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Occupational Safety and Health Administration

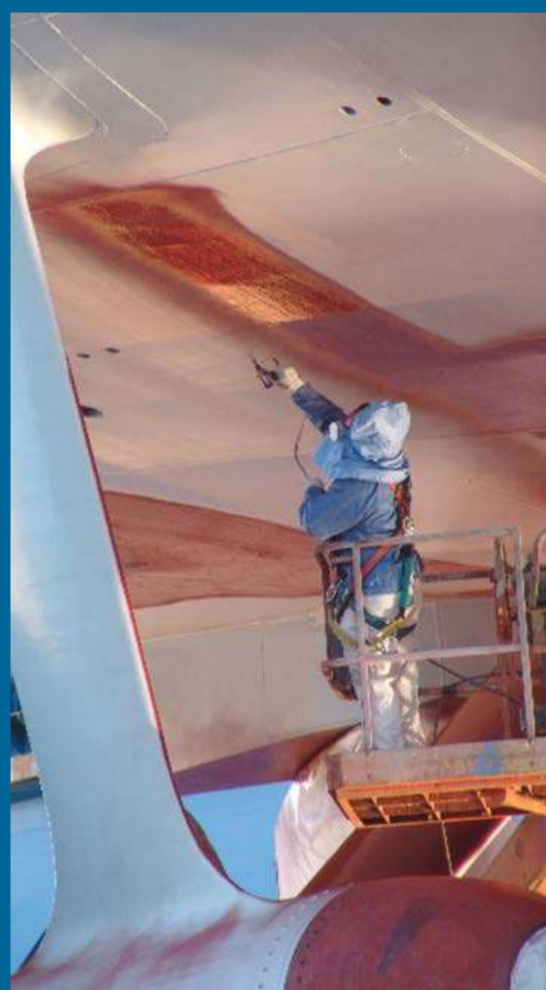
U.S. Department of Labor

SAFETY and **H**EALTH **I**NJURY **P**REVENTION **S**HEETS

Working with the Shipyard Industry

Process

Surface Preparation and Preservation



Establishing an Injury and Illness Prevention Program

The key to a safe and healthful work environment is a comprehensive injury and illness prevention program.

Injury and illness prevention programs are systems that can substantially reduce the number and severity of workplace injuries and illnesses, while reducing costs to employers. Thousands of employers across the United States already manage safety using injury and illness prevention programs, and OSHA believes that all employers can and should do the same. Thirty-four states have requirements or voluntary guidelines for workplace injury and illness prevention programs. Most successful injury and illness prevention programs are based on a common set of key elements. These include management leadership, worker participation, hazard identification, hazard prevention and control, education and training, and program evaluation and improvement. Visit OSHA's injury and illness prevention program web page at: **www.osha.gov/dsg/topics/safetyhealth** for more information.

How Can OSHA Help?

OSHA has compliance assistance specialists throughout the nation who can provide information to employers and workers about OSHA standards, short educational programs on specific hazards or OSHA rights and responsibilities, and information on additional compliance assistance resources. Contact your local OSHA office for more information.

OSHA's On-Site Consultation Program offers free and confidential advice to small and medium-sized businesses in all states across the country, with priority given to high-hazard worksites. On-site Consultation services are separate from enforcement and do not result in penalties or citations. Consultants from state agencies or universities work with employers to identify workplace hazards, provide advice on compliance with OSHA standards, and assist in establishing safety and health management systems. To locate the OSHA On-site Consultation Program nearest you, visit OSHA's website at **www.osha.gov/dcsp/smallbusiness/index.html,** or call 1-800-321-OSHA (6742).

OSHA's Cooperative Programs: OSHA offers cooperative programs under which businesses, labor groups and other organizations can work cooperatively with OSHA. To find out more about these programs, visit **www.osha.gov/dcsp/compliance_assistance/index_programs.html**.

Worker Rights

Workers have the right to:

- Working conditions that do not pose a risk of serious harm.
- Receive information and training (in a language and vocabulary they can understand) about workplace hazards, methods to prevent them, and the OSHA standards that apply to their workplace.
- Review records of work-related injuries and illnesses.
- Get copies of test results that find and measure hazards.
- File a complaint asking OSHA to inspect their workplace if they believe there is a serious hazard or that their employer is not following OSHA's rules. OSHA will keep all identities confidential.
- Exercise their rights under the law without retaliation.

For more information, see **www.osha.gov/workers/index.html**.

Contact OSHA

For questions or to get information or advice, to report an emergency, to report a fatality or catastrophe, to order publications, to file a confidential complaint, or to request OSHA's free on-site consultation service, contact your nearest OSHA office, visit **www.osha.gov**, or call OSHA at 1-800-321-OSHA (6742); TTY 1-877-889-5627.

Twenty seven states operate their own OSHA-approved plans. State Plans have and enforce their own occupational safety and health standards that are required to be at least as effective as OSHA's, but may have different or additional requirements. For a complete list of State Plans and their contact information, see **www.osha.gov/dcsp/osp/index.html**.

SAFETY and HEALTH INJURY PREVENTION SHEETS

Matrix

HAZARD/PROCESS	Falls	Burns/ Shocks	Over-exposure	Traumatic /Acute Injuries	Eye Injuries	Heat Stress
Hot Work: Welding, Cutting, and Brazing		A-17	A-25		A-12	
Ship Fitting/Unit Assembly	B-2	B-6	B-11	B-14	B-18	B-21
Rigging	C-9	C-12		C-13		
Shipboard Electrical		D-4, D-15, D-16, D-17		D-18 thru D-21		
Control of Hazardous Energy Lockout/Tags-plus		E-12		E-13, E-14		
Surface Preparation and Preservation	F-32 thru F-38	F-25 and F-26	F-28 thru F-31	F-14	F-27	F-28 and F-29

Disclaimer

This guidance document is not a standard or regulation, and it creates no new legal obligations. The information provided is designed to highlight safety and health hazards associated with surface preparation and preservation operations in the shipbuilding and ship repair industries only. Suggested preventative measures as well as descriptions of mandatory safety and health standards are also included. The recommendations are advisory in nature, informational in content, and are intended to assist employers in providing a safe and healthful workplace. The *Occupational Safety and Health Act* require employers to comply with safety and health standards and regulations promulgated by either federal OSHA or through an OSHA-approved State program. In addition, the Act's General Duty Clause, Section 5(a)(1), requires employers to provide their employees with a workplace free from recognized hazards likely to cause death or serious physical harm.

Standards Applicable to Surface Preparation and Preservation

The standards applicable to the hazards associated with surface preparation and preservation are:

- 29 CFR 1915, Subpart B – Confined and Enclosed Spaces and Other Dangerous Atmospheres
- 29 CFR 1915, Subpart C – Surface Preparation and Preservation
- 29 CFR 1915, Subpart D – Welding, Cutting and Heating
- 29 CFR 1915, Subpart H – Tools and Related Equipment

The diversity and dynamism of surface preparation work makes it impossible to list all applicable standards here. Requirements contained in 29 CFR Part 1915 apply to all shipbuilding and repair operations. The General Industry standards, such as 29 CFR 1910, Subpart G – Occupational Health and Environmental Control and 29 CFR 1910, Subpart Z – Toxic and Hazardous Substances, may also apply in some cases.

Resource Materials

OSHA's Shipyard **"Tool Bag" Directive, CPL 02-00-157**, dated April 1, 2014, provides guidance on the applicability of standards. See Appendix A for the application of 29 CFR Part 1910 standards where 29 CFR Part 1915 provisions do not address a recognized hazard in Shipyard Employment.

See the Shipyard e-Tool for additional compliance guidance at **www.osha.gov/SLTC/etools/shipyard/index.html**.

Work Processes Used in Surface Preparation and Preservation

Surface preparation, paint, and other protective coatings used in shipbuilding and ship repair pose a hazard to workers. Potentially harmful substances can enter the body through inhalation, ingestion, and contact with the eyes or skin. Surface preparation requires pre-planning and evaluation of the area for potential hazards before beginning work.

Employers must assess the work activity and, where necessary, implement engineering controls or provide workers with the appropriate personal protective equipment (PPE) (e.g., gloves, respirators, protective clothing, hearing protection) to prevent exposure to such harmful substances (**29 CFR 1915, Subpart I**). A Shipyard Competent Person (SCP), Certified Industrial Hygienist (CIH), or Certified Marine Chemist (CMC) may be needed to help evaluate hazards and recommend PPE. Surface preparation and preservation work performed in enclosed or confined spaces presents additional hazards and should be assessed with particular attention on those hazards.

Typical surface preparation and preservation operations include:

- **Abrasive Blasting** - This is the most common surface preparation technique used to remove old paint and other surface materials such as rust, mill scale, dirt, and salts. This method is usually conducted during vessel fabrication (e.g., on piping, steel plates and steel members used in structural assemblies, and other miscellaneous materials) and during maintenance and repair operations that include blasting and painting the ship's hull, and interior tanks and spaces. During abrasive blasting activity, there is a potential for workers to be struck by rebounding abrasive blast material (for example, sand, metal or slag) and be exposed to toxic dust from abrasive blast material and coatings (such as silica, paint and grease) being removed. Further, workers may be at risk for possible falls as a result of pressure surges in the hose line, tripping over equipment (such as hoses), and poor visibility. This is particularly a concern when workers are conducting abrasive blasting from elevated work surfaces, such as scaffolding. Static electricity and elevated noise levels are also hazards that workers could be exposed to during abrasive blasting operations.

- **Hydro-Blasting** - This is a cavitating (bubble-producing) high-pressure water jet stripping system that uses an engine-driven high-pressure pump, a large volume of water, high-pressure hose, and a gun equipped with a spray nozzle. The high-pressure water stream can reach as high as 50,000 psi, and the water can contain added abrasives to further assist with removing hard coatings from metal substrates. Some systems (e.g., robotically driven) reuse (recirculate) the water for additional blasting by automatically removing the paint chips or stripped materials from the water. Similar to abrasive blasting, use of this system may expose workers to elevated noise levels, falls, and toxic or hazardous substances in coatings. Further, this process may produce hazardous waste which would require compliance with applicable local, state, and Federal environmental regulations.

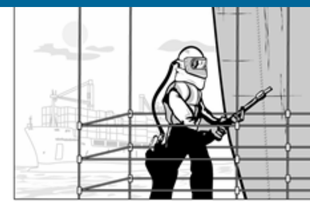
- **Chemical Stripping** - This is a coating removal method involving the use of organic (e.g., methylene chloride-based solutions) and inorganic (e.g., caustic soda solutions) strippers, often immersing small parts in dip tanks containing the solution. Parts are then rinsed to remove any stripping solution residue. Potential hazards include: inhalation of toxic vapors and skin or eye contact with liquids produced through reactions between the cleaner and the material being removed.

- **Thermal Stripping** - The use of a flame or a stream of superheated air to heat and soften hardened coatings (such as paint), allowing for easy removal. While useful for small parts, this method is labor intensive and not suitable for heat-sensitive surfaces. Workers could be exposed to fumes and smoke. A fire watch and/ or hot-work permit may be required when conducting this type of operation.

- **Mechanical Stripping** - The use of needle guns, chipping hammers, sanders, and grinders to remove coatings from small parts and surfaces. While some power tools may be equipped with dust collection systems, generally hazardous levels of paint waste and airborne particulate may be emitted. High noise, flying particles, and sparks produced when grinding are concerns for workers engaged in this activity. When performed from elevated work surfaces, such as scaffolding, workers have the potential risk for falls.

- **Painting** - The application of paint through brush, roller, and spray methods. Depending on which paint application method is used, there is a potential for workers to be exposed to toxic materials and flammable or explosive mists, particulates, and vapors. When performed from elevated work surfaces, such as scaffolding, workers have the potential risk for falls.

Abrasive Blasting



Abrasive blasting uses compressed air or water to direct a high-velocity stream of an abrasive material to clean an object or surface, remove burrs, apply a texture, or prepare a surface for the application of paint or other types of coatings. Air pressure is typically high, at 100 pounds per square inch, and nozzle velocities can approach 650 - 1,700 feet per second. Shipyard workers who engage in abrasive blasting, as well as those working in the vicinity, are at an increased risk of exposure to toxic dusts, high noise levels, and a range of other safety and health hazards that include particles becoming embedded in skin, eye damage, severe cuts, burns, loss of body parts (e.g., fingers and hands), and electric shock. Further, where poor housekeeping practices allow for the accumulation of dust particles from the abrasive material used, there exists the potential for explosions.

Commonly used abrasive materials include silica sand (crystalline), coal slag, garnet sand, nickel slag, copper slag, glass (beads or crushed), steel shot, steel grit, and specular hematite (iron ore). The application of many of these materials, blasted at a high velocity, may result in the release of toxic dust that is hazardous to workers. For example:

- Silica sand (crystalline) can cause silicosis, lung cancer, and breathing problems in exposed workers.
- Coal slag and garnet sand may cause lung damage similar to silica sand.
- Copper slag, nickel slag, and glass (crushed or beads) also have the potential to cause lung damage.
- Slags can contain trace amounts of toxic metals (such as arsenic, beryllium, cadmium, chromium, lead, nickel, silver, titanium, and vanadium).

When possible, alternative, less toxic blasting materials should be used to help prevent or reduce worker exposure to airborne hazards during abrasive blasting operations. Some less toxic abrasive blasting materials include plastic bead media, sponge, sodium bicarbonate (baking soda), ground walnut shells, high pressure water, ground corn cob, and other biodegradable materials. However, regardless of the type of blasting material used, employers must perform a hazards assessment of each workplace to determine what hazards are present, and provide workers with the appropriate PPE to protect them from the hazard(s) identified (**29 CFR 1915, Subpart I**). In determining the hazards for abrasive blasting operations, employers should not only account for the hazardous substances contained in the blasting materials, but the airborne toxins from metals such as lead, chromium, cadmium, and zinc, and any coatings applied to the surface where abrasive blasting is being performed.

Exposure to Noise

Abrasive blasting produces noise levels that can cause permanent hearing loss in unprotected workers and others close to the blasting process. The main source of noise is the discharge of compressed air at the blast nozzle. Other noise sources include: (1) the supply air inside the operator's helmet; (2) the impact of the abrasive on the surface being blasted; (3) air compressors; (4) exhaust ventilation systems; and (5) air released during grit pot blow-down. Small abrasive blasting cabinets are also sources of significant noise exposure for operators. The current permissible exposure limit (PEL) for noise exposure is 90 dBA, with employers required to take action at 85 dBA, both measured as eight-hour time-weighted averages (TWA). Employees who have experienced a standard threshold shift may not be exposed to noise above 85 dBA TWA. However, in this type of operation, noise levels range from 85 dBA (equivalent to that of a lawnmower running) to 145 dBA (equivalent to a shotgun blast). For those workers exposed to elevated levels of noise, employers must implement provisions for engineering and administrative controls (such as limiting frequency and duration of exposure), and/or hearing protectors, as well as a hearing conservation program including worker noise monitoring, audiometric testing, hearing protectors, training, and recordkeeping (**29 CFR 1910.95**).

Static Electricity

Static electricity can be generated by abrasive blasting equipment, the surfaces being blasted, and exhaust ventilation systems (fans and ductwork), resulting in shocks to workers, and fires or explosions when combined with flammable and combustible atmospheres or materials. The buildup of static electricity can be prevented through the proper use of bonding and grounding. Additionally, blast hoses can be constructed with anti-static rubber linings or fitted with a ground wire or similar mechanism to dissipate static electrical charges.

High-speed and High-pressure Hazards

Workers engaged in abrasive blasting can be struck by high-speed particles from the blasting media or the surface being blasted (substrate). In addition, they are exposed to high-pressure hazards through contact with high-pressure air or water streams, uncontrolled high-pressure hoses, and air or water leaks in the equipment. Potential injuries include particles becoming embedded in the skin, eye damage, severe cuts, burns, or loss of body parts.

Reduction of Hazards

Each abrasive blasting operation involves a unique set of circumstances, with different surfaces, coatings, blasting materials, and work conditions. OSHA requires that employers inspect each worksite prior to starting work to determine what hazards exist and what PPE, if appropriate, is necessary (**29 CFR 1915.152(b)**). Where PPE is required, employers must supply workers with the appropriate equipment, as well as ensure they are trained so that they understand when and what type of PPE is necessary; how to properly don, doff, adjust, and wear PPE; the limitations of PPE; and the proper care, maintenance, useful life and disposal of PPE (**29 CFR 1915.152(e)**). Further, employers should train all workers involved with abrasive blasting on health and safety hazards, how to use engineering controls, personal hygiene practices, and safe work practices. Manufacturers are also required to include appropriate health hazard information concerning the blasting materials on safety data sheets (SDS) as required by OSHA's Hazard Communication standard (**29 CFR 1910.1200**). Employers are responsible for maintaining SDSs for hazardous chemicals used in the workplace and ensuring that the SDSs are readily accessible to workers in their work areas during their work shift (**29 CFR 1910.1200(g)(8)**). Employers must make sure that workers understand the safety and health hazards associated with the abrasive blasting material and the safety measures that must be taken to protect them from these hazards (**29 CFR 1910.1200(h)**.

To help minimize safety and health hazards associated with abrasive blasting, employers must:

- Inspect all hoses and connections frequently and replace any that are worn or damaged before worker use **(29 CFR 1915.34(c)(2))**.
- Use metal nozzles and hose couplings **(29 CFR 1915.34(c)(1)(ii) and (iii))**, as well as equip the nozzle end of the blasting hose with a dead-man control device **(29 CFR 1915.34(c)(1)(iv))**.
- Provide workers with the appropriate PPE when blasting **(29 CFR 1915.34(c)(3)(i) through (v))**.

- Use exhaust ventilation systems in containment structures to capture dust **(29 CFR 1910.94(a)(3)(i))**. See ANSI Z9.2-1960 and ANSI Z33.1-1961 for detailed use of such systems.

- Clean and remove accumulated dust from tarps and other equipment on the worksite **(29 CFR 1910.94(a)(7))**.

- Prohibit eating, drinking, or using tobacco products in blasting areas **(29 CFR 1915.88(h))**.

- Provide wash stations so workers can wash their hands and face routinely and before eating, drinking, or smoking, and train workers on the need to remove surface contaminants from skin surfaces by thorough hand and face washing **(29 CFR 1915.88(e)(1) and (e)(3))**.

Other safety precautions that employers should take to protect workers during abrasive blasting operations include:

- Ensure that only one person operates each blast nozzle, when feasible.

- Install guards to protect the operator from high-speed particles.

- Use hose-coupling safety locks and hose whip checks.

- Substitute toxic or hazardous abrasive blasting materials with less toxic or hazardous alternatives, and use abrasives that can be delivered with water (slurry) to reduce dust.

- Train workers to never point a blast nozzle at a person, and to keep coworkers away from the blaster.

- Perform routine cleanup using wet methods or HEPA filtered vacuuming to minimize the accumulation of toxic dusts. Do not use compressed air to clean as this will create dust in the air.

- Schedule blasting when the least number of workers are at the site.

- Avoid blasting in windy conditions to prevent the spread of any hazardous materials.

- Vacuum or remove contaminated work clothes before eating, drinking or smoking.

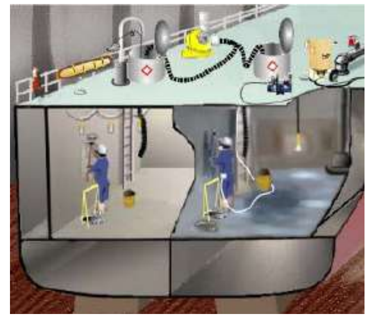
- Conduct abrasive blasting activities in a blasting enclosure or use isolated areas for non-enclosed blasting operations (e.g., barriers and curtain walls) and control access. This will reduce the possibility of workers and others being struck by high-speed particles.

For more information:

Abrasive Blasting and Control Measures	**Abrasive Blasting Hazards in Shipyard Employment Guidance Document** ***(https://www.osha.gov/dts/maritime/standards/guidance/shipyard_guidance.html)*** **Mechanical Removers (Ship Repair) eTool** ***(http://www.osha.gov/SLTC/etools/shipyard/shiprepair/surfaceprep/index_sp.html)*** **Protecting Workers from the Hazards of Abrasive Blasting Materials Fact Sheet** ***(https://www.osha.gov/Publications/OSHA3697.pdf)***
Hazard Communication in Shipyards	**Hazard Communication in the Maritime Industry**

	(http://www.osha.gov/Publications/OSHA3694.pdf)
Others	**Chemical Hazards and Toxic Substances Safety and Health Topics** *(https://www.osha.gov/SLTC/hazardoustoxicsubstances/)* **Permissible Exposure Limits – Annotated Tables**

Application of Toxic Coatings, Paint Strippers and Solvents



Many workers are exposed to hazardous and toxic solvents on a daily basis. Health hazards associated with solvent exposure include toxicity to the nervous system, reproductive damage, liver and kidney damage, respiratory impairment, cancer, and dermatitis.

Hazardous and toxic substances, used in coatings, paint strippers, and solvents, are defined as those chemicals present in the workplace which are capable of causing harm. In this definition, the term “chemicals” includes dusts, mixtures, and common materials such as paints, fuels, and solvents. “Solvents” refer to liquid organic chemicals used to dissolve solid materials, and can be made from natural sources such as turpentine and citrus solvents. However, most are derived from petroleum or other synthetic sources. Solvents are used widely because they dissolve materials like resins and plastics, and they evaporate quickly and cleanly.

Hazards associated with applying coatings include toxic exposures, fire, and explosions. As types of coatings and work practices evolve, these hazards are being reduced or eliminated. Modern paints and coatings often have higher flash points, which has helped to reduce the risk of fire and explosion. The improvement of atmospheric monitoring equipment has allowed for better detection of toxic and explosive atmospheres. Injury, illness, and fatality statistics reflect this trend of improved hazard control during surface preparation and preservation activities. However, coatings made with new chemicals that are not yet fully understood may pose risks to the health of workers. As a result, it is important to protect workers from exposure to these coatings.

Proper ventilation combined with respirator use is the most effective method to protect workers from exposure to toxic or hazardous substances in airborne gasses, vapors, and aerosols (spray). Air-purifying and air-supplied respirators are commonly used to prevent the inhalation of toxic compounds.

During cleaning operations where toxic solvents are used, OSHA requires that at least one, or a combination, of the following safety precautions be implemented: (1) enclose the operation to ensure that no toxic vapor escapes into surrounding areas; (2) use an effective means of natural or mechanical ventilation to remove the vapor at the source, and dilute the concentration of vapors in the space to a safe level; and (3) ensure that workers are equipped with and use suitable **respiratory protection** to protect them against toxic vapors, and where necessary, against exposure to skin and eye contact with toxic solvents and their vapors by necessary clothing and equipment (**29 CFR 1915.32(a)(1)** through **(a)(3)**). Further, a hazard assessment must be performed to identify and select the appropriate PPE (**29 CFR 1915.152(b)(1)**) . In addition, employers must train workers on how to use the required PPE (**29 CFR 1915.152(e)**).

Even when employers take the above safety precautions, workers may still develop sensitivity to airborne gasses, vapors, and aerosols (spray) used in the workplace. A common sensitivity involves isocyanates, which are compounds that make up all polyurethane products. Jobs in the shipbuilding and ship repair industry that may involve worker exposure to isocyanates include painting, use of adhesives, and the application or removal of insulation materials or surface coatings. The main effects of hazardous exposures are occupational asthma and other lung problems, as well as irritation of the eyes, nose, throat, and skin. Once a worker has developed sensitivity, even low concentrations can trigger symptoms. It is recommended that workers who have developed sensitivity be assigned to areas where no exposure is possible, or be provided with supplied-air respiratory protection and PPE to prevent any dermal (skin) exposure.

Where coatings, liquids, or solvents are capable of producing a flammable atmosphere under the conditions of its use, frequent atmospheric tests must be performed by a competent person to ensure the concentration of flammable vapors are kept below 10 percent of their lower explosive limit (LEL). If the vapor concentration is above this level, ventilation, at sufficient quantities, must be used to bring the concentration below it. Other precautions that employers must implement are **(29 CFR 1915.36)**:

- Prohibiting personnel from smoking in the work area.
- Eliminating the use of equipment with open flames, or that produce arcs or sparks.
- Storing scrapings and rags soaked with flammable liquids in covered metal containers.
- Permitting only the use of explosion-proof lights (approved by UL for Class I, Group D atmospheres, or approved as permissible by MSHA or the U.S. Coast Guard).
- Ensuring power or lighting cables in use are free of cracks and worn spots, and have no connections within 50 feet of the operation. Do not overload electrical cables and handle with care to prevent undue stress or chafing. The employer must have a competent person inspect the lines to ensure these conditions are met.
- Supplying suitable fire extinguishing equipment with immediate access and kept ready for use in the event of a fire occurs.

For more information:

Ventilation Purpose, Uses, and Requirements	**Ventilation in Shipyard Employment Guidance Document** ***(https://www.osha.gov/Publications/OSHA3639.pdf)***
Recognizing Potential Hazards and Relevant Safety Standards Related to Isocyanate Exposure	**OSHA Webpage – National Emphasis Program for occupational Exposure to Isocyanates** ***(http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=5616)***

Case History

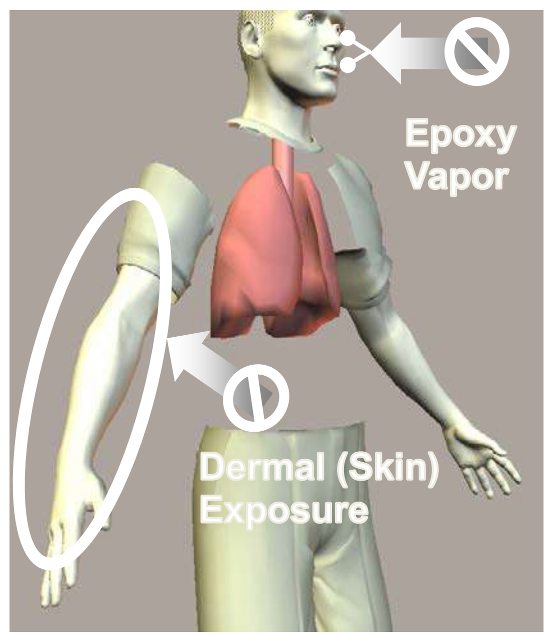
A worker entered a space that had recently been spray painted with epoxy paint. The space was declared safe to enter by a shipyard competent person who had tested the space for adequate oxygen levels and potentially explosive atmosphere.

After spending a brief time in the area, and removing her respirator, the worker began to have difficulty breathing. She sat down to catch her breath but the condition worsened. She signaled to her coworkers, who helped her onto the weather deck where she started to breathe easier.

A while later, her breathing returned to normal and she went back to the same job. Once back at work, she began to experience difficulty breathing again and left the space.

Her supervisor arranged for the worker to seek medical attention. The examination and evaluation indicated that the worker had developed sensitivity to the isocyanates in epoxy paint vapors, resulting in occupational asthma. She could no longer work in compartments where the paint was not fully cured and was assigned to work in a different part of the ship.

Analysis and Preventive Measures



Some workers exposed to epoxy and polyurethane coatings that contain isocyanate components, or other compounds that have not completely dried or hardened, may develop a sensitivity that causes symptoms. Symptoms include sore throat, difficulty breathing, and skin conditions including rashes, blistering, and reddening of the skin.

This sensitivity can develop without warning after single or multiple exposures. If symptoms occur, the affected worker should immediately move to fresh air, and undergo a medical evaluation before returning to work.

The use of respiratory protection and ventilation, as well as skin protection, will help prevent exposure to isocyanates during painting and curing activities. Skin exposure to isocyanates can lead to isocyanate-induced asthma. Once a worker has developed a sensitivity to epoxy, even low concentrations can trigger symptoms.

It is recommended that workers who have developed a sensitivity to epoxy be assigned to areas where no exposure is possible, or be provided with supplied-air respiratory protection and PPE to prevent any skin exposure.

Case History

Four workers were located in the inner bottom void of a tugboat that was under construction, working with flammable solvents to prepare the space for painting.

Despite employer knowledge of the flammability of the solvents in use, no effort was made to inspect and test the confined space prior to entry and as work took place. The concentration of flammable vapors soon exceeded the prescribed allowable limits, which led to an explosion when combined with the use of non-explosion proof lighting. Two of the workers died, while the other two suffered third-degree burns.

Analysis and Preventive Measures

This incident was preventable. Had the employer followed the appropriate safety precautions, loss of life and serious physical harm to the workers involved could have been avoided. These include:

- Ensuring that atmospheric monitoring by a competent person was performed to determine if an explosive atmosphere existed;
- Performing a hazard assessment prior to work to identify the potential hazards present, and determine ways to eliminate the hazards;
- Providing explosion-proof, self-contained temporary and portable lights for use in atmospheres that contain a concentration of flammable vapors at or above 10 percent of the LEL; and
- Ensuring an effective means of natural or mechanical ventilation was used to dilute the concentration of vapors in the space to a level less than 10 percent of the LEL.

Welding, Cutting, and Heating

During shipbuilding and ship repair activities involving welding, cutting, and heating, workers may be exposed to toxic fumes from metals such as lead, chromium, cadmium and zinc. Coatings applied to the metal surfaces of vessels or vessel sections may also contain toxic compounds that, when heated, release hazardous fumes. Manufacturers have made great progress in using alternative metals that meet structural requirements and reduce toxic fumes during hot work, and in using fewer toxic and flammable coatings. Despite these gains, the risk for adverse health effects such as damage to digestive, neurological, reproductive or respiratory systems in workers still exists and must always be evaluated. Subpart D of 29 CFR Part 1915 covers aspects of welding, cutting and heating, including ventilation, respiratory protection, and confined spaces (**29 CFR 1915, Subpart D – Welding, Cutting, and Heating**).

Before welding, cutting, or heating is performed on any surface covered by a preservative coating whose flammability is unknown, a competent person must test the substance to determine its flammability (**29 CFR 1915.53(b)**). If the substance is determined to be flammable or combustible, precautions must be taken to prevent its ignition by stripping the coating from the area to be heated (**29 CFR 1915.53(c)**).

In enclosed spaces where hot work will be performed toxic preservatives must be stripped for a distance at least four inches from the area where heat will be applied. Otherwise, workers must be protected by airline respirators meeting the requirements of 29 CFR 1915.154 (**29 CFR 1915.53(d)(1)**). Employers must post a fire watch during hot work where ignition may occur through spark, conduction, or radiation **(29 CFR 1915.504(b))**. Examples include:

1. Slag, weld splatter, or sparks that might pass through an opening (**1915.504(b)(1)**).

2. Failure to use fire-resistant guards, curtains, or flame-proof covers where combustible materials are located on or near decks, bulkheads, partitions, overheads, and within 35 feet of where hot work is performed (**1915.504(b)(2) and (3)**).

3. Hot work conducted on or near insulation, combustible coatings, or sandwich-type construction that cannot be shielded, cut back, or removed, as well as where its construction has the potential for being reactive (**1915.504(b)(4)**).

4. Combustible materials located adjacent to, or on the backside of the heated area (bulkheads, decks, overheads, or metal partitions), and have the potential for ignition (**1915.504(b)(5)**). A fire watch is also required where ignition may occur due to the close proximity of materials such as insulated pipes, coatings, combustible pipes, or cable runs (**1915.504(b)(6) and ((7)**).

A fire watch must also be posted when required by a competent person, Marine Chemist, or Coast Guard-authorized person (**29 CFR 1915.504(b)(8)**).

A competent person must test the atmosphere of any enclosed space where soft and greasy preservatives are present before hot work can begin (**29 CFR 1915.53(e)(1)**). Where explosive vapors (having flash points below 80 degrees Fahrenheit) are detected, no hot work may start until necessary measures are taken to ensure the work can be done safely (**29 CFR 1915.53(e)(1)**). For example, effective ventilation must be used where necessary to control atmospheric conditions to ensure that hot work can be performed safely. All motors and equipment used for mechanical ventilation must be grounded and designated explosion-proof, and fans equipped with nonferrous blades (**29 CFR 1915.13(b))**). Frequent tests to determine the concentration of solvent vapors must be conducted periodically by a competent person during welding, cutting, and heating operations (**29 CFR 1915.53(f)**).

Once it is determined that the atmosphere of the space is safe for entry and hot work, preservative coatings must be removed for a sufficient distance from the area to be heated to ensure that the temperature of the unstripped metal is not appreciably raised (**29 CFR 1915.53(e)(2)**). Flame or heat may not be used to remove soft or greasy preservative coatings, as this could result in the ignition of the substance or release of toxic vapors (**29 CFR 1915.34(b)(2)**).

Spray Painting

The three predominant spray methods used in shipyard employment include high-pressure, airless, and high volume low pressure (HVLP) systems. Not one method is better than the other, but preferences may be determined based on the desired outcome and facility resources. Regardless of which type of system is used, similar hazards exist with all.

Typical high-pressure conventional spray painting occurs when paint is applied to an object through the use of an air-pressurized spray gun. The air gun has a nozzle, paint basin, and air compressor. When the trigger is pressed, the paint mixes with the compressed air stream and is released in a fine spray. Normally, a manual operation method is used in vessel spraying where the air-gun is held by a skilled operator, about 6 to 10 inches (15–25 cm) from the object, and moved back and forth over the surface, each stroke overlapping the one previous to ensure a continuous coat.

Airless spraying systems are powered by a high-pressure pump, ranging in pressure from 300 to 7,500 pounds per square inch. This method allows coatings to better penetrate pits and crevices, applies a uniform thick coating, and reduces the number of coats needed to be applied. Also, airless pumps have the versatility to be powered by a range of different types of motors such as electric, compressed air (pneumatic) or hydraulic.

HVLP systems deliver air at a much higher volume, but with a much lower pressure so that more of the paint or coating ends up on the surface instead of in the air. There are two different types of HVLP spray gun systems; conversion high-volume low-pressure system and turbine air system. The first utilizes traditional air compressor equipment and accessories, but at a much lower pressure (approximately 25 pounds per square inch), while air turbine systems operate from an air turbine instead of an air compressor, delivering an extremely high volume of air at very low pressure (about 4 to 6 pounds per square inch).

Hazards and Control Measures

During spray painting operations, paint is forced into the atmosphere under pressure through a restricted opening. The breakup of a liquid into small particles to produce a fine mist is known as atomization. The atomization of paint increases the surface area of the liquid. Although this method is favored for painting large areas in a fairly short amount of time and, in some cases, using less product than with brush or roller applications, two primary hazards exist -- worker exposure to toxic or hazardous substances and fires or explosions.

Toxic/Hazardous Substances

While the use of highly toxic coatings has been greatly reduced over the years, the potential for workers to become exposed to compounds in excessive concentrations still exists. Workers performing spray paint operations are at a higher risk for respiratory exposure to these toxic vapors than with brush or roller applications. Exposure occurs when the paint becomes airborne -- not only increasing coverage of surface area, but the rate of release of toxic vapors into the atmosphere. This is especially true in a confined space. OSHA standards specify permissible exposure limits (PELs) for workers (29 CFR Part 1915, Subpart Z). However, OSHA recognizes that many of its PELs are outdated and inadequate for ensuring protection of worker health. This has been demonstrated by the reduction in allowable exposure limits recommended by many technical, professional, industrial, and government organizations, both inside and outside the United States. To provide employers, workers, and other interested parties with a list of alternate occupational exposure limits that may serve to better protect workers, OSHA has annotated the existing Z-Tables with other selected occupational exposure limits (**Permissible Exposure Limits – Annotated Tables**). Where adequate engineering and administrative controls are infeasible to control worker exposure to toxic or hazardous substances, employers must provide workers with the appropriate PPE for the work activity being performed (**29 CFR Part 1915.152**).

During the handling of highly volatile paints, workers face, eyes, head, hands, and all other exposed parts must be protected (**29 CFR 1915.35(b)(9)**). To prevent skin contact, an appropriate protective suit and gloves should be worn. Safety goggles, glasses, or face shields must be worn to prevent paint or coatings from coming into contact with workers' eyes. During spray paint operations, a full face respirator or loose fitting hood respirator can also serve as effective eye protection.

Due to the wide range of chemical hazards involved in coating operations, a "one type fits all" approach for protection does not exist. Employers should consult with the manufacturer, or look to the manufacturer's SDS, to determine the best type of material that will prevent exposure (**Appendix A to Subpart I of Part 1915 – Non-Mandatory Guidelines for Hazard Assessment, Personal Protective Equipment (PPE Selection, and PPE Training**). The same determination should be made with gloves, as not all gloves will provide an equal level of protection from the particular coating being used. In some cases, barrier creams may be an appropriate method of protection.

OSHA requires that workers wear respirators when working with paints and tank coatings mixed with or dissolved in volatile, toxic, or flammable solvents, even when mechanical ventilation is in use (**29 CFR 1915.35(a) and (b)**). During exterior paint spraying operations with paints dissolved in volatile, toxic, or flammable solvents, workers must be protected by a suitable filter cartridge type respirator (**29 CFR 1915.35(b)**). In confined spaces, tanks or compartments, airline (or supplied-air) respirators must be used during spraying operations with paints mixed with toxic vehicles or solvents (**29 CFR 1915.35(a)**). The air supplied to airline or supplied-air respirators must be tested and determined suitable for human consumption. Compressed breathing air shall meet at least the requirements for Grade D breathing air described in ANSI/Compressed Gas Association Commodity Specification for Air, G-7.1-1989, (**29 CFR 1910.134(i)(1)(ii)**).

Respirators are also required along with mechanical ventilation regardless of whether the work area is large and well-ventilated (**29 CFR 1915.35(a)(1)(i)** through **(iii)** and **(b)(1)**). Filter respirators are required during brush applications of paints with toxic solvents in confined spaces or in other areas where there is limited ventilation (**29 CFR 1915.35(a)(2)**). Workers entering such compartments for a limited time must also be protected by filter respirators (**29 CFR 1915.35(b)(13)**).

For operations involving the use of materials containing hazardous substances, such as cleaning solvents and isocyanate-containing epoxy and polyurethane coatings, ventilation must be used to remove the vapor at the source and to dilute the concentration of vapors in the space to a safe level (**29 CFR 1915.32(a)(2)**). If vapors cannot be diluted to a safe concentration, suitable respiratory protection in accord with the requirements of 29 CFR 1915, Subpart I must also be worn, as well as suitable clothing and equipment to provide skin and eye protection (**29 CFR 1915.32(a)(3)**).

Personal hygiene is also an important aspect to keeping workers safe. Effective hand washing practices after the application of paints and coatings will help to reduce possible ingestion of toxic chemicals. Employers must train workers on the importance of washing both hands and face, following the application of paints and coatings, at the end of the workshift and before eating, drinking or smoking, to minimize the risk of ingestion of hazardous substances (**29 CFR 1915.88(e)(3)**).

Fires/Explosions

Organic coatings, adhesives and resins are often dissolved with highly toxic, flammable and explosive solvents with flash points below 80°F. When the potential exists for paints or coatings to produce a flammable atmosphere, employers must follow the safety precautions provided in **29 CFR 1915.36** and **29 CFR 1915.35(b)**. Sufficient exhaust ventilation must be used when working with such materials to keep the concentration of solvent vapors below 10% of the lower explosive limit (LEL) (**29 CFR 1915.35(b)(1)**). A competent person must conduct frequent tests to ascertain the concentration of solvent vapors. If the concentration of solvent vapors reaches or exceeds the LEL, painting must stop and the area evacuated. If the concentration does not fall when painting is stopped, the employer must supply additional ventilation to bring the concentration to an acceptable level (**29 CFR 1915.35(b)(2)**). Exhaust ducts must be discharged to an area away from other work areas and sources of possible ignition. The employer must conduct periodic testing of the exhaust and surrounding areas (around the vessel or dry dock) to ensure that the exhausted vapors are not accumulating (**29 CFR 1915.35(b)(4)**).

Only certain types of equipment are permitted for use in and around work areas where highly toxic, flammable and explosive solvents with flash points below 80°F are present. All motors and associated control equipment must be explosion proof and properly maintained and grounded (**29 CFR 1915.35(b)(5)**). Also, fans must have non-sparking blades, and portable air ducts made up of non-sparking materials (**29 CFR 1915.35(b)(5)**). It is important to remember that while a ventilator may have a non-sparking fan it may not meet the requirements to be considered explosion-proof.

Additionally, in cases where liquid solvents, paint and preservative removers, and paints or coatings are capable of producing a flammable atmosphere, the below control requirements and hazard solutions must be taken.

Liquids/substances with flashpoints 80° F and above

- Hot work must not be performed in the space or adjacent spaces during painting operations (**29 CFR 1915.14(a)(1)(i)**).
- Rags soaked with solvents must be kept in covered metal containers (**29 CFR 1915.36(a)(3)** and **29 CFR 1915.81(a)(5))**.
- Paints, thinners, and solvents must be kept in fire-resistant covered containers when not in use (**29 CFR 1915.81(a)(5)**).
- Smoking and open flames must be prohibited in the area (**29 CFR 1915.36(a)(1)**).
- Arcing and sparking equipment and tools must not be used (**29 CFR 1915.36(a)(1)**).
- Equipment that may generate static electricity (e.g., ventilation systems) must be grounded and bonded. (**29 CFR 1915.35(a)(4)**).
- Only explosion-proof lights must be used (**29 CFR 1915.36(a)(4)**).
- Adequate ventilation must be maintained in storage, mixing, and transfer areas (**29 CFR 1915.36(a)(2)**).

- Frequent tests must be required during painting operations to determine if air concentrations are below 10 percent of the LEL (**29 CFR 1915.36(a)(2)**).

- Suitable firefighting equipment must be immediately available (**29 CFR 1915.36(a)(6)**).

- 30-gallon drums and containers of flammable or toxic liquids must be placed in an area where they will not be subject to physical damage (**29 CFR 1915.173(d)**).

- 55-gallon drums containing flammable or toxic liquids must be surrounded by dikes or pans (**29 CFR 1915.173(e)**).

- Power and lighting cables must be inspected by a competent person to verify that the insulation is in excellent condition and free of all cracks and worn spots, that lines are not overloaded, and that they are suspended with sufficient slack to prevent undue stress or chafing. The competent person must ensure there are no electrical connections within 50 feet of paint the operation (**29 CFR 1915.36(a)(5)**)[1].

- Spills of solvents should be cleaned up immediately.

Liquids/substances with flashpoints below 80° F

- Sufficient exhaust ventilation must be provided to keep the concentration of solvent vapors below 10 percent of the lower explosive limit (LEL). Frequent tests must be made by a competent person to ascertain concentrations (**29 CFR 1915.35(b)(1)**).

- If the concentration exceeds 10 percent of the LEL, work must be stopped and the compartment evacuated until the concentration falls below 10 percent of the LEL (**29 CFR 1915.35(b)(2)**).

- Ventilation must be continued after painting is complete until the space or compartment is gas free. (**29 CFR 1915.35(b)(3)**).

- Exhaust ducts must discharge clear of working areas and away from sources of possible ignition (**29 CFR 1915.35(b)(4)**).

- Periodic tests must be conducted by the Shipyard Competent Person to ensure the exhausted vapors are not accumulating in other areas within or around the vessel or dry dock (**29 CFR 1915.35(b)(4)**).

- All motors and control equipment must be explosion proof, and fan blades and portable air ducts non-ferrous (**29 CFR 1915.35(b)(5)**).

[1] On vessels, 29 CFR Part 1910, Subpart S is applicable when shore-based electrical installations provide power for use aboard vessels (e.g., the power from the electrical system comes from shore or from portable electrical generators), but does not apply to a vessel's permanently installed electrical systems. Under that standard, when determining what connections are safe or unsafe in or near paint operations, each must be evaluated based on the class of location in which they are intended to be used and the ignitable or combustible properties of the specific gas or vapor present (29 CFR 1910.307(c)(2)). The National Electrical Code, NFPA 70, lists and defines hazardous gases, vapors, and dusts by "Groups" characterized by their ignitable or combustible properties, and also contain guidelines for determining the type and design of equipment and installations that are approved for a specific hazardous (classified) location. Examples of such design principles and equipment characteristics may include the use of positive pressure ventilation, as well as explosion proof, non-incendive, intrinsically safe, and purged and pressurized equipment.

- All footwear worn during painting operations must be non-sparking (**29 CFR 1915.35(b)(9)**).

- PPE must not produce static electrical sparks (**29 CFR 1915.35(b)(9)**).

- No matches, lighted cigarettes, cigars, pipes, cigarette lighters, or ferrous articles are allowed into the work area (**29 CFR 1915.35(b)(10)**).

- All solvent drums taken into the compartment where painting operations are being performed must be placed on nonferrous surfaces and grounded to the vessel (**29 CFR 1915.35(b)(11)**).

- All metallic parts of paint spraying equipment must be grounded and bonded to the vessel (**29 CFR 1915.35(b)(12)**).

Static electricity during spray painting operations may be generated in ventilation or air moving equipment, and is a potential source of ignition in the presence of flammable substances. Electrical equipment rated for the specific flammable environment (i.e., explosion proof), and bonding and grounding of equipment are engineering controls that must be used to reduce the risk of ignition in the presence of flammable gases or vapors (e.g., from paints, cleaning agents, or other flammable liquids) (**29 CFR 1915.35(b)(5) and (b)(12)**). Prior to entry, a competent person must test the space to determine the concentration of flammable vapors and gases within the space (**29 CFR 1915.12(b)**). Explosion proof ventilation equipment (electrically rated for the specific flammability or explosion hazards) must be provided by the employer to maintain the concentration of flammable vapors and gases below 10% of the LEL before workers are permitted to enter the space (**29 CFR 1915.12(b)(2)**).

The following static electricity safety requirements apply where paints are dissolved in highly flammable liquids or gases, such as methane, acetylene, gasoline, acetone, or alcohols:

- All air-moving equipment or devices and metallic components, including ductwork, capable of generating a source of ignition through static electric discharge, must be electrically bonded to the structure of the vessel or vessel section or, in the case of land-side spaces, grounded to prevent an electric discharge in the space (**29 CFR 1915.13(b)(11)** and **29 CFR 1915.35(a)(4)**).

- Motors and associated control equipment must be properly maintained and grounded (**29 CFR 1915.35(b)(5))**.

- Use only non-sparking paint buckets, spray guns and tools. Metal parts of paint brushes and rollers must be insulated (**29 CFR 1915.35(b)(6)**).

- Erect staging (scaffolds) in a manner that ensures it is non-sparking (**29 CFR 1915.35(b)(6)**).

- Ensure the proper use of required PPE (**29 CFR 1915.35(b)(9), (b)(13) through (14)**).

Amputations, lacerations, burns, and loss of eye-sight are additional hazards associated with spray painting operations. Such injuries may result from contact with high-pressure painting equipment, uncontrolled high-pressure hoses, and air leaks. OSHA requires that compressed-air hoses and connections be inspected before use. Visually damaged and unsafe hose must not be used (**29 CFR 1915.131(h)**). The following are some recommended solutions to avoid such hazards:

- Control access to the area of operation.
- Maintain high-pressure spray equipment according to the manufacturer's instructions.
- Use paint pots with appropriate pressure regulators or ratings.

Waste Management and Prevention

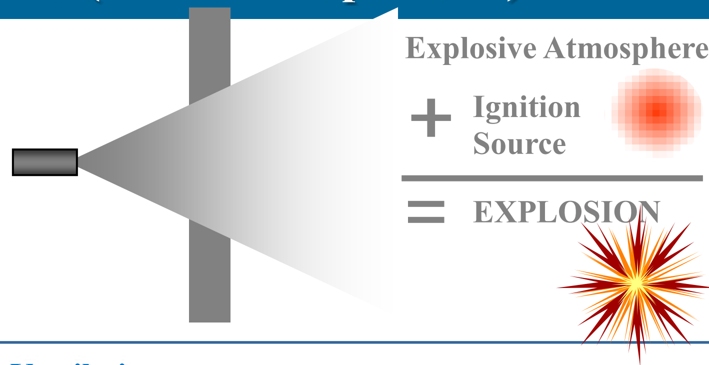
When spray paint operations are completed, the paint lines are typically flushed with a solvent to remove the coating from the line. Often the cleaning solvent can be as hazardous, or more hazardous as the coating being removed. The precautions discussed previously in regard to fire and explosion, as well as exposure protection for workers, must be followed. This includes limiting ignition sources, providing ventilation as necessary, and using appropriate PPE to prevent contact, inhalation or ingestion of the material. Also, grounding and bonding must be used to eliminate a potential ignition source.

Further, all waste materials need to be disposed of in accordance with local, state, and federal regulations.

Spray Painting: Problems and Solutions (Fire and Explosions)

Problem

The vapors produced by volatile solvents used in spray painting can cause fires and explosions. A spark from electrical equipment or static discharge can be enough to ignite volatile vapors.

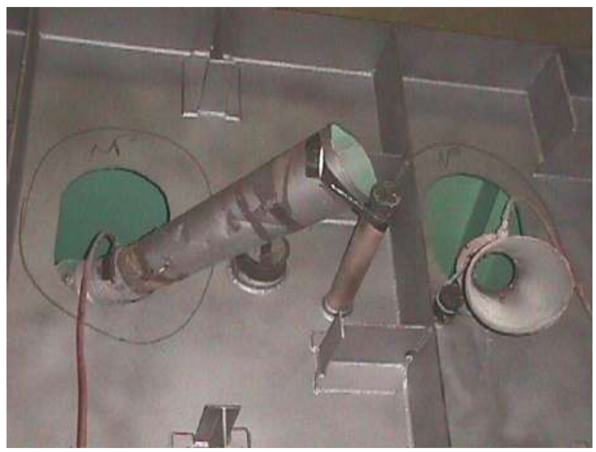


Solutions

Solution 1: Monitoring

Using a handheld meter to monitor for flammable gas concentration, which is typically expressed as a percent of the lower explosive limit (LEL).

Solution 2: Ventilation



Adequate ventilation must be provided to prevent paint-related explosions and fires which can result in serious injury or death.

Solution 3: Identification

Posting warnings can inform other workers of fire and explosion risks related to shipyard painting processes.

Solution 4: Explosion-Proof Lighting

Using explosion-proof lighting (e.g., examples A and B) is required in spaces where explosive vapors may reach 10 percent of the LEL. Non-explosion-proof lighting (e.g., example C) must never be used in potentially explosive atmospheres.

Solution 5: Authorization

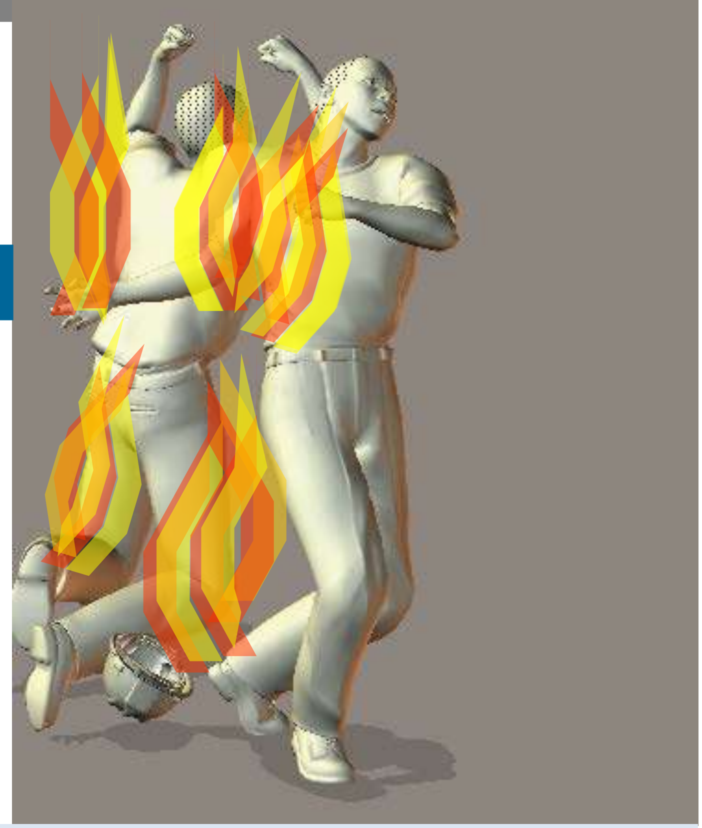
Implement an effective hot-work permit system to ensure that other work will not create an ignition source in adjacent spaces or spaces where newly-applied paint is still curing. The hot-work permit process requires a competent person to test for fire or explosion hazards and then post written notice to prohibiting hot work if these hazards exist or permit work if absent; while implementing appropriate controls (e.g., atmospheric monitoring to verify that conditions within the space remain the same).

Spray Painting: Case History (Fires and Explosions)

CASE HISTORY

Two workers were spray painting the interior of a barge. During a break, they came out of the space to smoke cigarettes. Neither worker realized that their clothes had become saturated with highly flammable paint vapors during their work inside the barge.

As soon as the ignition source (i.e., cigarette lighter) was lit, the vapors in the fabric of their clothing caught fire. Both men burned to death.



Analysis and Preventive Measures

The workers had been in an atmosphere with high concentrations of explosive vapors.
Several measures may have prevented this tragedy, including:

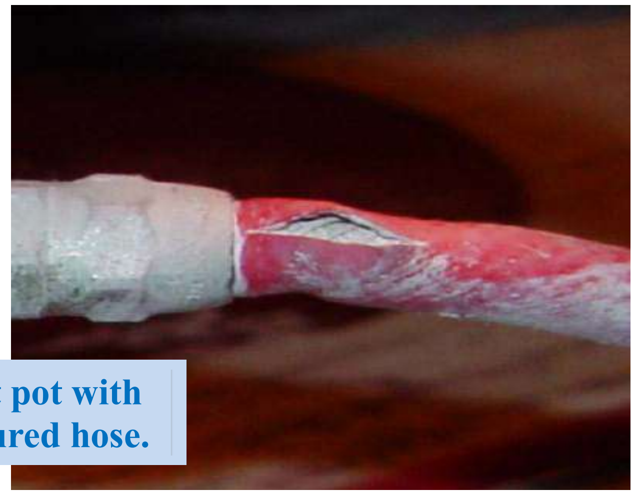
- Worker training (to include personal hygiene practices).
- Adequate ventilation in place.
- Ongoing air monitoring to ensure that safe atmospheric conditions are maintained.

Ventilation is critical for removing explosive vapors. Use supply and exhaust methods that have been proven effective.

LEL testing by a competent person is required, and is a critical step in determining whether a supply and exhaust ventilation system is effective in controlling a flammable atmosphere (**29 CFR 1915.36(a)(2)**).

Spray Painting: Case History (Eye Injuries)

While preparing to spray a compartment, a tender poured paint into the paint pot, while the sprayer stood by. An air line was attached to the paint pot and pressurized to 80 psi. Once pressure was applied to the spray hose and gun, the spray hose immediately ruptured at the coupling connection, causing the paint to discharge into the faces of the tender and the sprayer. The tender immediately removed his safety glasses and rinsed his eyes with an on-site eye wash bottle. The sprayer was wearing a full face respirator and, therefore, no paint came into contact with his skin or eyes.



Paint pot with ruptured hose.

Sprayed goggles and full face respirator as a result of ruptured paint hose.

Analysis and Preventive Measures

Serious injury was prevented because both workers had donned their protective equipment prior to starting the job. It is important that protective equipment fits properly, such as tight-fitting goggles, to provide greater protection to workers. Maintaining an eye wash bottle (or designated eyewash station) at the job site was immediately useful to the tender, and is required by OSHA **29 CFR 1915.87(e)**. However, proper examination of the paint hose and its connections before use, as required by OSHA, would have identified that the hose required replacement (**29 CFR 1915.131(h)**), preventing its use, rupture and the inadvertent discharge of paint on the tender and the sprayer.

Common Hazards Associated with Surface Preparation and Preservation

Common hazards in surface preparation and preservation include: overexertion and heat stress, falls, chemical exposure, fires and explosions, as well as other traumatic and acute injuries.

Overexertion is the most frequently observed hazard. Shipyard workers are at risk of overexertion when performing surface preparation and preservation operations. This is mainly the result of the physical demands of the work, plus the heat stress burden from the protective clothing and respiratory equipment that workers must wear to reduce exposure to airborne particles and chemicals.

Abrasive blasting work environments require workers to continuously relocate heavy hoses and redirect blast nozzles. Paint removal and spray painting often require repeatedly moving hoses at the work site and relocating and filling pressurized paint containers. These activities, combined with heavy and heat-trapping protective clothing contribute to employees' risk of overexertion.

Overexertion and Heat Stress

Abrasive blasters have a demanding job. The addition of PPE to prevent chemical exposures amplifies the physical stress of the task, increasing the potential for overexertion.

It is important to remember that while protective measures help to seal out the hazard, they may also seal in heat and inhibit the body's ability to adapt to thermal stress.

Abrasive blasters must wear some of the heaviest protective clothing found in shipyards. Their jobs require them to pull heavy blast hoses through tight spaces while managing air lines that supply their full-face respirators. They constantly wrestle with the force of blast nozzles to redirect streams of abrasive grit, while working in awkward positions. Spent grit accumulates on walking surfaces, making movement through the work area even more difficult.

Though protective clothing and respiratory equipment used by painters are typically not as heavy, heat and moisture can still become trapped. In addition, the work location needs to be factored in as a possible contributor to overexertion as a result of thermal stress. For example, paint buildings can accumulate heat at the upper levels of the workspace, and outdoor spray painting activities may expose workers to direct sunlight. Heat from direct sunlight can also accumulate in drydock and graving dock spaces.

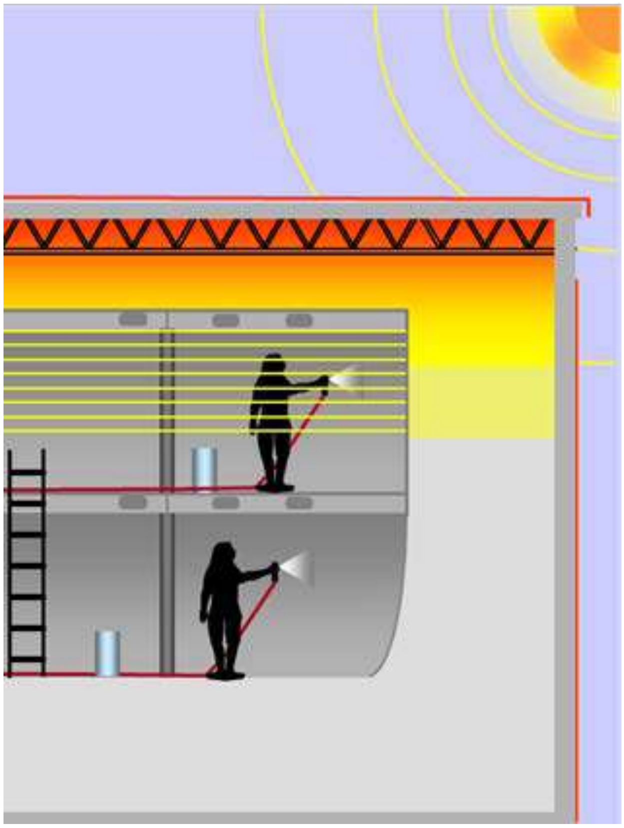
In addition, painting jobs can be physically demanding, requiring workers to handle large paint buckets while replenishing supply containers, as well as sustaining awkward postures for long periods of time that can lead to overexertion.

Typical protective clothing worn by workers engaged in surface preparation and preservation activities.

Example of tight and awkward positions workers must face, while wearing heat-trapping protective clothing during surface preparation and preservation activities.

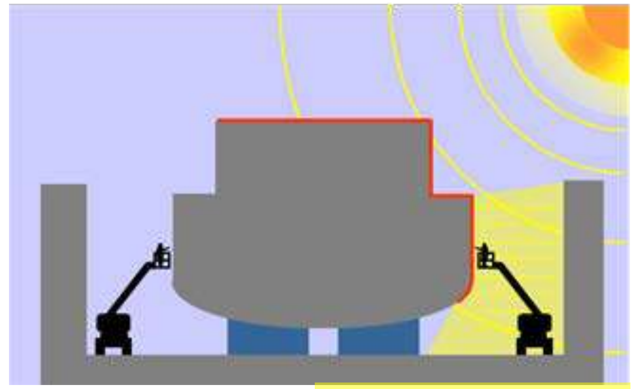
Overexertion: Problems and Solutions

Problem



Workers inside structures assigned to paint new ship assembly units are often at increased risk of thermal stress due to heat accumulating in the upper areas of the building.

Problem



Workers painting an exterior hull may have an increased risk of thermal stress from exposure to direct sun or job site areas in which solar heat can be trapped.

Protective equipment and clothing may create further thermal stress, since body heat cannot escape.

Refrigeration

Cooling vests are available in a range of styles. This option can help minimize heat buildup during peak activity.

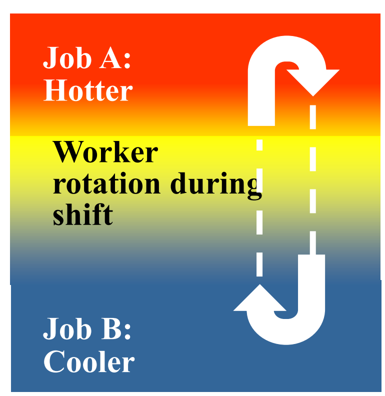
Additional products, such as air-conditioned respirators, are available that cool the air entering a supplied-air respirator. Using a loose-fitting hood can help to cool the head, face, and upper torso regions. The photo at right shows a vortex cooler. Other technologies exist that can chill greater amounts of air.

Hydration

Sufficient consumption of water, such as during rest cycles, is critical to avoiding thermal stress.

Rotation & Work/Rest Cycles

Frequent rotation of tasks to allow workers recovery time from high thermal stress.



Overexertion: Problems and Solutions

Problem

Spray painting and deck covering jobs require transporting heavy containers of consumable materials to the job site.

Having to use ladders to move through the ship increases the physical challenge of moving these materials.

Solutions

Solution 1:

Depending on the material requirements of the job, it may be appropriate to use smaller containers. Smaller containers require less physical exertion to safely balance the load.

Solution 2:

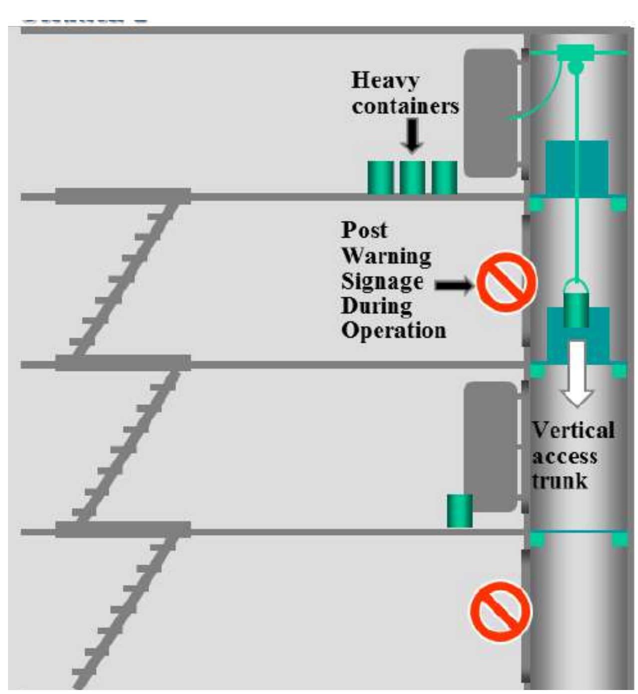
Vertical access trunks and mechanical assistance may substantially reduce the risk of overexertion when using large volumes of material.

Additional care must be taken to ensure that this alternative method of material handing is performed safely:

- Properly secure the mechanical hoist.
- Post warning signs near trunk accesses on levels not being used.
- Remove warning signs and close temporary trunk platforms when finished.

Solution 1

Solution 2



Overexertion Hazards to New Workers: Case History


Injury and illness rates for workers new to shipyard work tend to be higher than for those workers with experience. A significant contributing factor to these injuries and illnesses is overexertion, including heat exhaustion. For example, a worker was located inside a dry dock welding a bulkhead when he became incapacitated. Although later discovered by a coworker, slumped over part of the bulkhead, and CPR performed, he died from heat exhaustion. The incident occurred in Florida, during the extreme heat of August.

Analysis and Preventive Measures

Surface preparation and preservation work is physically challenging. Not only are workers faced with the physical demands of the work, such as welding and abrasive blasting, but are also exposed to extreme heat conditions and often are burdened from the heat stress that protective clothing and respiratory equipment can cause. A high number of overexertion incidents among new workers are the result of extended time on the job to learn their needed skill. Increasing work time also increases the risk for injury.

The death of the welder in the case history described above could have been prevented had proactive and preventative steps been taken to protect him, including:

- Provide an adequate supply of cool water for workers to drink.

- Modify work schedules to allow for frequent rest periods, such as rotation of workers.
- Pair newer workers with more experienced workers.

- Reduce rotation cycles of one week to one or two shifts, whenever possible.
- Supply workers with protective clothing that provides cooling.

These changes will not only protect workers from the hazards of overexertion, but may help to accelerate overall learning.

Falls

Falls during surface preparation activities may occur as a result of the following:

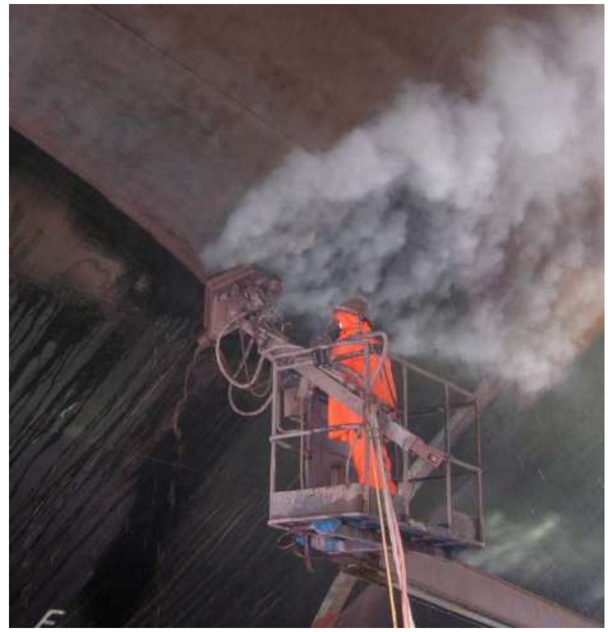
- Limited visibility due to bulky protective clothing and respiratory protection that may impair peripheral vision and depth perception.
- Failure to use effective fall protection while performing paint removal or application tasks that require workers to work from ladders, staging, or in mechanical lifts.
- Slipping on spent blast grit or tripping over obstacles on the deck while performing abrasive blast work.

Examples of situations where falls may occur.

Falls: Problems and Solutions

Problem

Applying or removing coatings from ship hulls often requires the use of aerial lifts or work platforms that are suspended at great heights. This exposes workers to potential falls that could result in serious injuries or death.



Worker engaged in the removal of coatings from a vessel's hull.

Solutions

Guardrails on baskets and surrounding platforms do not, by themselves, provide adequate protection. Workers must be tied off when working from aerial lifts or suspended work platforms. In addition, all workers must be properly trained before using personal fall arrest systems.

A worker spray-painting the hull of a vessel from an aerial lift with donned fall protection and the appropriate locking-type snaphook to prevent disengagement.

Falls: Problems and Solutions

Problem

Workers frequently use ladders to access areas for preparatory work and the removal or application of coatings. However, falls and other injuries are more likely to occur when a ladder or other means of access is used incorrectly in an effort to save time.

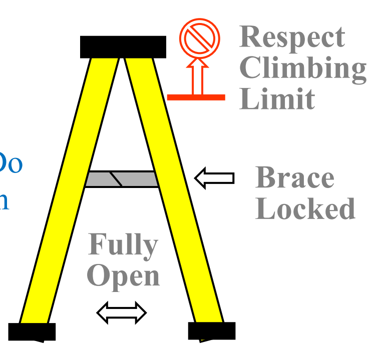
Examples of inappropriate ladder use:

- Using a stepladder as an extension ladder by leaning it against a bulkhead for support.
- Using the top steps of a supported ladder.

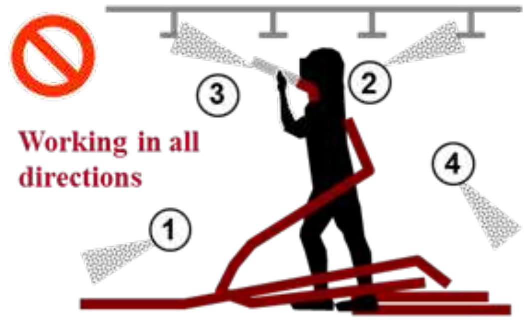
Solutions

Stepladder safety is basic . . . make sure to:

- Fully open the ladder on a secure, level surface.
- Lock spreaders (bracing) in place. Do not climb higher than the designated limit.
- Do not straddle the top of the ladder.

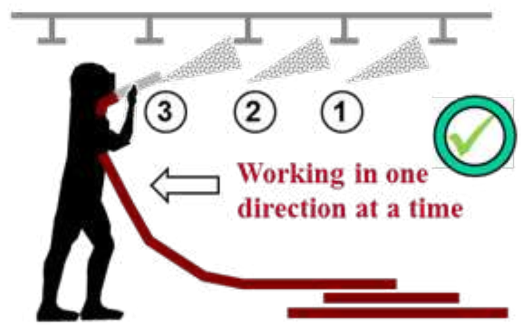


Problem



Without a logical sequence and clear plan for working through a compartment, blasters may trip and fall over their lines and hoses.

Solutions



A deliberate plan allows lines and hoses to be staged to minimize tripping hazards.

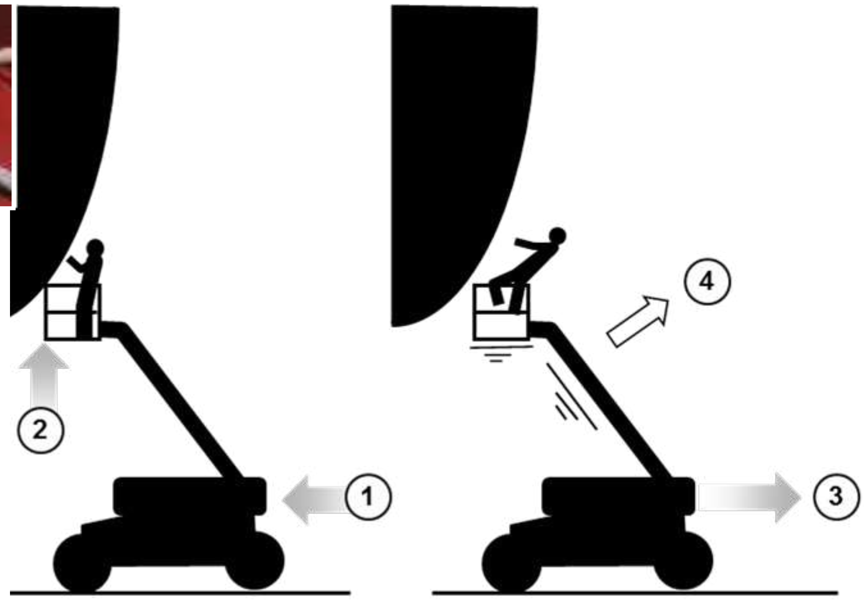
1st Pass

Lines and hoses should initially be staged at one end of a space and pulled in the direction of the work.

2nd Pass

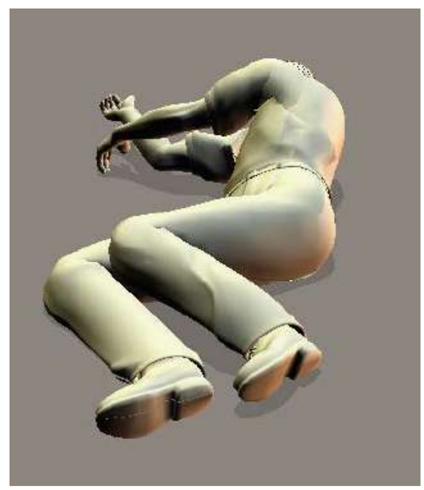
Lines and hoses should then be staged at the opposite end for a second pass in the other direction.

Falls: Case History



A worker was assigned to a painting job on the outside of a ship's hull. He drove his aerial lift under the ship and raised the basket. While adjusting the basket's final position under the hull, the worker unknowingly created spring tension on the boom of the lift.

When the worker completed painting in the initial area, he moved the lift backward without lowering the basket. This suddenly released the spring tension, throwing the worker over the top rail. The worker was not wearing a personal fall arrest system that was tied off, and as a result he was killed from the fall.



Analysis and Preventive Measures

Employers must ensure that workers understand all of the potential hazards associated with operating aerial lifts. Incidents can be prevented by implementing a training program and requiring each worker to have an operator's permit for mobile equipment.

The fall in the example above may have been prevented if the appropriate fall protection was used, as required in aerial lifts (**29 CFR 1910.67(c)(2)(v)**).

For additional guidance on aerial lift use over water, see the OSHA publication *Aerial Lift Fall Protection Over Water in Shipyards* (**OSHA 3452 – 2011 – English** and **OSHA 3475 – 2012 - Spanish**).

Scaffolds, Ladders, and Other Working Surfaces

Improper placement angle of ladder; less than 4 to 1 ratio (height of ladder to horizontal distance at base of ladder).

Improper practice; broken ladder rung.

Surface Preparation and the Use of Ladders

During surface preparation activities, workers often need to gain access to multiple levels and areas that are hard to reach. Workers often use ladders to access these areas, but falls can occur due to structural failure, poor placement, and unsafe use. The safe construction and use of ladders it vital to protect workers from fall hazards. Also, adequate training on safe ladder use, such as inspecting the condition of the ladder before use, are important components of an effective safety and health program.

Potential Fall Hazards:

- Structural failure of the ladder or its components.
- Unsafe use (e.g., over-extending, climbing with equipment in hand, not facing ladder when climbing down).
- Inappropriate ladder placement (e.g., ladder angle).
- Unsecured ladder, causing the ladder to fall.
- Working on ladders above the height of lifelines.

Requirements and Example Solutions:

- Defective ladders must be immediately removed from service (29 CFR 1915.72(a)(1)).
- When splicing ladders, special precautions are required (29 CFR 1915.72(a)(2)).
- Portable ladders must be secured (29 CFR 1915.72(a)(3)).
- Ladders used for access must extend at least 36 inches above the upper landing (29 CFR 1915.72(a)(3)).
- Portable metal or wood ladders must be manufactured in accord with ANSI standards (29 CFR 1915.72(a)(4) and (a)(6)).
- Do not use portable metal ladders near electrical shock hazards (e.g., conductors, electric arc welding) (29 CFR 1915.72(a)(5)).
- Any worker positioned at a height above the height of lifelines should be protected from falling over the edge through the use of fall protection equipment or by repositioning the ladder.

- Only one worker should be allowed on a ladder at a time, unless the ladder is designed for additional workers.

- Unless a ladder is designed to be used in the horizontal position, they should not be used as platforms, runways, or scaffolds.

- Workers visually restricted by blasting hoods, welding helmets, and burning goggles must work from scaffolds, not from ladders (**29 CFR 1915.77(c)**).

- If a ship's ladder in a cargo hold is defective, portable ladders must be used in their place (**29 CFR 1915.76(a)(3)**).

Note: *Specific requirements for the construction of portable wooden ladders that are less than 30 feet, and between 30 to 60 feet can be found at* ***29 CFR 1915.72(b)*** *and* ***(c)****, respectively.*

Use of Scaffolds (Staging) during Surface Preparation and Preservation

Scaffolds, or staging, are systems used to provide an elevated working surface. Staging comes in several varieties and is often constructed to fit the ship. Staging must be adequate for the work performed (**29 CFR 1915.71**).

Before working on or near any scaffolding, check to make sure that the scaffold is:

- Maintained in a safe and secured condition (**29 CFR 1915.71(b)(5)**).

- Capable of supporting the load (e.g., personnel, tools, and equipment) intended for its use (**29 CFR 1915.71(b)(1)**).

- Provided with safe access (such as ladders) (**29 CFR 1915.71(k)**).

- Appropriately decked (**29 CFR 1915.71(i)**).

- Equipped with guardrails and midrails (**29 CFR 1915.71(j)(1)**).

- Outfitted with toeboards if there is a danger of tools or materials falling on workers below (**29 CFR 1915.71(j)(5)**).

A worker grinding while protected by proper toprail, midrail, and toeboard.

Working Surfaces and Potential Hazards

The primary hazards associated with surface preparation and working surfaces are:

- Falls to solid surfaces.
- Falls into water.
- Falls due to limited visibility.

Requirements and Example Solutions:

- When trip hazards are present, provide temporary decking to ensure safe walking and working surfaces.

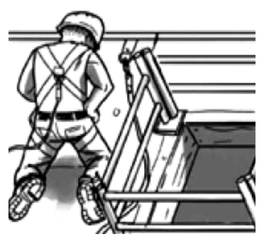


- When work is being performed more than 5 feet above solid surfaces (**29 CFR 1915.77(c)**):
    - Ensure scaffolds or sloping ladders are used to allow for safe footing.

      OR

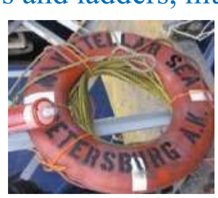
    - Have workers wear safety harnesses with lanyards.





- When working in restricted areas such as behind boilers, or in between congested machinery units and piping, make sure adequate work platforms – at least 20 inches wide -are used (**29 CFR 1915.77(d)**).
- Personal flotation devices (PFDs) are required when there is a chance of falling into the water; for example, when working near unguarded edges, boarding or leaving small boats, or working on floats (**29 CFR 1915.73(e)**, **29 CFR 1915.77(e)**, **29 CFR 1915.71(j)(3)**, and **29 CFR 1915.158(a)**).

- Good housekeeping must be maintained at all times (**29 CFR 1915.81(a)(1)**).
- Lifesaving equipment, such as life ring buoys with ropes and ladders, must be provided when working from vessels (**29 CFR 1915.158(b)**).



Respiratory Protection

Respirators protect the lungs and upper respiratory track from dust, mists, fumes, and vapors that are associated with cleaners and residues. Worker illness may result from:

- Inhalation exposure to toxic or corrosive chemicals.
- Exposure to oxygen-deficient atmospheres.
- Exposure to dust (such as silica, lead, and chromate).

There are two major classes of respirators:

- Air-purifying, which remove contaminants from the air.
- Atmosphere-supplying, which provide clean, breathable air from an uncontaminated source. As a general rule, atmosphere-supplying respirators are used for more hazardous exposures.

		
Air-purifying Respirator	**Supplied-air hood**	**Airline Respirator**

Air-purifying respirators use filters or sorbents to remove harmful substances from the air. They range from simple disposable masks to sophisticated devices. They do not supply oxygen and must not be used in oxygen-deficient atmospheres or in other atmospheres that are immediately dangerous to life or health (IDLH).

Atmosphere-supplying respirators are designed to provide breathable air from a clean air source other than the surrounding contaminated work atmosphere. They include supplied-air respirators (SARs) and self-contained breathing apparatus (SCBA) units. The breathing air must meet at least the requirements for Grade D breathing air described in ANSI/Compressed Gas Association Commodity Specification for Air, G-7.1-1989, to include: oxygen content of 19.5-23.5%; hydrocarbon (condensed) content of 5 milligrams per cubic meter of air or less; carbon monoxide (CO) content of 10 ppm or less; carbon dioxide content of 1,000 ppm or less; and lack of noticeable odor (**1910.134(i)(1)(ii)(A) through (E)**).

Choosing the right equipment involves:

- Determining what the hazard is and its extent.
- Considering user factors that affect respirator performance and reliability.
- Selecting an appropriate NIOSH-certified respirator. Equipment must be used in accord with specifications accompanying the NIOSH certification.

When selecting respirators, employers must consider the chemical and physical properties of the contaminant, as well as the toxicity and concentration of the hazardous material and the amount of oxygen present. Other selection factors include the nature and extent of the hazard, work rate, area to be covered, mobility of the worker, work requirements and conditions, as well as the limitations and characteristics of the available respirators.

The time needed to perform a given task, including the time necessary to enter and leave a contaminated area, is an important factor in determining the type of respiratory protection needed. For example, SCBAs, gas masks, or air-purifying chemical-cartridge respirators provide respiratory protection for relatively short periods. On the other hand, an atmosphere-supplying respirator that supplies breathable air from an air compressor through an air line can provide protection for extended periods.

If the total concentration of atmospheric particulates is low, particulate filter air-purifying respirators can provide protection for long periods without the need to replace the filter. Where there are higher concentrations of contaminants, however, an atmosphere-supplying respirator such as the positive-pressure SAR offers better protection for a longer period. SARs eliminate the need for concern about filter breakthrough times, change schedules, or using end-of service life indicators (ESLI) for airborne toxic materials, factors that must be considered when using air-purifying respirators.

Another factor to consider when using respirators is the air-supply rate. The wearer's work rate determines the volume of air breathed per minute. The volume of air supplied to meet the breathing requirements is very significant when using atmosphere-supplying respirators such as self-contained and airline respirators that use cylinders because this volume determines their operating life.

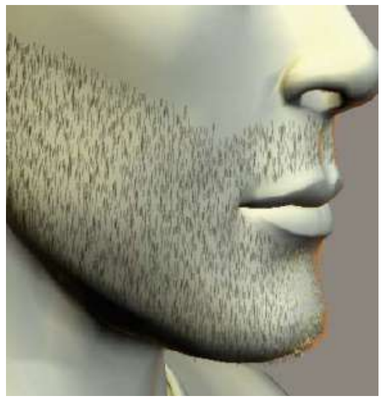
For additional information on respiratory protection program requirements; use of respirators; air monitoring for exposures; selection of respirators; employee training; fit testing of respirators; inspection and maintenance of respirators; medical evaluation of workers using respirators and breathing air requirements, see the following:

- **OSHA Bulletin – General Respiratory Protection Guidance for Employers and Workers**
- **Small Entity Compliance Guide for the Respiratory Protection Standard, 2011 (OSHA 3384-09)**
- **OSHA Respiratory Protection Advisor**
- **Appendix A to 29 CFR 1910.134: Fit Testing Procedures (Mandatory)**

Note: *There are additional PPE requirements for Health-Related Hazards (such as Lead [**29 CFR 1910.1025**], Arsenic [**29 CFR 1910.1018**], Asbestos [**29 CFR 1910.1001**], and Cadmium [**29 CFR 1910.1027**]).*

To prevent the inhalation of hazardous substances, respirators must form a complete seal. A complete seal prevents airborne contaminants in the work environment from seeping into the mask around the edges and being inhaled or contacting the skin.

Facial hair can break the respirator seal, allowing hazardous material to enter the respirator where it may be inhaled or make contact with the skin. Full beards and goatees are not the only facial hair that can create this risk. Even a single day of facial hair growth can create gaps in the respirator seal.



Respirator seals are broken by facial hair

Workers assigned to perform tasks requiring full- or half-face respirators must be clean shaven in order to have an effective seal.

No goatee, beard, or mustache hairs can be within the seal area. Depending on the full-face respirator design, large sideburns may also impact the seal.

The seal area also includes the neck and under the chin.

Respiratory Protection: Problems and Solutions

Problem

Damaged respirators lose their ability to protect workers' lungs. Paint and other debris can clog filters and interfere with air diaphragms in respirators.

Solutions

When not in use, respirators must be stored to protect them from contamination, damage, and deformation (i.e., kept in their protective coverings, such as a plastic bag).

Many respirator programs limit the amount of time a worker may use the same respirator before he or she must exchange it for a new one.

Problem

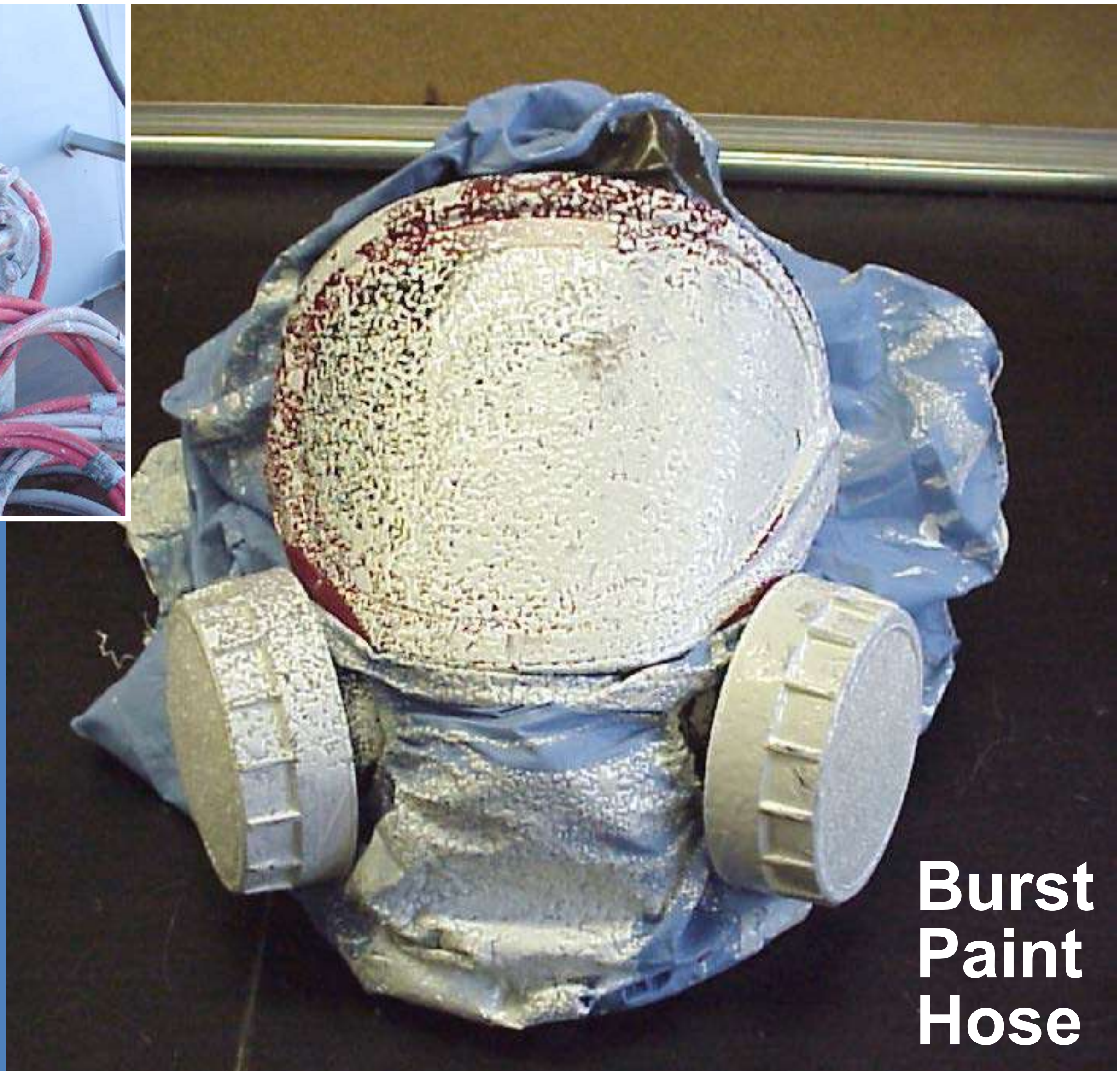
Correct respirator fit is critical in protecting workers from potentially harmful exposure to paint vapors or dust generated by removing coatings.

Worker awareness of proper fit and functioning of respirators is important for protection at the worksite.

Solutions

Annual fit-testing of workers is required and helps to ensure that individuals receive the full health benefits of properly fitted respirators. Employers must ensure that workers perform back-pressure checks (user seal checks) each time put on the respirator. It is also important to remind workers to check the condition of straps and valves.

MINI-POSTERS



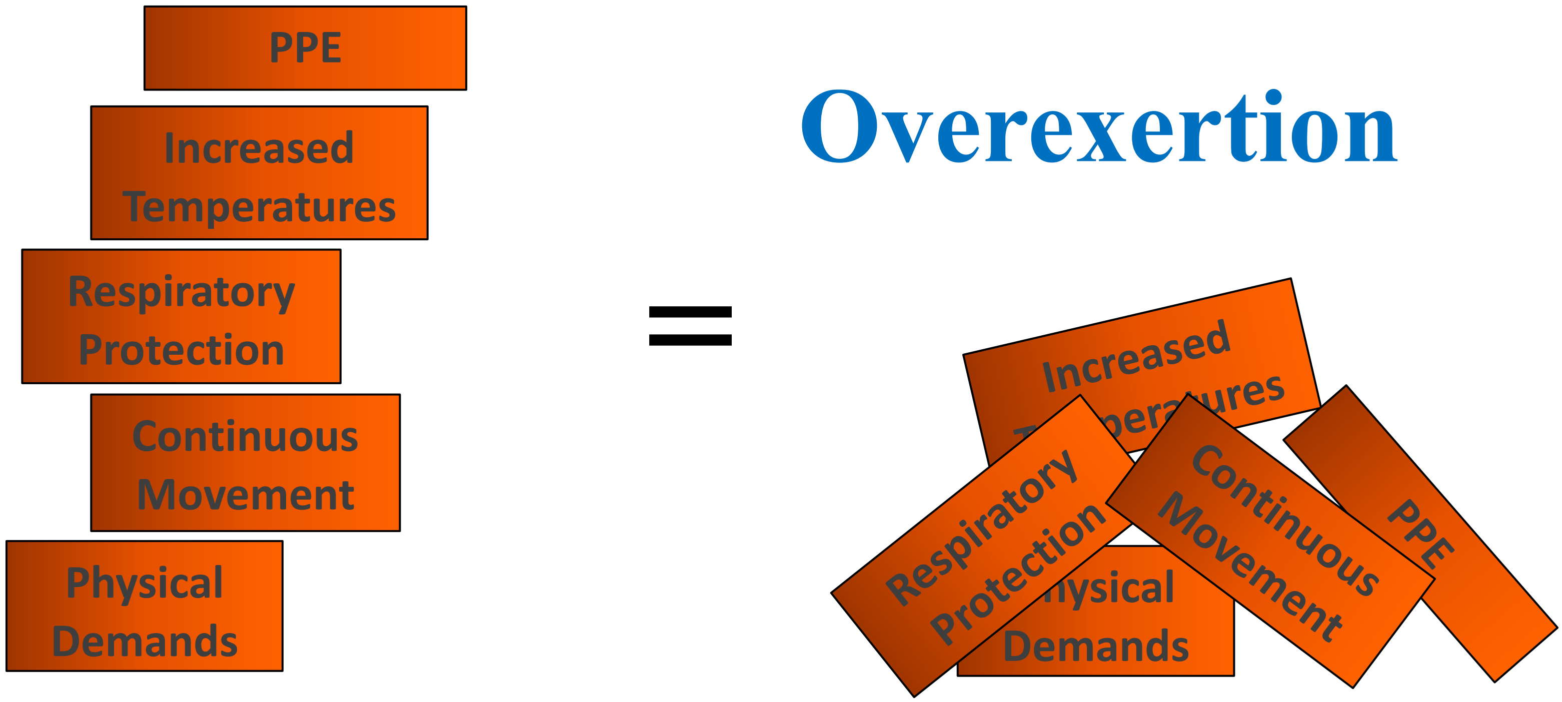
Expect the Unexpected . . . Always wear your safety gear!

- ☑ Make sure it is right for the hazard
- ☑ Inspect it often
- ☑ Maintain it regularly
- ☑ Wear it properly
- ☑ Replace it when needed

Before you pull that trigger, check these safety tips!!

- Post the risk for others to see
- Look for ignition sources (such as non-explosion-proof lighting or temporary power left behind)
- Monitor the air quality
- Make sure ventilation is working and at a sufficient rate

Know Your Limits



Pace yourself before you topple over!

Abate . . . Reduce material size for transport

Rotate . . . Allow for recovery with frequent job rotation

Hydrate . . . Take frequent water breaks

Refrigerate . . . Use technology to your advantage (e.g., cooling vests, air-conditioned respirators, etc.)