Preventing Lead Poisoning in Construction Workers

Workers are potentially exposed to lead during work on bridges or other steel structures such as water and fuel storage tanks. Workers who may be exposed to lead include abrasive blasters, inspectors, iron workers (welders and cutters), painters, and labourers. In 1987, an estimated 44,000 persons worked in bridge, tunnel, and elevated-highway construction (Standard Industrial Classification Code [SIC] 1622), and an estimated 14,000 persons worked in wrecking and demolition (SIC 1795) [Bureau of the Census 1990].

An estimated 90,000 bridges in the United States are coated with lead-containing paints [Katauskas 1990]. According to a survey of State departments of transportation, lead-containing coatings were found on approximately 77% of U.S. bridges that were repainted between 1985 and 1989 [Steel Structures Painting Council 1991].

Maintenance of Steel Structures

Before a new coating may be applied to bridges and other steel structures, deteriorated paint and corrosion must be removed and the metal surface must be properly prepared [Katauskas 1990]. In addition, all coatings of lead-based paints must be removed before another type of paint can be applied [Katauskas 1990]. This process is most commonly accomplished by using a portable device for abrasive blast cleaning. These devices are designed to deliver a high-velocity stream of abrasive to the metal surface. Compressed air is generally used, but some devices use water to deliver the abrasive. A variety of non metallic and metallic abrasives have been used, including silica sand, slag, and steel grit. The worker performing the blasting directs the blasting nozzle at the surface to be cleaned. As the paint is removed, small particles become airborne, and the used abrasives become contaminated with lead-containing particles.

Containment structures are used to reduce the release of lead into the environment by capturing paint chips, dust, and used abrasive. Where possible, containment structures are designed so that the used abrasives and debris are directed through chutes or tubes into a barge or hopper. Because the recovery systems in the containment structures are not completely effective, some of the material must be recovered manually by sweeping, shovelling, or vacuuming. Under the Resource Conservation and Recovery Act (RCRA), waste material must be tested, and if the leachable lead concentration is 5 parts per million (ppm) or greater, the material is classified as a hazardous waste [40 CFR** 260]. Containment structures are designed to reduce the dispersion of lead into the environment,

but they may increase worker exposure to airborne lead. Current techniques for containment are not well defined and vary in their efficiency in preventing lead from being released into the environment. Some containment structures consist of tarpaulins or open mesh fabrics placed over the blasting area; some use rigid materials of wood, metal, or plastic to enclose the blasting area; and some use a combination of flexible and rigid materials. Large air-moving devices may be mounted on trucks and connected to the containment structures to exhaust dust-laden air. The exhausted air is passed through dust separation devices and filters before it is released to the atmosphere. This ventilation technique may also create a negative pressure within the containment structure and help reduce environmental contamination.

Workers may receive additional exposure at some sites when the containment structures (which may contain residual lead dust and debris) are disassembled and moved. Workers should be adequately protected while performing these operations.

Potential for Exposure to Airborne Lead

At sites where workers performed bridge, tunnel, and elevated-highway construction (SIC 1622), OSHA reported airborne lead concentrations exceeding 200 micrograms per cubic meter ($\mu g/m^3$) for 65% of the samples collected between April 1984 and April 1988 [OSHA 1988]. Tables 1 and 2 summarize cases of occupational exposures to lead reported during abrasive blasting, sanding, burning, cutting, and welding. Most of the operations described were conducted outside containment structures. These data indicate that persons working at the jobsite outside the containment structure are also at risk of exposure to lead. ***Workers who do not shower and change into clean clothing before leaving the worksite may contaminate their homes and automobiles with lead dust.***

Other members of the household may then be exposed to harmful amounts of lead [Grand jean and Bach 1986; Kaye et al. 1987; Matte et al. 1989; Baker et al. 1977].

Table 1.--Airborne lead concentrations reported during operations on bridges and other painted steel structures

Operation	Job	Exposure range during task($\mu g/m^3$)	Comments
Bridge rehabilitation [New Jersey Department of Health 1988a]	Torch burner	**220-6,000**	Work conducted in semiconfined area
	Hammering and drilling	**40-360**	Workers were mechanically

Table 1.--Airborne lead concentrations reported during operations on bridges and other painted steel structures			
Operation	**Job**	**Exposure range during task(μg/m³)**	**Comments**
			disturbing painted surface in semiconfined area
Bridge demolition (no containment structure) [New Jersey Department of Health 1988b]	Torch burner	**110-1,200**	Workers were cutting beams on bridge
	Burner helper	**330**	These workers assisted burners who were cutting the bridge
	Power tool use	**5-50**	
Bridge demolition (no containment structure) [New Jersey Department of Health 1990]	Burner	**180-1,800**	--
	Rivet removal	**500-930**	
Paint removal from boiler (no containment structure) [Adkinson 1989]	Blaster	**230-860**	Samples were taken inside respirator
		640-1,400	Samples were taken outside respirator
	Power tool operators	**80-790**	Workers were spot-cleaning an existing surface
Power plant (no containment structure) [Rekus 1988]	Burner	**2,100-22,400**	--
Bridge repair (no containment structure) [Rekus 1988]	Welder	**2,200-4,200**	--
	Blaster	**10,400**	
	Burner	**840-4,900**	
	Blaster	**1,070-1,120**	
Paint removal from a tank [Lippy et al. 1988]	Abrasive blasting	**490-870**	Work conducted inside containment structure
	Carpenter	**8**	Work conducted

Table 1.--Airborne lead concentrations reported during operations on bridges and other painted steel structures			
Operation	**Job**	**Exposure range during task(μg/m^3)**	**Comments**
			outside containment structure
	Steam filter	**40-50**	Work conducted outside containment structure
	Blaster helper	**90-560**	Work conducted inside containment structure

Table 2.--Airborne lead concentrations reported for case studies				
Case No.*	**Location and description**	**Job**	**Range of airborne lead concentration during task (µg/m^3)**	**Comments**
1	**Connecticut, paint removal from bridge (with containment structures)**	Blaster	4-540	Work conducted inside containment structure
		Groundsman	20-640	
		[area samples]	3,110-3,150	
		[area samples]	230-410	Work conducted outside containment structure
3	**Louisiana, paint removal from bridge (with containment structures)**	Blaster	2-730	Work conducted inside containment structure
5	**New York, bridge demolition**	Burners	600-4,000	--
6	**Kentucky, paint removal from bridge (with containment structures)**	Blaster	3,690-29,400	Work conducted inside containment structure; samples taken outside respirator
		Blaster	9-190	Work conducted inside containment structure; samples taken inside respirator
		Groundsman	5-6,720	Work conducted outside containment structure

* No samples were collected for cases 2 and 4. [Return to top of table]

HEALTH EFFECTS OF LEAD EXPOSURE

The frequency and severity of medical symptoms increase with the concentration of lead in the blood. Many adults with blood lead levels (BLLs) of 80 μg/dl or greater have symptoms or signs of acute lead poisoning, although in some individuals, symptoms may be so mild that they are overlooked [NIOSH 1978; Rosen stock and Cullen 1986]. Common symptoms of acute lead poisoning are loss of appetite, nausea, vomiting, stomach cramps, constipation, difficulty in sleeping, fatigue, moodiness, headache, joint or muscle aches, anaemia, and decreased sexual drive. Severe health effects of acute lead exposure include damage to the nervous system, including wrist or foot drop, tremors, and convulsions or seizures. Acute lead poisoning from uncontrolled occupational exposures has resulted in fatalities [Hay hurst 1915].

Chronic lead poisoning may result after lead has accumulated in the body over time, mostly in the bone. Long after exposure has ceased, some physiological event such as illness or pregnancy may release this stored lead from the bone and produce adverse health effects such as impaired haemoglobin synthesis, alteration in the central and peripheral nervous systems, hypertension, effects on male and female reproductive systems, and damage to the developing foetus [Landrigan 1989]. These health effects may occur at BLLs below 50 μg/dl.

RELEVANT EXPOSURE CRITERIA AND REGULATIONS

In 1978, OSHA promulgated a comprehensive standard regulating occupational exposure to inorganic lead in general industry [29 CFR 1910.1025]. Under this standard, the permissible exposure limit (PEL) for inorganic lead is 50

$\mu g/m^3$ of air as an 8-hour time weighted average (TWA). However, the construction industry was exempted from this regulation and has a 200-$\mu g/m^3$ PEL for inorganic lead [29 CFR 1926.55]. Unlike the OSHA standard for general industry, the construction standard does not require medical monitoring of workers exposed to lead or removal of workers from the job when they show elevated concentrations of lead in the blood. Specific medical monitoring recommendations for these workers are discussed in the section on conclusions and recommendations.

The NIOSH recommended exposure limit (REL) for lead is less than 100 $\mu g/m^3$ of air as a TWA for up to 10 hours per day during a 40-hour workweek. This air concentration is to be maintained so that the worker's lead concentration remains below 60 μg/100 grams of whole blood (approximately equivalent to 60 μg/dl) [NIOSH 1988c; CDC 1990]. NIOSH is presently reviewing the data on the health effects of lead to determine whether our current recommendations need to be updated.

Several States have instituted programs to protect construction workers from the hazards of occupational lead exposure. For example, Maryland enacted in 1984 (and modified in 1988) a comprehensive standard regulating occupational lead exposure in construction work [Maryland Regulations Code 1988]. Under this standard, the permissible exposure limit for lead is 50 μg/m^3 as an 8-hour TWA. This standard must be incorporated in all contracts involving bridge work in Maryland. Connecticut is currently preparing similar requirements for inclusion in contracts [Connecticut Department of Transportation 1991].

CASE REPORTS OF LEAD POISONING

NIOSH recently learned of 42 construction workers at 8 different worksites who developed lead poisoning (BLLs exceeding 50μg/dl of blood) while working on bridges [Mintz 1990; Rae 1990; Johnson 1990; CDC 1989; Marino et al. 1989; NIOSH 1991b]. The BLLs for these workers ranged from 51 to 160 μg/dl. The mean BLL for the U.S. population is 13.9 μg/dl, and the upper 95th percentile is 25.0 μg/dl [NCHS 1984]. The airborne concentrations of lead ranged from 2 to 29,400 μg/m^3 (see Table 2). At least 26 of the 42 cases of lead poisoning (62%) were workers employed at a site using a containment structure. The actual number of cases of occupational lead poisoning nationwide is much larger than 42, but it cannot be accurately determined since employers are not required to routinely measure lead concentration in the blood of exposed construction workers.

Case No. 1

A study now being conducted in Connecticut has identified four workers with lead poisoning at three different bridge sites [Mintz 1990]. Containment structures were used at all three sites. The workers' BLLs ranged from 51 to 66μg/dl, but none reported symptoms of lead intoxication. Personal breathing zone samples indicated airborne lead concentrations of 4 to 640 μg/m^3. All workers wore respiratory protection (abrasive blasting, half-mask, or disposable respirators).

Case No. 2

In 1989, eight workers at a bridge site in Monroe, Louisiana, developed lead poisoning while working in a containment structure [Rae 1990]. The BLLs of these workers ranged from 56 to 146 μg/dl. Their complaints included malaise, arm numbness, abdominal discomfort, joint and muscle aches, headache, and diarrhea. Airborne concentrations of lead were not reported.

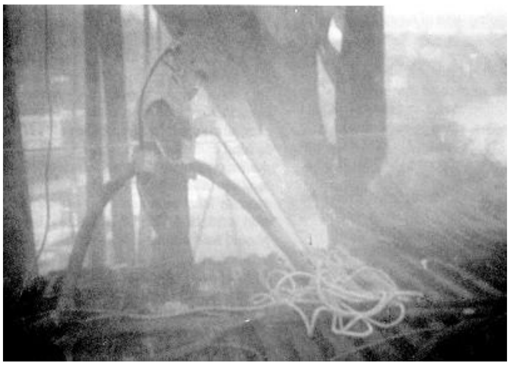
Case No. 3

In May 1990, 12 bridge workers in Baton Rouge, Louisiana, developed lead poisoning while working in a containment structure [Johnson 1990]. The BLLs of affected workers ranged from 52 to 102 μg/dl. Reported airborne concentrations of lead ranged from 2 to 730 $\mu g/m^3$. The worker with the BLL of 102 μg/dl developed joint pains and required hospitalization for intravenous chelation therapy.

Case No. 4

In March 1988, five workers developed lead poisoning during demolition of a bridge in Massachusetts [CDC 1989]. The BLLs of affected workers ranged from 67 to 160 μg/dl. All five workers reported symptoms consistent with lead poisoning. Four of the five workers were treated with intravenous chelation therapy. Airborne lead concentrations were not reported.

Case No. 5



In 1987, 11 workers who wore positive-pressure, air supplied respirators developed lead poisoning during demolition of a bridge in New York [Marino et al. 1989]. The BLLs of these workers ranged from 52 to 120 μg/dl. One worker with a BLL of 120 μg/dl reported symptoms of muscle soreness, weakness, lack of appetite, nausea, and vomiting. Another worker with a BLL of 105 μg/dl reported symptoms of headache, tiredness, and abdominal discomfort. Both workers required intravenous chelation therapy. Personal breathing zone concentrations of lead ranged from 600 to 4,000 $\mu g/m^3$.

Case No. 6

In March 1991, NIOSH investigators began a study of lead exposures in 12 workers engaged in abrasive blasting and repainting of a bridge in Kentucky [NIOSH 1991b]. BLLs were measured during the first week of work and ranged from 5 to 48 μg/dl. The BLLs were measured again after 1 month of exposure and ranged from 9 to 61 μg/dl. Two workers had BLLs exceeding 50 μg/dl. The airborne concentration of inorganic lead ranged from 5 to 29,400$\mu g/m^3$. Blasters wore continuous flow abrasive blasting respirators. Other workers used half-mask, air-purifying respirators with high-efficiency particulate air (HEPA) filters. However, there was no complete respiratory protection program consistent with OSHA requirements [29 CFR 1910.134] and NIOSH recommendations [NIOSH 1987a; NIOSH 1987b]. Running water, coveralls, and clean change-rooms were not available at the site.

CONCLUSIONS AND RECOMMENDATIONS

Preventing Lead Poisoning in Construction Workers

Lead poisoning may occur when workers inhale or ingest lead dust and fumes during abrasive blasting, sanding, cutting, burning, or welding of bridges and other steel structures coated with lead-containing paints. Data presented in this document reveal lead poisoning among workers who were wearing respirators. Therefore, a prudent policy is to minimize the risk of adverse health effects by keeping lead concentrations as low as possible and by using all available controls--including engineering controls, work practices, and respiratory protection. To help achieve the*Healthy People 2000* [DHHS 1990] objective of limiting worker blood lead concentrations to 25 μg/dl, NIOSH recommends the following measures for reducing lead exposure and preventing lead poisoning among workers involved in demolishing or maintaining bridges and other steel structures.

Air Monitoring

An industrial hygienist or other qualified professional should perform an initial hazard assessment of the worksite to determine the composition of the paint. Environmental monitoring should also be performed to (1) measure worker exposure to airborne lead and other hazardous agents (e.g., silica and solvents), and (2) select the engineering controls and PPE required. Environmental monitoring should be performed as needed to measure the effectiveness of controls and to determine whether the proper respiratory protection is being worn. Air samples should be collected and analyzed according to NIOSH methods [NIOSH 1984] or their equivalent.

Engineering Controls

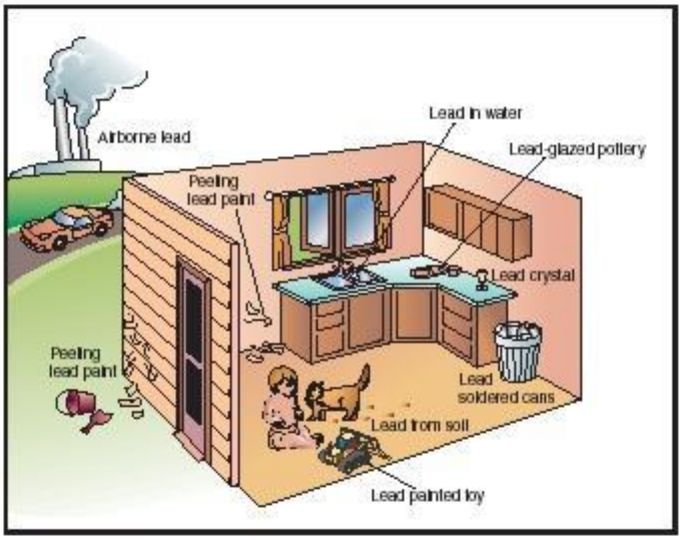
Engineering controls should be used to minimize exposures to lead at the worksite. At a minimum, airborne lead exposures should not exceed the current OSHA PEL for general industry (50 $\mu g/m^3$). Wherever possible, engineering controls should include material substitution (i.e., repainting of structures with less toxic material), process and equipment modification, isolation or automation, and local and general exhaust ventilation. The appropriate types of controls vary with the operation.

Welding, Cutting, or Burning

Before welding, cutting, or burning any metal coated with lead-containing materials, remove the coating to a point at least 4 inches from the area where heat will be applied [29 CFR 1926.354]. When removal of lead-containing paint is not feasible, use engineering controls (e.g., local exhaust ventilation) to protect workers who are welding, cutting, or burning lead-bearing materials. Such controls should be used to remove fumes and smoke at the source and to keep the concentration of lead in the breathing zone below the OSHA PEL. Contaminated air should be filtered before it is discharged into the environment well away from the source of intake air and other workers. Replace contaminated air with clean air [29 CFR 1926.353].

Surface Preparation

When performing abrasive blasting, scaling, chipping, grinding, or other operations to remove lead-containing paint, use work practices that minimize the amount of dust generated. Less dusty blasting techniques include centrifugal blasting (using rotating blades to propel the abrasive, which is recovered and recycled), wet blasting (using high-pressure water with or without an abrasive, or surrounding the blast nozzle with a ring of water), and vacuum blasting (shrouding the nozzle with local exhaust ventilation) [Rex 1990]. Other methods that reduce dust include scraping, heating and scraping, use of needle guns, and chemical removal.



Materials containing crystalline silica should ***not*** be used as abrasives for any blasting operation, including paint removal [NIOSH 1988b]. Crystalline silica is associated with silicosis and is classified by NIOSH as a potential occupational carcinogen [NIOSH 1988d].

Lead-containing dust and abrasive materials should be removed daily by using vacuums equipped with HEPA filters or by using wet methods to prevent lead-containing particles from becoming airborne [Steel Structures Painting Council 1991].

Work Inside Containment Structures

Containment structures are often used to reduce environmental contamination by capturing particles of paint and used blasting materials. Although such structures reduce environmental contamination, they may also increase lead exposures for workers (see Figure 1). Ventilation should be provided to reduce the airborne concentration of lead and increase visibility. Containment structures should be designed to optimize the flow of ventilation air past the worker(s). Insofar as possible, workers should be upstream from the blasting operation to reduce exposure to lead dust entrained in the ventilation air and to improve visibility. Designs for the containment structure and ventilation systems should be specific to each task because of varied conditions at the worksite (i.e., the type of steel structure being blasted, the type of blasting methods, and the type of materials used for construction).

Figure 1. **Construction worker using a HEPA-filter vacuum inside a containment structure. Note that the worker is obscured by a high airborne concentration of dust.**

Contract Specifications

All new contracts of Federal, State, and local departments of transportation should include specifications for a mandatory program of worker protection from lead poisoning during the maintenance, repainting, or demolition of bridges and other steel structures.

Personal Hygiene Practice

Personal hygiene is an important element of any program for protecting workers from exposure to lead dust [Ulenbelt et al. 1990]. OSHA requires employers to provide adequate washing facilities at the worksite so that workers can remove lead particles that accumulate on the skin and hair [29 CFR 1926.51]. Showers should also be available [OSHA/NIOSH 1991].

All workers exposed to lead should wash their hands and faces before eating, drinking, or smoking, and they should not eat, drink, or use tobacco products in the work area. Tobacco products (cigarettes, cigars, chewing tobacco, etc.) and food items should not be permitted in the work area. Contaminated work clothes should be removed before eating.

Workers should change into work clothes at the worksite. Work clothes include disposable or washable coveralls. Street clothes should be stored separately from work clothes in a clean area provided by the employer. Separate lockers or storage facilities should be provided so that clean clothing is not contaminated by work clothing and shoes. Workers should change back into their street clothes after washing or showering and before leaving the worksite to prevent the accumulation of lead dust in the workers' cars and homes and thereby protect family members from exposure to lead. Cars should be parked where they will not be contaminated with lead.

Employers should arrange for the laundering of protective clothing; or, if disposable protective clothing is used, the employer should maintain an adequate supply at the worksite and arrange for its safe disposal according to applicable Federal [40 CFR 260] and State regulations.

Warning Signs

Warning signs should be posted to mark the boundaries of lead-contaminated work areas. These signs should follow the example presented in the OSHA general industry standard [29

CFR 1910.1025], which warns about the lead hazard and prohibits eating and drinking in the area. Such signs should also specify any PPE required (for example, respirators). The sample sign in Figure 2 contains all the information needed for a lead-contaminated work area where respirators are required.

Figure 2. ***Sample of warning sign for lead work area requiring respirators.*** **Personal Protective Equipment (PPE)**

Engineering controls and good work practices should be used to minimize worker exposure to lead. Because of the variable exposure concentrations in the construction industry and the difficulty of monitoring a mobile workforce, PPE should be used whenever workers are potentially exposed to lead [OSHA/NIOSH 1991]. The use of PPE should supplement the continued use of engineering controls and good work practices.

Protective Clothing

Protective clothing not only shields workers from the hazards of welding and abrasive blasting, but it also minimizes the accumulation of lead on the worker's skin and hair. Workers should change into washable coveralls or disposable clothing before entering the contaminated work area. Because wearing PPE (especially protective clothing) can contribute to the development of heat stress [NIOSH/OSHA/USCG/EPA 1985], a potentially serious illness, regular monitoring and other preventive measures are vital [NIOSH 1986].

To minimize the amount of lead that may accumulate in the worker's car and home and to protect the members of the worker's household, lead-contaminated clothing (including work shoes) should be left at the worksite for cleaning or disposal. Workers who are welding, cutting, or burning should wear nonflammable clothing [NIOSH 1988a].

Respiratory Protection

Effective source control measures (such as containment or local exhaust ventilation) should be implemented to minimize worker exposure to lead. NIOSH prefers such measures as the primary means of protecting workers; but source control at construction sites is often ineffective, and airborne lead concentrations may be high or may vary unpredictably. Therefore, respiratory protection is also necessary for certain operations such as blasting, sweeping, and vacuuming, and for other jobs as determined at the worksite by an industrial hygienist or other qualified professional. However, respirators are the least preferred method of controlling lead exposure, and ***they should not be used as the only means of preventing or***

minimizing exposures. The use of respirators should supplement the continued use of engineering controls and good work practices [OSHA/NIOSH 1991].

When respirators are used, the employer must establish a comprehensive respiratory protection program as outlined in the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection*[NIOSH 1987a], and as required in the OSHA respiratory protection standard [29 CFR 1910.134]. Important

elements of the OSHA respiratory protection standard are (1) an evaluation of the worker's ability to perform the work while wearing a respirator, (2) regular training of personnel, (3) periodic environmental monitoring, and (4) respirator fit testing, maintenance, inspection, cleaning, and storage. The program should be evaluated regularly by the employer. Without a complete respiratory protection program, workers will not receive the protection anticipated.

Respirators should be selected by the person who is in charge of the program and knowledgeable about the workplace and the limitations associated with each type of respirator. Because exposures to lead during construction may vary substantially throughout a workshift and between days, the highest anticipated exposure should be used to determine the appropriate respirator for each job.

Respirator selection should be made according to the guidelines in Table 3. Employers must use respirators that are certified by NIOSH and the Mine Safety and Health Administration (MSHA) [NIOSH 1991a].

Table 3.--NIOSH recommended respiratory protection for workers exposed to inorganic lead

Condition	Minimum respiratory protection*
Less than or equal to 0.5 mg/m^3 (10 x PEL)**	Any air-purifying respirator with a high-efficiency particulate filter
Less than or equal to 1.25 mg/m^3 (25 x PEL)	Any powered, air-purifying respirator with a high-efficiency particulate filter, or Any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode (for example, type CE abrasive blasting respirators)
Less than or equal to 2.5 mg/m^3 (50 x PEL)	Any air-purifying, full-face piece respirator with a high efficiency particulate filter, or Any powered, air-purifying respirator with a tight fitting face piece and a high-efficiency particulate filter

Less than or equal to 50 mg/m^3 (1,000 x PEL)	Any supplied-air respirator equipped with a half-mask and operated in a pressure-demand or other positive pressure mode
Less than or equal to 100 mg/m^3 (2,000 x PEL)	Any supplied-air respirator equipped with a full face-piece and operated in a pressure-demand or other positive-pressure mode
Planned or emergency entry into environments containing unknown concentrations or concentrations above 100 mg/m^3 (2,000 x PEL)	Any self-contained breathing apparatus equipped with a full face piece and operated in a pressure-demand or other positive-pressure mode, or Any supplied-air respirator equipped with a full face-piece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode
Firefighting	Any self-contained breathing apparatus equipped with a full face piece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying, full- face piece respirator with a high-efficiency particulate filter, or Any appropriate escape-type, self-contained breathing apparatus