8.
Personal Protective Equipment

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8
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.

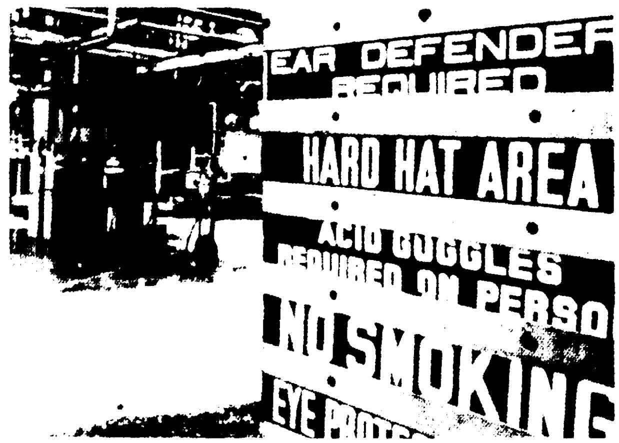


Photo *credit E.I. du Pont de Nemours & Co.*

Signs are frequently **used to indicate when the use of protective equipment is mandatory**

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 con**tinue 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.

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

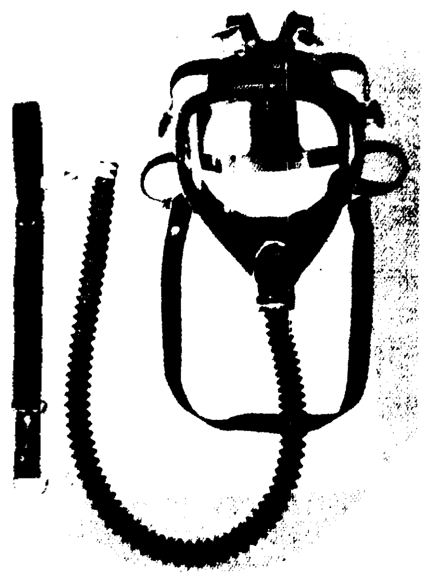
Figure 8-1 .- Respiratory Protection Devices

Abrasive bias.tlng helmet
by 3M

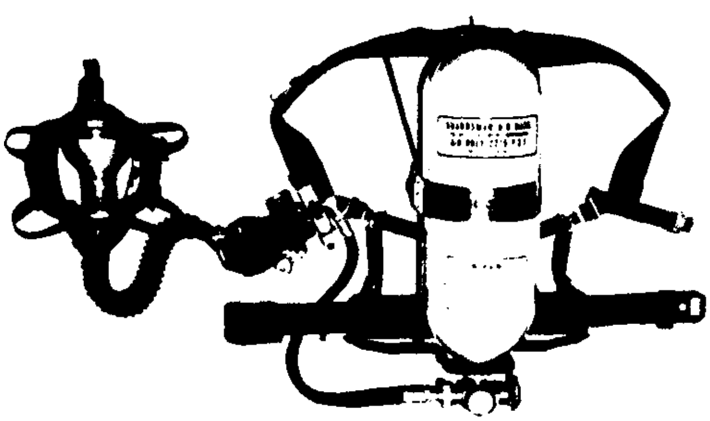
Disposable respirator
by 3M

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.

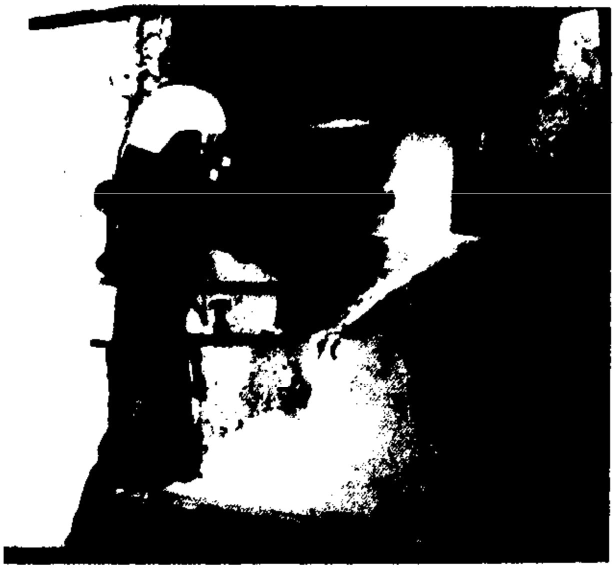


Photo credit: NIOSH

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-

[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.

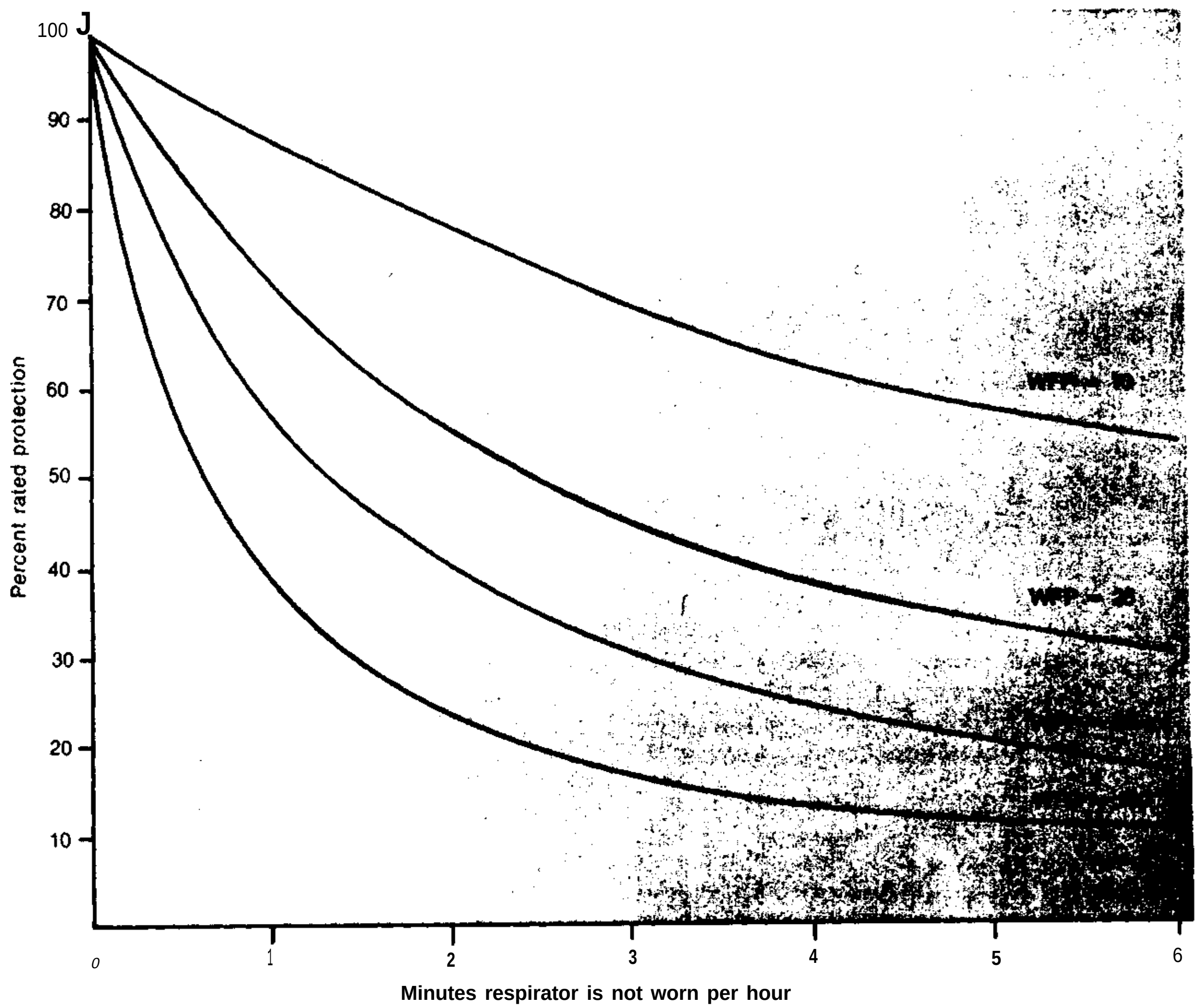
Smith, et al. (450) observed a wide range of EPFs (from 1.12 to 146) in a study of cadmium workers, which resulted partly from workers deciding whether or not to wear respirators in different situations.

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.

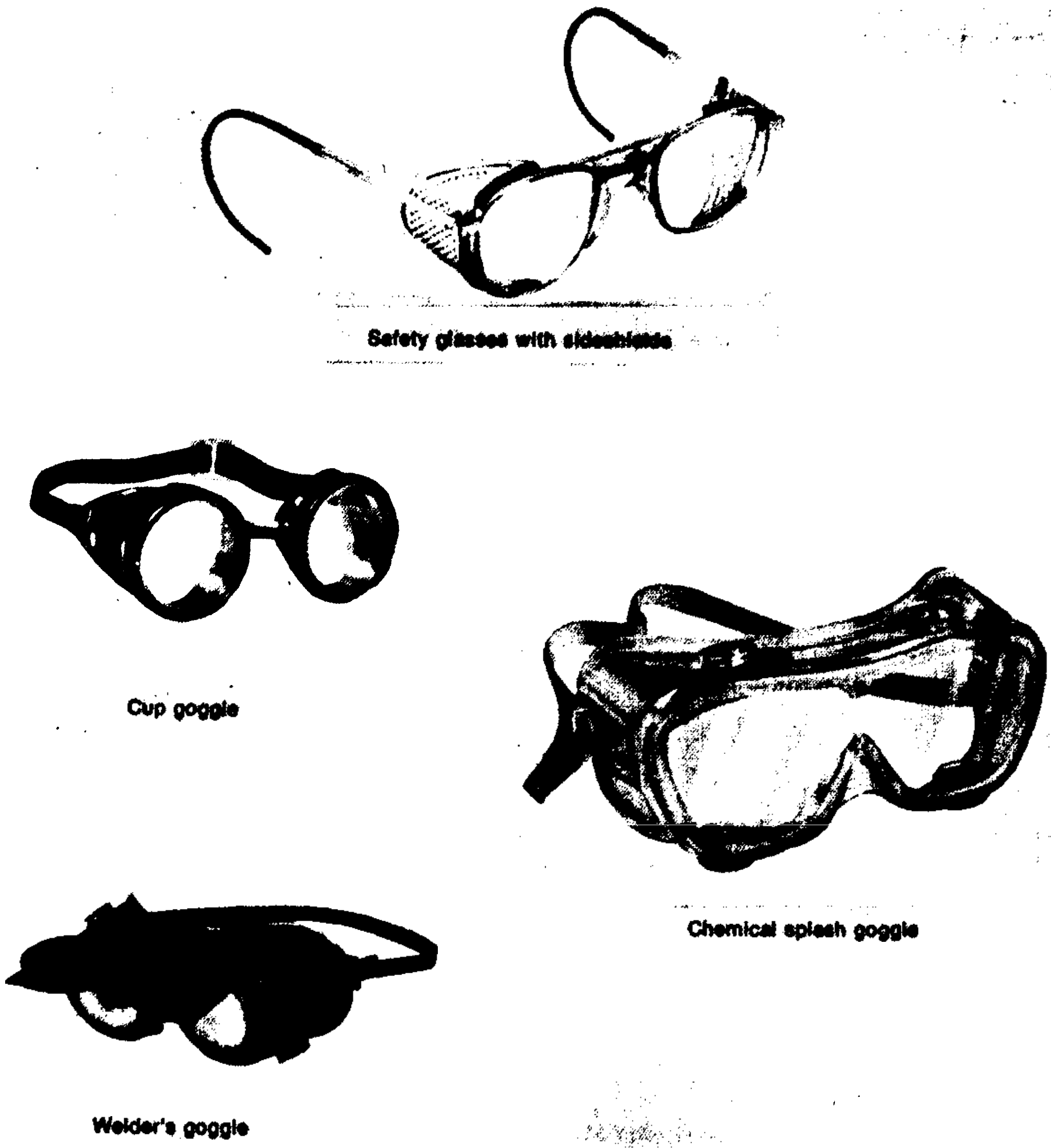
An obvious concern in safety eyewear is that the eyewear itself can present a hazard if it fails. A particle splintering the lens of spectacles may be the cause of an accident, but the injury may stem from fragments of the lens entering the eye. Since 1972, all spectacles sold in the United States must 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.