Safety Considerations in Coating and Painting Operations

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Chapter 10
Safety

10-1. Introduction

Coating and surface preparation operations inherently expose workers to many potential safety and health hazards. Because of the high frequency rate of accidents in the coating industry, painting is considered a high hazard occupation. Some common safety and health hazards associated with painting include: improper selection and/or use of personal protective equipment such as respirators for toxic chemical control; operating abrasive blast-cleaning equipment at high pressure; storage and use of flammable liquids; work in confined spaces; toxic effects from exposure to chemicals in coating materials; ignition sources such as welding, burning, and cutting that may cause solvents to ignite or produce toxic airborne contaminants.

10-2. Hazardous Material Handling

a. Coating materials. The primary components in industrial coating materials are commonly grouped into four general categories: binders, pigments, organic solvents, and additives. The chemicals that make up these components affect the nature and type of hazards presented during use. Most coating materials present both a health hazard and a flammability hazard. A coating material may be considered a health hazard when its properties are such that it can directly or indirectly cause injury or illness, either temporary or permanent, from exposure by direct skin contact, inhalation of vapors as the liquid portion evaporates, or inadvertent ingestion. The components of coating materials have varying health effects, depending on the toxicity of the particular component. Some chemicals may cause irritation, sensitization, central nervous system effects, or systemic effects. Chemical exposure for short periods of time at low doses can be tolerated; however, immediate sensitivity to some ingredients may occur. Extended exposure almost always will cause some type of reaction. Continued exposure may cause the body to become sensitized so subsequent contact may result in an aggravated reaction, especially for anyone with a chronic illness. A discussion of some health hazards related to coating material components follows.

(1) Binders. All resins or binders are toxic to some degree if exposure is excessive. The primary health hazard associated with binders generally is related to skin contact. Some binders may be strong sensitizers and cause an allergic reaction. Specifically, epoxy resins used in USACE formulations E303 zinc rich epoxy and C200 coal tar epoxy and military formulation MIL-P-24441A polyamide epoxy may cause allergic reactions with certain workers, depending on their sensitivity to these epoxy resins. The use of chemically resistant gloves, aprons, safety goggles, and face shields must be enforced to help avoid contact with the epoxy resins. Special attention also must be given to urethane coating systems such as those specified in MIL-C-83286B. The two-component urethane coating systems are formed by the reaction of the diisocyanate and a polyester. Diisocyanate compounds are irritants to the eyes, nose, and throat on initial exposure. Some workers exposed to low doses (low airborne concentrations) may develop respiratory tract sensitization. Once sensitized to diisocyanates, the health effect is similar to asthma-like symptoms. To control exposure, workers must wear protective clothing as described while handling epoxy resins. Protective clothing and a supplied-air respirator must also be worn while handling polyurethanes.

(2) Pigments. The use of common heavy metal compounds—including lead, cadmium, and chromium—historically have presented health hazards. These metals are all toxic to many internal body systems. The recent introduction of less toxic pigments such as iron, titanium, and zinc have helped to reduce this potential hazard. The heavy metal pigments present the greatest health hazard during coating-removal operations. This is especially true with lead.

(3) Organic solvents. A wide variety of organic chemicals, typically referred to as solvents and thinners, are used in the formulation of coating materials. Control measures to prevent the health effects of solvent exposures include providing adequate ventilation to dilute vapors to safe levels, referencing the MSDS to select the proper protective clothing, avoiding unnecessary or prolonged skin contact, and using appropriate respiratory protection if the concentration of vapor in the air is above permissible levels. The health hazards associated with solvents depend on many variables, including the toxic characteristics unique to that solvent, level of exposure (the dose), the duration of exposure, and the route of entry into the body. The principal routes of entry into the body for solvent exposure are inhalation of the vapors and skin contact. The most common result of skin contact with a solvent is irritation. It should be recognized that, although most solvents will cause skin irritation at the site of contact, some solvents also may be taken into the body through skin absorption. Some common solvents that can be absorbed through the skin include several alcohols, toluene, and some specific ketones. The MSDS for the solvent should be reviewed to determine skin absorption capabilities. The following summary is provided to illustrate the various health effects of solvents commonly found in industrial coating materials. Many solvents have overlapping symptoms that make determining

which solvent is causing a problem difficult if more than one type of solvent is used. Solvents also can have a synergistic effect, which means that, if two solvents are used that are both harmful in the same way, the symptom will be more than double.

(a) Skin irritants. Most organic solvents remove the natural oil from the skin. Removal of the oil causes reddening, chapping, drying, and cracking of the skin at the point where the solvent contacts the skin. Contact usually occurs on the hands and forearms. The effect usually is not serious, and affected areas heal when exposure ceases.

(b) Mild respiratory irritation. The vapors of some solvents will cause eye, nose, and throat irritation because they are highly soluble with the moist mucous membranes of the upper respiratory system. These effects usually are not serious, and they disappear as soon as the person is removed from the toxic environment and given fresh air. However, the concern is that the toxic substance has entered the body and may cause systemic problems.

(c) Nervous system effects (solvent neurotoxicity). Most solvent vapors can act on either the central nervous system or the peripheral nervous system (hands, legs, arms, and feet). These vapors can produce headaches, drowsiness, convulsions, behavior changes, tremors/shaking, and loss of feeling and control. Most of these effects are short term; however, some specific solvents produce permanent disabilities.

(d) Nephrotoxins (kidney) effects. Chronic exposure to nephrotoxins can cause damage to the kidneys. These effects must be considered serious; they are permanent and, in extreme cases, may be fatal.

(4) Additives. Most additives make up only a small percent of the coating material and usually do not present much of a health hazard. The MSDS should be reviewed to assess the types of additives in the coating material and the nature of the health hazards that may result.

b. Flammable/combustible liquids. The presence of organic solvents in industrial coating materials and thinners presents significant fire and explosion hazards. Virtually all solvent-based coatings and thinners are highly flammable in liquid form, and vapors released in the process of application are explosive in nature if concentrated in sufficient volume in closed or restricted areas.

(1) Classification of flammable and combustible liquids.

(a) According to the National Fire Protection Association (NFPA), a flammable liquid is a liquid with a flash point below 37.8 °C (100 °F). A flash point is the lowest temperature at which a liquid gives off enough vapor to form an ignitable mixture with air and to flash (produce a flame) when a source of ignition is present. Highly flammable liquids have extremely low flash points. At the typical ambient temperatures most coatings are applied, solvents such as alcohols, acetone, toluene, or methyl ethyl ketone can give off enough vapors to ignite easily.

(b) A combustible liquid is one with a flash point above 37.8 °C (100 °F). Common solvents include mineral spirits, high flash naphtha, and methyl isoamyl ketone. To determine the flash point of a coating material, refer to the MSDS.

(2) Lower explosive limit/upper explosive limit.

(a) Liquids do not burn or explode, but their vapors do. For this reason, understanding the concept of lower explosive limit (LEL) and upper explosive limit (UEL) is important for the prevention of explosions. The explosive or flammable range of a solvent is the percentage range of the solvent vapor in air, by volume, within which the vapor concentration is sufficient to support combustion. The range is defined by the minimum concentration (LEL) and the maximum concentration (UEL) of vapor in air necessary to allow the vapor to ignite. A mixture of air and flammable vapor will burn or explode only within these concentrations or limits. For example, toluene has an LEL of 1.2 percent and a UEL of 7.1 percent. This means the airborne concentration must fall in this range for the toluene vapor-air mixture to ignite or explode. Airborne concentrations of toluene less than 1.2 percent are too "lean" to support combustion. From a safety viewpoint, knowledge of the LEL is important because most operations start with concentrations of a flammable vapor well below this limit and build up to the explosive range.

(b) The airborne concentration of a solvent required to have an explosive atmosphere is much higher than that required to have a toxic atmosphere. For example, OSHA has established a permissible exposure limit (PEL) of 200 parts per million (ppm) for toluene. When workers are exposed to levels of 200 ppm or above, irritation and central nervous system effects may occur. As discussed in the previous paragraph, a concentration of 12,000 ppm (1.2 percent) is required to reach an explosive atmosphere of toluene.

(c) The LEL for solvents varies and depends on the specific chemical or mixture of solvent. Determining just how quickly an LEL can be achieved is difficult because it depends on the type and volume of vapor in a given space. LEL can be measured using a combustible gas indicator that measures total hydrocarbons in the atmosphere. OSHA Standard 29 CFR 1910.146, currently establishes a guideline that no space should be entered if the concentration of flammable vapors in air equals or exceeds 10 percent of the LEL.

(3) Determining ventilation needed to control explosion hazards.

(a) A danger when coating in enclosed spaces is that the solvent vapor buildup in the entire space, or a sizable portion thereof, will be enough to reach the LEL. However, coating in enclosed spaces can be made entirely safe if adequate ventilation is provided.

(b) The volume of air per hour required for the dilution of vapors to the LEL is calculated using Equation 10-1.

Volume of air (cubic feet per hour)

$$= \frac{\text{vapor volume per gallon liquid} \times 100}{\text{lower explosive limit (\%)}} \qquad (10\text{-}1)$$

The vapor volume is the number of cubic feet of solvent vapor formed by the evaporation of 3.78 L (1 gal) of solvent. Equation 10-2 shows how to calculate vapor volume.

Vapor volume (cubic feet per gallon)

$$= \frac{\text{specific gravity of solvent} \times 8.31 \times 392}{\text{molecular weight of the solvent}} \qquad (10\text{-}2)$$

Using toluene as an example, Equations 10-3 and 10-4 demonstrate how to calculate the total volume of air needed to prevent a flammable concentration if 3.78 L (1 gal) of toluene is evaporated per hour.

toluene: specific gravity = 0.9
molecular weight = 92
LEL = 1.2 percent

$$= \frac{0.9 \times 8.31 \times 392}{92} = 31.86 \qquad (10\text{-}3)$$

Volume of air per hour for dilution to LEL

$$= \frac{31.86 \text{ cubic feet} \times 100}{1.2\%}$$

$$= 2{,}655 \text{ cubic feet per hour} \qquad (10\text{-}4)$$

$$= 44.25 \text{ cubic feet per minute}$$

Therefore, the minimum volume of air needed to ensure dilution of toluene vapors to the LEL is 1.24 m^3 per minute (44.25 cubic feet per minute [cfm]). Generally, a safety factor of 10 is applied when controlling flammable vapor mixtures. Thus, by using a safety factor of 10, at least 120 (10 × 44) m^3 per minute (440 [10 × 44] cfm) should be exhausted and replaced with outside air for each gallon of toluene evaporated per hour in a space. Air in a confined space must be moving to prevent pockets of higher concentration.

(c) The next step is to determine the amount of solvent used per hour. For instance, the foregoing example would apply to one applicator rolling on 7.56 L (2 gal) of coating containing 50 percent by volume toluene in a 1-hour period. So 3.78 L (1 gal) of toluene, or 0.89 m^3 (31.86 cubic feet) of vapor, theoretically would evaporate in a 1-hour period. Spray guns will apply up to 1 quart of liquid per minute or 56.7 L (15 gal) per hour. Assuming a 50 percent concentration of toluene, 28.35 L (7.5 gal) of toluene could be evaporated per hour. In this situation the calculation for determining the amount of air needed for proper dilution is given in Equation 10-5.

$$= \frac{7.5 \text{ gal} \times 31.86 \text{ cubic feet} \times 100}{1.2\%}$$

$$= 19{,}912.5 \text{ cubic feet per hour}$$

$$= 332 \text{ cfm} \qquad (10\text{-}5)$$

$$= 3{,}320 \text{ cfm with safety factor of } 10$$

This example is based on the presence of toluene in a coating. Other solvents or complex blends of solvents commonly found in coatings may yield different vapor volumes per gallon of liquid coating. Currently, CWGS 09940 requires 140 m^3 per minute (5,000 cfm) of air per spray gun, independent of the solvent type/blend in the coating.

(c) Fire protection/prevention. Most solvent-borne coatings and thinners are highly flammable in liquid form. Concentrated vapors in sufficient volume also are explosive in an enclosed area. As a result, the engineer should recognize that proper storage and handling of flammable or combustible liquids is an integral part of fire protection/prevention. Provisions for bulk storage areas and paint/solvent storage containers will be discussed.

(1) Bulk storage areas. OSHA has established regulations that control the storage and use of flammable and combustible liquids in both the Construction and General Industry Standards. These are published in the

Code of Federal Regulations (CFR) Title 29, Part 1910, Section 106 (29 CFR 1910.106) of the Safety and Health Rules for General Industry. Basically, these regulations state that the quantities of flammable liquids and solvents must be limited, depending on the location of the storage area, its construction, and the fire prevention measures available. OSHA Construction Industry Standard 1926.152 simplifies the storage of containers of flammable or combustible liquids by limiting the quantities of liquid to 4,158 L (1,100 gal) in any one area. Unlike the General Industry Standard, this OSHA Construction Industry Standard makes no distinction between the classes of liquids to be stored. The OSHA General Industry Standard applies to both indoor and outdoor storage of flammable and combustible liquids. The tables in the OSHA standard list the quantities (in gallons) permitted based on the NFPA class of liquid in use. Flammable and combustible liquid storage indoors is further limited, depending on the building level where materials are stored and whether or not the container piles are protected by fire sprinklers, heat-resistant walls, dikes, explosion-proof lighting, and ventilation. Most of the quantities listed in the OSHA standard are more than normally would be stored inside a simple box trailer typically found at a jobsite without fire protection. OSHA and the NFPA do not specifically address coating storage in trailers at a construction jobsite, so OSHA inspectors in various states may try to interpret these regulations differently. Therefore, flammable and combustible liquids should always be safely and properly used and stored at a jobsite. The following items should be established to improve trailer storage of flammable and combustible coatings and solvents at a jobsite.

- Most coatings emit vapors heavier than air in a closed trailer; therefore, ventilation screens should be placed at floor level at each end of the trailer in case there is a leak or spill.

- A heavy steel industrial cabinet should be used to store aerosol spray cans within the trailer; these cans become flaming airborne rockets when on fire and can spread a small fire throughout the trailer unless contained.

- At least one fire extinguisher with a rating of not less than 20-B units must be placed outside, in the open, no closer than 3 meters (10 feet) from the trailer.

- No more than 4,158 L (1,100 gal) total are permitted in any one outdoor storage area, and containers are not permitted to exceed 226.8 L (60 gal) each.

- The storage trailer should not be closer than 6 meters (20 feet) to a building.

- Coating mixing should be done only outside the storage trailer.

- Only air-operated agitators or inherently safe electric mixers should be used for mixing to prevent spark generation.

(2) Storage containers and safe work practices. Even though the quantities of flammable and combustible liquids stored on site are within OSHA guidelines, safe practices for dispensing and handling must be followed. Combustible and flammable liquids form vapors that can be ignited by sparks, open flames, or static electricity.

(a) Dispensing a flammable liquid from a drum to a smaller container causes static electrical charges to be generated. If a static discharge occurs, the flammable vapor present near the container can ignite explosively; an ignition can be prevented by electrically bonding the receiving container to the drum to draw off any static electrical charge on the container generated by the liquid flow, and to pass it harmlessly into the grounding system. Bonding is accomplished with a special bonding wire connected to the drum and clamped to the receiving container.

(b) In addition to this bond connection, drums must be properly grounded to the earth to safely drain static charges. When flammable or combustible liquids are dispensed from a 208-L (55-gal) drum in the horizontal position, each drum should be fitted with a self-closing valve and vacuum relief vents. Drum pumps can be used and are preferred to dispense flammable liquids from drums in the upright position. Drip cans should be positioned below each drum faucet to catch spills or leaks from worn or damaged faucets. These cans are lidless and have a perforated fire baffle over the opening. Bonding and grounding wires must be in place.

(c) Underwriters Laboratories listed or Factory Mutual approved safety cans must be used to transport flammable liquids from the storage area to the jobsite. These cans (metal or nonmetallic) must be labeled and must be leak tight. They also must automatically vent vapors when the pressure rises above 34.45 kPa (5 psi), have flame-arresting screens to prevent fire from reaching the contents, and have an automatic closing spout cap. The maximum allowable size of container depends on what class of flammable liquid will be stored and the type of material the container is made of.

d. Material safety data sheet (MSDS).

(1) The MSDS is an informational sheet required by the OSHA Hazard Communication Standard 29 CFR 1926.59 for each coating material, thinner, or other chemical stored

at the jobsite. An MSDS must be provided with each shipment of chemicals received at the site. The MSDS can be used for several purposes such as:

- Identifying chemical ingredients in coating materials.
- Assessing technical data like flash point, LEL, OSHA PEL, odor, and health hazards.
- Selecting proper personal protective equipment.
- Establishing proper storage practices.
- Measures to take to clean up spills or leaks.

(2) The MSDS must be easily accessible and must be available for viewing without request for permission. The MSDS must be current, and the worker must be instructed on how to read and interpret the information on the MSDS.

10-3. Hand and Power Tools

a. All hand and power tools should be kept in good repair and used only for the purpose for which they were designed. The most common injuries resulting from the use of power tools include burns, cuts, electric shock, particles in the eye, and trips/falls due to flexible hoses, cords, and cables in walking areas. Loose clothing or jewelry should not be worn because they may be caught in the power tool.

b. Power tool cleaning equipment such as the roto-peen and needle gun generate noise levels in excess of the OSHA permissible limit of 90 decibels. Therefore, hearing protection should be worn when using power tool cleaning equipment. In addition, the use of eye protection is required when machines or operations present the hazard of flying objects or liquids. Eye protectors that fit snugly and do not impede the wearer should be worn when removing coatings with hand or power tools. Eye protection must be designed, constructed, tested, and used in accordance with the American National Standard for Occupational and Educational Eye and Face Protection Z87.1-1968.

10-4. Abrasive Blast-Cleaning Equipment

The primary hazards associated with abrasive blast cleaning are created by the high air pressures needed to propel an abrasive agent at high velocities toward a surface. This paragraph will cover safety hazards associated with blast-cleaning equipment.

a. Nozzles. Nozzles come in a variety of sizes, lengths, and liner materials. Prior to use, the liner material should be carefully inspected for wear or surface fractures. Blasters are often careless in the handling of nozzles: dropping them to the ground, using them as signal hammers, and losing the gasket between the nozzle and the nozzle holder. A broken liner can be shot out of a nozzle, bounce off the surface being cleaned, and injure the blast operator. Most nozzle manufacturers recommend replacing nozzles when the orifice is 3.175 mm (2/16 in.) larger than the original size, or if the liner appears cracked. The nozzle threads also should be checked for wear.

b. Deadman control. According to current OSHA standards (29 CFR 1926.302) all blast-cleaning machines must be equipped with “deadman” controls to protect the user. These are remote control systems that automatically shut off the blast machine when the operator releases a handle. This system usually is a spring-loaded control located near the nozzle end of the blast hose. When depressed, the flow of high pressure air and abrasive is started. When released, the flow is stopped.

c. Blast pots or pressure blast tanks.

(1) Blast pots and related pressure tanks for blast-cleaning operations must be built to standards set by the American Society of Mechanical Engineers (ASME). Pots not meeting these requirements must not be used. A pressure vessel meeting the ASME code will be labeled indicating that it has been built and tested to withstand the pressures used in field blasting operations. Unless otherwise specified by the manufacturer, the maximum working pressure of blast machines and related components must not exceed the ASME approved limit of 861.25 kPa (125 psi). The blast machine should be electrically connected to ground to help eliminate static electricity hazards. The ASME code prohibits any field welding or alterations to the pressure vessel.

(2) Pressure tanks for compressed air or blast pots under pressure should be checked regularly because these containers also are subject to abrasion and deterioration beyond that of normal pressure vessels. Pressurized abrasive tanks must have a removable plate for internal inspection. The blast system must be depressurized before opening any doors, panels, or lids. The manufacturer's instructions to maintain equipment at recommended intervals always should be followed.

d. Pot tender. The pot tender is responsible for maintaining the blast machine in support of the blasters. If the pot tender cannot see the blasters, a means of communication should be established. This may be two-way radios or a signal man, which allows for immediate shut down of equipment if there is an equipment failure or other problem.

e. External couplings and blast hose.

(1) Only externally fitted quick couplings should be used on blast hoses. Internal fittings can reduce the inside diameter and the air-carrying capacity of the hose by more than 50 percent. This reduction in the inside diameter of the hose sets up a turbulent condition in which the air and abrasive strike the leading edge of the nipple inside of the hose and create tremendous pressure drops and a heavy wear condition at this point. Most commercially available external couplings are equipped with sled-like runners so the coupling will not catch if it is dragged over irregular surfaces such as steel decking.

(2) When repairing a blast hose or installing hose couplings, the end of the hose should be cut square for proper fit in the coupling. An irregular or nonsquare cut will lead to a potential wear area between the end of the hose and the inside of the coupling or nozzle holder. Safety pins should be installed at every coupling connection to prevent accidental disengagement during use or hose movement. Safety cables also should be used at all air hose and blast hose coupling connections. These cables relieve tension on the hose and help control whipping action if there is a coupling blowout.

(3) The blast hose should be a natural gum tube treated with carbon black to prevent electrical shock to the operator.

(4) Proper care of blast hoses is essential. Hoses should be stored in dry areas to prevent rotting. During blast-cleaning operations, the hose should run as straight as possible. If the hose must curve around an object, a long radius curve should be used; sharp curves create rapid interior wear on the hose.

f. Helmets.

(1) The dust produced by abrasive blasting is a serious health hazard. The dust results from the breakdown of abrasives and the pulverizing of surface coatings, rust, mill scale, and other materials on the steel surface that is being blast cleaned. To protect workers from this dust, constant flow, air-fed blast helmets are used. The supplied-air system must meet the requirements established by NIOSH for type C respirators. Type C constant-flow air systems for abrasive blasting operations are classified further by NIOSH as Type CE respirators. Type CE systems are specifically designed for abrasive blasting work because they include protection for the head, neck, and upper body. The primary components of the system include: an air source (compressor), a delivery system (hoses, air filters, pressure regulator), and a NIOSH/MSHA (Mine Safety and Health Administration) approved blasting hood/helmet (with airflow control valve and belt clip) that maintains a minimum airflow of 0.167 m^3/min (6 cfm) and a maximum airflow of 0.42 m^3/min (15 cfm) to the hood.

(2) OSHA requires that the blasting hood be supplied with air meeting the requirements for Grade D air, as described by the Compressed Gas Association Specification G7.1, which was updated in 1989. The requirements for meeting Grade D breathing air are listed in Table 10-1.

Table 10-1
Grade D Breathing Air Requirements

Oxygen	19.5 to 23.5 percent
Oil mist	5 mg/m^3 or less
Carbon monoxide	10 ppm or less
Carbon dioxide	200 to 1,000 ppm
Odors	None perceived

Only breathing-air-type compressors should be used. They should be equipped with in-line air-purifying sorbent beds and filters, compressor failure alarm, high temperature alarms, and pressure regulators to the respirator air lines. Breathing air couplings shall be incompatible with outlets for nonrespirable air or other gas systems to prevent inadvertent servicing of air-line respirators with nonrespirable gases. Oil-lubricated compressors also should be equipped with a carbon monoxide alarm or they should be tested frequently to ensure that carbon monoxide levels remain below 10 ppm. Compressors should be situated to avoid entry of contaminated air into the system.

g. Protective clothing. In addition to respiratory protective equipment, blasters should wear apparel to prevent damage to their skin from abrasive blast-cleaning material and ricocheting. This includes safety footwear meeting the requirements of ANSI Z41, coveralls, leather or rubber capes, and gloves. Pants and sleeve cuffs should be secured with tape or other suitable fasteners.

10-5. Spray Equipment

a. Respiratory protection. Spray painting has the capability to release high concentrations of solvent vapors in a short period of time. Therefore, adequate ventilation is necessary to provide a safer work environment. (For a more detailed discussion of ventilation systems, see paragraph 10-5*c*.) When ventilation cannot maintain worker exposures to potentially harmful vapors within permissible exposure limit (PEL), respiratory protection needs to be provided. An overview of the requirements established by

OSHA for properly selecting, using, and maintaining respirators is discussed in paragraph 10-7.

b. Spray gun operations. Because airless spray systems operate at pressures in the range of 13,780 to 20,670 kPa (2,000 to 3,000 psi), safety considerations require special attention during operation. A tip guard and trigger lock must be on all airless spray guns to prevent injury to the worker. The extremely high fluid pressure developed in airless spray coating equipment causes a powerful stream of coating to be discharged for some distance. This pressure remains in the system even though the pump has been shut off, and the pressure can be relieved only by being discharged through the gun. Fluid sprayed from the gun is propelled with sufficient force to penetrate the skin and cause serious damage. The entire system is pressurized so a rupture or leak in the hose at the fittings can result in dangerous high pressure spray.

c. Ventilation.

(1) Good ventilation is essential when painting in enclosed areas. This usually is achieved by introducing "fresh" outside air into the painting area. All areas of the enclosed space should be swept by moving air. The volume of air needed to dilute vapors below their lower explosive limit is discussed in paragraph 10-2. A mechanical engineer familiar with design of ventilation systems may be required to ensure proper distribution of airflow through the space. In enclosed spaces, solvent vapors tend to concentrate at floor level. Therefore, ventilation systems should be designed to exhaust air from the lower portions of the enclosure. Make-up air should be introduced into the enclosure near the upper portions of the space and on the opposite side from which the exhaust is located. This will allow for a more even distribution of outside air through the enclosure. The ventilation must continue throughout the drying process.

(2) Although not applicable to most field painting operations, some spray application methods are performed using principles of local exhaust ventilation. Local exhaust ventilation (e.g., spray booth) is designed to remove the paint mist and vapors near their point of generation. Air velocity through the spray area and in the ductwork must be adequate to direct paint mist and vapors into the exhaust system. The American Conference of Governmental Industrial Hygienists (ACGIH) published a manual on industrial ventilation (ACGIH 1989). This manual recommends criteria for duct velocities and airflow through spray coating booths. For example, very fine, light dusts require a duct velocity of 610 meters per minute (m/min) (2,000 feet per minute [fpm]), and heavy or moist dust requires a duct velocity of 1,372.5+ m/min (4,500+ fpm). A spray coating operation requires a duct velocity of 2,000 fpm. For walk-in type spray booths, the ACGIH recommends an air velocity of 30.5 m/min (100 fpm) at the face of the booth.

10-6. Welding and Cutting of Coated Steel

a. A major hazard results from welding and cutting on surfaces coated with lead-based finishes. If possible, these coating materials should be removed mechanically by scraping, wire brushing, or blasting before welding or cutting. If this is not possible, local exhaust ventilation or respiratory protection must be used to protect the worker during welding and cutting.

b. OSHA standard 29 CFR 1926.354 addresses controls for this type of work in enclosed spaces and in open air. In enclosed spaces, all surfaces covered with a preservative coating that contains a toxic constituent such as lead must be stripped of that toxic coating for a distance of at least 101.6 mm (4 in.) from the area of heat application, or the employee must be protected by an air-supplied respirator. During welding and cutting work in open air, employees only need to be provided with a respirator adequate for the airborne level of exposure of the toxic constituent.

10-7. Respiratory Protection Overview

OSHA has established PEL for approximately 500 chemical substances. If workers are exposed to any one of these substances in excess of permissible limits, the employer is required to provide respiratory protection until feasible engineering controls can be implemented to reduce exposure levels. To ensure the proper use of respirators, OSHA requires the employer to provide a minimal acceptable respiratory protection program, as detailed in OSHA's respiratory protection standards 29 CFR 1926.103 and 1910.134. The following paragraphs outline the primary requirements of these standards.

a. Employee qualifications.

(1) Medical surveillance. Wearing any type of respirator imposes some physiological stress on the wearer. If the worker's cardiovascular or pulmonary function is significantly impaired, wearing a respirator could constitute an unacceptable risk. OSHA requires that persons should not be assigned to tasks requiring use of respirators unless it has been determined by a physician that they are physically able to perform the work and use the respiratory equipment. The physician will determine what health and physical conditions should be evaluated. The respirator user's medical status must be reviewed annually. The types of information generally included in the respirator user's

medical evaluation include: respiratory system evaluation (pulmonary function test), cardiovascular evaluation, history of respiratory disease, work history to identify previous chemical exposures, any other medical information that might affect the worker's ability to wear a respirator.

(2) Training. In addition to ensuring that workers required to use a respirator are medically qualified to wear the device, the worker also must be trained on the proper use of the equipment. A good training program for workers assigned to wear a respirator includes:

- Opportunity to handle the respirator.
- Proper fitting, including demonstrations and practice in wearing, adjusting, and determining the fit of the respirator.
- Test of facepiece-to-face seal.
- A familiarization period of wear in normal air.
- Wearing the respirator in a test atmosphere, such as during a fit test.
- Explanation of the nature of the respiratory hazard and what happens if the respirator is not used properly.
- Explanation of why a particular type of respirator has been selected, and its limitations.

(3) Fit testing. Workers assigned to wear an air-purifying type of respirator should receive fitting instructions and a fit test. The check must include demonstrations and practice in how to inspect, adjust, and wear the respirator. After successful completion of the fit check, the individual should pass a fit test. Two types of fit tests are acceptable to OSHA: qualitative and quantitative. A qualitative test relies on the wearer's subjective response to an irritant smoke or an unpleasant odor. A quantitative test is an actual measure of the protection provided by the respirator in a known concentration of a test atmosphere. Regardless of the type of test performed, the fit test should be documented, including the type of respirator, manufacturer, model of respirator, size of the mask, fit test results, date test was administered, and employee signature.

(4) Facial hair. Hair in the face-seal area of a respirator causes a significant decrease in the protection factor provided by either an air-supplied or air-purifying respirator. The amount of leakage in the face seal varies with the type or texture of facial hair. A fine-haired beard usually will compact and cause less leakage than a coarse-haired beard. However, any hair in the face-seal area will decrease the amount of personal protection a respirator is designed to provide. For this reason, OSHA regulations prohibit any hair in the facepiece sealing area. The rule of thumb is no more than one day's growth of facial hair.

(5) Corrective lenses. When a respirator user must wear corrective lenses, the respirator must be fitted to provide good vision and should not interfere with the seal of the respirator when in use. Glasses with straps or temple bars that pass through the sealing surface of air-purifying or air-supplied, tight fitting, full-facepiece respirators should not be used. Systems have been developed for mounting corrective lenses inside respirators. Mounting of corrective lenses to the facepiece should be conducted by a trained individual to provide good vision and comfort to the wearer. Contact lenses should not be worn in conjunction with a respirator. Contaminants may get into the eyes and cause severe irritation and/or discomfort with half-masks. A full facepiece can pull at the side of the eye and pop out the lens.

b. Respirator selection.

(1) Choosing the right equipment involves several steps: determining the hazard and its extent, choosing equipment that is certified for the function, and assuring that the device is performing the intended function. The proper selection of respirators must be made according to the guidance of ANSI Z88.2 or "NIOSH—Respirator Decision Logic."

(2) Chemical and physical properties of the contaminant, as well as the toxicity and concentration of the hazardous material and the amount of oxygen present, must be considered in selecting the proper respirators. The nature and extent of the hazard, work rate, area to be covered, mobility, work requirements and conditions, and the limitations and characteristics of the available respirators also are selection factors.

(3) There are two basic classes of respirators: air purifying and air supplying. Air-purifying respirators use filters or sorbents to remove harmful substances from the air. They range from simple disposable masks to sophisticated powered air-purifying respirators. Air-purifying respirators do not supply oxygen and may not be used in oxygen-deficient atmospheres or in atmospheres that are immediately dangerous to life or health. Atmosphere-supplying respirators are designed to provide breathable air from a clean air source. They range from supplied-air respirators and self-contained breathing apparatus (SCBA) to complete air-supplied suits.

(4) Air-purifying respirators present minimal interference with the wearer's movement. Atmosphere-supplying respirators may restrict movement and present potential

hazards. For example, supplied-air respirators with their trailing hoses can limit the area the wearer can move to and may present a potential hazard when the trailing hose can come into contact with machinery. Similarly, a SCBA respirator that includes a back-mounted, compressed-air cylinder presents both a size and weight penalty that may restrict climbing and movement in tight places.

(5) The protection factor assigned to the respirator by NIOSH is another consideration in selecting the proper respirator. A protection factor is a measure of the degree of protection afforded to the respirator wearer by that respirator. The protection factor may change depending on the chemical substance. The NIOSH assigned protection factor can be obtained from the respirator manufacturer; it usually is typed on the box containing the respirator. Protection factors can be used to determine the maximum allowable airborne concentration of a contaminant that the respirator is approved for. For example, the maximum allowable use concentration equals the NIOSH assigned protection factor for the respirator multiplied by the PEL for the contaminant.

c. Respirator issuance. Respirators should be issued only to employees who meet the qualifications outlined previously. Only properly selected respirators that provide an adequate degree of protection should be issued. Employees should not be permitted to use a respirator that has not been approved by the employer.

d. Respirator use. The respirator manufacturer's instructions should be read to understand the equipment's purpose and its limitations. The respirator must be worn in the manner in which it achieved NIOSH approval. All respirators must be inspected for wear and deterioration of their components before and after each use. Special attention should be given to rubber or plastic parts, which can deteriorate. The facepiece—especially the face seal surface, headbands, valves, fittings, and cartridges—must be in good condition. A respiratory protection program as required by OSHA (see Chapter 11) must be established; this program must describe cleaning, storage, and inspection practices.

10-8. Confined Space Entry

In 1993, OSHA issued a standard that dealt with working in confined spaces. The 29 CFR 1910.146 standard defines confined space as a space that is large enough and so configured that an employee can bodily enter and perform assigned work, has limited or restricted means for entry or exit, and is not designed for continuous employee occupancy. EM 385-1-1 also adds that a confined space may be defined as a space having unfavorable natural ventilation that could contain or has produced dangerous concentrations of airborne contaminants or asphyxiants.

a. Confined space program.

(1) In their definition of confined spaces found in 29 CFR 1910.146, OSHA includes both hazardous and nonhazardous spaces. In some situations, a space may be considered a nonpermit confined space. Nonpermit confined space means a confined space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm. Confined spaces may be entered without the need for a written permit or attendant if the space can be maintained in a safe condition for entry by mechanical ventilation alone. Permit-required, confined spaces are defined as any area presenting, or having the potential for containing, hazards related to atmospheric conditions, engulfment, configuration, or any other recognized serious hazard.

(2) To work in a permit-required confined space, the employer is required to have a written program. The written confined space program must:

- Prevent unauthorized entry.
- Identify and evaluate permit space hazards prior to entering.
- Describe the means, procedures, and practices for safe entry, including air testing.
- Provide specified equipment for entry, including personal protective equipment such as respirators, maintain the equipment, and ensure its proper use. Retrieval systems must be used when an individual enters a permit-required space to facilitate nonentry rescue, unless the retrieval equipment increases the risk of entry or would not contribute to the rescue.
- Designate the persons with active roles in entry operations (e.g., entrants, attendants).
- Describe the procedures for summoning rescue and emergency services and preventing unauthorized personnel from attempting a rescue.
- Describe the system for preparation, issuance, use, and cancellation of entry permits.
- Describe the procedures to coordinate entry operations when employees of more than one employer are working in a permit space.

- Require the review of the permit-required, confined space program within 1 year of entry, which would result in an annual review for employers who have at least one permit space entered each year.

b. Confined space hazards.

(1) The hazards associated with confined spaces include hazardous atmospheres and physical hazards. A hazardous atmosphere is an atmosphere that may expose employees to the risk of death, incapacitation, impairment of ability to self-rescue (that is, escape unaided from a permit space), injury, or acute illness from one or more of the following causes.

(a) Flammable gas, vapor, or mist in excess of 10 percent of its LEL. When vapors of a flammable liquid are mixed with air in the proper proportions in the presence of a source of ignition, rapid combustion or an explosion can occur. This proper proportion is called the flammable range and is often referred to as the explosive range. The flammable range includes all concentrations of flammable vapor or gas in air in which a flash will occur or a flame will travel if the mixture is ignited.

(b) Airborne combustible dust at a concentration that meets or exceeds its LEL.

(c) Atmospheric oxygen concentration below 19.5 percent or above 23.5 percent. An oxygen-deficient atmosphere is an atmosphere containing less than 19.5 percent oxygen by volume. The normal percentage of oxygen in air is approximately 20.9 percent.

(d) Atmospheric concentration of any substance for which a dose or a PEL is published in Subpart Z, Toxic and Hazardous Substances of 29 CFR 1910, and which could result in employee exposure in excess of its dose or PEL. An example of chemical substances found in Subpart Z that are common to painting include acetone, toluene, some ketones, and other solvents.

(e) Any other atmospheric condition that is immediately dangerous to life or health. An immediately dangerous to life and health atmosphere is defined as any condition that poses an immediate or delayed threat to life, that would cause irreversible adverse effects, or that would interfere with an individual's ability to escape unaided from a permit space.

(2) There are many safety hazards beyond atmospheric conditions that must be evaluated before permitting entry into a confined space. This includes physical hazards such as moving agitators, gears, and pistons that activate or move as a result of stored energy. This equipment must be blocked, braced, or chained, then locked out and tagged out to prevent accidental activation or unexpected movement.

(3) Valves and pipelines leading to a confined space also must be deactivated and tagged to prevent gases or liquids from entering that could explode, poison, burn, or drown a person. Valves should be chained or locked in the closed position. Pipelines should be disconnected, blanked off, and bled to empty out chemicals in the pipes.

(4) Noise also can be a hazard in a confined space where it is intensified, resulting in the workers not being able to hear important warnings or directions. Electronic communications and earphones may be necessary in noisy, confined areas.

(5) Heat can build up rapidly in a confined space and cause cramps, heat exhaustion, or heat stroke. Fresh air ventilation and cooling vests may be used to lessen the risks.

c. Self-contained breathing apparatus. SCBA may be one of the most important pieces of respiratory protective equipment used during emergencies and rescue attempts from confined spaces. The OSHA standard permits employers to have their own rescue team, or they may rely on offsite rescue services. The law requires the employer to ensure that the rescue team (in-house) or the rescue service (offsite) is provided with, and is trained to use, personal protective equipment (i.e., SCBA) and equipment necessary for making rescues. The rescue team or service must be capable of responding within 5 minutes of notification.

d. Standby person. A standby person is an individual stationed outside a permit-required confined space. This individual is assigned the responsibility of monitoring the workers authorized to enter the space and perform all duties assigned in the written confined-space program. OSHA refers to this person as an attendant. The person must be knowledgeable of the hazards associated with the confined space, be aware of the possible behavioral effects of exposure to any atmospheric hazards, maintain an accurate count of the number of workers in the space, remain outside the space while it is occupied, and establish a communication system to monitor workers inside and alert them to the need to evacuate the space.

e. Training. Each employee assigned to work in a confined space must be trained prior to being assigned duties, before there is a change in their duties, or whenever there is a change in the permit space operations for which the employee has not been trained. The training must allow the employee to acquire the understanding, knowledge, and skills necessary to perform duties safely. The employer is required to certify that the training has been accomplished. The certification must contain the employee's name, signature or initials of the trainer, and dates of training.

f. Ventilation equipment. Mechanical ventilation systems circulate fresh air throughout a confined space. The supply air fan should be located in an area that does not draw contaminated air into the confined space. Supply air fans should not be located near exhausts from gasoline or diesel powered equipment. The mechanical ventilation should remain in place the entire time the space is occupied. The standby person should test the atmosphere from outside the space periodically to ensure that no problem develops as a result of maintenance work performed in the space.

g. Atmospheric testing. Test equipment must be calibrated prior to use. Tests should be performed for oxygen content, flammable gases and vapors, and other potential toxic air contaminants such as carbon monoxide, hydrogen sulfide, aromatic hydrocarbon, and ammonia. The test for oxygen should be performed first because most combustible gas meters are oxygen dependent and will not provide reliable readings in an oxygen-deficient atmosphere. Combustible gases then are tested because, in most instances, the threat of fire or explosion is both more immediate and more life threatening than exposure to toxic gases and vapors. If necessary, tests for toxic gases are performed last. Atmospheric testing of the confined space usually is performed from top to bottom to allow time for each sample to reach the sensors in the equipment. The atmosphere within the space must be tested periodically as necessary to ensure that the continuous forced air ventilation is preventing the accumulation of a hazardous atmosphere. For permit-required spaces, continuous forced air ventilation must be used the entire time the space is occupied.

h. Entry permit. The OSHA standard requires a supervisor to authorize entry by preparing and signing a written permit. Permits must be available to all employees and extend through the duration of the project. The permit should be reauthorized by the supervisor for each work shift. The permit must be posted near the confined space for immediate reference. The OSHA confined space regulation (29 CFR 1910.146) specifies what must be documented on the permit.