9
Hierarchy of Controls

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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 involved 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 defense 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 employee 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 controls, 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 requir**ing 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.