other hand, separation may lead to inefficiencies, especially when the activities of the two agencies are poorly coordinated. One observer argued in 1976 that "the enforcement function and priority setting in OSHA are barely connected to the research and manpower development mandated for NIOSH" (30). In 1977, the General Accounting Office concluded that OSHA and NIOSH needed to improve the coordination of their activities concerning the development of workplace health standards (501). In 1978, an Interagency Task Force also made recommendations to better coordinate NIOSH research with OSHA's needs (228). The two agencies have created mechanisms to coordinate activities, although OTA has not attempted to determine how well these agencies work together today.

Besides being separated from OSHA, NIOSH is lower than OSHA in the Federal bureaucracy. Since July 1, 1973, NIOSH has organizationally been part of the Centers for Disease Control. Thus the Director of NIOSH reports to the Director of CDC, who in turn reports to the Assistant Secretary for Health, who reports to the Secretary of HHS. OSHA, on the other hand, is headed by an Assistant Secretary of Labor who reports directly to the Secretary of Labor.

Some Members of Congress have criticized the placement of NIOSH within CDC. For example, in 1973, three Senators argued that this was "contrary to the expressly stated intent of Congress in creating NIOSH, which was to elevate the status of occupational safety and health research in HEW from its relatively low level in 1970. . . " In addition, they criticized the average Federal personnel grade levels that had been established for NIOSH because they were substantially lower than those for OSHA personnel and personnel at the Environmental Protection Agency (232).

The geographical location of NIOSH has also generated considerable interest. In 1981, it was announced that the NIOSH headquarters would be moved from Rockville, MD, to Atlanta, GA, where the headquarters of CDC is located. (Most NIOSH staff, however, continue to work in the NIOSH laboratories in Cincinnati, OH, and Morgantown, WV.) In support of the move of NIOSH headquarters, it was suggested that the scientific and technical base of NIOSH would be strengthened through greater interaction with other CDC programs (303). Further, it was thought that NIOSH would benefit from CDC's expertise in disease and health hazard surveillance and that there would be greater NIOSH involvement in environmental health. Cost savings of approximately $1.5 million per year were predicted to result from this action.

But many people from labor, management, academia, and the occupational safety and health professions believed that moving would be detrimental to NIOSH's ability to perform its mandated responsibilities. In 1981 and 1982, Congress attached a restriction on the appropriations for NIOSH that prohibited this move. At the end of 1982, this restriction was lifted and the move to Atlanta was completed shortly thereafter.

Federal Spending for Occupational Health and Safety

Table 12-1 presents the total budgets (in cur rent dollars and in real, inflation-adjusted dollars) for OSHA and NIOSH and the authorized personnel ceilings. Figures 12-1 and 12-2 present the budget totals graphically. Although OSHA's budget in current dollars has grown over time, in real dollars it peaked in fiscal year 1979, decreasing nearly 13 percent by fiscal years 1982 and 1983.

In current dollars the NIOSH budget grew from 1971 to 1980, but since then it has been substantially reduced, both in current, nonadjusted dollars, as well as in real terms. After adjusting for inflation, the 1983 NIOSH budget is the lowest since 1973 and represents a 42 percent decrease since the peak in 1980. The 1984 budget includes an increase in current dollars ***over*** 1983, largely because Congress restored NIOSH funding for professional training programs. The 1985 budget proposed by the President would reduce the NIOSH budget by completely eliminating these funds.

The reduction since 1980 is illustrated in figure 12-3, which shows the percentage changes in appropriations for several health-related agencies. Funding of agencies with responsibilities for regulating health and safety in the workplace has increased in current dollars over the last 4 years (OSHA and MSHA), while overall funding for NIOSH has consistently decreased. Overall, NIOSH's share of Federal spending for occupational health and safety has been declining. In fiscal year 1974, the NIOSH budget of $35.4 million was about half as much as the OSHA budget of $70.1 million. From fiscal year 1975 through fiscal year 1980, the NIOSH budget varied from being 34 to 42 percent as large as the OSHA budget. The President's budget request for 1985 proposed funding NIOSH at about 26 percent of the level of OSHA funding.

The authorized numbers of personnel for both OSHA and NIOSH generally rose from 1971 to peaks in 1980. From 1980 to 1984, the number of authorized OSHA positions decreased about 25 percent, while NIOSH positions dropped about 16 percent.

Assistant Secretaries and Directors

Table 12-2 lists the men and women who have served as Assistant Secretaries for Occupational Safety and Health and Directors of NIOSH, The first Assistant Secretary for OSHA was George Guenther, who had been head of the Bureau of Labor Standards (the Labor Department predecessor agency to OSHA). He was responsible for the issuance of OSHA's first standards and the beginnings of OSHA's inspection activity. Within 2 years he was replaced by John Stender, who had been an official of the Boilermaker's Union and a State legislator, but who had no previous professional background in occupational health and safety. He presided over the growth of the agency, dramatically increased the number of inspections conducted, and encouraged the development of State plans.

In late 1975 Stender was replaced by Morton Corn, a professor of industrial hygiene at the University of Pittsburgh, who served as Assistant Secretary for just over 1 year. Corn took steps to increase OSHA activity concerning health standards and to conduct more health inspections.

Table 12.1.--Federal Spending for Worker Health and Safety

	Occupational Safety and Health Administration			National Institute for Occupational Safety and Health			State programs		
Fiscal year	Budget (current dollars) (millions)	Budget[a] (1972 dollars) (millions)	Personnel positions	Budget (current dollars) (millions)	Budget[a] (1972 dollars) (millions)	Personnel positions	Federal grants[b] (current dollars) (millions)	Federal grants[b] (1972 dollars) (millions)	Inspector positions
1971 ...., .	7.6[c]	8.2	970	17.7	19.1	501	NA	NA	NA
1972	33.9[c]	33.9	1,696	26.3	26.3	745	NA	NA	NA
1973	69.3	65.6	1,699	25.9	24.5	611	NA	NA	NA
1974	70.1	61.0	1,830	35.4	30.8	611	NA	NA	NA
1975 ...,.	95.8	74.7	2,435	34.0	26.5	735	16.7	13.0	NA
1976	114.9	84.7	2,494	39.3	28.9	848	28.7	21.2	NA
1977	130.2	90.0	2,717	49.7	34.3	898	24.6	17.0	1,139
1978.	138.7	90.2	2,817	56.3	36.6	913	31.4	20.4	1,116
1979.	172.8	106.4	2,944	62.6	38.5	913	37.0	22.8	1,132
1980, ...	186.4	103.1	3,015	80.4	44.5	932	40.0	22.1	1,175
1981	209.4	102.4	3,009	67.8	33.2	841	42.3	20.7	1,110
1982.	195.5	93.1	2,354	62.1	29.6	784	44.1	21.0	1,105
1983.	206.6	93.1	2,258	57.5	25.9	783	47.6	21.5	1,081
1984[d]. . . .	212.6	NA	2,259	65.9	NA	785	49.6	NA	1,036
19850	217.8	NA	NA	56.4	NA	785	NA	NA	NA

[a]Adjusted to constant (1972) dollars using the implicit price deflator for Federal Government nondefense purchases of goods and services for 1972-82 and then rounded to the nearest thousand dollars For 1971, index used was for total Federal Government purchases of goods and services. See *Economic Report of the President*, (1984), table B-3

[b]These figures represent only the Section 18(b) grants given to the States by Federal OSHA For the years presented in this table, these grants were generally for 50 percent of the operating costs of the State program

[c]Activities financed from the appropriation for the Workplace Standards Administration

[d]Appropriation

[e]Request.

NA–Not available.

SOURCE. Office of Technology Assessment, based on data supplied by OSHA and NIOSH

Figure 12-1.—OSHA Budget 1971-85

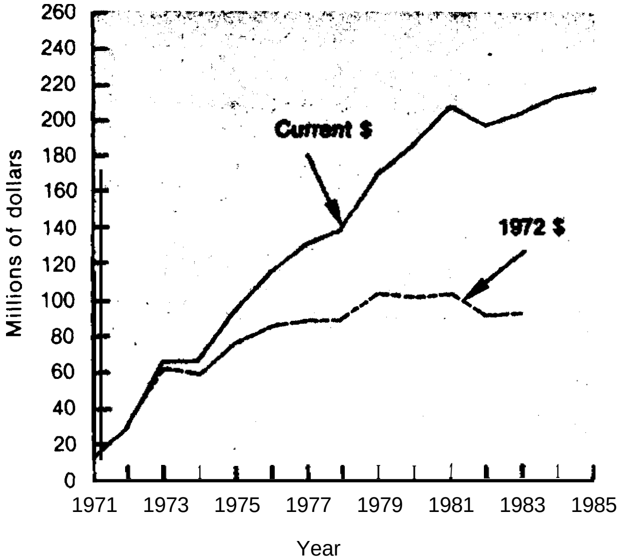
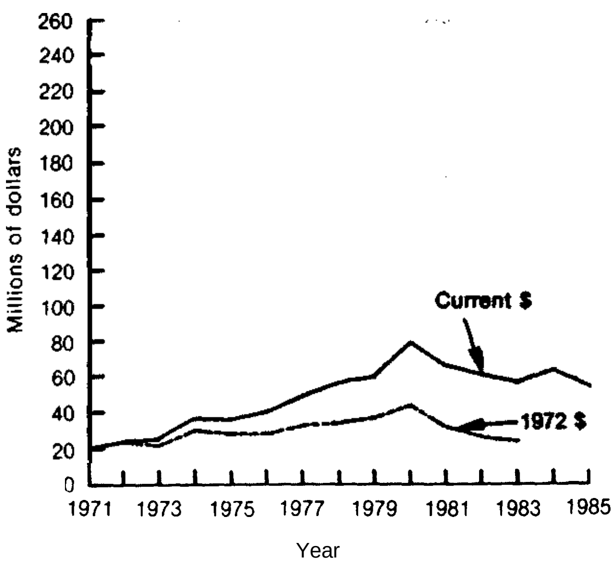


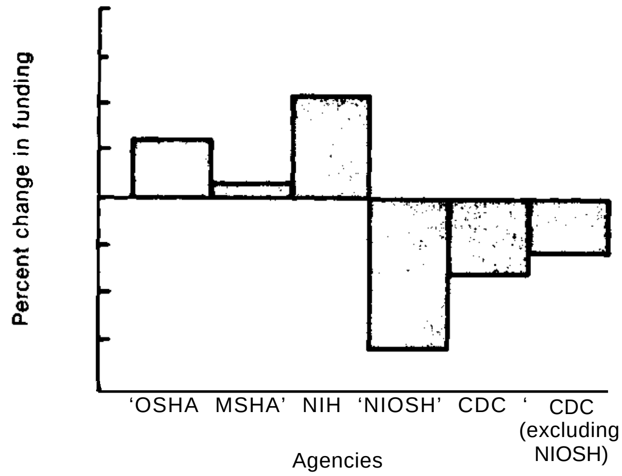
Figure 12-2.— NIOSH Budget 1971-85



He also worked to improve the professional expertise of OSHA staff, especially its inspectors, who had been criticized for their inexperience.

In 1977, Eula Bingham was named to head OSHA. She had been a professor of toxicology and had served on an OSHA advisory committee concerning the coke oven emissions standard.

Figure 12-3.—Percent Change in Appropriations for Selected Health.Reiated Agencies 1980-84



SOURCE Budget of the United States Government

Table 12-2.—OSHA Assistant Secretaries and NIOSH Directors

OSHA	
1. George Guenther	April 1971-January 1973
2. John Stender	April 1973-July 1975
3. Morton Corn	December 1975-January 1977
4. Eula Bingham	April 1977-January 1981
5. Thorne Auchter	March 1981-March 1984
6. Robert Rowland	July 1984-Present
NIOSH	
1. Marcus Key	June 1971-September 1974
2. John Finklea	September 1974-January 1978
3. Anthony Robbins	October 1978-May 1981
4. J. Donald Miller	June 1981-Present

SOURCE Office of Technology Assessment

She acted to eliminate a number of the "nit-picking" standards, for which OSHA had been criticized, and emphasized the development of health standards and "generic standards" (those that would cover exposures to a group of substances, such as carcinogens, or would provide worker access to information, such as employer records concerning exposures, medical care, and chemical substance identity). She also established the New Directions grants program and increased the number of OSHA-funded onsite consultative visits, especially for small businesses.

Theme Auchter, a construction firm manager, took office in 1981. He emphasized a 'balanced" approach to OSHA activities and improved management of agency operations, established a new approach for "inspection targeting, " and encouraged cooperation with employers, especially concerning negotiations about citations, fines, and abatement. Auchter reconsidered a number of the standards issued in previous administrations, reduced the funding for the New Directions Program, increased the funding for onsite consultation, and encouraged the development of State programs. He resigned in March 1984.

In July 1984, Robert Rowland was named to head OSHA. An attorney, he had practiced law privately before being appointed as the Chairman of the Occupational Safety and Health Review Commission. He served in that position from August 1981 until his appointment as Assistant Secretary for OSHA.

In June 1971, Secretary Richardson of the Department of Health, Education, and Welfare announced the establishment of NIOSH. Marcus Key, M. D., previously chief of the Bureau of Occupational Safety and Health in the U.S. Public Health Service, was appointed as the first NIOSH Director. He focused on making NIOSH a functioning organization. Key stepped down in September 1974, after 3 years of his 6-year appointment. John Finklea became the second Director of NIOSH in September 1974 and also served 3 years. He emphasized the production of NIOSH criteria documents to be delivered to OSHA.

Anthony Robbins, a former Commissioner for Public Health in Vermont and Colorado, became the third Director in October 1978. He deemphasized criteria documents and focused on health hazard evaluations and epidemiological field studies. He, too, did not complete a 6-year term, but was fired by HHS Secretary Schweiker in 1981. J. Donald Millar took office as the fourth NIOSH Director in June 1981. Millar has taken several steps to improve the quality of NIOSH research.

THE OCCUPATIONAL HEALTH AND SAFETY ADMINISTRATION

Figure 12-4 presents the organization of OSHA. The main activities of its national office in Washington, DC, are performed by seven directorates, which specialize in developing health and safety standards, coordinating operations of OSHA's inspectors, providing educational and service programs, monitoring State plans, and furnishing administrative and technical support. However, the majority of OSHA staff, including its inspectors, are assigned to area offices that are grouped into 10 different regions.

OSHA Standard-Setting

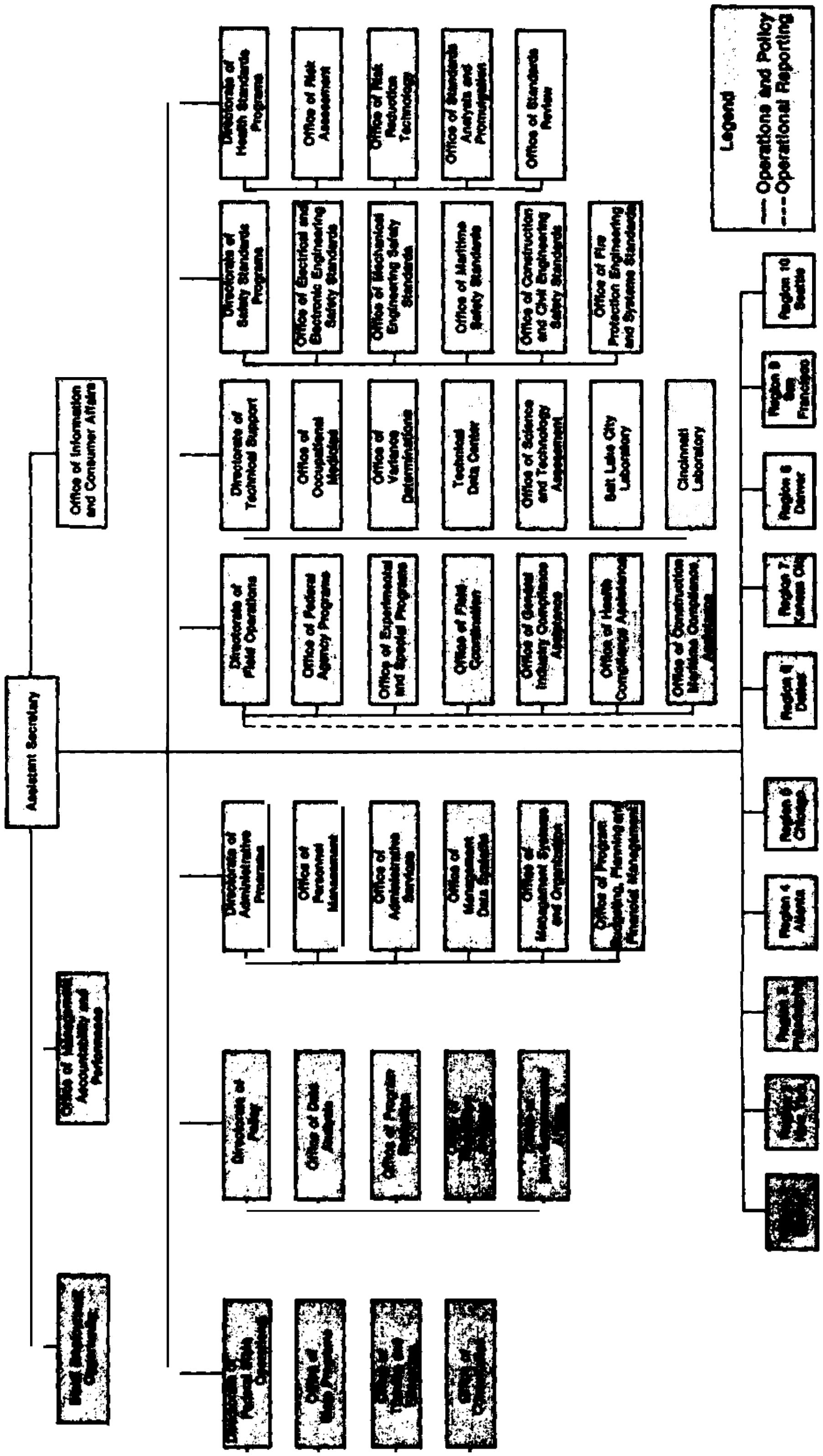
Section 5(a)(1) of the OSH Act, the "general duty clause, " imposes a general requirement that workplaces must be kept safe and healthful. It provides that each employer:

> . . . shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees; . . .

The purpose of the general duty clause is to provide employee protection from some of the hazards that are not currently addressed by OSHA's more detailed regulations. The interpretation of the "general duty clause" is complex and controversial (see brief discussion later in this chapter).

Section 5(a)(2), the "specific duty clause, " requires employers to comply with the more detailed standards issued by OSHA. These standards are Federal regulations that, for example, require employers to observe certain precautions, conduct their operations in specified ways, or install and use certain kinds of equipment. The OSH Act provided OSHA, in sections 6(a), 6(b), and 6(c), with three different methods to issue health and safety standards. The standards issued under these three methods have been termed interim, new or permanent, and emergency temporary standards (333,408). But many of the "interim" standards have not been changed since OSHA began. At the same time, OSHA has taken actions to change some of the "permanent" stand-

Figure 12-4.—Occupational Safety and Health Administration



ards. Mintz (307) suggests that OSHA standards be termed: startup standards, standards issued after rulemaking, and emergency temporary standards.

Startup Standards

Congress mandated that OSHA adopt, without additional rulemaking[1], those health and safety standards that had already been established by Federal agencies or had been adopted as national consensus standards (OSH Act, section 6(a)). This authority was limited to the first 2 years after the act went into effect (April 1971 to April 1973).

The established Federal standards had been adopted by the Department of Labor using procedures that included publication of the proposed requirements and provided the public with an opportunity to comment. The national consensus standards, issued by groups such as the American National Standards Institute (ANSI) and the National Fire Protection Association, were defined by the OSH Act as standards created in ways that allowed the consideration of diverse points of view and the formation of a substantial consensus or agreement by interested persons (Section 3(9)). During hearings before the passage of the OSH Act, industry representatives had argued that the consensus standards were already widely accepted by industry (300).

Congress concluded that because these established Federal standards and national consensus standards were already in effect or represented a voluntary consensus, there was no need for further rulemaking. Rather, the existing standards could be used to provide a minimum level of protection until OSHA could issue its own standards.

Many believe that the new agency, however, acted more quickly than required, by completing work on these standards in only 2 months. Unfortunately, a number of the national consensus standards adopted by OSHA were outdated, unnecessarily specific, or unrelated to occupational health and safety. These included a regulation that prohibited the use of ice in drinking water and a regulation that mandated a specific shape for toilet seats (406). In 1978, under Eula Bingham, OSHA rescinded about 600 of these "nit-picking" provisions that applied to general industry and about 300 that applied to several special industries. However, the process of revising the startup standards continues.

Of more serious consequence, many types of hazards are not adequately addressed by the startup standards. A Presidential task force in 1976 estimated that the OSHA machine-guarding standards (which had been adopted in 1971) covered only 15 percent of the types of machines in use (276). As of 1984, that standard had not yet been revised or expanded. In many cases the organizations that wrote the standards adopted by OSHA in 1971 have revised their standards. OSHA, however, cannot incorporate these changes without going through rulemaking.

Moreover, many of the startup standards specified in great detail the kinds of equipment necessary for compliance. As pointed out by the 1976 task force, this can hinder the development of improved control techniques and lead to unnecessarily costly expenditures for compliance. This task force recommended, and OSHA has accepted, the goal of developing *performance* ***standards*** that require employers to control workplace hazards without specifying the details of equipment design. (The task force also recommended that OSHA publish nonmandatory appendixes to provide information on designs that OSHA considers acceptable to meet its performance standards.)

The startup standards were almost exclusively safety standards. Most of the relatively few startup ***health*** standards had originated in Federal standards adopted under the Walsh-Healey Act prior to the creation of OSHA. These included the Threshold Limit Values for nearly 400 substances that had been set by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1968. In addition, OSHA adopted about 20 ANSI consensus standards that set exposure levels for toxic substances. After eliminating the overlap between these two lists, the startup permissible exposure limits covered nearly 400 toxic substances. Since 1971, the agency has adopted new or revised standards for 23 substances and one physical agent (discussed in the

[1] "Rulemaking" refers to the procedures that Federal regulatory agencies use for adopting regulations.

next section). Some of these were revisions of OSHA's startup standards. Thus the total number of OSHA-regulated substances stands today at about 410.

The latest Registry ***of the Toxic Effects of Chemical Substances*** (586) compiled by NIOSH (as discussed later in this chapter) lists nearly 60,000 separate chemical substances. Not all the 60,000 are found in the workplace and not all are toxic, but there is uncertainty concerning how many hazardous substances are missing from the OSHA list of regulated chemicals. Most of the exposure limits adopted by OSHA have not been revised, and many are now outdated due to increased knowledge about the hazards posed by particular substances. Furthermore, all the startup standards set only a permissible exposure limit. None includes additional requirements for exposure monitoring, medical surveillance, employee training and education, record keeping, or warning labels and signs. (In the mid-1970s, OSHA and NIOSH started actions to add these requirements in what was called the "standards completion project." No regulatory actions were ever completed under that project and it is now "dormant." The only result of that effort is a series of NIOSH publications with recommendations concerning use, monitoring, surveillance, and protective equipment for workers exposed to these substances.)

Standards Issued After Rulemaking

OSHA also has the authority to issue new standards and to modify or revoke existing ones through informal rulemaking. This is authorized by section 6(b) of the OSH Act, which provides for a multistep process. This may start with the receipt of a criteria document from NIOSH, with reports from employers, labor unions, or academics concerning a hazard, or with a petition for a standard from an interested group.

ONHA may convene an ad hoc advisory committee for recommendations. If appointed, such a committee must have an equal number of representatives from labor and management, as well as at least one representative from State health and safety agencies. In addition, other persons with professional expertise may be appointed to the committee. For standards affecting the construction industry, OSHA has adopted a regulation requiring consultation with a standing Construction Safety Advisory Committee. Except for construction standards, OSHA has not used advisory committees to assist in developing standards since the mid-1970s.

In some cases, OSHA publishes an "Advance Notice of Proposed Rulemaking" in the ***Federal Register*** to solicit information from the public. This step, however, is not required.

The first mandatory step is to publish a "Notice of Proposed Rulemaking" that describes the proposed new rule, modification to existing rules, or revocation of existing rule, and that gives interested persons and organizations time in which to comment. An informal, administrative hearing will often take place, which any interested person or organization can attend to present testimony and to cross-examine other witnesses. The agency may later receive written, posthearing comments. After the final decisions have been made, the agency publishes the text of the standard and a statement of reasons in the ***Federal Register.***

A standard typically has staggered startup dates and deadlines. Some provisions go into effect shortly after publication, while others are delayed to allow employers time to plan for compliance. Standards that involve the installation of engineering controls generally allow employers a year or more to complete installation. For example, the OSHA lead standard allows some industries up to 10 years to comply with the requirements for engineering controls.

The agency is also required to develop an economic analysis of the expected effects of the standard. This analysis and the content of the proposed and final regulations are now subject to review by the Office of Management and Budget prior to publication by OSHA. In addition, after final publication by OSHA, a major standard is almost invariably the subject of review by one of the U.S. Courts of Appeals after an interested party challenges its validity. One major issue in the legal challenges to 6(b) rulemaking actions has concerned the interpretation of "feasibility" under the OSH Act, including the extent to which the agency could or must consider employer costs when setting standards (see ch. 14).

Emergency Temporary Standards

OSHA is authorized by section 6(c) of the OSH Act to issue emergency temporary standards (ETS) that require employers to take immediate steps to reduce a workplace hazard. As outlined by the OSH Act, an ETS can be issued after OSHA determines that employees are exposed to a "grave danger" and that an emergency standard is "necessary to protect employees from such danger." An ETS, issued without providing an opportunity for comments or for a public hearing, goes into effect immediately upon publication in the Federal *Register.* The ETS also initiates the process of setting a standard under section 6(b), with the published ETS generally serving as the proposed standard. The act mandates that a final standard be issued within 6 months of publication of the emergency standard.

Major OSHA Rulemaking Actions

Table 12-3 lists the major health standards issued by OSHA since 1971. Through 1984, OSHA issued 18 separate health standards after rulemaking, or about 3 rules every 2 years. The average time required from first announcement of proposed rulemaking until final publication amounts to a little more than 2 years, although the time for particular standards varied from 6 months to 6 years. (This does not include additional time for resolution of legal challenges after publication of a final rule, nor does it consider the standards that OSHA has begun to develop but has not issued in final form.)

Table 12-3.—OSHA Health Standards

OSHA regulation	Final standard
1. Asbestos[a b]	6/07/72
2. Fourteen carcinogens	1/29/74
3. Vinyl chloride[a]	10/04/74
4. Coke oven emissions	10/22/76
5. Benzene[a]	2/10/78
6, DBCP[ac]	3/1 7178
7. Inorganic arsenic.	5/05178
8. Cotton dust/cotton gins	6/23/78
9. Acrylonitrile[a]	10/03/78
10. Lead	11/14/78
11. Cancer policy.	1/22/80
12. Access to employee exposure and medical records	5/23/80
13. Occupational noise exposure/hearing conservation	1/16/81
14. Lead—reconsideration of respirator fit-testing requirements	11/12/82
15. Coal tar pitch volatiles—modification of interpretation	1/21/83
16. Hearing conservation-reconsideration	3108/83
17. Hazard communication (labeling)	1/25/83
18. Ethylene oxide	6122184

[a]Subject of an Emergency Temporary Standard,
[b]Emergency standards were issued for asbestos in 1971 and 1983
[c]1,2-dibromo-3-chloropropane.
NOTE: Additional details on these standards can be found in table A-1 of appendix A.
SOURCE: Off Ice of Technology Assessment.

Ten of OSHA's final actions on health standards established new Permissible Exposure Limits (PELs) and other requirements for monitoring and medical surveillance (asbestos, vinyl chloride, coke oven emissions, benzene, DBCP, arsenic, cotton dust, acrylonitrile, lead, and ethylene oxide). Two others did not institute or change a PEL: the"14 carcinogens" standard created new requirements for work practices and medical surveillance for a group of carcinogens, while the hearing conservation amendment modified an existing standard with requirements concerning noise monitoring, audiometric testing, hearing protection, employee training, and record keeping.

Thus 12 separate proceedings resulted in new or revised requirements concerning 24 specific substances and 1 physical agent. However, the hearing conservation amendment, the 1978 standard for benzene, and the requirements for one of the 14 carcinogens have been ruled invalid by the courts. (As described in table A-1 in app. A, some of these standards are still under judicial review and several are being reconsidered by OSHA. The application of some requirements in several industries has also been delayed by OSHA or the courts.)

Three regulatory proceedings established new "generic" requirements. The access to records standard created requirements concerning the keeping of exposure and medical records and for providing employee access to those records, while the hazard communication standard requires that hazardous substances be labeled and information provided to employees about the substances and the precautions to be taken, The cancer policy set a general OSHA policy concerning future standards regulating carcinogens. Finally, three proceedings reconsidered and then modified existing requirements (respirator fit-testing for lead exposure, coal tar pitch volatiles, and hearing conservation).

Table 12-4 lists the safety standards issued by OSHA after rulemaking. In OSHA's first 13 years there were 26 such regulations. Many of these safety standards have involved rewriting regulations adopted as startup standards, while two proceedings have revoked a number of specific provisions and advisory language that OSHA inherited from the consensus standards adopted in 1971. In general, these changes in safety standards did not impose large increases in costs to employers. Most of them can be grouped by subject: electrical, mechanical, fire protection, construction, or maritime safety.

Tables 12-3 and 12-4 also indicate the hazards and substances for which OSHA has published emergency temporary standards. In all, there have been seven separate emergency actions concerning 19 specific substances, one ETS concerning an activity (diving), and an attempt to regulate a group of 21 pesticides with an emergency standard. (It should be noted that asbestos has been the subject of an ETS twice-in 1971 and in 1983.) Of the 11 completed proceedings on specific substances, six began with the issuance of an ETS. But because an ETS requires employers to take action before giving them an opportunity to file comments or objections, these emergency actions have often been controversial and several of them have been ruled invalid by reviewing courts. OSHA's successes with emergency standards have been those cases in which labor, management, and professionals all agreed that a problem existed and that swift action was appropriate. But in those cases challenged by employers, the courts have been reluctant to allow OSHA to impose an ETS.

Box N outlines OSHA's regulation of vinyl chloride monomer. See Ashford (30), Kelman (245), and McCaffrey (290) for short histories of

Table 12-4.--OSHA Safety Standards

OSHA regulation	Final Standard
1. Miscellaneous amendments for construction	2/17/72
2, Cranes/derricks (load indicators)	7/14/72
3. Roll-over protective structures (construction)	4/05/72
4. Miscellaneous amendments for construction	11/16/72
5. Power transmission and distribution	11/23/72
6. Scaffolding, pump jack scaffolding, and roof catch platforms	12/02/72
7. Lavatories for industrial employment	5/03/73
8. Trucks, cranes, derricks, and indoor general storage	6/01/73
9. Temporary flooring—skeleton steel construction	7/02/74
10. Mechanical power presses–("no hands in dies")	12/03/74
11. Telecommunications.	3/26/75
12. Roll-over protective structures for agricultural tractors	4/25/75
13. Industrial slings.	6/27/75
14. Guarding of farm field equipment, farmstead equipment, and cotton gins	3/09/76
15. Ground-fault protection	12/21/76
16. Commercial diving operations.	7/21/77
17. Standards revocation	10/24/78
18. Servicing multi-piece rim wheels	1/29/80
19. Fire protection	9/12/80
20. Guarding of low-pitched roof perimeters during the performance of built-up roofing work.	11/14/80
21. Design safety standards for electrical standards	1/16/81
22. Latch-open devices (on gasoline pumps)	9/07/82
23, Diving exemptions	11/26/82
24. Marine terminals	7/05/83
25. Servicing of single-piece and multi-piece rim wheels	2/03/84
26. Revocation of advisory "should" and repetitive standards	2/10/84

[a]Subject of an Emergency Temporary Standard

NOTE: Additional details on these standards can be found in table A-2 In appendix A.

SOURCE" Off Ice of Technology Assessment.

Box N.—Regulation of Vinyl Chloride

Vinyl chloride was first synthesized in the 19th century, but it did not become commercially important until the 1930s when it was discovered that its polymer, polyvinyl chloride (PVC), could be used to make products that resembled natural rubber. By the 1970s, PVC had become the second most widely used plastic in the United States, used in the production a large number of industrial and consumer goods.

Prior to 1970, several health effects had been associated with exposures to vinyl chloride, including liver damage, dermatitis, effects on the central nervous system, and a bone disease known as acroosteolysis. In [illegible], the American Conference of Governmental Industrial Hygienists adopted a Threshold Limit Value of 500 parts per million (ppm) for vinyl chloride, based on its acute liver toxicity. This limit was adopted by OSHA in 1971 as a startup standard under section 6(a) of the OSH Act.

A group of Italian scientists first discovered that vinyl chloride was a carcinogen when they found tumors in rats that had been exposed to very high levels (30,000 ppm) of vinyl chloride vapor. This finding was reported at a U.S. conference in July 1970. In January 1973, another Italian researcher confirmed the cancer-causing properties of vinyl chloride, this time at levels (250 ppm) below the OSHA standard, but these results were not widely disseminated. There was no regulatory activity based on these animal studies.

In December 1973, the plant physician at a B.F. Goodrich PVC plant in Louisville, KY, learned that a worker had died of a very rare form of cancer—angiosarcoma of the liver. The physician recalled that another worker from the same plant had also died of this disease and began to investigate the possible work-relatedness of these two deaths. Shortly thereafter, a third angiosarcoma death was discovered, and B.F. Goodrich informed NIOSH and the public about these deaths in January 1974. NIOSH sent personnel to several plants with vinyl chloride exposures, conducted industrial hygiene surveys, and made recommendations for controls.

A week later, OSHA announced that it would hold a public fact-finding meeting in mid-February. By that meeting date, Goodrich had discovered two additional angiosarcoma deaths, and at about the same time the results of the study linking exposures of 250 ppm to cancer in rats were publicly released. In April 1974, OSHA issued an emergency temporary standard limiting exposures to a 50 ppm ceiling.

A few days later, OSHA learned that rats exposed to 50 ppm had also developed liver tumors. In the months after the original Goodrich announcement, a number of other worker deaths from angiosarcoma [illegible] were discovered. (By August 1974, 21 such cases had been uncovered, and preliminary [illegible] results also indicated an increase of lung, brain, and the lymphatic system cancers among [illegible] exposed to vinyl chloride (225,571)). With this accumulating evidence, OSHA decided to propose a more stringent standard. In May 1974 it published a proposal to limit employee exposure to [illegible] of vinyl chloride using a specified measurement technique. This followed an earlier [illegible], which had concluded that this method of measurement could be used to detect [illegible] ppm or greater.

[illegible] dominated the public hearings held in June: first, whether the standard was supported by [illegible] evidence, and second, whether it was technologically and economically feasible. Industry [illegible] did not dispute the evidence that vinyl chloride was a carcinogen, but they did argue [illegible] not enough evidence to show that it was a human carcinogen at levels below 250 ppm. [illegible] that it was technologically impossible to meet the "no detectable level" specified [illegible]. If OSHA issued this standard, these representatives argued, the entire vinyl chloride [illegible] would shut down. A study they had commissioned concluded that if such a shutdown [illegible] would lead to a loss of 1.7 to 2.2 million jobs and a loss of $65 billion to $90 billion [illegible]. Labor unions and a public interest group, on the other hand, [illegible] the OSHA proposal at the hearings.

OSHA published the final standard for vinyl chloride in October 1974. Instead of setting an exposure ceiling at a "no detectable level," it issued a limit of 1 ppm, measured as an 8-hour time weighted average (TWA), and a ceiling limit of 5 ppm measured over any 15-minute period. Setting a TWA of 1 ppm, instead of an exposure ceiling set at a "no detectable level," represented some concession to the concern about the feasibility of the standard. But in the subsequent court challenge, industry attorneys argued that even this standard was technologically impossible. The Court of Appeals for the Second Circuit, however, rejected the industry arguments and upheld the OSHA standard.

Actual compliance with the standard occurred almost as swiftly as the regulatory proceedings. The technology to reduce worker exposures to within the allowable limits was developed quickly (see ch. 5). Some of these control techniques also increased productivity by reducing leaks, improving product quality, reducing the time for cleaning the reactor vessels, and combining previously separate processes. Several companies were able to sell the new production techniques to other companies, thus obtaining income through licensing fees (142). Only a few months after the standard went into effect, it was reported by a trade journal that compliance would "not . . . be a serious operating or cost problem" (142,149). OSHA inspection data from 1976 and 1977 revealed that more than 90 percent of the samples taken were in compliance with the standard (142).

A trade association estimated in 1975 that the vinyl chloride industry invested $200 million in capital expenses and $100 million in research costs (142). A group of researchers at the University of Pennsylvania concluded that the industry spent between $158 million and $182 million in capital costs for compliance with the standard. In addition, they estimated that compliance might increase annual operating costs by $7 million to $10 million (332). These estimates, however, do not take into account the increases in production efficiency, the reduction in raw materials costs, and the licensing revenues that resulted from the standard (142).

The Pennsylvania researchers also concluded that several vinyl chloride plants had shut down or reduced production after the standard was issued, resulting in the loss of 375 production jobs (although only 60 workers were actually laid off) and a 15 to 20 percent cutback in industry capacity. The researchers noted that these plant cutbacks are the result of several factors, although the industry representatives they interviewed frequently cited the OSHA standard as "the straw that broke the camel's back" (332). The production cutbacks, however, appear to have occurred in older plants and at a time of slack demand for vinyl chloride products (142). The other existing plants appeared to have had little difficulty in complying with the standard.

In addition, construction costs for new plants were not significantly increased by the OSHA standard. In fact, by 1979, the industry had added new plants that increased vinyl chloride production capacity by 41 percent and PVC capacity by 85 percent over 1974 levels. Since the standard was issued in 1974, several existing producers of vinyl chloride and PVC have expanded their operations and a number of firms have entered these markets for the first time (142,332). These expansions have created an estimated 2,000 jobs since 1974, more than offsetting the estimated job losses. In addition, during the years immediately after the issuance of the standard, the growth rates for these industries were substantially above the average for U.S. industry and profits increased (142).

Irving Selikoff has summarized the events surrounding the regulation of vinyl chloride:

> It was a success for science in having defined the problem; success for labor in the rapid mobilization of concern; success for Government in urgently collecting data, evaluating it, and translating it into necessary regulations; and success for industry in preparing the necessary engineering controls to minimize or eliminate the hazard (671).

SOURCES: (38,75,142,149,225,245,332,365,381,412,561,571,615,616,617,671.)

some of OSHA's standards. Mintz (307) provides a number of excerpts of the formal documents concerning many of these standards.

Enforcement

Inspections and enforcement are the heart of the regulatory scheme in the OSH Act. Congress created an agency that is predominantly an enforcement agency conducting unannounced inspections and levying penalties for the "first instances" of violations, as well as for repeated violations.

The goals of enforcement are both to correct identified hazardous conditions in inspected plants and to provide an incentive for uninspected plants to eliminate or reduce hazards. This second goal has often been called "voluntary compliance," although it is misleading to label as "voluntary" actions taken by employers in the face of mandatory standards with the potential threat of inspection and civil penalties. "Reinspection compliance" is perhaps a better term (408). In practice, the incentive for preinspection compliance is actually quite small, because of both the low probability of inspection and the low level of penalties (see discussion later in this section).

Inspection Types and Priorities

OSHA conducts a number of different kinds of inspections. The first basic division is between inspections for safety hazards and those for health hazards (table 12-5). The percentage of health inspections increased from about 6 percent in the early 1970s to a peak of about 19 percent in fiscal year 1979. This has fallen slightly to a range of 17 to 18 percent in the last three fiscal years. (The decline would be larger, to about 15 percent, if "records review" safety inspections were included in the totals on table 12-5.)

OSHA also classifies its inspections by priority. It attempts to investigate first those hazards posing the greatest threat to employee health and safety. The order of priority is:

- Imminent danger
- Catastrophe and fatality investigations
- Employee complaints
- Special inspection programs
- Programed inspections.

Imminent danger inspections are conducted when OSHA learns of a hazard that can be expected to cause death or serious physical harm before it could be eliminated through normal enforcement activity. Catastrophe and fatality investigations, second on the list, are spurred by reports of fatal occupational injuries or of incidents that result in the hospitalization of five or more employees.

The third priority is employee complaints. Under section 8(f) of the Act, employees and their representatives who believe that an employer is

Table 12-5.--Federal OSHA Safety and Health Inspections

Federal OSHA fiscal year	Establishment Inspections (number)	Safety Inspections (number)	Safety Inspections (percent)	Health Inspections (number)	Health Inspections (percent)
1973	48,409	45,225	93.4	3,184	6.6
1974	77,142	73,189	94.9	3,953	5.1
1975	80,978	75,459	93,2	5,519	6.8
1976	90,482	82,885	91.6	7,597	8.4
1977	60,004	50,892	84,8	9,112	15.2
1978	57,278	46,621	81.4	10,657	18.6
1979	57,734	46,657	80.8	11,077	19.2
1980	63,404	51,565	81.3	11,839	18.7
1981	56,994	46,236	81.1	10,758	18.9
1982	52,818[a]	43,609	82.6	9,209	17.4
1983	58,516[b]	48,269	82.5	10,247	17.5
1984 (first six months)	30,606'	25,086	82.0	5,520	18.0
Total.	734,365	635,693	86.6	98,672	13.4

[a]Does not include 8,444 "Records Review" inspections.
[b]Does not include 10,402 "Records Review" inspections.
[c]Does not include 4,9S3 "Records Review" inspections.

SOURCE: Office of Technology Assessment, based on data supplied by OSHA.

violating a health and safety standard may request an inspection. OSHA schedules inspections to respond to what it determines are valid complaints. The fourth priority-special inspection programs—includes programs to give special attention to certain designated hazards and industries. Over the last decade, the agency has announced several such programs: the Target Industries Program, the Target Health Hazard Program, and the National Emphasis Program. Currently, OSHA is giving special attention to the construction industry, oil-well drilling, and grain elevators.

The lowest priority inspections, but by far the most frequent, are programed ones. (In the past, these have been termed "general schedule" inspections.) Although sometimes called "random inspections, " they now focus on industries with high injury rates or those with known health hazards. Over the past 12 years, OSHA has used a series of different scheduling systems. For safety inspections, industries are ranked using injury rate information from the Bureau of Labor Statistics (BLS) Annual Survey. Only industries with injury rates above the national average for the private sector are now selected for safety inspections. For health inspections, OSHA now selects industries based on the last 5 years of OSHA health inspections. Industries are ranked based on their respective violation rates. Individual establishments are selected by using commercially available lists of employers to identify the establishments with 10 or more employees in these selected industries (635).

One other inspection category should be noted. Follow-up inspections can be conducted at any time to determine if workplace conditions have changed following an inspection. In particular, OSHA is interested in verifying that abatement of a hazard has taken place by a scheduled date. (For information on the types of inspections, see 307,333,408,635.)

OSHA has, through policy changes, varied the distribution of inspection activity among these categories. For example, the proportion of inspections triggered by employee complaints increased from about 10 percent in fiscal year 1976 to over 30 percent in fiscal year 1977, In recent years the percentage of complaint inspections and follow-up inspections has declined, while the percentage devoted to programed inspections has increased (see table A-5 in app. A).

Enforcement Procedures

The conduct of all these inspections follows the same general outline. The inspector (formally, the Compliance Safety and Health Officer) arrives at the workplace, almost always without advance warning, presents his or her credentials, and speaks with the employer, manager, or other person in charge. An opening conference is held with the employer (and a union representative, if any) to describe the purpose of the visit. The inspector asks to see any employer-maintained records that might be relevant (logs of injuries and illnesses, exposure and medical surveillance records, etc.).

Then the inspector conducts a "walk-around," visiting all or part of the workplace. Both the employer and an employee representative have the right to accompany the inspector on this tour. The inspector observes workplace conditions and takes notes, photographs, and exposure samples as may be appropriate. After the walk-around, a closing conference is held (either jointly with both employer and employee representatives, or separately), at which time apparent violations of OSHA standards are discussed. Normally, citations are not issued at this closing conference, but are mailed later. This is to allow consultation between the inspector and the area director and to obtain the results of laboratory analysis of exposure samples.

The Fourth Amendment to the U.S. Constitution generally protects persons from "unreasonable searches and seizures" by government officials. There are certain circumstances in which police are allowed to search without consent, but in general a warrant must be obtained for such a search. The question of whether OSHA is also subject to these requirements in conducting its inspections of workplaces was raised most prominently in a 1976 case concerning an Idaho employer, Barlow's Incorporated. The case was ultimately appealed to the Supreme Court, which ruled that OSHA had the constitutional authority to conduct inspections, but that if the employer did not voluntarily consent to the inspection, the agency would need to obtain a court-issued warrant (see 307,333,408).

Although Congress has never amended the OSH Act, it has limited OSHA inspection activity by attaching restrictions to OSHA's appropriations. Currently OSHA is prohibited from conducting programed safety inspections in establishments with 10 or fewer employees in an industry with a led-workday rate lower than the national average; from assessing penalties for the "first instances" of nonserious violations (unless 10 or more total violations are cited); from assessing penalties against an employer with 10 or fewer employees who had requested an onsite consultation and is acting to eliminate identified hazards; from issuing or enforcing standards for small farming operations (10 or fewer employees); and from activities that would affect recreational hunting, shooting, or fishing. There are also restrictions on visits designed to monitor State programs and on OSHA activities on the Outer Continental Shelf (489a).

Current Inspection Targeting

A new procedure for safety inspections was instituted on October 1, 1981. Since then, OSHA inspectors conducting programed safety inspections have also examined the injury and employment records of the employer and calculated an average lost-workday case rate for the previous 2 years (or 3 years, for establishments with 10 to 20 employees). If the lost-workday case rate is less than the national average rate for manufacturing, the inspection is terminated. The national average injury rate is derived from the BLS Annual Survey and currently is 4.2 cases per 100 full-time employees (644). (In table 12-5, these visits are termed "records review. " Termination of inspection because of a below-average injury record does not currently apply to safety inspections in the construction industry, nor does it apply to health inspections in any industry.)

In theory, this policy of ending inspections for "low-hazard" establishments can create an incentive for employers to take steps to reduce injury rates. It also may help OSHA to use its scarce inspection resources efficiently by concentrating attention on establishments with higher-than-average injury rates. There is concern, however, that this policy may also serve as an incentive for systematic underrecording of the number of injuries, although inspectors are instructed to verify the accuracy of employer injury records.

Compliance with Standards and the General Duty Clause

Unless they have obtained a variance, employers are required by section 5(a)(2) of the OSHA Act (the specific duty clause) to comply with the terms of OSHA standards and regulations. During inspections, inspectors look for any violations, following the procedures and interpretations issued by OSHA in its *Field Operations* ***Manual, Industrial Hygiene Manual,*** and program directives.

Employers must also comply with section S(a) (1) of the act–the general duty clause. This has been used to cover hazards not treated by OSHA's more specific standards. There has been controversy concerning the interpretation of this clause and its application to employers by OSHA.

To prove a violation of the general duty clause, OSHA must demonstrate that the employer failed to render the workplace free of a "recognized" hazard that was causing or was likely to cause death or serious physical harm. OSHA and the courts have held that a hazard is recognized if the employer had knowledge of the hazard or if it is of common knowledge in the industry in question and detectable by the senses or by techniques generally known and accepted by the industry (307, 333,408). OSHA uses a number of different sources of information to demonstrate that a hazard is "recognized," including voluntary standards, statements of industry experts, implementation of abatement programs by other companies in the same industry, manufacturers' warnings, or studies conducted by the industry, its employees, the government, or insurance companies (203).

The Role of OSHRC

An employer who disagrees with OSHA concerning a citation, a proposed penalty, or the date for abatement of the hazard can file a notice of contest. Employees also have an independent right to contest the reasonableness of the length of the proposed period of time for abatement of a hazard. Unless contested within 15 days, an OSHA citation becomes final. When contested, a hearing is held before an Administrative Law Judge (ALJ), who is an employee of the OSHRC, an independent review body.

At the hearing before the ALJ, both OSHA and the employer present their sides of the case. Affected employees and their representatives have a right to participate in these proceedings. During the period when the citation is under contest, no abatement is required.

The ALJ examines the evidence and decides whether to affirm, vacate, *or* modify OSHA's citation and proposed penalties. After this decision, any party can petition the Occupational Safety and Health Review Commission to review the decision of the ALJ. The Commission can grant such review either upon request or by its own choice. Unless it is ordered to be reviewed within 30 days by a member of OSHRC, the ALJ decision becomes a final order of the Commission. Any adversely affected person can then petition a U.S. Court of Appeals for judicial review (307,333,408).

Informal Conferences

Current OSHA policy encourages the use of informal conferences between employers and OSHA's area directors to reach settlements concerning citations. Using such conferences to settle citations might facilitate prompt abatement of hazards and improve employee health and safety, as well as reduce the time spent by government personnel, employers, employees, and their representatives resolving contested citations. The first directive on this was issued by Eula Bingham in 1980.

Assistant Secretary Theme Auchter strongly encouraged the use of these settlements by OSHA's Area Directors. During his tenure as head of OSHA, the number of informal settlements increased dramatically. But there have been suggestions that some of these settlements may not sufficiently protect worker health and safety (440). Moreover, if the settlement agreement provides for eliminating penalties, or reducing them to very low levels, the incentive for preinspection compliance is virtually eliminated.

Recent court decisions limit the rights of employees and unions to object to settlements that they view as insufficiently protective. If the employer is no longer contesting the citation, the rights of employees and unions to object is limited to the "reasonableness of the abatement period. "

(In addition, OSHA enforces the provisions of the OSH Act that prohibit employers from discriminating against employees who exercise any of the rights provided by the OSH Act. See ch. 15 for a discussion of this protection and other employee rights.)

Incentives for OSHA Compliance

In theory, OSHA's enforcement activities will lead employers to comply with OSHA regulations and to improve employee health and safety. But in practice OSHA has never had the resources to inspect more than a relative handful of the Nation's workplaces. In addition, the average penalties levied for violations uncovered in the "initial" visits to workplaces are very small, especially when compared with the costs of many types of controls (see box T in ch. 15). Thus, there is only a weak incentive for employers to comply prior to an OSHA inspection.

In fiscal year 1983, OSHA conducted about 58,500 establishment inspections and about 10,400 "records ***review"*** visits, The various State programs conducted an additional 104,000 establishment inspections and about 2,500 "records review" visits. This makes for a Federal-State total of about 162,000 establishment inspections and 13,000 "records review" visits. As there are about 4.6 million private sector establishments in the United States (553), OSHA and the State programs can inspect less than 4 percent of U.S. establishments.

The probability of a health inspection is substantially less than the probability of a safety inspection. Of all fiscal 1983 inspections, about 21,000 were health inspections. Thus, of each 1,000 establishments, about 31 receive a safety inspection, 3 receive a "records review" visit (which covers only safety), and fewer than 5 receive a health inspection.

OSHA and the States do, however, concentrate their activities on certain industries. For example, in fiscal year 1983 the agency conducted about 58 percent of its establishment inspections in construction and about 33 percent in manufacturing. This would imply about 54,000 establishment inspections in the approximately 321,000 manufacturing establishments nationwide (assuming that the State plans conduct the same proportion of inspections in manufacturing as does OSHA). Therefore, OSHA and the State programs are currently able to inspect a maximum of about 17 percent of manufacturing establishments (assuming one inspection per establishment in any given year).

At this rate of inspection, OSHA and the State programs can inspect each establishment in manufacturing only once every six years. The inspection rate for most other industries with fixed establishments—transportation, wholesale and retail trade, finance, services, and agriculture—is substantially less than this. (Because of the limits of available statistics, it is difficult to estimate the probability of inspections at construction sites.)

Even if an establishment is inspected, the penalties for violations are quite low. The average proposed penalty for a "serious" violation (one that creates a "substantial probability [of] death or serious physical harm") for OSHA and the State programs in fiscal year 1983 was about $172. Of course, this is only for violations that are actually discovered and cited, and does not include the penalties levied for "other than serious," "willful," "failure to abate," and "repeat" violations. In fiscal year 1983, OSHA and the State programs proposed penalties totaling about $13.4 million for all violations in the 162,000 establishment inspections that were conducted, an average penalty of about $83 per inspection.

As discussed in chapter 14, employers making decisions to maximize profits will tend to choose the least costly alternative. Thus the employer faces a choice of spending a certain sum to control a hazard and comply with OSHA standards, or not controlling a hazard and possibly being inspected and penalized for noncompliance. The decision will be based on a number of factors, including the probability of inspection and the likely penalties if an inspection takes place and the hazard is detected.

As discussed above, for establishments in manufacturing, the probability of inspection is only about one in six, while the average proposed penalty for "serious" violations was about $172. A decision based purely on a desire to maximize profits would be to spend on controls only when the annual cost of controls is less than the annual expected costs of noncompliance. If it is assumed that the inspection will detect the violation, the expected costs for each serious violation equals one-sixth of $172 or about $29. The average proposed penalty for all violations was $39. With a one in six probability of inspection, this implies an expected penalty for noncompliance of about $6.50. (See 64,127,287, and 685 for similar estimates based on older data.)

Of course, employers may take actions out of altruistic concern about the health and safety of their workers or because of the other incentives described in chapter 15. In addition, for employers who have been inspected recently, there is the threat of a repeat inspection. In these cases, the fines for "failure to abate" an identified hazard can be very substantial. Thus the incentives for compliance are much larger after an OSHA inspection. What is clear, however, is that the economic incentive for ***preinspection*** compliance is small.

In fiscal year 1983, compared with fiscal year 1980, OSHA issued 40 percent fewer serious violations, 55 percent fewer repeat violations, and 85 percent fewer willful violations. Consequently, the total penalties it has proposed declined by nearly 60 percent (see tables A-8 and A-10 in app. A). This change has also been accompanied by a decline in the number of inspections with contested citations (from nearly 12 percent of inspections to less than 2' percent) and may lead to prompt abatement of hazards in firms that have been inspected. However, the reduction in penalties also significantly weakens the small economic incentive for employers to comply with OSHA standards.

At least one commentator has suggested that "OSHA will not be a meaningful deterrent until the cost of noncompliance becomes greater than the cost of compliance" (406). Violations of some requirements for pollution control have been penalized with fines that are equivalent to the financial benefits that a firm receives from noncompliance. This began in 1973 in Connecticut, and at the Federal level with the 1977 Clean Air Act Amendments. Recently, the Environmental Protection Agency announced plans to extend this policy to other pollution control requirements, along with other changes in its policies concerning civil penalties (163).

An Interagency Task Force on Workplace Safety and Health recommended that OSHA develop procedures to set its penalties at levels equal to the benefits of noncompliance (228). Such a change, although clearly providing employers a larger incentive to comply with OSHA standards, would probably increase the level of controversy in OSHA enforcement proceedings.

Public Education and Service

The third major category of OSHA activities can be called public education and service. This includes OSHA-funded consultation, the projects assisted by grants under the New Directions program, and OSHA's "voluntary protection programs." These activities, although different in many ways, are all designed to improve workplace health and safety through methods other than direct standard-setting and enforcement.

The OSH Act devotes only a few lines to education and service activities, in contrast to the many paragraphs establishing the new agencies and specifying the authority of these agencies for standard-setting, enforcement, and research. Section 2(b)(2) declares that one purpose of the Act is to

> . . . encourage] employers and employees in their efforts to reduce the number of occupational safety and health hazards at their places of employment, and to stimulate employers and employees to institute new and to perfect existing programs for providing safe and healthful working conditions; . . .

Section 21(c) provides specific authorization for OSHA to conduct "education and training of employers and employees in the recognition, avoidance and prevention of unsafe or unhealthful working conditions" and to "consult with and advise employers and employees, and organizations representing employers and employees as to effective means of preventing occupational injuries and illnesses. "

Consultation

Consultation is the provision of information, measurements, and advice about controls without threat of citation or penalty. Section 9(a) requires that when OSHA personnel discover violations of standards, the agency "shall with reasonable promptness issue a citation to the employer" (emphasis added). This absolute language has been interpreted to prohibit the agency from engaging in employer consultation at the worksite. Rather, OSHA personnel must issue citations if violations are found. This language originated in response to the history of frequently ineffective State health and safety agencies, which prior to 1970 often gave inspectors the discretion of issuing or not issuing citations and penalties.

OSHA, therefore, has limited its direct consultation to phone calls, letters, office visits, and speeches at employer gatherings. Partly from congressional interest, expressed through proposed legislation and the appropriations process, and partly from OSHA itself, actions have been taken to provide for onsite consultation for employers desiring this service. Because of the section 9 language, Federal OSHA personnel do not themselves conduct these visits. Rather, through various contractual and grant mechanisms under sections 18(b) and 7(c)(1), OSHA pays for visits by State personnel (usually in departments of labor, industry, or health) or private consultants.

The purpose of the onsite consultation program is to provide employers with a confidential evaluation of the health and safety hazards in their workplaces, and to recommend means of hazard abatement. An onsite consultation will let an employer know how the business measures up to the relevant OSHA standards. This service is provided at no cost to the employer, and priority is given to requests from small businesses. Visits occur only at the request of the employer and the results of the visit are provided only to the employer. Consultation is not available to employees or their unions, nor do they have a right to the information provided to the employer by the consultant, although employers may voluntarily turn that information over to employees. This program has increased substantially from 1975 to today. In fiscal year 1983, OSHA funded about 28,000 onsite visits, at a cost of $23.4 million (see table 12-6).

In 1978, the General Accounting Office (GAO) issued a report criticizing OSHA's management of the consultation program, suggesting that OSHA's policies were not sufficient to ensure protection of worker health and safety (505). Changes in the program have been made since then, but a continuing controversy concerns the relative emphasis of enforcement versus consultation, which parallels the debate about the relative merits of mandatory standards versus voluntary efforts. Many think that Government should engage in consultation in order to assist well-meaning but ignorant employers to improve health and safety. Others suggest that such an approach is largely ineffective and tends to divert resources from enforcement activities that require, rather than merely encourage, health and safety improvements.

In 1982, OSHA began an experimental program in two regions to grant employers a one-year exemption from programed inspections if they apply for and receive a health and safety consultation. In 1984 that program was made permanent and extended nationally. Now employers who agree to a comprehensive onsite consultation, correct all hazards detected during the consultation, and implement the "core elements of an effective safety and health program" can be given a one-year exemption from programed inspections (355, 648). However, given the low probability of an inspection, this one-year exemption may not represent a very large incentive to participate in this program.

OSHA has also modified its policy concerning the provision of onsite information by agency inspectors. OSHA still issues citations for apparent violations, but inspectors are now required to provide "general assistance" to employers in identifying abatement methods for alleged violations (629). In addition, OSHA has recently announced plans to create "full-service area offices. " The goal is the creation of "resource centers" that employers can use to obtain information on occupational safety and health and on compliance with OSHA standards.

New Directions Program

The New Directions program was established by OSHA in 1978 to provide grants to employee, employer, educational, and nonprofit organizations for the purpose of providing workplace health and safety training, resources, and services for employers and employees. Grantees have used these funds to develop educational materials, conduct training sessions, provide technical assistance concerning health and safety hazards, and hire technical staff. OSHA has provided the bulk of the funds for this program, and additional money has come from the National Cancer Institute, NIOSH, the Federal Emergency Management Agency, and the National Institute of Mental Health (636).

The program has recently been cut back substantially, from $13.9 million in fiscal year 1981, to $6.8 million for fiscal years 1982 and 1983. (This does not, however, include funds from the National Cancer Institute that are also included in this program.) Similarly, the number of organizations receiving grants has declined from 156 in fiscal year 1980 and 142 in fiscal year 1981 to 100 in fiscal year 1983 (34).

Table 12-6.—OSHA Onsite Consultation Program

	1975	1976	1977	1978	1979	1980	1981	1982	1983
Budget (in millions of dollars)	3.0	9.0	9.0	11.5	17.0	17.0	21.0	21.0	23.4
Requested consultations (estimated)	3,500	10,500	11,750	17,400	20,750	22,650	22,304	28,192	30,706
Visits conducted	3,357	10,527	11,326	16,882	20,231	22,110	21,820	27,477	28,272
Serious hazards	Data not available							25,361[a]	28,849
Other-than-serious hazards	Data not available								68,059[b]
Cost per consultation	$ 894	$ 855	$ 795	$ 681	$ 840	$ 769	$ 962	$ 764	$ 827

[a]Serious hazards total is for the last three quarters of fiscal year 1982 only.
[b]Other-than-serious hazards total is for the last two quarters of fiscal year 1983.
SOURCE: OSHA.

Voluntary Protection Programs

In 1982, OSHA created three programs that both recognize the achievements of companies that are "leaders" in providing health and safety to their employees and provide additional opportunities for OSHA-employer consultation and cooperation. Collectively referred to as "voluntary protection programs, " they are individually named: "Star, " "Try," and "Praise." They are a mixture of consultation and recognition for superior performance. In the course of developing a program, OSHA personnel may make an onsite visit and offer suggestions for program improvement. So far, only a handful of companies have applied to participate in these programs. Participating companies are exempted from OSHA programed inspections and are promised expedited action on variance applications.

These programs represent a more cooperative approach toward employers than OSHA has taken in the past and are intended to enhance worker health and safety. Critics of voluntary protection, on the other hand, are concerned about the general policy of exempting participating companies from scheduled inspections and fear that these programs divert OSHA resources away from inspections and standard-setting activity,

Other Programs

OSHA has also, from time to time, set up cooperative programs with trade associations, unions, etc. to disseminate health and safety information. In 1982, for example, OSHA agreed to assist the American Electronics Association with its efforts to conduct training courses and prepare booklets on health and safety. Another agreement was signed with the National Agricultural Chemicals Association to develop a slide/tape program on good workplace practices for pesticide manufacture and formulation (632).

OSHA also has an in-house training institute in Des Plaines, IL. It offers 52 health and safety courses of 1 to 2 weeks each at no cost to the students. Since its start in 1972, approximately 40,000 trainees have attended the institute. The training is generally designed to meet the advanced training needs of OSHA Compliance Officers, State agency personnel, and staff from other Federal agencies who need health and safety training. OSHA also makes available a certain number of classroom spaces for private sector personnel. In fiscal year 1983, approximately 6,700 trainees completed a course at the OSHA institute—nearly 1,850 from Federal OSHA, about 1,650 from State agencies, 2,800 from other Federal agencies, and about 500 from the private sector (34,630,636).

State Programs and Other Federal Agency Activities

State Programs

Many who supported passage of the Occupational Safety and Health Act in 1970 believed that a Federal program was necessary because existing State programs were inadequate. But during congressional consideration, a coalition of business leaders, State officials, a number of State-oriented members of Congress, and the Nixon administration pushed for the inclusion of State-inn OSHA programs in the act. It has been suggested that the act could not have passed without a provision allowing State plans (30,460).

In passing the OSH Act, Congress established a mechanism that enables States to regulate worker health and safety subject to Federal monitoring and approval. A State program must, in general, "provide for the development and enforcement of safety and health standards which . . . are or will be at least as effective" as Federal standards (OSH Act, Section 18).

The development of a State program is a stepwise process. After application and initial approval from OSHA, the State can begin to enforce health and safety standards. States can adopt the existing Federal standards, as have 18 of the 24 plans approved before 1984. Half of these 18 also enforce some State standards. The other 6 States enforce mostly their own standards, which OSHA has deemed to be "at least as effective" as the corresponding Federal ones.

The first 3 years of a State plan are called the developmental stage. At the time of initial plan approval, both OSHA and the State agency have concurrent jurisdiction—both have the authority to conduct inspections and cite employers, and employers must therefore comply with both Federal and State standards. (Any time after initial approval, however, as soon as the State is "operational, " OSHA may suspend its concurrent enforcement jurisdiction through an "operational status agreement.") After all developmental steps are completed and approved, OSHA can issue a certification of the plan. If the State meets all of OSHA's requirements, it becomes eligible for "final approval" 1 year after certification. Even after "final approval, " Federal OSHA still monitors the State program.

The requirement that States maintain a program "at least as effective" as OSHA's means that if OSHA issues new or revised regulations, State agencies must follow suit by adopting the change, issuing an equivalent change, or making the case that, for local reasons, there is no need to alter the regulation. (For example, a State without textile mills need not adopt the OSHA cotton dust standard.)

There are also procedures for OSHA to withdraw approval and / or reintroduce Federal enforcement for a State that does not comply with OSHA's requirements (307,333,408). In all stages of its operation, OSHA monitors the quality of the State program. Monitoring may involve "spot checks" (inspections by Federal personnel after a State-conducted inspection) or "accompanied" monitoring visits in which Federal personnel observe a State inspector during an inspection. (More recently, a computerized data system has replaced much of this onsite monitoring.)

History of State Programs Under the OSH Act

The policies of OSHA toward State programs have varied-sometimes permitting State programs to operate relatively free from oversight, while at other times setting high standards for State programs. OSHA's efforts to allow and encourage or disallow and discourage State programs have also been subjects of litigation (249,307).

From 1978 to 1983, 24 State programs were in operation—21 States plus Puerto Rico and the Virgin Islands covered private and public employment and one program (Connecticut's) covered only public employment. In 1984, New York became the 25th State program, although it applies only to State and local government employees (table 12-7). "Final approval" had not been granted to any jurisdiction until 1984, when the Virgin Islands, Hawaii, and Alaska received this designation.

An important issue for OSHA policy concerning State programs has been a continuing dispute concerning the level of funding and the number of compliance personnel a State must have to meet the requirements of the OSH Act. In the mid-1970s OSHA had interpreted this to mean that State staff levels need only be equivalent to those of OSHA, even though OSHA's staffing levels were not considered optimal. The AFL-CIO sued OSHA on this issue.

In a major decision in 1978 ***(AFL-CIO v. Marshall),*** the reviewing court agreed with the AFL-CIO. According to its opinion, the "at least as effective" requirement applies only to the *standards* issued by the State program. For staffing and funding, the court ruled that Congress intended that OSHA could use "current Federal levels of personnel and funds as benchmarks for State programs, provided they are part of a coherent program to realize a fully effective enforcement effort at some point in the foreseeable future." Thus while current Federal levels, described by OSHA itself as only "a percentage of what is really needed, " were deemed to be adequate as *interim* benchmarks, they were not adequate as goals for "fully effective" State programs (307).

Table 12-7.–State Programs (1984)

Jurisdlctions with approved plans:	
Alaska	North Carolina
Arizona	Oregon
California	Puerto Rico
Hawaii	South Carolina
Indiana	Tennessee
Iowa	Utah
Kentucky	Vermont
Maryland	Virgin Islands
Michigan	Virginia
Minnesota	Washington
Nevada	Wyoming
New Mexico	
Plans cover/rig ***only pub//c employees:***	
Connecticut	New York

SOURCE: (408).

In 1980, with the concurrence of the AFL-CIO, OSHA submitted to the court staffing-level "benchmarks" designed to achieve the goal of State programs becoming "fully effective" rather than only "at least as effective" as Federal operations. This plan would have required the jurisdictions with approved State programs to increase the total number of safety inspectors from 849 to 1,154 within 5 years and of health inspectors from 332 to 1,683 (subject to an annual reassessment of the availability of qualified health personnel). The agency also released a "benchmark model" that could be used to generate or revise staffing levels as necessary. The model considered the hazard rank of various industry sectors and the number of establishments of each rank in each State when calculating the number of programed inspections, the factor that ultimately determines State health and safety staffing requirements.

Since then, OSHA has taken steps to change these required benchmark levels. Beginning in 1981, it has sought congressional approval to prohibit the spending of any funds to achieve State staffing levels that are greater than current Federal levels. Although enacted in two continuing resolutions concerning appropriations in fiscal years 1982 and 1983, this language was not included in the final appropriations actions for those years (34). In 1984, it was reported that OSHA is no longer seeking this appropriations language (350). In 1982, OSHA also formally proposed to recalculate the benchmark formula. One result of this would be the lowering of the required State staffing levels (249).

Pros and Cons of State Programs

A number of arguments have been made for and against State takeover of OSHA responsibilities. Proponents of State programs argue that they can adapt to local needs better, are more efficient and more fairly enforced, and continue the traditional State and local roles in occupational health and safety regulation. Opponents argue that, compared with OSHA, these programs are less effective, understaffed, underfunded, inefficient, less evenly enforced, and more susceptible to local political influence (408).

Organized labor, especially at the national level, is principally concerned that many State programs devote insufficient resources to health and safety and are ineffective. Although many people in the business communities of affected States support such programs, large businesses with establishments in more than one State often express a desire for regulatory consistency-something that is hard to achieve with a variety of different State standards. Recent employer support for an OSHA "labeling" standard, for example, derives in part from a desire to preempt State and local laws on this subject.

Local control over job safety and health could be desirable in its own right, and the use of State programs can create a combined Federal and State effort that is larger than the Federal effort alone could be. But most States do not have the research capability needed to set standards, nor would it be efficient to have each conducting the same research for standards development (30). However, because they can simply adopt Federal standards verbatim, it is usually not necessary for them to have such a capability (34).

But the possibility exists that States may compete with each other in order to attract new businesses by relaxing the enforcement of health and safety standards. In theory, this should be restricted by the requirement that State programs be "as effective as" Federal OSHA. Examination of inspection data shows that, on average, State programs issue fewer serious violations and, for this reason, propose lower penalties overall than OSHA does. Moreover, the States with programs, as a group, devote a smaller fraction of their inspection resources to health inspections than does OSHA (see tables A-l to A-11 in app. A). On the other hand, State programs conduct proportionately more inspections than OSHA does and some States have proportionately larger enforcement staffs, particularly in safety (34). In 1976, the GAO criticized OSHA's policies toward the development of State programs and expressed concern that these policies were not sufficient to ensure employee health and safety (500).

The friction over benchmarks, final approval, and Federal monitoring of State programs reflects the underlying tension between the national and the State governments, which historically had been responsible for job safety and health. Federal policies concerning State programs have responded to those tensions, as well as to more general views concerning the rightful role of the Federal Government.

For example, the 1973 President's Report on Occupational Safety and Health referred to the approval of 20 State programs in 1973 as a step that moves the United States closer to the "Federal/State occupational safety and health partnership intended by Congress. " Assistant Secretary Bingham took a very different view, stating that "[t]he Federal agency is given a leadership role which does not lend itself to a traditional partnership of equality as I believe a number of States desire." Thorne Auchter returned to an earlier policy of actively encouraging State programs. In his words, "It is my belief—and the belief of this administration—that in the last analysis, local problems are best addressed by those closest to them" (249).

Other Federal Agencies

Although OSHA and the State programs are directly responsible for ensuring the health and safety of most private sector workers in the United States, some workers are the responsibility of other agencies. The OSH Act does not apply to "working conditions" for which other Federal agencies and certain State agencies "prescribe or enforce standards or regulations affecting occupational safety or health" (OSH Act, Section 4). For example, the health and safety of coal miners is regulated by the Mine Safety and Health Administration, while protection of certain railroad employees is provided by the Federal Railroad Administration.

Health and safety conditions for most public sector workers are not directly regulated by OSHA. State and local employees, however, are covered by State programs in the 25 States with approved plans. The heads of Federal agencies are required by the OSH Act to provide their employees with an occupational safety and health program that is "consistent with" OSHA standards. Three different Executive Orders have been issued concerning health and safety protections for Federal Government employees.

Lastly, the regulations issued by several other Federal agencies also affect job safety and health, even though workplace conditions are not the primary focus of these agencies. The constellation of governmental bodies with workplace safety and health responsibilities is summarized in table A-12 in appendix A.

THE NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

The need to provide for research to identify, evaluate, and control work-related illness and injury, to disseminate information to workers, employers, and health professionals, and to train occupational safety and health professionals did not provoke much controversy during the debate about passage of the OSH Act. All parties agreed there was overwhelming evidence that scientific knowledge about work-related injury and illness was lacking, that the supply of trained personnel was inadequate, and that meaningful statistical data were unavailable.

The OSH Act established the National Institute for Occupational Safety and Health within the Department of Health and Human Services (then called the Department of Health, Education, and Welfare) to carry out research and related activities. Congress listed several major activities for NIOSH:

- develop criteria for recommended occupational safety and health standards;
- conduct educational programs to provide an adequate supply of qualified personnel;
- conduct informational programs on the importance of the use of adequate safety and health equipment;
- conduct Health Hazard Evaluations; and
- conduct industry-wide studies of the effects of chronic or low-level exposures.

In contrast to OSHA, most NIOSH personnel work in only two locations, at the NIOSH facilities in Cincinatti, OH, and Morgantown, WV. As mentioned earlier in this chapter, NIOSH headquarters are now in Atlanta, GA. There are also very small staffs, usually two to three, in the 10 HHS regional offices (located in the same cities as OSHA regional offices).

NIOSH's organization reflects the various topics of its research and dissemination program. These activities are conducted by NIOSH's seven divisions, each of which conducts research concerning a particular aspect of occupational health and safety or provides for the dissemination of information or training and education (fig. 12-5).

For this description, OTA divides NIOSH activities into three major program areas:

- ***Identification*** of occupational health and safety problems;
- Development ***of controls*** to prevent work-related illnesses and injuries; and
- ***Dissemination*** of findings and recommendations and provision of ***Professional Training and Education.*** [2]

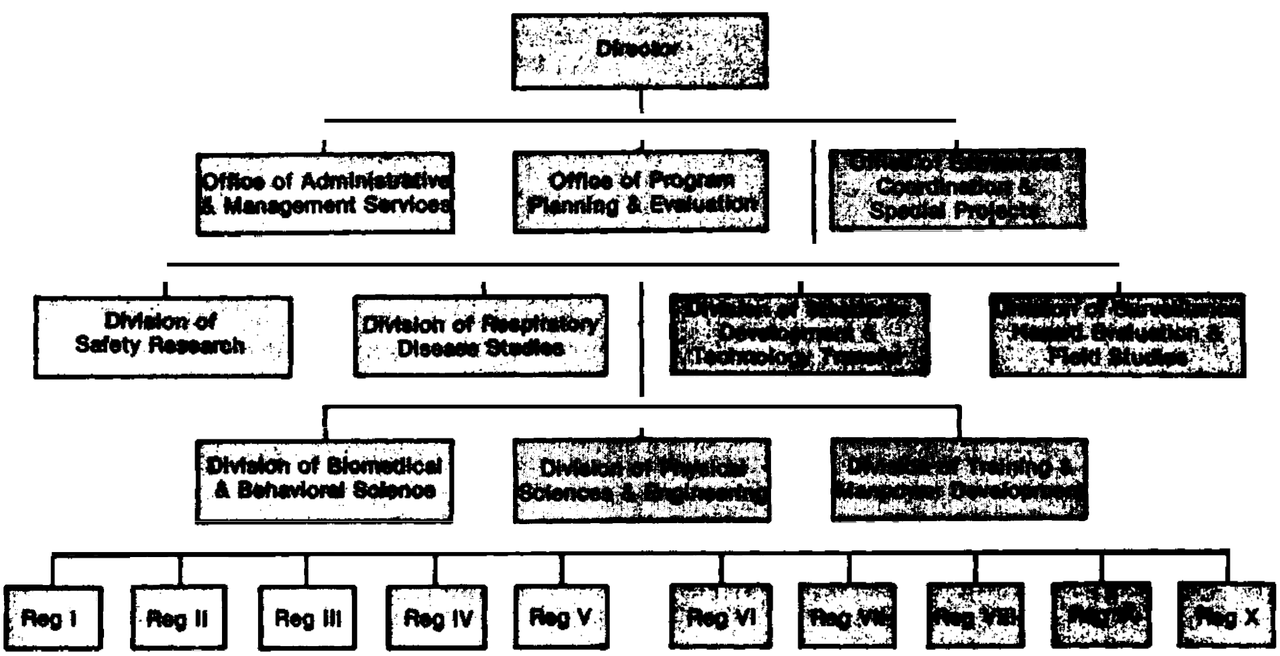
The funding for the three activities is not,equal. Identification now receives the largest share of NIOSH's budget, with information dissemination and control technology research receiving substantially less funding. In addition, although its mandate extends to both health and safety, NIOSH has concentrated almost exclusively on questions of occupational health.

Identification

Identifying work-related illness and injury and understanding the mechanisms of disease and injury causation involve using the skills of medicine, industrial hygiene, safety engineering, epidemiology, toxicology, and statistics. It is the first step toward prevention (chs. 3 and 4). The specific NIOSH activities directed toward identification include illness and injury surveillance sys-

[2]NIOSH itself divides its activities into five areas: identification, evaluation, control, dissemination, and administration (s79). The first three appear to have derived from the language of industrial hygiene, which refers to recognition, evaluation, and control. OTA has grouped what NIOSH calls identification and evaluation into one category, largely because there really are no clear boundaries between these two activities, and both depend on a variety of professional skills. Moreover, the term "evaluation" is commonly used in the Federal Government to refer to the process of assessing the administration and impacts of particular programs. Administration, the fifth NIOSH program area, is not a research area and is not discussed in detail in this chapter.

Figure 12-5.—National Institute for Occupational Safety and Health



terns, Health Hazard Evaluations, and NIOSH's toxicologic and epidemiologic research programs.

Surveillance

NIOSH surveillance systems identify workplace hazards and work-related injuries, diseases, disabilities, or deaths, and generate hypotheses concerning the possible relationships between workplace exposures and adverse effects. NIOSH conducts work-related illness and injury surveillance in several ways. For illnesses, NIOSH's activities have included two large surveys of working conditions and the Health Hazard Evaluation program (discussed in detail below).

Until relatively recently, NIOSH did very little on the identification of the causes of injuries. Now it collaborates with the Bureau of Labor Statistics and OSHA in conducting work injury surveys, which are special-topic mail surveys of injured workers. Epidemiologic methods for injury investigation are being developed. National work-related injury data are being collected in conjunction with the Consumer Product Safety Commission's National Electronic Injury Surveillance System.

National occupational hazard and exposure surveys.—The first NIOSH survey of working conditions, called the National Occupational Hazard Survey (NOHS), was completed in 1974. Presently, a major task of NIOSH's surveillance program is analysis of data collected in the second national inventory of potentially hazardous exposures to workplace agents, the National Occupational Exposure Survey (NOES).[3] The data for both of these surveys were collected through visits to a random sample of workplaces. Potential exposures to workplace hazards were observed and recorded during comprehensive tours of these worksites. The surveyors collected information on the nature of the potential hazards, the number of workers at risk, and the controls in place to protect them.

These surveys represent a large effort. The recent survey, patterned after the first one, covered a random sample of nearly 5,000 worksites in 67 major metropolitan areas over a 2-year period starting in 1981. Potential exposure estimates for the Nation are based on the probability sample in which over 9,000 chemicals and physical agents were observed in industrial use. These observations included exposures of workers in 450 separate occupational classifications.

The results of these two surveys can provide national estimates of potential exposure to workplace hazards by industry and occupational groups that can be useful for research planning, for estimating the impact of proposed standards, and for planning OSHA's enforcement activities. For instance, occupational safety and health professionals have used the 1974 NOHS to identify groups of workers exposed to various hazards or combinations of hazards. One finding from NOHS was that over 22 million of the 38 million workers in the survey universe were exposed to at least one potential hazard.

Trade-name chemical products (products with a commercial name but often lacking information about the identity or properties of the chemical constituents on their containers) are prevalent in the workplace. Analysis of the NOHS data showed that potentially toxic substances are frequently present in them. About 70 percent of 86,000 products identified in NOHS (made by 10,500 manufacturers) had trade names. NIOSH requested information about the composition of these approximately 60,000 separate trade-name products from the 10,500 manufacturers. The manufacturers supplied information on 45,000 trade-name products. Of these, 40 percent contained at least one OSHA-regulated substance and over 400 of these trade-name products contained at least one of the OSHA-regulated carcinogens.

However, while NOHS estimates are the only national base of information on exposure to potential workplace hazards, they have been questioned for their accuracy, for being nonquantitative, and for their validity. NOHS estimates for agents for which there is a high degree of awareness (such as asbestos) sometimes appear

[3] **The word "hazard" in the title of the NOHS survey was changed to "exposure" in the second survey in part because employers' representatives argued that the survey was really an inventory of all potential exposures, of which hazardous ones were only a part.**

at odds with figures put forward by others. Estimates of the numbers of people exposed to low-toxicity substances, such as sodium chloride, dominate some parts of the data base, leaving a casual observer with the impression that the data are weak for determining exposure to more hazardous substances. Many users have wished for quantitative estimates of actual exposure levels, since these would strengthen the data and increase its usefulness. Collecting actual exposure data, while theoretically possible, would be expensive since accuracy and validity would depend on collection and chemical analysis of a large number of samples taken over sufficient time to make sure the results were representative of workplace conditions.

The usefulness of NOHS is reflected by requests for it and reports developed from the collected data. In fiscal year 1982 alone, there were over 5,000 requests for data from NOHS. Further analysis of potential exposures to hazardous substances, including analysis of trends, will be possible when analysis of NOES, the second survey, is completed. A similar NIOSH environmental survey focusing on the mining industry is planned to comply with the mining surveillance mandate of the Mine Safety and Health Act of 1977.

Health hazard evaluation and technical assistance programs.—The identification program area also includes the Health Hazard Evaluation (HHE) and Technical Assistance (TA) programs. The HHE program responds to employee and employer requests from the private sector for evaluation of specific hazards, while the TA program responds to requests from government agencies.

However, the technical aspects of HHEs and TAs are the same. The purpose of both of these programs is to "determine toxic effects of chemical, biological, or physical agents . . . in the workplace" through medical, epidemiologic, and industrial hygiene investigations of the worksite of concern. Upon completion of an evaluation, NIOSH reports the results back to the worker and to the employer. If the substance proves to be toxic as it is used and exposure is not covered by any standard, NIOSH is required to report its findings to OSHA.

In fiscal year 1981, NIOSH received 513 requests for mining and general industry HHEs, a 10 percent increase over 1980. Twenty-one percent of these requests came from employers, 55 percent from employees or unions, 23 percent from Government agencies, and 4 percent from other sources. Twenty percent of these requests came from establishments with fewer than 100 employees. NIOSH investigators made over 600 site visits and produced 234 final reports documenting HHEs conducted.

In 1978, the General Accounting Office criticized the administration of the HHE program (503). GAO suggested that NOSH needed to publicize the program more, issue HHE reports more quickly, establish an evaluation program, and disseminate HHE reports more widely, When Anthony Robbins was its Director, NIOSH quadrupled the number of evaluations (465). This rapid growth of the HHE program created some concern in the business community. It has also been suggested that the the HHE program has reached too few workers, that the investigations take too long, that NIOSH has attempted to reach conclusions about toxicity based on too few data, and that the program has not found many new work-related illnesses and injuries, especially when compared with the expense of conducting the studies.

In some cases, the data gathered by an HHE are insufficient to identify a particular cause for worker health complaints. For instance, individual HHEs concerning health problems from unknown sources of indoor air pollution have seldom identified a causal agent. The accumulated findings from these studies, however, have pointed to lack of ventilation as a common factor. Frequently, reported illnesses disappear after improvements in ventilation.

State surveillance programs.—NIOSH is now attempting to involve State health departments in surveillance programs for identifying work-related illness and injury. After surveying State Health Officers to learn about their current capabilities for carrying out surveillance and prevention programs, NIOSH established agreements to cooperate with five States. NIOSH is devising methods to assign Epidemic Intelligence Service

Officers to State Health Departments for general epidemiological duties related to preventing work-related illness and injury.

Epidemiologic and Toxicologic Studies

The goal of epidemiologic and toxicologic studies is to understand the causes of occupational health and safety problems and thus reveal areas for preventive actions. Since 1971, NIOSH has sponsored a number of studies through its research grants programs and NIOSH staff have themselves conducted important studies.

NIOSH describes its current research efforts by referring to its list of 10 leading work-related diseases and injuries. These are occupational lung diseases; musculoskeletal injuries; occupational cancers; amputations, fractures, eye loss, lacerations, and traumatic deaths; cardiovascular diseases; reproductive disorders; neurotoxic disorders; noise-induced hearing loss; dermatoses; and psychologic disorders. As examples of current NIOSH activities, a few studies of lung disease, cancer, and reproductive health are discussed.

Work-related lung disease. -Lung disease is the highest priority work-related health problem and includes a number of debilitating diseases. The health and safety HHS prevention objectives (see discussion below) set a goal of virtually no new cases of asbestosis, byssinosis, silicosis, and coal workers' pneumoconiosis. NIOSH efforts concerning lung disease focus on these four diseases plus lung cancers and occupational asthma.

NIOSH studies in this area include animal testing to study the carcinogenicity of short asbestos fibers, those less than 5 um in length. The study lasted 2 years, at which time the animals' lungs were examined. Asbestos fibers were found in the lung, but fibrosis, lung tumors, and other lesions were absent. The researchers concluded that although short asbestos fibers did not by themselves appear to cause tumors, there is still a need for further study of the possible interactions between short asbestos fibers and other substances that cause cancer.

NIOSH researchers have sponsored the development of criteria for the pathologic diagnosis of pleuro-pulmonary disease associated with asbestos dust exposure and a method for grading disease severity. An expert committee of pulmonary pathologists assembled in cooperation with the College of American Pathologists reviewed surigical and autopsy evidence and reached a consensus as to what the criteria should be.

There have also been investigations of the immunologic aspects of work-related lung disease to examine the natural defense systems of the lung and potential ways they are stressed by work-related exposures. For instance, the effect of certain particulate matter often found in the workplace was tested on the interferon system in a laboratory experiment. One finding was an association of inhibition of interferon production with increasing coal rank (coal, that is, with higher carbon content such as anthracite). The growth of influenza virus, introduced into a treatment system, increased more among those treated with coal particulate than among controls.

Work-related cancer.—Both laboratory and epidemiologic studies are conducted to determine the carcinogenic potential of workplace exposures. In cooperation with the National Toxicology Program, NIOSH sponsors carcinogenicity assays for workplace chemicals.

As an example of epidemiologic studies, a NIOSH retrospective cohort mortality study of paper and pulp workers found a suggestive increase in lymphatic disease, although associations with exposure to workplace agents including wood dust, formaldehyde, sulfur compounds, and other chemicals were unclear. A proportional mortality study of automotive workers suggested that makers of wood dies and models suffer more often than expected from fatal colorectal cancer, leukemia, and other cancers.

NIOSH has developed a registry of workers exposed to dioxins that contaminate certain chemicals. Follow-up studies of the members of the registry will, it is hoped, provide clarifying information about the possible carcinogenicity of dioxin. Although information about the exposure levels of these "dioxin workers" is limited, at least some of them were exposed to much higher levels than any "environmental" exposure through air, water, or soil. Therefore, the registry will be important in the dioxin controversy. This activity also illustrates that studies of industrial exposures, often carried out by NIOSH, have important impacts on other aspects of public health.

Work-related reproductive health problems.—Studies of work-related reproductive system health problems include both animal studies and pregnancy outcome studies among wives of male workers. NIOSH tested several industrial chemicals—ethylene oxide, propylene oxide, and n-butyl acetate—for teratogenicity in exposed female animals. Rats and monkeys were exposed to high levels of these substances prior to breeding. The test animals had a significant reduction in the number of fetal implantation sites and live fetuses, but it was not possible to conclude that these were definitely teratogenic effects. The investigators did conclude that in these cases teratologic effects did not occur at exposure levels below those that are toxic to the mother animals.

Epidemiologic studies are being conducted among workers exposed to polychlorinated biphenyls (PCBs) to determine the effect of exposure on pregnancy outcome among women. Animal studies of PCB suggest that it is toxic to the fetus and that it may be teratogenic. NIOSH investigators are conducting a case-control study of neonatal deaths and infants with low birth weight among infants of women workers at a capacitor plant using PCBs.

The effects of carbon disulfide, which is used to manufacture rayon, on the central nervous system have long been known, but recent studies have suggested that its health effects also include increased risk of death and illness from cardiovascular disease and increased risk of reproductive system effects among both men and women. Sexual dysfunction, loss of libido, semen abnormalities, and impotence have all been found among exposed male workers and menstrual abnormalities and increased risk of fetal loss and premature births among exposed female workers. NIOSH is now conducting a case-control study of the wives of exposed workers to determine the potential effects on pregnancy outcome from fathers exposed to carbon disulfide.

Development of Controls

Development of control technologies includes developing, assessing, and improving measures to reduce workplace hazards, especially through control technology, protective equipment, work practices, and hazard-detection devices. NIOSH investigations of control technologies commands a smaller proportion of NIOSH resources than any other research area. In fiscal year 1983 only 12,8 percent of the NIOSH budget of $57.5 million and less than 14.0 percent of the 911.7 person-years of staff time were allocated to the control-technology budget,

NIOSH's efforts in control technologies are divided into three research program areas: about 21 percent of the control technology budget is spent for control systems research; 14 percent for respirator research; and 3 percent for other personal protective equipment research (table 12-8). However, the control technology budget also includes funds for performing chemical analyses in support of NIOSH industrial hygiene studies (37 percent); for developing methods for sampling and analyzing airborne contaminants (15 percent); and for testing respirators (10 percent) (584).

Control Systems Research

NIOSH conducts Control Technology Assessments (CTAs) to identify, evaluate, and document the most effective engineering controls used for particular hazards within a given industry. Information collected in a CTA is reported back to the industry so that other plants can use it to solve problems. Table 12-9 shows some of the areas in which CTAs have been done. Other research has been done concerning improved local exhaust ventilation and in the use of air recirculation for general dilution ventilation.

Engineering control research concentrates on industrial processes, since it is here that toxic substance emissions can be controlled. Research is split by industry: chemicals, mining and minerals, materials processing, and general industry. Recent research includes evaluation of emission con-

Table 12-8.—NIOSH Budget for Control Technology

Program area	Projects	Person years	Nonstaff (dollars in thousands)	Total (dollars in thousands)	Percent
Control systems.	10	29.0	542.9	1,535.8	20.86
Respirator research	10	16.7	462.6	1,000.0	13.58
Other PPE	3	4.8	99.3	253.7	3.45
Sampling/analysis	12	36.9	1,500.8	2,751.8	37.38
Method development,	6	24.2	272.8	1,090.5	14.81
Respirator testing	4	15.7	224.2	729.4	9.91
Totals	45	127.3	3,102.6	7,361.2	100.00

SOURCE (584)

Table 12-9.—Control Technology Assessments Performed by NIOSH in Fiscal Year 1982

Completed:

Seals and fittings in chemical processing technology
Nonferrous metals production including aluminum reduction and nonferrous smelters
Fire building
Foundries
Spray painting
Pesticide manufacture
Dry cleaning

Ongoing:

Dust control in dusty unit operations
Chemical processing unit operations
Unit processes used in general manufacturing

SOURCE: (584)

trol of the suspected carcinogen formaldehyde (both in its manufacture and **as** it is found in adhesives during hot-press wood veneering) and control of worker exposure to styrene, an agent that can cause dermatitis and neurotoxic illness, in boat building plants.

NIOSH is also conducting control technology research in selected petroleum-refining operations. Although most processes in this industry are contained, workers may be exposed to toxic substances through leaks, during equipment failure or maintenance, while collecting quality control samples, while loading or unloading materials, and during waste treatment. NIOSH investigated engineering and work practices at a hydrogen fluoride acid alkylation unit, at a benzene-loading facility, and during other processes in petroleum refining.

CTAs have been conducted in some unit processes. In the pharmaceutical industry, for example, the substances used to manufacture contraceptives are capable of causing gynamastia or enlarged breasts among both exposed female and male workers, and menstrual irregularity among exposed female workers. Because the batches of these products are relatively small, the process has not been mechanized and there are many opportunities for worker exposures. Good engineering controls used in these situations included isolation, highly efficient local exhaust ventilation and, as an additional safeguard, the use of supplied-air suits.

Other assessments have been made in industries expected to grow in future years. These include hazardous waste disposal, semiconductor manufacturing, and fermentation processes. The studies of waste disposal included investigations of waste incinerators and automated drum handling.

Toxic materials used or found in the manufacture of microelectronic components include lead, arsine, phosphine, boron trifluoride, carbon tetrafluoride, phosphorous oxychloride, and hydrofluoric acid. In many cases, NIOSH found well-designed and effective engineering controls and ventilation systems for these hazards, but also discovered one previously unidentified exposure problem—arsenic off-gassing of silicon wafers impregnated with arsenic.

Fermentation processes are expected to be used more frequently in biotechnology. NIOSH is investigating the enzyme production industry to learn which control technologies are most effective in containing potentially hazardous biological material **(582).**

Respirator Certification and Research

NIOSH, in conjunction with the Mine Safety and Health Administration, tests and certifies respirators. During fiscal year 1982, 44 new respirators were evaluated for approval and 60 were evaluated for extension of approval. Audits were conducted of 33 off-the-shelf respirators to ensure that certified respirators continue to meet test requirements. Respirator quality-control programs are also reviewed to make sure that certified respirators continue to meet requirements. As detailed in chapter 8, however, there are many complaints about respirators and about NIOSH's inability to publish new regulations concerning respirator-testing requirements.

Field testing is conducted to measure certified respirator performance in actual working conditions. Research is under way on sorbent efficiency for organic vapor respirators, filter efficiency and optimum flow rates for aerosol air-purifying respirators, the effects of filter resistance and efficiency on protection factors and reduced air flow use in powered air-purifying respirators, and the physiological effects of using respirators simultaneously with protective clothing.

Other Personal Protective Equipment Research

Chapter 8 outlines NIOSH investigations of various types of personal protective equipment, including head protection (hard hats), eye protection (protective glasses), face protection (face shields), foot protection (steel-toed shoes and metatarsal guards), hand protection (protective gloves), motion restraints, and protective clothing. All of those studies were done in the late 1970s. Currently, resource constraints have limited research in this area to chemical protective clothing. The absence of assurance that personal protective equipment works as advertised could be addressed by NIOSH, with sufficient funds and effort, or by NIOSH in cooperation with other organizations.

Sampling and Analysis

Analysis of chemical samples is necessary for many industrial hygiene and medical studies. In fiscal year 1982, 17,200 exposure samples were analyzed for 42,000 determinations. About one-quarter of the samples were done in NIOSH laboratories and three-quarters on contract.

NIOSH also has a role in laboratory quality control. Approximately 375 private and government industrial hygiene analytical labs participate in the NIOSH Proficiency Analytical Testing program, which periodically sends out reference samples for analysis. For example, a sample of airborne lead dust would be analyzed by each laboratory, NIOSH then collates results from all of the participating laboratories and reports them back in summary so each lab can see how closely its results match those of other laboratories. Participating in this program and performing analyses within the quality control boundaries for the tested substances is required for maintaining laboratory certification by the American Industrial Hygiene Association.

Sampling and Analytical Methods Development

To facilitate accurate and precise assessment of worker exposure to chemical hazards, NIOSH develops and refines methods for sampling and analysis. In 1981, it published the seventh volume of the Manual of ***Analytical Methods,*** which added 21 methods for monitoring chemical hazards.

NIOSH has also participated in the development of new sampling devices. In 1981, it developed performance specifications, testing protocol, and evaluation criteria for passive monitors, which are devices requiring only the natural motion of contaminant molecules in air, thus saving the costs of sampling pumps. NIOSH and the Bureau of Mines collaborated in a comparison of X-ray diffraction and infrared spectroscopy for analyzing quartz or crystalline silica. These tests were done to help refine reliable, low-cost analytical methods. Other sampling research has led to real-time, direct-reading sampling methods. Such devices, while costing more at the outset, will reduce the overall cost of monitoring chemical workplace hazards by eliminating the costs, risk of error, and delays in obtaining results that are associated with laboratory analysis.

Dissemination

NIOSH disseminates its research findings through criteria documents, reports, and published papers informing professionals and the public of identified problems and solutions, as well as through Health Hazard Evalution reports. Efforts are now being made to disseminate HHE findings to hard-to-reach audiences. For example, a finding that irritating vapors from duplicating machines were affecting teachers' aides and that an easy way to control the exposure was available was disseminated through teachers' organizations.

The OSH Act provides that NIOSH shall make recommendations to OSHA concerning health and safety standards. Since 1971, NIOSH has transmitted to OSHA over 100 "criteria documerits, " which contain extensive bibliographies of available scientific literature on the chemical or process in question, followed by an analysis and assessment of the substance's toxicity and a recommendation to OSHA for a potential standard. The criteria documentation process has covered about 151 substances since 1970. Priority for the substances for which criteria documents were written was based in part on estimates of the number of workers exposed, the volume of production of the substance, and the severity of toxicity.

The third NIOSH Director, Anthony Robbins, deemphasized the production of criteria documents in part because many of them "were mostly toxicological reviews" that ". . . did not contain a great deal of epidemiology, which is needed. They were inconsistent" (482). In addition, as discussed in chapter 13, OSHA has not issued standards for most of the hazards addressed by NIOSH criteria documents.

Few criteria documents are being developed now, but from time to time NIOSH has prepared other kinds of reports, transmitting them to OSHA, as well as disseminating them to the public. These include ***Occupational Hazard Assessments,*** which contain recommendations but that are less thorough and less specific than criteria documents. In addition, NIOSH prepares ***Current Intelligence Bulletins,*** which contain new findings about workplace hazards, are also published and transmitted to OSHA, to worker and employer representatives, and to health and safety professionals. NIOSH also participates in the public hearings that are part of OSHA's standard-setting process and provides recommendations concerning the standard under consideration.

NIOSH technical publications are widely disseminated. In fiscal year 1982, for example, one research division-the Division of Surveillance, Hazard Evaluation, and Field Studies—submitted over 300 reports on industrial hygiene and medical studies to the National Technical Information Service, published 63 articles in technical journals, published 3 articles on research findings describing hazards and means for reducing them in industry and labor trade journals, had 6 articles in the ***Morbidity and Mortality Weekly Report,*** published 2 summaries of approximately 80 recently completed HHEs, and provided over 200 reports to people requesting information from NOHS.

The OSH Act requires that MOSH publish annually a list of all known toxic substances or groups of toxic substances, their observed effects, and the concentrations at which they occurred. In compliance with this requirement, NIOSH publishes the ***Registry of the Toxic Effects of Chemical Substances. The*** current edition contains 218,746 listings of chemical names, of which 59,224 are different chemicals (the rest of the names are synonyms). The listings are extracted from the published literature, including journals published abroad, but are not evaluated for quality, accuracy, or reproducibility, The substance name is given, followed by its synonyms, chemical data, and toxicity data by the general categories of irritation, mutation, reproductive effects, tumorigenic effects, and general toxicity. The citation for each toxic effect reported is included so that the orginal article can be found for further detail.

NIOSH is also becoming involved in education to prevent work-related illness and injury. A health motivation working group has been formed to examine ways in which NIOSH's research could be applied to combine health protection (control of work-related illness and injury) and health promotion (improvement of personal health behaviors).

In addition, NIOSH has responsibility for the education of occupational safety and health professionals through both direct short-term training and academic programs, It is estimated that over 5,000 professionals have received training through these NIOSH programs. (These activities are described in detail in ch. 10.) Training grants for Educational Resource Centers have been successful in establishing coordinated multidisciplinary programs. They have received some attention recently because of proposals by the current administration to eliminate their Federal funding (102).

NIOSH Priorities

Setting priorities for preventing work-related illness and injury has been a challenge to NIOSH management. During John Finklea's tenure as Director, NIOSH activity was concentrated on the production of recommendations to OSHA concerning health and safety standards-NIOSH's "criteria documents. " He believed that the criteria documents should be the primary product of NIOSH and that once published would be considered public health policy documents that would force OSHA into setting and revising health standards.

Anthony Robbins, the next NIOSH Director, reemphasized criteria documents and focused NIOSH activity on health hazard evaluations and epidemiologic studies (465,482). The fourth NIOSH Director, Donald Millar, has set special emphasis on efforts to assure high-quality research and focus research on the most important work-related problems. He is also working to expand the participation of State and local health agencies and to increase workplace health promotion efforts (584).

Present research priorities are influenced by the HHS Prevention Objectives for the Nation, the NIOSH list of 10 leading work-related health problems, and the HHS National Toxicology Program. These are used to identify subjects for criteria document development and to set priorities for research on hazard assessment and control.

The Prevention Objectives include 20 objectives for preventing work-related injury and illness. Thirteen of these have been designated priority objectives. The Prevention Objectives, shown in Box O, are divided into several categories:

- ***Improved health status*** (measured by fewer deaths, injuries, and illnesses);
- ***Reduced risk factors*** (by implementing hazard controls);
- ***Improved public/professional awareness*** (as reflected by increased worker, employer, and professional knowledge about occupational hazards);
- ***Improved services/protection*** (through the use of generic standards and increased NIOSH activity in studying hazards); and
- ***Improved surveillance/evahation*** (including creation of coding systems and enhancing existing efforts to include occupational factors) (556).

The NIOSH list of 10 leading work-related health problems (see table 5 in ch. 3) was compiled by NIOSH's division directors. Frequency of occurrence, severity, and amenability to prevention of the work-related injury and illness were the criteria used for selection (583). This priority list is used by NIOSH to identify subjects for criteria document development and to set priorities for research for hazard assessment and control. It was also published to encourage discussion among occupational safety and health professionals and to assist them in setting their control priorities. NIOSH intends to collect data on the 10 and periodically update it as conditions change (581).

The National Toxicology Program coordinates the Federal Government's testing of chemicals for possible human health hazards. Two of its activites are important for NIOSH. First, it carries out the testing of substances that NIOSH identifies as possible concerns, and NIOSH contributes to the costs of those tests. Second, the results of tests requested by other agencies are also provided, so NIOSH can evaluate the potential workplace hazards presented by these substances.

[page omitted]

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Improved services/protection:

'16. By 1990, generic standards and-other forms of technology transfer should be established, where possible, for standardized employer attention to such major common problems as: chronic lung hazards, neurological hazards, carcinogenic hazards, mutagenic hazards, teratogenic hazards, and medical monitoring requirements.

17. By 1990, the number of health hazard evaluations being performed annually should increase ten-fold, and the number of industry-wide studies being formed annually should increase three-fold. (In 1979, NIOSH performed approximately 450 health hazard evaluations; 50 industry-wide studies were performed.)

Improved surveillance/evaluation:

-18. By 1985, an ongoing occupational health hazard/illness/injury coding system, survey, and surveillance capability should be developed, including identification of workplace hazards and related health effects, including cancer, coronary heart disease, and reproductive effects. This system should include adequate measurements of the severity of work-related disabling injuries.

19. By 1985, at least one question about lifetime work history and known exposures to hazardous substances should be added to all appropriate existing health data reporting systems, e.g., cancer registries, hospital discharge abstracts, and death certificates.

20. By 1985, a program should be developed to: 1) follow up individual findings from health hazard and health evaluations, reports from unions and management, and other existing surveillance sources of clinical and epidemiological data, and 2) use the findings to determine the etiology, natural history, and mechanisms of suspected occupational disease and injury.

"Priority objectives of NIOSH.

SOURCE: (556).

SUMMARY

OSHA and NIOSH were created by the Occupational Safety and Health Act of 1970 and both began operations in 1971. The separation of regulatory activities from research may help ensure the objectivity of the research, but it has also been criticized because oftentimes the two agencies have not coordinated their activities. After a period of growth during the 1970s, the budgets for both OSHA and NIOSH have declined in recent years. After adjusting for inflation, OSHA's has decreased nearly 13 percent since its peak in 1979. NIOSH's has declined 42 percent since a peak in 1980 and is now lower, in real terms, than any NIOSH budget since 1973.

OSHA's main activities are setting occupational health and safety standards, conducting workplace inspections to ensure compliance with those standards, monitoring State programs, and providing for several different types of educational and service programs. Although many of OSHA's startup standards have provided some worker protection, there were many problems with these standards and OSHA has been slow in revising them. Since 1971, OSHA has completed 18 separate proceedings for setting health standards and 26 proceedings for safety standards. However, the scope of some of these standards has been very limited, and several involved only a rewriting of requirements that had been issued earlier by OSHA. Those that involved major changes have frequently been the subjects of judicial review. OSHA has also published nine emergency temporary standards, but the courts have been reluctant to support these standards.

OSHA inspection activity has generated a great deal of controversy because employers can be compelled to install health and safety control technology. Together, Federal OSHA and the State programs operating under the OSH Act conducted about 162,000 establishment inspections and 13,000 "records review" visits in fiscal year 1983. However, for most workplaces, the threat of an inspection is quite low. On average, OSHA penalties are also low, often lower than the costs of many controls.

OSHA's public education and service activities include its consultation program, New Directions grants program, and Voluntary Protection Programs. All these programs attempt to approach health and safety in a way that is more cooperative than OSHA citations and penalties. But there have been concerns expressed about OSHA's management of funds in these areas, the quality of the work performed, and the relationship of these activities to OSHA's inspections.

Federal OSHA also monitors the 25 jurisdictions that have assumed responsibility for the health and safety of all or some of the work force within their borders. These State programs can potentially meet local needs better than a centralized Federal agency and can enhance the total governmental resources devoted to worker health and safety. But there has been controversy here too, especially concerning appropriate staffing levels for these operations.

NIOSH activities are chiefly related to hazard identification, research on control technology, and providing for information dissemination and professional education. The largest share of the NIOSH budget is now devoted to identification of hazards. This includes a large survey of workplaces to determine the extent of potential exposures to toxic substances, the Health Hazard Evaluation program, and NIOSH research in epidemiology and toxicology.

Control technology receives a relatively small portion of the NIOSH budget. This research includes Control Technology Assessments, respirator certification and research, research on other types of personal protective equipment, as well as developing sampling and analytical techniques and performing laboratory analysis of exposure samples. Information dissemination includes the preparation of reports on Health Hazard Evaluation, industry-wide studies, Control Technology Assessments, and guides to good practice. Several NIOSH publications are standard reference sources for industrial hygiene, and the ***Registry of the Toxic Effects of Chemical Substances*** is a comprehensive listing of the literature about the toxicity of over 59,000 different chemicals. NIOSH has also prepared Criteria Documents containing recommendations to OSHA concerning new or revised health and safety standards. Finally, NIOSH grant programs have provided for the education of a number of health and safety professionals.

13.
Assessment of OSHA and NIOSH Activities

Contents

LIST OF TABLES

13. Assessment of OSHA and NIOSH Activities

This chapter presents a discussion of several aspects of the activities of the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH). It is not a complete assessment of Federal and State activities concerning occupational health and safety, but only a relatively brief treatment of several important areas. First is a presentation of the results of an OTA comparison of the standards and recommendations of OSHA, NIOSH, and the American Conference of Governmental Industrial Hygienists (ACGIH). Second is a discussion of estimates of employer investments in health and safety, followed by a summary of the research on the effectiveness of OSHA in reducing injury rates and toxic exposures. Finally, there is a short discussion of the difficulties in assessing the results of NIOSH activities.

COMPARISON OF RECOMMENDATIONS AND STANDARDS

This section discusses an OTA comparison of current OSHA standards for certain toxic and hazardous substances with NIOSH Recommended Standards and with the Threshold Limit Values (TLVs) recommended by the American Conference of Governmental Industrial Hygienists. This comparison provides an analysis of the stringency of OSHA standards, and NIOSH and ACGIH recommendations. In most cases, OSHA standards for chemical exposure appear to be less stringent.

When there is more than one required or recommended level, engineers and designers can find themselves in a quandary as they seek to design a productive process and a system for the protection of worker health. Obviously, the designers must comply with the OSHA standard and cannot choose to comply only with a less protective recommendation from another organization.

But when the recommendations of NIOSH or ACGIH are more protective than OSHA standards, it would be desirable, from a health standpoint, for companies to adhere to these more protective recommendations. This is especially true when building new facilities or rebuilding old plants, when it is possible to increase worker protection and to take advantage of the reduced costs of controls introduced as part of the design. At the current time, however, this is not required. (As discussed in ch. 16, one option might be to encourage companies to meet more protective limits when undergoing "reindustrialization. ")

OSHA currently has standards for about 410 chemical substances. In most cases, OSHA specifies the maximum levels for employee exposures (the Permissible Exposure Limits, or PELs). As described in chapter 12, nearly 400 of these standards were adopted in 1971 by OSHA under section 6(a) and consisted of consensus standards and established Federal standards. In addition, OSHA has issued 18 separate health standards. Twelve of these covered 24 specific substances and one physical agent. Among these 12 standards, there were 10 that set new or revised Permissible Exposure Limits.

Each year the ACGIH publishes a list of TLVs. These are recommended to the ACGIH membership by the TLV Airborne Contaminant Committee—17 members and 9 nonvoting consultants who represent companies and other countries. ACGIH has a second committee that considers recommendations for physical agents. Although qualified technical consultants from unions have been and are sought by ACGIH (244), unions have not participated on either of these committees in recent years because they believe that standard setting should be a Government activity. The committee members are unpaid and may meet two to four times each year to deliberate. New TLVs that are accepted by the membership at the annual business meeting are placed on a list of "intended changes" for at least 2 years, during which comments and additional data are requested. At the end of this period the membership votes on whether to add the TLVs to the list of Threshold Limit Values.

The 1983-84 TLV list contains recommended exposure limits for 615 chemical substances and mineral dusts. In May 1984, ACGIH adopted TLVs for 15 substances, and proposed to add TLVs for 7 substances not currently on their list as well as to revise the TLVs for 21 other substances (352). Changes in ACGIH TLVs are not automatically incorporated by OSHA, even for the PELs originally based on the 1968 ACGIH list.

As outlined in the Occupational" Safety and Health (OSH) Act, NIOSH makes recommendations, in the form of Criteria Documents or other documents, to OSHA concerning health and safety standards. It was apparently intended that OSHA would issue mandatory standards after receiving recommendations from NIOSH.

A NIOSH list, Recommendations ***for Occupational Health Standards,*** details the proposals made to OSHA since 1971 for exposures to 163 hazardous substances and working conditions. Five of these concern hazardous working conditions: logging, hot environments, coal gasification, confined spaces, and emergency egress from elevated work stations. None of these five has resulted in a completed OSHA rulemaking.[1]

Ten recommendations concern exposures to categories of hazardous substances or to harmful physical agents (benzidene dyes, chrysene, coke oven emissions, fluorocarbon decomposition products, ethylene thiourea, kepone, noise, pesticides, ultraviolet radiation, waste anesthetic gases). Only two of these, coke oven emissions and noise, have resulted in any regulatory action by OSHA. For coke oven emissions, a standard was issued in 1976. For noise, OSHA issued a Hearing Conservation Amendment in 1981 and revised it in 1983. For both versions of the Hearing Conservation Amendment, however, the published provisions covered only monitoring, audiometric testing, hearing protection, training, warning signs, and record keeping. The NIOSH recommendation to lower the Permissible Exposure Limit from an 8-hour time-weighted average of 90 decibels to 85 decibels has not been acted on. (The ACGIH TLV for continuous noise is also ***85*** decibels for an 8-hour exposure.)

Finally, NIOSH has made recommendations concerning 148 specific chemical substances. But only 123 of those recommendations include a specified numerical exposure limit.

Methodology for Comparison

OTA's analysis compares the protective levels either recommended or required by NIOSH, ACGIH, and OSHA, for the 123 specific substances included on the NIOSH list. The use of the NIOSH data set as a basis for comparison does not mean that the NIOSH exposure levels are the most important. The NIOSH data are simply a convenient source for analysis. (See app. A for a discussion of the selection of substances and the major points of inconsistency among these organizations.)

Unfortunately, OSHA, NIOSH, and ACGIH use different terminology for describing their standards and recommendations. OSHA refers to the basic requirement of its health standards as a "Permissible Exposure Limit. " This is the requirement that employee exposures be kept below a specified numerical limit. NIOSH prepares "Criteria for Recommended Standards" and transmits those recommendations to OSHA. ACGIH uses the term Threshold Limit Values for its recommended exposure limits.

For these comparisons, OTA has used the term "Protective Level" to refer to the standards, recommendations, and TLVs. Protective Levels can be specified in two basic ways:

- time-weighted averages (TWAs), and
- ceiling limits, short-term limits, or peak levels.

[1]One other NIOSH recommendation, concerning underwater diving operations, is not included in the NIOSH list. This recommendation was issued in August 1976 after OSHA had already issued an Emergency Temporary Standard on diving operations. OSHA's final standard was published in July 1977.

Protective Levels can have an 8-hour Time-Weighted Average, a Ceiling Limit, or both. ACGIH recommendations often have TLVs for both a TWA and a short-term limit. OSHA standards often have only an 8-hour TWA. NIOSH recommendations also generally have just one Protective Level.

A Protective Level is defined to be only the number listed as the PEL, recommendation, or TLV. No attempt has been made to quantify the number of workers exposed either above or below that Protective Level or to assess the additional protection provided by monitoring, medical surveillance, and other health and safety activities often included in standards and recommendations.

This comparison does not quantify all possibIe aspects of worker protection. Rather, it represents only a numerical comparison of the standards and recommendations for a group of toxic substances. The results of this comparison are expressed in terms of strictness or stringency. A standard or recommendation is more stringent than another if the specified numerical exposure limit is lower. Depending on the nature of the hazard, the expected health effects, the relationship between exposure and these health effects, "stringency" and the degree of worker protection afforded by a standard or recommendation are usually closely related.

There can be cases for which a more stringent protective level does not provide improved protection. However, for this comparison, OTA has not conducted a detailed analysis of expected health effects and the dose-response relationship for each of these 123 substances. Thus, the results only describe the relative stringency of the standards and recommendations of these three organizations.

Results

The rows of table 13-1 present three different comparisons–OSHA and NIOSH, OSHA and ACGIH, and NIOSH and ACGIH. To simplify presentation, in most cases the table provides only the number of cases for which the first organization listed has a numerical Protective Level that is less than the corresponding Protective Level of the second organization.

For example, the OSHA standard (TWA) for carbon dioxide equals 9,000 mg/m^3, while the NIOSH recommendation is 18,000 mg/m^3 (see table A-13 in app. A). In this case, the OSHA standard is more stringent and would be included in the total number of cases presented in the first column of table 13-1. For phosgene, both OSHA and NIOSH have the same protective level for an 8-hour TWA (0.4 mg/m^3). Because these TWAs are equal, phosgene is not included in the first column of the table. But because NIOSH has also set a Ceiling Limit, while OSHA has not, there would be an entry in the second column of table ***13-I.*** There will be an entry in column 3 or column 4 only if both the TWA and ceiling limits are more stringent or equal. (Although not included in the table, the number of times that two

Table 13-l .—Comparison of Protective Levels for Selected Substances

	Number (percent) of substances			
Case	TWA[b] is more stringent	Ceiling Limit[b] is more stringent	Both TWA and Ceiling Limits are more stringent	Both TWA and Ceiling Limits are equally stringent
OSHA standards compared with NIOSH recommendations.	28 (23%)	5 (4%)	2 (2%)	22 (18°/0)
OSHA standards compared with ACGIH TLVs[b].	11 (9%)	12 (10%)	10 (8%)	15 (12%)
NIOSH recommendations compared with ACGIH TLVs[b].	35 (28%)	50 (41%)	28 (23%)	15 (12%)

[a]For 123 substances for which NIOSH has made recommendations to OSHA.

[b]TWA is an abbreviation for Time-Weighted Average exposure level. The TWAs compared are typically calculated for an &hour workday and a 40-hour workweek. Ceiling Limits are defined for this comparison, in most cases, as a 15-minute Time-Weighted Average exposure level ACGIH uses the term Short Term Exposure Limit (STEL) for this. TLV or Threshold Limit Value is ACGIH's term for its recommendations concerning airborne concentrations of substances. See text and app. A for a more complete discussion.

[c]The number presented is the number of cases for which the first organization listed has a protective level more Stringent than the second organization.

SOURCE: Office of Technology Assessment.

organizations have identical TWAs or ceiling limits is included in the following discussion.)

Overall, NIOSH recommendations are more strict than the OSHA standards. Even when the Protective Levels are separated into TWA and Ceiling Limits, OSHA generally permits higher exposures. Only 28 TWA PELs set by OSHA are more stringent than NIOSH's. In all but 2 of those cases (lead and carbon dioxide) the TWAs used by OSHA appear to be more stringent because NIOSH did not set a TWA but only set a Ceiling Limit. In many cases (22 of the 28), this NIOSH Ceiling Limit is lower than or equal to the TWA used by OSHA.

There are, however, 5 instances in which the OSHA Ceiling Limit is more strict than the NIOSH one, although in each case this is because NIOSH has not recommended a Ceiling Limit. There are 33 instances (27 percent) where OSHA PELs are equal to NIOSH recommendations, either in the TWA or Ceiling or both. Of these, 22 represent situations in which both the TWA and Ceiling Protective Levels are identical.

As mentioned, ACGIH updates its TLVs every year but OSHA's PELs remain virtually frozen at the levels adopted by ACGIH in 1968. Obviously, then, OSHA PELs and ACGIH TLVs will be equal in those cases in which ACGIH has not changed its 1968 levels (15 instances). It is noteworthy that ACGIH now has TLVs for over 600 toxic and hazardous substances—some 200 substances more than OSHA regulates.

OSHA standards are stricter overall than ACGIH TLVs in 10 cases (8 percent). ACGIH has no recommendation for 4 of those substances: acetylene, DBCP, ethylene dibromide, and petroleum solvents. OSHA's TWAs are stricter than ACGIH TLVs in 11 cases (9 percent) and OSHA's Ceiling Limits are stricter than ACGIH's in 12 cases (10 percent). In all but 6 of these, if the TWA used by ACGIH is weaker than OSHA's, then the ACGIH Ceiling Limit is stricter than OSHA's (or vice versa). On the whole, instances where OSHA is more strict occur because ACGIH has not made any recommendation at all.

NIOSH recommendations are stricter than ACGIH TLVs for 28 substances (23 percent) out of the 123. In 4 instances, as mentioned above, this is because ACGIH has not set any TLVs for these substances. NIOSH has stricter TWAs than ACGIH in 35 cases (28 percent) and stricter Ceilings in so cases (41 percent). NIOSH recommendations and ACGIH TLVs are equal in 15 cases (12 percent). Sometimes one set of Protective Levels, such as the TWA, is equivalent and the other is not (33 cases), For example, the TWAs for xylene are the same for both NIOSH and ACGIH, but ACGIH's Ceiling is stricter than NIOSH's. There is only one chemical with an OSHA PEL and an ACGIH TLV for which NIOSH has not set an exposure limit (boron trifluoride).

Discussion

These three organizations use different formal decision rules when setting their standards and recommendations. However, in practice, many more informal factors enter into the decisions, including the experience of the individuals involved, their professional judgments on what is protective of worker health, and the values and goals for public policy that are held by these individuals and their organizations.

For OSHA and NIOSH, the formal guidelines for recommendations and standards derive from the OSH Act, which appears to distinguish between the "criteria" developed by NIOSH and the "standards" set by OSHA. NIOSH is required to develop "criteria" solely on health and safety grounds, without consideration of the feasibility of the "criteria. " OSHA, on the other hand, is directed to set standards that are "reasonably necessary or appropriate" and, in the case of health standards, to protect employee health "to the extent feasible. " (For a discussion of OSHA decisionmaking, see ch. 14.)

ACGIH sets its TLVs at levels "under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect." ACGIH cautions, however, that because of variation in individual susceptibility, some workers may still develop an occupational illness from exposures at a TLV. The TLVs "should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations" (8).

This comparison shows, in a limited way, that OSHA has tended to lag behind NIOSH's and ACGIH's Protective Levels. There are several interrelated reasons for this lag. The first, and most important, is that OSHA is a governmental regulatory agency. Employers can, if they wish, ignore NIOSH recommendations and ACGIH TLVs. But even though OSHA's inspection activity is limited (see ch. 12), OSHA standards can potentially be used as the basis for civil penalties and required abatement. Thus they receive more attention.

Opposition has often accompanied that attention. Most of OSHA's health standards have been challenged in the courts. Resolution of these cases has taken time–in most cases, several years. The courts now require that OSHA standards be based on adequate evidence that the hazard addressed by the standard poses a "significant risk" and that compliance is "feasible" for the affected industry. Moreover, Executive Orders since 1974 have required that OSHA examine the economic impact of its standards prior to issuing them. (For a discussion of this aspect of OSHA decisionmaking, see ch. 14.)

In addition, although OSHA is to use NIOSH's recommendations as one element for its standard-setting, it is not required to respond to those recommendations within any specified deadline. Beyond this, OSHA has often concluded that the NIOSH Criteria Documents did not provide an adequate basis for developing standards. Thus OSHA has usually developed its own scientific and technical information concerning hazards and controls. These factual and legal requirements, as well as the requirements of the Executive Orders, have consumed time, stressed OSHA's limited resources for standard-setting, and slowed the agency.

NIOSH and ACGIH have their own resource constraints, too. But they do not have the same potential for public opposition and legal challenge. They can issue recommendations based on their judgments about employee protection from adverse health effects, without formal analysis of the feasibility or costs of these recommendations.

In 1983, it was reported that a memorandum had been prepared by OSHA staff recommending that the agency stop working on the development of revised exposure standards for 116 substances that are regulated under OSHA's startup standards. OSHA's activities concerning these 116 chemicals include requests for information on 61 of the chemicals, preparation of advance notices of proposed rulemaking on 55 of them, issuance of proposed rules for 23, and hearings on rules to regulate 9 of the chemicals. According to the memorandum, a decision to stop working on rules for these chemicals would be practical, as the agency no longer has the staff or resources to pursue this activity, Although OSHA has stated that a decision not to pursue regulation of these chemicals has not been made, there has been little recent activity regarding these 116 substances. The last hearing to be held on any of them concerned beryllium, in 1977, and there has been no public activity on any of the others since 1975 (110,366, 517a).

As discussed earlier, from 1971 to 1984, OSHA issued 18 separate health standards. But only 12 of these established Permissible Exposure Limits or other requirements for 25 specific exposures. Requirements for 3 of these have been overturned by the courts. Thus, of the approximately 410 OSHA-regulated substances, nearly all are still the same as those OSHA initially adopted in 1971.

In direct contrast to this is the experience of some European nations. For example, in July 1984, Sweden issued a revised list of health standards that included 18 revisions of existing exposure limits and the addition of limits for 22 new substances previously not regulated. This is the result of only 3 years of effort, as the last revision of the Swedish health standards was published in June 1981. Although it is generally believed that the Swedes are leaders in occupational health and safety, it is difficult to gather quantitative information on actual exposure conditions in Sweden and the United States. Thus, it is not clear to what extent the Swedish limits are translated into actual protection. It is clear, however, that the process of revising the exposure limits in the United States is dramatically slower.

IMPACTS OF OSHA

Cost of OSHA Compliance

There are a number of difficulties and problems in securing accurate and meaningful information on the costs of health and safety regulation. These problems generally plague both estimates of the costs of any particular regulation or proposed regulatory change and estimates of the total costs of all OSHA regulations.

First, the basic source of data on the costs of compliance with regulations is employers, either because they are the most knowledgeable about day-to-day conditions and equipment in their plants or because they have given permission to outsiders to visit their facilities. But businesses generally do not arrange their accounting systems to keep track of all health and safety expenditures. Although information is sometimes available for certain health and safety expenses (e.g., the salary of a company physician), there is generally no account entry for the ***total*** expenditures for health and safety. Thus, estimates of current costs and predictions of future costs are generally based on inexact information and guesses rather than on data that can be verified and audited.

Furthermore, when asked to provide these estimates, there is a tendency for employers to overestimate regulatory costs. Employers have a strategic interest, if they oppose a particular regulation or Government intervention in general, in overestimating the costs. In addition, lower- and middle-level managers, when asked how much a regulation will cost in their areas of responsibility, will tend to overestimate the costs because, in the words of a senior official at ALCOA, "it is better to be under budget than over budget" (140). Facing the possibility that they will have to budget expenditures within the estimates they make, managers may overestimate costs in order to have a sufficient budget.

Second, compliance cost estimates have generally not been offset by the benefits of health and safety compliance. In fact, in many cases what appear as new costs to the business firm are merely costs that previously had been borne by workers and society. For example, the costs to a business of preventing occupational injuries may merely represent costs previously borne by injured workers in terms of lost wages, pain, and suffering. In addition, the increased costs to employers often represent increased revenues for suppliers of control technologies and an increased number of jobs for health and safety professionals. Moreover, when complying with regulations, employers often are able to offset, at least partially, the costs of compliance with improvements in productivity and reductions in the costs of lost wages, medical care, down time, etc. that are associated with workplace injuries and illnesses.

Third, there are several difficulties in correctly separating and attributing health and safety expenditures. The first of these concerns how to allocate the costs of equipment and personnel that perform multiple functions, including normal business activity, or that enable compliance with several regulations. For example, an employer installs a ventilation system that both reduces the level of a toxic air contaminant and provides heating and air conditioning. What percentage of the cost of the duct work, fans, switches, installation costs, etc. should be attributed to the industrial hygiene function and what percentage is a normal business expense for heating and air conditioning?

A second, and related, difficulty arises most particularly in attempts to estimate the costs related to existing OSHA regulations or proposals for new standards. This concerns how to separate incremental costs (those due solely to the presence of regulation) from total costs, which include spending that would have taken place even in the absence of regulation. These could include the costs incurred because of corporate good citizenship, collective bargaining agreements, and fear of legal liability. For new, more stringent regulations, the distinction is often made between the total costs of compliance and the incremental costs for reducing hazards beyond the existing requirements.

Finally, cost estimates generally assume the use of currently available technologies, neglecting the potential for cost savings with improvements in control technology. Over time, industry may learn how to control more cheaply and control technologies themselves may improve. Thus control may become less costly. Basing the costs on current technology will thus tend to overestimate the costs of compliance (33).

Estimates of Total OSHA Compliance Costs

Robert Smith *(446)* has reported a National Association of Manufacturers estimate that its members needed to spend between $35,000 and $350,000 each to comply with OSHA startup standards. No other details of the methodology behind this estimate were given.

The Economics Department of the McGraw-Hill Publications Co. annually surveys a group of large companies about actual and planned capital expenditures and about the percentage of their capital spending that is for employee health and safety and for air, water, and solid waste pollution control, McGraw-Hill then develops national estimates based on these survey responses *(298).* There is no independent verification of the survey responses, although a limited check is conducted to ensure internal validity of survey questionnaires. Information is not collected on annual operating expenses, but only on capital spending. Nor is information collected on what companies would be spending on health and safety even in the absence of OSHA activity.

The total capital spending for occupational health and safety was estimated to be $4.5 billion in 1982 and $4.9 billion in 1983, representing 1.4 percent and 1.6 percent of total capital spending, respectively (table 13-2). When measured in current dollars, capital spending for health and safety has ranged from ***$3.3*** billion to ***$6.6*** billion (from ***$2.4*** billion to ***$4.4*** billion in 1972 dollars). The latest estimate of investment, about $5 billion, is only about one-sixth as large as the National Safety Council estimate regarding the costs of work injuries alone—over $30 billion each year (324, 530).

In both current and real dollars the peak for reported capital spending appeared in 1978. From 1979 to 1983, the expenditure ranged between $2.4 and $2.9 billion (in 1972 dollars). In addition, the share of total capital spending that has been devoted to employee health and safety, which never fell below an average for all industries of 2.0 percent from 1972 to 1978, has been in the range of 1.4 to 1.6 percent for the last 5 years for which data are available (298). This decline in recent years in the percentage share of capital spending devoted to health and safety is similar to the decline in the share of capital spending for pollution control (410).

Table 13-2.—McGraw Hill Survey of Capital Spending for Worker Health and Safety

	Health and safety investment		
Year	Current dollars (millions)	1972 dollars[a] (millions)	Percent of capital spending
1972	3,279	3,279	2.7
1973	3,616	3,552	2.6
1974 ... , . .	4,403	4,028	2.8
1975	3,842	3,044	2.4
1976	3,415	2,550	2.0
1977	4,291	3,043	2.2
1978	6,645	4,439	2.9
1979	4,317	2,719	1.6
1980	4,128	2,441	1.4
1981	5,112	2,848	1.6
1982	4,503	2,459	1.4
1983	4,945	2,704	1.6

[a]Adjusted to 1972 dollars using the implicit price deflator for nonresidential producers' durable equipment Economic *Report of the President* (1984), table B-3

SOURCE (298)

Another source of information on OSHA compliance costs is a study prepared for the Business Roundtable by the accounting firm of Arthur Andersen & Co. They surveyed 48 very large corporations to estimate the incremental costs of Government regulations of six Federal agencies in 1 year-1977. The 48 companies were estimated to incur about $2.6 billion in compliance costs. Of this, only $184 million or about 7 percent was attributed to OSHA. About ***37*** percent of ***the*** OSHA compliance costs were capital costs, ***56*** percent operating and administrative expenses, and 6 percent research and development costs ***(26).***

Wiedenbaum and DeFina have developed what is probably the most widely quoted estimates of the costs of Federal regulation. Their estimate for the total costs of all Federal regulations in ***1976*** amounted to about ***$65*** billion ***(669),*** while for ***1979*** their estimate was over $100 billion ***(670).*** (See 195,428,470 for criticism of these estimates.) They did not, however, develop any new or original cost estimates for OSHA compliance. Rather, their estimate for OSHA was based on the McGraw-Hill survey plus an estimate of the costs incurred by universities for OSHA compliance.

OSHA and a number of participants in its regulatory hearings have provided estimates of the costs of complying with many of the proposals offered by the agency. The quality of these estimates has been quite variable and has usually been colored by the controversies surrounding the particular regulatory proposal. Because they have been especially subject to the difficulties discussed above, OTA has not attempted to summarize these estimates.

Impacts on Productivity and Paperwork Burdens

OSHA may also have an impact on economic productivity by diverting resources from "productive" uses to compliance with health and safety regulations. Unfortunately, available information on economic productivity generally does not include the benefits of improved worker health and safety. But even without considering those offsetting factors, the negative effects of OSHA regulation on traditional measures of productivity appear to be small.

Denisen (137) has studied the determinants of U.S. economic growth and has attempted to explain the sources of declines during the 1970s in the economic growth rate. He estimated the incremental costs of occupational safety and health regulation in three areas: costs of safety equipment on motor vehicles used by businesses, costs of mine safety regulation, and the costs of OSHA regulation. He then estimated the percent of economic inputs (land, labor, and capital) that had been "diverted" to provide for health and safety protection. In 1975, the latest year of his estimates, business vehicle safety equipment had diverted 0.09 percent of inputs, mine safety regulation had diverted 0.24 percent, and OSHA regulation had diverted 0.09 percent, compared with a 1967 baseline. All three together, then, diverted 0.42 percent of inputs. Thus, if occupational safety and health regulation and other economic inputs had been the same in 1975 as they were in 1967, net output would have been 0.42 percent larger than what was actually produced.

Thus, the estimated adverse impact of OSHA on productivity is quite small. Moreover, in some cases OSHA compliance has been accompanied by improvements in productivity. As discussed in box N (in ch. 12) and chapter 16, these cases include the OSHA standards regulating exposures to vinyl chloride and cotton dust.

One other area in which Government regulation may have had an adverse impact is in increasing the burden of paperwork on businesses. Concern about the burden of Federal forms and other record keeping was important in congressional consideration and enactment of the Paperwork Reduction Act of 1980 (Public Law 96-511). But OSHA record keeping is only a very small part of the total record-keeping "burden. " For the year ending in September 1983, the time spent in keeping OSHA-required records is estimated to be 36.9 million hours. This amounts to slightly less than 2 percent of the total for all Federal information collection activities (171,358).

OSHA's Impact on Injury Rates

During congressional debates concerning the OSH Act, one sponsor of the act expressed the hope that the creation of a Federal regulatory agency would lead to a 50 percent decline in injury rates (459). Have OSHA standards and inspections reduced occupational injury rates? As discussed in chapter 3, analysis of injury rate trends since the creation of OSHA is difficult, but it is hard to find any large changes in national, aggregated injury rates that do not appear to be associated with the effects of the business cycle.

A number of researchers have conducted statistical analyses of the possible effectiveness of OSHA in reducing occupational injury rates. Because of their greater detail, these studies can provide more information than a simple analysis of trends. Two basic approaches have been used. The first is to develop a statistical model to "explain" injury rates and changes in those rates. Such an explanatory model can include a variable that measures the activity of OSHA (usually the number of inspections per year). The analysis can examine whether changes in injury rates correlate with OSHA activity. Another use of this approach is to extrapolate results from before OSHA existed to predict injury rates. If the actual rates are below those predicted, OSHA may have been the cause.

The second major approach is to compare the injury rate experience of plants that have-been inspected with those that have not. This approach encounters difficulties if OSHA tends to inspect plants with the highest injury rates. A variation is to compare the injury records of plants inspected "early" in the year with those inspected "late" in the year. Because the data are collected annually, the records of "early inspectees" will probably reflect whatever effect OSHA has had during the year, while the records for the "late inspectees" will reflect plant experience before the inspection. Any "OSHA effect" will be seen the following year. Although this approach has the advantage of being able to estimate effects on inspected plants, it will not be able to detect any deterrent effect of OSHA in plants that have not been inspected.

In both approaches, researchers must try to correct for other factors that may influence the number of injuries and injury rates. Some of these factors include the kind of industry, the effects of the business cycle, the pace of production and overtime worked, the demographics of the work force (including age, experience, and family income), changes in the administration of workers' compensation, changes in the practice of medicine, and variations in the mix of industries and occupations.

In addition, several other factors make the task of discovering an "OSHA effect" difficult. The first concerns the low probabilities of inspection, the low average OSHA penalties, as well as variations in inspection probabilities and penalties among industries and geographic areas. Second, many OSHA inspections do not find any violations or any "serious" violations. Research that groups inspections without violations with inspections that found violations may mask OSHA's effect on employers who violate OSHA standards. Third, not all types of injuries are equally preventable by current OSHA safety standards and OSHA's inspection activity. Indeed, it is likely that some types of injuries are better addressed by the current scheme than others are, and that other types (e. g., musculoskeletal problems such as back injuries) are not currently addressed at all. Analyzing data that aggregates all injury types together may mask a favorable OSHA effect on some types of injuries.

Fourth, OSHA's shift from conducting almost entirely safety inspections toward conducting more health inspections may change the expected OSHA effect on injury rates. Fifth, the effectiveness of Federal OSHA and the various State programs may differ. Analysis of a data set that combines safety and health inspections and that groups OSHA activity with State program activity may not detect the positive effects or either OSHA or individual State programs. Sixth, the effectiveness studies that have been done have used data from employer-maintained records. If there are biases in those data, or if employers keep better records after an inspection than they did before inspections, the effects of OSHA may be difficult to evaluate.

To date, research results on this question are mixed. DiPietro (141) found that inspected firms had higher injury rates, a result that DiPietro attributed to a tendency for OSHA to inspect more hazardous plants. Smith **(446)** used a model to predict injury rates in several high-hazard industries targeted by OSHA. He found declines over time, but these were not statistically significant. In a later study (447), Smith compared early and late inspections, finding a significant decline in 1973 and an insignificant decline in 1974. McCaffrey (291) used the same methodology and found no significant OSHA effects in 1976, 1977, or 1978. Cooke and Gautschi (121) compared early and late inspections in Maine for ***1970-76*** and found a statistically significant reduction in the number of lost workdays per worker.

Mendeloff (300) was able to disaggregate injury data for California by type of injury. Using a model to predict injury rates in the absence of OSHA, he found significant decreases in several types of injuries he judged more likely to be preventable by OSHA activity. This parallels research by the State of California that shows large declines in amputations, explosions, and crushing injuries ***(668).*** Mendeloff found no OSHA effect, however, for California or the Nation using data that aggregated all types of injuries.

Two studies have used variables concerning the level of OSHA inspection activity. Viscusi (658), using data that did not distinguish between Federal and State OSHA programs, found no significant effect related to the level of Federal activity. His results did reveal, however, a significant decline in injury rates over time, which may have been a statistical artifact or the result of a favorable OSHA effect. Bartel and Thomas (45) limited their study to States covered by Federal OSHA, and found that OSHA activity had a significant effect on employer compliance with OSHA standards, but that this compliance led to only a modest reduction in injury rates.

Taken together, these results tend to support the conclusion of chapter 3 that most of the injury rate changes since *1972* have been due to the effects of the business cycle and are not related to OSHA activities. (For a more detailed discussion of these studies, see Working Paper #l.)

OSHA has analyzed the effect of one OSHA standard on the reported frequency of injuries. Between 1970 and 1978, about 47 injury-producing accidents occurred each year with one type of wheel rim used on trucks and buses. In 1980, OSHA issued a new regulation concerning the servicing of these wheels, and since then the agency estimates that the frequency of injuries has fallen by 76 percent, to about 11 per year (631). A workplace standard issued by the State of California concerning another type of wheel has also led to an injury reduction of about *80* percent *(631).* Although these declines are encouraging, they represent only **a very** small change in the total number of work-related deaths from all causes. Moreover, this appears to be the only case for which OSHA has reported the actual effects of any particular safety standard on injury rates.

The Mendeloff (300) and Smith (447) studies have been used to estimate the possible benefits in the United States of OSHA safety regulation. Green and Waitzman (195) have calculated that the 5 percent reduction in fatalities and a 2 to 3 percent reduction in lost-workday cases found by Mendeloff translate into a nationwide reduction of *350* deaths and prevention of *40,000* to *60,000* injuries per year. They also estimated that the Smith findings of 5 to 16 percent reductions in injury rates in inspected workplaces imply a reduction of *144,000* to *450,000* injuries in a year with 180,000 inspections,

Assigning a dollar value to these reductions is very difficult (see ch. 14). Using one estimate of the minimum social losses due to disabling injuries, Green and Waitzman (195) estimate that the benefits of OSHA safety regulation are, using Mendeloff's results, at least *$408* million to $610 million annually. Smith's results for lost-workday cases, they argue, imply monetary benefits of up to $4.59 billion. The reduction of 350 deaths per year might be valued at over $5 billion if one "willingness to pay" estimate of the value of life is used.

The research concerning OSHA can be compared with research about Federal regulation of mine safety. The number of fatalities in mining has fallen during the last half-century. In *1926-30,* **a** total of 11,175 miners were killed on the job, while during 1971-75, the figure was 715 (536). Congressional activity concerning coal mining has included legislation in 1941, 1952, 1969, and 1977.

Two studies have evaluated this legislation using aggregated data over time. Lewis-Beck and Alford (270) examined fatality rates from 1932 to 1976 and concluded that Federal legislation passed in 1941 and in 1969 significantly diminished the risk of fatal injuries in mining, but that the 1952 legislation had no significant impact on fatality rates. Weeks and Fox (665) concluded that there had been no change in underground fatality rates from 1950 to 1969, but a significant decline from 1970 to 1980. This decline in mining fatality rates may have recently reversed. Weeks and Fox found that in 1981 the fatality rate was significantly higher than would be expected from the rates from 1970 to 1980.

Three other studies have used more detailed information to control for nongovernmental factors that influence injury rates in mining. Boden *(63)* found that Government inspections reduced injuries and fatalities for the period 1973-75. Connerton (114), using data from 1965 to 1975, found that the 1969 Coal Act had reduced fatality rates, but that nonfatal injury rates had stayed the same or increased slightly. Neumann and Nelson *(327)* concluded that the 1969 act had significantly reduced fatality rates (they estimated that in 1976 it had been lowered by 9 percent), but that nonfatal accident rates had risen. It is not completely clear why fatality rates have fallen while nonfatal injury rates have increased since the *1969* act. Part of the reason may be improved reporting of nonfatal injuries *(536).*

Several reasons have been suggested to explain why mine safety regulation appears to have been more effective than OSHA's safety regulation in nonmining industries. First, the funding of the Government agencies has been greater for mine safety, about *$150* per worker, as opposed to $3 per worker in general industry. Second, inspection coverage is much greater. Every coal mine is inspected every year—at least twice a year for surface operations and at least four times a year for underground operations. Third, the hazards of mining are more similar from establishment to establishment than for the wide variety of industries covered by OSHA. Thus, standards and inspections can be more narrowly focused. Finally, mine safety regulations require mandatory safety training of all miners, which includes both training for new employees and refresher training for current employees *(530).*

Some critics believe that safety regulation itself represents the wrong approach to the problem of workplace injuries; they suggest injury taxes, workers' compensation, and tort liability as preferred alternatives (see discussion in ch. 15 and 16). Moreover, some have criticized OSHA's safet y standards because they mostly concern equipment and not worker activities. OSHA's safety inspections can only detect relatively permanent features of the workplace and not the transient hazards that lead to many injuries. ***Thus,*** these critics claim, it is not surprising that the studies on OSHA's effectiveness have found only limited impact or no significant impact at all.

For example, Mendeloff (302) found that only 13 to 19 percent of the 645 deaths reported in 1976 in California were related to violations of safety standards. He then asked a panel of safety engineers to review the written reports of these cases to determine if the violations would have been detected by an OSHA inspection on the day before the accident. Based on the panel's evaluation, Mendeloff concluded that only 55 percent of the serious violations would have been detected.

The California Department of Industrial Relations has analyzed occupational injuries and reports that between *30* and 50 percent of the injuries examined in several different industries could have been prevented by compliance with standards. Nearly all of the remaining injuries, they concluded, could be prevented by improved training and education *(84, 85, 86, 87, 88, 89).* Bacow (37) concludes that most injuries cannot be prevented by OSHA activity. To reach this he relies on studies of "unsafe acts" and "unsafe conditions" (summarized in ch. 4) and two studies in Wisconsin and New York that found violations of standards to be related to, at most, 30 percent of nonserious accidents and 57 percent of fatalities. A Federal Interagency Task Force on OSHA concluded that only about 25 percent of workplace fatalities could be prevented by current OSHA standards (228).

However, the information contained in inspection reports can be limited, especially for determining injury causes and in designing preventive measures. Moreover, often these studies do not consider how changed standards could prevent injuries. Many of these studies either explicitly or implicitly rely on the belief that most accidents are due to "unsafe acts" by workers. But, as pointed out in chapter 4, oftentimes changes in equipment and workplace design can prevent these "unsafe acts" from occurring or reduce the potential for injury from "human errors." Similarly, new standards concerning design and installation of equipment might increase the proportion of injuries that are deemed "preventable. "

In fact, several of these studies automatically exclude motor vehicle fatalities as "not preventable." Current OSHA standards do not generally address motor vehicle safety, but there are technologies available to reduce the incidence of deaths in vehicle crashes (664). These could be mandated by the Federal Government, probably through regulations issued by the National Highway Traffic Safety Administration.

Critics of safety standards frequently point to the importance of worker training for preventing injuries. Industrial leaders in occupational safety also emphasize worker training programs. Although perhaps more difficult than regulating machinery design, OSHA could encourage or even require safety training programs. Thus, new standards that improve the design of equipment, address hazards not currently regulated, or that improve training programs may have a beneficial effect on injuries.

Trends in Exposure Levels

It is often asserted that exposures to toxic substances have been going down over time. However, data that would permit evaluation of this claim are scarce. Some individual firms have conducted industrial hygiene measurements for some time (see 215 for several examples). But it is not clear, even when records from these firms have been maintained and are available, that it would be appropriate to generalize from their experience. Moreover, while some exposures have declined, others have risen.

The analysis of exposure levels over time could be used to measure the impact of OSHA. Of course, this evaluation encounters similar, but not identical, problems to those found when evaluating OSHA's impact on injury rates. For hazardous exposures, however, comparatively little research has been conducted to identify the factors that influence exposure levels.

Mendeloff ***(301)*** analyzed information contained in the OSHA Management Information System about OSHA health inspections for asbestos, trichloroethylene, silica, and lead from 1973 to 1979. Although there are a number of limitations to those data, the data show substantial declines in asbestos exposures over this period. For trichloroethylene, silica, and lead, Mendeloff's analysis reveals no major changes over time.

Using OSHA inspection data, Carol Jones ***(237)*** has also found declines in asbestos exposures. She estimates that the decline in average exposures from the period 1972-76 to 1977-79 amounted to about three fibers per cubic centimeter. This exposure decline is equal to the decline in 1976 of the permissible exposure limit from five fibers per cubic centimeter to two fibers per cubic centimeter and thus may be linked to the OSHA standard. However, other factors, particularly the increase in the number of lawsuits concerning asbestos-related disease, may also have contributed (see ch. ***15).***

It has been estimated that the OSHA asbestos standard issued in 1972 would result in a reduction of between 630 and 2,563 deaths per year, resulting in social cost savings, in 1970 dollars, of between $110 million and $652 million per year (432). These totals may underestimate the benefits of the asbestos standard (433). In the case of vinyl chloride, exposures declined substantially after the issuance of a new, more stringent OSHA standard (see box N). It has been estimated that this standard would prevent about 2,000 deaths over the years ***1976-2000 (32).***

Two case studies commissioned by OTA for this assessment also show favorable effects after the issuance of new, more stringent OSHA health standards (see ch. 5 for a fuller discussion). Ruttenberg (413) reports that cotton dust exposures have declined substantially in the past few years, halving the number of workers who were exposed above the new permissible limit. Several textile mills appear to be completely in compliance, while others fully expect to be in the near future. In addition, these changes appear to have been accompanied by or created by the installation of new technologies that both decrease employee exposures and increase productivity.

Goble, Hattis, et al. (184) report that in the last two years there have been large declines in both employee exposures to lead in the air as well as in measured employee blood lead levels. For example, the percentage of workers exposed above 200 micrograms/ma in primary smelting has declined by nearly 20 percentage points. Blood lead levels have declined even more dramatically. New OSHA standards for vinyl chloride, cotton dust, and lead have clearly r-educed workplace exposures.

Conclusions About OSHA's Impacts

OSHA's activities can be grouped as standard-setting, enforcement, and public education and service (see ch. 12). OSHA has had the resources to develop only a few new standards each year.

But many of its revised safety standards (see table 12-4 in ch. *12)* have been limited in their scope and have not addressed major workplace hazards. There are many areas for which standards could be issued, to improve equipment design, address hazards not currently covered, and establish workplace training programs. Moreover, many of the current safety standards most frequently cited by OSHA inspectors are only rarely involved in workplace fatalities *(302).*

Many critics of OSHA's safety standards, however, believe that there must still be a role for health standards *(446, 685)).* Indeed, analysis of several of OSHA's health standards reveals substantial reductions in workplace exposures, reductions that should lead to improved worker health. However, analysis of OSHA standards and the recommendations of ACGIH and NIOSH reveals that OSHA's adoption of health standards has lagged behind professional recommendations.

Criticisms about OSHA's health standards are less likely to be about whether they are needed than about the desirable level of protection. In particular, employers have been concerned that OSHA has not taken account of the costs of these standards (see ch. 14), or that OSHA requires the use of engineering controls to reduce or eliminate these hazards, instead of allowing the use of personal protective equipment (see ch. 9). Labor, on the other hand, has criticized the slow pace of standard-setting, as well as the increasing attention to the predicted costs of standards.

Finally, OSHA and the State programs have been able to inspect (combining health and safety inspections), at most, 4 percent of all establishments and less than 20 percent of manufacturing establishments each year. In addition, the penalties for violations are, on average, very low, and in most cases, much smaller than the potential costs of controls. Because of the low frequency of inspection and the low penalties, it is particularly important that the people who are always in the workplace—workers and managers—be fully informed about occupational hazards. In addition, steps can be taken to provide other incentives to ensure that appropriate control technology is installed (see chs. 15 and 16).

Analysts can disagree on the number of cases of occupational disease and injury that the current regulatory scheme may be able to prevent. But, in practice, there have been substantial limitations on these regulatory activities. Any changes in this, however, would require agreement by Congress and the executive branch to increase OSHA staff and funding, as well as to expand its ability to influence business decisions on workplace investments and operations.

There is a general belief that the presence of OSHA has increased manager and worker awareness of occupational health and safety. Kochan, et al. *(253)* report, from interviews with company and union officials, that "management has assigned a higher priority to plant safety, the ability of the union to influence management decisionmaking on safety issues has increased, and the role of the union-management safety committees has been bolstered" since the passage of the OSH Act. This increased attention has also created a need for health and safety professionals and probably increased their role in company decisionmaking. The presence of a Federal regulatory agency may lead employers to anticipate potential health and safety problems and solve them before regulatory action becomes necessary. The OSH Act also created new rights for worker information and participation concerning health and safety. Although all these changes may be desirable, it appears that OSHA activity has, thus far, not had a very large effect on injury rates. It has had some effect on several clearly defined health hazards, but its effects on the many hazards it has not addressed are still in doubt.

IMPACTS OF NIOSH

OTA has divided NIOSH research activities into three categories: hazard identification, development of controls, and dissemination of information (see ch. 12). Assessing the impact of NIOSH in these areas is even more difficult than assessing that of OSHA. In theory, quantitative measures of inspection activity and injury rates can be analyzed although, of course, there are great difficulties in doing so. But the impact of an agency that conducts research is not subject to even these limited measures. In fact, quantitative measures can be especially misleading" when assessing research. It is not the number of studies completed or papers published that is important, but the quality of the research.

Does this research and dissemination contribute to the advance of knowledge in the field of occupational health and safety? Are the epidemiologic and toxicologic studies based on well-designed protocols followed by comprehensive and accurate data collection? Can the studies be reproduced? Do the NIOSH-developed sampling and analytical methods provide accurate and valid results? Do the control technologies developed or described actually work as indicated? Is the information provided by NIOSH accurate and useful? Are the educational programs sponsored by NIOSH worthwhile? Finally, do all these activities lead to improvements in working conditions and in the health and safety of the work force?

In the late 1970s, some concern was expressed that the quality of NIOSH research was suffering (primarily following criticism by affected companies and industrial consultants of a NIOSH study of workers exposed to beryllium). When Donald Millar became Director, he took several steps to improve NIOSH research. One of these was the establishment of a Board of Scientific Counselors to advise the Director on all aspects of research conducted by NIOSH. The Board consists of 10 scientists who are knowledgeable about occupational safety and health research. The board has only recently been appointed and held its first meeting in early 1984. Although the appointment of a board is a concrete step, it is not clear what effects this will have on the quality of NIOSH research.

As in the case of OSHA, the ideal would be to know what the situation would have been in the absence of NIOSH activities. Certainly some research and information dissemination would have taken place at universities and in the private sector, even without Government activity. Although it is difficult to quantify this, it is unlikely that private sector parties by themselves would have devoted the same level of resources to health and safety research as the Federal Government has through NIOSH. Because information is, to some extent, a "public good, " private parties have only a limited incentive to develop it on their own. Once published, many can benefit, but because the information is already public, the original researcher would encounter great difficulty in charging each beneficiary for that information. Thus, it can be argued, the Government needs to be involved in order to provide this "public good."

NIOSH is the only Federal agency dedicated to occupational health and safety research and dissemination. Although NIOSH is not the only organization that conducts or sponsors epidemiologic and toxicologic studies of workplace hazards, its studies have advanced knowledge in this field. Controls are developed in the private sector, but NIOSH has provided many of the detailed sampling and analytical methods used by private sector industrial hygienists. NIOSH publications are widely distributed and serve as an important source of reference on occupational hazards and controls. Today, most newly graduated occupational health and safety professionals in the United States are educated in programs that receive funding from NIOSH, and many come from the programs at the institutions that have been designated as Educational Resource Centers.

SUMMARY

An OTA comparison of the standards and recommendations from OSHA, NIOSH, and ACGIH reveals that OSHA has tended to lag behind the recommendations of both NIOSH and ACGIH. OSHA's startup standards included nearly 400 Threshold Limit Values published by ACGIH in 1968. ACGIH has increased the number of substances on its list to over 600 and has revised the TLVs for many substances from the 1968 list. Since 1971, NIOSH has formally transmitted recommendations concerning over 160 different substances, classes of substances, or hazardous working conditions to OSHA, After adopting the initial group of startup standards, OSHA has issued new or revised Permissible Exposure Limits and other requirements for 10 substances, and work practice, monitoring, and personal protection requirements for 14 other substances and one physical agent. A detailed numerical comparison for a group of 123 substances shows that, overall, OSHA standards are less stringent than NIOSH and ACGIH recommendations.

The impacts of OSHA and NIOSH are hard to evaluate. Accurate estimation of the costs of OSHA regulation is difficult for a number of reasons. The most comprehensive cost estimates derive from a survey conducted by McGraw-Hill. According to this survey, the share of capital spending devoted to employee health and safety has changed little in the last 5 years, remaining at a percentage substantially below the levels of the 1970s.

Assessing OSHA's impacts on injury rates and exposure levels is also difficult. The research on OSHA effects on injury rates divides into two groups—studies that find a statistically significant, but small effect, and those that do not find any significant effects. The limited research on exposure levels appears to show positive effects for hazards that were the subjects of new or revised OSHA regulations during the 1970s—vinyl chloride, asbestos, cotton dust, and lead.

Because NIOSH's major activity is research, its impacts are even more difficult to quantify. The quality of NIOSH research has been criticized although NIOSH has recently taken steps for improvement. A number of other aspects of its operations have been criticized as well. However, many occupational health and safety professionals have graduated from NIOSH-sponsored training programs. NIOSH has also been an important source for the dissemination of information in this field.

One final impact of both OSHA and NIOSH is that their presence has served to increase the attention given to occupational health and safety* by workers, employers, and health and safety professionals. This increased attention facilitates the identification of hazards and the development of controls. Thus, indirectly, OSHA and NIOSH activities have spurred improvements in worker health and safety, although these effects probably cannot be quantified.

14. Decisionmaking for Occupational Safety and Health: The Uses and Limits of Analysis

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TABLE

14. Decisionmaking for Occupational Safety and Health: The Uses and Limits of Analysis

A number of different criteria are used for judging the desirability of changes that might improve workers' health and safety. Some have proposed that greater reliance be placed on the use of cost-benefit analysis, cost-effectiveness analysis, and other techniques of economic analysis for decisions concerning workplace health and safety. This chapter discusses some general issues concerning decisionmaking for occupational safety and health, the history of the use of economic analysis by the Occupational Safety and Health Administration (OSHA), and the merits and limitations of the techniques of formal analysis.

GENERAL ISSUES IN DECISIONMAKING

The process of improving occupational safety and health involves the identification of hazards, the development of control techniques, and the decision to control. Choices need to be made concerning products and workplace design by many actors—the engineers in charge of design, the managers who make decisions concerning production, and public officials with responsibilities for protecting the health and safety of workers and the public.

> The decisions we need to make. . . turn on the question: Which hazards are acceptable, which not, in what amounts, and why?, . . And who should be empowered to make this decision? (281)

In many cases, the answers to these questions are not simple. Oftentimes facts are uncertain and in dispute. Sometimes, values and ideals conflict with each other. To resolve such disputes, societies rely on various institutional arrangements. In the field of occupational health and safety in the United States, the principal institutions are Congress, the courts, the Occupational Safety and Health Review Commission, and OSHA itself.

This issue of decisionmaking—the question of who is authorized to make decisions and on what basis—is important because the participants can differ greatly on the nature of occupational hazards and the best means to reduce or eliminate them. Labor, on the one hand, believes that employers have often not done enough to reduce or eliminate workplace hazards and desires a strong governmental presence in setting and enforcing standards. Employers, on the other hand, are often concerned about investing money in unnecessary controls, believing either that their workplaces are not hazardous or that effective, but less costly control methods are available. They also often contend that they, as employers, should be permitted to decide on appropriate control methods, without the involvement of Government agencies or labor unions.

Some disputes about the Government's role in occupational health and safety concern very technical questions about the application of the principles of industrial hygiene and safety engineering; some are debates at the very frontiers of scientific knowledge on the mechanisms of toxicity. But beyond these disputes are more general debates concerning the criteria on which decisions will be made and who shall be empowered to make them. The proposed resolutions of these issues are based on interpretations of technical information about risk as well as the moral and ethical values, the political beliefs, and the immediate economic interests of the various parties involved. In fact, one prominant feature of disputes on occupational health and safety is that debates over technical questions are often combined with discussions of more general issues of policy, ethics, and social values.

To develop and present the information needed for a fully informed decision on workplace hazards, various observers have suggested different kinds of formal analysis. The techniques are, in many cases, connected with proposals to specify the criteria on which decisions must be based. These criteria range from a vague injunction to consider "all relevant effects" to requirements that controls can be required only when "the benefits exceed the costs. "

Private Decisionmaking

On what basis do employers make decisions concerning worker health and safety? What decision rules will they follow? Some employers, of course, take actions to protect the health and safety of their employees either out of altruism or enlightened self-interest. But in general decisions made by employers follow the dictates of the competitive market system in which they operate.

Economists have developed models to explain this market-oriented behavior. The simplest and most commonly used model seeks to explain the actions of firms in terms of profit-maximization and cost-minimization. If this is a company's goal, it will take an action only if the expected revenue is at least equal to the costs of that action. Using the technical language of economics, this means that the firm will produce only up to the point at which the marginal revenue from the last additional product unit is equal to the marginal costs of that unit.

Applied to investments and expenditures for occupational safety and health, this model predicts that to prevent an occupational injury or illness, employers will spend only as much as they can expect to gain in terms of reduced workers' compensation costs, improved employee productivity, reduced "down time, " etc. Thus, **any** investment for health and safety must be justified in terms of the short-term and long-term financial benefits to the firm. If the company is attempting to be as profitable as possible, it will not take actions to protect employee health and safety solely because health and safety are important goals, but only when there are financial benefits to the firm. If the firm does not follow this rule, it may find itself spending money to improve health and safety without receiving any corresponding financial benefit. Competitors that do not also make such improvements will be able to produce the same products at lower cost and then increase sales and / or profits at the expense of the firm that invested in health and safety.

Health and safety professionals have often cited the slogan "Safety Pays" as a justification for improving occupational health and safety. Although in many cases this is true, in other cases it is not. Moreover, even when it does pay, it generally pays only up to a point.

Therefore some businesses will not always take voluntary actions because they will not reap any advantage over their competitors. One benefit of Government regulation is that it puts all firms on an equal footing. A company can undertake investments in employee health and safety without fear that it will lose money to competing firms that do not do so. Expressed differently, Government regulations may require certain measures beyond those that "pay" from the point of view of the individual firm ***(245).***

This is not to say that all employers will ignore occupational safety and health. Indeed, there are numerous examples of employers and their professional staffs who have taken extensive actions to improve worker health and safety, even without pressure from a Government agency. This could be because of the commitment of professionals and companies to goals of ethical behavior or corporate altruism; a decision by the firm to pursue goals other than maximizing profits; or the belief by company officials that such investments, although not profitable in the short term, will ultimately be to the long-term benefit of the firm. (See additional discussion on voluntary activities in ch. 15.)

Public Decisionmaking

During the congressional debates concerning the Occupational Safety and Health (OSH) Act,

Photo credit Department of Labor, Historical *Office*

Rescue workers attempt to extricate a trapped worker

many references were made both to the rights of American workers to safe and healthful working conditions and to the high cost of work-related illnesses and injuries. Congress concluded that too many illnesses and injuries were occurring and that the efforts being made and the institutions of that day were not sufficient to achieve the goal of preventing disease and injury in the workplace.

Broadly speaking, two different types of reasoning have been suggested to justify Government intervention. The first is based on ethical arguments, MacCarthy ***(277)*** describes four different ethical justifications for Government action that are based on utilitarianism, workers' rights, distributive justice, and public values. Others argue that Government intervention must be justified by economic criteria. In particular, the Government should intervene only in cases of "market failure" and only after balancing costs and benefits of its decisions ***(425,446,463,685).*** Three sources of "market failure" are particularly important for worker health and safety: inadequate information, lack of labor mobility and unequal bargaining power, and the presence of externalized costs.

Decision Tools and Rules

The techniques of cost-benefit and cost-effectiveness analysis have been developed to assist private and public decisionmakers. In previous assessments concerning medical technology, OTA has considered cost-effectiveness analysis and cost-benefit analysis as parts of a family of related techniques (539). Both are designed to compare the costs and effects of projects or alternative projects. The principal difference between them is that in a cost-benefit analysis, both costs and benefits are expressed by the same measure, which is nearly always monetary. In cost-effectiveness analysis, on the other hand, costs and benefits are expressed by different measures. Costs are usually expressed in dollars, but benefits or effectiveness are ordinarily expressed in terms such as "years of life saved, " "days of morbidity or disability avoided, " or other relevant measures . (539).

Cost-benefit techniques became widely used in the United States in the 1930s and 1940s for the evaluation of public works projects (in particular, for analyzing investments of public capital in projects for irrigation, hydroelectric power, and flood control). The Flood Control Act of 1936 ***ex***plicitly called for a cost-benefit decision rule by permitting the Government to finance a water project only when "the benefits to whomsoever they may accrue are in excess of the estimated costs" ***(280).*** In the 1960s and 1970s, the techniques of cost-benefit and cost-efectiveness analysis were applied in formal budget planning systems in the Federal Government. To some extent, these techniques have **also** been applied to questions of health policy (539).

Analysis can be a *tool* to assist in the decisionmaking process or it can be used as a formal decision ***rule.*** As a tool, the collection of information and its analysis can assist policymakers to reach sound, well-informed, reasoned decisions about the management of workplace hazards. There is widespread agreement, at least in principle, that decisionmakers need to have some minimal understanding of the important features of the problem to be addressed, the factors involved in the decision, and the implications of various courses of action. There are, of course, disagreements concerning the application of this principle. In particular, there are often disputes about how much information needs to be collected and to what extent policymakers should be allowed to **act** on the basis of uncertain and incomplete information.

As a decision rule, however, formal analysis is considerably more controversial. A decision rule specifies the criteria on which decisions must be based and usually requires that certain findings be made before action is permitted. For instance, a cost-benefit decision rule would be to "select the alternative that produces the greatest net benefit" *(463).*

As a tool, a ***cost-benefit analysis*** of a proposed action can be provided to a decisionmaker, who can still decide to undertake the proposed action even if the analysis shows that the quantified costs exceed the quantified benefits. The decision could reflect a concern for the distributional consequences of a failure to act or consideration of some important benefits of the action that could not be quantified. Thus a cost-benefit analysis provides information, but the decisionmaker still has the flexibility to act even when the "bottom line" of the analysis says, "Don't act." If a formal cost-benefit decision rule were in effect, the decisionmaker would not be able to include those other considerations in the final decision, but could only act on the basis of the quantified comparison of costs and benefits.

As a decision-assisting tool, ***cost-effectiveness analysis*** can be used to describe many of the consequences of an action. But because the costs (in dollars) and the benefits (e.g., in lives saved) are left in incomparable units, cost-effectiveness analysis will provide a clear decision rule only in two circumstances. If a health goal is specified, then a decision rule based on cost-effectiveness analysis will mandate the selection of the least costly alternative that achieves that goal. Alternatively, if a budget or expenditure is fixed, then a cost-effectiveness rule will require selecting the alternative with the greatest health benefit.

In occupational health and safety, two other types of analysis have become important—risk assessment and feasibility analysis. What these imply for OSHA, however, has been the subject of considerable dispute. The meaning of these terms and requirements concerning their use by OSHA have evolved over the last 14 years.

OSHA DECISIONMAKING ON STANDARDS

Principles Embodied in the OSH Act

When the OSH Act was passed in 1970, Congress clearly decided to involve the Federal Government in research and regulatory activity. In particular, Congress mandated the adoption of health and safety standards and set forth a mechanism for writing new standards. To some extent, the law removed decisions concerning health and safety from the competitive marketplace by limiting employer discretion. Congress, however, was less clear about the precise decision rules that OSHA would have to follow when setting these standards.

At the beginning of the OSH Act, Congress declared a purpose for Government activity in the occupational health and safety field: "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions." The act empowered the newly created agency to set and enforce mandatory occupational health and safety standards. Section 6 laid forth the procedures for adopting these standards: public notice of proposed actions, an opportunity for public comment, the conduct of a public hearing if requested, and a final decision based on the evidence presented to the agency. (Further details about these procedures are given in ch. 12.)

Two subsections of the Act define health and safety standards and specify the criteria on which standards are to be based. Section 3(8) of the Act provides:

> The term "occupational safety and health standard" means a standard which requires conditions, or the adoption or use of one or more practices, means, methods, operations, or processes, reasonably necessary or appropriate to provide safe or healthful employment and places of employment.

Section 6(b)(5) specifies the criteria for standards concerning toxic materials or harmful physical agents:

> The Secretary . . . shall set the standard which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no ***employee will suffer material impairment*** of health or functional capacity even if such employee has regular exposure to the hazard . . . for the period of his working life. . . . In addition to the highest degree of health and safety protection for the employee, other considerations shall be the latest available scientific data in the field, the feasibility of the standards, and experience gained under this and other health and safety laws (emphasis added).

The extent to which the goals of environmental, consumer, and worker protection are to be balanced against the costs of protection has defined much of the debate on regulatory policy during the last decade. Discussions of the standard-setting authority of OSHA and the proper role for cost considerations have focused on these two subsections.

The legislative history of the OSH Act that is relevant to this question is, in the words of the Supreme Court, "concealedly not crystal clear. " In particular, it does not explain what the Congress meant by "feasibility" or how OSHA was to balance economic and technological considerations in setting standards. Neither the original Senate bill nor the House version included specific provisions about regulating toxic substances; in both, the section was added in committee.

The criterion of "feasibility" was first proposed by Senator Jacob Javits (R-NY), who was concerned that the other bills then under consideration "might be interpreted to require absolute health and safety in all cases." The final amendments that resulted in section 6(b)(5) were added on the Senate floor. They reflect the objections to that section from several Senators. Senator Peter Dominick (R-CO) argued, in particular, that "[i]t is unrealistic to attempt. . . to establish a utopia free from any hazards. " After some discussion, a compromise was reached (280). The language adopted by the Senate was later accepted by the House-Senate Conference Committee and incorporated in the final bill signed by President Nixon.

There is no evidence that cost-benefit analysis was ever explicitly proposed during those debates as a decision rule for the new agency. Congress had previously issued laws that did contain cost-benefit decision rules, starting with the flood control legislation of the 1930s. The nonuse of such a rule in the OSH Act, if not its explicit consideration and rejection, was important in the Supreme Court's decisions concerning the decisionmaking authority of OSHA (discussed below).

MacLean (280) suggests that one possible reason that cost-benefit analysis did not enter the debates is that it simply did not occur to Congress that such an analysis could be applied to balance health risks against economic costs. At that time—1970—the theory and techniques of cost-benefit analysis, which had been used to evaluate public works projects, were still being developed for application to health and safety issues.

Because of concern about the costs of the OSH Act, language was added to require that OSHA take into account the "feasibility" of its standards. But the final bill also included the goal that "no employee will suffer material impairment. " In the floor debate, Senator Ray Yarborough (D-TX) expressed the sentiment behind this language: "We are talking about people's lives, not the indifference of some cost accountants. " As commentators have noted, since the passage of the OSH Act "the degree to which the complete protection of safety and health should be compromised by the technological difficulty and economic cost of achieving that protection has been an issue of constant controversy" (51).

Regulatory Relief

In the early to mid-1970s, policymakers began to face the simultaneous problems of price inflation and unemployment. Added to these was the growing perception, which was not always based on empirical analysis, that the Government's health, safety, and environmental regulations were at least partially to blame for these economic ills. (For discussions of more general issues in Federal regulation and regulatory reform, see 3,72, 133.)

A series of Executive Orders and other procedural requirements reflected this new perception and placed new requirements on the regulatory agencies. In 1971, the Office of Management and Budget (OMB) issued a memorandum to all heads of departments and agencies to improve interagency coordination concerning standards and guidelines for environmental quality, consumer protection, and occupational and public health and safety. Known as the Quality of Life Review Program, it covered, in theory, any agency action that would significantly affect other agencies, impose costs on "non-Federal sectors, " or increase the need for Federal funds. Agencies were ordered to submit to OMB schedules of future activities and prepublication copies of proposed and final actions. In addition, proposed and final regulations were to be accompanied by a summary that indicated the principal objectives of the rules, alternatives that had been considered, "a comparison of the expected benefits or accomplishments and the costs . . . associated with the alternatives considered, " and the reasons for picking the selected alternative (424).

Although this program was theoretically applicable to all regulatory agencies, in practice only activities of the Environmental Protection Agency were examined by OMB (158,401). The memo had little effect on the activities of OSHA (47).

President Ford issued the first formal Executive Order (E.O. 11821) on regulatory relief on November 27, 1974, as part of his "Whip Inflation Now" program. This order required all major rules or regulations issued by executive branch agencies to be accompanied by "a statement which certifies that the inflationary impact of the proposals has been evaluated" (176). These were called "Inflationary Impact Statements, " probably after the "Environmental Impact Statements, " required by the National Environmental Policy Act.

A Presidential "oversight process" concerning Federal Government regulatory activity was also established at this time (659). A new agency, the Council on Wage and Price Stability (CWPS), was established in the Executive Office of the President to monitor the inflationary implications of private sector wages and prices. CWPS was also authorized to monitor the inflationary impact of Federal regulatory activity, to review the Inflationary Impact Statements prepared by the regulatory agencies, and to participate in agency rulemaking proceedings "in order to present its views as to the inflationary impact that might result" (659).

The text of Executive Order 11821 did not specifically refer to cost-benefit analysis. However, in its review of regulatory activities, CWPS defined **as** "inflationary" those regulations for which the costs exceeded the benefits (304).

Just before leaving office, President Ford extended his Executive Order, without any significant change in substance, with E.O. 11949, issued on December 31, 1976. The name of the required statements, however, was changed to "Economic Impact Statements" (177).

President Carter issued his own Executive Order on the topic of regulatory procedures (E.O. 12044, March ***23, 1978;*** renewed by E.O. **12221,** June ***27, 1980),*** which bore the title "Improving Government Regulations. " The name of the required statements was changed to "Regulatory Analyses" and in them the agencies were to present:

> . . . a succinct statement of the problem; a description of the major alternative ways of dealing with the problem that were considered by the agency; an analysis of the economic consequences of each of these alternatives and a detailed explanation of the reasons for choosing one alternative over the others.

Regulatory Analyses were required for any regulation that would have an "annual effect on the economy of $100 million or more" or a "major increase in costs or prices for individual industries, levels of government or geographic regions" ***(98,99).***

The primary thrust of E.O. ***12044*** **was** to improve the content of Government regulations and to encourage agencies to compare alternative approaches. Cost-benefit analysis was viewed as a tool "to compare alternative approaches to a given goal; . . . not to evaluate the goal, itself" ***(157, 170).*** The CWPS continued to prepare analyses of agency regulations. The Carter administration also created two other organizations: the Regulatory Council to compile calendars of future regulatory actions and to encourage innovative regulatory techniques, and the Regulatory Analysis Review Group to review particularly important regulations (157).

President Reagan issued E.O. 12291 on February 19, 1981, as a central component of his campaign for "regulatory relief." Once again, the analysis requirement was renamed, this time to "Regulatory Impact Analysis" (382). Unlike the previous orders, however, which had only required the agencies to evaluate the economic impacts of their decisions, E.O. 12291 set an explicit cost-benefit decision rule: "Regulatory action shall not be taken unless the potential benefits to society for the regulation outweigh the potential costs. " This Executive Order further specifies that "regulatory objectives shall be chosen to maximize the net benefits to society" and requires, to the extent possible, that all benefits and costs be quantified in monetary terms, Thus, E.O. 12291 was the first to require explicitly that regulatory decisions be based on a comparison of quantified costs and benefits.

In addition, the Reagan administration centralized regulatory review in one agency -OMB— and required agencies to submit to OMB copies of proposed and final regulations and the accompanying Regulatory Impact Analysis in advance of publication. Although the legal authority for proposing and issuing regulations still remains with the heads of the regulatory agencies, in practice the requirement for submission to OMB has meant that the agency must receive approval from OMB prior to publication. A Presidential Task Force on Regulatory Relief, chaired by the Vice President, was also established to resolve disputes between OMB and regulatory agencies.

Congress has also added procedural requirements for Federal regulatory agencies. In September ***1980,*** the Regulatory Flexibility Act (Public Law 96-354) was enacted. It requires agencies to prepare "regulatory flexibility analyses" for regulations that would have a "significant economic impact on a substantial number of small entities" (defined as small businesses, small nonprofit organizations, and small governmental jurisdictions). In December 1980, Congress enacted the Paperwork Reduction Act (Public Law 96-511). In general, the purpose of this act was to reduce the "burden" of federally required paperwork. OSHA and other Federal agencies are required to obtain the approval of OMB before conducting research or issuing regulations that require the "collection of information ." This includes survey questionnaires and written report forms as well as requirements for record keeping. In addition, Congress has considered, but has not enacted, a number of bills that would require Federal agencies to conduct risk assessments and cost-benefit analyses and that would change other regulatory procedures.

OSHA Standard-Setting

OSHA standard-setting activity has been a source of disputes between management and labor, between advocates of stringent regulation and those desiring regulatory relief, and between those proposing the use of cost-benefit analysis and those who reject any consideration of economic effects. Important to understanding those disputes is the legislative history of the OSH Act, the attitudes of business and labor, and the attitudes of the health and safety professionals who staff OSHA and the National Institute for ***Occu***pational Safety and Health. The disputes concerning OSHA standards have often been settled in the courts.

During its first decade, OSHA was criticized by business representatives for failing to take account of the costs of complying with its standards and for not ensuring that those costs bore a "reasonable relationship" to the benefits of the standards. Labor representatives, on the other hand, criticized OSHA for including compliance costs as a factor in its decisions.

The values of OSHA personnel have been described as "pro-protection" and, it has been argued, derive from the professional training and background of the health and safety professions and from their view of the agency's mission. Most OSHA staff have worked or been educated in the occupational health and safety professions. As one observer noted, "they believe strongly that workers ought to be protected from hazards and that larger reductions of risk are preferable to smaller ones (without much thought of cost). " These values led the agency to tend to adopt "the more protective of alternatives presented to them by the parties (from outside the agency] or by credible scientific research" (245).

The agency did, however, recognize the need to collect information concerning the technical feasibility and estimated costs of its regulatory proposals. From as early as OSHA's first year (1971), the agency has endeavored to develop this information using a combination of in-house staff and outside consultants. The goal of this early activity was not to perform cost-benefit analyses, but to provide feasibility and cost-of-compliance estimates to counter the cost estimates and claims of infeasibility made by the opponents of particular regulations (47).

The first major dispute concerning the use of economic criteria involved a more stringent standard for asbestos exposure, which was issued in 1972. At that time OSHA lowered the permissible exposure limit for asbestos from 12 fibers per cubic centimeter to 5, with a further lowering to 2 fibers per cubic centimeter by 1976. The delayed effective date for the 2-fiber limit was designed "to allow employers to make the needed changes for coming into compliance." OSHA was sued by the Industrial Union Department of the AFL-CIO for, among other issues, having considered economic factors in setting this limit. The Industrial Union Department argued that the phrase "to the extent feasible" in section 6(b)(5) should be interpreted to mean only technological feasibility—i.e. whether or not the technology to control exposures was available.

The D.C. Court of Appeals ruled in this case that OSHA could take account of the costs of complying with a new standard. Thus, in this decision, "feasibility" under the OSH Act was defined to include both technology and economics. According to the court, a standard would be considered economically feasible if compliance with it would not threaten the viability of an industry as a whole, even if individual firms might close because they could not meet the standard (223).

Two subsequent decisions refined this two-pronged definition of feasibility. The AFL-CIO challenged OSHA's decision to relax a regulation concerning the guarding of mechanical power presses ("no hands in dies"). In this case, the Third Circuit Court of Appeals ruled that while the OSH Act was a "technology forcing piece of legislation," OSHA's determination that the standard was technologically infeasible was adequately supported. In addition, this court, following the reasoning of the earlier asbestos decision, ruled that OSHA could consider "economic consequences" when setting standards. In particular, OSHA could not "disregard the possibility of massive economic dislocation caused by an unreasonable standard" (1).

Secondly, in an industry challenge to OSHA's regulation of vinyl chloride, the Second Circuit Court of Appeals upheld a "technology-forcing" standard. By this decision, a standard could be considered feasible even if the technology necessary for compliance was not already widespread in the regulated industry. All that was necessary was that the technology was "looming on today's horizon" and could be brought into widespread use. A standard would be considered technologically infeasible only if meeting the standard was shown to be "clearly impossible" (454a).

> . . . the Secretary is not restricted by the status quo. He may raise standards which require. . . improvements in existing technologies or which require the development of new technology.

At about the same time as these judicial decisions, President Ford issued the first Executive Order requiring inflationary impact statements. In following years, OSHA came under pressure from the Council on Wage and Price Stability to base its decisions on the results of cost-benefit analysis. A proposed standard concerning coke oven emissions was the basis for the first clash between OSHA and CWPS. CWPS participated in the rulemaking proceeding and argued that OSHA had overstated the expected benefits of the proposed standard. Using its own estimates of the expected number of lives saved and two estimates of the "value of life" from the economics literature, the Council suggested that the proposed standard was not worthwhile. Finally, CWPS recommended that OSHA consider allowing the use of respirators to comply with the standard (290).

Between the time of proposal and of final promulgation, a new Assistant Secretary for OSHA, Morton Corn, was appointed. About the use of cost-benefit analysis he has written (122):

> After arriving at OSHA, I engaged in an in-depth consideration of cost-benefit analysis, applying the methodology to the coke-oven standard. . . .With the dose-response data at our disposal, various assumptions were used to ring in changes on different methodologies for estimating benefits. The range in values arrived at, based on the different assumptions, was so wide as to be virtually useless. The conclusion I reached after this exercise was that the methodology of cost-benefit analysis for disease and death effects is very preliminary, and one can almost derive any desired answer.

In October 1976, when OSHA actually issued its regulation concerning coke oven emissions, its statement of reasons clearly rejected the use of cost-benefit analysis. In part, this position was a reaction to the arguments of CWPS, whose intervention **was** perceived as an attempt to reduce the level of worker protection. In the preamble to the final regulation, OSHA based its rejection of cost-benefit analysis on the difficulties of accurately estimating the expected benefits of the new standard and the lack of "an adequate methodology to quantify the value of a life" (620).

This attitude toward cost-benefit analysis continued during the Carter administration. In 1977, Eula Bingham, as Assistant Secretary for OSHA, expressed concern about proposed procedures concerning economic impact analysis (56):

> While one can argue over the specific role of economics in establishing regulations, it is clear to me that economics should not be a paramount consideration in setting safety and health standards. The overriding purpose of the OSH Act is to protect workers, tempered by considerations of feasibility, Accordingly, I would agree that some economic impact analysis should be performed to provide a basis for evaluating industry representations as to economic impacts and possibly to influence the length of the compliance period allowed for a given standard. I do not believe that policy decisions impacting worker safety and health can or should be subject to a formalized benefit-cost test.

CWPS continued to participate in OSHA's standard-setting proceedings and generally was very critical of OSHA's proposals. In a widely publicized case, Charles Schultze (then chairman of the Council of Economic Advisers), his staff, and CWPS became involved in the cotton dust rulemaking process in 1978. They suggested changes in OSHA's draft standard. After an appeal to President Carter, the major requirements for engineering controls in the standard ***were*** not changed, although some features of the standard were modified. The intervention by Schultze and CWPS, however, was viewed by many as an attempt to reduce the cost and the protectiveness of that regulation (135,290,479).

In 1978, OSHA issued final standards for benzene, DBCP, arsenic, cotton dust, acrylonitrile, and lead. Four of these six final standards were challenged in the courts. The cases concerning the benzene and cotton dust standards are particularly relevant to the evolution of the use of economic analysis at OSHA.

OSHA's more stringent standard for occupational exposure to benzene was challenged by the petroleum industry. The Court of Appeals for the Fifth Circuit ruled in this case that the phrase "reasonably necessary or appropriate" contained in the definitional section of the act (section 3(8)) meant that OSHA could issue a more stringent regulation only if it estimated the risks addressed by the standard and determined that the benefits of the standard bore a "reasonable relationship" to the costs. This ruling, in effect, erected a cost-benefit decision rule for the agency to follow. The court invalidated the standard because it concluded that there was insufficient evidence that this more stringent standard would have any "discernible benefits" (13).

This decision was appealed to the Supreme Court, which in the summer of 1980 upheld the lower court's decision to vacate the standard, although it did not follow the same reasoning. In fact, while the Court voted 5 to 4 to strike down the standard, the majority could not agree on a common set of reasons. Five separate opinions were issued by the Court, but no single opinion had the support of more than four justices. Justice Stevens presented the views of four of the justices who had voted to strike down the standard. In that opinion, the issue of whether the OSH Act required the agency to follow a cost-benefit rule was not addressed. Instead, this plurality declared that the agency had not made a "threshold finding" that risk presented by benzene exposure was "significant" (224):

> By empowering the Secretary [of Labor] to promulgate standards that are "reasonably necessary or appropriate to provide safe or healthful employment and places of employment," the Act implies that, before promulgating any standards, the Secretary must make a finding that the workplaces in question are not safe. But "safe" is not the equivalent of "risk-free.". . . a workplace can hardly be considered "unsafe" unless it threatens the workers with a significant risk of harm.
>
> Therefore, before he can promulgate any permanent health or safety standard, the Secretary is required to make a threshold finding that a place of employment is unsafe-in the sense that significant risks are present and can be eliminated or lessened by a change in practices.

After an extensive review of the record in this case, the plurality ruled that because OSHA had not made this threshold finding and because the record before the agency did not contain "substantial evidence" to support such a finding, OSHA had exceeded its authority in issuing the more stringent standard for benzene exposure. The Court did not rule on the issue of whether the OSH Act required a cost-benefit test in addition to this requirement to demonstrate "significant risk."

The Court provided only limited guidance as to what was meant by "significant risk, " words that do not actually appear in the language of the act. To quote the plurality opinion (224):

> First, the requirement that a "significant" risk be identified is not a mathematical straitjacket. It is the agency's responsibility to determine. . . what it considers to be a "significant" risk. Some risks are plainly acceptable and others are plainly unacceptable. If, for example, the odds are one in a billion that a person will die from cancer by taking a drink of chlorinated water, the risk clearly could not be considered significant. On the other hand, if the odds are one in a thousand that regular inhalation of gasoline vapors that are two percent benzene will be fatal, a reasonable person might well consider the risk significant and take appropriate steps to decrease or eliminate it. Although the agency has no duty to calculate the exact probability of harm, it does have an obligation to find that a significant risk is present before it can characterize a place of employment as "unsafe. "

In a footnote, the Court noted that the ultimate decisions of the Agency concerning the acceptable level of risk "must necessarily be based on considerations of policy as well as empirically verifiable facts" (224).

Justice Marshall filed a dissenting opinion for the four Justices who voted to uphold OSHA's benzene standard. In that opinion, Marshall argued that the plurality's review of the record was "extraordinarily arrogant and extraordinarily unfair" because the plurality had improperly made its own findings concerning factual issues and had unfairly described OSHA's analysis of these issues. Moreover, this dissent argued that the requirement to demonstrate a "significant risk" was "a fabrication bearing no connection with the acts or intentions of Congress and is based only on the plurality's solicitude for the welfare of regulated industries" (224).

The issue of whether the OSH Act required a cost-benefit test in addition to a finding of significant risk was taken up in a case concerning a more stringent standard for exposure to cotton dust. Textile industry representatives argued that OSHA had exceeded its statutory authority because it had neither conducted a cost-benefit analysis nor explictly determined that the benefits of the standard justified the costs of compliance. Labor representatives and OSHA argued that the OSH Act did not require such a cost-benefit decision rule. Instead, after determining that exposure to cotton dust presented a "significant risk" (as required by the decision in the benzene case), the agency was required to issue the most protective standard subject only to the constraint that compliance with the standard be technologically and economically feasible.

The Supreme Court affirmed the OSHA cotton dust standard by a vote of 5 to 3. The majority opinion held that cost-benefit analysis was not required by the OSH Act. Instead, Congress had erected a requirement for "feasibility analysis. " Citing dictionary definitions that "feasible" means "capable of being done, " the Court ruled (17) that section 6(b)(5) of the OSH Act

> . . . directs the Secretary to issue the standard that "most adequately assures. . . that no employee will suffer material impairment of health, " limited only by the extent to which this is "capable of being done. " In effect. . . Congress itself defined the basic relationship between costs and benefits, by placing the "benefit" of worker health above all other considerations save those making attainment of the "benefit" unachievable. Any standard based on a balancing of costs and benefits by the Secretary that strikes a different balance than that struck by Congress would be inconsistent with the command set forth in sec. 6(b)(5).

In a footnote, the Supreme Court also endorsed the definition of economic feasibility that had been suggested by OSHA. According to this, to prove a standard economically feasible, OSHA must show "that the industry will maintain long-term profitability and competitiveness" (17). This definition is consistent with the earlier courts of appeal rulings on the standards for asbestos, coke oven emissions, and lead (10,223,654).

The legal battles concerning OSHA standards were not just about the details of economic analysis and risk assessment. In part, these battles took on symbolic meanings. That is, people on both sides of these issues took positions based on what they believed these cases symbolized for Government regulatory activity. Some supported the standards issued by OSHA because these standards were believed to represent strong efforts to control occupational health and safety problems after decades of neglect. They viewed cost-benefit analysis as a technique that was being introduced to weaken governmental protections. Others opposed these standards and supported legal restrictions on OSHA, including requirements for cost-benefit analysis, because they believed that the agency had gone too far in imposing regulatory costs on businesses.[1]

[1]Table A-3 in appendix A presents a list of the legal cases concerning OSHA standards. For further discussion of OSHA's legal obligations concerning the development of standards, see (333,408). Mintz (307) provides excerpts from primary source documents related to this history of standard-setting, including legal briefs and court opinions.

Current OSHA Criteria

OSHA now uses a four-step process for making decisions about health standards, as expressed by former Assistant Secretary Thorne Auchter. First, the agency determines that the hazard in question poses a "significant risk." Second, OSHA determines that regulatory action can reduce this risk. Third, it sets the regulatory goal (for health standards, this is the permissible exposure limit) based on reducing this risk "to the extent feasible." Finally, OSHA conducts a cost-effectiveness analysis of various options to determine which will achieve this chosen goal in the least costly manner (434,638).

However, it is not clear what criteria apply to *safety* standards and other regulations issued by OSHA. In the cotton dust decision, the Supreme Court left this issue unresolved, but did state that it is possible that Congress could have set different criteria for health standards than for safety standards. It also noted that the "reasonably necessary or appropriate" language of section 3(8) would apply to safety standards (224).

"Significant risk"

To determine whether a hazard poses a "significant risk of material health impairment, " OSHA now generally uses the techniques of quantitative risk assessment. In several publications since the Supreme Court decisions concerning benzene and cotton dust, OSHA has presented quantitative risk assessments, These risk assessments have calculated the estimated risk at the currently permitted exposure levels and the anticipated risk at the new, lowered exposure levels, in order to show that its proposed standards are addressing "significant risks" and that they will serve to reduce the risk of occupational disease.

As discussed above, the Supreme Court provided only limited guidance on what occupational risks should be considered significant. The plurality opinion appears to have indicated that a l-in-1,000 risk of death is "significant" while a one-in-one-billion risk is not. However, the example in this opinion refers to a one-in-one-billion risk from a single drink of water and a l-in-1,000 risk from ***regular inhalation*** of gasoline vapors. If this is adjusted for the total ***amount*** of water the average person consumes, the resulting risk estimates for these hypothetical examples concerning inhalation of gasoline and consumption of chlorinated water are about the same. (McGarity has reached a similar conclusion by calculating the total number of cases expected in the exposed populations for these two examples (297a).)

OSHA's "significant risk" determinations have principally relied on comparing the estimated risks for a particular hazard to the I-in-l, (X)() guideline. For additional support, OSHA has also included comparisons with the risks of fatal occupational injury (derived from the data of the BLS Annual Survey) and with the quantified risks of several occupational health hazards. For example, OSHA has argued that a particular level of arsenic exposure presents a "significant risk" because the estimated death rate at that level (8 deaths per 1,000 workers) is

> . . . 1/4 to 1/2 the death rate [from injuries] in the riskiest occupations, 2 to 5 times higher than the risks in occupations of average risk, and 10 to 100 times the risk of the low risk occupations. It is also 1/3 of the maximum permitted radiation cancer risk but about 3 times higher than the cancer risk which 95 percent of radiation workers are under (638).

Finally, OSHA has compared the estimated risks of exposure at currently permissible levels to the estimated risks for exposure that were regulated in previous years. For instance, in proposals concerning new standards for ethylene dibromide and asbestos, OSHA compared the estimated risks for those substances to the risks of exposures to cotton dust and coke oven emissions (642,647).

In one case, OSHA has exempted one group of employers from the OSHA commercial diving standard because the agency determined that the estimated risks of injuries for this group were below those for industries with low injury rates. In explaining its decision, OSHA relied on a calculation showing that the injury rate for scientific and educational divers was lower than the injury rates for a number of industries, including banking (634).[2]

Feasibility

As indicated earlier, for both technological and economic feasibility the general requirement is that OSHA must show that compliance with the new standard is possible, that it is "capable of being done." ***Technological feasibility*** refers to the availability of technologies and methods to comply with the new standard. To prove this, OSHA can, of course, refer to plants and technologies that already meet the new standard. But OSHA is not bound just to the status quo. The courts have ruled that the agency has the authority to require technological improvements. The agency must present substantial evidence to prove that it is reasonable to expect that efforts by industry will lead to compliance, even if the exposure reductions are greater than those that have previously been achieved. In the words of one court (654),

> OSHA's duty is to show that modern technology has at least conceived some industrial strategies which are likely to be capable of meeting the PEL [permissible exposure limit] and which the industries are generally capable of adopting.

To meet this duty, OSHA uses the information provided in public comments and the public hearings. A feasibility determination usually relies on the reports and opinions of expert consultants, the availability of control technologies, descriptions of plants and companies already achieving the new standard, and general comments submitted to OSHA.

Economic feasibility refers to the economic capability of the regulated industries to afford the technologies needed for control. The Supreme Court has ruled that an analysis of economic feasibility does not mean cost-benefit analysis. Rather, OSHA is required to show that compliance with a standard is affordable by the regulated industry us ***a whole.*** A standard can be considered feasible even if it adversely affects profits and causes ***some*** employers to go out of business

[2]This calculated injury rate was based on the number of reported deaths and injuries divided by 2,000 hours per year, the equivalent of full-time employment, 40 hours per week for 50 weeks per year. This calculation, howwer, substantially understates the risk during diving operations because none of these employees is actually underwater for 2,000 hours per year. In fact, the actual underwater exposure time for these divers is usually less than one-tenth of the time assumed by OSHA (249a). The actual risk estimates for this group of employees while engaged in diving would, therefore, be over 10 times greater than the risk shown by the OSHA calculation.

rather than comply with the standard. However, OSHA must show that the long-term profitability and competitiveness of an industry will be maintained.

To analyze economic feasibility, OSHA generally estimates the costs of compliance for a standard. These compliance costs are usually presented in several ways: for example, average cost per affected firm, average cost per exposed worker, compliance costs as a percentage of industry sales, and compliance costs as a percentage of total payroll costs. OSHA has not set forth any mathematical formula for determining when these costs would be considered economically infeasible. Rather, it presents the costs, and expresses a judgment about whether or not they would impose a substantial burden or have a significant impact on the market structure of the affected industries.

Cost-Effectiveness Analysis

Finally, OSHA uses the techniques of cost-effectiveness analysis to evaluate alternative methods of achieving the health protection goal that has been selected on the basis of the risk and feasibility analyses. Cost-effectiveness analysis at this point is applied in a relatively narrow way. It is not used to judge the "worth" or desirability of the standard, but only to select among alternative approaches for meeting that standard.

Regulatory Impact Analyses

Executive Order 12291, issued in early 1981, requires that OSHA prepare Regulatory Impact Analyses. These consist of detailed discussions of the quantified benefits, compliance costs, and economic impacts for alternative standards considered by OSHA.

The order also requires that all OSHA regulatory actions be reviewed by OMB, which, to the extent permitted by law, requires regulatory agencies to demonstrate that their regulations are cost-beneficial. Generally, the results of the OMB review and agency responses need not be made public. Thus, it is difficult to determine if OSHA decisions have been altered by OMB's cost-benefit review (510). It has been argued that OMB and the Presidential Task Force on Regulatory Relief have improperly influenced at least two OSHA regulatory proceedings, concerning hazardous communication and commercial diving, after private meetings with representatives of the industries affected by the regulations (519,520).

In several cases concerning proposed standards, OSHA has published alternatives suggested by OMB. These include, for example, the 1981 proposal for hearing conservation (637) and the 1984 proposal on grain elevators, which included OMB-suggested alternatives (348). Two disputes between OMB and OSHA concerning proposed standards have been appealed to the Presidential Task Force on Regulatory Relief. In both cases (the cotton dust and hazard communication standards), OSHA was allowed to publish its proposals (637).

OMB suggestions have been incorporated in at least two final standards. For the hearing conservation amendment, several technical requirements were altered (637). In another case concerning a final standard for ethylene oxide exposure, OMB expressed "reservations" about part of the OSHA-drafted standard (in particular, the provision establishing a short-term exposure limit). In response, OSHA removed that provision from the final, published standard, and requested additional public comment (649). OSHA considers OMB review to be "akin to internal review," after which all final decisions are made by OSHA and the Department of Labor (637).

The General Accounting Office has studied agency compliance with Executive Orders 12044 and 12291 and has collected information on the costs of preparing economic analyses. For ON-IA, these analyses cost an average of $338,000 (510). Although it is difficult to determine the value and effects of these analyses, the amount of resources used by OSHA to develop them has been substantial.

Effects of Decision Rules

Questions remain, however, concerning the actual application of the current OSHA criteria. How large does a risk need to be in order to be considered significant? How is risk to be measured? How is technological feasibility determined?

How costly can a standard be before it threatens the viability of an industry and thus is considered economically infeasible (277)? Indeed, there have been and continue to be disputes about the application of any set of decision criteria by a regulatory agency. In practice, decision criteria may only define a range of allowable decisions and will often not mandate a particular result.

The positions adopted by the participants in OSHA's regulatory proceedings, general political considerations, and the personal judgments of OSHA's Assistant Secretaries and its staff have been and continue to be important to OSHA's decisionmaking. Moreover, OSHA has always balanced various factors before issuing standards. For instance, OSHA stated in its preamble to the vinyl chloride regulation that its "judgments have required a balancing process, in which the overriding consideration has been the protection of employees." These more informal judgments may be even more important than the formal decision rules used by an agency.

In addition, the court battles about OSHA decisions and more general discussions of "regulatory reform" were not only about what the decision rules should be, but also about who should be empowered to interpret and apply those rules. Should the Assistant Secretary for OSHA have the authority to make these decisions with only limited review by the courts? Or should reviewing judges become extensively involved in analyzing the factual record and OSHA's judgments? And to what extent should outside agencies, such as CWPS and OMB, be involved in examining and approving OSHA's decisions?

Because judgment and the identity of the decisionmaker are important, and because there are many uncertainties in estimating effects (discussed below), the adoption of a cost-benefit rule may not lead to decisions that are different from those adopted under a feasibility test. DeMuth (136) has suggested that "just as the Corps of Engineers became adept at demonstrating that every dam that could be built would pay for itself, so the regulatory agencies will learn to demonstrate, with increasing analytical verve, that every new regulation is cost-beneficial. "

Would OSHA's decisions have been different under a cost-benefit decision rule? One contract report (262) prepared for this assessment suggests that for at least some of the major OSHA health standards, the use of a cost-benefit decision rule would have led to less stringent standards.

Judith and Lester Lave (262) applied several different decision frameworks to four health standards issued by OSHA--those for coke oven emissions, benzene, vinyl chloride, and cotton dust. They compared the regulations actually issued by OSHA using its criteria of technological **and eco**nomic feasibility and those that the Laves believe would have been issued under a cost-benefit decision rule. In three of these cases-for coke oven emissions, benzene, and vinyl chloride-a cost-benefit analysis would have led to a less stringent regulation. For cotton dust, the conclusion of an analysis is very dependent on the discount rate chosen and the value placed on preventing additional cases of byssinosis (see below for a discussion of these issues). This case, they concluded, is one in which "reasonable analysts can choose values within the range accepted by the economics profession and wind up with opposite conclusions about the desirability of a stringent standard."

The conclusions about the fates of the vinyl chloride and cotton dust standards are noteworthy because in both cases improvements in productivity accompanied compliance with a stringent OSHA standard. In part, those improvements may have been spurred by the necessity to comply with OSHA's stringent requirements. If a cost-benefit decision rule had been in effect for OSHA, these gains in employee health and in economic productivity might not have occurred.

It cannot be conclusively shown that the application of a cost-benefit decision rule would have changed OSHA's decisions and the nature of technological change in affected industries. Lave and Lave had to rely on currently available information. Had a cost-benefit rule been in effect, OSHA might have prepared additional quantitative information, especially on the benefits of its standards.

However, their conclusion does support the concern of many participants and observers that cost-benefit analysis in practice would not be a neutral decision rule, but one that is biased against improvements in worker health and safety (43,65,115,194,411). For example, Baram (43) has concluded that in many cases "[c]ost-benefit analysis is a 'numbers game' that is used to oppose regulatory actions that have been proposed to protect public health and the environment ." Connerton and MacCarthy (115) believe that the use of cost-benefit analysis will prevent regulatory agencies from carrying out their responsibilities to protect health and safety and will lead to extensive delays in an already slow regulatory process—in other words, to a "paralysis by analysis. " Boden (65) has expressed concern that under current circumstances, the use of cost-benefit analysis "may bias political decisions against even those regulatory decisions that are cost-effective. "

THE USES AND LIMITS OF ECONOMIC ANALYSIS

Value of Economic Analysis

Economic analysis—including cost-benefit analysis, cost-effectiveness analysis, and the feasibility analysis performed by OSHA—can provide decisionmakers with important information on the problems and alternatives they face and the consequences of various courses of action. In "The Implications of Cost-Effectiveness Analysis of Medical Technology" (539), OTA described 10 general principles of analysis that are applicable to the conduct of both cost-effectiveness and cost-benefit analyses. These principles are:

- Define problem.
- State objectives.
- Identify alternatives.
- Analyze benefits and effects.
- Analyze costs.
- Differentiate perspective of analysis.
- Perform discounting.
- Analyze uncertainties.
- Address ethical issues.
- Interpret results.

Following these principles can lead to the development of clear and useful analyses. But the process of collecting information, ordering it, and analyzing it can be just as important as the final results of an analysis.

> Performing an analysis of costs and benefits can be very helpful to decisionmakers because the process of analysis gives structure to the problem, allows an open consideration of all relevant effects of a decision, and forces the explicit treatment of key assumptions (539).

Lave and Lave (262) have suggested that the use of economic analysis "sharpens the questions, clarifies the implications of policies, and generally manages to attain solutions at lower cost. " In addition, when the necessary data are available and when the quantification of intangible effects is not a problem, cost-benefit analysis can shed light on the implications for economic efficiency of alternative projects.

As one element of the decisionmaking process, as a decision-assisting tool, economic analysis can provide guidance and information. In addition, economic analysis can provide support for decisions or actions that may be taken on other grounds. For example, in some cases, decisions based on noneconomic grounds will also be supported by the results of economic analysis. In those cases, most people would support the use of economic analysis. Arguments arise when the analysis supports less stringent standards than those chosen for other reasons.

Difficulties in Implementation

The limitations of these techniques are particularly evident when they are considered as ***decision rules.*** In 1980, OTA concluded that cost-effectiveness and cost-benefit analyses exhibited too many methodological and other limitations to justify sole or even primary reliance on them in making decisions (539). That conclusion is still applicable for the analysis of measures to improve occupational safety and health.

A number of the analytical principles-defining the problem, stating objectives, identifying alternatives, differentiating the perspective of the analysis, analyzing uncertainties, and interpreting results—are relatively uncontroversial, in large part because they are components of any process of rational decisionmaking. However, the quantification of benefits and costs and application of a discount rate to them are distinctive features of these types of analyses. They are also the features that present the most difficult methodological issues and arouse the most controversy, especially when applied to governmental regulation of worker health and safety.

Benefits Analysis

The benefits of various alternatives must be identified, and if possible, quantified. Quantification bears the danger that the effects that can be measured will receive more attention than those that are not quantified, even if the unquantified are believed to be more important. Lave (263) has called this a "Gresham's law of decisionmaking. " On this danger, Mishan has written (308):

> . . . the outcome of all too many cost-benefit studies follows that of the classic recipe for making horse and rabbit stew on a strictly 50-50 basis, one horse to one rabbit. No matter how carefully the scientific rabbit is chosen, the flavor of the resulting stew is sure to be swamped by the horseflesh. The horse, needless to say, represents those other [unquantified] considerations . . . .

The uncertainties of any quantification of benefits begins with uncertainties concerning the relationship between exposures and health hazards. Epidemiologic studies are often limited by small sample sizes, a lack of information on past exposures, and the presence of confounding variables. The results of animal testing present problems in determining the applicability to human populations and in extrapolating from the high doses often used in such studies to the lower doses found in the workplace (see ch. 3 and 542).

Even after identifying the risks involved, an analysis of the benefits of controlling them must discuss the effectiveness of the various technologies that could be applied. Often, information crucial to that analysis is lacking. For example, personal protective equipment is often suggested as a cost-effective alternative to engineering controls, but there is only limited information available on the actual workplace effectiveness of such devices (ch. 8).

After identifying and quantifying the benefits to be expected from a given action, a cost-benefit analysis (but not a cost-effectiveness analysis) requires that these be converted to units that can be directly compared with the costs of the action. Analysts almost invariably choose monetary units for this.

There are two major approaches to placing a value or a price on human lives or lifesaving programs. The first is to consider the value of a life to be the present discounted value of the person's future income. Because this method, known as the human capital approach, assumes that the value of a person's life is equal to their expected income, it implies that "women are valued less than men, blacks less than whites, retired people less than workers, and low-paid textile workers less than higher-paid steel workers" (115). In addition, it cannot include the value that other people attach to saving a particular person's life.

The other major approach has been to evaluate lifesaving programs on what people are "willing to pay" for them. This approach, too, runs into problems. It is difficult to find out exactly what people are "willing to pay." A survey could be used, but the interpretation of the results is difficult.

Another measure can be obtained from analysis of the additional pay that workers may receive for taking unsafe jobs. (These have been termed hazard premiums or compensating wage differentials. See ch. 15 for a discussion.) It is also possible that consumers are willing to pay "extra" for less hazardous consumer products. Some economists, using the techniques of statistical analysis, have attempted to measure the extent of these "revealed preferences. " These studies are subject to a number of technical problems in the measurement of risk levels and in adjusting for other factors that influence wages and prices. The results of these studies have been used to calculate the "value of a life. "

Table 14-1 shows the wide range of implied values for human lifesaving derived from such

Table 14-1.—Willingness-to-Pay Estimates of the Value of Life[a]

Method	Value per statistical life (thousands of 1977 dollars)[b]
Survey approach:	
Acton (1973)	38
Jones-Lee (1976)	8,440
Landefeld (1979)	1,200
Revealed preference:	
Labor market:	
Dillingham (1979)	277
Thaler and Rosen (1975)	364
Viscusi (1978)	1,650
Smith (1976)	2,045
Olson (1981)	5,935
Consumption activity:	
Dardis (1980)	101[c]
Ghosh, Lees, and Seal (1975)	260
Blomqist (1979)	342
Portney (1981)	355

[a]Where a study included a "central" or "most reasonable" estimate, that is shown, where only a range was given, the lowest value is presented
[b]Values were converted t. 1977 dollars using the U S Bureau of Labor Statistics Consumer Price Index
[c]It is unclear from the Dardis study what year's dollars apply, although the estimate presented here appears to be based on an average value for the period 1974-79

SOURCE. (262)

studies. Two different types of studies are cited. The first, labeled the survey approach, involves surveying groups of people and asking them what they think should be spent on lifesaving programs. The second type, revealed preference, uses data concerning either work and employment (labor market) or consumer purchasing (consumption activity) to calculate either workers' or consumers' "willingness to pay" for risk reduction.

The wide range in these values creates difficulties for analysts attempting to use the "willingness to pay" approach to place a value on the benefits of programs. Besides this practical problem of choosing a figure for valuing benefits, there are also several conceptual problems with using the "willingness to pay" approach to assess lifesaving programs. (See 277 and 297 for a discussion.)

Recently a third approach has been suggested (259). Called "adjusted willingness to pay," it attempts to combine the two traditional approaches by estimating what an individual should be willing to pay to avoid the financial losses associated with premature death. However, it still is not able to include the willingness of family, friends, coworkers, and strangers to contribute to lifesaving programs. Moreover, the value of life derived from this approach remains a function of income and wealth.

Cost Analysis

The estimation of costs is often thought to present fewer difficulties than the analysis of benefits. Nevertheless, the costs of controls are often hard to estimate accurately. In part this is because many control technologies involve changes in the actual productive process or have multiple uses. For example, what portion of the costs of installing duct work in a new plant should be attributed to the need to dilute an air contaminant? And what percentage should be listed as the cost of providing heating and air conditioning to a plant—an ordinary cost of doing business?

In addition, company officials are usually in the best position to know what needs to be changed in their plants to comply with a proposed standard. But these people also have a vested interest in the regulatory proceeding. Moreover, line managers and plant engineers would rather overstate than understate expected costs in order to ensure that they will be given a sufficient budget within the company to pay for the controls (140). Finally, when OSHA "forces" the diffusion of technology, there is little or no experience on which to estimate the costs of widespread use of a particular new technology. Consequently, the costs of proposed regulations are often overestimated. (For examples of this, see 195.)

Uncertainties

Estimates of both costs and benefits are usually surrounded by uncertainty. The combined effect of these uncertainties and of assumptions made by the cost-benefit analyst, both of which are found at every stage of the estimation of costs and benefits, can produce large differences in the analyses conducted by different people. Thus it is possible for one analyst to take a high estimate of costs and a low estimate of benefits and conclude that the program should not be undertaken, while another analyst can take a lower cost estimate and higher estimate of the benefits and conclude that the program is worthwhile. Often these disputes cannot be resolved. (For a discussion of several kinds of uncertainty, see 175.)

Discounting

Finally, these analyses require that costs and benefits be made commensurate over time. This usually involves adjusting future costs and benefits at a specified discount rate to calculate the present value of the costs and benefits. The general justification for discounting derives from the fact that resources can be invested to earn interest over time. Thus, in order to compare costs and benefits that occur in different years, all future effects are discounted and expressed in terms of "present values. "

In practice, there is considerable disagreement over what discount rate should be used (539). Moreover, although the logic of discounting is derived from several basic propositions of economic theory, the discounting of future costs and benefits has two effects that create some controversy.

First, the effects (both costs and benefits) on future generations are almost completely ignored with most discount rates. Second, the process of discounting implies that risks that manifest themselves in the very near future are to be prevented before risks 10, 15, or 20 years in the future. This means that, all other things being equal, the risks of occupational injury should be reduced before reducing the risks of occupational cancer. Or, for example, that OSHA should act to reduce the risks of exposure to beta-naphthylamine (which has caused cancer in some workers after a latent period of less than 5 years) before it acts to reduce the risks of exposure to asbestos (which causes various types of cancer with latent periods ranging from 15 to 30 years).

Distributional Effects

Although cost-benefit and cost-effectiveness analyses were designed to evaluate economic efficiency, they are not very well developed for the evaluation of distributional implications. This is an important problem for the application of these techniques to programs designed to improve occupational health and safety. Usually these programs are aimed at benefiting a group of workers, while the costs of the programs fall largely on employers. In addition, the benefit to the workers often involves the prevention of irreversible damage to their health or well-being while the costs to employers involve increased expenses and, possibly, reduced profits. This further complicates the comparison of costs and benefits.

Alternatives to Aggregated Analysis

Some analysts believe that ultimately solutions to these problems can be found. OTA (539) has suggested that the alternative of "arraying" the various effects of a program or proposal should be investigated, rather than trying to reduce all effects to a single "bottom line. " Ashford, et al. (33), for example, have suggested "trade-off analysis." This approach would involve a comprehensive description of the expected effects of an agency's actions on three "flows": economic, environment/health, and legal. To avoid the problems of monetization and valuation, all effects are left in their natural units. To reduce discounting problems, the time pattern of the effects is presented. Finally, the analysis provides a matrix of effects and actors, to present a clear picture of who gains or loses what from the regulatory action.

Ethical Considerations

The use of cost-benefit and cost-effectiveness analyses also raises ethical considerations. Supporters of the greater use of these techniques point to the limited resources available for improving health and safety. This, they believe, implies that the only moral course of action is to use those resources in a way that maximizes net social benefit. As a moral doctrine, this belief derives from the traditions of utilitarianism (246). The advocates of cost-benefit analysis believe that the use of formal analysis will help achieve the greatest possible level of human welfare (304,446).

> . . . estimating benefits and costs is often difficult, especially . . . where the benefits may be in terms of lives saved or pain and suffering avoided. Some say this means putting a value on human pain, suffering, and death, which is not only ludicrous, but downright immoral. If anything, we would argue, the reverse is true. Since resources are limited, we cannot avoid the need to identify—and, in some way, to estimate-benefits and costs. The more compassion we have for our fellow human beings, the more important this becomes (304).

In disagreement, MacLean and Sagoff (281) discuss the philosophical justifications used to support cost-benefit decisionmaking and conclude that these justifications fail. Cost-benefit analysis is not, in their view, a neutral decisionmaking rule because it is unable to take account of many commonly held ethical principles and values. In order to include concerns for equity and justice, a formal cost-benefit analysis would either have to find some **way** to assign a price to these concerns or ignore them. But justice and equity are not merely matters of consumer preference; they depend on political and moral arguments: "Equity is a matter of right or wrong; it is to be thought over and argued about. It is not a consumer service or a fungible good" (281).

On examining the cost-benefit decision rule presented in President Reagan's Executive Order 12291, MacLean and Sagoff conclude that its unitary yardstick of positive net benefits is severely limited: How can cost-benefit analysis claim to be either neutral or comprehensive if it cannot deal with a wide range or moral, cultural, aesthetic, and political concerns? There may be some issues that raise few important cultural ***or*** moral issues; for example, the commodities markets may be left to determine the prices of hog bellies or potash. This does not show, however, that markets or market analysis can give us an adequate policy for public safety and health. On the contrary, where moral, political, and cultural values—not simply economic ones—are at stake, we need to make moral, political, and aesthetic judgments. Cost-benefit analysis does not replace these "subjective" judgments with "objective" or "neutral" ones. Rather, it distorts or ignores the noneconomic values it cannot handle (281). (See 205,246,277, and 297 for additional discussion of the ethical implications of cost-benefit analysis.)

SUMMARY

Improving occupational safety and health involves the identification of hazards, the development of control techniques, and the decision to control. The issue of decisionmaking—the question of who is to make decisions and on what basis—is important because interested parties can differ greatly about the nature of occupational hazards and the best means to reduce or eliminate them. Employers' decisions tend to follow the dictates of the competitive market system; public decisions can consider a number of other factors.

Various techniques of economic analysis including cost-benefit and cost-effectiveness analyses have been developed to assist private and public decisionmakers. As decision-assisting *tools,* these techniques can help policymakers to reach sound, well-informed, reasoned decisions about the management of workplace hazards. There is widespread agreement, at least in principle, that decisionmakers need to have some minimal understanding of the important features of the problem to be addressed, the factors involved in the decision, and the implications of various courses of action. As decision roles, however, formal analysis is considerably more controversial and significantly more limited in its uses.

In 1980, OTA concluded that cost-effectiveness and cost-benefit analyses exhibited too many methodological and other limitations to justify sole or even primary reliance on them in making decisions. That conclusion is still applicable for the analysis of measures to improve occupational safety and health.

These limitations include difficulties in quantifying the magnitude of the expected benefits, in valuing these benefits, in calculating the expected costs of improved health and safety, in performing discounting, and in analyzing the distributional implications of alternative policies. The use of cost-benefit and cost-effectiveness analyses also involves ethical considerations. The advocates of cost-benefit analysis believe that the use of formal analysis will help achieve the greatest possible level of human welfare. Critics of formal analysis, however, argue that cost-benefit analysis is limited because it is unable to take account of

many commonly held ethical principles and values.

The history of decisionmaking at OSHA is intertwined with debates over the allowable use of cost considerations. Some of that debate has been over the specific requirements of the OSH Act and whether OSHA must base its decisions on a cost-benefit analysis. When it passed the OSH Act, Congress brought the Federal Government into the field of occupational health and safety. Congress, however, was less clear about the precise decision rules for OSHA to follow when setting health and safety standards. Because of the concern of a number of Congressmen about costs and economic effects, OSHA was required to consider the "feasibility" of its standards. But the final bill also included the goal that "no employee will suffer material impairment . . . " In addition, during the 1970s, a series of Executive Orders and other procedural requirements have affected OSHA's standard-setting activities.

A number of legal challenges to OSHA standards have brought the courts into this arena. Two of these challenges were decided by the Supreme Court. The Supreme Court has ruled that the OSH Act does not require that OSHA base its decisions on the results of cost-benefit analyses; instead the agency must base its decisions on determinations of "significant risk" and "feasibility. "

OSHA now uses a four-step process for making decisions about health standards. First, the agency determines that the hazard in question poses a "significant risk." Second, OSHA determines that regulatory action can reduce this risk. Third, it sets the regulatory goal based on reducing this risk "to the extent feasible. " Finally, OSHA conducts a cost-effectiveness analysis of various options to determine which will achieve this chosen goal in the least costly manner.

OSHA also prepares Regulatory Impact Analyses to comply with the requirements of Executive Order 12291. Because the results of the OMB review of these analyses are not made public, it is difficult to determine if OSHA decisions have been altered by OMB's cost-benefit review. In addition, one contract report prepared for this assessment suggests that for at least some of the major OSHA health standards issued in the 1970s, the use of a cost-benefit decision rule would have led to less stringent standards.

15.
Incentives, Imperatives, and the Decision to Control

Contents

TABLE

FIGURE

15
Incentives, Imperatives, and the Decision to Control

OTA has identified a number of incentives and one major imperative for the implementation of control technologies. As used here, an "incentive" is something that encourages an employer to implement a control. Because of the special value placed on health and safety, many people believe that society should, by law and regulation, require employers to take the steps necessary to prevent work-related illnesses and injuries. This belief underlies the basic approach of the Occupational Safety and Health (OSH) Act of 1970, which is an "imperative" for implementing controls.

A great deal that is known about controlling the causes of occupational illness and injury has not been applied in many of the Nation's 4.5 million workplaces. Examining incentives and imperatives can assist in understanding the decisions to implement controls and can outline areas for improvement. Most incentives and imperatives can be used together and, in some cases, they interact and build on each other. In some other cases, however, various historical circumstances have led to compromises that bar the use of some incentives (e.g., workers' compensation laws generally prohibit employees from suing their employers), This chapter presents a description and assessment of these incentives and imperatives.

ASSESSMENT OF EXISTING INCENTIVES

Voluntary Efforts

After being informed of or discovering the existence of job hazards, some employers will take action to reduce, minimize, or eliminate those hazards. They do so either because of altruism toward their workers or out of enlightened self-interest. Strictly speaking, pure altruism implies that the employers take these actions only because of concern for their workers without thought of the ultimate implications for the firm in terms of worker good will, productivity, profits, or future sales. Although this will often be true for the personal motivations of health and safety professionals, most decisions concerning company policy will consider carefully the potential effects on profits.

Photo credit Office of Technology Assessment

Signs are often used to provide information to workers. This one is a gentle reminder about the use of safety shoes

Probably more common than pure altruism are voluntary actions out of enlightened self-interest. These actions are taken because a firm perceives that voluntary efforts, although not necessarily profitable in the short term, will benefit the firm in the long run. This long-term benefit could be an enhanced corporate image or the perception that a given firm is a "good place to work. " In addition, voluntary efforts may be undertaken to solve a particular problem before the Government or other groups become involved. (Of course, there may be other benefits to the firm in terms of reduced workers' compensation costs, reduced capital costs if accidents damage plant and equipment, or a reduced threat of potential liability or an Occupational Safety and Health Administration (OSHA) fine.)

The pressures of the competitive marketplace will, however, substantially limit the ability of individual companies to improve employee health and safety. As described in chapter 14, if a company spends resources on improving workplace conditions and its competitors do not, this company can easily find itself at a disadvantage because its competitors can use the resources thus saved to expand or improve production. Unless the company can save money in some other way, it will have lost money by attempting to do the "right" thing.

There are several ways in which the company may receive a financial return on its health and safety investment—through reduced workers' compensation premiums, for example, or an improved labor relations atmosphere, or reduced vulnerability to fines for violating Government regulations. In this case, the action is not exactly "voluntary, " but results from some other incentive.

Voluntary actions may result in a firm saving on both the direct and indirect costs of occupational accidents. The direct costs include workers' compensation payments for lost wages and medical care, while the indirect costs include loss of productivity, disrupted schedules, equipment and property damage, administrative time for accident investigations, and training of replacements. Estimates of the size of indirect costs range from 4 times to 20 times the direct costs of accidents (82,380). The National Safety Council has estimated that the average total cost (both direct and indirect) to an employer of a lost-workday accident is about $9,400 (324). Sheridan (436) reports that one large firm has estimated the total direct and indirect cost to be $14,000 for a lost-work-time injury, $100,000 for a fatality, and $200,000 for injuries involving permanent disability.

As noted in chapter 10, it has frequently been said that the most important variable in determining whether a firm will be generally protective of employee health and safety is the commitment of top management. Two studies (441,443) have found that low-accident-rate plants tended to have "greater management commitment and involvement in plant safety matters" (443), although both of these studies involved relatively small numbers of companies. In addition, a number of companies, particularly large ones, have created departments to handle issues of occupational and environmental health and safety, have hired professional staffs with technical expertise concerning health and safety, and have established internal review mechanisms to ensure compliance with health and safety standards. (See 179 for a discussion of some of these arrangements, and box P.)

The important role played by management commitment to the goals of occupational safety and health must be stressed. In the United States, employers are responsible for the organization, design, and management of workplaces. If improvements in employee health and safety are to occur, they will have to involve decisions by management. It is therefore not surprising that management commitment **has** been called the single most important ingredient in effective health and safety programs.

The other incentives and imperatives described in this chapter can be thought of as ways of obtaining the commitment of employers when voluntary efforts are insufficient to correct occupational health and safety hazards. These incentives and imperatives generally reward or penalize companies. It has also been suggested that the compensation of individual line managers should be linked to improvements in product safety, pollution control, and occupational health and safety (139).

In addition, there are a number of voluntary organizations and associations that have been active in the occupational safety and health field. These include professional societies, voluntary standards organizations, trade unions, and employer associations. Companies and their employees may participate in these voluntary organizations and these voluntary organizations are sometimes involved in the development of some of the other incentives and imperatives. This is

Box P.—Example of Voluntary Control Efforts: Du Pont

Effective company-run safety and health organizations require strong impetus and initiative on the part of management. At E. I. du Pont de Nemours and Co., this is reflected in the company's "nine safety principles" (described inch. 6). The commitment of Du Pont to worker safety dates to the 19th century, when it produced gunpowder.

> In the early days the company's mills blew up so regularly that they were built with three sturdy stone walls and one flimsy wooden wall, facing Brandywine Creek. When the inevitable explosion came, the wooden wall would blow out. The rest of the mill would remain standing and could be economically restored to service. "Going across the creek" became a company euphemism for being blown to bits (284).

In fact, two du Pont family members were killed in these explosions.

Du Pont requires all levels of management and all employees to be responsible for health and safety on the job. Not only does this attention improve employees' working conditions, but whether dealing with 19th century gunpowder or 20th century petrochemicals, this attention reduces the chances of destroying valuable plant and equipment and incurring expensive downtime. In addition, Du Pont integrates safety with the management of the firm and uses the safety records of managers in making decisions about promotions.

Du Pont established the Corporate Environmental Quality Committee in 1966 to carry out "top management's commitment to environmental quality, including safety and health." It meets weekly and is the overseer of four supporting committees, including an "Occupational Safety and Health Committee."

At the plant level, Du Pont has Central Safety Committees consisting of plant staff managers and assistant managers, the superintendent of safety and health, the environmental control manager, and the plant physician or medical supervisor. This committee directs the plant safety and health program, and meets at least once a month. Plant subcommittees, headed by first-line supervisors, vary in number and function, depending on plant size and needs. Anywhere from 6 to 10 workers serve on subcommittees; there are no requirements, however, for minimum employee representation on the subcommittees. Individual employees are selected by the plant manager to serve on subcommittees, which are considered the focal point for plant involvement in safety policy. Their findings are reported to the Central Safety Committee.

About 95 percent of all safety hazards are corrected by line organization, and the resolution of individual safety hazards rarely requires involvement of a subcommittee. The minority of complaints that are referred to the committee concern issues that potentially involve plant-wide policy changes.

It has been noted that because of its low injury rate, Du Pont annually saves millions of dollars for workers' compensation compared with what its costs would be if its injury rate equaled the national average for all manufacturers (284). But the chemical industry as a whole, of which Du Pont is a part, generally has had a lower injury rate than that for all manufacturers, although Du Pont's injury rates are better than even the chemical industry average. Little information is available on what it costs Du Pont to achieve this savings in workers' compensation costs.

Finally, while Du Pont is also a widely recognized leader in providing a comprehensive occupational health program for its employees, data on the incidence of occupational *illnesses are* limited (see ch. 2). Thus it is impossible to quantify Du Pont's occupational illness rates and compare them with averages for the chemical industry or for all manufacturers.

especially true for OSHA regulatory proceedings, in which both trade unions and employer associations are often extensively involved.

Voluntary Standards

These voluntary activities may include cooperative efforts to develop voluntary standards, industry standards, or consensus standards. However, comparatively few of these standards are concerned with occupational health and safety.

Some voluntary standards are purely advisory; others, because they specify certain product attributes or dimensions, are ignored by firms only at their peril. For example, some voluntary standards specify the design and dimensions of nuts and bolts. If a firm wishes to manufacture nuts to fit the bolts of other manufacturers, the firm must follow the "voluntary" standard. Another example would be the various standards concerning the electronic components, such as stereo components and computers. The use of voluntary standards in these areas enables consumers to purchase several pieces of equipment from different manufacturers and then hook them together into a smoothly functioning system.

Still other "voluntary" standards have been adopted by Government agencies and now have the force of law. For example, the National Electrical Code, developed under the auspices of a voluntary organization, the National Fire Protection Association, is widely used as the basis for the mandatory building codes of many localities **(203). Similarly, most of the existing** OSHA safety standards, which now have the force of law behind them, began as "voluntary" standards developed under the auspices of the American National Standards Institute (ANSI). (See discussion in ch. 12.)

The standard-writing work of technical organizations, professional organizations, and trade associations is often delegated to subgroups or committees. OTA has not precisely determined what fractions of the participants in these voluntary standard-setting groups represent employers, manufacturers, labor unions, public interest groups, government, and others. It is clear, however, that labor and public interest groups have been and continue to be underrepresented in the deliberations of these committees. Small businesses may also be underrepresented.

There are several reasons for this. First, participation involves the commitment, at the very least, of staff resources. Oftentimes, unions and public interest groups lack sufficient staff resources to participate. Second, standard-setting groups have generally been created and staffed by manufacturers and employers, in part because these groups began the process in order to standardize equipment and designs (the "nuts and bolts" standards). Labor and public interest groups are generally not interested in those issues and do not participate. This historical nonparticipation may have carried over into the safety and health standards activities. Third, the membership of the committees is often unbalanced. For example, the committee that drafted the ANSI standard for abrasive blasting operations consisted of 14 manufacturer and trade association representatives, 6 people from professional organizations, 5 representatives of government agencies, 3 individual members, and 1 person representing a labor organization. Such unbalanced representation not only provokes questions about the degree of protection afforded by voluntary standards, it also makes labor and public interest groups hesitate to participate for fear that their involvement will imply approval of a voluntary standard that they had only minimal influence on.

In addition, voluntary standards are just that, "voluntary, " and probably cannot be enforced. Enforcement by a trade association or other organization may violate the antitrust laws. The Supreme Court has ruled that companies can exchange safety-related data and set standards to protect the public's health and safety or to protect themselves from product liability actions. The Court has also cautioned, however, that the standards must not be used as a guise for excluding competitors or for facilitating price fixing. The Federal Trade Commission, which **shares** authority for the enforcement of antitrust laws with the Justice Department, has advised that compliance with such a standard must remain voluntary. There appears to be a limited exception to this general rule-trade associations can require members to abide by a standard that is established to provide the legitimacy of something (e.g., a breed of cattle) or to establish a network in which the rules or standards are fundamental to its functioning (e.g., the arrangements surrounding the purchase of flowers by telephone) (203).

It is not likely, therefore, that a trade association would try to enforce a health or safety standard by excluding an offending company from membership, organizing a boycott, or taking some other punitive action. It may make efforts to encourage companies to comply, but the possibility of running afoul of the antitrust laws will make it stop short of requiring companies to comply (203). Thus even if a company follows a recommendation concerning worker health and safety made by a trade association or standards organization, the employer has no assurance that competitors will follow suit. (Voluntary standards also play some role in liability actions and the enforcement of the "general duty" clause of the OSH Act (203).)

Moreover, there is concern about the adequacy of voluntary standards, even if they are fully adhered to by employers. Beyond the common lack of labor and public interest representation on the committees that write these consensus standards, some people object to the standards because they often involve a compromise among the various interests, which may reduce the level of protection afforded by these standards. In addition, the employer and manufacturer representatives on these committees are likely to agree to a standard that each of them can already adhere to. They are unlikely to adopt a standard that would require large changes in their current operations, even if some industry leaders have achieved higher levels of protection. Thus these standards are likely to represent the "lowest common denominator" of performance within an industry.

Voluntary standards are an important source of information for employers, workers, government agencies, and others involved in the health and safety field. They represent hours of effort by many practitioners and professionals in this field and can often be useful sources of technical information, especially for defining terms and standardizing certain technical aspects of measurement and control.

Although they can be updated more quickly than OSHA has tended to rewrite its regulations (see ch. 12), unions and public interest groups question whether voluntary standards are sufficiently protective. The existence of these standards might bring the practice of companies to a common level, but, in general, voluntary standards and the voluntary approach will often lead to only limited changes in the health and safety conditions of the workplace.

Provision of Information

The availability of information about occupational hazards and their control is a necessary first step for many improvements in workplace health and safety. It may be provided by private sector organizations, including professional societies, voluntary standards organizations, insurance companies, employers' associations, trade unions, universities, and individual experts. Or it may be provided through the research and dissemination efforts of Federal and State Governments. The availability of information can combine with the other incentives to prompt employer action. For example, a company management committed to improving job safety and health would use available information to analyze job conditions and to make improvements. But without both commitment and information, no actions will be undertaken.

The provision of information through research and dissemination is an important activity unlikely to be met by private parties because information, once disclosed, becomes a "public good. " This means that the developer of the information cannot capture its full economic benefit because that person cannot always charge for the information. Furthermore, as illustrated by the description of a company's use of computer conferencing (ch. 10), a company may elect to hold private its safety and health information or to release it only under its own terms.

State and local "right to know" laws, and the development of an OSHA regulation concerning "hazard communication" (labeling) promise to provide more information to workers and employers. The impetus for three laws has been provided by coalitions of unions, health and safety professionals, and public interest groups who believe that workers and their doctors have a right to be informed of the identity of substances they work with and the potential hazards of those substances. Economists have also suggested that one way in which the existing market system may have failed is by not providing workers with sufficient information about hazards. In either case, one possibility is to require that information be provided to workers (628).

The new OSHA "hazard communication" regulation requires, among other things, that containers of "hazardous" chemical substances bear a label with information on the name of the substance and the precautions to be taken. Both the laws and the OSHA regulation enhance the dissemination of information to individual workers in expectation that this will lead to improvements in on-the-job health and safety conditions. In addition, labels provide important information to "down-stream" employers who previously had been ignorant about hazards in the materials they purchase.

One important issue in this area concerns manufacturers' desire to limit the information provided in order to preserve trade secrets, such as the chemical composition of a product. A second issue concerns which substances are deemed "hazardous" and who determines this. A third concerns the coverage of the laws and regulations. Do citizens and communities, in addition to workers, have access to this information? And what industries are covered? Fourth, there are questions about the relationship between the new OSHA regulation and the State and local "right to know" laws. In particular, Federal OSHA is arguing that, in general, its "hazard communication" regulation preempts State and local "right to know" laws. All of these issues are being considered in the recent legal challenge to the OSHA regulation. (For a general discussion of these issues, see 44.)

The increased availability of information on workplace hazards may serve as an incentive for companies to introduce controls. However, while the provision of information through both research and dissemination is an important first step, it is not sufficient by itself to guarantee improvements in health and safety. It may not counterbalance other factors that affect employers' decisions about whether or not to implement controls (box Q), which may be more important than a lack of information in explaining why many employers have not invested in health and safety improvements. (In addition, as described in ch. 12, the OSHA consultation program also provides information on hazards and controls to employers.)

Workers' Compensation and Insurance

Employers may take actions to improve job safety in order to reduce the costs of workers' compensation and property insurance. The most important purpose of the workers' compensation system is to provide workers suffering from workplace injuries and illnesses with medical treatment

Box. Q.—The Effect of New Information About Hazards

Using data from the results of OSHA health inspections, Mendeloff (301) analyzed exposure levels over time for:

- substances for which recommendations for lower exposure levels were made by either the American Conference of Governmental Industrial Hygienists or the National Institute for Occupational Safety and Health and for which no new OSHA standard was issued,
- substances for which no new recommendations were made, and
- substances for which new OSHA standards were issued.

The OSHA health inspection data may not be a perfect indicator of employee exposure levels over time, but presumably any biases affected the measurements for all three groups of substances.

Mendeloff's analysis showed no statistically significant trends in exposure levels for group 1 and group 2 substances over time. [illegible] and to compensate them for the income lost because of those injuries and illnesses. But the improvement of occupational safety and health is also a goal of workers' compensation. To the extent that employers, through this system, pay for the costs of medical treatment and lost wages, there is a monetary incentive to reduce those costs. Thus, employers may install control technologies in order to save on their workers' compensation premiums. In addition, the insurance companies and the state agencies that provide workers' compensation insurance often provide services to improve health and safety conditions in their client companies.

Similarly, actions to reduce the costs of property insurance may coincidentally benefit worker health and safety. For example, preventing fires and explosions in a factory may result in lower property insurance costs, as well as reducing the number of workers injured.

The history of workers' compensation reveals different motives and goals for the various interested groups (described further in ch. 11). Progressive reformers sought to alleviate the loss of income suffered by accident victims and their families and to encourage prevention. Businesses wanted to stabilize the uncertainties inherent in the liability system, to limit the growth in the size of awards, and to restrict more sweeping social changes. They were also interested in prevention, in part as an additional means to control or reduce costs. The National Association of Manufacturers, for example, was very impressed with the preventive effects of the German compensation system. In their view, the causes of accidents needed to be given equal consideration with the consequences ***(274).*** Nearly every contemporary observer includes prevention as one of the goals for workers' compensation (30,46,106,131,317, 656,657),

Workers' Compensation and Occupational Injuries

Although many employers and insurance companies believe that workers' compensation is an incentive for prevention of occupational injuries, the precise circumstances under which this is true are fairly complex (see, e.g., ***656,657).*** Moreover, empirical evidence concerning the effect of this incentive is thin.

There are, of course, difficulties in estimating what injury rates would have been in the absence of workers' compensation. In theory, various statistical techniques can be used to analyze the effects of particular programs, after adjusting for other factors that influence injury rates. One study ***(105)*** found a decrease occurred in the number of certain occupational fatalities at the same time **that** workers' compensation was created. Several other studies (53,104,106,107), however, have not found a favorable effect on injury rates from workers' compensation.

The economic incentive regarding occupational injuries is diluted to some extent because many employers pay premiums that are based on the average experience for their industry or line of business (so-called manual rates). These rates apply, it was estimated in 1972, to the 85 percent of companies that employ about 15 percent of the work force (317). These firms are so small that year-to-year injury rates vary widely purely by chance. Thus, in order to ensure year-to-year certainty of payout by the insurance carriers, as well as to minimize administrative costs, these ***com-***panies are grouped and pay rates determined from the manual.

At the other extreme are firms large enough to predict with a high degree of confidence their accident rates from year to year. Except in States that prohibit it, these firms generally insure themselves. It has been estimated that less than 1 percent of firms self-insure, but that those firms employ 10 to 15 percent of the workers included under the compensation system (317).

Finally, firms in the middle are "merit-rated," generally using either "experience-rating" or "retrospective-rating," which are methods for tying a firm's premiums to its actual loss experience. Under experience-rating, insurers modify the manual or class rate for a firm by its actual accident experience for the most recent three years. Thus, successful efforts to prevent injuries in the current year will lead to premium savings in the following three years. As the firm's size increases, more weight is given to the company's actual experience and less to the employer's class or industry average (409,656). Under retrospective-rating, the employer pays for losses up to specified ceiling limits and the insurer pays for losses above the ceiling. Thus this plan "provides the firm with a combination of insurance and self-insurance" (656,657).

In addition, premium discounts are given to large policyholders and some insurance companies pay dividends to their policyholders (682). These dividends can be either "flat rate" (the same to all policyholders) or "sliding scale" (higher rates paid to employers with better loss records and to larger policyholders). The sliding scale plans, because they tie dividends to the loss experience of firms, may provide safety incentives (657).

Although the rates for small companies are generally not directly based on their experience, if such a firm has a particularly bad record it might be placed in an "assigned risk pool," with a correspondingly higher premium. Small firms with very good records, however, generally do not receive a reduction in their premiums (317).

A primary goal of insurance is to spread risks among employers, thus preventing, for a given employer, a very large or catastrophic loss in any one year. The losses to be paid out are made, through insurance arrangements, into predictable and regular annual payments. Moreover, when the pooling of risks places safe employers in the same group with less safe employers and both have the same premium rate, the less safe will not have any incentive to improve performance. Thus, the goal of insurance or loss spreading acts to dilute the incentive provided by workers' compensation.

Although this effect has been often noted, the degree of dilution is unclear because, although most employers do not appear to be experience-rated, most employees work for employers who are. Moreover, as Victor (656) has shown, the size at which a firm becomes eligible for experience rating varies dramatically among industries, largely because of the differences in injury rates among industries. Finally, although most employees work in firms that have some form of experience-rating, it is difficult to determine what portion of all occupational injuries and illnesses occur in these firms.

There have been only a few empirical studies of the effects of experience-rating on injury rates. Russell (409) found that large firms, which are generally experience-rated, had lower injury rates than medium-sized firms. But she also found that small firms had low injury rates as well, even though they, as a group, are not experience-rated. Two other published studies have not been able to isolate any measurable effects for the experience-rating system used in workers' compensation (109,464).

A second limitation on the safety incentive provided by workers' compensation is found in the benefit levels. Employers' incentives are directly related to the degree that the workers' compensation system provides for the full social costs of injuries. Generally speaking, workers' compensation pays the medical expenses associated with the injury but only a portion of the employee's lost wages.

The States generally replace two-thirds of lost wages up to a maximum amount or ceiling. This replacement, however, is usually based on the employee's wages just before the injury and are often not adjusted for potential increases in the employee's earnings over his or her career. In addition, many States have mandatory waiting periods or minimum lengths of time that a disability must last before any payment will be made. Although workers' compensation benefits are not taxable, the system does not replace lost fringe benefits, which have become an increasingly larger portion of employee wage packages in the last decade. Moreover, the ceiling on payments is frequently so low that many workers receive much less than the theoretical two-thirds replacement. It was estimated that during the late 1960s, workers' compensation had a median wage-replacement rate of only 50 percent (52). More recently, a group of researchers found earnings-replacement rates of 46 percent, 59 percent, and 75 percent in California, Florida, and Wisconsin (81). But it is not clear to what extent this applies to other States.

Furthermore, as a general rule, workers' compensation replaces only lost earnings. It does not usually compensate for "pain and suffering" or even the loss of physical capabilities that do not directly result in loss of earnings ***(260).*** "In [workers'] compensation . . . the only injuries compensated for are those which produce disability and thereby presumably affect earning power" (144). One example of this are injuries that are limited to damage to the workers' reproductive system. The States generally do not allow compensation for this because such damage does not reduce the workers' earning power (144,260). In these cases, injured and ill workers are not fully compensated.

However, in nearly all of the States, workers with certain kinds of permanent partial injuries (e.g., loss of a hand or leg) receive compensation payments based on schedules of fixed dollar amounts for the part of the body affected. (For a list of these, see 484.) For the same injury, all workers receive that same payment, even if their wage levels differ. Thus, compensation for permanent partial injuries is often not directly tied to an individual's lost wages, although the payments may ultimately be based on the average wages of all workers.

A third limitation is that some occupational injuries (and most occupational illnesses) are not compensated at all because the worker fails to file a claim, Some of these workers become dependent on other social insurance programs (e.g., Social Security) or pension programs that provide disability benefits. Although this is mainly a problem for occupational diseases (see discussion in **the** next section) it may also be a factor for occupational injuries.

Based on data from the 1972 Survey of Disabled and Non-Disabled Adults, a Department of Labor report (596) concluded that only 43 percent of people severely disabled by work-related injuries received workers' compensation payments. Severe disability was defined as complete inability to work. The work-related disabilities were determined by analysis of survey responses and thus the results of these surveys need to be interpreted cautiously.

An analysis of a similar survey conducted in 1978 found that only 33.1 percent of those whose main disability was due to an on-the-job injury were currently receiving workers' compensation benefits (437). This analysis also found that workers' compensation appeared to provide only 22.5 percent of the income maintenance for those totally disabled by occupational injuries. The remaining three-quarters of their support came from Social Security, employer/union retirement and disability funds, veterans' benefits, private insurance, welfare, and other sources. Workers' compensation should not necessarily be "charged" with replacing all the lost income of injured workers if other factors contributed to the total disability. It is, however, surprising that most of the income support for this group comes from other sources, Employees and other public welfare programs thus may be bearing much of the cost of occupational injuries (437).

These results may occur because the disabled workers did not apply for workers' compensation benefits, because no benefits were ever awarded or because the workers' compensation benefits ran out while the disability remained. Further research is needed to determine the factors that contribute to this apparently inadequate compensation. But from the standpoint of evaluating the incentives of workers' compensation for prevention, the conclusion is the same. To the extent that these costs do not enter the workers' compensation system, employer premiums will not rise, and employers do not face the full financial incentive to reduce the incidence of injuries and illnesses.

Finally, one other factor may influence the safety incentives provided by the workers' compensation system. As is discussed later in this chapter, under certain assumptions it is possible that employers may pay workers additional wages in order to attract them to hazardous jobs. If these additional wages or hazard premiums do exist, the creation of a workers' compensation system may lead only to reductions in the hazard premiums. In effect, compensation would shift from before the accident to after the accident, and from all exposed workers to those who incur injuries.

However, this shift may not result in any change in injury rates (131,151,300). Three recent studies (83,150,151) have found, in fact, that increases in workers' compensation costs and benefits are associated with decreases in employee wages. Two of these studies (150,151) found that increases in workers' compensation costs were, at **least for nonunion workers, completely offset by decreases in employee wages. This result implies that for these employees, workers' compensation has no net effect on employer safety incentives.**

Workers' Compensation and Occupational Disease

As opposed to the situation regarding workplace injuries, most observers agree that many cases of work-related disease fail to enter the workers' compensation system. It is clear that any economic incentive provided by workers' compensation will be reduced substantially if only a few occupational illnesses are compensated. **However, representatives of the insurance industry claim that only a few occupationally related diseases go uncompensated (285,286).**

There have been several estimates of the number of cases of occupational disease that are compensated. Data collected by the Bureau of Labor Statistics in the Supplementary Data System suggest that only 3 to 3.7 percent of all first reports of workers' compensation concern an occupational disease. Barth and Hunt (46) report that the percentage of all compensation cases that concerned occupational diseases ranged from 0.1 percent to 5.5 percent for the 12 States for which data were available in 1975. Half these States fell in the range between 1 and 2 percent. They also report the results of a large survey conducted by Cooper & Co. of 44,066 workers' compensation cases in the fall of 1975. About 0.8 percent of the cases concerned on-the-job heart attacks and about 2.1 percent were related to other occupational diseases.

Because there are no firm estimates of the total number of occupational disease cases, it cannot be said with certainty that this range of 2 to 4 percent means the compensation level for disease is too low, too high, or just right. However, as mentioned in chapter 2, the number of all work-related **cancer cases** currently reported to worker's compensation agencies is substantially less than the number of cancer cases estimated to be caused by occupational asbestos exposure. In addition, because of the difficulties faced by anyone filing a claim for **occupational disease** compensation (discussed in this section), it is probable that many disease cases go uncompensated.

Barth and Hunt (46) describe a number of scientific, legal, and regulatory barriers that impair the certain and timely compensation of occupational illnesses. They note that the system provides a bifurcated response to disease claims. Those that are readily connected to workplace exposure and that are relatively inexpensive (e.g., acute dermatoses) are compensated much like accidental injuries. Disease claims that involve serious disabilities that are less clearly linked to workplace exposures (e.g., chronic respiratory disease) are marked by extended controversy and long waiting periods between a claim being filed and first payment. Moreover, these cases create a disproportionate amount of administrative costs for the system. They note that "[f]or such claims the system retains many of the undesirable features of the tort system that workers' compensation was supposed to supplant" (46).

For occupational illnesses that manifest themselves only after a latent period of years there may not be a strong economic incentive for prevention. Firms contemplating an investment that will reduce their workers' compensation payments 20 to 30 years from now (or even payments for product liability, as discussed later) can invest the money elsewhere for a better return. That alternative investment may be more profitable than the possible reduction in future compensation costs. Moreover, the firm may not even be in existence in **20 or 30 years, and its managers will almost certainly have changed. Thus a firm may fail to take actions to prevent occupational illness. On the other hand, the threat of having an occupational disease disaster similar to that associated with asbestos may outweigh this financial calculation (286).**

A number of State statutes and interpretations of them impede compensation for occupational diseases. For example, some States have restrictive definitions that make it difficult for disease victims to receive compensation. Most States have abandoned or gone beyond the "schedules" or lists of occupational diseases, which were often unduly restrictive (such as textile producing States that did not list byssinosis on their schedules, or coal mining States that did not compensate coal workers' pneumoconiosis). Many States, however, deny compensation for "ordinary diseases of life" and will compensate only those that are "peculiar or particular" to some line of work. This rule has been applied even for occupations that face an increased risk of contracting an "ordinary disease of life. " Legal strictures concerning time limitations and the requirements for proving causation also create difficulties for compensating people with occupational diseases (46,261).

The Surveys of Disabled and Non-Disabled Adults provide some information concerning the sources of income for people disabled by disease, though, as mentioned earlier, the self-identification of "job-related" diseases means care must be taken in analyzing the results. The 1978 survey showed that of those who attributed their disability to bad working conditions, only 21.8 percent had ever applied for workers' compensation, as opposed to 64.4 percent for on-the-job injuries. This application rate was static between the 1972, 1974, and 1978 surveys (437).

The 1972 survey found that of those who thought their disabling illness was due to workplace conditions, only 3 percent were receiving workers' compensation. The 1974 figure is essentially the same-5 percent (596). By 1978, of those citing "bad working conditions, " about 13 percent were receiving workers' compensation benefits, compared with 33 percent for those with job-related injuries (437). Although about 23 percent of total income replacement for job-related injuries comes from workers' compensation, for disabilities due to "bad working conditions, " the figure is about 12 percent. Nearly half the income maintenance for this disease-disabled group comes from Social Security Disablity Insurance. These estimates have been criticized for various reasons related to the design of the survey, the size of the survey population, and the use of self-reporting to describe both health conditions **and** the work-relatedness of those conditions (214,285,680).

However, more detailed studies of two well-known occupational hazards, asbestos and cotton dust, support the general conclusion that most of the income support for workers disabled by occupational illnesses does not come from the workers' compensation system (217,431). Because both asbestos and cotton dust have been clearly linked to occupational disease and have received widespread public attention, they represent the "best **cases"** for the compensation of disease by the workers' compensation system.

A study (431) of a group of insulation workers who died from asbestos-related disease found that of those who stopped working because of their terminal illness, two-thirds never filed for disability benefits from workers' compensation before their deaths. Of the claims that were filed, nearly half were still pending at the time of the workers' deaths. When there was a surviving widow, claims for death benefits were filed in fewer than half the cases.

In addition, workers' compensation was the sole or primary source of medical benefits for only about 4 percent of these workers. The workers and their families appear to have relied on union welfare funds, Medicare, other private insurance plans, and their own savings to pay for the medical costs of asbestos-related disease. A tort liability suit was filed in fewer than one-fifth of the cases for which data were available. In only 9 percent of the cases did the worker or spouse file both a claim for workers' compensation and a lawsuit. In over half the cases (57 percent), neither a workers' compensation claim nor a liability suit was filed. The most important factor in explaining the failure to file for workers' compensation appears to be "ignorance, either of the source of the disease or of the legal rights of survivors to compensation. "

Johnson and Heler (236) have calculated the expected monetary losses for the families of these workers. They estimated that the gross loss due to disability and death from asbestos-associated disease amounted to over $250,000 per family. Half the widows they studied received no benefits at all. The other half received a variety of benefits. About 28 percent of these benefits came from workers' compensation, while 16 percent came from tort suits and settlements. The remainder came from Social Security, private pensions, and veterans' benefits. Johnson and Heler also calculated the net financial losses for these families. On average, the widows who received benefits had approximately one-third of their losses replaced.

In theory, through the workers' compensation system, employers bear the costs of occupational disease. But for this group of workers, about 85 percent of the gross wage loss was borne by the families of the affected workers. Of the small portion of lost wages that were replaced, less than half were paid for by employers through workers' compensation and by producers through tort suits and settlements.

Hughes (217) has similarly studied income replacement for a group of workers exposed to cotton dust who developed byssinosis, He found that workers' compensation replaced only **6.9 percent of the estimated lost income for this group. Forty percent of lost income was replaced by funds from Social Security, 3.5 percent from Veterans Administration benefits, and 2.6 percent from private pension plans.** The total income replacement amounted to about 53 percent of expected earnings. "Even with Social Security funds in crisis, it is apparent that a massive shift of costs has been made from the employers to the general taxpaying public, due to an almost nonexistent workers' compensation system—a form of public subsidy to disease-producing industries . . . " (217).

Role of Insurers

Beyond the incentives faced by private employers, insurance carriers might have an independent financial incentive to prevent injuries and illnesses. If an insurance company can improve the loss experience of its policyholders, it maybe able reduce the amount that must be paid out in claims.

In practice, however, this incentive is limited, too. Low benefit levels reduce the incentives to insurers just as they reduce the incentives to employers. In addition, if the merit-rating system is working properly, insurers will have little incentive to improve the loss experience of firms that are fully merit-rated. For such companies, the benefits of reduced claims will be received by the employer.

Insurers will receive an independent benefit only if they can cut losses in the time period before the premiums are adjusted by the experience factors. Insurers will also benefit if they can reduce the losses for firms that are not fully merit-rated. However, insurance industry representatives argue that reduced rates are important for attracting and holding customers, and that maintaining customers is a powerful incentive for reducing claims and therefore rates (286).

In fact, many insurers provide loss-control services to their policyholders. The results of one survey imply that private insurers and State workers' compensation funds provided a total of 1.6 million such visits to policyholders in 1974. Private insurers provided 1.5 million of these visits (472,473). More recently it has been estimated that the insurers who are members of the two major trade associations (the Alliance of American Insurers and the American Insurance Association, or AIA) employed about **8,600 loss-control specialists in 1983, while independent firms added about another 1,000, for a total of 9,600. The** 8,600 specialists working for the members of the two associations conducted about 1.5 million visits to policyholders. It is also estimated that about 177,000 samples of suspected toxic substances were analyzed in 1983, while approximately **40,000 policyholders participated in train**ing programs provided by the Alliance and AIA member companies (286).

Some of the expenditures for "loss control" are expenses for inspecting workplaces in order to determine the nature of the operations and to set premiums (30,473), rather than to suggest or mandate preventive actions. Little statistical information is available to determine the percentage of insurer visits that are primarily for collecting information for rate-setting and the percentage of visits that provide safety advice (473).

Aside from this rate-setting activity, insurers have offered loss-control services as one way of competing in an industry that until recently was subject to detailed price and service regulation by State agencies. In general, that regulation did not allow insurers to compete by charging different rates. It is not clear what effect various efforts to "deregulate" this industry will have on the provision of loss-control services (268).

However, although insurers do provide consultative services to their policyholders, they generally do not grant rate decreases to employers who accept such services. It is likely that the advice provided by insurers has a positive effect on safety, but this effect may be limited by fear that the employer, a valued client, will simply change insurance companies rather than make a large expenditure for health and safety controls.

To the extent that occupational diseases do not enter the compensation system, there is no financial incentive to prevent them, either on the part of the employer or the insurer. Compensation for illnesses will also be discounted substantially because of the latent period between exposure and disease manifestation. The insurance industry, however, maintains that it is taking steps to avoid future occupational disease disasters similar to the asbestos situation (286,675).

Changes in Workers' Compensation

In practice, the workers' compensation system only provides a limited economic incentive for prevention, especially for occupational illnesses. Changes have been suggested to improve economic incentives provided by this system. These include increasing the degree of experience-rating in the compensation system (317), instituting employer deductibles or copayments for the first $500 of compensation expenses (449), and changing the Federal income tax deductions allowed for workers' compensation premiums (228). However, because workers' compensation is currently administered by the States, the first two suggestions would involve changes in each of the States or creation of a single Federal system.

Moreover, the effects of the suggested changes are not completely clear. For example, Victor **(656)** suggests that the creation of employer deductibles might increase the incentives faced by some employers while decreasing the incentives faced by other employers. The net effect on injuries is unclear. In addition, increasing the economic incentives of workers' compensation could increase employers' incentives to contest claims, as well as their incentives to prevent illness and injury. Finally, many of the limitations of injury taxes (discussed in ch. 16) **also** apply to these suggested changes in the workers' compensation system.

There has been considerable recent discussion concerning the possibility of creating a Federal system to compensate for occupational exposures to asbestos (517). Prevention should be a consideration in any changes in compensation. A compensation system should be designed to "internalize" the costs of disease. In other words, producers and employers should bear the costs of occupational disease (14). However, the use of Federal funds to supplement an occupational disease fund may dilute this incentive. If Congress takes action concerning occupational disease compensation, this action could include a requirement that companies take concrete steps to prevent future cases of disease.

Tort Liability

The effects of court-enforced tort liability on employer practices concerning health and safety has been highlighted by the large number of lawsuits concerning worker exposure to asbestos (box R). In particular, attention has focused on the well-publicized case of one supplier of asbestos, the Manville Corporation (formerly Johns Manville), which has filed for a corporate reorganization under the bankruptcy laws because of the burden of paying numerous liability suits. Facing the threat of potentially costly lawsuits and large awards for damages, employers and manufacturers may take action to improve workplace health and safety.

As discussed in chapter 11, before the passage of workers' compensation laws in the early part of this century, injured workers could sue their employers for damages. They encountered substantial difficulties in winning these suits, however. Workers' rights to sue their employers were greatly restricted with the creation of the workers' compensation system. For most cases of occupational injury or illness, workers are not allowed to sue their employers for such compensation. Instead, the workers' compensation system, in theory, provides a specified level of benefit that is awarded to pay medical costs and compensate for lost wages.

In general, the law of torts provides the opportunity to sue for monetary compensation when property has been damaged or a person has been injured, but precisely defining the field of tort law is difficult. One noted scholar has written:

> A really satisfactory definition of a tort has yet to be found. . . . Included under the head of torts are a miscellaneous group of civil wrongs, ranging from simple, direct interferences with the per-

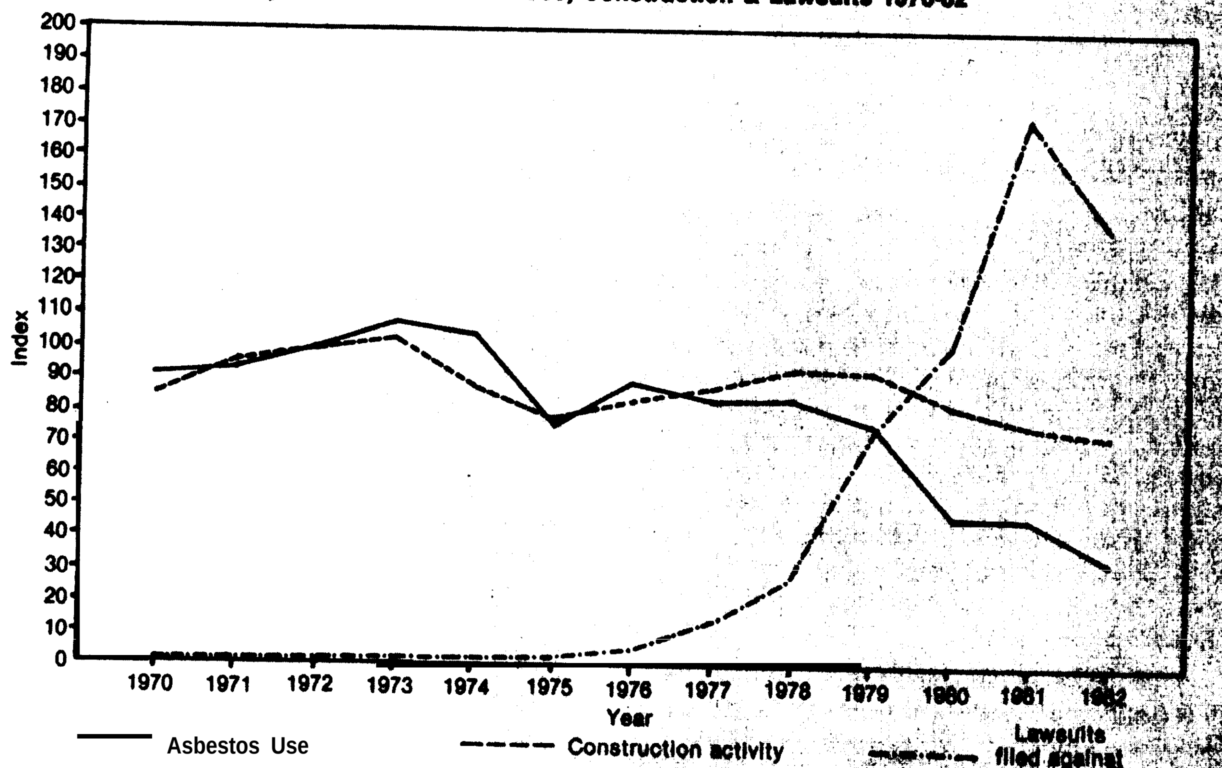
Box R.—The Effect of Tort Liability on Asbestos Consumption

Asbestos consumption in the past generally followed the pattern set by construction activity (see fig. 15-1). This usage pattern was partially a result of the use of asbestos for building insulation. When construction activity increased, asbestos consumption increased; when construction activity decreased, as in the recession of 1974-75, asbestos consumption decreased. The first indication of a divergence from this pattern can be seen after 1977. Overall, asbestos consumption declined 72 percent from 1973 to 1982.

In 1972, OSHA lowered the permissible levels for exposure to asbestos. This took effect in two stages, a limit of five fibers per cubic centimeter (c.c.) was issued in 1972, while a limit of two fibers per c.c. became effective in 1976. In 1975, OSHA proposed to lower this limit to one-half fiber per c.c. During the 1970s, the Environmental Protection Agency and the Consumer Products Safety Commission also issued regulations restricting the uses of asbestos. In November 1983, OSHA issued an emergency temporary standard that set the maximum workplace exposure limit to one-half fiber per cubic centimeter. This emergency standard, however, was struck down by the Fifth Circuit Court of Appeals. OSHA now is developing a new standard and held public hearings on it in the summer of 1984. Analysis of data from OSHA inspections by two different researchers (237,301) indicates that the levels of worker exposure to asbestos have declined from those that existed before the more stringent limit went into effect (see discussion in ch. 13).

But another important factor was the dramatic increase in liability suits filed against asbestos producers. For example, in 1976 there were 160 cases pending that named Johns Manville as one of the

Figure 15-1.—Asbestos Use, Construction & Lawsuits 1970-82



NOTE: For asbestos use and construction activity, the index for 1972 was set equal to 100. For the number of lawsuits filed, the index equals 100 for 1980.

defendents. The number of lawsuits facing the asbestos company increased twelvefold in 1979, to 2,000, and the number of cases has increased nearly exponentially since then (see fig. 15-1) (480). Although it is difficult to describe with certainty the factors that have affected production and consumption, it is widely believed that this increasing trend in the filing of lawsuits and the increasing size of the awards in those suits has been the major factor.

In addition to having to comply with environmental and occupational health regulations, the fear of successful liability actions has provided a strong incentive to producers and manufacturers to find substitutes for asbestos in their products. For example, a combination of polyester fibers and glass fibers is used in pipe insulation in place of asbestos (391). Other materials that have been used in place of asbestos are rockwool (rock fiber), wool astonite, newsprint and other wood pulp fibers, steel fibers, textile fibers, and polypropylene fibers.

> son . . . or with property . . . up through various forms of negligence. . . The law of torts . . . is concerned with the allocation of losses arising out of human activities. . . So far as there is [a general principle] . . . it would seem that liability must be based upon conduct which is socially unreasonable . . . or unreasonable interference with the interests of others . . . (Presser. Quoted in 379).

Baram (379) notes that controversies involving risks to human health have traditionally involved legal concepts grouped under tort law. Four areas of tort law have been used to resolve controversies that involve such risks: negligence, product liability, nuisance, and strict liability. Of these, negligence, product liability, and strict liability are applicable to issues of workplace health and safety.

Negligence has been defined as "conduct which falls below the standard established by law for the protection of others against unreasonable risk of harm. " To maintain a suit based on negligence, four elements must be shown: the existence of a legal duty or obligation to protect people from harm, a failure to conform to that duty, a proximate causal connection between that failure and a resulting injury, and an actual injury (379). Under the general doctrine of negligence, a person can be held liable for an injury if he or she failed to act in a "reasonable" way to prevent the injury.

Product liability developed out of warranty law. The courts have ruled that manufacturers and sellers implicitly warrant that their products are suitable and safe for all reasonably anticipated uses. Whether or not the seller was legally negligent is irrelevant in this situation because the very fact of the defect indicates a breach of the warranty **(203).**

Under ***strict liability,*** the manufacturer is liable for injuries resulting from a defective product that is unreasonably dangerous, without regard to fault or contractual limitations. Here, the degree of diligence or care in preventing injuries is immaterial (203). Strict liability has traditionally been used for "ultrahazardous" ***or*** "abnormally dangerous" activities (42). In recent years, the courts have adopted in the field of product liability law some of the concepts of strict liability. In fact, product liability suits can be based on negligence, warranty, and strict liability. Liability is now applied in cases where: 1) a product was defectively designed, 2) a product was defectively manufactured, or 3) a product was sold without proper warnings concerning its use and dangers.

The "duty to warn" has been the basis for many of the successful lawsuits concerning asbestos exposures, in which courts have ruled that the manufacturer has an obligation to take reasonable actions to discover the hazards associated with a product and to warn accordingly. This duty may include specialized testing (69):

> The manufacturer is held to the knowledge and skill of an expert. . . [This] means at a minimum he must keep abreast of scientific knowledge, discoveries, and advances and is presumed to know what is imported thereby. But even more importantly, a manufacturer has a duty to test and in-

spect his product. The extent of research and experiment must be commensurate with the dangers involved.

By far the most common use of tort actions in occupational safety and health are suits against a third party—for example, the manufacturer of products purchased by the employer for use in the workplace. Thus, employees injured by a malfunctioning punch press can sue the manufacturer of the press, while employees who used asbestos in their work can sue the manufacturer of the asbestos product. Because the ill or injured worker is not directly employed by this third party, lawsuits concerning work-related illness or injury are not prohibited by workers' compensation laws.

Although many employers are concerned about legal liability, in most cases it does not directly affect them as employers. Rather, it affects the products that they sell to consumers or to other employers. In 1978 it was estimated that while only 11 percent of all product liability awards involved work-related injuries and illnesses, these cases accounted for 44 percent of the total dollars awarded for product liability (228).

This slightly roundabout approach of third-party suits may lead ultimately to improvements in working conditions and in the health and safety of the work force, but a number of factors limit its effectiveness. The first is that it does not apply to employers, even in cases in which the employer may have been in the best position to ensure that the equipment and products were being used in a safe and healthful fashion. In these cases, the manufacturer is still held responsible.

Other limitations on the usefulness of third-party suits are found in the traditional degree of proof demanded by the courts in liability actions. This burden of proof is often very difficult for the worker, especially in cases of occupational disease. The problems employees can encounter include:

- It is difficult to prove (or even recognize) that harm has occurred when a disease, such as cancer, may be caused by many factors, including occupational ones.
- The isolation of the product or products that "caused" the harm is difficult, especially if there are harmful interactions with other products, or when the proof for the causal connection is only through statistical inference.
- The long periods of time that often elapse between exposure and effect make the causal connection and the identification of products and manufacturers much more difficult.
- Even if the manufacturer can be identified, the firm may have gone out of business, be currently unprofitable, or otherwise not able to pay damages.
- In some States, statutes of limitations bar suits for damages beyond a certain length of time (generally 3 to 10 years) after the last exposure to the hazard, even if the disease only manifests itself 20 or 30 years later (203).

As noted earlier, State workers' compensation laws generally bar suits by employees against their employers, although there are several exceptions to this. First, any employer that is not covered by the State workers' compensation law may be sued. Some employment categories that commonly fall in this group are agricultural employees, domestic servants, employees of very small businesses, railroad workers, and employees of charitable organizations **(407).**

Second, courts may grant employees "injunctive and declaratory relief. " In one case, ***Shimp v. New Jersey Bell Telephone Co.,*** an employee obtained a court injunction to require the employer to prohibit smoking in general working areas. The court ruled that such an injunction would not be barred by the workers' compensation law of New Jersey and that the employee, who was allergic to cigarette smoke, had a common-law right to a healthful work environment. It is not clear whether other courts will also adopt this reasoning (407).

Third, in nearly all States workers can sue employers for damages in cases of willful or intentional acts. This includes situations in which the employer actually intended that the employee be injured, as well as cases that involve fraud or deceit. by the employer. For example, if an employer deliberately conceals from a worker information concerning a work-related illness, employees may be successful in collecting damages from the employer. The West Virginia Supreme Court extended this rule to cases of willful, wanton, or reckless employer misconduct (407), although this was subsequently restricted by a new State law (2,342).

Fourth, in some jurisdictions an employer may be sued by an employee when acting in a "dual capacity. " The three main types of dual capacity cases involving workplace health and safety issues are based on the obligations of the employer as land owner, medical practitioner, or seller of products. Thus an employer, for example, who offers an onsite medical service and who negligently treats an employee maybe sued for medical malpractice. Similarly, an employer may also be sued by a worker for injuries or illnesses incurred due to a product manufactured by the employer. It should be noted that only a minority of jurisdictions currently allow such "dual capacity" suits (407).

It has been suggested that employees be allowed to sue their employers. For example, Amchan (2) has proposed that workers and their families be allowed to sue employers if the worker ***is*** killed or permanently disabled due to the "willful, intentional, or grossly negligent conduct" of the employer. Although such change might enhance employer incentives for prevention, it would also have a number of social, legal, and economic implications that need to be considered carefully.

The future importance of tort liability as an incentive to control workplace hazards is unclear. Although much attention has been given to the circumstances of asbestos exposure, asbestos may not be typical. Currently the prohibition of most employee suits against employers severely weakens the incentive. In addition, the practical problems of proving causation will tend to limit to just a few hazards the lawsuits by workers against suppliers.

Congress is currently considering legislation to change certain aspects of product liability law. As suggested earlier for changes in workers' compensation it is important that the effect of these changes on incentives for prevention be considered carefully,

Labor Market Forces, Collective Bargaining, and Workers' Rights

To some extent, employers are motivated to improve employee health and safety because of pressures from the labor market. Economists since Adam Smith have hypothesized that employers would have to pay more to attract workers to jobs with unsafe conditions or other adverse working conditions. In theory, if there is complete information about workplace hazards and alternative job opportunities, employers may find that they cannot attract enough workers. There are then two basic choices—raise the wages or reduce the hazards. Thus, the possibility exists that this labor market pressure may induce improvements in employee health and safety.

The payment of additional wages for occupational risks can be seen in the existence of "hazardous duty pay" in certain high-risk occupations. But these additional wages may also be built into the general pattern of wages for an industry or occupation. In this situation, they would not be directly observable, but would be included as part of the total **wage.** The additional wages paid for workers exposed ***to*** occupational risks have been termed "hazard premiums" or "compensating wage differentials. " In theory, various statistical techniques could be used to separate the factors that determine wages, thus testing whether a "hazard premium" existed and determining its size. In practice, the data are difficult to analyze because of problems in measuring job risks and in adjusting for other factors that influence wages.

To date, the published studies on this question have generally found compensating wages for increased risks of death, but are inconsistent on whether there are also compensating wages for increased risks of nonfatal injuries. In fact, several studies have found, contrary to expectations, that some groups of workers were not receiving compensating wages. In some cases hazardous work was associated with ***lower*** **wages** (138,192). Moreover, even the studies that have found increased wages for hazardous work have not been consistent on the size of these increased wages or the implied “value of life.” (See ch. 14 for a table presenting this wide range of values. For reviews of this literature, see 191 and 448.)

In addition, employers may find that their workers are quitting soon after starting work because of unsafe or unhealthful working conditions (658a). Efforts to reduce such turnover and to improve employee morale may lead to investments in health and safety controls.

Of course, all these labor market pressures are vitally dependent on the existence of alternative job opportunities. In areas and times of high unemployment, this incentive to control hazards will be substantially reduced. Moreover, other labor market imperfections, such as incomplete information about job hazards, the costs of searching for jobs, and unequal bargaining power also limit this incentive.

Collective Bargaining Agreements

Negotiation and collective bargaining can also bean incentive. This requires that unions be committed to the recognition of health and safety concerns and assign high priority to these issues in collective bargaining. Other important union obligations for the success of this strategy include being fully informed about **OSHA regulations, enforcement procedures, and employee rights under the** OSH Act. In addition, the union must establish a system to monitor employer actions, usually through safety stewards or trained local representatives, as well as develop procedures for hazard identification, management negotiation procedures, enforcement of committee findings, and rank-and-file feedback about these findings (253).

Labor unions can exert influence because their representatives can be present for all plant operations, every working day. However, because the collective bargaining process involves a process of negotiation and compromise, unions may make tradeoffs between economic benefits (including greater wages, job security, and fringe benefits) and more attention to occupational hazards.

There are approximately 150,000 separate collective bargaining agreements in the United States, and 82 percent of these contain some reference to health and safety. Apparently, emphasis on these issues at the plant level has increased during the last decade. This may be because of a belief “that control and prevention of job hazards can be improved through the combination of more effective OSHA rules, regulations, and enforcement programs with trade union programs, including more effective collective bargaining contracts and their administration” (185).

The Bureau of National Affairs (BNA) has tabulated the major provisions in over 5,000 collective bargaining agreements and analyzed closely a representative sample of 400 contracts (77). Table 15-1 illustrates the frequency of health and safety provisions in collective bargaining language from 1954 through 1981. Until 1971, according to the BNA, there was only a slight increase in the prevalence of such provisions: for example, from 38 percent of contracts **in 1954 requiring management to “take measures” to protect the workers to 42 percent by 1971. The only type of contract provision that** showed more than a slight increase was that for safety committees.

Passage of the OSH Act in 1970 coincided with an increase in the number of contracts that included health and safety clauses, and the provisions became increasingly specific. The overall frequency of safety and health clauses between 1954 and 1970 had remained between 60 and 65 percent, but by 1975, 82 percent contained such clauses. There was also an increase of 11 percentage points in clauses requiring employer compliance with laws from 1971 to 1975.

The general statement of responsibility in most contracts states that the company must make “reasonable provision for the health and safety of the employees, “ which appears to be redundant with the general duty clause of the OSH Act (see ch. 12). Moreover, 29 percent of the contracts in 1981 required the company to comply with present legal standards. These provisions enable local unions to use the grievance process (an internal dispute mechanism negotiated by labor and management for the resolution of employee complaints) to change or influence health and safety conditions, in addition to filing an OSHA complaint.

Table 15-1.—Percentage of Contracts Containing Health and Safety Clauses,[a] 1954-81

		Company obligation				Employee obligation		Other provisions
Years	Clauses	To take measures	To meet legal standards	To provide safety equipment	To provide first-aid equipment	Must wear safety equipment	Must obey safety rules	Safety committees
1954	600/0	380/0	13 "/0	270/0	11 "/0	7%	17"/0	180/0
1961	65	34	11	32	16	7	11	28
1966	62	35	NA	28	12	6	8	29
1971	65	42	15	32	14	7	13	31
1975	82	50	26	36	21	NA	NA	39
1981	82	50	29	42	21	NA	NA	43

[a]Considerable overlap was noted in all categories
NA—Not available

SOURCE (77)

Joint Labor-Management Health and Safety Committees

Joint committees vary in structure, organization, and capacity for intervention. The role of the committee ranges from a limited monitoring of workplace routines to a strong source of pressure on workers, union, management, and OSHA. The proportion of contracts with a clause concerning health and safety committees rose from 18 percent in 1954 to 43 percent in 1981, with most of the increase following passage of the OSH Act (see table 15-1).

The growth in labor-management safety and health committees may represent an attempt on the part of both labor and management to resolve issues at the local level. An important factor in **a** union's ability to improve safety and health is rank-and-file concern about these issues and the relative priorities that union members and their leaders place on health and safety in relation to other negotiable provisions, such as wages, work hours, seniority, and grievance procedures. According to Kochan and his colleagues, the most important determinant of committee effectiveness from the management perspective is the attitude and commitment of the top management. It is also important that there be a balance of strengths between both bargaining groups. Acting as an external pressure, the presence of OSHA may place a weak union in a more equal bargaining position with management (253).

Collective bargaining is commonly associated with opposition in interests and an atmosphere of limited trust, but there may be "integrative" issues over which parties share common goals. It has been suggested that safety is such an "integrative" issue, leading to a capability for cooperative problem solving on safety issues through health and safety committees in the context of an overall bargaining relationship (253).

Collective bargaining often serves as a direct and immediate stimulus for setting up these committees. However, it does "not guarantee that an active and ongoing committee will develop" (253). Indeed, there are numerous instances where the presence of a contract clause requiring safety committees has not resulted in regular meetings or useful recommendations by functioning committees.

There has been only a limited amount of research assessing the impact on worker health and safety of these joint committees. Kochan, Dyer, and Lipsky studied union and management attitudes in *59* plants (253). For several reasons, they were unable to obtain data on actual injury and illness experience at these plants. Thus their results are generally based on subjective perceptions of workers and managers from surveys and interviews.

They attempted to describe the conditions under which labor-management committees would have a high level of activity and would continue to function. These conditions occurred **when OSHA** pressure was perceived to be strong, when the local union was perceived to be strong, when there was substantial rank-and-file involvement in health and safety issues, and when management approached these issues in a problem-solving manner. The committees that produced the largest number of recommendations tended to have a high level of input from the local union membership, frequently reported back to those members, and were in workplaces with a high proportion of young workers. The degree of top management commitment was also a very important variable for determining the success of these committees. In particular, management tended to adopt a problem-solving approach to health and safety issues when they were under pressure from OSHA to comply with particular regulatory requirements **(253).**

Cook and Gautschi (121) used data for 113 manufacturing firms in Maine to study the effectiveness of OSHA and labor-management committees. They found a favorable effect on plant injury rates from OSHA citations. In addition, there was some evidence that union-management safety committees were also effective in reducing injury rates. For the plants with 300 or more employees, this effect was significant **at** the 90 percent confidence level. However, for all the plants with 200 or more employees, the effect was not statistically significant.

California has created a program to encourage the formation of joint committees on construction sites. Under this "Cooperative Self-Inspection Program," a site will be exempt from routine OSHA inspections if a joint committee is set up to perform regular inspections of the workplace. This program has been implemented on six projects. The California Division of Occupational Safety and Health reports that the injury rates at these worksites are "substantially lower" than both the rates for other California construction projects and the experience of these same companies at other sites not included in the program **(337,347).**

In a study of survey responses from 127 firms in Massachusetts, Boden and colleagues (66) found that the "mere existence" of a joint committee in a workplace had no effect on either the number of OSHA inspections prompted by worker complaints or the relative hazardousness of the firm as measured by serious OSHA citations. The researchers also conducted more detailed interviews with union and management representatives at 13 of the firms with labor-management committees. The data from these interviews suggest that the committees that were perceived as "effective" apparently increased perceived safety (leading to fewer worker complaints to OSHA) and improved employer compliance with OSHA standards (leading to fewer citations) (see also 335 and 341 and box S.)

OSHA and Workers' Rights

The OSH Act itself created a number of opportunities for worker participation concerning occupational safety and health. The act provided that workers could:

- request OSHA inspections,
- participate in the conduct of an OSHA inspection,
- participate in any of the stages of a proceeding before the Occupational Safety and Health Review Commission,
- contest the "reasonableness" of the abatement date set by OSHA,
- participate in standards development and the issuance of variances, and
- request a Health Hazard Evaluation from the National Institute for Occupational Safety and Health.

The right to participate in Occupational Safety and Health Review Commission proceedings and to contest OSHA citations has been the subject of several court cases. The result of these cases, interpreting the language of the OSH Act, is that employees and their unions can participate in these proceedings if the cited employer is contesting a citation. Employees and unions also have an independent right to contest the reasonableness of the prescribed abatement date. However, employees and unions do not have an independent right to contest an agreement between OSHA and the employer concerning the nature of the required controls, the type of citation, or the penalty amount. If OSHA and an employer agree on these issues and the employer withdraws its "contest" before the Review Commission, the employees can object only to the specific abatement dates. (See 307 for excerpts from several of the important cases on this issue.)

In addition, the act created a mechanism in section 11(c) to protect employees from job discrimination for having exercised any of the rights listed above. However, the resources devoted to OSHA's

Box S.—Collective Bargaining Results: Worker Training and Health and Safety Committees

Training Concerning Health, and Safety

Approximately 420,000 of the total 800,000 General Motors (GM) employees are members of the United Automobile Workers (UAW). The UAW-GM contract provides for training of full-time union health and safety representatives for each GM plant with more than 600 employees (37). The full-time union safety representatives, selected first by the locals and finally by the UAW international headquarters, train alongside GM's own safety representatives for 40 hours at the General Motors Institute. Training involves hazard recognition, OSHA complaint procedures, and OSHA regulations. In accord with the UAW-GM contract, the union representative accompanies his or her management counterpart twice monthly on inspections, and also walks with OSHA inspectors on their tours. The union member's role also includes reviews of training and education programs and accident reports, and the person is empowered to shut down a hazardous operation, but only with joint approval by the plant safety officer. In addition, the union safety and health representative is involved in the initial stages of grievance resolution concerning health and safety issues.

Some unions that represent workers who move frequently from worksite to worksite, such as the International Brotherhood of Painters and Allied Trades (IBPAT) and the United Association of Plumbers and Pipefitters, also place high priority on the training and education of their workers and union safety representatives. Part of this attention is directly related to securing desirable contract language concerning health and safety. IBPAT has concluded, for example, that its training program had a "statistically significant impact on collective bargaining, leading to more and better safety and health bargaining language in both local and district."

Labor-Management Committees

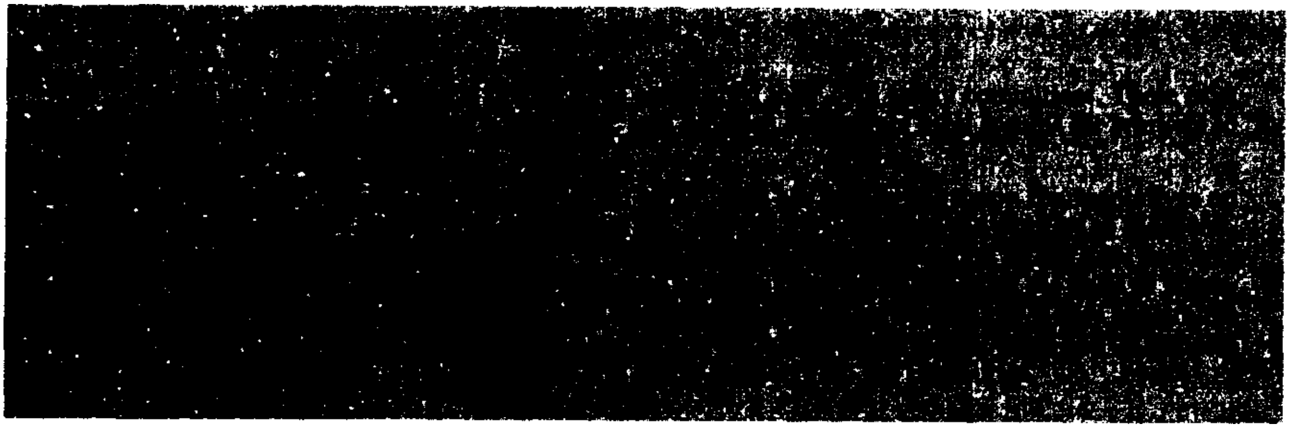
One refinery plant of the Shell Oil Company that has 2,000 workers organized by the Oil, Chemical and Atomic Workers (OCAW) also has contractual provisions for union-management committees. The current contract language was drawn up in 1973. Unlike most OCAW contracts, this one provides no trained hygienist to survey worksites regularly. It does, however, provide for a union-management health and safety committee that:

> . is to be composed of an equal number of representatives from the hourly and staff [management] groups and is to meet periodically to discuss health and safety matters and make recommendations to management. Where a recommendation made to the company is not accepted, an explanation will be made to the committee. Decisions by the company with respect to health and safety recommendations *shall not* be subject to the grievance and arbitration procedures of the articles of agreement (emphasis added).

Union representatives are unhappy with their negotiated position that makes them unable to use the grievance procedure or arbitration.

In discussions with OTA, OCAW representatives cited difficulty in presenting and resolving health hazards as compared to safety problems. Safety hazards, usually readily visible, are quickly identified and consequently more easily eliminated than health hazards, which can involve multiple factors and the effects of which become evident only slowly due to varying latency periods.

Company perceptions, however, differ. Shell has described the joint committee policies as having "dispelled rumors and improved relations" between the adversarial parties, and having "removed the mystery" with regard to company initiative and support of workplace health and safety. Management representatives felt that these issues were best handled in the joint committee setting, and contended that union desires to use the grievance procedure were often motivated by wanting to push other issues into the grievance setting "under the guise of safety."



enforcement of this have been very limited. Moreover, employees do not have a right to pursue a court-ordered remedy independently, but must rely on OSHA to negotiate a settlement or file suit. Thus, one commentator has suggested that the implementation of this provision "has been seriously flawed" (406).

This protection from discrimination covers workers who refuse to engage in imminently hazardous work. An OSHA regulation prevents employers from disciplining employees for such a refusal if there is insufficient time to eliminate the danger of **death or serious injury through any other means. In *Whirlpool Corp. v. Marshall,*** the U.S. Supreme Court unanimously upheld this regulation (307,408). This right is limited to refusing imminent injury hazards and does not extend to most chronic health hazards.

Under **a** provision in the National Labor Relations **Act,** employees who refuse to perform hazardous work **may be** protected from disciplinary action if they are **acting** together and in good faith (408). Recently, however, the National Labor Relations Board ruled that this did not apply to one worker who refused a hazardous assignment because he **was acting** only by himself **(328).**

Of great **importance to effective worker participation** in labor-management activities is the availability of information to workers and their unions about plant-specific hazards. The OSH Act has several provisions requiring that employees be fully informed about health and safety issues. The act provides that OSHA issue regulations requiring that employers inform employees of the protections and obligations provided by the act and the standards that apply to their workplaces (section **8(c)(l)).**

The OSH Act also mandates OSHA to issue regulations requiring employers to maintain records of employee exposures, to provide employees and their representatives with the opportunity to observe employer-conducted exposure monitoring, and to provide access to these records. Employers are also required to notify employees who have been or are being exposed above permissible limits and inform them of "the corrective **action being** taken" (section **8(c)(3)). Finally, the Act requires that standards issued by OSHA "shall prescribe the use of labels or other appropriate forms of warning as are** necessary to insure that employees are apprised of all hazards to which they are exposed, relevant symptoms and appropriate emergency treatment, and proper conditions and precautions of safe use and exposure" (section **6(b)(7)).**

Several OSHA regulations give workers and their unions the right to obtain information from employers. For example, an OSHA regulation issued in 1978 requires that the employer-maintained Log of Injuries and Illnesses be made available to workers upon request, and employers are required to post a summary of the log each year. The OSHA Access to Records regulation and recent rulings by the National Labor Relations Board also assist unions and workers in obtaining information concerning exposures and employer-held medical records. Finally, as discussed earlier in this chapter, various state and local right-to-know laws and the recent OSHA regulation concerning hazard communication may also aid workers and their unions in learning about hazards. (For further discussion of employee rights, see 307, 333, and 408.)

Possible Changes in Workers' Rights and Collective Bargaining

It has been proposed that workers' rights concerning workplace health and safety be expanded. Several observers have argued, based on the experience of other countries, that health and safety improvements could be made by enhancing workers' rights to full information on job hazards, ***re-***quiring worker participation in health and safety decisions, and permitting workers to refuse all work assignments they consider to be hazardous ***(64,242,677).***

In Sweden, for example, since 1974, every establishment with five or more employees must have at least one worker-elected health and safety steward; larger workplaces typically have a steward for each area of the workplace with one worker designated as the chief health and safety steward. The health and safety stewards have the authority to inspect the workplace for hazards, are involved in the design of the workplace, and have the right to examine company records. They also have the authority to order, for health and safety reasons, that a particular plant operation be shut down, even over the objections of management. In cases of a labor and management dispute, the operation remains shut down until a government inspector visits the workplace and resolves the issue.

In addition, all workplaces with 50 or more employees must have a labor-management health and safety committee. The committee discusses plans to improve working conditions, is involved with the design of new facilities and worker training, and supervises the company health and safety staff. Although the workers have a majority on these committees, most decisions are reached by consensus of both labor and management representatives. Finally, a number of different types of training courses have been developed for workers, supervisors, and the worker health and safety stewards. These courses are commonly administered by the Swedish trade unions, both at trade union schools and in worker-organized "study circles" ***(64,242,677).***

As described in chapter 10, employers, unions, universities, and other groups in the United States have developed and administered worker training and education programs. The "right to know" movement in this country (discussed earlier) reveals the desire of many workers, unions, and communities for complete information about workplace hazards and for greater involvement in health and safety issues. In addition to the "right to know, " Mazzocchi has suggested that workers be afforded a "right to act ." This would mean that, in each workplace, a worker would be "deputized" to represent fellow workers in seeking outside assistance to evaluate information obtained under the "right to know" laws and the OSHA "hazard communication" standard (345).

However, direct application in the United States of the experience of other countries will be impaired by differing legal, cultural, economic, and political conditions. In addition, greater employee involvement in health and safety would represent changes in the traditional authority of **management to make decisions concerning all working conditions.**

It has also been suggested that greater use of collective bargaining could improve occupational safety and health. Collective bargaining agreements can detail procedures and investments that are tailored for individual plants and firms, thus decentralizing the process of implementing health and safety controls. The result, it is claimed, can be health and safety improvements that are both "more efficient and more effective" than those produced by the current system of national regulatory standards (37).

There are three significant factors that limit the effectiveness of collective bargaining in improving occupational safety and health. First, only about **20 million workers, or about 20 percent of the U.S. work force of 100 million, belong to la-**bor unions. Moreover, the percentage of the labor force belonging to unions has been declining since the 1950s. This may represent the result of social and cultural patterns and the preferences of U.S. workers and managers, but it should also be noted that U.S. law has not always permitted collective bargaining. Because of this, one labor union representative on the advisory panel for this assessment suggested that changes in labor relations law have health and safety implications.

Second, not all unions have the kinds of expertise in industrial hygiene, injury prevention, or occupational medicine needed to negotiate and enforce agreements on occupational health and safety. A recent survey of 14 U.S. labor unions shows that union spending on worker health and safety ranged from about 20 cents to over $15 per member. These 14 unions employed only two full-time physicians and one part-time one, while the majority of these unions employ few full-time industrial hygienists, public health professionals, or other health and safety staff ***(678).***

Third, by definition safety and health provisions must compete for attention and resources with other bargaining issues. In periods of economic downturn, workers and their unions, concerned about maintaining wage levels and preserving employment security, may push safety and health issues down the list of priorities.

Government Regulation

The final factor that influences employer decisions to control hazards is an imperative: the regulations and standards issued by Government agencies, mainly OSHA. As detailed in chapter 12, OSHA has been empowered to issue mandatory regulations, to conduct inspections, and to propose penalties and require correction when it finds violations of those regulations. OSHA regulations are often the focus of health and safety discussions because they require response and compliance. Nevertheless, they are limited as a factor in health and safety because few regulations have been promulgated and enforcement is spotty. Any changes in this, however, will occur only if Congress and the executive branch act to increase **OSHA resources or change standard-setting and enforcement procedures.**

(As part of this assessment, Mendeloff analyzed some of the factors that affect compliance with several OSHA health standards. See box T.)

In addition to OSHA, other Federal agencies may require employer actions that either directly or coincidentally improve worker health and safety. Using the authority granted by several different statutes, both the Environmental Protection Agency (EPA) and the Consumer Product and Safety Commission (CPSC) regulate products that may also be workplace hazards. For example, EPA regulates the production of pesticides and requires notification before other chemicals are manufactured in order to protect public health and the environment. EPA's regulations, in many cases, also reduce worker exposures.

For some toxic substances, in fact, workers may be the only significantly exposed group. In light of their overlapping authorities, EPA and OSHA have considered joint regulatory proceedings. The most recent public announcement of this has involved possible regulation of methylenedianiline, although it now appears that the agencies have decided that OSHA, not EPA, will take responsibility for regulating workplace exposures (346, 354).

Regulation of the products purchased by businesses may, in some cases, be more cost-effective than requiring installation of industrial hygiene controls. For example, a number of workers exposed to formaldehyde are employed in establishments where the only source of exposure is the emission of formaldehyde from products supplied by other industries. These include apparel manufacturers using cloth treated with formaldehyde-based resins and office workers who are exposed to formaldehyde from particleboard or plywood products in their offices. In these cases, standards concerning formaldehyde emission rates or product content might be both less expensive and easier to enforce than efforts to increase general ventilation in numerous small establishments in dispersed locations ***(206).***

One way to issue standards for these hazardous products used in the workplace would be coordinated regulatory efforts between OSHA and the EPA or the CPSC . This approach holds some promise for reducing the hazards of products purchased by small businesses. However, this approach will have only a limited impact on hazards related to the improper use of products in the workplace. In addition, there are difficulties in regulating products already manufactured and in use.

Box T.—Factors Affecting Worker Exposures

On contract to OTA, Mendeloff analyzed OSHA inspection data from 1973 through 1979 for four substances: lead, trichloroethylene, asbestos, and silica. Mendeloff developed several different measures of employee exposure and attempted to explain observed variations in exposure using other information included in the OSHA data. His analysis was limited because, first, not all inspection results were included in the OSHA computer system. Second, the results of his analysis explain only between 5 and 25 percent of the variation in the dependent variables. Thus, the variables he was able to test do not capture all the factors that determine success in controlling hazards (301).

Mendeloff found that complaint and programed inspections were equally effective in discovering employer noncompliance with OSHA standards. Mendelhoff predicted that the presence of a union at an inspected establishment would contribute to lower exposures and fewer citations. However, this was not supported by the OSHA inspection data. He did find that, other things being equal, exposures tended to be higher at plants in nonmetropolitan (rural) areas compared with those in metropolitan areas. It might be speculated that workers in nonmetropolitan areas have fewer job choices and are thus more willing to tolerate higher exposure levels. Alternatively, it could be that information about hazards and controls reaches rural areas more slowly or is adopted more reluctantly there.

Size of establishment was also examined. The results indicate that both large and small establishments were less likely to have overexposures than medium-sized establishments, paralleling the situation with injuries in which medium-sized establishments appear to have higher rates. However, in many cases the differences between the various establishment sizes were not statistically significant. Moreover, interpretation of the observed differences was hampered by ambiguities in the definitions of the employee exposure variables.

Mendeloff also examined the possibility that employer efforts to control hazards depended on the cost of doing so. Using information from an OSHA report, he calculated the average costs per exposed worker of complying with OSHA's proposed lead standard. The industries with the higher average compliance costs (primary smelting, secondary smelting, battery manufacturing, brass, bronze, and copper foundries) tended to have higher employee exposures. The industries with lower average compliance costs (newspapers, commercial printing, can manufacturing, gray iron foundries), whose costs were one-tenth to one-twentieth those of the higher cost group, had a substantially lower proportion of overexposures. These results support the claim that employees tend to be protected from exposures when protection is cheap and overexposed when it is expensive.

Mendeloff reviewed the results of a number of recent inspections with OSHA inspectors. For firms in violation of OSHA standards, the compliance officers estimated the costs of reaching compliance. In some cases the compliance costs were modest, but for others, the costs were quite large. This group of cases may not be a representative sample, but for most of them, the costs of compliance would be substantially larger than both the average OSHA fine and the maximum OSHA penalty for serious violations ($1,000). Profit-maximizing businesses that take actions based on the "bottom line" will invest in health and safety only to the extent that such investments minimize their costs of doing business. If compliance costs are substantially higher than expected penalties, the profit-maximizing firm will not voluntarily udertake these health and safety investments.

Jones *(237)* examined *OSHA* inspection data for asbestos exposures from 1972 to 1979. She found that an increase in engineering control costs of $l00 per employee was associated with an increase in the average asbestos exposure level of 0.7 fibers per cubic centimeter, while an increase in OSHA penalties of $350 per citation was associated with a decrease in average exposure level of 1 fiber per cubic centimeter. Thus employers appear to be sensitive to costs: as the costs of control go up, employers decide not to implement controls (leading to higher worker exposure levels), while as the expected costs of OSHA penalties go up, compliance improves. However, increased penalties were also associated with employers more frequently deciding to contest the OSHA citations, again consistent with the theory that employer decisions are sensitive to costs. Jones found that an increase in the total penalties of $1,000 was associated with a 27 percent increase in the probability that the employer would contest the results of the inspection.

SUMMARY

OTA has identified a number of incentives or imperatives for the implementation of control technologies. These include: voluntary efforts by employers and voluntary associations, the availability of information, the desire to reduce insurance or workers' compensation losses, fear of tort liability actions, labor market pressures and collective bargaining agreements, and government regulations. One or all of these may influence employers to install and maintain appropriate controls. However, all have significant limitations.

Management commitment has been called the single most important ingredient in effective health and safety programs. After being informed of or discovering the existence of job hazards, some employers will take action to reduce those hazards, although the pressure of competition will substantially limit these voluntary employer activities. In addition, employers and their employees often participate in the development of voluntary standards, which are an important source of information in the health and safety field. But because they are voluntary, these standards will often have only a limited impact on worker health and safety.

Making information about occupational hazards and their control available is a necessary first step for many improvements in workplace health and safety. Providing information through research and dissemination- is an important governmental activity. The increased availability of information on workplace hazards may serve as an incentive for companies to introduce controls, but it is not sufficient by itself to guarantee improvements in worker health and safety.

Employers may take actions to improve job safety in order to reduce the costs of workers' compensation and property insurance. The costs of medical treatment and lost wages paid through the workers' compensation system provide a monetary incentive to reduce those injuries and illnesses. In addition, insurance companies and State agencies that sell workers' compensation insurance usually offer 'loss-control services" to improve health and safety conditions in their client companies. It is likely that workers' compensation is an incentive for prevention of occupational ***injuries,*** although data supporting this conclusion are limited. For occupational ***illnesses,*** the economic incentive provided by workers' compensation is reduced substantially because few **cases of** work-related illnesses enter the workers' compensation system. This appears to be true even for well-studied occupational diseases, such as those associated with asbestos and cotton dust.

By far the most common use of tort actions in occupational safety and health **are** suits against a third party—for example, against the manufacturer of products purchased by the employer for use in the workplace. These suits may **lead** to improvements in working conditions, but a number of factors limit their effectiveness. The first is that suit cannot usually be brought against employers because workers' compensation laws bar employees from suing their employers in cases involving work-related disease and injury. Other limitations involve recognizing and proving causation, and identifying the responsible manufacturers. It is not now clear how important tort liability will be as an incentive, although it has probably encouraged the development of substitutes for asbestos.

To some extent, employers maybe motivated to improve employee health and safety because of pressures from the labor market. However, a slack labor market, with relatively high unemployment, and other market imperfections limit this incentive.

Negotiation and collective bargaining can also bean incentive. Passage of the OSH Act in 1970 coincided with an increase in the number of contracts that included safety and health clauses, and the clauses became increasingly specific. But this is significantly limited because, first, only a small percentage of U.S. workers belong to labor unions. Second, not all unions have the kinds of expertise in industrial hygiene, injury prevention, or occupational medicine needed to negotiate and enforce agreements concerning health and safety. Third, by definition safety and health provisions must compete for attention and resources with other bargaining issues. Many workplaces have

joint labor-management health and safety committees, but the research assessing the effectiveness of committees in improving worker health and safety is limited.

The OSH Act itself created a number of opportunities for worker participation concerning occupational safety and health. For example, State and local "right-to-know" laws and the OSHA "hazard communication" standard will provide workers with more information about hazards. However, there is still controversy about the requirements of these regulations.

The final factor that influences employer decisions to control hazards is an imperative: the regulations and standards issued by government agencies, mainly OSHA. In addition, some of the regulatory actions of other Federal agencies may require employer actions that either directly or coincidentally improve worker health and safety.

16.
Economic Incentives, Reindustrialization, and Federal Assistance for Occupational Safety and Health

Contents

TABLE

16. Economic Incentives, Reindustrialization, and Federal Assistance for Occupational Safety and Health

Economic incentives, tax programs, and financial assistance have all been suggested for stimulating improvements in occupational safety and health, but have been little used in the United States. In addition, the process of industrial change can itself be harnessed as a mechanism for improving occupational safety and health. During a time of reindustrialization, it may be possible to integrate productivity-improving investments in plant and equipment with the installation of control technologies that safeguard worker health and well-being. Finally, the Federal Government could also establish new programs for financing research and training activities and for assisting small businesses.

ECONOMIC INCENTIVES AND FINANCIAL ASSISTANCE

The general notion behind economic incentives is to use the economic self-interests of individuals and firms to accomplish social goals. For occupational health and safety, the aim is to set incentives so that employers, while seeking to earn profits, will also prevent injuries and illnesses.

In theory the workers' compensation system provides an economic incentive for prevention, but in practice it is limited, especially for illnesses (see ch. 15). Another possible type of economic incentive would substitute an injury tax or an exposure tax for traditional regulatory standards. A third possibility involves the use of various governmental tax policies and financial assistance programs.

Injury/Exposure Taxes

The idea an "injury tax" is generally well-received among economists as a substitute for health and safety regulations (see, for example, ***330,425,445,446).*** Although the idea has been criticized as politically infeasible (37,300), it has officially surfaced at least twice—in a draft 1976 report of the Council of Economic Advisers and in **a 1977** memo to President Carter from his chief economic adviser, his budget director, and his domestic policy adviser. In both cases, union officials were outraged and the injury tax reference was either deleted or suggested as a supplement, not an alternative, that should be studied by an interdepartmental task force (300). The task force later rejected the injury tax approach (228).

As opposed to the regulatory system, which penalizes firms for violations of regulations, an injury tax system would levy direct financial penalties on firms for each injury. Firms would be free to choose the least costly methods of accident prevention. Under certain assumptions, this would be the most "cost effective" way to reduce the number of injuries. Moreover, an injury tax is appealing because it is directly related to safety outcomes. (Similarly, it has been suggested that effluent taxes or emission fees be used in the area of environmental protection. See, for example, 251.)

The advocates of injury taxes believe them to be better than regulatory standards, which are considered inflexible and unnecessarily uniform across firms and industries, not necessarily related to workplace or work-force characteristics that cause injuries, and not necessarily the least costly way to reduce injuries *(445,446)*. In addition, an injury tax, if set at an appropriate level, might provide employers with a stronger incentive to prevent injuries than the current Occupational Safety and Health Administration (OSHA) programs. It could also reward employers for efforts to go beyond current regulatory standards, as well as for conducting research on improved controls.

Smith *(445,446)* concluded that firms do respond to financial incentives and estimated the effect that various levels of injury tax would have on injury rates. To be effective, the taxes would have to be fairly large. Using 1970 data on injuries, Smith estimated that a tax of $500 per injury would lead to a 2.2 to 3.2 percent reduction in the disabling injury rate (injuries involving lost work time as defined by standard *Z-16* of the American National Standards Institute). A tax of $1,000 would reduce injuries 4.4 to 6.2 percent, while one of $2,000 would reduce injuries 8.8 to 12.5 percent (446).

Although Smith suggests moderate fines for each injury as a replacement for safety regulation, he does not extend that approach to health regulation. Because occupational diseases often manifest themselves only after a latent period, there would be considerable difficulty in determining which of several employers was responsible for the disease (446). Moreover, as discussed in chapters 2, 3, and 15, there are considerable difficulties in distinguishing job-related diseases from nonoccupational ones.

Taxing hazardous exposure levels rather than illnesses might be one possible way to affect job-related diseases. This could work like an effluent or emission tax, under which firms pay a fixed amount for each additional unit of pollution they add to the water or air. Nichols and Zeckhauser (330) have suggested such a tax on occupational noise exposure. But Smith points out that enforcing an exposure tax approach would require a "monumental inspection and monitoring program" *(446)*. The attending administrative costs would probably offset the advantages of such a system. (To a limited extent, provisions of the OSHA lead standard that require paying workers their usual wages if they must be removed from lead-contaminated work areas have some characteristics of an illness/exposure tax.)

An injury tax, even if limited to cases of acute trauma, would encounter serious difficulties. The first would be in setting an appropriate level for the injury tax. Smith (445) estimated in *1970* dollars that a tax of $1,000 per disabling injury would lead to a decline in injury rates of about 5 percent, while a $2,000 tax per injury would be associated with a 10 percent decline. Adjusting his estimates to account for inflation since 1970 yields injury taxes in the range of $2,500 to $5,000 (in 1983 dollars) per lost-workday injury to achieve a 5 to 10 percent injury rate decline.[1]

Furthermore, if a tax for deaths or permanent disabilities were set equal to the lost earnings of the killed or disabled worker, it would be extremely high-ranging from tens of thousands to hundreds of thousands of dollars. These values, large as they are, do not include the psychic costs, the pain and suffering associated with such injuries. To maximize the efficiency of the tax system it would be necessary to prohibit firms from insuring themselves against these large losses to ensure that firms would pay the full tax. But such large penalties would generate considerable political opposition *(64)*.

A second problem would be ensuring the accuracy of the injury records on which any tax would be based. With a direct financial penalty for each injury, employers have an incentive not only to prevent injuries but also to underreport them. (Ch. 2 and Working Paper #l discuss the controversy about the accuracy of current employer-maintained records.) Independent, firm-by-firm audits to guarantee the accuracy of these data would be quite expensive. Moreover, assessment of the results of an injury tax would be difficult because any declines in injury rates following implementation might represent decreased reporting, not increased prevention (64). In some cases there would also be problems in distinguish-

[1]This approximate adjustment for the effects of inflation is based on the two-and-a-half-fold increase in average hourly earnings from 1970 to 1983 and is consistent with the increases during that period in the most commonly used price indexes (the Consumer Price Index, Producer Price Index, and Implicit Price Deflator for the Gross National Product).

ing occupational (and taxable) injuries from non-occupational ones. These would include many sprains and strains, as well as many injuries to the back.

Third, an injury tax might increase the level of controversy in this field. Boden and Wegman (64) argue that it would be politically feasible only for the less severe injuries. Mendeloff *(300)* suggests that even a tax of ***$250*** per injury might be more expensive to firms than current OSHA safety standards. In theory, an injury tax should apply to all injuries. But in practice, there would be controversies concerning application of an injury tax in **cases** of claimed "employee misconduct. "

Fourth, the operation of such a system would be relatively invisible to workers. Employers would calculate the number of injuries and send the Government a check (64). If an injury tax system replaced existing standards, and suspended unannounced inspections and workers' rights to request "complaint inspections, " it would change dramatically the worker and governmental roles in solving health and safety problems.

Fifth, an injury tax might create an incentive for larger firms to subcontract dangerous jobs to smaller, less financially solvent firms that lack the resources to prevent injuries as well as to pay the injury tax. An injury tax might also lead to changes in employment policies, for example, in hiring and firing decisions. The effectiveness of these policies in reducing injuries has been questioned (64) (see **also** ch. 4), and such a response by employers may have other social and economic implications that would need to be considered.

Finally, injury taxes have been criticized on ethical grounds. It has been asserted that such a tax would be a "license to maim" or a "license to kill." By providing a system of "taxes" and "licenses, " society would seem to be saying that it is all right for a certain number of occupational deaths and injuries to occur. But if an injury tax reduced injuries while preserving other social values, it would probably be considered an advance because fewer workers were being harmed,

The operation of an injury tax would also lead to variations in the level of protection that depended on the costs of prevention. Workers in industries facing low prevention costs would have safer jobs than those in industries with high prevention costs. Job risks would thus ***remain*** unequally distributed. This, however, runs counter to **a** commitment to the goal of equal protection for all ***(277).***

Tax Programs and Financial Assistance

When the topic of economic incentives is raised, most employers think of changing the taxes they are most familiar with—the business income tax system. Congress could modify the structure of business taxes to encourage investment in health and safety control technologies or could assist businesses in financing such investments.

A congressional decision to modify the tax structure or provide financial assistance can be thought of as providing some level of "social funding" for investments in occupational safety and health. The general rationale for this is to reduce the costs of health and safety investments, thus encouraging firms to undertake them. Burstein (531) states that tax policy can be used to lower business taxes on certain kinds of investments, thereby increasing the returns to business "to reflect the external benefits provided by the activity." These external economic benefits, such as reductions in the cost of medical care due to improvements in employee health, are ones that individual firms would not ordinarily receive because companies do not shoulder all the costs of ill health. Some of those costs are borne by employees, by other insurance policyholders, and by the Government. Tax policy might be used to reward the individual firm for actions that reduce these "social costs, "

Many believe that society ought to assist businesses in meeting certain social goals, such as reducing pollution or improving worker health and safety. This is especially true when, for various reasons, society changes the goals by, for example, increasing the stringency of applicable regulations. Thus these tax and financial assistance programs lead to subsidies for businesses, but this may be appropriate to reach socially valued goals of environmental and worker protection.

Four kinds of programs are of interest: investment tax credits, accelerated depreciation, Government loan programs, and direct subsidies. All have **already** been used in the area of environmental protection and loan programs have been used, to a limited extent, for occupational safety and health.

An investment tax credit allows a business to apply a certain percentage of the purchase price of a capital good directly against the taxes owed by the firm, in addition to the normal depreciation of the investment over time. When firms have been allowed such credits, some of the investments may have included controls for workplace hazards or pollution. However, Federal tax policies have not created an investment tax credit especially for employee health and safety investments, although such credits have been proposed.

Accelerated depreciation or rapid amortization of investments is a second tax subsidy mechanism. This permits businesses to write off the costs of an investment more rapidly than the normal depreciation rules would allow. Federal tax law has allowed 5-year amortization of pollution control equipment (651). This accelerated depreciation for assets that will last longer than 5 years has been permitted only for investments that lead to pollution control without also creating "significant" changes in other aspects of the facility. It has not, however, been available for investments to protect worker health and safety (31).

A proposal to allow accelerated depreciation for OSHA-mandated investments moved through the legislative process to the conference committee stage in 1978. A compromise reached in conference was to request a Treasury Department feasibility study of such a change in the tax law (228). (The major conclusions of that study are discussed later in this section.)

A third kind of Government program is to provide financial assistance, either directly or indirectly. Financial assistance is defined here to mean programs that provide loans or other types of financing (such as bonds) to assist businesses in paying for health and safety investments. Businesses must repay the loans or bonds, but the cost of these obligations is often partially subsidized and they provide a source of capital for investments that may not return a profit to the firm. Private lenders are often reluctant to loan money for such "nonproductive" investments so, it is argued, the Government has a role in providing such financing.

Financial assistance can take a number of forms, including Government guarantees of private loans, Government interest subsidies for private loans, direct Government loans (often at reduced interest rates), and the use of tax-exempt financing by private firms. In loan guarantee programs, the Government promises to repay a private loan if the borrower defaults. This can be combined with interest subsidies, under which the Government pays a share of the interest costs. Under direct loan programs, the Government acts as if it were a bank and loans the money directly at market interest rates or at a lower, subsidized rate. Tax-exempt financing allows private business to take advantage of the lower interest rates on bonds issued by States and local governments.

When Congress passed the Occupational Safety and Health (OSH) Act in 1970 it concluded that the burdens of compliance would often disproportionately affect small businesses. Rather than exempt such firms from the requirements of the act, Congress chose to amend section 7(b) of the Small Business Act to allow the Small Business Administration (SBA) to make or guarantee loans for OSHA compliance expenditures. The requirements were, first, that the expenditures must be to comply with OSHA regulations and, second, that the small business was "likely to suffer substantial economic injury" without such assistance (OSH Act).

From September 1971 to August 1981, the SBA processed 261 OSHA-related loans for $72.8 million—about 26 loans per year, each averaging about $280,000. In fiscal year 1981, 9 loans were made for a total of $7.1 million.

These loans constituted a very small part of SBA loans. Although exact figures are not readily available, in recent years the agency has been making or guaranteeing between ***20,000*** and 30,000 loans annually for between $2.5 billion to $4 billion. It is possible that some firms have used regular SBA loans to finance OSHA compliance expenditures in addition to other investments, The dedicated OSHA loans, however, usually carried a lower interest rate than the regular loan program (233).

The OSHA loans program, as well as the SBA loans for pollution control, were eliminated by the Omnibus Budget Reconciliation Act of 1981 (Public Law 97-35, Section 1905). It is not clear how effective this loan program was in improving health and safety in the handful of firms that received loans. In ***1979,*** the General Accounting Office (GAO) criticized the program, in part because few loans had been made. In addition, **GAO** concluded, after an examination of SBA files concerning a sample of loans, that it was not clear that the loans had been granted only to businesses that needed the loans or that the use of the loans actually resulted in the elimination of workplace hazards ***(509).***

Tax-exempt bonds, issued by State or local governments to provide financing for private firms, are backed by the credit of the borrowing firm, the revenue from the project financed, or the value of the facility. Defaults are borne by those who hold the bonds, not the State or local government that issued them. Because the interest on such bonds is exempt from Federal income taxes, lenders are willing to accept lower interest rates. Thus, private firms that use these bonds are able to finance investments at interest rates lower than they would otherwise pay. In 1968, Congress limited the use of bonds that exceeded **a** certain size to those that finance pollution control and certain public facilities (such as airports, convention centers, parking garages, sports stadiums, etc.) ***(492).***

The Internal Revenue Service (IRS) has had difficulty in administering this provision of the tax code. More than 6 years passed before it published temporary regulations, and they encountered difficulties in ensuring that this financing is limited to pollution control and is not used by firms for "productive investments" ***(651).*** The IRS has tended to limit "pollution control" to certain "end-of-pipe" technologies that have no productive value, such as effluent water treatment. More fundamental process changes that also reduce the amount of pollution have generally not qualified for tax-exempt financing ***(538).*** The IRS has also disallowed tax-exempt financing for containment devices for nuclear power plants, as well as spending for the disposal of hazardous wastes, because these were considered to be normal expenses for plant operations, not extra costs due to pollution control requirements.

Despite these restrictions, it has been estimated that about 48 percent of all capital spending for pollution control has been financed with tax-exempt bonds ***(538).*** However, the IRS has not allowed tax-free financing for investments that protect employees from toxic substance exposure in addition to preventing environmental damage, apparently on the belief that the company would have invested in worker protection in any case as part of a prudent personnel policy (651). In the last few years, Congress has also enacted several restrictions on the amount of tax-free financing that can be issued by State and local governments to private businesses.

Finally, the Government could assist businesses by giving them direct subsidies or grants. Economists generally prefer direct subsidies to indirect tax subsidies or loan programs because they create fewer market distortions, are simpler for the IRS to administer, and can often be more cost effective. Direct grants do, however, enter directly into the appropriations process and thus may be ***more*** visible and hence more difficult to legislate. Moreover, a firm will probably incur **a** greater paperwork burden while applying for a direct grant than it would with an indirect tax subsidy.

As noted earlier, in the Revenue Act of 1978, Congress requested the Department of the Treasury to study the feasibility of tax incentives for occupational health and safety spending. The report, written by the Office of Tax Analysis of the Treasury Department and published in January 1981, was very critical of tax subsidies for OSHA and Mine Safety and Health Administration (MSHA) compliance. It noted that such a subsidy program would be difficult to administer, mostly because of problems in distinguishing health and safety expenditures from normal business costs. Second, the Treasury Department analysis expressed concern that subsidies for capital costs only would encourage firms to adopt unnecessarily capital-intensive compliance methods. Third, they criticized special investment tax credits, accelerated depreciation, and tax-exempt financing on several more technical grounds, including the differential treatment of assets with

different lifetimes, the differential advantage incurred by profitable (as opposed to unprofitable) firms and by capital-intensive (versus labor-intensive) companies, and the large benefit that tax-exempt financing gives to upper-income bondholders (651).

The Interagency Task Force had previously examined the issue of direct economic incentives. In contrast to the negative comments by the Treasury Department report, they recommended, if general economic conditions permitted, both the extension of the investment tax credit to noncapital expenditures for health and safety investments and the creation of a program of direct financial assistance. This should, they suggested, take the form of a direct subsidy rather than a tax credit. The subsidy would be limited to high-hazard firms within hazardous industries, and would only apply to the firm's health and safety spending that represented an increase over their spending in a baseline year. The program could be administered either through the Treasury Department or through the regulatory agencies (OSHA and MSHA) (228). To date, these recommendations concerning financial assistance have not been acted upon.

OTA concludes that the use of tax incentives and financial assistance programs might spur the implementation of controls, assist businesses in compliance, and possibly reduce the controversy of regulatory proceedings because of the availability of sources of finance. However, there are several disadvantages.

First, they would represent either a reduction in Federal tax revenues or an increase in budget outlays. Second, a tax incentive program would also tend to increase the complexity of the tax law, while a direct assistance program would require personnel and resources for program administration. Third, these programs will often provide financial benefits to firms that would have installed controls even in the absence of a subsidy program. Fourth, there would be difficulties in dividing the purchase price of equipment between features that are health and safety controls and those that are normally part of the equipment for purely productive reasons. Finally, each of these programs has its own limitations, and would have differing effects on other aspects of business investment behavior, as well as on the distribution of wealth, income, and the burden of income taxes. All of these would need to be considered before establishing any program.

REINDUSTRIALIZATION AND OCCUPATIONAL SAFETY AND HEALTH

Some recent discussions of the U.S. economy have included references to "reindustrialization" and "industrial policy. " Commentators have generally focused on the international competitiveness of certain U.S. industries—principally in manufacturing. Little of the discussion has been about occupational health and safety policy or even about regulation. But many proponents talk about using economic incentives—including tax law changes and Government financing—to implement the new policies. Moreover, some have suggested changes in health and safety regulations in order to facilitate business reinvestment and plant modernization.

OTA considers the reindustrialization debate to be relevant to this report for two reasons. First, reindustrialization policies might have either a beneficial or an adverse impact on worker health and safety. Second, if the Federal Government stimulates economic revitalization through tax, expenditure, or financing programs, it may be advantageous to incorporate health and safety considerations into those policies. OTA, in this assessment, is not advocating any form of industrial policy. Indeed, industrial policies and more general economic policies are areas beyond the scope of this report. But there do appear to be connections between these policies and possibilities for improving the implementation of control technologies.

Reindustrialization and Industrial Policy

The terms reindustrialization and industrial policy often have meaning only in the eye of the beholder. An enormous range of suggestions concerning U.S. economic productivity and international competitiveness have been made under these labels ***(528).*** Some think the problem is that the Government has interfered too much in the market through existing tax and regulatory policies. The solution they propose is to reduce the size of Government and limit its intervention to providing certain "public goods," such as national defense. Others think that economic revitalization can best be achieved by shifting Government policies. These commentators want policies that increase incentives to work and save and that reduce incentives to consume. Specifically, they have advocated across-the-board changes in business tax laws to encourage investment. Some of these suggestions were legislated in the Economic Recovery Tax Act of ***1981.***

Still another group wants to see explicit Federal policies that will encourage the growth of "sunrise" industries and that will ameliorate or prevent the decline of "sunset" industries. Critics of this position question whether the Government can correctly identify sunrise and sunset industries and some wonder if this is an appropriate role for Government at all. (See 493 and 528 for a discussion of these views.)

All three groups are attempting to create conditions that will lead to economic revitalization, but generally only the third group is advocating selective or targeted industrial policies. These analysts differ in their explanations of what has gone wrong and in their prescriptions for new policies and institutional arrangements. (Some of the leading advocates of industrial policies include Reich ***(383,384),*** Magaziner and Reich ***(283),*** Rohatyn ***(395),*** Bluestone and Harrison (62), and Etzioni ***(167).*** For contrasting views, see, for example, Economic Report of the President (169) and Schultze ***(426).)***

The Congressional Budget Office (CBO) has outlined three major strategies that have been proposed as alternative industrial policies. The first is to work with current policy instruments and rely on economic recovery and private-market adjustments to solve existing problems. A second strategy is to "modernize existing policies . . . that may now have become impediments to growth and efficiency, " including changes in antitrust and trade policy, as well as programs to assist dislocated workers, and changes in ***regulatory*** policy that would assist businesses in achieving economic growth (493).

A third strategy for industrial policy would involve the creation of new institutions, among which could be an information and / or consensus development agency, an executive branch coordinating agency, and a Government financial institution. An information / consensus agency could gather, synthesize, and disseminate information on American industry, including assessments of U.S. Government policies and of foreign activities. Several proposals would also include creation of a council, composed of representatives from business, labor, and Government, to develop a consensus on the goals of an industrial policy. An executive branch coordinating agency could attempt to coordinate the policies of the Federal Government toward a particular industry or group of industries, in order to encourage growth and competitiveness. The proposed Government financial institution would be a national industrial development bank or several regional development banks, often modeled after the Depression-era Reconstruction Finance Corporation ***(493,527).***

As noted, environmental regulation and workplace health and safety regulation have received little attention in this debate. Magaziner and Reich (283), for **example, devote only one paragraph to the issue.** In it they call for regulations that apply to "emerging" industries that are "harmonized as far as possible with the needs and requirements of other nations. " "Declining" industries, on the other hand, "should only be required to meet standards that are appropriate to the remaining useful life of the industry. " Bluestone and Harrison (62) note that reindustrialization should be directed toward several goals, including the creation of safer work environments, but they do not elaborate on this point.

Some discussions of industrial policy have, however, advocated the relaxation of environmental and occupational safety and health regulations as part of a plan for industrial modernization. For example, Etzioni (166) has suggested that the United States must choose whether reindustrialization or improvements in the "quality of life" will be made the Nation's "top priority." These discussions assume that Federal regulations have seriously hampered the growth of the U.S. economy and improvements in productivity and international competitiveness. However, as discussed later in this chapter, the adverse impact on productivity of ***occupational*** health and safety regulation is actually fairly small. Moreover, in some cases OSHA regulation has played a role in inducing or facilitating several industrial innovations that improved both health and safety, as well as productivity.

OTA analyzed the role of technology in international competitiveness in a 1980 assessment on technology and the steel industry and in a 1981 report comparing the competitiveness of three industries—steel, electronics, and automobiles. These reports examined the general issues of technology and productivity in these industries, including the effects of regulatory policies. In the case of steel, OTA found that several major new steelmaking processes are not only more efficient, but also create less pollution. Moreover, modest technological improvements have resulted from the "push" provided by health and safety, and by environmental regulations, including improved emissions controls and better door **seals** for coke ovens ***(538).*** More generally, the ***1980*** report outlined a number of policy options.

> The most critical policy option may be that of a governmental steel industry sector policy, that is, for a coherent set of specific policies designed to achieve prescribed goals. , . . The lack of a sector policy and the designation of a lead agency to implement such a policy has led to policies that often conflict with one another, create an adversarial relationship between Government and industry, and fail to address critical issues.

In its comparison of the competitiveness of steel, electronics, and automobiles, OTA outlined two prerequisites for industrial policy (543):

- mechanisms for reaching agreement on ***objectives*** that are acceptable to Government and various interest groups; and
- improved ***analytical capability*** on the part of Government agencies concerned with economic efficiency and competitiveness.

In addition to taxation and spending policies, Congress and the executive branch have already created programs that might be considered forms of industrial policy and **have** considered others. For example, there are already a large number of Federal programs that provide grants, loans, loan guarantees, and economic assistance for various purposes (512,529).

The Steel Tripartite Advisory Committee, appointed by President Carter, consisted of representatives from Government, labor, and business who discussed issues concerning modernization of the U.S. steel industry. Among other recommendations, they suggested delays in several environmental protection requirements in order to facilitate plant modernization (458). In 1981, Congress enacted the Steel Compliance Act, which postponed certain deadlines of the Clean Air Act for the steel industry.

Finally, a number of bills have been introduced in recent sessions of Congress concerning industrial policy (see 534). Hearings have been held on some of the topics addressed by these bills (513, 515,525,534,549).

Reindustrialization and Occupational Health and Safety

The continuous process of industrial change (including the replacement of plant and equipment) can lead to safer and more healthful workplaces. In fact, a large portion of the improvements in worker **health and safety during this century may not have been the result of conscious decisions to add controls to existing processes, but may have occurred coincidentally as new technologies, new processes, and new industries were introduced. Unfortunately, it is extremely difficult to gather definitive data on this question.**

Industrial and other policies that facilitate the process of industrial change might simultaneously improve occupational safety and health. Moreover, regulations can have a favorable impact on the productive efficiency of an industry either because they directly spur innovations and changes or because they provide an opportunity to change productive aspects of plant operations. But there is some danger that combining policies that are

designed to improve productivity with those that address employee health and safety will lead to an emphasis on the former at the expense of the latter.

Industrial change does not automatically improve worker health and safety, nor are new plants necessarily safer than old ones. What is true is that it is generally cheaper and more effective to control any given health and safety hazard when constructing new plant and equipment than it is to retrofit existing plant and equipment (see box U).

By stimulating changes in plant and equipment for productivity reasons, new industrial policies may also present an opportunity to improve worker health and safety. The various tax incentives, loan guarantees, and other subsidies that have been suggested to improve industrial competitiveness might also be used as incentives for health and safety improvements. Such policies can thus make compliance with health and safety regulations easier. In addition, if desired, the opportunity presented by reindustrialization could be used to achieve greater levels of protection.

It has been argued that health and safety regulation has hampered economic productivity by requiring expenditures for control technologies that are "nonproductive. " Money spent for controls could have been invested in improving plant pro-

Box U.—The Costs of Add-On and New Process Controls

It is widely believed, indeed it is pretty much common sense, that controls are cheaper and more effective when designed into new plants than when added or retrofitted. Nearly every control that could be included as a retrofit could also be included in the design stage. There is no reason to believe that it would cost more to purchase a control for a new plant of the same size with the same hazard than it would be to buy the control for an older plant,

Second, in designing the new plant, the architects, designers, and engineers have a greater opportunity to make sure that everything "fits together." For example, ventilation systems can be designed efficiently rather than having to wind their way around existing equipment, building structures, or other duct work. Work stations and tasks can be designed with ergonomics in mind (see ch. 7) **to enhance worker productivity and to be less stressful. Thus the design can improve a number of different features, including employee health and safety.**

Third, installing retrofit controls always involves **disruptions-cutting through existing equipment, temporarily closing down portions of the plant (or paying overtime rates to have the work done on weekends or at night), or taking machinery apart-that can be very costly. Fourth, retrofit controls can easily outlive the rest of the plant and equipment, especially in older facilities. Thus the plant's life may end before the firm has reaped the full life of the control devices. For some devices there will be a salvage market, but for many there will not.**

OTA has found several examples to support this reasoning. Rollover protection for mining vehicles is more expensive when retrofitted than when purchased on new equipment (248). In the OSHA vinyl chloride rulemaking hearings, the Firestone Plastics Co. estimated that reaching a 100 parts per million standard would cost 34 percent more in a 25-year-old plant than in an 8-year-old one; meeting a 10 parts per million standard would cost twice as much in the older plant (38). Swedish research in the 1960s led to "designed-in" noise control for one company that cost only a fraction of what retrofit controls would have cost (228).

Direct **comparisons of the costs of control in new plants versus retrofitting old plants are often difficult, however, because other relevant variables change. For example, the new plant may be larger or have a different production process. A comparison of the experience of two plants in controlling radia-**tion exposures illustrates this. Retrofitting an old uranium processing plant to meet new, more stringent radiation exposure standards cost approximately 30 percent as much as **the original total cost of the plant. Later a new plant was built to meet the same radiation standards. The control costs for this plant amounted to only** 8 percent of the new construction costs. But there were confounding variables: the new plant was larger and had at least one significantly different type of process equipment (97).

ductivity. In the aggregate, however, this diversion is relatively small. Employee health and safety regulations have been estimated as having led to a 0.4 percent decline in traditional measures of productivity (137). Of course, these measurements do not capture any of the health and safety benefits of regulation (see additional discussion in ch. 13).

But compliance with regulations can also provide an opportunity to make changes that improve plant productivity. As one group of analysts has noted, "[b]ecause it is less expensive and disruptive to make multiple changes simultaneously, rather than individually, businessmen naturally **take the opportunity of regulation to introduce other improvements" (31). (See 228 for several examples for which productivity improvements occurred at the same time as health and safety improvements.)**

According to several studies, regulation can stimulate new research or, more likely, speed up the tempo of existing research. One group of researchers reports that 33 percent of their study's respondents indicated process improvements spurred by regulatory changes (231), while two other studies reported similar conclusions **(70,101).** In a five-country comparison of Government activities that affected innovation, the researchers concluded that regulatory requirements concerning environmental protection "may be more important" for inducing innovation than other programs that were designed explicitly to influence the innovation process ***(29).***

Ruttenberg (412) has pointed out a number of instances in which regulation has been a stimulus for new markets, new jobs, and basic product and process innovation. "To a surprising degree, regulation is the mother of invention, " she noted. This occurs because in redesigning products and processes to comply with health, safety, and environmental regulations, companies often fundamentally redesign the product or process through the use of new technology. Second, the existence of Government standards creates "assured markets" for the results of the research efforts.

In the OSHA arena, the stimulus of the vinyl chloride regulation accelerated a then-developing improvement in polymerization technology. Some of the controls that were applied to reduce vinyl chloride exposures also increased production efficiency. (See box N in ch. 12.)

Ruttenberg's case study of the OSHA cotton dust standard, commissioned for this assessment, reveals a similar phenomenon. Although a direct cause-and-effect relationship is difficult to prove, it seems clear that the recent modernization of the American textile industry was at least accelerated by the OSHA cotton dust standard. Compliance with the standard involved, in large part, the installation of new and more productive capital equipment. Some "nonproductive" investments (such as for additional ventilation) have been required, but process and equipment changes included in new designs have substantially lowered cotton dust levels. This new equipment is also more productive because it consolidates several previously separate processes, reduces energy consumption, operates faster, and produces cloth of improved quality. Although the new technology has some limitations, the textile industry has been able to raise productivity and improve worker health and safety at the same time (413).

A recent report to OSHA concerning the costs of complying with the lead standard discusses the potential for new technology simultaneously reducing worker exposures, reducing the costs of controlling exposures, and improving productivity in a primary lead smelter (see box V). It must be noted that this technology has not yet been implemented on a large scale and there are uncertainties about its adoption. But what is not seriously questioned is that process redesign is the most effective way of achieving both productivity and employee health and safety goals.

As previously noted, industrial policies would require not only agreement among the affected parties, but also analytical capability. The National Institute for Occupational Safety and Health (NIOSH) and the Environmental Protection Agency have developed a methodology for industry-specific research planning (220). The general objectives of this work were to improve the coordination of environmental and occupational regulations and to identify health and environmental problems and solutions at an early stage. Although the focus of this project was research

Box V.—Reducing Lead Exposures: Add-on Controls v. New Processes

The OSHA lead standard sets a limit for occupational lead exposures at 50 micrograms of lead per cubic meter of air (50 micrograms/m^3). In a study done for OSHA, Charles River Associates (103) (discussed by Gobel, Hattis, et al. (184)) examined work exposures and *controls in* a primary lead smelter with an annual capacity of 225,000 tons. The highest exposures, considering both the number of workers exposed and the exposure levels, occurred in two departments-the sinter plant and the blast furnace area. The Charles River Associates report compared the costs and emission reductions expected from using each of two methods of moving toward compliance with the lead standard.

The first method considered was conventional “add-on” or “end-of-pipe” control technology. None of the manufacturing process would be changed, and no new production equipment would be installed. Instead, enclosure and ventilation systems would be added to separate workers from airborne lead or to dilute it to acceptable levels. The second method considered a number of new technologies, which involved new production machinery, to smelt lead. Installing new production machinery would reduce worker exposures more than add-on controls would, and the new machinery also achieves some savings in labor and materials costs and an increase in income from the sale of sulfuric acid (a byproduct of lead smelting). But at the same time, the capital costs of new production machinery are higher (table 16-1).

The difference in costs might be reduced by current tax preferences for investments. Investment tax credits and rules concerning depreciation for capital investments might offset mom of the costs of new machinery than of add-on *con*trols, but the quantitative impact of those preferences was not calculated. Moreover, changes in the tax laws to encourage health and safety investments might have an additional effect.

If a new smelter is to be constructed, both health and economic considerations would favor the new Machinery. Its construction cost and the cost of a conventional smelter would be similar, and its reduced emissions and reduced operating costs would sway the decision. But installing the new process in an existing smelter, given the economic factors, would require a card weighing of tax advantages and the other capital and operating costs.

Table 16-1.—Summary of Costs for a Smelter Equipped with Add-on Controls and a Smelter with Process Changes

	Annual costs in thousands of dollars	
	Smelter equipped with add-on controls	Smelter with process changes
Capital and operating costs associated with control devices:		
Control system, capital cost, assuming 12%/yr	2,439	1,348
Control system, operation and maintenance	1,734	1,017
Materials (savings)	—	(4,671)
Labor (savings)	—	(3,420)
Acid byproduct (increased income)	—	(2,476)
Total	4,173	(8,202)
Annualized capital cost of process change:		
With interest at 12%/yr	—	16,735
Total annual costs	4,173	8,533

SOURCE: (184).

planning for two agencies, the general idea could be extended to other Federal financial and regulatory policies. In particular, the methodology follows the industry breakdown used in the Commerce Department's annual report, *U.S. Industrial Outlook*, and develops a series of indicators that could be used to coordinate Federal policies.

A Federal Interagency Task Force on Workplace Safety and Health recommended in 1978 that OSHA take steps to identify hazards for which engineering controls could be installed along with the normal replacement of plant and equipment (228). Both types of analytical work might be usefully considered in developing industrial policies.

OSHA regulations can also be designed to consider the capital and investment cycles of plants and firms. To some extent, the use of delayed implementation schedules takes these concerns into **account.** Industries then have some flexibility concerning the timing of engineering controls. Feasibility is an important consideration in such cases: something that may not be feasible in ***6*** months **may be** feasible ins **years. One** suggestion, made in the OSHA proceeding concerning noise exposure rulemaking, is the possibility of different permissible exposure limits for new and old plants. Such "grandfathering" may ease the compliance burden in old plants but needs to be done cautiously lest it create an unwanted incentive for continuing the operation of inefficient, older plants. In addition, it tends to create two classes of protection, with workers in new plants being protected more than workers in older facilities.

As described in chapter 1, this assessment suggests several options related to occupational health and safety, industrial policies, and reindustrialization. First, if funds or tax incentives are created for the building or rebuilding of industry, applications for those benefits might be required to include a discussion of methods to be used to control expected health and safety hazards. These funds could be extended to expenditures for control technologies to reduce those hazards. Second, companies receiving reindustrialization assistance might be required to design health and safety into their new plant and equipment, either to meet existing health and safety standards, or to achieve lower exposure levels or safer processes.

Two other options consider the relationship between OSHA regulatory actions and reindustrialization. Because of the potential for improving health and safety, as well as productivity, during the process of modernization, OSHA regulatory actions could consider explicitly the capital and investment cycles of plants, firms, and industries. Information could be developed concerning the health, safety, investment, and productivity needs of various industries. In particular, if studies show that an industry is going to make major changes to improve productivity, OSHA might consider delaying the required attainment of a standard through engineering means until the modernization is undertaken. Alternatively, OSHA regulations might be used to spur the development of new technologies and accelerate the process of industrial change. The history of OSHA's vinyl chloride and cotton dust regulations shows that, at least in some cases, employer efforts to comply with health and safety standards can also be associated with productivity improvements.

FEDERAL AID FOR RESEARCH AND INFORMATION DISSEMINATION

Creation of an Occupational Safety and Health Fund

The advisory panel to this assessment expressed concern about the large swings in occupational safety and health policy that have occurred recently. Funding has been reduced for two areas in particular—education and training programs, and research on workplace illnesses and injuries. One way to provide for more stable and enhanced funding would be to establish an Occupational Safety and Health Fund. This fund might also provide a focus for the enhanced efforts in control technology research, education and training, and information dissemination.

The Work Environment Fund of Sweden offers a possible model for a U.S. fund ***(468).*** Sweden, partly because of its commitment to providing extensive education and training, as well as funding for research on hazards and controls, is viewed by many as an international leader in occupational safety and health. Two organizations are particularly responsible for these activities. The first is the Work Environment Fund itself, established in 1972, which is funded by a payroll tax on employers of 0.155 percent. The fund is administered, in typically Swedish fashion, by a tripartite board composed of representatives of management, labor, and Government.

In its first 10 years, over 1,800 research and development projects and about 1,500 for training and information were funded. The research and development grants have included funding of epidemiological **and toxicological studies, measurement techniques, and development of control techniques for a** variety of **hazards.** In recent years, these have focused on the hazards of working with various chemicals, including solvents, metals, minerals, welding and cutting products, **and rubber and plastics. The fund has also sponsored work on physical agents, including** noise, vibration, radiation, and in issues concerning ergonomic design related to working postures and lifting requirements ***(468).***

The training and information projects have included the development of course materials for the introductory and advanced training of worker safety stewards and supervisors. From 1972 to 1981, nearly 400,000 individuals received some form of training. The Joint Industrial Council, which was created by an agreement of Swedish employers and unions in the **1940s,** has produced most of the educational materials concerning workplace health and safety used for this training ***(468).***

There are only a few U.S. examples of cooperative labor-management-Government research and training activities related to health and safety. One example is a set of experiments concerning the use of "washed cotton" to control the hazards of cotton dust. This project is funded by both Government and industry, with oversight and direction provided by a group of labor, management, and Government officials. There have also been jointly administered research efforts and training programs that have resulted from collective bargaining.

Congress could consider several possible administrative arrangements if it created a fund. It could follow the Swedish model by creating a tripartite board to administer this fund, or it could delegate administrative responsibilities to NIOSH or OSHA. It could create this fund and its research and training projects to exist alongside the existing projects and arrangements at OSHA and NIOSH, or it could consolidate with this fund all existing research and training, including NIOSH extramural research grants, NIOSH training grants, OSHA New Directions grants, and OSHA-funded consultation.

Financing could be through a payroll tax on employers or through a tax or surcharge based on the level of workers' compensation premiums paid by employers (with some adjustments for the presence of health hazards in various industries). For example a 0.1 percent employer tax on the total U.S. payroll of $1.6 trillion (in 1982) would result in annual revenues of about $1.6 billion. A payroll tax of 0.01 percent would raise $160 million. A 1.0 percent surcharge on workers' compensation premiums (about $25 billion in **1980)** would produce annual revenues of ***$250*** million.

Assessments for health, safety, and environmental activities have been used in the United States in at least two cases. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 created a "superfund" to pay for activities related to releases of hazardous wastes. Most of the funding for this is from taxes on oil and chemicals ***(546).*** The recently enacted right-to-know law in the State of Washington includes an assessment of 75 cents for each employee in the State, to be paid by employers (351). One bill concerning asbestos compensation, now under congressional consideration, proposes establishing an assessment to be used for research (517).

Although creation of an Occupational Safety and Health Fund would enhance the commitment to **research and training** in this area, there are disadvantages to consider. The relationship between this fund and the existing agencies (OSHA and NIOSH) would need to be determined. Moreover, **a new tax or** surcharge, even though one of modest size, runs against recent reductions in business taxes.

Federal Assistance to Small Businesses

Improvements in employee health and safety can be difficult for smaller businesses, which often lack technical expertise in industrial hygiene, safety engineering, and occupational medicine. Smaller businesses commonly face financial difficulties as well.

As discussed above, from 1971 to 1981, the Small Business Administration issued a limited number of loans to assist small businesses in complying with **OSHA** standards. In 1981 Congress eliminated authorization for this program. One option would be to study the results of this loan program, especially to learn why it was used so infrequently. After such a study, Congress could consider reauthorizing the loan program and providing an adequate level of funding.

Other kinds of Federal assistance for small business could include providing technical assistance and facilitating the creation of programs to provide technical assistance. Chapter 12 discusses OSHA consultation, which is the major OSHA activity for providing assistance to small businesses.

NIOSH and OSHA could also encourage the development of programs to provide industrial hygiene, safety engineering, medical surveillance, and worker health and safety training. These could be established to service industries, regions, and employers who do not offer such services. Especially helpful would be programs for servicing small businesses in particular areas.

Because it is inefficient and impractical to require each small business to provide a full range of safety and health services, programs to provide shared resources might be cost effective. Federal funding could be used to start such programs. However, there may be difficulties in sustaining these programs after the startup period. Even though the price of shared programs should be less than if a company were to purchase the services entirely on its own, some small businesses might find it beyond their means. The steps that are needed to aid those companies are not addressed by providing shared resources.

As discussed in chapter 15, the regulation of the products purchased by small businesses may also be a way of improving, to some extent, the health and safety of their work forces. This approach could also be applied to nonregulatory testing programs. For example, NIOSH could conduct occupational safety and health performance tests of products used by small businesses and publish the results in a fashion easily accessible to small businesses, which could then use the results of these tests in purchasing decisions.

SUMMARY

Several approaches to improving occupational safety and health have not been extensively used in the United States. These include the use of economic incentives, tax incentives, and financial assistance. Although in theory the workers' compensation system provides an economic incentive to prevent worker injuries and illnesses, in practice it provides only a limited economic incentive for prevention, especially for occupational illnesses.

Another possible type of economic incentive involves injury or exposure taxes. As a substitute for the regulatory system, which penalizes firms for violations of regulations, an injury tax system would levy a direct financial penalty on the firm for each injury. Such an approach appeals to many economists, but it presents a number of difficulties.

Congress could also modify the structure of business taxes to encourage investment in health and safety control technologies, or it could provide direct assistance to businesses in financing health and safety investments. Either decision would provide some level of "social funding" for investments in occupational safety and health, thus reducing their costs and encouraging firms to undertake them. Four kinds of tax and assistance programs could be considered: investment tax credits, accelerated depreciation, Government loan programs, and direct subsidies. All have been used to stimulate adoption of pollution controls, and loan programs have been used, to a limited extent, for occupational safety and health.

Tax incentives and financial assistance programs might spur the implementation of controls, assist businesses in compliance, and possibly reduce the controversy of regulatory proceedings because of the availability of sources of finance. However, they would cause either a reduction in Federal tax revenues or an increase in budget outlays and could increase the complexity of U.S. tax law or increase administrative burdens. Moreover, these programs can be inefficient, and would affect other aspects of business investment behavior, as well as the distribution of wealth, income, and the burden of income taxes.

Federal policies concerning reindustrialization might have either a beneficial or an adverse impact on workplace health and safety. It is possible that many of the improvements in worker health and safety during this century occurred coincidentally with the introduction of new technologies, new processes, and new industries and not as the result of conscious decisions to add controls to existing processes. A time of reindustrialization offers opportunities to integrate productivity-improving investments in plant and equipment with the installation of control technologies, as well as to exploit the fact that it is cheaper and more effective to control a hazard when designing new plant and equipment than it is to retrofit existing operations. Reindustrialization also affords an occasion to achieve greater levels of protection. However, there is also the danger that combining policies that are designed to improve productivity with those that address employee health and safety will lead to an emphasis on productivity at the expense of health and safety.

Health and safety regulation may have negative effects on productivity, by requiring spending for controls that are "nonproductive," compared with traditional measures of productivity. But in the aggregate, this diversion is relatively small, and may, in many cases, be offset by regulation-induced changes that improve plant productivity as well as employee health and safety protection. Facing the need to redesign products and process to comply with health, safety, and environmental regulations, companies may fundamentally redesign product ***or process*** through the use of new technology. For both the OSHA vinyl chloride and cotton dust standards, employer compliance was associated with improvements in productivity. For the lead industry, it is possible that new technology could be introduced that would simultaneously reduce worker exposures, reduce the costs of controlling exposures, and improve productivity.

Financing for research and training activities and for assisting small businesses could be provided by an Occupational Safety and Health Fund. The Work Environment Fund of Sweden offers a possible model for a U.S. fund that could provide a new focus for enhanced efforts in control technology research, education and training, and information dissemination.

Small businesses face special problems in making improvements for employee health and safety. They often lack technical expertise in industrial hygiene, safety engineering, and occupational medicine, and they face financial difficulties as well. Assistance to such firms could include Government loan programs, consultation, and Government testing and regulations of products purchased by small businesses. In addition, OSHA and NIOSH could encourage the development of programs to provide industrial hygiene, safety engineering, medical surveillance, and worker health and safety training to small businesses, especially in regions currently lacking such services.

17.

Preventing Work-Related Injury and Illness in the Future

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17. Preventing Work-Related Injury and Illness in the Future

Looking ahead in occupational safety and health, except in the most general way, is as difficult and open to error as predicting the future in any field. In general, changes in plant and manufacturing techniques, shifts in types of jobs, and attention to controlling hazards are expected to reduce work-related injury and illness. Some new and exotic hazards are certain to accompany new processes, but what has been learned from controlling or failing to control current workplace hazards can be applied to recognizing and controlling the new ones.

To some extent, the workplace of tomorrow will be the workplace of today. Some worksites and industries will change little, and even in those that change, seemingly mundane factors will continue to contribute to workplace injury and illness. Inadequate guarding of machinery, poorly designed hand and power tools, and inappropriate walking and working surfaces will not go away without attention to injury prevention. Some long-known health hazards remain problems. For instance, silica dust in plants, mines, and foundries continues to cause ill health. The absence of controls in such situations underlines the importance for policymakers to understand how incentives for adopting controls work and do not work.

The look at the future in this chapter is very much constrained by knowledge of the present. The changes that are described are evolutionary, not revolutionary. That is not intended to imply that revolutionary changes will not take place, but it acknowledges that revolutionary changes are far harder to predict. For example, the drafters of the National Cancer Plan in 1970 failed to mention one of the most important biological advances, recombinant DNA (544), for the simple reason that it had yet to be “invented. ”

The future will present a mix of the problems of today and tomorrow. The mix, it can be said with some confidence, is bound to change, and certain new, just emerging problems, are expected to capture the attention and efforts of safety and health professionals in the years ahead. This expectation is in keeping with the observation made earlier in this report that concern about the new sometimes seizes the imagination and attention of expert and lay person alike. This is particularity likely to happen when the old problems are concentrated in industries or trades that are seen to be on the way out and there is little incentive to invest in them. It is a sure bet, however, that old problems in old industries will not take care of themselves if attention is diverted from them.

FUTURE TRENDS

There are a few sources of information about expected trends in employment and other sources for predicting where new technologies are likely to be used; careful consideration of trends by leaders in health and safety could lead to the development of controls to accompany the new technologies.

The 1984 edition of ***U.S. Industrial Outlook: Prospects For Over 300 Industries (554),*** prepared by the Bureau of Industrial Economics, Department of Commerce, estimates that the U.S. population will grow throughout the 1980s at a rate similar to that of the 1970s-0.9 percent per year. The rate remains the same because the effects of changes in fertility, immigration, the age of the population, and mortality roughly cancel out. The predictions for increases in fertility rates and legal and illegal immigration and decreases in mortality would, by themselves, lead to an expected increase in the population growth rate. Balancing those is the fact that women born during the baby

boom of the 1940s and 50s are passing out of their most fertile years, reducing the number of women having children. Reduced mortality and aging of the baby boomers will produce an increase in the average age of the population.

The labor force increased by 23 million (26 percent) between 1972 and 1982. Part of the growth resulted from the unprecedented increase in the number of women entering the work force, the remainder from the entry of young men. This spectacular rate of growth will not continue during the next decade, when 17 million people (a ***16*** percent increase) are expected to enter the work force. These projections indicate that prevention of injury and illness in the next 5 years will be affected by an aging work force including an increasing number of women.

Even this very general information can be of value to health and safety professionals as they look ahead to the next decade. For instance, older workers may respond differently to prevention training than younger workers. Women will require different considerations in the ergonomic design of jobs and personal protection equipment.

Information about which industries are likely to **grow and which are likely to decline is useful for directing research in control technology and for encouraging companies to consider injury and illness prevention before a new plant is built and new technologies installed. Anticipation of prob**lems in the planning stages can help prevent serious problems later on. Gaining industries cited in the 1984 report include the motor vehicle and electronic-product-related groups. However, the most rapid growth was expected in the service industries. The injury rate in those industries—computer, banking, legal, and medical services and related activities—is lower than the all-industry average. Nevertheless, the number of people employed in them means that attention to safety and health in those industries will be increasingly important in the future.

The Environmental Protection Agency (EPA), in cooperation with the National Institute for Occupational Safety and Health (NIOSH), has considered the production of a document that would concentrate on environment and occupational health and safety. As planned, the outlook would have two parts. In the first, data available from Federal sources about current and expected employment levels, injury and illness rates, compliance with Occupational Safety and Health Administration (OSHA) regulations and EPA air and water quality regulations, solid waste disposal, and energy and water use would be presented for each four-digit Standard Industrial Classification code. Insofar as possible, information about occupational and environmental measures would be presented for each industry covered in the Department of Commerce Industrial Outlook. A very useful feature of the EPA/NIOSH document is that all the data are entered in a computer network so that users with personal computers can carry out their own analyses. The second part of the document is a narrative, profiling each of the industry groups in terms of environmental safety and health, highlighting trends in the work force, the use of new technology, the handling of hazardous substances, and other related matters (220).

OPPORTUNITIES FOR PREVENTION

Many new technologies should be inherently safer for workers than those of the past, but new processes will require modification of old or fabrication of new controls. Eight kinds of workplaces are discussed here as examples of changes that are expected:

- Energy-related industries:
  - Synthetic fuel production
  - Coal mining
  - Off-shore oil drilling
- Modernizing old industries
  - Steelmaking
  - Automobile manufacturing
- New industries
  - Semiconductor manufacturing
  - Biotechnology industries
- Rapidly growing occupations
  - Office work

In terms of expected numbers of workers, the industries vary. Synthetic fuels may or may not become important in the future and even if they do, large-scale production will take time to achieve. Should that happen, a new work force will have to be trained, and employment in the industry could take off. Coal mining and offshore oil drilling are employing more workers now. With the introduction of larger, more efficient machinery in mining, the number of miners is expected to plateau and then decline. Oil drilling employment will increase or at least remain constant so long as the search for oil fields is profitable. Steel and auto manufacture, despite some recent resurgence, are not expected to employ as many as they did in the **1970s.**

Jobs in the semiconductor-related technologies are expected to increase. Biotechnology is, perhaps, at a point in its development analogous to that of the semiconductor business a decade or two ago. If some of the newly created biotechnology firms are successful, there should be more jobs in this field, but the maximum number of workers is likely to be small and they will be highly trained.

Technologies affecting office work crosscut all sectors, both public and private, and are rapidly growing as the U.S. economy becomes increasingly information-oriented. It is expected that the number of workers in offices or at least doing work that is now associated with offices will increase over the next few decades.

Consideration of future employment opportunities is directly related to health and safety. Not only do different jobs carry different risks, but more important, work is essential to good health. A number of studies have shown that medical services are more heavily used during periods of unemployment, that mental health problems increase in number and severity, and that suicides increase. Working is good for health, and proper attention to identifying and controlling hazards in the workplace can prevent injuries and illnesses.

Energy-Related Technologies

The fuel crises of 1973 and 1978 led to dramatic changes in the production and use of energy in the United States. The Department of Energy was formed, and resources were marshaled for the Nation to become energy independent through finding new energy sources and new technologies for conserving energy. Production of liquid fuels from coal, oil shale, and tar sands will involve new technologies and new hazards, and new controls will be needed. Increased coal use will stimulate the purchase and use of new mining machinery that will require appropriate controls.

Synfuel Production

Synthetic fuel (synfuel) production methods break down complex molecules of relatively **abun**dant and naturally occurring carbonaceous material such as coal or oil shale to produce simpler, cleaner, more efficient fuel. Although these technologies have been used before on a small scale, they have never been economically competitive with fuel production from crude oil and have remained commercially undeveloped. These technologies, though, could eventually be adopted by the United States to achieve energy independence.

Congress established the U.S. Synthetic Fuels Corporation (SFC) to fund projects that would lead to production of clean and safe energy. The SFC has proposed guidelines to monitor emissions in the workplace and to the surrounding environment (653):

> Any contract for financial assistance shall require the development of a plan, acceptable to the Board of Directors, for the monitoring of environmental and health-related emissions from the construction and operation of the synthetic fuel project **(486).**

Plans requesting financial assistance are to include details of a monitoring system, listing substances to be monitored; the frequency, location, methods, and durations of monitoring; and worker exposure and health surveillance programs. A worker registry is required to integrate worker exposure data, medical records, demographic information, and job classification codes so that any trends in work-related injury and illness can be identified.

Production of liquid fuel from shale oil involves liberation of some chemicals that are carcinogenic, and studies of pilot plant workers in this country report dermatitis, eye irritation, and thermal burns from job exposures. Fire and explosion are hazards because of the operating temperatures and pressures necessary for synfuel production.

Table 17-1 lists the potential hazards that could be expected in a coal liquefaction plant. Problems are encountered during coal handling and preparation, during the process itself, and during waste treatment. Estimates have been made of the chemical products and byproducts that might be found at each point in the process so that worker protection can be considered during design (575).

Concern about these hazards has contributed to systematic analysis of plans of future synfuel plants in an effort to anticipate causes of injury or illness. For instance, NIOSH reports one example of the success of this approach. High pressure vessels for coal liquefaction operate at extremely high pressures and temperatures and contain flammable material. Engineers, recognizing the potential hazard from a high-pressure vessel used in a bench-scale (laboratory-sized) coal liquefaction process, placed protective barriers around it. When the vessel unexpectedly exploded, harm was prevented. In another instance, reinforced concrete walls between the liquefaction system and the operating control room protected operators from injury and operating controls from damage. The unharmed operators were able to shut down the process, thus preventing further explosions and fire. These same techniques could be applied in future operations to prevent harm at all levels of operation *(575).*

Coal Mining

Most coal is **used** in the traditional way to generate power directly in steam plants, and its use has increased during the past decade of uncertainty about oil supplies. Use is expected to increase further, to double, in fact, by the year 2000, to as much as two billion tons per year (536).

Mining and moving coal are hazardous. Over 100,000 coal miners have been killed since 1900), and coal workers' pneumoconiosis (black lung disease) has taken a high toll. **A** mortality study of 23,233 miners selected randomly from those eligible for United Mineworkers of America health and retirement funds as of January 1, 1959 and followed through December 31, 1971 with 99 percent followup, reported excess mortality for stomach cancer, influenza, asthma, tuberculosis, and accidents (392) (see table 17-2). Unless steps are taken to assure prevention of work-related injury and illness in coal mines, an increase in production may lead to excess morbidity and mortality.

Changes in technology are introducing new hazards into the mine. For instance, the diesel en-

Table 17-1 .—Potential Occupational Hazards in Coal Liquefaction Plants

System, unit operation or unit process	Potential hazards
Coal handling and preparation system.	Coal dust, noise, fire, explosion, asphyxia (nitrogen and carbon monoxide gases), burns
Liquefaction system	Phenols, ammonia, tars, thiocyanates, PAH's, carbon monoxide, hydrogen sulfide, hydrocarbons, fires, explosions, burns, high pressures, noise, ash, slag, mineral residue, spent catalyst
Separation system	Oils, phenols, hydrogen cyanide, ammonia, hydrogen sulfide, burns, fires
Upgrading and gas purification	Light hydrocarbons, phenols, ammonia, hydrogen sulfide, carbon dioxide, carbon monoxide, burns, fire, explosion, high pressures
Shift conversion	Tar, naphtha, hydrogen cyanide, fire, catalyst dust, burns, hot gases (carbon monoxide, hydrogen)
Methanation [a].	Carbon monoxide, methane, nickel carbonyl, spent catalyst dust, fire, burns
Waste treatment facilities	Hydrogen cyanide, phenols, ammonia, particulate, hydrocarbon vapors, sludges, spent catalyst, sulfur, thiocyanates

[a]Indirect liquefaction

SOURCE: (575),

Table 17.2.-Standardized Mortality Ratios Among Coal Miners[a]

	Deaths		
Cause of death	Observed	Expected	SMR[b]
All causes	7,628	7,506.1	101.6
All malignant neoplasms	1,223	1,252.2	97.7
Respiratory organs	373	331.0	112.5
Stomach cancer	127	91.9	134.9[b]
Major cardiovascular diseases	4,285	4,501.2	95.2[b]
Chronic and unqualified bronchitis	26	29.0	89.7
Influenza	28	14.8	189.6[b]
Emphysema	170	118,3	143.7[b]
Asthma	32	18.3	174.9[b]
Tuberculosis	63	43.3	145.5[b]
Coal worker's pneumoconiosis	187	—	—
Accidents	408	283.0	144.2[b]

[a]Coal miners covered by the United Mineworkers of America health and retirement funds The vital status of 22,998 miners was verified.
[b]Standardized mortality ratio (SMR) is significantly different from 100 at the 5 percent confidence level

SOURCE (392)

gine is increasingly replacing electrically powered mine equipment. The exhaust emissions from such engines include cancer-causing polynuclear aromatic hydrocarbons, respiratory system irritants, and asphyxiating carbon monoxide and carbon dioxide.

Control technologies for diesel engines are well known. Diesels operating under ideal conditions, with proper maintenance and operation, produce minimal amounts of contaminants. In underground coal mines, ventilation can be increased to keep contamination at a minimum. Filters, recirculation of exhaust gases through the engine, catalytic converters, and exhaust scrubbers can also be used to clean the exhausts (477). Such controls are difficult and require high degrees of maintenance to assure that they are functioning properly.

Other examples of a production technology that may increase risk of injury in the mines include continuous miners and long-wall mining. Continuous miners are machines that cut into a coal vein and transfer loose coal back to a conveying mechanism for transport to the surface. While they increased productivity when they were phased into the mines from **1950 to 1970, the fatality rate rose slightly and the disabling injury rate continued at a relatively constant level. Long-wall mining is a mining method** in which a machine extracts coal by moving back and forth across a face while conveying the coal to one of two tunnels dug parallel to each other and at right angles with the coal face. The coal is transported to stations for transfer to the surface via conveyors running through the tunnel. Supports at the face protect miners while allowing the roof to cave in behind the face just worked, preventing unwanted roof fall. Longwall mining may reduce fatalities but not necessarily injuries or harmful dust levels ***(536).***

Outer Continental Shelf Oil Production

Another energy area expected to grow is oil and gas production on the outer continental shelf. Demand for energy has led to the development of technologies for deep water oil and gas exploration in remote locations and under extreme environmental conditions. An increasing number of workers, already at high risk because of the nature of oil extraction, will face even greater risks of work-related injury and illness. In the period 1970-79 employment in outer continental shelf oil and gas exploration grew by 71 percent (to a work force of 61,500) for an average annual growth of 3 percent. Moreover, there was a 20 percent per year increase in two years, 1978 **and 1979 (319).**

There are two areas of concern. The first is the design **and stability of drilling rigs. A combination of bad weather and inadequate structural strength has resulted in major catastrophes, such as the failure of a mobile offshore drilling unit** in 1982 in the North Atlantic that killed 84 ***workers.***

The second area is the risk to workers from the work itself. Drilling is frequently continuous, being done in shifts 7 days a week, under difficult conditions. Drill space is cramped and pipes, tubing, tongs, and other material are heavy and cumbersome. Walking and working surfaces are slip pery from drill fluids. The work is outside, so weather is often a factor. The severity of these conditions is heightened on offshore drill rigs and may be expected to be even more severe on offshore units located in remote areas, where weather may be extreme.

Modernizing Old industries

U.S. manufacturers are facing intense competition from Japanese and Western European companies, and that sector of the U.S. economy may be declining. The declines have been attributed to inadequate investment in new plant, changing market conditions, rising labor costs, and cost-generating Government regulations. Whatever the exact reasons—and they are a matter of argument—it is agreed that the U.S. steel industry is no longer the first in the world. Changes in the qualities of cars that induce people to buy an auto resulted in U.S. consumers buying more foreign-built models, and U.S. domination of auto sales is a thing of the past. Both these industries are retooling and retrenching to meet the foreign threats, and there will be opportunities to build in features to prevent work-related injury and illness.

Steelmaking

Steelmaking is one older U.S. industry that must change if it is to survive. Increased research, development investment, and the use of new technology are all required to compete with steelmaker from other countries (538). Unfortunately, this has become a chronic public policy problem. As mentioned in chapter 16, the Steel Tripartite Advisory Committee, made up of steelworkers, steelmaker, and Government officials, was established by President Carter in the 1970s to attempt to revitalize this industry.

The Committee's Working Group on Technological Research and Development concluded that (458):

> environmental and occupational safety and health issues should be considered as an integral part of technological research and development in the steel industry. Research in steel technology should continue to take into consideration features for protecting workers and improving the ambient environment both with respect to new and to existing steel facilities.

The Working Group went on to recommend Federal funding for research and development and for demonstration plants. These recommendations were agreed to in recognition of the high risk of work-related injury and illness in steelmaking, and the opportunity to reduce costs through development, demonstration, and adoption of control technologies.

New technologies for steelmaking are more productive and likely to cause fewer work-related injuries and illnesses. For example, continuous casting is used to produce 80 percent of Japanese steel and 32 percent of U.S. steel. It requires less energy, costs less per ton of steel produced, and produces higher quality steel and less pollution. It also eliminates soaking pits and reheating furnaces and requires less coke making, three steps in the traditional process that produce emissions that are associated with disease. In general, better working conditions exist in continuous casting steelmaking plants.

Another new steel technology is direct reduction of iron ore rather than the current process of blast furnace and coke oven. Since direct reduction can be done without coke, risk of lung cancer from coke oven emissions can be eliminated. Other technologies that show promise for the 1990s and that can be made less likely to cause work-related injury and illness include formcoking (another process reducing coke oven emissions), direct casting of sheet and strip metal from molten steel, and one-step steelmaking directly from ore. In the latter two processes, potentially hazardous steps in the process are eliminated, thus reducing risk of worker harm.

The same changes that improve production and reduce risks will cause further shrinking of the work force. In the late 1970s, 450,000 workers were employed in steel; in 1983, the number was less than 250,000, and it continues to decline.

Automating

Automating includes many kinds of industrial operations, ranging from metalworking in steel-

works and foundries, to forging and machining of metal parts, to fabrication of plastic parts, and, finally, to assembly. Hazards in the steelworks and foundries include noise, heat, dust, and gas. Forging and machining are also hazardous. Auto body painting presents special hazards due to the large volumes of paint and solvents used during assembly. Stress-related illness may result from monotonous work and shift work.

Conventional controls are available for these hazards. Local exhaust and dilution ventilation are widely used in all phases of manufacture and can be expected to be improved in new processes. Automated spray painting in booths reduces or eliminates worker exposure. The use of robots in areas of high hazards can reduce risks to workers.

Robots or automated manufacture also introduces hazards. There have been cases here and abroad of workers being injured or killed by automated machines. This points to the need for machines to stop when workers inadvertently come in contact with them or to be installed where they keep workers out of danger zones while the machine is connected.

New Technologies

New technologies that are burgeoning or promise to burgeon into full-scale industries present opportunities to prevent work-related injury and illness in the early stages at low cost. The most successful of the new industries is the semiconductor industry, and the most glamorous of the promising ones is biotechnology.

Photo credit: NIOSH

This paint spraying line has been automated using robots. Future developments in robotics may reduce worker exposures in other hazardous operations

Semiconductor Manufacture and Related Industry

The continuing demand for computer and video devices for industry and commerce, coupled with consumer electronics and computer technologies for microelectronic applications, is expected to fuel the growth of this industry.

Microelectronics has been estimated to have a world market of more than $19 billion and employ a work force of 500,000 worldwide (258).

The risk of work-related injury appears to be lower and illness appears to be higher in this industry. In 1981 the Bureau of Labor Statistics reported the injury incidence rate for semiconductor and related devices as 4.6 cases per 100 full-time workers and lost-workday cases as 2.0 per 100 workers, compared with an all-industry average incidence rate of 8.3 cases per 100 workers and lost-workday cases of 3.8 per 100 full-time workers (608). The California Department of Industrial Relations conducted a survey in 1980 that showed workers manufacturing semiconductors had 1.3 illnesses per 100 workers compared with a rate of 0.4 per 100 workers in the general manufacturing industries. Lost time resulting from work-related illness was three times more common among semiconductor workers (18.6 percent of all lost-workday cases) than in general manufacturing industries (6.0 percent of all cases) from 1980 to 1982. Almost half (46.9 percent) of all work-related illness among Californian semiconductor workers in this period was reported to result from exposure to toxic substances (258).

Known health hazards include metal fumes from soldering, toxic chemicals such as epoxy resins and chloronaphthalene, silica flour used in making insulating materials and dielectrics, solvents for decreasing solder joints, and acids for etching printed circuits. The volumes of these chemicals used in California in 1979 were large: Over two million gallons of solvents; more than two million gallons of sulfuric, hydrofluoric, and other acids; more than one-half million gallons of sodium hydroxide and other caustics; and over one and one-half million cubic feet of arsine, phosphine, diborane, and other toxic cylinder gases were used in processing semiconductors (258).

Existing technologies, if applied, should be sufficient to control these hazards. Local exhaust ventilation is appropriate for soldering and etching operations. Substitution may be appropriate where solvents are found to be more toxic than expected. Replacement of carbon tetrachloride and trichloroethethylene (after they were shown to be carcinogenic among laboratory animals) with perchloroethylene is an example of this.

Biotechnology

Recombinant DNA technologies, operating at moderate pressure and temperature, have fewer inherent physical hazards than traditional chemical processes, which sometimes operate at dangerously high pressures and temperatures. Furthermore, to the extent that biotechnology uses pinpoint production techniques to produce particular chemicals, it will eliminate the currently encountered mixtures of chemicals, contaminated with unwanted toxic compounds, that are common in conventional chemical synthesis.

Biotechnology's hazards center on the possibility that the microbes used in it or products produced from them will be harmful to human health or the environment. Since some of these organisms are "new," in that they have been produced by genetic engineering, there is concern among some people that they present significant risks (541,548). Most experts in the field see the organisms being used for or proposed for use as production organisms as "crippled" and unable to survive outside the laboratory or workplace.

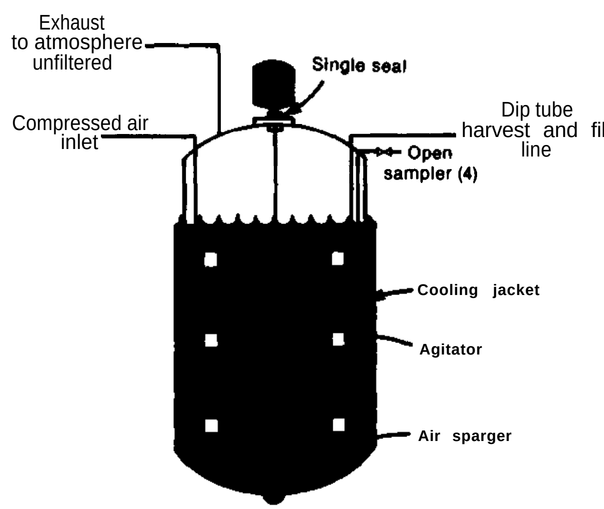
More of a problem are "new" micro-organisms developed to be released into the environment. Because they will have to compete with organisms that occur naturally, they cannot be crippled. For that reason, EPA is now considering regulating the intentional release of such organisms, and Congress has expressed interest in a regulatory scheme.

In the area of using micro-organisms for production, the United States appears to have studied questions of worker health more carefully than other countries. The U.S. voluntary approach to worker protection is monitored by the Research Advisory Committee of the National Institutes of Health, and NIOSH has developed guidelines for medical surveillance of fermentation and biotechnology plant workers (259a).

NIOSH industrial hygiene surveys of six industrial laboratories using recombinant DNA technologies found wide variation in safety and health practice among them. Practices ranged from "exemplary" plants with health and safety programs for workers to plants where workers were allowed to smoke and drink in the laboratory and to store beverages in laboratory refrigerators, and where procedures for biological waste-disposal were undocumented—all unacceptable practices.

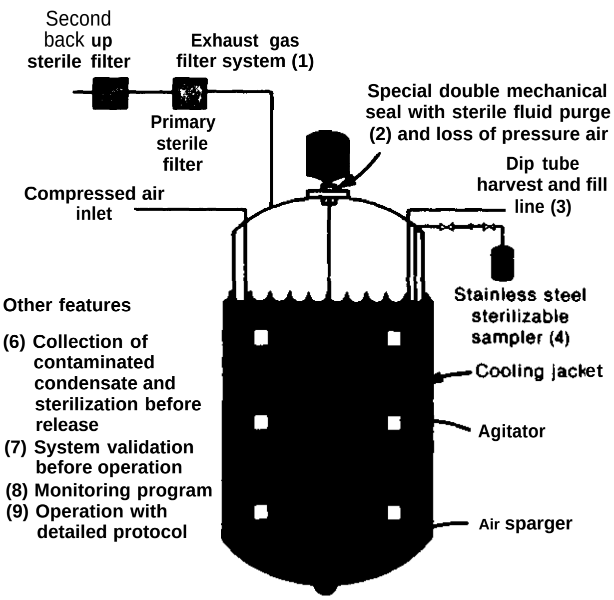
Figures 17-I and 17-2 contrast a standard fermenter with a contained one, which would contain organisms and culture media used in biotechnology. The contained fermenter provides for double filtering of exhaust gases to control emissions, a special mechanical seal at the top to provide extra protection against loss of growth medium that contains bacteria, and an alarm to warn operators of ruptured seals, thus helping prevent possible loss of contaminated broth. These features of the contained fermenter provide increased protection both to workers and the environment.

Figure 17-1 .—Features of Standard Fermenter



SOURCE: NIOSH

Figure 17-2.—Features of Contained Fermenter



SOURCE: NIOSH

Rapidly Growing Occupations

Office Work

Thirty-three million people work in office jobs in this country. The advent of new technology such as computers using video displays and advanced copying machines have changed the office. To some extent, machines can pace the work, introducing a new source of stress. Lighting and furniture, ignored in the installation of the first computers and word processors, are important to worker comfort and probably to health and safety.

The energy crisis has resulted in office buildings being tightly insulated. Unfortunately, improved insulation that keeps heat or cooled air in also prevents air exchange from cracks and other tiny **leaks** and increases indoor air pollution. Because building air is recirculated to conserve energy rather than directly exhausted to the outside, many ventilation standards are now inadequate. Formerly unacceptable, the practice of recirculation has been adopted to reduce the relatively high costs of heating and cooling. Harmful air contaminants, aerosol can chemicals, tobacco smoke, and pathological micro-organisms may reach unacceptable levels. Some building technologies also contribute to the contamination. For example, the irritating and potentially carcinogenic compound formaldehyde is emitted ***from*** plywood, and naturally occurring radioactive radon gas may be emitted from certain building sites. Even when the exact causes of workers' health problems remain unidentified, the problems have been reversed with increased ventilation.

Health effects have been related to indoor air pollution. At high concentrations, indoor air contaminants may cause irritation of sensitive tissues, and acute or chronic illness. Many substances appear to act primarily as irritants at low exposure levels, inducing local inflammatory reaction in the eyes, nose, lung, or other sites **(25).** NIOSH made 159 health hazard evaluations in response to requests between 1971 and 1983. Table 17-3 shows that irritation of eyes and throat were reported in 81 and 71 percent of the cases respectively (661).

Control of indoor air pollution maybe achieved by increasing ventilation rates, eliminating the source of contamination, and air cleaning (25). Air cleaning is generally limited; although it filters particles, it does not remove gases and vapors.

Table 17-3.-Frequency of Health Complaints in 55 Office Environment investigations

Symptom	Percent of buildings with complaint
Eye irritation	81
Dry irritated throat	71
Headache	67
Fatigue	53
Sinus congestion	51
Skin irritation	38
"Shortness of breath"	33
Odor	31
Cough	24
Dizziness	22
Nausea	15

SOURCE: (661).

Ventilation standards, if they are to guard against indoor air pollution under the new conditions, need to be rewritten.

There are reports that office work, especially work involving routine use of computers for document completion and filing, is being moved from the office to the home. While working at home is attractive to many people, it will also introduce new concerns. Stress may be increased by a sense of isolation from the workplace and coworkers, and opportunities for advancement, which are a positive force in most workers' lives, may not exist. Also, to the extent that office machines bear hazards, those are likely to go unrecognized in the dispersed workplace and even more likely to go uncontrolled (25).

SUMMARY

The ability to anticipate change is fundamental to preventing work-related injury and illness. Knowledge about the sectors of the economy where changes are likely to take place, what the changes might be, and how they might affect workers will help responsible officals carry out their mandate under the Occupational Safety and Health Act and to improve occupational health and safety in other ways.

Changes can be expected in energy-related industries, modernization of older industries, industries relatively new to the economy, and in the rapidly growing area of office work. New technologies are being introduced, some of which could cause work-related injury and illness. But these changes also present opportunities for preventing work-related illnesses and injuries.

The production of synthetic fuels also creates possible worker exposures to a number of different hazardous substances, as well as a potential for fires and explosions. Coal mining has always been hazardous, not only in terms of injuries, but is also associated with increased worker illness. The use of diesel engines and new production technologies introduce new hazards underground. Operations on offshore oil and gas rigs result in relatively high injury rates.

Modernizing older industries such as steelmaking and automating should provide opportunity for additional protection of workers. Meanwhile, brand new technologies, such as electronics and biotechnology, are being introduced. Greater attention should be paid to worker health problems in the manufacture of semiconductors because of the use of toxic chemicals. Biotechnology has the potential of reducing exposures to inherently dangerous chemical processes and potentially hazardous chemical mixtures. But care must also be taken in handling the micro-organisms used in these processes.

Office work is one of the most rapidly changing occupations as new technologies are proliferating. Since one-third of the work force are in offices, even low rates of work-related injury and illness can be of concern. Three areas where attention is needed in offices are indoor air pollution, stress, and the ergonomic problems associated with VDTs.

But the problems of the past will also remain. It will be difficult to convince smaller firms to invest in control technologies, especially as they will find the financing difficult. Companies relying on older technologies, such as those found in the basic industries, remain reluctant to install controls, especially when times are hard. The tortuous process of court battles over standards is likely to continue, leaving the public and workers somewhat bewildered about the protection the Federal Government attempts to afford them.

The incentives for control that are discussed in this assessment deserve careful attention to discern how they work or do not work to encourage better health and safety programs. It is by now clear that regulations are slow to emerge from OSHA, that enforcement will always be limited by the small corps of inspectors, and that OSHA consultation services cannot reach every workplace that could benefit from them. Continuing demands from a work force and a public less willing to accept risk of injury and illness will impose greater pressures on workers' compensation, liability law and the courts more generally, and insurance companies and voluntary associations interested in health and safety.

The great interest in environmental health that developed in the 1970s remains alive and well, and interest in the role of the general environment and the workplace in health has probably become part of the overall social consciousness of the Nation. One of the measures of the importance of those ideas will be improvements in occupational health and safety in the years to come.

Appendixes

Appendix A.—Supplemental Information on OSHA and NIOSH

Other Reports on OSHA and NIOSH

The General Accounting Office (GAO) has examined a number of aspects of OSHA and NIOSH operations. It has reported on standards-setting activities of OSHA and the criteria-setting activities of NIOSH in two different reports **(494,501)** and generally criticized the slow pace of the development of new standards, and the lack of coordination between the two agencies. GAO has examined emergency temporary standards **(495,496)** and the procedures used by OSHA to grant employers variances from standards (497), and expressed concern that OSHA's activities were not sufficient to ensure worker health and safety. GAO has also criticized OSHA's management of its consultation program **(505),** OSHA's monitoring of State Programs (500), as well as the administration of NIOSH's HHE program (503).

GAO has reviewed OSHA's health inspections (502), its safety inspections (504), and the procedures used for scheduling complaint inspections (507), and was critical of several aspects of OSHA's inspection activity. GAO has in two reports criticized OSHA's data collection efforts, pointing to inadequacies in data on injuries and health hazards and OSHA's failure to use the information it collects through accident investigations **(499,508). A 1984** GAO report examined OSHA's policies of encouraging the informal settlement of citations (511).

Mary Jane Belle, of the Congressional Research Service, prepared a report in 1981 ***on*** OSHA reform (530). She has also written and updated a Congressional Research Service Issue Brief on OSHA (533).

Crisis in the Workplace by Nicholas Ashford (30) and Bitter ***Wages*** by Joseph Page and Mary-Win O'Brien (361), provide accounts of some of OSHA's early history and present their evaluations of governmental activities. Other studies of occupational health and safety regulation are Robert Smith's The Occupa***tional Safety and Health Act (44*** and John Mendeloff's ***Regulating Safety*** **(300).** David P. McCaffrey, ***OSHA and the Politics of Health Regulation*** **(290)** gives a history and analysis of the health standards issued during OSHA's first decade, while Steven Kelman's ***Regulating America, Regulating Sweden*** **(245)** provides a comparison of OSHA and its Swedish counterpart. In his collection entitled ***OSHA: History, Law, and Po/icy*** **(307),** Benjamin W. Mintz provides numerous excerpts from primary source documents related to many of the important disputes about OSHA standards and enforcement activity, employee rights, and the history of State programs,

Three other reports on OSHA are of special interest. Two were prepared by Presidentially appointed groups. The first, appointed by President Ford and often referred to as the MacAvoy Commission, examined OSHA's safety standards and recommended that OSHA issue performance standards**(276). The** second, an Interagency Task Force appointed by President Carter, made a large number of recommendations on OSHA inspection activity, creation of economic incentives for OSHA compliance, establishing cooperative programs, and reforming regulatory activity **(228).** In addition, two academic economists, Richard Zeckhauser and Albert Nichols, studied OSHA regulation at the request of the Senate Committee on Governmental Affairs, which published their report in 1978 (685),

OSHA Standards Issued After Rulemaking

As described in chapter **12,** OSHA has the authority to issue new standards, and to modify or revoke existing standards using procedures specified in the Occupational Safety and Health Act (OSH Act). Tables A-1 and A-2 present details of the rule-making proceedings that have resulted in final standards during OSHA's first 13 years. These proceedings **can** begin with the receipt of a Criteria Document from NIOSH, the creation of an ad hoc advisory committee, ***or*** the publication of an Advance Notice of Proposed Rulemaking. Although, in theory, both of these latter two might occur in the same proceeding; in practice they have not. In fact, in recent years, OSHA has tended to use the Advance Notices, and has not used ad hoc advisory committees. (The exceptions are standards involving the construction industry, for which OSHA is required, by its own regulations, to consult with the standing Construction Safety Advisory Committee.) Moreover, in recent years, NIOSH has issued few criteria documents. Proceedings are now more likely to begin with a petition from an interested group, such as a union, for a standard,

The formal Notice of Proposed Rulemaking and publication of the Final Standard and statement of reasons are necessary steps in order to issue a standard. A public hearing is not essential, unless an interested party requests it. For major and controversial standards, a hearing is invariably requested.

Under section 6(f) of the OSH Act, "[a]ny person who may be adversely affected by a standard issued" by OSHA can challenge the standard in any of the U.S. Courts of Appeal. A column in tables A-1 and A-2 indicate if any challenge occurred, the circuit in which it was filed, and the date of the decision. Table A-3 lists the names and citations for these cases.

Finally, OSHA has for a number of its standards, taken formal steps to reconsider and revise standards that had been issued in final form. The last column of tables A-1 and A-2 list these actions.

OSHA Enforcement Activity

Tables A-4 to A-n present detailed information concerning inspection activity by OSHA since Fiscal Year 1973 and the State programs since Fiscal Year 1976. The data for these tables were provided by OSHA. Table A-4 provides the number of inspections, both for safety hazards and for health hazards. Table A-s presents these inspections according to OSHA's priority categories—fatality/catastrophe investigations, complaint inspections, programed inspections, and follow-up inspections. Table A-6 gives the numbers of inspections by major industry groups.

Tables A-7 to A-11 include information on the various types of violations issued by OSHA. The OSH Act specifies that penalties be imposed on employers for violations of standards. Except in the case of de minimus violations that have "no direct or immediate relationship to safety or health, " and other-than-serious violations, OSHA must issue a citation, propose a penalty, and set a "reasonable" abatement period.

A "serious" violation is issued for hazards that present a "substantial probability of death or serious physical harm" to employees. A fine of up to $1,000 for each serious citation can be imposed. An other-than-serious violation is not explicitly defined in the Act, but it falls between serious and de minimus violations. These violations have also been termed "non-serious violations." OSHA and OSHRC interpret other-than-serious violations to involve conditions that have a direct and immediate relationship to worker safety and health, but without a substantial probability of death or serious physical harm. Although a fine of up to $1,000 could be imposed for these violations, in practice the proposed fines are substantially smaller.

'Willful" violations are defined as those that are "intentional and knowing, as distinguished from accidental, and display a careless or reckless disregard or plain indifference to the Act or its requirements. " (333). Employers will usually correct a hazard after being found in violation. Employers who subsequently are found to violate the same standard or a similar standard may be issued "repeated" violations. Fines of up to $10,000 may be imposed for both willful and repeated violations. OSHA's largest penalties usually involve an employer's "failure to abate" or correct a hazard. The OSH Act authorizes penalties of up to $1,000 for each day that the hazard continues beyond the day it was supposed to have been abated. In practice, these have been limited to a maximum of 10 days or $10,000.

The Act also authorizes criminal prosecution in several situations: First, a willful violation that results in an employee's death may be punished by criminal penalties including a fine of up to $10,000, or 6 months imprisonment, or both. For a second conviction, these maximum penalties are doubled. There have been only a handful of these cases under the Act. In addition the Act provides for criminal penalties for OSHA officials who give an employer unauthorized advance notice of an inspection, and against anyone who falsifies OSHA-required records, or uses force to interfere with the work of an inspector, although there have not been any cases brought for these last three types. (For a more detailed discussion, see 307,333,408.)

In practice, penalties are substantially lower than the maximum penalty amounts outlined above, reflecting, in part, OSHA's discretion in setting penalties. In proposing penalties, OSHA considers the gravity of the violation, the good faith of the employer, the size of the business, and the employer's previous history of compliance.

Activities of Other Federal Agencies

OSHA and the 25 State Programs are directly responsible for ensuring the health and safety of most private sector workers in the U.S. However, workplace health and safety for some private sector workers are the responsibility of other Federal agencies. In general, health and safety conditions for most public sector workers are not directly regulated by OSHA, although State Programs, at least in theory, cover State and local employees in States with State Programs. Finally, the regulations issued by several other Federal agencies also affect job safety and health, even though workplace conditions are not the primary focus of these agencies.

The constellation of governmental bodies with workplace safety and health responsibilities is summarized in table A-12. The OSH Act directly regulates "employers," who are defined as persons and businesses who have employees and are engaged in interstate commerce (Section 3(s)). This generally covers private sector employers, although anyone who is self-employed and who has no employees is not directly subject to OSHA regulation.

In addition, the occupational health and safety of some private sector employees is regulated by other agencies. Section 4(b)(1) of the OSH Act provides that the OSH Act does not apply to "working conditions" for which other agencies "prescribe or enforce standards or regulations affecting occupational safety or health." These exclusions are, in some instances, for all aspects of occupational safety and health; in others only for certain hazards. For instance, the Mine Safety and Health Administration (MSHA) is responsible for all safety and health hazards associated with mining. The Nuclear Regulatory Commission, in contrast, is responsible for assuring that the workers under their jurisdiction are adequately protected from radiation exposure only; OSHA is responsible for all other workplace hazards.

The boundaries of authority are clear in some cases, while in others disputes have arisen. The Federal Aviation Administration (FAA) has requirements concerning the health and safety of flight crews, but coverage of aviation ground crews has been a focus of dispute between the FAA and OSHA.

Certain jurisdictional uncertainties have been resolved by agreements between OSHA and other agencies. The Department of Energy, through a letter of understanding, has responsibility to "prescribe and enforce occupational radiological and nonradiological safety and health standards" for the workers it covers. That 1974 agreement reaffirmed a 1964 letter of understanding between the then Atomic Energy Commission and the Department of Labor concerning responsibilities under the Walsh-Healey Act.

Recently, Congress temporarily transferred jurisdiction over stone and gravel quarries from the Mine Safety and Health Administration to OSHA for several months. Inspection authority for this industry has now returned to MSHA. Current and future jurisdictional disputes may be resolved through letters of understanding and inter-agency agreements, or through congressional and court actions.

The employees of the Federal Government, as well as of State and local governments, are not directly regulated by OSHA. However, Section 19 of the OSH Act requires that the head of each Federal agency provide an occupational safety and health program for agency employees that is "consistent with" the standards issued by OSHA. Three different Presidents have issued Executive Orders concerning the health and safety of Federal workers (Executive Order (E. O.) 11612, July 26, 1971; E.O. 11807, Sept. 28, 1974; E.O. 12196, Feb. 26, 1980). There is a Federal Advisory Council on Occupational Safety and Health, appointed by the Secretary of Labor, that consists of 16 members--8 representing Federal agencies, and 8 representing Federal employee labor organizations. OSHA also provides technical assistance to other Federal agencies concerning the health and safety of Federal workers.

The health and safety of State and local government employees is the responsibility of the States and localities that employ them. Any State that establishes a State Program must provide an occupational safety and health program for state and local employees that is "as effective as the standards" adopted for private sector workers. But State and local government employees in States without State Programs are not covered by this requirement.

In addition, several other Federal agencies can take actions that affect worker health and safety. The Environmental Protection Agency (EPA) regulates pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act and regulates toxic substances under the Toxic Substances Control Act. In either case, EPA actions to allow, limit, or prohibit the use of particular substances may affect employee health and safety. In fact, in many cases, the exposed workers may be the group most affected by these actions. This may also happen with actions taken by the Consumer Product Safety Commission in regulating hazardous consumer products.

Comparison of Protective Levels

The NIOSH list in ***Summary of NIOSH Recommendations for Occupational Health Standards*** contains recommendations for a total of 163 hazardous substances and work conditions. There are 74 substances which have no complications, and these are included on the comparison list. There are also 11 groups of 71 separate substances for which NIOSH has made recommendations. Only 43 of these, however, were conducive to comparison. In addition, there are six substances in three classes which OSHA or ACGIH treat separately, but NIOSH treats the same. These are cadmium, which OSHA separates into dust and fume; PCBs, which are divided by the percent of chlorine present; and the explosive nitro compounds, nitroglycerin and ethylene glycol dinitrate. Finally, 10 NIOSH recommendations cover exposures to general categories of toxic substances or harmful physical agents, while 5 others cover hazardous working conditions. These are described in chapter 12, but because most of them are not easily compared on a numerical basis, they were excluded from this comparison. Thus the total number of Protective Levels compared equals 74 plus 43 plus 6 or 123.

Table A-13 presents the numerical Protective Levels from OSHA, NIOSH, and ACGIH that were compared. Alternative chemicals names are not used in table A-13. In most cases, the name used is the one NIOSH uses. Abbreviations have been included in most cases for those substances which have them, and, in fact, some substances are seldom referred to by their chemical names, abbreviations being more convenient. In this table, all protective levels are listed in mg/m^3 (milligrams substance/cubic meter of air). Generally, the protective levels in the actual recommendations and standards are given in ppm (parts per million) or mg/m^3 or both. For convenience and ease of comparison, all ppm concentrations were converted to mg/m^3 using the formula:

$$(MW \times (X)\ ppm)/24.45 = Y\ mg/m^3$$

(at 25°C and 760 mm Hg pressure, where MW = Molecular Weight).

Table A-13 lists 123 toxic and hazardous substances and the corresponding Time-Weighted Average (TWA) and Ceiling permissible exposure limits for each substance that are recommended by NIOSH and ACGIH, and mandated by OSHA. The 123 chemicals included in the comparison are all those that appear on the NIOSH list that also appear on either the OSHA or ACGIH lists. The names of the NIOSH list substances that were left out for various reasons are listed in the Notes (No. 36).

When there is only one exposure limit in a protective level the word "none" in small letters indicates which exposure limit is not part of the standard. For example, "none" under the NIOSH Ceiling Limit for carbaryl means that the NIOSH recommendation does not have a Ceiling exposure limit for carbaryl, but it does have a TWA exposure limit. When there is no recommendation or standard for a particular substance, the word "NONE" is capitalized and present in both exposure limit columns.

Approaches differ among OSHA, NIOSH and ACGIH. For example, many of NIOSH's recommendations are based on a lo-hour workday and not an 8-hour workday as are OSHA's PELs. For this comparison, it was assumed that this difference would have only a negligible effect on the level of protection.

For most substances, NIOSH recommends only one TLV (98 cases out of 131), either a TWA or a Ceiling Limit, but not both. OSHA has only one PEL, an 8-hour TWA, for most of the substances it covers. On the other hand, ACGIH recommends both a TWA and a Ceiling TLV in over half of the cases included in this comparison (73/131). With differing specifications concerning the type of Protective Level, it can be difficult to compare them. In addition, recommendations that no exposure be allowed for carcinogens is often not reflected in the numerical levels recommended by an organization.

There are also differences in defining specific substances since some descriptions are more inclusive than others. For example, ACGIH has four TLVs for asbestos (one for each type), while NIOSH has a single protective level. A similar problem occurs if the substances being compared are not exactly the same, or if related substances are grouped differently, then the standards limiting exposure will differ. An example of this is the different exposure limits for soluble chromium, insoluble chromium, chromous salts, and chromic acid. These are detailed in the notes to table A-13.

Table A-1.—Dates of Completed OSHA Rulemakings for Health Standards

OSHA regulation[a]	NIOSH recommendation (criteria document)	Advisory committee (first meeting)	Emergency temporary standard[b] (ETS)	Advance notice of proposed rulemaking (ANPR)	Notice of proposed rulemaking	Hearings (beginning day or month)	Federal Register (vol. and starting p.)	Final standard	Section 6(f) legal challenge to final rule—(court and date of decision)[c]	Formal reconsideration
1. Asbestos	0 /21/72	02/03/72	12/07/71	none	01/12/72	none	06/07/72	37:3155	D.C. Cir. (04/15/74)	see footnote (d) below
2. Fourteen carcinogens	none	06/25/73	05/03/73	none	07/16/73	09/73	01/29/74	39:3756	3d Cir. (08/26/74); 3d Cir. (12/17/74)	MOCA[k] standard deleted 08/20/76
3. Vinyl chloride	03/11/74	none	04/05/74	none	05/10/74	06/25/74	10/04/74	39:35890	2d Cir. (01/31/75)	none
4. Coke oven emissions	02/28/73	/08/74	none	none	07/31/75	11/04/75	10/22/76	41:46742	2d Cir. (03/28/78)	none
5. Benzene	07/24/74	none	05/03/77	none	05/27/77	07/19/77	02/10/78	43:5918	5th Cir. (10/05/78); S.Ct. (07/02/80)	standard deleted 06/19/81; request for information 07/08/83
6. DBCP[l]	09/02/77	none	09/09/77	none	11/01/77	12/13/77	03/17/78	43:11514	none	none
7. Arsenic (inorganic)	11/08/74	none	none	none	01/21/75	04/08/75	05/05/78	43:19584	9th Cir. (09/13/84)	supplemental statement (risk assessment) 01/14/83
8. Cotton dust	09/26/74	none	none	2/27/74	12/28/76	04/05/77	06/23/78	43:27350	D.C. Cir. (10/24/79); S.Ct. (06/17/81)	see footnote (e) below
9. Acrylonitrile	09/29/77	none	01/17/78	none	01/17/78	03/21/78	10/03/78	43:45762	none	none
10. Lead	01/05/73	none	none	none	10/03/75	03/15/77	11/14/78	43:52952	D.C. Cir. (08/15/80)	See footnote (f) below; see also #14 below
Cancer Policy	none	none	none	none	10/04/77	05/16/78	° /22/80	45:5001	5th Cir. (pending)	ANPR published 01/05/82; administrative stay of candidate list 01/04/83
12. Access to employee exposure and medical records	none	none	none	none	07/21/78	12/05/78	05/23/80	45:35212	5th Cir. (05/16/84)	proposal to modify rule 07/13, 82
13. Occupational noise exposure/hearing conservation amendment	08/ 4/72	02/2 /74	none	none	10/24/74	06/23/75	01/16/81	46:4078	4th Cir. (1 /07/84)	see footnote (g) and #16 below
14. Lead—reconsideration of respirator fit-testing requirements	none	none	none	none	05/19/81	09/22/8	/ 2/82	7:51 10	none	none
15. Coal tar pitch volatiles—modification of interpretation[h]	09/77	none	none	none	none	05/28/82	01/21/83	48:2764	none	none
16. Hearing conserv reconsideration	—	—		none	08/21/81	03/23/82	03/08/83	48:9738	4th Cir. /07/84)	
17. Hazard communication (labeling)	1974	09/19/74	none	01/28/77	03/19/82[i]	06/15/82	01/25/83	48:53280	3d Cir. (pending)	none
18. Ethylene oxide	—[j]	none	none	01/26/81	04/21/83	07/19/83	06/22/84	49:25734	D.C. Cir. (pending)	none

[a]Generally, these regulations are standards issued after rulemaking under the authority of Section 6(b) of the OSH Act. In 1982, OSHA also issued a regulation expressly authorizing OSHA compliance officers to use personal sampling devices during workplace inspections. Because this only applies to OSHA's inspection authority, it is not included in this table. See *Federal Register* 47:55478 (12/10/82).

[b]In addition to those listed, OSHA also issued an ETS for a group of 21 pesticides on May 1, 1973. The emergency standards for the fourteen carcinogens, benzene, acrylonitrile, pesticides, and asbestos 1983) were the subjects of legal challenges. See table A-3 for the citations to these cases. The emergency standards for asbestos (1971), vinyl chloride, and DBCP were not challenged.

[c]See table A-3 for the complete citations to these cases.

[d]OSHA first proposed to revise the asbestos standard on Oct. 9, 1975. On Nov. 4, 1983, it issued an ETS, but this was vacated by 5th Circuit Court of Appeals on March 7, 1984. OSHA published a new proposal on Apr. 10, 1984 and hearings on this began in June 1984.

[e]Court decisions on the cotton dust standard also include: S. Ct. (Oct. 6, 1980) affecting the warehousing industry; 5th Cir. (Nov. 14, 1980) affecting the cotton ginning industry. Administrative stays have been issued for waste processing and utilization (Sept. 1, 1978), warehousing and classing (July 29, 1980), and knitting industries (Feb. 4, 1983). The D.C. Circuit vacated the standard for the cotton seed oil industry. Formal reconsiderations on the cotton dust standard include: deleted standard (June 10, 1981) for cotton ginning; ANPR (Feb. 9, 1982); proposed rule (June 10, 1983).

[f]Lead—Formal Reconsideration: Supplemental Statement of Reasons (Jan. 21, 1981); ANPR (Apr. 21, 1981); Revised Supplemental Statement of Reasons and Amendment of Standard (Dec. 11, 1981. In addition, in 1981, OSHA has on several occasions delayed implementation of several provisions of the lead standard, particularly those involving the trigger levels for medical removal protection.

[g]OSHA deferred the effective date of the hearing conservation amendment from Apr. 15, 1981 to Aug. 21, 1981, when major portions of the standard went into effect. The administrative stay was continued on other provisions to allow reconsideration. See #16 above.

[h]In 1972, OSHA adopted an interpretation of the coal tar pitch volatile standard (Nov. 21, 1972). In 1982, OSHA modified this interpretation to exclude petroleum asphalt from coverage under this standard.

[i]The first proposal for Hazard Communication was published Jan. 16, 1981 and then was withdrawn Feb. 12, 1981.

[j]No criteria document, but NIOSH issued a "Special Occupational Hazard Review" in 1977 and a "Current Intelligence Bulletin" in 1981 for ethylene oxide.

[k]4,4'-methylene-bis (2-chloroaniline).

[l]1,2-dibromo-3-chloropropane.

Table A-2.—Dates of Completed OSHA Rulemakings for Safety Standards

OSHA reg la ion	Advisory[b] committee	Emergency temporary standards (ETS)	Advance notice of proposed rulemaking (ANPR)	Notice of proposed rulemaking	Hearings (beginning day or month)	Final standard	Federal register (vol. and starting p.)	Section 6(f) legal challenge to final rule—(court and date of decision)[c]	Reconsideration
1. Miscellaneous amendments for construction	yes	none	none	09/28/71	11/10/71	02/17/72	37:3512	none	none
2. Cranes/derricks (load indicators)	yes	none	none	09/28/71	11/10/71	07/14/72	37:13763	none	none
3. Roll-over protective structures (construction)	yes	none	none	10/29/71	12/13/7	04/05/72	37:6837	none	none
4. Miscellaneous amendments for construction	yes	none	none	07/29/72	none	11/16/72	37:24345	none	none
5. Power transmission and distribution	yes	none	none	05/10/72	06/27/72	11/23/72	37:24880	none	none
6. Scaffolding, pump jack scaffolding, and roof catch platforms	yes	none	none	06/07/72	07/26/72	12/02/72	37:25712	none	none
7. Lavatories for industrial employment	none	none	none	07/15/72	11/08/72	05/03/73	38:10930	2nd Cir. (10/04/73)	deleted portion of standard (04/28/75)
8. Trucks, cranes, derricks, and indoor general storage	none	none	none	09/ 4/72	none	06/0 /73	38:1437	none	none
9. Temporary flooring—skeleton steel construction	yes	none	none	01/16/74	none	07/02/74	39:24360	none	none
10. Mechanical power presses ("no hands in dies")	none	none	none	03/ 4/72	05/13/74	12/03/74	39:4184	2d Cir. (12/3 /75)	revised standard and reasons (09/17/76)
11. Telecommunications	none	none	none	08/28/73	10/24/73	03/26/75	40:13435	none	none
12. Roll-over protective structures for agricultural tractors	2/20/72	none	none	02/04/75	06/13/74	04/25/75	40:18253	none	none
13. Industrial slings	none	none	none	08/30/73	none	06/27/75	40:27367	3d Cir. (02/ /76)	deleted portion of da (03/30/76)
14. Guarding of farm field equipment, farmstead equipment, and cotton gins	2/19/72	none	none	02/08/74	08/22/74	03/09/76	41:10190	none	none
15. Ground-fault protection	yes	none	none	04/07/75	12/09/75	12/21/76	41:55695	D.C. Ct. of Appeals (06/28/78)	reaffirmed standard (10/13/78)
16. Commercial diving operations[d]	08/76	06/15/76[e]	none	11/05/76	12/16/76	07/21/77	42:37650	5th Cir. (07/16/79)	deleted portion of standard; see also #23 below
17. Standards revocation	none	none	none	12/13/77	none	10/24/78	43:49726	none	none
18. Servicing multi-piece rim wheels	none	none	none	04/24/79	none	01/29/80	45:6706	none	see #25 below
19. Fire protection	none	none	none	12/22/78	08/28/79	09/21/80	45:60656	none	none
20. Guarding of low-pitched roof perimeters during the performance of built-up roofing work	yes	none	none	08/ 7/79	none	1 /14/80	45:75618	none	none
21. Design safety standards for electrical standards	none	none	none	09/25/79	05/06/80	o /16/81	46:4034	none	none
22. Latch-open devices (on gasoline pumps)	none	none	none	03/30/82	none	09/07/82	47:39161	none	none
23. Diving exemptions	none	none	08/17/79	02/26/82	06/29/82	11/26/82	47:53357	D.C. Ct. of Appeals (01/17/84)	none
24. Marine terminals	06/74	none	none	01/16/81	05/25/82	07/05/83	48:30886	D.C. Ct. of Appeals (pending)	none
25. Servicing of single-piece and multi-piece rim wheels	none	none	none	1 / 2/82	none	02/03/84	49:4338	none	none
26. Revocation of advisory "should" and repetitive standards	none	none	none	05/28/82	none	02/10/84	49:5318	none	none

[a]Generally, these regulations are standards issued after rulemaking under the authority of section 6(b) of the OSH Act. In addition, OSHA has rewritten two groups of standards without making any substantive changes: the construction safety standards were reformatted in 1979 (see *Federal Register* 44:8577, 02/09/79) and the shipyard requirements were consolidated in 1982 (see *Federal Register* 47:16984, 04/20/82).
[b]Safety standards concerning construction are reviewed by the standing Advisory Committee for Construction Safety and Health. These are indicated with the notation "yes" in this column. For the ad hoc advisory committees convened only for one specific standard, the date given is for their first meeting.
[c]See table A-3 for the complete citations to these cases.
[d]NIOSH published the equivalent of a criteria document, *Recommended Operating and Medical Standards for Commercial Divers*, Aug. 16, 1976.
[e]The ETS for diving was the subject of a legal challenge. See table A-3.

Table A-3.—Court Cases Involving OSHA Health Standards*

Access to Employee Exposure arid **Medical Records-Louisiana** *Chemical Association et al. v. Bingham et* al.—Fifth Circuit Court of Appeals remanded this case to the U.S. District Court for the Western District of Louisiana 657 F. 2d. 777 (5th Cir., 1981). District Court affirmed the standard, 550 F. Supp 1136 (1982); Fifth Circuit Court of Appeals affirmed, without opinion, the decision of the District Court (May 16, 1984).

Acryionitrile— *Vistron v. OSHA* (6th Cir., Mar. 28, 1978), emergency temporary standard contested, request for stay of standard was denied, 6 OSCH 1483. The petition for review was then withdrawn.

Arsenic (Inorganic)–ASARCO *Inc. et al. v. OSHA, 746* F.2d 483 (9th Cir., Sept. 13, 1984)-Court remanded arsenic standard to OSHA (Apr. 7, 1981). After OSHA developed a risk assessment to comply with the Supreme Court's ruling in the Benzene case, the Ninth Circuit Court of Appeals affirmed the arsenic standard.

Asbestos—industrial Union Department, AFL-CIO v. Hodgson, 499 F.2d 467, (D.C. Cir., Apr. 15, 1974)—Affirmed OSHA's 1972 asbestos standard.

Asbestos— *Asbestos Information Association/North America v. OSHA, 727* F.2d. 415 (5th Cir., Mar. 7, 1984)-Vacated the emergency temporary standard issued on Nov. 4, 1983.

Benzene–American Petroleum Institute v. OSHA, 581 F.2d 493 (5th Cir., Oct. 5, 1978); *Industrial Union Department, AFL-CIO v. American Petroleum Institute, 448* U.S. *807* (Supreme Court, July 2, 1980)-Both the 5th Circuit Court of Appeals and the Supreme Court vacated the OSHA benzene standard, although for different reasons.

Cancer *Policy—American Petroleum Institute, et al. v. OSHA, et al., Nos. 80-3018,* et al. (5th Cir., pending).

Coke **Oven** *Emissions—American Iron & Steel Institute v. OSHA, 577* F.2d 825 (3d Cir., Mar. 28, 1978)—Third Circuit Court of Appeals largely affirmed the Coke Oven Emissions standard. The Supreme Court agreed to review this decision, but the request for review was withdrawn before the case could be heard. 448 U.S. 917 (1980)

Cotton Dust—AFL-CIO v. *Marshall,* **617 F.2d** 636 **(D.C.** Cir., Oct. 10, 1979); *American Textile Manufacturers Institute, Inc. v. Donovan, 452* U.S. **490** (June 17, 1981)-D.C. Court of Appeals and the Supreme Court both upheld the major requirements of the cotton dust standard as applied to the textile industry.

Cotton Dust–Cotton *Warehouse Association v. Marshall, 449* U.S. 809 (Oct. 6, 1980)-Supreme Court granted a petition for review and vacated the decision of the court of appeals with respect to the warehousing and classing segments of the industry.

Cotton Dust—Texas *Independent Ginners Association v. Marshall, 630* F.2d 398 (5th Cir., November 14, 1980)-Vacated cotton dust standard as applied to cotton ginning operat ions.

Ethylene *Oxide—Public Citizen Health Research Group, et al. v. Auchter, 554* F. Supp. 242 (D.C. District Court, Jan. 5, 1983). Public Citizen's Health Research, et al,, v. *Auchter, et al., 702* F.2d. 1150 (D.C. Cir., Mar. 15, 1983)–Public Citizen requested a court order compelling OSHA to issue an emergency temporary standard. The District Court decided to issue such an order. The case was appealed to the D.C. Court of Appeals, which refused to order that an emergency temporary standard be issued, but did order that OSHA expedite its section 6(b) rulemaking.

Fourteen Carcinogens—Dry *Color Manufacturing Association v. Department of Labor, 486* F.2d 98 (3d Cir., Oct. 4, 1973)—Vacated the emergency temporary standard for two of the fourteen carcinogens.

Fourteen *Carcinogens-Synthetic Organic Chemical Chemical Manufacturers Association v. Brennan, 503* F.2d 1155 (3d Cir., Aug. 26, 1974)–Affirmed standard for ethyleneimine under the 14 Carcinogens standard (SOCMA l). A petition for rehearing was denied Oct. 6, 1975. The Supreme Court denied a request for review, 420 U.S. 973 (Mar. 17, 1975).

Fourteen Carcinogens-Synthetic *Organic Chemical Manufacturers Association v. Brennan, 506* F.2d 385 (3d Cir., Dec. 17, 1974)—Third Circuit Court of Appeals vacated the standard for MOCA (1 of the 14 carcinogens) (SOCMA II). The Supreme Court denied **a** request for review. Oil, *Chemical and Atomic Workers International Union, AFL-CIO v. Dunlop, 423* U.S. 830 (Oct. 6, 1975).

Hazard Communication *(Labelling--United Steelworkers of America, Public Citizen, State of Massachusetts, Fragrance Materials Association, People of the State of II-iinois, Flavor& Extract Manufacturing Association, State of New York v. Auchter, Nos. 83-3554, 83-3561, 83-3565, 84-3066, 84-3087, 84-3093, 84-3117, 84-3128* (3d Cir., pending).

Occupational Noise Exposure/Hearing Conservation Amendment *—Forging Industry Association v. Sec. of* Labor *No. 83-1232* (4th Cir., Nov. 7, 1984)-Fourth Circuit Court of Appeals vacated the Hearing Conservaton Amendment.

Lead–United Steelworkers of America v. Marshall, 647 F.2d 1189 (D.C. Cir., Aug. 15, 1980)-The D.C. Court of Appeals affirmed the lead standard in part, but directed OSHA to determine the feasibility of engineering controls for 38 industries and occupations. The Supreme Court denied a request for review *Lead Industries Association, Inc. v. Donovan, 453* U.S. 913 (1981)

Pesticides—Florida *Peach Growers Association, Inc. v. Department of Labor, 489* F.2d 120 (5th Cir., Jan. 9, 1974)–The Fifth Circuit Court of Appeals vacated the emergency temporary standard for pesticides.

Vinyl Chloride-Society of *the Plastics Industry, Inc. v. OSHA, 509* F.2d 1301 (2d Cir., Jan, 31, 1975)—The *Second Circuit* Court of Appeals affirmed the vinyl chloride standard. The Supreme Court denied a request for review Firestone Plastics Co. v. *U.S. Department of* Labor 421 U.S. 992 (May 27, 1975).

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Lavatories for Industrial Employment-Associated *industries of New York State, Inc. v. Department of Labor, et al., 487* F.2d 342 (2d Cir., Oct. 4, 1973)—The Second Circuit Court of Appeals vacated the OSHA lavatory standard.

Mechanical Power *Presses-AFL-CIO v. Brennan, 530* F.2d **109 (3d Cir., Dec. 31, 1975)–The Third Circuit Court of Appeals remanded to OSHA for a new statement of reasons and then affirmed OSHA's changes to the "no hands in die" standard.**

Commercial Diving Operations— Taylor *Diving and* Salvage

Table A-3.—Continued

v. U.S. *Department of Labor* 537 F.2d 819 (5th Cir.,1976)—Court issued an indefinite stay of the ETS for commercial diving.

Commercial **Diving Operations– Taylor** *Diving* **and** Salvage v. *U.S.* ***Department of Labor 599*** F.2d 622 (5th Cir., July 16, 1979)—Vacated the medical requirements section (29 CFR 1910,411) of the final standard for commercial diving.

Diving Exemptions-United Brotherhood ***of*** Carpenters **and** *Joiners of America, AFL-CIO v. U.S. Department of Labor, No. 82-2509,* D.C. Cir,, Apr. 4, 1984)-After oral argument, court remanded case to OSHA for additional information.

Ground-Fault ***Protectlon--National Constructors Association v. Marshall 581*** F.2d. 960 (D.C. Cir., June 28, 1978)—The Court of Appeals for the D.C. Circuit remanded the record to OSHA with specific instruction to consult the Advisory Committee.

Fire Protection-Fim Equipment v. Marshall 679 F.2d 679 (7th Cir., May 27, 1982)-case was dismissed for lack of standing. Request for rehearing was denied (July 22, 1962).

Industrial Slings--Bethlehem Steel Corp. v. Dunlop 540 F.2d, 157 (3d Cir., Feb. 11, 1976)—Vacated one paragraph of the standard (29 CFR 1910.184) and remanded the standard to the Secretary of Labor.

Marine ***Terminals--National Grain and Feed Association (D.C.*** Cir., pending).

"NOTES: F.2d—Federal Reporter, Second Series.
U. S.–U.S. Supreme Court Reports.
F. Supp.—Federal Supplement.

Table A-4.-Safety and Health Inspections

Fiscal year	Establishment inspections (number)	Safety inspections (number)	Safety inspections (percent)	Health inspections (number)	Health inspections (percent)	Employees covered by inspections (number)
Faderal OSHA:						
1973	48,409	45,225	93.4 "/0	3,184	6.6%	5,440,303
1974	77,142	73,189	94.9	3,953	5.1	6,448,067
1975 ....., ...	80,978	75,459	93.2	5,519	6.8	6,180,881
1976	90,482	82,885	91.6	7,597	8.4	6,601,729
1977	60,004	50,892	84.8	9,112	15.2	5,285,946
1978	57,278	46,621	81.4	10,657	18.6	4,522,582
1979 ...., ...	57,734	46,657	80.8	11,077	19.2	4,262,749
1980	63,404	51,565	81.3	11,839	18.7	3,690,993
1981	56,994	46,236	81.1	10,758	18.9	2,672,129
1982	52,818[a]	43,609	82.6	9,209	17.4	2,235,823
1983	58,516[b]	48,269	82.5	10,247	17.5	2,925,049
1984 (Oct. -Mar.) . .	30,606[c]	25,086	82.0	5,520	18.0	1,552,120

Fiscal year	Establishment inspections (number)	Safety inspections (number)	Safety inspections (percent)	Health inspections (number)	Health inspections (percent)	Employees covered by inspections (number)
State programs:						
1976[d]	166,612	144,780	86.9	21,832	13.1	7,078,294
1977	143,469	130,643	91.1	12,826	8.9	6,000,009
1978	122,761	112,446	91.6	10,255	8.4	5,739,574
1979	107,636	99,509	92.4	8,127	7.6	4,932,303
1980	106,191	98,829	93.1	7,288	6.9	4,340,266
1981	108,376	99,303	91.6	9,073	8.4	4,404,364
1982	92,942	84,570	91.0	8,372	9.0	3,464,146
1983	103,879[e]	93,406	89.9	10,473	10.1	3,818,287
1984 (Oct. -Mar.) . .	51,072[f]	46,065	90.2	5,007	9.8	1,858,114

[a] Does not include 8,444 "Records Review" inspections in fiscal Year 1982.
[b] Does not include 1(),402 "Records Review" inspections in fiscal Year 1983.
[c] Does not include 4,9s4 "Records Review" inspections during the first 6 months (Oct. -Mar.) Of fiscal year 1984.
[d] No data available prior to 1976
[e] State data does not Include 2,554 "Records Reivew" inspections in fiscal Year 1983.
[f] State data does not include 1,383 ', Records Review" inspections during the first 6 months (Oct.-Mar.) of fiscal year 1964,

SOURCE' Office of Technology Assessment, based on data supplied by OSHA.

Notes to Tables A-4 Through A-11.-State Program Data

Fiscal Year	States included in totals
1976	AK, AZ, CA, CO, CT, HI*, IN*, IA, KY, MD, MI, MN, NV*, NM*, NC, OR, PR*, SC, TN, UT, VT, VI, VA*, WA, WY*
1977	AK, AZ, CA, CO, CT, HI, IN, IA, KY, MD, MI, MN, NV, NM, NC, OR, PR*, SC, TN, UT, VT, VI, VA, WA, WY
1978	AK, AZ, CA, CO*, CT, HI, IN, IA, KY, MD, MI, MN, NV, NM, NC, OR, PR*, SC, TN, UT, VT, VI, VA, WA, WY
1979	AK, AZ, CA, CT, HI, IN, IA, KY, MD, MI, MN, NV, NM, NC, OR, PR*, SC, TN, UT, VT, VI, VA, WA, WY
1980	AK, AZ, CA, CT, HI, IN, IA, KY, MD*, MI, MN*, NV, NM*, NC*, OR, SC, TN, UT, VT, VI, VA*, WA, WY
1981	AK, AZ, CA, CT, HI, IN, IA, KY, MD, MI, MN, NV, NM, NC, OR, SC, TN, UT, VT, VI*, VA, WA, WY
1982	AK, AZ, CA, CT, HI, IN*, IA*, KY*, MD, MI, MN*, NV, NM, NC, OR*, SC*, TN, UT*, VT, VA, WA, WY
1983	AK, AZ, CA, CT, HI, IN, IA, KY, MD, MI, MN, NV, NM, NC, OR, PR, SC, TN, UT, VT, VI, VA, WA, WY
1984	AK, AZ, CA, CT, HI, IN, IA, KY, MD, MI, MN, NV, NM, NC, OR, PR, SC, TN, UT, VT, VI, VA, WA, WY

*One or more quarters of data missing from totals.

Table A-5-Types of **Inspection**

Federal OSHA

Fiscal year	Establishment inspection (number)	Fatality/ catastrophe (number)	Fatality/ catastrophe (percent)	Complaint (number)	Complaint (percent)	Programed (number)	Programed (percent)
1973	48,409	2,454	5.1%	6,618	13.7%	32,207	66.5%
1974	77,142	2,221	2.9	6,415	8.3	56,384	73.1
1975	80,978	1,885	2.3	7,161	8.8	56,560	69.8
1976	90,482	1,923	2.1	9,217	10.2	68,451	75.7
1977	60,004	1,781	3.0	19,415	32.4	24,855	41.4
1978	57,278	2,086	3.6	21,518	37.6	20,239	35.3
1979	57,734	2,281	4.0	20,041	34.7	23,735	41.1
1980	63,404	2,300	3.6	16,044	25.3	33,390	52.7
1981	56,994	2,221	3.9	13,353	23.4	36,018	63.2
1982	52,818	1,884	3.6	6,766	12.8	42,601	80.7
1983	58,516	1,472	2.5	6,493	11.0	48,949	83.6
1984 (Oct.-Mar.) ..	30,606	706	2.3	3,566	11.7	25,535	83.4

State programs

Fiscal year	Establishment inspection (number)	Fatality/ catastrophe (number)	catastrophe (percent)	Complaint (number)	Complaint (percent)	Programed (number)	Programed (percent)	Follow-up (number)	Follow-up (percent)
1976	166$612	4,278	2.6%	13,966	8.4%	119,120	71.5%	29,216	17.5%
1977	143,469	3,652	2.5	14,404	10.0	101,571	70.8	23,842	16.6
1978	122,761	4,609	3.8	15,467	12.6	81,762	66.6	20,923	17.0
1979	107,636	5,181	4.8	15,285	14.2	70,762	65.7	16,408	15.2
1980	106,191	5,264	5.0	13,823	13.0	72,899	68.6	14,168	13.3
1981	108,376	5,259	4.9	14,365	13.3	75,839	70.0	12,858	11.9
1982	92,942	4,663	5.0	10,721	11.5	68,100	73.3	9,455	10.2
1963	103.879	5.366	5.2	11.623	11.2	78.796	76.0	8.094	7.8
1984 (Oct.-Mar.)..	51,072	2,849	5.6	5,754	11.3	39,085	76.5	3,384	6.6

SOURCE: Office of Technology Assessment, based on data supplied by OSHA.

Table A-6.—Inspections by Industry

Fiscal year	Establishment inspections (number)	Construction (number)	Construction (percent)	Maritime (number)	Maritime (percent)	Manufacturing (number)	Manufacturing (percent)	Other Industries (number)	Other Industries (percent)
Federal OSHA									
1973	48,409	13,246	27.4%	7,811	6.1%	21,871	45.2%	5,481	11.3%
1974	77,142	26,820	34.8	5,457	7.1	33,541	43.5	11,324	14.7
1975	80,978	23,395	28.9	2,229	2.8	36,773	45.4	18,581	22.9
1976	90,482	23,639	26.1	1,647	1.8	39,566	43.7	20,630	22.8
1977	60,004	15,561	25.9	1,368	2.3	31,290	52.1	11,785	19.6
1978	57,278	14,561	25.4	1,335	2.3	29,969	52.3	11,413	19.9
1979	57,734	17,798	30.8	1,450	2.5	27,428	47.5	11,058	19.2
1980	63,404	26,317	41.5	1,078	1.7	27,189	42.9	8,820	13.9
1981	56,994	25,922	45.5	1,096	1.9	22,576	39.6	7,400	13.0
1982	52,818	29,313	55.5	848	1.6	18,030	34.1	4,627	8.8
1983	58,516	34,020	58.1	849	1.4	19,054	32.5	4,593	7.8
1984 (Oct.-Mar.) ..	30,606	18,217	59.5	362	1.2	9,234	30.2	2,793	9.1

State programs

Comparable data for State programs are not readily available

SOURCE: Office of Technology Assessment, based on data supplied by OSHA.

Table A-7.—Inspections With Violations; Inspections Contested

Fiscal year	Establishment inspections (numbed	Inspections with serious violations (number)	(percent)	Inspections with willful violations (number)	(percent)	Inspections with repeat violations (number)	(percent)	Inspections with other-than-serious violations (number)	(percent)	Inspections contested (number)	(percent)
1973	48,409.	1,535	3.2%	18	0.0%	41	0.1%	23,814	49.2%	1,3 5	2.7%
1974	77,142	2,735	3.5	58	0.1	495	0.6	48,024	62.3	2,447	3.2
1975	80,978	3,335	4.1	104	0.1	1,175	1.5	50,985	63.0	3,188	3.9
1976	90,482	5,930	6.6	153	0.2	2 a	2.4	59,091	65.3	5,007	5.5
1977	60,004	11,0%?	18.5	169	0.3	2,356	3.9	31,126	51.9	4,209	7.0
1978	57,278	14,620	25.5	428	0.7	2,191	3.8	25,257	44.1	5,4 '4	9.6
1979	57,734	16,624	28.8	587	1.0	2,243	3.9	25,068	43.4	6,6913	11.6
la m	63,404	19,358	30.5	595	0.9	2,021	3.2	27,366	432	7,39n	11.7
1981	56,994	16,237	28.5	241	0.4	1,318	2.3	26,717	46.9	&582	6.3
1882	52,818	12,852	24.3	86	0.2	810	1.5	26,187	49.6	1,47'0	28
1963	58,516	14,886	25.4	105	0.1	1,032	1.7	30,472	52.0	1,142	1.9
1984 (Oct.-Mar.)	30,606	8.156	26.7	65	0.2	610	2.0	15201	48.7	584	1.9

State Programs

Fiscal year	Establishment inspections (number)		Inspections contested (number)	(percent)
1876	166,612		&277	3.8%
1977	143,469		5,024	3.5
1878.	122,761		4,703	3.8
1979	107,636		5,171	4.8
1860	106,191	Comparable data for state programs are not readily available	4,308	4.1
1981	106,376		4,452	4.1
1862	92,942		3,292	3.5
1983	103,878		3,322	3.2
1964 (oCt.-Mar.)	51,072		1,686	3.3

SOURCE: Office of Technology Assessment, based on data supplied by OSHA.

Table A-8.—Violations by Type

Federal OSHA

Fiscal year	Serious violations (number)	Willful violations (number)	Repeat violations (number)	Other-than-serious violations (number)	Other-than-serious violations with penalty (number)	Total all violations (number)
1973	1,767	20	80	141,623	52,535	143,490
1974	3,111	108	913	286,032	98,594	290,164
1975	4,047	176	2,327	306,329	95,616	312,879
1976	7,790	207	4,514	367,279	110,431	379,790
1977	20,794	231	4,347	156,137	15,402	181,509
1978	32,989	711	4,195	96,170	3,664	134,065
1979	37,545	970	3,882	85,776	2,363	128,173
1980	44,350	1,027	3,482	83,147	1,891	132,006
1981	32,143	523	2,177	76,518	1,147	111,361
1982	22,522	111	1,251	73,233	742	97,117
1983	26,292	150	1,561	83,732	2,009	111,735
1984 (Oct.-Mar.)	14,907	88	908	40,541	298	56,444

State programs

Fiscal year	Serious violations (number)	Willful violations (number)	Repeat violations (number)	Other-than-serious violations (number)	Other-than-serious violations with penalty (number)	Total all violations (number)
1976	6,010	119	6,338	416,055	119,330	422,065
1977	9,966	142	7,195	342,179	54,282	352,145
1978	21,979	112	5,383	298,569	24,512	320,548
1979	28,923	159	4,662	246,519	16,745	275,442
1980	28,446	193	3,898	214,803	11,110	243,249
1981	29,724	215	4,002	205,014	10,658	234,738
1982	21,813	112	2,937	172,506	5,962	194,319
1983	27,192	172	3,587	198,892	4,684	229,843
1984 (Oct.-Mar.)	13,385	88	1,302	93,073	2,428	108,348

SOURCE: Office of Technology Assessment, based on data supplied by OSHA.

Table A-9.—Percentage Distribution of Violations

Fiscal year	Total all violations (number)	Serious violations (percent)	Willful violations (percent)	Repeat violations (percent)	Other-than-serious violations (percent)	Other-than-serious violations with penalty (percent)
Federal OSHA						
1973	143,490	1.2%	0.0%	0.1%	98.7%	36.6%
1974	290,164	1.1	0.0	0.3	98.6	34.0
1975	312,879	1.3	0.1	0.7	97.9	30.6
1976	379,790	2.1	0.1	1.2	96.7	29.1
1977	181,509	11.5	0.1	2.4	86.0	8.5
1978	134,065	24.6	0.5	3.1	71.7	2.7
1979	128,173	29.3	0.8	3.0	66.9	1.8
1980	132,006	33.6	0.8	2.6	63.0	1.4
1981	111,361	28.9	0.5	2.0	68.7	1.0
1982	97,117	23.2	0.1	1.3	75.4	0.8
1983	111,735	23.5	0.1	1.3	74.9	1.7
1984 (Oct.-Mar.)	56,444	26.4	0.1	1.6	71.8	0.5

Fiscal year	Total all violations (number)	Serious violations (percent)	Willful violations (percent)	Repeat violations (percent)	Other-than-serious violations (percent)	Other-than-serious violations with penalty (percent)
State programs						
1976	422,065	1.4%	0.0%	1.5%	98.6%	28.3%
1977	352,145	2.8	0.0	2.0	97.2	15.4
1978	320,548	6.9	0.0	1.7	93.1	7.6
1979	275,442	10.5	0.1	1.7	89.5	6.1
1980	243,249	11.7	0.1	1.6	88.3	4.6
1981	234,738	12.7	0.1	1.7	87.3	4.5
1982	194,319	11.2	0.1	1.5	88.8	3.1
1983	229,843	11.8	0.1	1.6	86.5	2.0
1984 (Oct.-Mar.)	108,348	12.4	0.1	1.7	85.9	2.2

SOURCE: Office of Technology Assessment, based on data supplied by OSHA.

Table A-10.—Total Proposed Penalties

Fiscal year	Serious penalties (dollars)	Willful penalties (dollars)	Repeat penalties (dollars)	Failure to abate penalties (dollars)	Other-than-serious penalties (dollars)	Total penalties (dollars)	Total penalties collected[a] (dollars)
Federal OSHA							
1973	1,114,937	116,100	107,904	81,833	2,339,218	3,759,992	
1974	1,792,061	292,195	225,914	154,095	4,053,018	6,517,283	
1975	2,189,846	446,721	530,754	381,682	3,991,375	7,540,378	
1976	4,244,531	637,762	932,778	781,833	4,626,169	11,223,043	
1977	6,039,780	690,800	1,053,085	773,537	937,439	9,494,641	6,788,851
1978	9,406,461	2,460,327	1,799,512	829,249	322,210	14,817,759	8,085,291
1979	10,256,108	3,637,291	1,666,055	1,023,773	221,194	16,804,421	9,530,601
1980	11,301,487	3,331,606	1,664,652	1,257,232	208,218	17,763,195	10,605,040
1981	6,724,971	1,914,298	836,457	526,221	103,531	10,105,478	9,694,752
1982	4,396,899	484,354	400,178	169,662	63,463	5,514,556	5,037,087
1983	4,645,850	683,235	540,541	384,186	149,376	6,403,188	6,299,232
1984 (Oct.-Mar.)	2,783,716	437,993	370,666	209,556	30,177	3,832,108	8,512,482

Fiscal year	Serious penalties (dollars)	Willful penalties (dollars)	Repeat penalties (dollars)	Failure to abate penalties (dollars)	Other-than-serious penalties (dollars)	Total penalties (dollars)	Total penalties collected[a] (dollars)
State programs							
1976	2,522,890	430,214	727,800	766,433	3,892,393	6,415,283	
1977	2,921,754	353,218	721,969	954,000	2,126,456	5,048,210	
1978	4,610,529	355,523	1,060,287	1,267,645	1,665,914	6,276,443	
1979	6,925,293	456,156	1,170,743	1,049,838	1,242,639	8,167,932	Not readily available
1980	7,056,566	693,343	985,647	674,843	924,403	7,980,969	
1981	6,276,557	678,577	1,802,737	,933,254	796,261	7,072,818	
1982	4,377,598	352,369	676,836	1 396,656	604,681	4,982,279	
1983	4,542,914	535,399	685,413	618,140	651,498	7,033,364	
1984 (Oct.-Mar.)	2,359,324	356,855	384,335	285,391	335,365	3,721,270	

[a]Penalties collected in a year do not directly relate to penalties proposed in that year.

SOURCE: Office of Technology Assessment, based on data supplied by OSHA.

Table A-11.--Average Proposed Penalties

***Federal** OSHA*

Fiscal year	Violations: Serious (average penalty)	Willful (average penalty)	Repeat (average penalty)	Other-than serious (average penalty)	Average penalty per inspection	Average penalty per violation
1973	631	5,805	1,349	45	78	26
1974 ...., ...	576	2,706	247	41	84	22
1975	541	2,538	228	42	93	24
1976	545	3,081	207	42	124	30
1977	290	2,990	242	61	158	52
1978	285	3,460	429	88	259	111
1979	273	3,750	429	94	291	131
1980	255	3,244	478	110	280	135
1981	209	3,660	384	90	177	91
1982	195	4,364	320	86	104	57
1983	177	4.555	346	74	179	257
1984 (Oct.-Mar.) . .	187	4;977	408	101	211	68

State programs

Fiscal year	Violations: Serious (average penalty)	willful (average penalty)	Repeat (average penalty)	Other-than-serious (average penalty)	Average penalty per inspection	Average penalty per violation
1976, ...	420	3,615	115	33	39	15
1977, ...	293	2,487	100	39	35	
1978.	210	3,174	197	68	51	20
1979.	239	2,869	251	74	76	30
1980	248	3,592	253	63	75	33
1981	211	3,156	450	75	65	30
1982	201	3,146	230	101	54	26
1963	167	3,112	191	139	68	31
1984 (Oct.-Mar.) . .	176	4,055	213	138	73	34

SOURCE: Office of Technology Assessment, based on data supplied by OSHA.

Table A-12.—Occupational Safety and Health: Coverage of Workers

Agency	Type of workers covered	Number of workers covered	Basis for agency authority	Comments
Department of Labor				
Occupational Safety and Health Administration (OSHA) and State Programs approved by OSHA	All employees and working conditions except: Federal employees, and those covered by other governmental agencies according to other statutes	75,031,000[a] (1979 estimate)	Occupational Safety and Health Act of 1970	In some cases, another Federal agency is responsible for only certain aspects of safety and health, and the same workers may be covered by OSHA for the remaining aspects (see e.g., NRC in this table)
Mine Safety and Health Administration (MSHA)	Coal, metal and nonmetal mining workers. All employees on mine property are covered	467,095 (1 2 preliminary estimate)[b]	Federal Mine Safety and Health Act of 1977	
Department of Transportation:				
Bureau of Motor Carrier Safety (BMCS) (Federal Highway Administration)	Employees in, on, or about motor vehicles engaged in interstate commerce	Approximately 4.5 million[c]	Interstate Commerce Act	Does not include workers in repair garages, or workers on loading docks, who are all covered by OSHA
Federal Aviation Administration (FAA)	All flight crews; ground crews and mechanics during some activities	Approximately 170,000[d]	Federal Aviation Act of 1956	Coverage of ground crews is the focus of a dispute between the FAA and OSHA
Federal Railroad Administration (FRA)	All operating employees, i.e., employees on rolling stock plus certain railroad yard employees	143,617 (1979 preliminary estimate)[e]	Federal Railroad Safety Act of 1970	
U.S. Coast Guard	Seamen on Coast Guard-inspected and certificated vessels	About 100,000[f] (1963 estimate)	The Marine Safety Laws	OSHA has jurisdiction over shipyard workers and longshoremen
Other Federal Agencies:				
Department of Energy (DOE)	Employees in Government-owned contractor operator (GOCO) facilities, e.g., those involved in research in nuclear energy, weapons research and production, production of enriched uranium.	116,323[g] (1962 estimate)	Atomic Energy Act of 1954, as amended	DOE has adopted OSHA's health and safety regulations; DOE does not cover employees during initial construction of facilities
Nuclear Regulatory Commission (NRC)	Workers exposed to radiation hazards from materials licensed by the NRC, including: 1) source material (uranium and thorium); 2) special nuclear material (material capable of being fissioned); 3) by-products of a) fission; and b) tailings from uranium ore processing	327,350[h] (1979 estimate)	Atomic Energy Act of 1954, as amended	NRC covers only radiation hazards; OSHA is responsible for all other safety and health aspects. NRC licenses State plans in some States, similar to OSHA State Programs

Table A-12.—Occupational Safety and Health: Coverage of Workers-Continued

Agency	Type of workers covered	Number of workers covered	Basis for agency authority	Comments
Federal Government departments and independent agencies	Each covers its own federally-employed workers.	6,271,736[i] (fiscal year 1962)	Occupational Safety and Health Act of 1970	Agency programs must be "consistent with" occupational safety and health standards promulgated by OSHA
Environmental Protection Agency	Mixers, loaders, and applicators of pesticides; farm field workers		Federal Insecticide, Fungicide, and Rodenticide Act	For mixers, loaders and applicators, protection from pesticide exposure is through labeling requirements. OSHA has jurisdiction for other health and safety aspects of these jobs.

[a]Office of Statistical Studies and Analysis, OSHA. Includes all private-sector employees covered directly by Federal OSHA and State Programs.
[b]Personal communication, MSHA, Mar. 3, 1983.
[c]Personal communication, BMCS.
[d]Persoal communications. Air Transport Association and Regional Airline Association
[e]*Yearbook of R&"/o@ Facts*, June 1980.
[f]Personal communication, U.S. Coast Guard.
[g]DOE, Rep@ of *Employment &@ Labor Turnover*, Sept. 30, 1982.
[h]NRC, "Occupational Radiation Exposure, Twelfth *Annual Report, 1979* (1982).
[i]U.S. Department of Labor, *Federal Compliance Activity Report*, Jan. 4, 1983.

SOURCE: Office of Technology Assessment.

Table A-13. -Analyses of OSHA, NIOSH, and ACGIH Protective Levels

Substance (notes) (36)	OSHA TWA mg/m³	OSHA ceiling mg/m³	NIOSH TWA (1) mg/m³	NIOSH ceiling mg/m³	ACGIH TWA mg/m³	ACGIH ceiling mg/m³
Acetylene (10)	2,662	none	none	2,662	NONE	NONE
Acrylamide (35)	0.3	none	0.3	none	0.3	0.6
Acrylonitrile (11)	4.3	21.7	none	8.7	4.5	none
Aldrin/Dieldrin (12,27,35)	0.25	none	0.15	none	0.25	0.75
Alkanes: (14)						
Pentane	2,945	none	350	1,800	1,800	2,250
Hexane	1,800	none	350	1,800	180	none
Heptane	2,000	none	350	1,800	1,600	2,000
Octane	2,350	none	350	1,800	1,450	1,800
Allyl chloride	3	none	3.1	9.3	3	6
Ammonia		none	none	34.8		27
Antimony	0.5	none	0.5	none	0.5	none
Arsenic, inorganic compounds	0.01	none	none	0.002	0.2	none
Asbestos (9)....	2	10	0.1	0.5	2	none
Asphalt (petroleum) fumes	NONE	NONE	none	5		10
Benzene (2,16)	32	80	none	3.2	30	75
Benzoyl peroxide	5	none	5	none	5	none
Benzyl chloride	5	none	none	5	5	none
Beryllium (2,16)	0.002	0.005	0.0005	none	0.002	none
Boron trifluoride (13,15)	none	3	NONE	NONE	none	3
Cadmium, fume (2,23)	0.1	0.3	0.04	0.2	0.05	0.2
dust (2,23)	0.2	0.6	0.04	0.2	0.05	0.2
Carbaryl	5	none	5	none	5	10
Carbon black (18)	3.5	none	3.5	none	3.5	
Carbon dioxide (17)	9,000	none	18,000	54,000	9,000	27,000
Carbon disulfide (2)	62	93	3	30	30	none
Carbon monoxide	55	none	40	229	55	330
Carbon tetrachloride (2,16)	63	157	none	12.6	30	125
Chlorine	none	3	none	1.45	3	9
Chloroform (15,16)	none	240	none	9.78	50	225
Chloroprene (35)	90	none	none	3.6	45	none
Chromium (VI), water soluble(3)	0.5	none	0.025	0.05	0.05	none
Chromium (VI), insoluble (3)	1	none	0.001	none	0.05	none
Coal tar products (5)	0.2	none	0.1	none	0.2	none
Cotton dust(6)..	0.2	none	0.2	none	0.2	none
Cresol	22	none	10	none	22	none
Cyanide (17,35)	5	none	none	5	5	none
DDT (26,37,35)		none	0.5	none	1	3
I,2-dibromo-3-chloropropane (DBCP) (16,34)	0,0096	none	none	0.1	none	none
Diisocyanates:						
Toluene-2,4-diisocyanate (15)	none	0.14	0.035	0.14	0.04	0.15
Diphenylmethane diisocyanate (13,15)	none	0.2	0.05	0.2	none	0.2
Isophorene diisocyanate	NONE	NONE	0.045	0.18	0.09	none
Dinitro-ortho-cresol (35)	0.2	none	0.2	none	0.2	0.6
Dioxane (35).....	360	none	none	3.6	90	360
Epichlorohydrin (35)	20	none	2	19	10	20
Ethylene dibromide (2)	154	230	none	1	none	none
Ethylene dichloride (2)	202	405		8	40	60
Ethylene oxide (27,37)	90	none	90	135	2	none
Fibrous glass, (dust) (29)	15	none	5	none	10	none
Fluorides, inorganic(2)	2.5	none	2.5	none	2.5	none
Formaldehyde (2,13,16)	3.7	6	none	1.2	1.5	3
Furfuryl alcohol ....,	200	none	200	none	40	60
Glycidyl ethers:						
Allylglycidyl ether (15)	none	45	none	45	22	44
n-Butyl glycidyl ether	270	none	none	30	135	none
Di-2,3-epoxypropyl ether (diglycidyl ether) (DIE)	none	2,8	none	1	0.5	none
Isopropyl glycidyl ether	240	none	none	240	240	360
Phenylglycidyl ether (PAGE)	60	none	none	5	6	none

Table A-13.--Analysis of OSHA, NIOSH, and ACGIH Protective Levels

Substance (notes) (36)	OSHA TWA mg/m^3	OSHA ceiling mg/m^3	NIOSH TWA (1) mg/m^3	NIOSH ceiling mg/m^3	ACGIH TWA mg/m^3	ACGIH ceiling mg/m^3
Hydrszines: (16)						
Hydrazine (16,35)	1.3	none	none	0.04	0.1	none
1,1-DImethyl hydrazine (16,35),	1	none	none	0.15		2
Phenyl hydrazine (16,35)	22	none	none	0.6	20	45
Methyl hydrazine (13,15,16,35).	none	0.35	none	0.08	none	0.35
Hydrogen fluoride (2)	2.45	none	2.5	5	2.5	5
Hydrogen sulfide (2,17)	none	16	none	15	14	21
Hydroquinone	2	none	none	2		4
isopropyl alcohol.	980	none	984	1,968	9 2	1,225
Ketones:						
Acetone	2,400	none	590	none	1,780	2,375
Methyl ethyl ketone (MEK)	590	none	590	none	590	885
Methyl n-propyl ketone	700	none	530	none	700	875
Methyl n-butyl ketone.	410	none	4	none	20	none
Methyl n-amyl ketone	465	none	465	none	235	465
Methyl isobutyi ketone..	410	none	200	none	205	300
Methyl isoamyl ketone (20)	NONE	NONE	230	none	240	none
Diisobutyl ketone	290	none	140	none	150	none
Cyciohexanone	200	none	100	none	100	400
Mesityl oxide...		none	40	none	60	100
Diacetone alcohol.	240	none	240	none	240	360
Isophorone (13)	140	none	23	none	none	25
Lead, inorganic (33)	0.05	none	0.1	none	0.15	0.45
Malathion	15	none	15	none	10	none
Mercury, inorganic (2,4,24).	0.1	none	0.05	none	0.1	none
Methyl alcohol..	260	none	262	1,048	260	310
4,4-Methylene-bis-2-chloroaniline (MOCA) (8,27)..	NONE	NONE	0.003	none	0.22	none
Methyl parathion	NONE	NONE	0.2	none	0.2	0.6
Methylene chloride (2,19)	1,736	3,476	261	1,740	350	1,740
Nickel carbonyl (27)	0.007	none	0.007	none	0.35	none
Nickel, inorganic and compounds	1	none	0.015	none	0.1	0.3
Nitric acid	5	none	5	none	5	10
Nitrides:						
Acetonitrile	70	none	34	none	70	105
Tetramethyl succinonitrile.	3	none	none	6	3	9
Nitrogen, oxides NO_2: (15)	none	9	none	1.8	6	10
(Nitric oxide) NO:	30	none	30	none	30	45
Nitroglycerin (15,16)	none	2	none	0.1	0.5	
Ethylene glycol dinitrate (15).	none	1	none	0.1	0.3	0.6
Parathion	0.1	none	0.05	none	0.1	0.3
Phenol	19	none	20		19	38
Phosgene	0.4	none	0.4	0.8	0.4	none
Polychlorinated biphenyls: (35)						
Chlorodiphenyl (42%).	1	none	0.001	none	1	2
Chlorodiphenyl (54%).		none	0.001	none	0.5	1
Refined petroleum solvents (7).	2,950	none	350	1,800	NONE	NONE
Silica (quartz, respirable dust)	0.098	none	0.05	none	0.1	none
Sodium hydroxide (13)	2	none	none	2	none	2
Sulfur dioxide	3	none	1.3	none	5	10
Sulfuric acid....	1	none	1	none	1	none
1,1,2,2-Tetrachloroethane (35)		none	6.87	none	7	35
Tetrachloroethylene (2).	679	1,358	339	678	335	1,340
Thiols: (21)						
Butyl mercaptan	35	none	1.8	none	1.5	none
Methyl mercaptan (15)	none	20	1	none	1	none
Ethyl mercaptan (15).	none	25	1.3	none	1	3
Tin, organic compounds	0.1	none	0.1	none	0.1	0.2
o-Toluidine (35)	22	none	none	0.02	9	none
Toluene (2,17)...	753	1,129	375	750	375	560
1,1,1-Trichloroethane	1,900	none	none	1,190	1,900	2,450
Trichloroethylene (2)	536	1,072	134	none	270	1,080

Table A-13.-Analysis of OSHA, NIOSH, and ACGIH Protective Levels—Continued

Substance (notes) (36)	OSHA TWA mg/m³	OSHA ceiling mg/m³	NIOSH TWA (1) mg/m³	NIOSH ceiling mg/m³	ACGIH TWA mg/m³	ACGIH ceiling mg/m³
Tungsten: (31)						
insoluble compounds	NONE	NONE	5	none	5	10
soluble compounds	NONE	NONE	1	none	1	3
Vanadium, as V_2O_5 (dust) (15,32)	none	0.5	none	0.5	0.5	none
(fume) (15,32)	none	0.1	none	0.05	0.05	none
Ferrovanadium (32)	1	none	1	none	1	3
Vinyl acetate	NON E	NONE	none	15	30	80
Vinyl halides: (22)						
Vinyl bromide	NONE	NONE	none	4	20	none
Vinyl chloride	2.5	13	none	2.55	10	none
Vinylidene chloride	NONE	NONE	none	4	20	80
Xylene (17)	435	none	434	868	435	655
Zinc oxide (fume)	5	none	5	15	5	10

SOURCE Office of Technology Assessment

1 NIOSH TWA recommendations are based on up to a 10-hour exposure unless otherwise indicated

2 Under OSHA regulations, the ceiling levels for these substances are labelled "Acceptable Ceiling Concentration" In addition, for each of these chemicals them is an "Acceptable Maximum Peak above the acceptable ceiling concentration for *an 8-hour* shift," which lists a third concentration level and maximum duration. Details can be found m table Z-2 m the OSHA Standards (29 CFR1910.1000).

3 *Chromium (VI)–There* are several ways to separate chromium (VI) compounds into different classifications The difficulty m comparing the recommendations and standards is that each organization uses different classifications Chromium (VI) can be classified carcinogenic or not, soluble and nonsoluble, salts, and chromates. Chromic acid is chromium (VI) oxide and includes aqueous solutions thereof

The OSHA standard for chromium (VI) separates chromium into "soluble chromic and chromous salts" and "metal and resoluble salts," both having different PELs. These values can be found m OSHA table Z-2 There is a different PEL for chromic acid and chromates

The 1975 N1OSH criteria document for chromium (VI) revises the 1973 recommendations for Chromic acid Chromic acid (or chromic acid anhydride) is an oxide of chromium (VI) and is classified as a noncarcinogenic chromium (Vi) Under N1OSH recommendations, there are two recommended standards for chromium (VI) One standard addresses Occupational exposure to a group of noncarcinogenic, but otherwise hazardous, chromium materials, while the other standard covers occupational exposure to other chromium materials that are associated with an increased Incidence of lung cancer However, there is no practical means of distinguishing between these two groups on the basis of chemical analysis of airborne materials Until the airborne chromium in a particular workplace is demonstrated to be of the noncarcinogenic type, all airborne chromium is considered to be carcinogenic

ACGIH recommends two standards for chromium (VI) by separating the compounds into "water soluble" and "certain water insoluble" compounds which are labelled carcinogenic However, the TLV is the same for both types

This comparison table deals with this ambiguity by listing two standards for chromium (VI) water soluble (non-carcinogenic), and resoluble, metal and salts (carcinogenic) Under the OSHA category, only the chromium values m the table Z-I are used, chromic acid in table Z-2 is ignored

4 Mercury Under the OSHA standards, mercury is listed in table Z-2 The PEL for mercury is 1 mg /10 m' This is equal to O 1 mg/m³

5 Coal Tar *Products*—Protective Levels for coal tar products, or coal tar pitch volatiles, are misleading and difficult to compare because the methods of measuring • xposure levels differ among OSHA, NIOSH, and ACGIH The OSHA PEL addresses the benzene soluble fraction (anthracene, BaP, phenanthrene, acridine, chrysene and pyrene), as does the ACGIH recommended TLV The NIOSH recommendation pertains to the cyclohexane extractable fraction The comparison table contains all the protective levels but direct comparison is not applicable in this case.

6 Cotton *Dust*—OSHA standards for cotton dust are set out in 19101043 of the standards. There are three different standards for three major processes, yam manufacturing, dashing and weaving, and all other operations. The PEL for yam manufacturing is the most stringent, and this is the protective level that the comparison table lists

NIOSH has only one standard for cotton dust (described as lint-free cotton dust). ACGIH also recommends just one standard for "lint-free dust According to all three standards (OSHA, NIOSH, and ACGIH), measurement of the • xposure level is by the vertical elutriator cotton dust sampler.

7 *Refined* petroleum *solvents*—OSHA lists these substances simply as "petroleum distillates (naphtha)" The N1OSH recommendation controls exposure to petroleum ether, rubber solvent, varnish makers' and painters' naphtha, mineral spirits, Stoddard solvents and kerosene The assumption is that the recommendation for these substances are equivalent and are measured the same way

8 4 4 -*Methylene-bis (2-chloroaniline)*—The OSHA standard for 4,4 -methylene-bis-2-chloroaniline (MOCA), section 1910 1005, was deleted from the OSHA standarda on August 2s3, 1976 Both N1OSH • nd ACGIH recommend TWA protective levels for MOCA.

9 *Asbestos*—OSHA, NIOSH, and ACGIH measure asbestos concentration by the number of fibers longer than 5 micrometers per cubic centimeter of air: e.g., 2 fibers/cc > 5pm in length In the comparison *table* the numbers • re listed under mg/m³ for • asy comparison, but they have not been converted to mg/m³.

OSHA and NIOSH have one standard for asbestos, while ACGIH divides asbestos mto four types with different recommendations for • ach. However, the standard for chrysotile (the moat common) is used in the table. The rest of the ACGIH list contains amosite (0.5 fibers/cc >5µm in length), crocidolite (0.2 fibers/cc > 5um in length), and other forms (2 fibers/cc > 5pm in length). ACGIH does not indicate whether this is a TWA or ceiling TLV recommendation; in the comparison table it is placed under TWA.

10 Acetylene-The OSHA PEL for • cetylene is not in the OSHA health standards list (29 CFR 1910. IIXM3) but the N1OSH summary booklet does list one; this is the protective level used in the comparison table. There is an added note under the OSHA PEL, "10 percent of lower exposure limit," with no further explanation. The NIOSH recommendation for acetylene says, 'Occupational exposure to • irborne • mtylene shall be controlled so that no employees will be exposed to acetylene at • concentration in excess of 2,500 ppm. This is not the same • s an "acceptable ceiling concentration." However, to allow some comparison among standarda, the recommended TLV is in the ceiling column. ACGIH classifies acetylene as a simple asphyxiant; a TLV is not recommended because the limiting factor is the availabk oxygen. ACGIH accompanies the description of simple asphyxiants with warnings, including the additional fact that several simple asphyxiants present an explosive hazard.

11 *Acrylonitrile The* OSHA PEL for • crylonitrile is in section 191O.1W of the OSHA standards. In addition to the TWA and ceiling PELs, the standard states that "the employer shall assure that no employee is exposed to akin contact or eye contact with liquid • crylonitrile." ACGIH classifies acrylonitrile as a human carcinogen with an assigned TLV.

12 *Aldrin/Dieldrin*—NIOSH *recommends as an exposure level* the 'lowest reliably detectable level; 0.15 mg/m³ TWA by NIOSH validated method." All three organizations indicate that skin contact is to be avoided.

13 The TLVS under ACGIH for the following chemicals • re • bsolute ceiling limits, the concentration of which should not exceed the ceiling limit even *instantaneously*: boron trifluoride, diphenylmethane diisocyanate (MDI), methyl hydrazine, isophorone, sodium hydroxide, and formaldehyde. This fact should be taken into consideration when doing a direct comparison among recommendations and standards.

14 *Alkanes*—The NIOSH recommendation, unlike OSHA's or ACGIH's, have a protective level for mixtures of alkanes: "no employee shall be exposed to individual C5-C8 alkanes or mixtures of these alkanes at ceiling concentrations greater than 1,800 mg/m³ • s determined over a sampling time of 15 minutes."

15 Under OSHA standards, the following substances have only ceiling PELs. Exposure to these chemicals "shall at no time exceed the ceiling value given for that materials," The chemicals regulated in this way are: boron trifluoride, chlorine, chloroform, methylene biphenyl isocyanate (MDI), toluene-2,4-diisocy anate, allyglycidyl • ther (AGE), diglycidyl • ther (EXE), methyl hydrazine, nitroglycerin, ethylene glycol dinitrate, nitrogen dioxide, • thyl mercaptan, methyl mercaptan, and vanadium (dust and fume).

16. *Long maximum exposure*—The NIOSH recommendation for benzene and carbon tetrachloride lists the maximum time limit for exposure to *concentrations at or above the* ceiling limit as 60 minutes (not the usual 15 minutes). Other maximum time limits for exposure to concentrations at or above the N1OSH ceiling limit are as follows: beryllium (130 minutes), formaldehyde (30 minutes), hydrazines (120 minutes), chloroform (60 minutes), dibromochloropropane (30 minutes), and nitroglycerin (20 minutes),

17. Short *Maximum Exposure*—Under the NIOSH recommendation, the maximum time limit is 5 minutes for worker exposure to concentrations of ammonia at or above the acceptable ceiling limit, Other maxiumum *time limits for exposure to concentrations*

● ▼ or above the acceptable NIOSH ceiling limit are as follow,: carbon dioxide (lo minutes), cyanide (10 minutes), hydrogen sulfide (10 minutes), toluene (10 minutes), xylene (10 minutes).

18. Carbon black—NIOSH has two recommended TWAs for carbon black. When carbon black is in the presence of polycyclic hydrocarboN, the recommended TWA is 0.1 mg/m^3. In all other exposures, the recommended TWA for carbon black is 3.5 mg/m^3 and this is the value listed in the comparison table.

19. Methylene chloride—Under the NIOSH recommendation for methylene chloride the ceiling (500 ppm) is to be lowered in the presence of carbon monoxide.

20. Ketones—OSHA does not eet a standard for Methyl isoamyl ketone.

21. Thiol and mercaptan are synonyms. OSHA uses the name mercaptan and has standards for ordy three of these compounds. NIOSH labels them thiols utd recommends standards for 16 thiols. In addition, NIOSH makes ● note that "mixtures of thiols are to be controlled by calculation of equivalent concentrations." The comparison table only contains the TLVs for the three thiols that are revered by all three organizations.

22. Vinyl hdides-in the summary of NIOSH Reco mmendations, vinyl halides are classified In one catagory; the note under the exposure limit states "as promulgated for vinyl chloride In 29 CPR 1910.1017 with eventual goal of zero exposure." In the Joint NIOSH/OSHA Current Intelligence Bulletin 28 d Sept. 21,1978, the vinyl halide exposure standards specify exposure limits for four vinyl halides monomers in addition to vinyl chloride: vinyl bromide, vinylidene chloride, vinylidene fluoride, and vinyl fluoride. (These are listed in the comparison table.) The NIOSH recommendation includes the suggestion that occupational exposure to vinyl bromide and vinylidene chloride be reduced to the lowest possible levels because they are suspected carcinogens. In the OSHA standards for toxic and hazardous substances there are no standards for these four vinyl halides, either singly or as a group. However, the summary d NIOSH recommendations lists the OSHA standard for vinyl halides as ● group as 1 ppm TWA and 5 ppm ceiling protective level. These are the protective levels used in the comparison table.

ACGIH doe, * have ● recommended exposure limit for vinyl halides as ● group but doee have recommendations for two member, of the group; vinyl bromide and vinylidene chloride. The ACGIH recommendation for Vinyl bromide carries an added Warning that it has suspected carcinogenic potential for man.

23. Cadmium-The OSHA standards separate cadmium into dust and fumes, and five different PELs for each. The summary of NIOSH recommendations also separates cadmium into dust and fumes. However, comparing these recommendations to ACGIH TLVs b more difficult. ACGIH lists "cadmium, dusts and salts, as Cd" and "cadmium Oxide, fume, as Cd" and "production." Cadmium oxide fume has ● ceiling limit of 0.05 mg/m^3 under ACGIH. The comparison table uses the protective levels for cadmfum dust and salts for comparison to both OSHA and NIOSH protective levels.

24. Mercury—NIOSH and OSHA have only one classification for mercury, which is "inorganic." ACGIH divides mercury into three catagories, each with different TLVs; alkyl compounds, all forms except alkyl vapor, and aryl and inorganic compounds. In the comparison table, the exposure limit for aryl and inorganic compounds is used to compare with NIOSH and OSHA protective levels.

25. Nickel—The OSHA standards label nickel as "metal and soluble compounds, u Ni." The summary of N1OSH recommendations describes nickel as "inorganic and compounds." ACGIH separates nickel into two groups, "metal" and "soluble compounds, as Ni." The latter classification is used in the comparison table.

24. DDT—The NIOSH recommendation for DDT, as described in the summary d recommendations, reads as follows: "Lowest reliably detectable level; 0.S ~/ml TWA by NIOSH validated method. Skin contact to be avoided."

27. The following substances are labelled "special hazard review" by N I O S H : aldrin/dieldrin, benzidene-based dyes, chrysene, DDT, ethylene oxide, ethylene thiourea, 4,4'-methylene-bis (2-chloroaniline), and nickel carbonyl.

28. Nitriles—The summary of NIOSH recommendations notes, ● t the bottom of the list of nitrile recommendations, that "when present as mixtures or with other sources of cyanide, exposure to be considered additive and en vironmental limit to be calculated." NIOSH recommends TLVs for ten nitrile compounds; TWA values for six compounds and ceiling values for three compounds. OSHA and ACGIH set TLVs for onfy two nitrile compounds. The comparison table includes all three nitrile compounds for which N1OSH sets ceiling TLVs.

29. Fibrous glass—The OSHA standard for fibrous glass is listed in the summary of NIOSH recommendations, but not in the OSHA standards. In the OSHA standard, fibrous glass is classified as "nuisance dust" and measured by respirable fraction. NIOSH classifies fibrous glass as "total fibrous glass." ACGIH simply classifies it as "fibrous glass dust."

30. Silica—Standards and recommendations for silica are complex; usually utilizing formulas for different percentages of silica or quartz in respirable dust. The measure is usually $\mu g/m^3$. In the comparison table, the "wont case" standard or 100% silica is used as the comparison among the three organizations. The NIOSH recommendation for silica is ● single TLV. OSHA and ACGIH TLVs for silica are calculated by ● formula, and the standard changes according to the percent quartz in respirable dust. The 198344 ACGIH recommendations no longer require that a formula be used to measure exposure, instead ACGIH has simplified the table to chow numerical TLVs. In the OSHA standards, silica formulas for the standards are covered in table z-3.

31. Tungsten-Them ● re no OSHA standards for tungsten. NIOSH divides tungsten into four categories. Both NIOSH and ACGIH have recommendations for soluble and insoluble tungsten and these are included in the comparison table. NIOSH also recommends TLVs for "dust of cemented tungsten cubicle that is 2 percent cobalt (0.1 mg/m^3 TWA) and for "dust d cemented tungsten carbide that of 0.3 percent nickel (15μg (nickel)/m^3 TWA).

32. Vanadium—The OSHA standards separate vanadium into vanadium pentoxide dust and fume (I/lo,), and ferrovanadium dust which is listed separately in the OSHA table. NIOSH recommends the same standard for vanadium compounds (without further description), and metallic vanadium and vanadium carbide. The NIOSH recommended TLV for metallic vanadium is used in the comparison table under ferrovanadium. ACGIH, like OSHA, classifies vanadium or vanadium pentoxide as respirable duet and fume, and ferrovanadium.

33. Lead—The OSHA standard for lead has ● TWA TLV. In addition, there is ● formula to determine the TLV for exposures over 8 hour, long. NIOSH has only a recommended ceiling knit. ACGIH describes lead exposures as inorganic fume and dust and recommends TWA and ceiling TLVs.

34. 1,2-dibromo-3-chloropropane—The OSHA standard for DBCP can be found in section 1910.1044 of the OSHA standards. Eye contact and skin contact with DBCP are prohibited and to be ● olded. In addition, OSHA notes that it has been known to cause sterility in humans and is ● potential cancer risk. NIOSH recommends a ceiling protective level of 0.1 mg/m^3 for a maximum of 30 minutes. ACGIH does not have ● mommeddetandard for DBCP. .

3s. In the OSHA standards the following chemicals are listed indicating that skin contact b to be avoided: acrylamide, aldrin/dieldrin, chlorodiphenyl (both 42 percent and 54 percent), chloroprene, cyanide, DDT, 1,1-dimethylhydrazine, dinitro-ortho-cresol, dioxane, epichlorohydrin, hydrazine, malathion, methyl hydrazine, Nitroglycerin (both), phenyl hydrazine, parathion, phenol, 1,1,2,2, -tetrachloroethane, o-toluidine.

36. The following groups of hazards can be found in the NIOSH summary of recommendations, but they are not included in the comparison table: decomposition products of fluorocarbons, pesticide manufacturing and formulation, ultraviolet radiation, and waste anesthetic gases and yapors, ethylene thiorea, chrysene, and benzidene-based dyes.

37. In 1983 OHSA held hearing on ● proposed revision to its ethylene oxide standard, At those hearings NIOSH recommended that OSHA should set ● PEL lower than 0.1 ppm as an O-hour TWA and 5 ppm as ● ceiling limit for ● period of 10 minutes. In June 1904, OSHA issued ● find standard of 1 ppm or 2 mg/m^3 for an 8-hour TWA, but did not issue a ceiling limit. That revised recommendation and revised standard have not been Incorporated in the table or the comparison.

Appendix B. —Working Papers

For this assessment, OTA commissioned a number of reports on various topics concerning occupational health and safety. These contract reports, as well as two papers written by OTA staff, are being **made available** through the National Technical Information Service as Working Papers.

The Working Papers have been grouped into three parts. Part A includes analyses of available data, historical discussions of several topics, descriptions and critiques of the techniques of economic analysis, and a discussion of nonregulatory incentives. Part B covers descriptions of the personal protective equipment industry, theories of injury causation and control, information exchange, and worker training and education, Part C consists of five Case Studies of different occupational hazards and diseases.

Working Papers

Part A:

#1—Kronebusch, K., ***Data on Occupationa/ Injuries and Illnesses,*** working paper, December 1984.
#2—Mendeloff, J., An ***Analysis of OSHA Health Inspection Data,*** contract report, April 1983.
#3—Corn, J. C., ***Historical Perspective: The Evolution of the Definition of Certain Work-Related Illnesses,*** contract report, July 1983.
#4—Kent, M., ***A History of Occupational Safety and Health in the United States,*** contract report, April 1983.
#5—MacLean, D., ***A History of the Consideration of Economic Jmpacts in the Determination of the Feasibility of Standards Under the OSH Act,*** contract report, April 1983.
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Appendix D.—Glossary of Acronyms and Terms

Glossary of Acronyms

AAIH —**American Academy of Industrial Hygiene**
ABET —**American Board of Engineering and Technology**
ABIH —**American Board of Industrial Hygiene**
ACGIH —**American** Conference of Governmental Industrial Hygienists
AEPIC —Architectural and Engineering Performance **Impact Center**
AIHA —**American Industrial Hygiene Association**
ANSI —**American National Standards Institute**
AOMA —**American Occupational Medical Association**
ASSE —American Society of Safety Engineers
ASTM —American Society for Testing and Materials
ATMI —American Textile Manufacturers Institute
AUPOHS —American University Programs for Occupational Safety and-Health
BLS –Bureau of Labor Statistics (DOL)
CBO –Congressional Budget Office (U.S. Congress)
CDC –Centers for Disease Control (PHS)
CFR —Code of Federal Regulations
COSH –Committee for Occupational Safety and Health
CRS –Congressional Research Service (U.S. Congress)
CSHO —Compliance Safety and Health Officer (OSHA)
DHEW –U.S. Department of Health, Education, and Welfare
DHHS –U.S. Department of Health and Human Services
DOL —U.S. Department of Labor
EPA —U.S. Environmental Protection Agency
ERC —Educational Resource Center
GAO –General Accounting Office (U.S. Congress)
MSHA –Mine Safety and Health Administration (DOL)
NAS –National Academy of Sciences
NCHS —National Center for Health Statistics (DHHS)
NCI —National Cancer Institute (NIH)
NFPA —National Fire Protection Association
NHIS —National Health Interview Survey (NCHS)
NIEHS —National Institute of Environmental Health Sciences
NIH –National Institutes of Health (DHHS)
NIOSH —National Institute for Occupational Safety and Health (CDC)
NOES —National Occupational Exposure Survey (NIOSH)
NOHS —National Occupational Hazard Survey (NIOSH)
NRC –National Research Council (NAS)
NSC —National Safety Council
NSMS —National Safety Management Society
OMB —Office of Management and Budget
OSHA –Occupational Safety and Health Administration (DOL)
OSH Act —Occupational Safety and Health Act (Public Law 91-596)
OTA —Office of Technology Assessment (U.S. Congress)
PEL –Permissible Exposure Limit (OSHA)
PHS –Public Health Service (DHHS)
SEER –Surveillance, Epidemiology, and End Results program (NCI)
SIC —Standard Industrial Classification
TLV –Threshold Limit Value (ACGIH)

Glossary of Terms

Acute: Used to describe a disease or injury that is manifest soon after exposure to a hazard.

Add-on controls: Measures for injury and illness prevention which are put into place after the workplace is built and equipment installed [see chs. 5, 6, and 16].

Administrative controls: Methods of reducing worker exposures to occupational hazards through administrative arrangements. For example, rotating a worker from areas of high exposure to areas of low exposure reduces that worker's average exposure level. Also includes scheduling of jobs or processes that generate hazards at times when few workers are present. See ***engineering controls, personal protective equipment,*** and ***work practice controls [see*** also chs. 5, 6, and 9].

Asbestosis: A restrictive chronic disease of the respiratory system resulting from exposure to asbestos dust.

Asthma: Constriction of the bronchial tubes, in the upper regions of the lung, in response to irritation, allergy, or other stimuli.

Bioassay: The use of animals to test chemicals or physical agents for harmful effects.

Bronchitis: Inflammation of the bronchial tubes in the upper respiratory system.

Byssinosis: An obstructive chronic disease of the respiratory system resulting from exposure to cotton dust [see ch. 5].

Cancer: The unrestrained growth of tissue.

Carcinogen: A substance or physical agent that causes cancer.

Carpal Tunnel Syndrome: An affliction among workers doing hand work caused by compression of the median nerve in the carpal tunnel, the passage in the wrist through which blood vessels and nerves pass to the hand from the forearm [see ch. 7].

Chronic: Used to describe a disease or injury that is manifest long after exposure to a hazard. Also used to describe persistent disease.

Collective bargaining: Negotiation between employers and unions concerning wages, hours, and working conditions [see ch. 15].

Complaint inspections: OSHA inspections that respond to worker or union complaints about workplace hazards. See *fatality/catastrophe, follow-up,* and *programmed inspections* [see also ch. 12].

Compliance Safety and Health Officer (CSHO): The formal title for OSHA inspectors.

Consultation: As used in this assessment, an OSHA-funded program that provides employers with a confidential evaluation of the health and safety hazards in their workplaces and recommendations concerning hazard abatement [see ch. 12].

Contaminant: An undesirable chemical constituent of a system or environment.

Control Technology Assessments: The name given to a series of National Institute for Occupational Safety and Health reports assessing measures for preventing work-related injury and illness.

Cost-benefit analysis: An analytical technique that compares the costs of a project or technological application to the resultant benefits, with both costs and benefits expressed by the same measure. This measure is nearly always monetary [see ch. 14].

Cost-effectiveness analysis: An analytical technique that compares the costs of a project or of alternative projects to the resultant benefits, with costs and benefits/effectiveness expressed by different measures. Costs are usually expressed in dollars, but benefits/effectiveness are ordinarily expressed in terms such as "lives saved," "disability avoided," "quality-adjusted life years saved," or any other relevant objectives [see ch. 14].

Criteria Document: A series of National Institute for Occupational Safety and Health reports which assess available literature to develop the background necessary for standards. Upon completion these documents are transmitted to the Occupational Safety and Health Administration as recommended standards [see ch. 12].

Dermatitis: Inflammation or irritation of the skin.

Dibromochloropropane (DBCP): A chemical used as a pesticide. In the mid-1970s, a group of male workers discovered that their exposure to DBCP had rendered them sterile. An OSHA regulation limiting exposures to DBCP was issued in 1978.

Dose: The amount of energy or substance absorbed in a unit volume or an organ or individual. Dose rate is the dose delivered per unit of time.

Educational Resource Centers (ERC): Fifteen academic centers established by the National Institute for Occupational Safety and Health to provide multidisciplinary training for industrial hygienists, safety specialists, occupational health nurses, and physicians. These centers also provide continuing education and technical assistance for their regions.

Emergency Temporary Standard (ETS): A standard issued under section 6(c) of the Occupational Safety and Health Act. Such a standard may be issued when OSHA determines that workers are exposed to a "grave danger" from an occupational hazard and that an emergency standard is necessary to protect them from that danger.

Emphysema: A condition of the lungs characterized by an increase beyond the normal in the size of air spaces in the furtherest reaches of the lung either from dialation of the alveolii (the tiny sacs in the the lung where oxygen from the air and waste carbon dioxide in the blood are exchanged) or from the destruction of their walls.

Engineering controls: Methods of controlling worker exposure by modifying the source or reducing the amount of contaminants released into the workplace. Engineering controls include process design and modification, equipment design, enclosure and isolation, and ventilation. See *administrative controls, personal protective equipment,* and *work practice controls* [see also chs. 5, 6, and 9].

Epidemiology: The study of the distribution of diseases and their precursors in human populations.

Ergonomics: The study of how humans and machines interact. In the occupational setting, one goal of ergonomics is to design the workplace to match worker capabilities.

Ethylene dibromide (EDB): A chemical used as a fumigant and as a gasoline additive. It causes cancer in mice.

Experience rating: A system for setting worker compensation insurance premiums that is based on the employer's record or experience concerning injuries and illnesses.

Exposure: The length of time and dose of chemical or physical agent to which a worker is subjected.

Fatality/catastrophe inspection: An OSHA inspection to investigate occupational fatalities or incidents that result in the hospitalization of five or more employees. See *complaint, follow-up,* and *programmed inspections* [see also ch. 12].

Follow-up inspection: An OSHA inspection conducted to verify employer abatement of a violation uncovered in a previous OSHA inspection. See *complaint, fatality/catastrophe, and programed inspections* [see also ch. 12].

General Duty Clause: Section 5(a)(1) of the Occupational Safety and Health Act. This section provides that "each employer shall furnish . . . employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees." OSHA has used this clause for workplace conditions that present serious occupational hazards that are not covered by OSHA's more detailed health and safety standards.

Health and Safety Committees: Groups made up of both management and labor within a plant that meet to discuss and take mutual action to resolve health and safety problems.

Health Hazard Evaluation (HHE): A hazard identification service provided by NIOSH. After receiving a request from employees or an employer, a team of NIOSH researchers evaluate a workplace to determine the toxicity of substances or processes.

Hierarchy of controls: The preference for using engineering controls to reduce or eliminate hazards. This preference, long a tenet of professional health and safety practice, has been followed by OSHA. For example, to reduce exposures to air contaminants, OSHA requires that employers use engineering controls except when those controls are not feasible, not capable of reducing exposures to the required levels, or while they are being designed and installed.

Labeling standard: OSHA's Hazard Communication standard which requires that certain information be provided to workers about the identity of workplace chemicals and their hazards [see ch. 15].

Loss-control service: Service provided by insurers to client companies. Loss-control specialists visit worksites and offer advice on the prevention of property loss and work-related injuries and illnesses [see ch. 15].

Lost-workday case: As defined by OSHA and BLS, a work-related injury or illness that results in an employee missing time from work or that restricts the employee's work activity [see ch. 2].

Medical Removal Protection (MRP): A program specified by the OSHA lead standard. It requires removal of workers from lead-contaminated environments when their blood lead levels exceed specified levels [see ch. 5].

Medical treatment case: As defined by OSHA and BLS, a work-related injury or illness that requires medical treatment beyond first aid [see ch. 2].

Merit rating: See experience *rating.*

Mesothelioma: A malignant tumor of the membrane that lines the internal organs of the body.

Monomer: A chemical substance that can undergo polymerization. See *polymer.*

Mutagen: A substance that causes mutations—changes in the genetic material of. cells.

New Directions Program: An OSHA program to provide grants to employee, employer, educations, and nonprofit organizations for the purpose of providing workplace health and safety training, educational materials, and services.

Permissible Exposure Limit (PEL): The maximum airborne concentration of a toxic substance permitted by OSHA standards [see ch. 13].

Personal protective equipment: Equipment and clothing designed to control hazards. It includes hard hats, safety shoes, protective eyewear, protective clothing and gloves, hearing protectors, and various types of respirators, such as dust and gas masks. See *administrative, engineering,* and *work practice controls* [see also ch. 8].

Polymer: A chemical substance formed by the joining together of many simple molecules or monomers. For instance, many vinyl chloride monomers are chemically joined to form polyvinyl chloride (PVC). See *monomer.*

Positive pressure mask: Respirators in which air pressure inside the facepiece exceeds the outside air pressure.

Programed inspection: Programed or general schedule inspections are those OSHA inspections that are scheduled using the injury experience or compliance history of an industry. See also *complaint, fatality/catastrophe,* and *follow-up inspections* [see ch. 12].

Protection factor: The ratio of measured concentrations of an airborne contaminant inside and outside the facepiece of a respirator, A measure of the effectiveness of the respirator.

"Records review" inspections: After arriving at a workplace, an OSHA inspector examines the employer's injury and employment records. The inspector calculates the lost-workday injury rate for the employer. If that rate is below the national average for manufacturing, the inspection will usually be terminated. For this assessment, these inspections have been termed "records review" inspections. Currently, this policy applies only to programed safety inspections [see ch. 12].

Repetitive motion disorders: Diseases caused by repetitive movement of part of the body. See *Carpal Tunnel Syndrome.*

Retro-fit controls: See *add-on controls,*

Right-to-know laws: State and local laws requiring companies to identify the chemical names and hazards of their products to workers and the communit y.

Rulemaking: The administrative process by which OSHA and other regulatory agencies set standards.

Silicosis: A restrictive chronic disease of the respiratory system resulting from exposure to airborne silica dust,

Standards issued after rulemaking: Health and safety standards issued by OSHA using the procedures established by section 6(b) of the Occupational Safety and Health Act. These procedures require that OSHA provide notice of intended changes and an opportunity for public comment.

Startup standards: The initial group of standards adopted by OSHA under section 6(a) of the Occupational Safety and Health Act. These consisted of established Federal standards and consensus standards.

State Program: Under section 18 of the Occupational Safety and Health Act, States may set and enforce workplace health and safety standards. In this assessment, these programs are termed "State Programs" [see ch. 12].

Teratogen: A chemical or physical agent that causes physical defects in offspring.

Threshold Limit Value (TLV): Maximum airborne concentrations of toxic substances set as guidelines by the American Conference of Governmental Industrial Hygienist [see ch. 13].

Tort liability: A legal basis for compensation when property has been damaged or a person has been injured. For occupational injuries and illnesses, most lawsuits between employees and employers are barred by State workers' compensation laws, although suits against "third parties, " such as manufacturers of machinery or producers of asbestos products, are generally permitted [see ch. 15].

Toxicology: As used in this report, the testing of substances for toxic effects in animals.

Vinyl chloride monomer (VCM): The basic building block chemical for polyvinyl chloride plastic. See *monomer.*

Voluntary Protection Programs: OSHA programs designed to recognize the achievements of employers and to provide additional opportunities for OSHA-employer consultation and cooperation. The three programs are called "Star," "Try," and "Praise."

Voluntary standards: Protective limits developed by companies, trade associations, and professional organizations, but which do not have the force of law.

Walsh-Healey Public Contracts Act: This Federal law, enacted in 1936, directed the Department of Labor to issue requirements for safe work by Federal Government contractors and to "blacklist" contractors who did not comply with these requirements.

Work practice controls: Methods of controlling hazards that involve only changes in job procedures and housekeeping. See *administrative controls, engineering controls,* and *personal protective equipment* [see also chs. 5, 6, and 9].

Worker's compensation: State-required insurance programs which pay for medical costs and replace a portion of employees' wages lost due to work-related injury and illness.

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