

Section 4: SELECTION OF COATINGS

4.1 Available Guidance. Guidance for specifying coating systems for original or maintenance painting of shore facilities is found in specialized guide specifications such as NFGS-13283 or CEGS 09900 or in Air Force Engineering Technical Letters. In these documents, surface preparation for the primer is usually considered a part of the system because of its importance in system performance and is included in the guidance. Recommendations for coating systems are also available from an Army, Navy, or Air Force coatings specialist. These specialists are particularly helpful when criteria for a specialized job are not available or when guidance documents are out of date.

4.2 Selection Criteria. The best selection of a coating system for a particular service is determined by a variety of factors. These include desired properties, work requirements and limitations, safety and environmental restrictions, compatibilities, and costs.

4.2.1 Desired Film Properties. In selecting a coating system, the first consideration is the desired properties of the system for the particular service. Desired properties may include one or more of the following aspects:

- a) Resistance to exterior weathering (chalking; color and gloss retention)
- b) Water, fuel, or chemical resistance
- c) Abrasion, heat or mildew resistance
- d) Appearance (color, gloss, and texture)
- e) Drying time
- f) Ease of application and maintenance

4.2.2 Work Requirements or Limitations. The following work requirements or limitations may have to be considered:

- a) Type of surface preparation
- b) Access to work
- c) Drying times
- d) Necessary applicator skills
- e) Necessary equipment

f) Scaffolding for access to work

4.2.3 Safety and Environmental Restrictions. It will be necessary to conform to all prevailing safety and environmental regulations concerning materials and processes to be used for surface preparation and for coating application. These regulations are discussed more fully in Section 3 of this handbook.

4.2.4 Compatibilities. Coating systems must be compatible with the surfaces to which they are applied. Coating incompatibility can cause failures at or just after application or after a much longer time. Failures occurring just after application are due to solvent incompatibility or wetting problems. Failures associated with slow chemical reactions, such as those occurring between alkaline surfaces (e.g., concrete and galvanized steel) and oil-based paints or mechanical property mismatches (e.g., a rigid coating applied over a more flexible one) cause failure in a longer timeframe. The failure more often is peeling. For existing coatings being repainted, compatibility generally means that topcoats should be of the same generic type or curing mechanism as undercoats. One exception to this rule is inorganic zinc coatings. Since inorganic zinc coatings frequently do not bond well to themselves, it is safest to repair them with zinc-rich organic coatings.

A simple test to classify coatings is to determine solvent sensitivity using an methylethyl ketone (MEK) or acetone rub test. To do this, soak a cloth in MEK or acetone, rub it against the existing paint, and visually check for pick up of paint. The paint is classified as "solvent soluble" if paint is picked up, and as "solvent insoluble" if not.

Another practical method of ensuring topcoat solvent compatibility is to coat a small test area of the existing coating with the paint selected for the work. If situations permit, this test is preferred over the MEK rub test because it is specific for the surface to be repainted. The test area should be visually inspected the following day (or preferably after 3 or more days) for bleeding of undercoat, wrinkling, loss of adhesion, or other coating defects. Although most incompatibility problems are apparent in a couple of days, some types of incompatibility may not become apparent for several months or until after a change of seasons. These types are usually associated with mechanical film properties.

4.2.5 Costs. Life cycle cost has always been one of the most important considerations in selection of coating systems. Life cycle costs include original surface preparation, materials, and application and necessary maintenance throughout the life of the

coating system. Today, the expense of containment of old paint during its removal and disposal of debris that is often considered to constitute hazardous waste must be included. This usually means that the system with the maximum maintainable life is the best choice.

4.3 Specifications for Lead- and Chromate-Free Coatings With VOC Limits. The coating specifications listed below in Table 5 are lead- and chromate-free and have limitations on their contents of VOC.

Table 5
Lead- and Chromate-Free Coating Specifications With VOC Limits

Latex Coatings	
Listed latex coatings are available with a VOC content of no more than 250 grams per liter unless otherwise specified	
TT-P-19	Exterior acrylic emulsion coating, available in a wide variety of colors and flat gloss finishes
TT-P-29	Interior latex paint, flat, available in white and tints
TT-P-650	Interior latex primer coating for gypsum board or plaster
TT-P-1510	Latex exterior flat finish coating, available in a variety of colors
TT-P-1511	Latex interior coating, available in gloss and semigloss in white and tints
TT-P-1728	Latex, interior, flat, deep-tone coating
TT-P-001984	Primer, latex, for wood
TT-P-002119	Latex high-traffic coating, available in flat and eggshell and a variety of colors
TT-E-2784	Acrylic emulsion exterior enamel, gloss and semigloss, available in a wide variety of colors
MIL-E-24763	Acrylic water-emulsion coating intended for shipboard use, available in 275 and 340 grams per liter VOC classes; high, medium, low, and flat glosses; and a limited number of colors
MIL-P-28577	Corrosion-resistant latex primer for metals
Stains	
MIL-P-28578	Waterborne acrylic semigloss finish, available in a wide variety of colors
TT-S-001992	Exterior latex stain, semi-transparent and opaque, available in a variety of colors
Clear Floor Finishes	
A variety of clear floor finishes are available from the Maple Flooring Manufacturers Association (MFMA) specifications, <u>Heavy-Duty and Gymnasium Finishes for Maple, Beech, and Birch Floors</u> . Suppliers on the attached list must be contacted to determine VOC content.	
Oil and Alkyd Coatings	
SSPC PAINT-25	Corrosion-resistant raw linseed oil and alkyd primer, usually available at 300 grams per liter VOC but no requirement listed

Table 5 (Continued)
Lead- and Chromate-Free Coating Specifications With VOC Limits

TT-P-25	Oil-based primer for wood, normally available with a VOC content less than 350 grams per liter
TT-P-31	Red and brown oil ("roof and barn") paint, usually available with 250 grams per liter VOC content but no requirement specified
TT-E-489	Alkyd enamel, with 420 grams per liter VOC limitation, available only in gloss, but in a wide variety of colors
TT-P-645	Corrosion-resistant alkyd primer, with a 340 VOC limitation
TT-P-664	Corrosion-inhibiting alkyd quick-dry primer, with a 420 grams per liter VOC limitation
MIL-E-24635	Silicone alkyd enamel, available in limited colors, 275, 340, and 420 grams per liter VOC types, and high, medium, low, and flat gloss classes
MIL-P-28582	Alkyd primer normally available at less than 350 grams per liter
Epoxy Coatings	
MIL-P-24441	Epoxy-polyamide, two- and three-coat systems, available in types with 340 VOC and limited colors
MIL-P-53022	Fast-dry epoxy primer with 420 grams per liter maximum VOC content
MIL-P-85582	Waterborne epoxy primer with 340 grams per liter maximum VOC content
Textured Coatings	
TT-C-555	Waterborne or oil- or rubber-based textured coating available at 250 grams per liter
Urethane Coatings	
MIL-C-85285	High-solids aliphatic urethane coating, with 340 and 420 grams per liter VOC types, available in a variety of colors and in glass and semigloss
Zinc-Rich Coatings	
MIL-P-24648	Zinc-rich coating, aqueous and organic solvent types, self-curing and post-curing classes, organic and inorganic vehicles, with 340 grams per liter maximum VOC content

4.4 Recommendations for Different Substrates. This portion of Section 4 provides general recommendations for wood, concrete and masonry, steel, galvanized steel, and aluminum surfaces. The recommended dft in mils is provided for coating specification recommended for a particular substrate. More detailed recommendations for coating particular structures are presented in Section 5 of this handbook. Referenced standards for coatings provide for lead- and chromate-free products that are low in VOCs. Although such requirements may not be necessary at all activities, such requirements may occur in the near future.

In making local repairs of damaged coatings, loose paint should be removed by scraping with a putty knife before lightly sanding or abrasive blasting any exposed substrate and feather-edging existing sound paint to obtain a smooth transition with the repaired area. Coats of repair material should be extended 1 inch onto the surrounding sound coating.

4.4.1 Recommendations for Wood. Oil-based and waterborne coatings and stains (frequently called latex) perform quite well on new wood. A two-coat system, paint or stain, is normally applied. However, as additional coats are applied to resurface or repair weathered paint, the film thickness may become sufficient to reduce the total flexibility to the point that results in disbonding of the total paint system from the surface. Thus, when topcoating or making localized repairs, no more coating should be applied than necessary to accomplish the desired goal.

Surface preparation of new wood normally consists of lightly hand sanding or power sanding, carefully controlled so that it does not damage the wood. Sanding is also appropriate for preparing weathered surfaces for refinishing and for spot repairing areas of localized damage.

4.4.1.1 Oil-Based Paints. Historically, wood has been successfully painted with oil-based products that penetrate the surface well. These coatings are very easy to apply.

Oil-Based Paint System for Wood

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
Sand	one coat TT-P-25 or MIL-P-28582 2 mils dft	one-two coats MIL-E-24635 or TT-P-102 2 mils dft per coat

4.4.1.2 Water-Emulsion Paints. More recently, latex coatings have been found to be very effective in providing attractive, protective finishes. They are also less affected by moisture than are oil-based finishes and are generally more flexible and thus less susceptible to cracking as the wood swells and contracts with moisture changes.

A problem sometimes arises when repairing or topcoating existing smooth alkyd coatings with latex paints. To obtain good intercoat adhesion, it may be necessary to lightly sand the existing paint and/or apply a surface conditioner containing tung oil or some other oil that wets surfaces well before applying the first coat of latex paint.

Waterborne Paint System for Wood

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
Sand	one coat TT-P-001984 1.5 mils dft	one-two coats TT-E-2784 or other appropriate latex paint in Table 5 1.5 mils dft per coat

4.4.1.3 Semi-Transparent Stains. Because oil-based and waterborne paints form continuous films, they may form blisters or disbond because of moisture in the wood attempting to escape. Semi-transparent stains do not form continuous films on wood and so do not have this problem. Thus, they are a good alternative on new wood. Additional coats applied over the years or heavy-bodied stains will, however, form continuous films.

Stains for Wood

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
Sand	one coat TT-S-001992 1.5 mils dft	one coat TT-S-001992 1.5 mils dft

4.4.1.4 Clear Floor Finishes. A variety of clear floor finishes are available from MFMA Heavy-Duty and Gymnasium Finishes for Maple, Beech, and Birch Floors. Suppliers on the attached list must be contacted to determine VOC content. Surface preparation for hard wood floors is described in detail in NFGS-13283 or CEGS 09900.

4.4.2 Recommendations for Concrete and Masonry Surfaces. Concrete and masonry surfaces, as well as those of stucco, plaster, wallboard, and brick, can be coated with a variety of systems depending upon the desired purpose and appearance.

Surface preparation is usually accomplished by power washing with aqueous detergent solution to remove dirt and other loose materials. Any oil or grease will have to be removed by solvent or steam cleaning; any mildew, by scrubbing with bleach; and any efflorescence or laitance, by brushing, followed by acid treatment. These techniques are described more fully in Section 6.

4.4.2.1 Waterborne Coatings. A two-coat waterborne (latex) system provides an attractive breathing film that is normally less affected by moisture in the concrete than non-breathing systems. The latex material is a self-primer in this service,

unless otherwise stated. Alkyd and other oil-based coatings should not be applied directly to concrete or masonry surfaces, because the alkalinity in the concrete will hydrolyze the oil in the binder and cause the coating to peel. However, they can be applied over concrete or masonry surfaces primed with waterborne coatings to produce a tougher, more washable finish.

Waterborne Coating System for Concrete/Masonry

Surface

Preparation

Primer/Topcoat

Power wash

two coats of TT-E-2784 or other appropriate* waterborne coating
1.5 mils dft each coat

*Interior or exterior product, desired gloss and color available. TT-P-29 is less expensive and normally used on interior surfaces.

4.4.2.2 Elastomeric Coatings. Elastomeric, waterborne acrylic coating systems also perform well to seal and protect concrete/masonry surfaces and are normally very low in VOCs. They can successfully bridge fine or larger caulked cracks. There are no Government or military specifications for them.

Elastomeric Waterborne Acrylic System for Concrete or Masonry

Surface

Preparation

Primer

Topcoat

Power wash

one coat primer recommended by supplier of elastomeric coating dft varies with supplier

one coat elastomeric acrylic coating
10 - 20 mils dft

4.4.2.3 Textured Coatings. Textured coatings system can bridge fine cracks and waterproof from wind-driven rain. They are normally applied over a primer recommended by the supplier to insure good adhesion. They are available in a variety of textures and may be waterborne or oil or rubber-based products with a VOC limit of 250 grams per liter.

Textured Coating System for Concrete or Masonry

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
Power wash	one coat primer recommended by supplier of textured coating dft varies with supplier	one coat TT-C-555 20 - 30 mils dft

4.4.2.4 Epoxy Coatings. A two-coat epoxy system will seal and protect concrete/masonry surfaces well. An aliphatic urethane finish coat should be used rather than the second epoxy coat on exterior surfaces to improve the weatherability.

Exterior Epoxy/Urethane System for Concrete or Masonry

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
Power wash	one coat MIL-P-24441 Formula 15 3 mils dft	MIL-C-85285 Type II 2 mils dft

Interior Epoxy System for Concrete or Masonry

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
Power wash	one coat MIL-P-24441 Formula 150 3 mils dft	one coat MIL-P-24441 of another color 2 mils dft

4.4.3 Recommendations for Steel. Presently, a high-performance coating system is recommended to prolong the service before it becomes necessary to remove and replace it. Costs in coating removal, especially where there are restrictions on abrasive blasting, are very high.

Abrasive blasting is always preferred to alternative methods of preparing steel surfaces for painting. It cleans the steel and provides a textured surface to promote good primer adhesion. A commercial blast (SSPC SP 6) is normally adequate for alkyd and epoxy primers for a moderate environment. A near-white blast (SSPC SP 10) is required for epoxies, including zinc-rich epoxies, exposed to a severe environment such as marine atmospheric or water or fuel immersion. Some manufacturers may specify a white metal blast (SSPC SP 5) for particular coatings for special applications. It is important that a contract specification does not conflict with the coating manufacturer's

written directions. A white metal blast (SSPC SP 5) is recommended for zinc-rich inorganic primers. If abrasive blasting cannot be done, then power tool cleaning to bare metal (SSPC SP 11) is recommended. It provides a surface cleanliness and texture comparable to those of a commercial blast (SSPC SP 6). Hand tool cleaning (SSPC SP 2) or power tool cleaning, however, may be adequate in making localized repairs.

4.4.3.1 Alkyd Systems. In the past, most military steel structures with atmospheric exposures were coated with an alkyd or other oil-based system. Three-coat alkyd systems provided adequate protection in moderate atmospheric service. On new painting, they are being replaced in significant part by epoxy systems that provide longer protection. Alkyd systems, however, will still be used in large volume for repairing old deteriorated alkyd systems.

Alkyd Coating System for Steel

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
SSPC SP 6	one coat TT-P-645 or SSPC PAINT 25 2 mils dft	two coats MIL-E-24635 or TT-E-489 2 mils dft

4.4.3.2 Epoxy Coating Systems. A three-coat epoxy system provides good interior service in harsh as well as moderate environments. An aliphatic urethane finish system is used in place of the third epoxy coat in exterior service to provide greater resistance to deterioration by ultraviolet light. Several different epoxy mastic systems, some aluminum-filled, have been used successfully on steel structures. However, there is no specification for one at this time.

Epoxy System for Exterior Steel

<u>Surface Preparation</u>	<u>Primer/Mid Coat</u>	<u>Topcoat</u>
SSPC SP 6 or 10	one coat each MIL-P-24441 Formulas 150 and 151 3 mils dft per coat	one coat MIL-C-85285 Type II 2 mils dft

Epoxy System for Interior Steel

<u>Surface Preparation</u>	<u>Primer/Mid Coat</u>	<u>Topcoat</u>
SSPC SP 6 or 10	one coat each MIL-P-24441 Formulas 150 and 151 3 mils dft per coat	one coat MIL-P-24441 of desired color 3 mils dft

4.4.3.3 Zinc-Rich Coatings. Good protection from corrosion and abrasion can be provided by zinc-rich inorganic coatings. They perform well untopcoated in a variety of environments except acidic or alkaline. They may be topcoated with an acrylic latex finish coat to provide a variety of color finishes. Epoxy (for interior) or epoxy and aliphatic urethane (for exterior) topcoats may also be used. Localized repair of inorganic zinc systems is usually accomplished with a zinc-rich organic coating to permit good bonding to any exposed steel, inorganic coating, or organic topcoats.

Zinc-Rich System for Steel

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
SSPC SP 5	1-MIL-P-24648 Composition B (inorganic), 3 mil dft (Composition A (organic) can be used when a more "forgiving" system is needed, refer to pars. 2.3.8 and 2.3.9)	None, or one or more coats of acrylic or latex, epoxy, etc.

4.4.4 Recommendations for Galvanized Steel. Galvanized steel corrodes very slowly in moderate environments but may be painted with organic coating systems to provide color or additional corrosion protection, particularly in severe environments. It should never be coated directly with an alkyd paint, because the alkalinity on the surface of the galvanizing will hydrolyze the oil in the binder, degrading the binder, and cause paint peeling.

New galvanizing should be solvent or steam cleaned (SSPC SP 1, Solvent Cleaning) to remove any grease or oil before coating. Older, untopcoated galvanizing should be power washed to remove any dirt or loose zinc corrosion products. Any loose coatings should also be removed by power washing or scraping and sanding to produce a clean, sound surface. Rust should be removed by waterblasting or careful abrasive blasting to limit the removal of galvanizing.

4.4.4.1 Epoxy Systems. Two coats of epoxy will provide long-term protection to galvanizing in interior service, as will one coat of epoxy and one coat of aliphatic urethane to galvanizing in exterior service.

Epoxy Coating System for Exterior Galvanizing

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
SSPC SP 1	one coat MIL-P-24441 Formula 150 3 mils dft	one coat MIL-C-85285 Type II 2 mils dft

Epoxy Coating System for Interior Galvanizing

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
SSPC SP 1	one coat MIL-P-24441 Formula 150 3 mils dft	one coat MIL-P-24441 of desired color 3 mils dft

4.4.4.2 Waterborne System for Galvanizing. Two coats of latex paint will provide a pleasing appearance and good protection to galvanized steel in moderate environments. They are easy to apply.

Waterborne Coating System for Galvanizing in Moderate Environment

<u>Surface Preparation</u>	<u>Primer</u>	<u>Topcoat</u>
SSPC SP 1	one coat TT-E-2784 1.5 mils dft	one coat TT-E-2784 * 1.5 mils dft

* Other commercially available acrylic latex systems will also perform well.

4.4.5 Recommendations for Aluminum. Aluminum surfaces corrode very slowly in moderate environments. They may be coated to provide color or additional protection, particularly in severe environments. Epoxy and epoxy/urethane systems perform well in interior or exterior service, respectively. Alkyd systems usually require surface pretreatments containing toxic materials.

Because aluminum surfaces are relatively soft, they should not be cleaned by blasting with conventional abrasives or grinding to avoid damage. Any grease or oil should be removed by solvent or steam cleaning (SSPC SP 1). Dirt and other loose

contaminants should be removed by power washing. Existing coatings are best removed by careful blasting with a soft abrasive (e.g., plastic). Alkaline strippers should never be used, because they will attack the aluminum.

Coating System for Aluminum

Surface
Preparation

See above

Primer

one coat MIL-P-24441
Formula 150 or
MIL-P-53022
3 mils

Topcoat

one-two coats
MIL-C-85285 Type II
2 mils per coat

Section 5: COATING SYSTEMS FOR SPECIFIC USES

5.1 General. Section 4 of this document provides general guidance for the selection of coating systems for wood, concrete/masonry, steel, galvanized steel, and aluminum surfaces. This section provides more detailed information on systems for specific structures or components of structures. These structures include metal storage tanks, pipe lines, towers, waterfront structures, siding, fences, and hot surfaces; concrete storage tanks, swimming pools, catchment basins, pavements, and floors; and wood floors. This section also describes problems associated with mildew on painted surfaces.

5.2 Painting New Construction. The designer of the first coating system for a new fuel tank, pipe line or other constructed facility has the unique opportunity to specify a system that can provide the best service. Much of the coating system - surface preparation, priming and in some cases application of the complete coating system - can be carried out in a shop environment where the environmental and application parameters can be controlled. By controlling these conditions, the surface can be very well prepared and the film properties obtained after curing are optimum. Further, worker safety and environmental controls may be more easily accomplished. Since the cost difference of a white metal blast as compared to a near-white blast may be small for new steel, and since the cost of the "best" materials may not be much greater than the cost of "poor" materials, the use of these procedures and materials should be considered when selecting the coating system. Maintenance painting is always more difficult than shop painting and frequent maintenance painting on constructed facilities may interfere unacceptably with the mission of the structure. Thus, in summary, it is recommended that high-performance systems be specified on new construction.

5.3 Fuel Storage Tanks. Steel fuel tanks are coated to keep the fuel clean and prevent leaks resulting from corrosion. Leaks can cause fires or serious contamination of soils or ground waters. Underground steel fuel tanks should also be cathodically protected or double walled to meet Department of Transportation requirements directed at environmental protection from fuel leaks.

For new tanks in most environments, effective performance of most chemically cured (e.g., epoxies and polyurethanes) has been obtained with a near-white finish (SSPC SP 10) before coating. However, it is essential that the surface preparation specified for a coating not be in conflict with that provided by the coating manufacturer on the written coating data

sheet. In some cases, a coating manufacturer may state that a coating should only be used over a white-metal finish (SSPC SP 5). After application of the total system, it should be checked for holidays with a low-voltage holiday detector as described in the National Association of Corrosion Engineers (NACE) RPO188, Standard Recommended Practice, Discontinuity (Holiday) Testing of Protective Coatings. Any holidays that are located should be repaired.

Repair of damaged coatings will vary somewhat with the existing coating system. Normally, repairs are made with the type of coatings already on the tanks. If these are not available, another compatible coating system must be used. Compatibility of coatings can be determined as described in par. 5.6.2. Localized exposed steel should be spot abrasively blasted to an SSPC SP 10 condition and the intact coating surrounding these areas should be brush-off blasted (SSPC SP 7) to a 2-inch width. The patch of the same or a compatible coating system should be applied to steel and extend 2 inches onto the cleaned intact coating.

5.3.1 Interiors of Steel Fuel Tanks. Interiors of steel storage tanks should be cleaned as described in NFGS-13219, Cleaning Petroleum Storage Tanks, and inspected regularly. Because it may not be possible to do this conveniently, it is critical that they receive long-lasting, high-performance interior coating systems. Corrosion occurs most frequently on the floors of the tanks, where water is always present despite its frequent removal from sumps. Thus, the bottoms of steel tank interiors should be measured for adequate thickness before blasting and recoating is initiated. It may be necessary to fill pits with weld metal, apply a false bottom of fiberglass-reinforced plastic as described in NFGS-13217, Fiberglass-Plastic Lining for Steel Tank Bottoms (for Petroleum), or install a new replacement steel bottom. All steel storage tank interiors should be given a near-white blast (SSPC SP 10) immediately prior to priming. For many years, fuel tank interiors have been successfully lined with a three-coat epoxy system with a total dry film thickness of 9 mils. Coats of epoxy-polyamide conforming to Formulas 150, 151, and 152 of MIL-P-24441 have been the epoxy system most frequently used to line military steel fuel tanks. It is described in NFGS-09973, Interior Coating System for Welded Steel Petroleum Storage Tanks.

More recently, a urethane system was developed for lining steel fuel tanks. As described in NFGS-09970, Interior Coatings for Welded Steel Tanks (for Petroleum Fuels), it consists of a pretreatment wash primer, a polyurethane primer, a polyurethane intermediate coat, and a finish coat. The finish

coat may be a polyurethane or a special fluorinated polyurethane. These coatings currently exceed the VOC limit of 340 grams per liter that exists in many locations, the fluorinated polyurethane coating is very expensive, and the pretreatment wash primer and the primer contain chromate. However, because of the reported much longer life of the system with the fluorinated polyurethane finish, it is recommended for Navy fuel tanks, wherever it is legal to use it.

After application of each coat of interior paint, tank interiors must be thoroughly ventilated to remove organic solvent vapors and to assist in curing (solvent release) of coatings. Ventilation requirements vary with tank size, shape, and number of openings. Safety requirements and instructions of coating manufacturers should be followed. Heated air can also be used to accelerate curing of coatings. Blasting and painting hoses, as well as other electrical equipment, should be grounded and sparkproof. The local industrial hygienist can provide information on health and safety requirements for the lining operation. It is especially important to require holiday testing of the interior tank coatings. In this way, small defects can be found and repaired, preventing sites for premature initiation of corrosion.

5.3.2 Exteriors of Steel Fuel Tanks. The exterior coating of steel fuel tanks is described in NFGS-09971, Exterior Coating System for Welded Steel Petroleum Storage Tanks. For new tanks, a system that has performed well is two coats of epoxy-polyamide (e.g., MIL-P-24441 Formulas 159 and 151) and a finish coat of aliphatic polyurethane (e.g., MIL-C-85285) to a total dry film thickness of at least 8 mils. The recommended surface preparation is an SSPC SP 10 near-white blast. Refer to par. 4.4.3 for maintenance painting of exterior tanks.

5.4 Steel Water Tanks. Newer steel water storage tanks have welded sections. Older riveted or bolted tanks are still used, however, at some activities. The seam areas of such tanks are much harder to completely coat. Cathodic protection, as described in NFGS-13112, Cathodic Protection System (Steel Water Tanks), CECS 16641, Cathodic Protection System (Steel Water Tanks), and MIL-HDBK-1004/10, Electrical Engineering Cathodic Protection, is recommended for water tank interiors to supplement the protection afforded by coatings. Corrosion of cathodically protected water tanks generally is usually concentrated at the top of the tank along sharp edges, crevices, and beams supporting the roof, where cathodic protection does not occur. Thus, it is important to coat and inspect these areas especially well.

5.4.1 Interiors of Steel Water Tanks. Most states presently require or are expected to require the use of coating systems approved by the National Sanitation Foundation (ANSI/NSF Standards 60 and 61) for the lining of potable water tanks. Coating approval is based on tests (NSF Standards 60 and 61) for leaching of toxic materials. The tests do not address durability of the coatings for water immersion service. The coatings are usually epoxies. In states that have no requirements, the three-coat epoxy-polyamide system described in par. 5.3.1.1 for the interiors of steel fuel tanks can also be used, except that Formula 156 (red) is used in place of Formula 151 (gray) as the intermediate coat. Metal and coating repairs for water tanks can be made in the same manner as described for fuel tanks, but those for potable water tanks must be covered with an NSF-approved coating system, where these requirements prevail.

5.4.2 Exteriors of Steel Water Tanks. Exteriors of water tanks should be coated in the same manner as described in par. 5.3.2 for the exteriors of fuel tanks.

5.5 Other Steel Tanks. Steel tanks may contain waste water, chemicals, or other corrosive materials. Cathodic protection is also recommended for these tanks. Refer to par. 5.4.

5.5.1 Interiors of Other Steel Tanks. Interiors of steel tanks containing waste water, chemicals, or other corrosive liquids should be coated with a suitable corrosion-resistant lining (e.g., fiberglass-reinforced polyester) to protect the steel from corrosion. Since there are no Federal specifications for such products, specialty coating suppliers should be consulted about them.

5.5.2 Exteriors of Other Steel Tanks. Exteriors of steel tanks containing wastewater, chemicals, and other corrosive liquids should be coated with the system described for steel fuel tank exteriors in par. 5.2.2.

5.6 Steel Distribution Lines. Steel distribution lines containing water, fuel, or other liquids are coated to prevent loss of product from corrosion and contamination of soils and groundwater.

5.6.1 Steel Fuel Lines

5.6.1.1 Buried Steel Fuel Lines. Buried steel fuel lines must be coated and cathodically protected to meet Department of Transportation regulations and to provide their most economical protection.

a) The desired properties of coatings for buried, cathodically protected pipelines are:

- (1) Good electrical insulation
- (2) Good moisture resistance
- (3) Good adhesion
- (4) Resistance to cathodic disbonding
- (5) Resistance to damage during handling
- (6) Ease of repair

b) Coatings for piping to be buried should be applied in a shop under controlled conditions. Blasting with automatic equipment that recycles the abrasive should provide a high level of cleanliness (SSPC SP 5 or 10). Coatings that have been commonly used on buried piping include:

(1) Coal Tar Enamels - Coal tar enamels use different combinations of fiberglass and felt wraps to provide mechanical strength and thickness (1/8 inch or more). Their use has greatly declined because of environmental concerns about coal tar.

(2) Asphalt Mastics - Asphalt mastics are combinations of asphalt, sand, and other materials that are extruded over pipes at thicknesses up to 1/2 inch. They are quite moisture-resistant but lack resistance to both hydrocarbons and sunlight and, like coal tar enamels, are a health concern.

(3) Extruded Coatings - Extruded coatings typically have a 10 to 15 mil mastic base covered with a polyethylene or polypropylene outer jacket. They are sensitive to sunlight and must be covered if they are to be exposed to it for long periods of time.

(4) Fusion-Bonded Powder Coatings - Fusion-bonded powder coatings are usually applied by electrostatic spray to pre-heated pipe (400 to 500 degrees F) cleaned to a near-white surface (SSPC SP 10). The 10 to 30 mil coating is water-cooled before storage and subsequent use.

(5) Plastic Tapes - Polyethylene, vinyl, and coal tar tapes are available with different adhesives and thicknesses. Because they are relatively easily damaged, they are often installed with a secondary rock shield. Portable wrapping machines are also available for over-the-ditch application.

(6) Heat-Shrinkable Tapes - Heat-shrinkable tapes of polyolefin provide tight bonding to pipes. They are shrunk in place by heating at 300 to 400 degrees F. Their relatively high cost limits their use to special areas such as joints.

5.6.1.2 Immersed Steel Fuel Lines. Immersed pipes lines can be in fresh or salt water, near the surface where they are exposed to ultraviolet (UV) light or deep where UV light is not of concern. Further, some pipe lines are exposed to abrasion from particulates and debris in the water. A coating that has been successful in some applications is the three-coat epoxy system described for steel fuel tank interiors in par. 5.3.1. Vinyl coatings are effective where there is abrasion. The pipe lines can also be cathodically protected.

5.6.1.3 Aboveground Fuel Lines. Aboveground fuel lines can be coated much the same as fuel tank exteriors described in par. 5.3.2. A petrolatum paste/tape system has also been used very effectively in protecting fuel lines under piers. The system can be applied by hand over wire-brushed steel. It is very easy to repair when damaged.

5.6.2 Steel Water Distribution Lines. Steel water distribution lines should be coated as described for steel fuel distribution lines in pars. 5.6.1.1, 5.6.1.2, and 5.6.1.3, depending upon the environment, buried, immersed, or aboveground. Although buried steel water distribution lines do not present the same level of environmental hazard as do buried steel fuel lines, it is recommended that they be cathodically protected, as well as coated. For steel water distribution lines that are buried but not cathodically protected, use the three-coat epoxy-polyamide system described for steel fuel tank interiors in par. 5.3.1.

5.7 Communication Towers and Other Tall Structures. The military has thousands of communication towers of various sizes and configurations in many geographical and climatic regions. The tower designs and initial treatments of the steel construction materials often vary from site to site and within the same site. These variable factors often cause problems in obtaining cost-effective painting of the towers.

Many towers require either a painted pattern of alternate aviation orange and white markings for daytime visibility, or lighting (strobe for high towers). Requirements for marking and lighting are described in detail in Federal Aviation Administration (FAA) Advisory Circular 70/7460-1G. Compatibility of coatings can be determined as described in par. 5.6.2. The use of painted patterns over zinc-coated structures is a better choice over lighting for long-term use and operation

of towers. While lighting may be less expensive in initial construction and maintenance, an unprotected bare zinc surface will erode and require more expensive repairs than a bare surface. Further, some studies have shown that the lifetime of the zinc plus organic coating system is significantly greater than the sum of just the zinc coating and of an organic coating. While painting automatically brings maintenance problems, these are normally much less than those occurring to unpainted towers. The orange and white colors required by the FAA are available in aliphatic polyurethane, alkyd, and latex formulations.

5.7.1 New Towers. Today, new tower components are usually built with galvanized structural steel or steel thermally sprayed with zinc metal, if too large to be placed in a dipping tank.

5.7.1.1 New Galvanized Steel Towers. Galvanizing applications for steel tower components are typically heavy (e.g., 4 to 7 mils of zinc) and accomplished by hot dipping. Whether thermally sprayed or hot dipped, the zinc coating can provide several years of protection by itself. However, it will subsequently be necessary to apply a paint system to extend this corrosion protection, after the zinc is consumed. Because quality painting of towers after erection is both difficult and expensive, it is always best to apply organic coatings beforehand, preferably in a shop setting. Surface preparation and painting of tower components in a shop can be accomplished under controlled conditions to provide optimum protection of the metal. Shop cleaning of zinc-coated surfaces is normally limited to detergent washing to remove loose contaminants and/or solvent cleaning (SSPC SP 1) to remove grease or oil. Sometimes, a thin film of grease or oil is applied at the factory to protect galvanizing from corrosion during exterior storage. Also, new galvanizing is sometimes treated with chromate corrosion inhibitors for corrosion protection during storage. Such treatment should specifically be excluded in specifications for galvanized steel components to be coated.

Galvanized steel components are best protected with one coat each of epoxy-polyamide (e.g., MIL-P-24441 Formula 150) and aliphatic polyurethane (e.g., MIL-C-85285) coatings as described above. If a delay of over 4 days occurs before topcoating, the finish coat of polyurethane may not adhere because of the solvent resistance of the nearly fully cured epoxy coat. A thin (2-mil wet film thickness) film of the epoxy primer applied and allowed to cure to a tacky finish (e.g., 4 hours) will provide a suitable surface for the polyurethane finish coat. Epoxy and urethane coatings must have at least a 6-hour pot life for practical coating of towers in place. Oil-based paints (including oil/alkyds) are not

recommended because of the inherent incompatibility of oil-based paints with the alkaline surface of galvanizing. Premature failure by peeling is predictable.

A two-coat latex system (e.g., 1-1/2 mils dry film thickness each of MIL-P-28577 primer and MIL-P-28578 topcoat or SSPC PAINT 24) can also be used on galvanizing, but the protection and gloss and color retention may not be quite as good as with the epoxy/polyurethane system. The corrosivity of the exposure environment should be considered when choosing between the two systems.

5.7.1.2 New Thermally Sprayed Steel Towers. Thermally sprayed zinc is relatively porous and protects steel by cathodic protection. It should be sealed to provide maximum protection. Application of epoxy polyamide MIL-P-24441, Formula 150 thinned 50/50 has been very effective in sealing of thermally sprayed ship components. Where restrictions on the solvent (VOC) content prevail, sealing can be accomplished with a mist coat. Sealing should be followed with a full coat of Formula 150 applied at the usual 3-mil dry film thickness and a finish coat of aliphatic polyurethane (e.g., 2 mils dry film thickness of MIL-C-85285).

Some private companies have successfully coated thermally sprayed steel components with a single, heavy (e.g., 6 to 8 mils dry film thickness) coat of commercially available aluminum-filled epoxy mastic. Such a product is not covered by Government or industry specifications.

5.7.1.3 New Steel Towers. If new steel tower legs are not galvanized or thermally sprayed with a zinc coating, use of an inorganic zinc coating should be considered if the coating can be applied in the shop. A controlled shop environment can provide the proper conditions for obtaining a very corrosion-protective inorganic-zinc coating. These coatings (e.g., SSPC SP 5 surface preparation and MIL-P-24648, inorganic zinc) have been shown to provide long-term service with minimal maintenance requirements. If the coating must be applied in the field, an organic zinc-rich coating is probably preferred since they are more forgiving of surface preparation lapses and can be applied and cured over a wider range of environmental conditions. For either system, an intermediate coat of epoxy polyamide (e.g., MIL-P-24441, Formula 150) and a finish coat of aliphatic polyurethane (e.g., MIL-C-85285) can complete the system.

5.7.2 Existing Towers. It is best to repair damaged tower coatings on existing towers on a regular schedule before the damage becomes significant. To repair or topcoat existing coatings, it is necessary to know the generic type of the present coating. The same or another compatible coating must be used.

In some cases (e.g., with vinyl or chlorinated rubber coatings), another generic type coating may have to be used, because the old one is no longer permitted by many local environmental regulations.

Before contracting any tower painting, it is necessary to determine if any existing paint on the tower contains lead. Lead may be present as one or more components of alkyd paints or as pigmentation for the aviation orange color. Unless the absence of lead is definitely known, samples should be taken and submitted to a laboratory for analysis. Refer to NFGS-13283 or CEGS 02090 for information on removal, containment, and disposal of lead-containing paint. If the generic type of the existing finish coat is not known, a compatible coating may be selected by merely determining its solvent solubility. To do this, soak a cloth in methyl ethyl ketone or acetone, rub it against the existing paint, and visually check for pickup of paint. The paint is classified as "solvent soluble" if paint is picked up, and as "solvent insoluble" if not.

The common practice of applying paint by glove is not recommended. It produces neither a continuous nor a uniformly thick paint film. Roller application is also not recommended because of difficulties in coating irregular surfaces. Spray application by portable equipment produces the most attractive finish but generally produces much overspray. Electrostatic spraying can eliminate overspray, if it is available on high platforms. Spray cans can provide a quick cosmetic touch-up for small damaged areas. Brushing is generally the most practical application method to coat sharp edges, crevices, and corners. It also can produce a relatively uniform, continuous film.

5.7.2.1 Towers With Only Cosmetic Coating Defects. Maintenance painting to correct fading, discoloration, or limited intercoat peeling should be undertaken when the existing aviation orange on the upper portion of the tower fails to meet the requirement of the color tolerance chart of the FAA (refer to Advisory Circular 70/7460-1G). Whatever the construction material, the only surface preparation that is required is removal of loose contaminants with a bristle brush or by washing. One or two coats of acrylic latex finish (e.g., TT-E-2784), as required for complete hiding of the existing paint, should be applied to the cleaned surfaces. Normally, weathered exterior coatings are sufficiently textured for good adhesion and general compatibility of latex topcoats. However, severe chalking of the old coating may present an adhesion problem for latex coatings.

5.7.2.2 Zinc-Coated Steel Tower Components With Deteriorated Organic Coatings. Zinc-coated steel (either galvanized or thermally sprayed) with damaged organic coatings should be scrubbed with a bristle brush to clean the exposed metal surface and remove loose coatings. The coatings should also be lightly sanded, if necessary, to feather edge the damaged areas. If the old paint is oil, alkyd, latex, vinyl or solvent soluble, apply one coat each of latex primer and finish to the exposed zinc coating and overlay it 1 inch onto the surrounding tight coating. If the repaired area matches the intact paint, it will not be necessary to topcoat the undamaged areas.

If the existing finish coat is polyurethane, epoxy, or solvent insoluble, apply one coat of epoxy primer and one coat of aliphatic urethane finish to damaged areas. Again, if the match is good, topcoating of undamaged areas will be unnecessary.

If an inorganic zinc-primed steel component has suffered topcoat damage, it should be repaired with the original topcoat system. If the inorganic zinc primer itself is damaged, it should be repaired with a zinc-rich epoxy primer (e.g., MIL-P-24441, Formula 159) and then given an epoxy intermediate coat and an aliphatic polyurethane finish coat. Sometimes, corrosion of the galvanizing has been so severe that underlying steel is exposed. Such areas should be treated as described below for steel tower components.

5.7.2.3 Steel Tower Components (With No Zinc Coating) With Damaged Organic Coating. Steel components of towers that have never received a zinc coating and currently have damaged coatings should be hand (SSPC SP 2) or power tool (SSPC SP 3 or 11) cleaned to remove rust and loose paint. The preferred method of surface preparation is SSPC SP 11. This method not only removes all visible rust but also produces a roughened surface so that it is considered comparable to SSPC SP 6. Powered needle guns and grinders with flexible wheels and disks can produce the SSPC SP 11 surface. The steel should be cleaned and primed the same day, before flash rusting occurs.

If the old paint is oil, alkyd, latex, vinyl or solvent soluble, apply two coats of alkyd primer to the exposed steel to a total of 3 mils dry film thickness and overlay it 1 inch onto the surrounding tight coating. A primer with raw linseed oil (e.g., SSPC PAINT 25) will penetrate the surface better but dry relatively slowly. A totally alkyd primer (e.g., TT-P-645) will dry faster but may not penetrate the surface as well. After priming, apply two alkyd or silicone alkyd (e.g., MIL-E-24635, Enamel, Silicone Alkyd Copolymer (Metric)) finish coats at the same thickness. Two additional coats of primer followed by one or more latex finish coats can be used instead of the alkyd

finish coats, if the alkyd finish coats are unavailable because of environmental regulations. If the repaired area matches the intact paint, it will not be necessary to topcoat the undamaged areas.

If the existing finish coat is urethane, epoxy, or solvent insoluble, apply two coats of epoxy primer and one coat of aliphatic urethane finish. Again, if the match is good, topcoating of undamaged areas will be unnecessary.

5.7.3 Galvanized Steel Guy Lines for Towers. Tall towers are usually supported with galvanized steel stranded guy lines. These are frequently coated with a commercial preservative grease, as they are installed. These greases or pastes are most frequently petroleum or drying oil products. Care should be taken not to contaminate the guys before they are coated. Some equipment is available for applying the grease after installation of guys. Equipment for remote application is described in NCEL Techdata Sheet 76-04. Galvanized steel anchor support systems securing guys in place can also be protected by preservative greases.

5.8 Waterfront Structures. The coating of steel waterfront structures is described in NFGS-09967, Coating of Steel Waterfront Structures. Coating systems are best applied in a shop under controlled conditions. Systems which have provided good protection have included abrasively blasting to a near-white condition (SSPC SP 10) and application of one of the following coating systems:

a) Epoxy polyamide system - e.g., three coats of MIL-P-24441 starting with Formula 150 primer (each 3 mils dry film thickness).

b) Coal tar epoxy-polyamide System - e.g., two coats of SSPC PAINT 16 (each 8 mils dry film thickness).

Repainting or spot repairing coatings in or below tidal areas is a real problem. Quick-drying lacquers that can dry between tidal changes are not permitted at many locations because of VOC restrictions. One approach to resolve the problem is to use a cofferdam to apply suitable materials such as MIL-P-24441 or SSPC PAINT 16 that can cure underwater. Another approach is to use viscous splash-zone compounds that are applied manually or thinner epoxy materials that can be applied underwater by brush, roller, or pads.

5.9 Hydraulic Structures and Appurtenant Works. Coating of hydraulic structures and associated pipe lines and equipment is described in CWGS 09940, Painting: Hydraulic Structures and

Appurtenant Works. Cathodic protection of gates is described in CWGS 16643. Coatings for use on locks and dams must have good abrasion resistance in addition to providing good corrosion control. Vinyl systems have worked well for many years.

5.10 Factory Finished Metal Siding. Factory-finishing of steel, galvanized steel, or aluminum siding is usually accomplished by specialized procedures (e.g., coil coating) using commercial products. It is best to consult the manufacturer of the siding for recommended coating repair methods.

5.11 Chain Link Fences. Chain link fences are usually made of galvanized steel (refer to NFGS-02821, Chain Link Fences and Gates, or CECS 02831, Fence, Chain Link). Occasionally, they are made of vinyl-clad steel or aluminum-coated steel. As the protective metals or vinyl corrode or erode away, they may need coating to further protect them and/or to restore an attractive finish. The fencing must be washed with a detergent solution to remove loose contaminants before coating with a long-nap roller or electrostatic spray equipment. The coating system should be composed of two coats of acrylic latex (e.g., TT-E-2784) or one coat each of epoxy-polyamide (e.g., MIL-P-24441, Formula 150) and aliphatic polyurethane (MIL-C-85285).

5.12 Hot Steel Surfaces. Mufflers, stacks, and other hot steel surfaces are not protected by conventional coatings, because they are quickly burned away. Even thin fused aluminum coatings such as TT-P-28 provide only limited protection, provided that they are fused properly. (These coatings must be exposed to at least 400 degrees F for a short time for fusion to take place.) Such steel surfaces are better protected by thermally sprayed zinc (withstand up to 700 degrees F) or aluminum (withstand up to 1600 degrees F or higher when sealed) after blasting to a white metal finish (SSPC SP 5). Thermal spraying of aluminum is described in DOD-STD-2138(SH), Metal Spray Coatings for Corrosion Protection Aboard Naval Surface Ships (Metric).

5.13 Concrete Fuel Tanks. The DOD has many concrete fuel tanks (mostly underground) that were built during World War II. They have been lined with the cloth-reinforced latex coating system described in NFGS-09980, Interior Linings for Concrete Storage Tanks (for Petroleum Fuels), epoxy systems, and other systems. Cloth-latex reinforced systems have been found to work as well as any. However, they may not work well over concrete that is contaminated with oil. Oil contamination is difficult to remove and latex coatings do not bond well on this surface.

5.14 Concrete Swimming Pools. Concrete swimming pools require periodic painting to keep them watertight and attractive. Even fiberglass-reinforced plastic pools may require refinishing to restore them to an acceptable appearance should they fade or chalk significantly. Chlorinated rubber coatings (e.g., TT-P-95, Type I) have been used effectively for many years for lining pools. Although these coatings are high in VOCs (solvent content), they have received a temporary exemption for coating concrete pools in most locations with VOC limitations. Epoxy coatings perform well on interior concrete pools, but some of them chalk to such an extent, even underwater, that the water is clouded in exterior pools. Waterborne pool coatings have not proven to be durable.

a) Exterior pools are usually coated in the spring before the swimming season when the temperature is between 50 and 80 degrees F. New concrete pools should be allowed to cure at least 2 months before painting. The first step in preparing concrete pools for painting is to make necessary repairs:

- (1) Remove loose concrete
- (2) Repair small cracks and holes
- (3) Repair large cracks and spalls

b) Repair small cracks and holes with a non-shrinking patching compound. Cracks greater than 1/2 inch and spalls should be repaired with cementitious material (e.g., a mix containing two parts of clean, hard, sharp sand to one part of Portland cement). The repair area should be thoroughly wetted and enough water added to the mix to make a heavy paste.

c) After repairs have been made, any efflorescence or laitance on the surface of the concrete should be removed by brushing with a dry bristle brush, treating with 5 to 10 percent muriatic (hydrochloric) acid, and rinsing with clear water. Mildew should be removed as described in par. 5.18, and body oils should be removed with trisodium phosphate or other detergent. Any deteriorated old paint should be removed by wire brushing or careful light abrasive blasting.

d) Application of chlorinated rubber paint should occur in two coats to completely dry surfaces. The first coat is best applied by brush to fill the concrete pores, but the second can be applied by roller or spray. A minimum of 24 hours should occur between coats to ensure complete evaporation of solvent from the first coat. Painting of individual walls should continue until completion to avoid lap marks where the work was interrupted. Because the coating dries very fast, it may be

necessary to paint walls in the shade or at night during hot weather. A minimum of 7 days should elapse between painting of the pool and filling it with water.

5.15 Concrete Catchment Basins. Concrete catchments are used by some activities with limited water supplies to collect rainwater for both industrial and domestic use. The catchments are usually sealed with a coating material and the joints caulked with a flexible material to minimize water losses. Both of these materials must be approved for potable water use, if the collected water is to be for domestic use.

Thick cementitious coatings have been used satisfactorily for many years to seal catchments. The Government of Bermuda requires catchments to be free from unsightly mildew. This is often a limiting factor there for cementitious coatings, since their textured surfaces become mildew-defaced much sooner than smooth coatings. Treatment with hypochlorite solution, as described in par. 4.17, can restore mildew-defaced catchments to a cosmetically pleasing appearance.

Acrylic latex elastomeric coatings have been found to perform very well on concrete catchments. They provide excellent resistance to water migration, weathering, and mildew. A primer is usually required for good adhesion.

5.16 Chemically Resistant Finishes for Concrete Floors. Chemically resistant urethane coatings (resistant to fuels and hydraulic fluids) are sometimes used to impart improved lighting to work areas such as under aircraft. Because of the smoothness of these coatings, skid resistance is usually imparted by sprinkling granules into the wet coating. Such a system is described in A-A-50542, Coating System: Reflective, Slip-Resistant, Chemical-Resistant Urethane for Maintenance Facility Floors. A commitment to maintenance is essential when deciding to coat a concrete floor. Cleaning and repair will be needed on a frequent and regular basis to maintain the reflectivity and appearance of the floors.

Chemical resistance may also be required for floors where chemicals or hazardous waste is stored to permit rapid neutralization and removal without contaminating other stored materials. The coating should be chosen to be resistant to the stored materials, so that it is best to consult the activity industrial hygienist. Chemical-curing polyurethane or epoxy systems as described for fuel tank interiors in par. 4.2.1 are good candidates.

5.17 Slip-Resistant Floors. A slip-resistant coating is often applied as a finish for other coating systems to prevent accidental slipping. The resistance is imparted by sprinkling granules in the wet coating. MIL-E-24635 is used for alkyd systems and MIL-C-24667, Coating System, Non-Skid, for Roll or Spray Application (Metric) for epoxy systems. The MIL-C-24667 may also be used on alkyd systems where MIL-E-24635 may exceed local VOC limitations.

5.18 Fouling-Resistant Coatings. Antifouling coatings are often used over a coating system that imparts corrosion resistance to ships or other structures to be immersed in sea water. A toxic material, usually copper ion, is slowly leached into the sea water to deter attachment and growth of biological fouling organisms. MIL-P-24647, Paint System, Anticorrosive and Antifouling, Ship Hull is normally recommended for this purpose. It has a large list of qualified products. Such a copper-containing product should not be used on an aluminum boat, because direct contact of a copper product with aluminum will result in accelerated galvanic corrosion. Commercial organo-tin antifouling paints are permitted on aluminum boats. There are restrictions on their use on large Navy ships.

5.19 Mildew-Resistant Coatings. Mildew growth on painted or unpainted surfaces of buildings can cause unsightly defacements, especially at tropical and subtropical locations. This occurs on interior and exterior surfaces of steel, concrete/masonry, asbestos-cement, or wood. Mildew can also damage delicate communications and utilities equipment. In addition serious bronchial problems may be associated with living in quarters contaminated with mildew-covered surfaces. The different species of microorganisms usually present in mildew growths include molds, yeast, algae, and bacteria. These same organisms are found on mildew-defaced surfaces throughout the world. The darkly pigmented organisms are most conspicuous and contribute to most of the defacement.

5.19.1 Factors Affecting Mildew Growth. Factors that affect likelihood of mildew growth include:

a) Weather - Higher temperatures and dampness promote growth, and light inhibits it.

b) Building Design - Rough surfaces assist pickup of spores and dirt, roof overhang keeps wall surfaces damp longer, poor drainage, and porous substrates such as wood retain moisture; alkalinity on concrete surfaces inhibits growth; and air exchange, temperature, and humidity may control growth.

c) Paint - Textured, tacky, and peeling paint pick up and retain spores and dirt; incompletely removed mildew may rapidly reinfect new paint; drying oils in paints may be used as nutrients. Mildewcides in paints can control the growth of mildew organisms.

5.19.2 Use of Mildewcides in Paints. Mercury-containing mildewcide additives were used very successfully in paints for many years to control mildew growth. Only a small amount of the mercury compound leaching from the paint was necessary to kill microorganisms. Unfortunately, it also contaminated the environment with toxic material. Thus, mercury-containing mildewcides are no longer used in paints. EPA has approved alternative nonmercurial compounds for use as paint mildewcides. Some of these products, however, have not proven to be effective in retarding mildew growth.

5.19.3 Removal of Mildew. Mildew must be killed before repainting a mildewed surface to obtain control of the mildew. If spores are just painted over, the mildew will quickly grow and become unsightly. When a surface is to be cleaned for repainting, scrub with a solution of 2/3 cup of trisodium phosphate, 1 liquid ounce of household detergent, 1 quart of 5-1/4 percent sodium hypochlorite (available as household bleach), and 3 quarts of warm water. Use rubber gloves with this caustic solution and rinse it from the surface with water after scrubbing. It will degrade alkyd and other oil-based coatings, but this will be no problem, if the surface is to be repainted. An alternate procedure is to remove all the visible mildew by waterblasting at about 700 pounds per square inch (psi) and kill the rest by rinsing with a solution of 1 quart of 5-1/4 percent sodium hypochlorite and 3 quarts of warm water.

If a painted surface is to be merely cleaned without repainting, apply the scrubbing solution without the trisodium phosphate to avoid damage to the paint. Apply it first to a small test area to see if the hypochlorite bleaches the paint. If it does, merely clean with detergent and water.

Mildew on field structures can be distinguished from dirt with bleach. Common household hypochlorite bleach will cause mildew, but not dirt, to whiten.

5.20 Pavement Markings. Asphalt and concrete airfield and road pavements on military bases are generally striped with paint to show center and sidelines, as well as other information. These markings are described in NFGS-02761, Pavement Markings, and CECS 02580, Joint Sealing in Concrete Pavements for Roads and Airfields.

5.20.1 Painted Markings. Military airfields and roadways have been successfully marked with alkyd paints for many years. Chlorinated rubber was added to the alkyd resin to obtain faster drying times. More recently, environmental restrictions on total paint solvent have in many geographical locations eliminated or restricted the use of these marking paints. Thus, most pavements at military activities are marked with latex paints today.

Yellow marking paints constitute a possible safety and environmental problem. Historically, a lead chromate pigment has been used to impart this color because it is relatively light, stable, and inexpensive. Lead pigments were recently restricted from use in consumer paints because of concerns that dust from weathering paints might be ingested by children. More recently, concern has been expressed about the hazards of chromate pigments. New regulations impose restrictions on the removal of old paints containing lead and chromium because of possible adverse health effects the dust produced may have on workers or residents in the area. Also, residues of lead and chromate-containing paints may constitute hazardous waste which must be specially handled, stored, and disposed of properly. This has led to the virtual elimination of lead and chromium constituents in paint. The State of California Department of Transportation and other state highway departments have had good success with yellow striping paints with organic pigments that do not constitute a health or environmental hazard.

5.20.1.1 Specifications for Marking Paints. Currently, there are five federal specifications for marking paints. Specification TT-P-85, Paint, Traffic and Airfield Marking, Solvent Base is for a solvent-based traffic and airfield marking paint, available in white and yellow. Alkyd formulations have generally been used, even though no specific generic type is required. Paints of this specification are high in VOCs and so cannot be used in areas where such paints are prohibited (urban areas with air pollution). Water-based marking paints conforming to TT-P-1952 are used in such areas, as well as in areas without such restrictions.

a) Specification TT-P-87, Paint: Traffic, Premixed, Reflectorized is for a premixed, solvent-based, reflectorized traffic paint, available in white and yellow. Low index of refraction (road) beads are premixed with the paint before packaging. The embedded beads are reported to be exposed as vehicular traffic erodes away the marking. They are not suitable for use on airfields because of the low index of refraction beads.

b) Specification TT-P-110, Paint, Traffic, Black (Nonreflectorized) is for a solvent-based, black, nonreflectorized traffic paint generally made with alkyd binders. It is used mostly to outline white or yellow markings to make them stand out or to obliterate old markings on asphalt pavements. Such paints are not VOC-conforming, and there is no specification for a black water-based marking paint.

c) Specification TT-P-115, Paint, Traffic (Highway, White and Yellow) is for a solvent-based traffic paint, available in white and yellow. Once, this specification called for alkyd formulations for conventional-dry paints and chlorinated rubber-alkyd formulations for fast dry types. This is no longer the case. Because of VOC and safety concerns described below, this specification is no longer recommended.

d) Specification TT-P-1952, Paint, Traffic and Airfield Marking, Water Emulsion Base is for a water-based traffic and marking paint, available in white or yellow. Currently, there are no environmental restrictions on its use. Acrylic and polyvinyl acetate resins are most frequently used in paints conforming to this specification.

e) Specifications TT-P-85, TT-P-115, and TT-P-1952 are formulated to permit glass beads to be dropped into the wet paint immediately after spray application to provide night retroreflectivity. Coarse beads are evenly dropped into wet TT-P-87 paint to impart immediate retroreflectivity.

5.20.1.2 Specification for Reflective Glass Beads.

Specification TT-B-1325, Beads (Glass Spheres) Retro-Reflective is for beads (glass spheres) to impart retroreflectivity to painted markings. Lights from a plane or car are reflected back to the eyes of the pilot or driver. Type I (low index of refraction) is intended for use on roads. It is available in Gradations A (coarse-drop on), B (fine-premix), and C (fine-drop on). Type II (medium index of refraction), Gradation A (coarse-drop on) is not commercially available today. Type III (high index of refraction) is intended for use on airfield pavements.

5.20.1.3 Application of Painted Markings. Although the five above marking paint specifications are different from each other, each is applied at about the same thickness. Some achieve this by specifying a 15-mil wet film thickness, which results in a dry film thickness of half that, since they contain 50 percent solids by volume. Others specify a spreading rate of 100 to 110 square feet per gallon. The water-based paint of specification TT-P-1952 must be applied at temperatures at or above 45 degrees F. The other products, which are solvent based, can be applied at even lower temperatures. Surfaces to be marked must be well

prepared for painting, free from dirt, oil and grease, other surface contaminants, and from loose, peeling, or poorly bonded paint. If removing lead-containing traffic marking paints (e.g., some yellows), environmental and worker safety regulations apply. Refer to Section 3 for more information.

When airfield markings are to be reflectorized, TT-B-1325, Type III beads are applied immediately after spray application at the rate of 10 pounds per gallon of paint. Roadways are reflectorized with TT-B-1325, Type I beads applied at the rate of 6 pounds per gallon of paint. In both cases, any more beads would have insufficient paint available to be retained. Type I beads have a much lower specific gravity than Type III beads.

For marking pavements, striping machines (specially equipped trucks) are used. They have tanks that hold large quantities of paints and beads. Striping machines for airfields have arrays of multiple spray gun and bead dispensers and necessary power and support equipment to apply long painted lines 3 feet wide. The spray guns and dispensers are adjusted to give a uniform paint thickness and bead density across the entire width of the marking.

5.20.1.4 Inspection of Marking Operation. Inspection procedures for monitoring contracts for striping airfields are distinctly different from other painting inspections. They are presented below in the general order in which they might be used.

a) Procedure 1: General Appearance of Paint and Beads. Visual examination of paint in the can and beads is done to check for any apparent deficiencies. Products with apparent discrepancies should receive a laboratory analysis or be replaced. Product labels should also be checked to verify that they are the ones specified. Paints must be homogeneous in color and consistency. They should be stirred to assure that they are free of settling, skinning, caking, strings, and foreign bodies and have a viscosity suitable for spraying. Method 3011.2 of FED-STD-141, Paint, Varnish, Lacquer, and Related Materials: Methods of Inspection, Sampling, and Testing describes precisely how to check for "Condition in Container." Beads must be clean, dry, free flowing, and free of air intrusions. They should be only a few extremely large, small, or out-of-round beads. Type I beads have a pure white color; Type III beads have a brownish cast.

b) Procedure 2: Sampling of Paint and Beads. Paints and beads may be sampled for immediate analysis or merely taken for later use, if problems arise later. In any event, it is necessary to procure samples that authentically represent the material to be applied to the pavements. Incompletely cleaned

paint tanks may contain significant amounts of water or another batch of paint. Incompletely emptied bead tanks may contain beads of another type. Paint and bead samples should be taken from drums or sacks to determine whether the supplier's material meets all requirements. Excessive mixing of latex marking paints should be avoided prior to testing, because their wetting agents cause them to froth when heavily mixed, and this may result in testing errors. Excessive stirring of beads may cause smaller or lighter density beads to migrate to the bottom of the container. Full sampling and inspection procedures are presented in Method 1031 of FED-STD-141.

c) Procedure 3: Percent by Weight of Paint Total Solids and Pigment. These tests are run to provide information on the paint composition and a quick check for its conformance to specification. These tests are done with the same sample using ASTM D 2369, Volatile Content of Coatings and ASTM D 3723, Pigment Content of Water-Emulsion Paints by Low-Temperature Ashing. By using the relationships percent total solids equals percent binder plus percent pigment and percent total solids equals 100 minus percent volatile, results of the two referenced test procedures can provide data on any of these components (e.g., solvent, binder, pigment, and total solids). Testing should be done in triplicate to indicate repeatability. The percent by weight of total solids (or the percent volatile) of latex paints is determined by measuring the loss of weight after the solvent has been evaporated off by heating the sample at 110 degrees C for 2 hours. The percent by weight of pigment is determined by measuring the weight after further heating of the samples for 1 hour at 450 degrees C to burn up the organic binder.

d) Procedure 4: Specific Gravity of Paints. In ASTM D 1475, Density of Paint, Varnish, Lacquer, and Related Products, a metal cup of precisely selected volume is weighed first empty and then filled with paint until it is forced out a hole in the cap. The additional weight is a direct measure of specific gravity.

e) Procedure 5: Paint Binder Identification. ASTM D 2621, Infrared Identification of Vehicle Solids From Solvent-Reducible Paints can readily identify the generic type of marking paints as 100 percent acrylic. Only a small sample of the wet or dry (e.g., 1 square inch) paint is necessary.

f) Procedure 6: Specific Gravity of Beads. The specific gravity of beads can easily be determined by field personnel with access to an inexpensive balance following the procedure of par. 4.3.5 of TT-B-1325. A sample of dried and weighed beads (about 60 g) is placed in a glass graduated

cylinder containing 50 ml of xylene, and the resultant increase in volume is noted. The specific gravity is then determined by simple division:

$$\text{Specific Gravity} = \frac{\text{Weight of Sample (about 60 g)}}{\text{New Total Volume} - 50 \text{ ml}}$$

g) Procedure 7: Index of Refraction of Beads. The index of refraction of glass beads can be determined by immersing them in standard liquids with different refractive indexes and observing whether the beads blend into the liquid. Blending occurs when the liquid has a higher refractive index than do the beads. Indentations of a ceramic spot plate can be conveniently used for holding the beads and liquid. Run this test when substitution of TT-B-1325, Type I beads for Type III beads is suspected. This is normally suspected from a low specific gravity value in Procedure 6.

h) Procedure 8: Preparation of Drawdowns for Determining Retroreflectivity. Drawdown specimens are prepared using a metal drawdown bar as described in ASTM D 823, Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels. A paint film of 16 mil or other wet film thickness is screeded onto a the white surface of a black and white chart by drawing it across the paper in front of a bar of proper clearance. Immediately after this action, beads are manually sprinkled into the wet paint. After drying, the drawdowns are measured with a retroreflectometer. The instrument can be held in either direction, since the application procedure does not have a directional effect.

i) Procedure 9: Surface Preparation. Inspection of pavement surfaces prepared for marking with paint is basically determining whether the surface is clean enough and sound enough to permit tight bonding of the paint. Cleaning of concrete for painting is described in ASTM D 4258, Surface Cleaning Concrete for Coating. Of the several procedures described for cleaning, high-pressure water blasting with truck-mounted equipment is almost always the procedure selected for rubber and paint removal. Washing with an aqueous detergent solution may be necessary to remove oil, grease, and tightly bonded dirt. The extent of paint removal should be verified visually. If only loose paint is to be removed prior to restriping, the remaining paint can be checked with a dull putty knife to determine whether only sound paint remains. After a build-up of five coats (a dry film thickness of 37 mils), the film becomes rather inflexible and subject to cracking, and the skid resistance significantly reduced. Thus, complete removal of the old marking is recommended at this time. From a standpoint of eliminating the

hazard of hydroplaning on wet pavements, it is not necessary to remove 100 percent of the rubber build-up on runways. From a standpoint of surface preparation for marking pavements, however, virtually complete removal is more important. While one contractor was observed to be able to achieve 100 percent removal with his equipment without apparent difficulty, others could not do so using their equipment without considerable expense and damage to the pavement. It may be necessary to settle for less than 100 percent (e.g., 90 percent) removal to permit competitive bidding until the technology for 100 percent removal becomes widely available.

j) Procedure 10: Check of Application Equipment. Paint spray guns and bead dispensers should be checked to determine that they are properly metered and functioning. Metering can be checked individually, directing paint or beads into a container for collection. To check for proper application and overlap of paint patterns (fans) from spray guns and beads from dispensers, apply a small area of paint and beads onto roofing paper or other disposable material taped to the pavement.

k) Procedure 11: Monitoring of Marking Operation. The prevailing conditions should be recorded before starting to apply markings. This includes temperature; dew point, if solvent-based paints are used; rain or prospects of rain; wind; type of equipment used; and any unusual conditions. Wind can cause overspray of the paint onto the beads to significantly reduce their retroreflectivity. General weather forecasts are normally available from operations offices. A variety of thermometers are available for measuring temperature, and inexpensive sling psychrometers are usually used for measuring humidity and dew point. Photography can be an excellent method of recording conditions. Solvent-based paints should not be applied unless the temperature is at least 5 degrees above the dew point and above 40 degrees F and rising or if rain is expected within an hour. In addition, water-based paints should not be applied when the temperature is below 45 degrees F. Paint should be applied when the wind is over 5 mph, unless it can be shown that the marking can be applied properly with the existing equipment. None should ever be applied when the wind is over 10 mph. The marking should be continuous (no underlap at all or overlap of adjacent spray patterns greater than 1/4 inch) with a constant color that matches the standard or submittal, and free from wind-blown dust and dirt. The edges of the marking should be relatively sharp and straight. The marking should be touched with a finger to determine if complete drying has occurred within the time specified for the paint. Dried paints should be probed with a dull putty knife to determine that they are well bonded.

The beads should be relatively uniformly spread across and along the marking. At least 25 beads should be found in every square inch, to obtain desired level of retroreflectivity.

l) Procedure 12: Wet Film Thickness of Stripes. Wet film thickness can easily be determined using the procedure of ASTM D 1212, Measurement of Wet Film Thickness of Organic Coatings. A metal or plastic gage with calibrated notches cut into each of four faces is used for this purpose. The face calibrated for the desired wet film thickness is pushed squarely into a freshly painted surface and withdrawn. The wet film thickness of the marking is equal to the depth of the deepest notch with paint on it. A sample of wet paint without beads must be applied to a rigid test panel by the striping machine in a test run. It is best made on roofing paper or other disposable material to avoid contamination of a pavement. Obviously, a series of plates secured across the width of 3-foot-wide stripes must be used for each test run to determine localized application rates.

m) Procedure 13: Dry Film Thickness of Paint Film. The dry film thickness of a paint film can be estimated from the wet film thickness by the relationship:

$$\text{Dry Film Thickness} = \frac{\text{Wet Film Thickness} \times \text{Percent Solids by Volume}}{100}$$

Dry film thickness of paint applications can be determined quite precisely using a magnetic gage as described in ASTM D 1186, Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base. A ferrous plate is coated with marking paint by the striping machine but no beads are applied. The paint is allowed to cure completely before its dry film thickness is determined by magnetic gage. Again, a series of test plates must be used on runway stripes to determine thicknesses across the stripe. Tin-plated steel panels used in paint elongation testing by ASTM D 522, Mandrel Bend Test of Attached Organic Coatings are convenient to use for this purpose.

n) Procedure 14: Spreading Rate of Paint. After the wet film thickness of a marking has been made, as described above, the spreading rate of the paint can be estimated by the relationship:

$$\text{Spreading Rate of Wet Paint in Square Feet/Gallon} = \frac{1600}{\text{Wet Film Thickness in Mils}}$$

From a practical standpoint, it is easier to specify a paint's wet film thickness than its spreading rate.

o) Procedure 15: Retroreflectivity of Pavement Markings. Measure the retroreflectivity of airfield markings for conformance to contract specification using a Mirolux 12 or Erickson instrument. In addition to following the instrument manufacturer's instructions, these precautions should be taken:

- (1) Keep an extra fully charged battery available.
- (2) Frequently check instrument calibration.
- (3) Systematically make five measurements across stripes at each test site rather than in the direction of or opposite to application to avoid directional effects.
- (4) Select numerous random test areas to obtain representative measurements.

Use of a portable computer while making retroreflectivity measurements can greatly accelerate the procedure. This is especially important on busy runways with limited access time. Typically, a two-person team has a driver who stays in the vehicle keeping radio contact with the tower, recording data into the computer and driving to the different test locations. The other team member measures retroreflectivities and calls out the data to the driver.

5.20.2 Alternative Markings. A variety of tapes, buttons, and reflectorized squares have been successfully used to mark roadways. Tapes have been used at military installations to provide temporary markings. They may be damaged by turning wheels of heavy trucks. None of these alternative marking materials are recommended for use on runways because of concern for foreign object damage.

5.21 Wooden Floors. The surface preparation (scraping and sanding) and coating of wooden floors is described in NFGS-09900 and CEGS 09900. These finishes include stains and alkyd and moisture-curing coating systems. For hardwood floors for gymnasium-type use, a selection can be made from the MFMA Heavy Duty and Gymnasium Finishes for Maple, Beech and Birch Finishes. The products addressed include sealers, heavy-duty finishes, gymnasium-type finishes, moisture-cured urethane finishes, and water-based finishes. The individual suppliers should be contacted for special applications such as handball and racquetball.

Section 6: SURFACE PREPARATION

6.1 Introduction. Surface preparation is the single most important factor in determining coating durability. Available data and experience indicate that in most situations, money spent for a clean, well-prepared surface reduces life-cycle costs. A proper surface preparation:

a) Removes surface contaminants (e.g., salts and chalk) and deteriorated substrate surface layers (e.g., rust and sunlight-degraded wood) which hinder coating adhesion and;

b) Produces a surface profile (texture) that promotes tight adhesion of the primer to the substrate.

6.1.1 Selection Factors. Factors which should be considered in selecting the general type and degree of surface preparation are:

a) Type of the substrate

b) Condition of the surface to be painted

c) Type of exposure

d) Desired life of the structure, as some procedures are much more expensive than others

e) Coating to be applied

f) Environmental, time, and economical constraints

6.1.2 Specification Procedure. A performance-based requirement for surface preparation, rather than a prescriptive requirement, is recommended for contract use. That is, it is usually better to describe the characteristics of the cleaned surface (e.g., profile and degree of chalk removal) than to specify the specific materials and procedures to be used. Often the general type of surface preparation (washing, blasting, etc.) is specified, because of job or other constraints, along with requirements for characteristics of the cleaned surface. In this way, the specifier allows the contractor to select the specific equipment, materials and procedures to get the job done and avoids putting contradictory requirements into the job specification.

6.1.3 Section Organization. This section is organized into: discussions of repair procedures usually done in conjunction with a painting contract and prior to painting; specific

recommendations for surface preparation procedures and standards for specific substrates; recommendations for coating removal; and general background information on surface preparation methods. Surface preparation methods are summarized in Table 6.

6.2 Repair of Surfaces. All surfaces should be in good condition before recoating. If repairs are not made prior to painting, premature failure of the new paint is likely. Rotten wood, broken siding, and other deteriorated substrates must be replaced or repaired prior to maintenance painting. Water-associated problems, such as deteriorated roofs and nonfunctioning drainage systems, must be repaired prior to coating. Interior moist spaces, such as bathrooms and showers must be properly vented. Cracks, holes, and other defects should also be repaired.

Areas in need of repair can sometimes be identified by their association with localized paint failures. For example, localized peeling paint confined to a wall external to a bathroom may be due to inadequate venting of the bathroom. Refer to Section 11 for more examples.

6.2.1 Joints, Cracks, Holes, or Other Surface Defects. Caulks and sealants are used to fill joints and cracks in wood, metal and, in some cases, in concrete and masonry. Putty is used to fill holes in wood. Glazing is used to cushion glass in window sashes. Specially formulated Portland cement materials are available for use in cracks and over spalled areas in concrete. Some of these contain organic polymers to improve adhesion and flexibility. Other materials are available to repair large areas of interior plaster (patching plaster), to repair cracks and small holes in wallboard (spackle), to fill joints between wallboards (joint cement), and to repair mortar. Before application of these repair materials, surfaces should be clean, dry, free of loose material, and primed according to the written instructions of the material manufacturer.

Caulking and sealant compounds are resin based viscous materials. These compounds tend to dry on the surface but stay soft and tacky underneath. Sealants have application properties similar to caulking materials but tend to be more flexible and have greater extendibility than caulks. Sealants are often considered to be more durable than caulks and may also be more expensive. Commonly available generic types of caulks and sealants include oil-based, butyl rubber, acrylic latex, silicone, polysulfide, and polyurethane. The oil-based and butyl-rubber types are continually oxidized by exposure to sunlight and become brittle on aging. Thus, their service life is limited. Acrylic-latex and silicone caulks tend to be more

stable and have longer service lives. Applications are usually made with a caulking gun. However, some of these materials may also be available as putties or in preformed extruded beads that can be pressed in place.

Putty and glazing compounds are supplied in bulk and applied with a putty knife. Putties are not flexible and thus should not be used for joints and crevices. They dry to form a harder surface than caulking compounds. Glazing compounds set firmly, but not hard, and thus retain some flexibility. Rigid paints, such as oil/alkyds, will crack when used over flexible caulking, sealing, and glazing compounds and should not be used. Acrylic-latex paints, such as TT-P-19, Paint, Latex (Acrylic Emulsion, Exterior Wood and Masonry) are a better choice.

6.2.2 Cementitious Surfaces. Epoxy resin systems for concrete repair are described in MIL-E-29245, Epoxy Resin Systems for Concrete Repair. This document describes epoxy repair materials for two types of application. They are: bonding hardened concrete to hardened concrete, and using as a binder in mortars and concrete. These types are further divided into classes based on working temperature. Thus, an appropriate material can be specified.

6.3 Recommendations by Substrate. Each different type of construction material may have a preferred surface preparation method. For substrates, grease and oil are usually removed by solvent or steam cleaning and mildew is killed and removed with a hypochlorite (bleach) solution, as described in par. 5.17.4.

6.3.1 Wood. Bare wood should not be exposed to direct sunlight for more than 2 weeks before priming. Sunlight causes photodegradation of surface wood-cell walls. This results in a cohesively weak layer on the wood surface which, when painted, may fail. If exposed, this layer should be removed prior to painting by sanding. Failure of paint caused by a degraded-wood surface is suspected when wood fibers are detected on the backside of peeling paint chips.

When the existing paint is intact, the surface should be cleaned with water, detergent, and bleach as needed to remove surface contaminants, such as soil, chalk, and mildew. When the existing paint is peeling and when leaded paint is not present, loose paint can be removed by hand scraping. Paint edges should be feathered by sanding. Power sanding may damage the wood if improperly done. Water and abrasive blasting are not recommended for wood, because these techniques can damage the wood. When leaded paint is present, special precautions, such as wet scraping, should be taken. Refer to Section 3.

Table 6
 Commonly Used Methods of Surface Preparation for Coatings
 (IMPORTANT NOTE: Methods may require modification or special control when leaded paint is present.)

Cleaning Method	Equipment	Comments
Organic solvent	Solvent such as mineral spirits, sprayers, rags, etc.	Removes oil and grease not readily removed by other methods; precautions must be taken to avoid fires and environmental contamination; local VOC regulations may restrict use.
Detergent/power washing	Pumps, chemicals, sprayers, brushes	At pressures not exceeding 2000 psi, removes soil, chalk, mildew, grease, and oil, depending upon composition; good for smoke, stain, chalk and dirt removal.
Acid	Chemicals, sprayers, and brushes	Removes residual efflorescence and laitance from concrete after dry brushing. Thoroughly rinse afterwards.
Chemical paint strippers	Chemicals, sprayers, scrapers, washing equipment	Removes coatings from most substrates, but slow, messy, and expensive; may degrade surface of wood substrates.
Steam	Heating system pump, lines, and nozzles	Removes heavy oil, grease, and chalk; usually used prior to other methods.
Water blasting	High pressure water pumps, lines, and nozzles	At pressures of 2000 psi and above, removes loose paint from steel, concrete and wood; can damage wood or masonry unless care is taken; inhibitor generally added to water to prevent flash rusting of steel.
Hand tool	Wire brushes, chipping hammers, and scrapers	Removes only loosely adhering contaminants; used mostly for spot repair; slow and not thorough.
Power tool	Wire brushes, grinders, sanders, needle guns, rotary peelers, etc.	Faster and more thorough than hand tools because tightly adhering contaminants can be removed; some tools give a near-white condition on steel but not an angular profile; slower than abrasive blasting; some tools are fitted with vacuum collection devices.
Heat	Electric heat guns	Can be used to soften coatings on wood, masonry, or steel; softened coatings are scraped away, torches SHOULD NOT be used.
Abrasive blasting	Sand, metal shot, and metal or synthetic grit propelled onto metal by pressurized air, with or without water, or centrifugal force	Typically used on metal and, with care on masonry; can use recyclable abrasives; special precautions are needed when removing lead containing paint. Water may be added to control dust and its addition may require use of inhibitors. Vacuum blasting reduces dust but is slower than open. Centrifugal blasting is a closed cycle system in which abrasive is thrown by a spinning vaned wheel.

Paint should be removed from wood when failure is by cross-grain cracking (that is, cracking perpendicular to the wood grain). This failure occurs when the total paint thickness is too thick and/or the paint is too inflexible. Painting over this condition almost always results in early failure of the maintenance paint layer. Paint removal from wood is difficult and may not always be feasible. Chemical strippers can be used, but the alkaline types may damage (chemically degrade) the surface of the wood and cause a future peeling-paint failure. Failure caused by a stripper-degraded wood surface is more likely for exterior exposures than for interior exposures. This is because the greater expansion and contraction of wood in exterior exposures requires that the surface wood have a greater mechanical strength.

6.3.2 Concrete/Masonry. Bare concrete and masonry surfaces, as well as painted surfaces, are usually best cleaned with water and detergent. Use low-pressure washing (less than 2000 psi) or steam cleaning (ASTM D 4258) to remove loose surface contaminants from surfaces. Use high-pressure water blasting (greater than 2000 psi and usually about 5000 psi) (ASTM D 4259, Abrading Concrete) to remove loose old coatings or other more tightly held contaminants or chalk. If existing paints are leaded, special worker safety and environmental controls will be needed.

Abrasive blasting (ASTM D 4259 and D 4261, Surface Cleaning Concrete Unit Masonry for Coating) or acid etching of bare surfaces (ASTM D 4260, Acid Etching Concrete) may also be used to obtain a surface profile as well as clean surfaces for coating. Care must be taken to avoid damaging surfaces with high-pressure water or abrasives. Grease and oil must be removed with detergents or steam before abrasive blasting. Any efflorescence present should first be removed by dry wire brushing or acid washing. Special worker safety and environmental controls may be needed.

Concrete surfaces must be completely dry prior to paint application for all types of paints except waterborne. The plastic sheet method (ASTM D 4263, Indicating Moisture in Concrete by the Plastic Sheet Method) can be used to detect the presence of water (i.e., tape a piece of plastic sheet to the surface, wait 24 hours and look for condensed moisture under the sheet - the inside of the sheet should be dry).

6.3.3 Steel. The first step in preparing steel for coating is solvent cleaning as described in SSPC SP 1. Cleaning methods described in SSPC SP 1 include organic solvents, vapor degreasing, immersion in appropriate solvent, use of emulsion or alkaline cleaners, and steam cleaning with or without detergents.

SSPC SP 1 is specifically included as the first step in the SSPC surface preparation procedures.

For large areas of uncoated steel and coated steel with badly deteriorated coatings, the preferred method of removing mill scale, rust and coatings is abrasive blasting (SSPC SP 7, SSPC SP 6, SSPC SP 10, SSPC SP 5). These methods can both clean the surface and produce a surface profile. The specific abrasive method selected depends upon the conditions of the steel, the desired coating life, the environment and the coating to be applied. If leaded paint is present, special precautions must be taken to protect workers and the environment. Refer to Section 3. High-pressure water blasting, with or without injected abrasives, should be considered if dry abrasive blasting cannot be done because of environmental or worker safety restrictions.

For small localized areas, other cleaning methods such as hand tool cleaning (SSPC SP 2) or power tool cleaning (SSPC SP 3 or SSPC SP 11) may be more practical.

6.3.3.1 Specific Surface Preparation Requirements for Coatings for Steel. Different types of coatings may require different levels of cleaning. Commonly agreed upon minimum requirements are listed below. However, manufacturers of some specific coatings may require or recommend a cleaner surface. Conflicts between manufacturer's written instructions (tech data sheets) and contract specifications should be avoided.

<u>Coating</u>	<u>Minimum Surface Preparation</u>
Drying Oil	SSPC SP 2 or SSPC SP 3
Alkyd	SSPC SP 6 or SSPC-SP 11
	SSPC SP 3 for limited localized areas
Asphaltic	SSPC SP 6 or SSPC SP 11
Latex	SSPC SP 6 or SSPC SP 11
Vinyl Lacquer	SSPC SP 10
Chlorinated Rubber	SSPC SP 10
Epoxy	SSPC SP 6 or SSPC SP 10
Polyurethane	SSPC SP 10
Organic Zinc	SSPC SP 6 or SSPC SP 10
Inorganic Zinc	SSPC SP 10 or SSPC SP 5

For immersion or other severe environments, the higher level of the two options should be used. Higher levels may also be used to ensure the maximum lives from coating systems.

6.3.4 Galvanized and Inorganic-Zinc Primed Steel. The recommended method of cleaning uncoated galvanized steel varies with the condition of its surface. Simple solvent (organic or

detergent-based) cleaning (SSPC SP 1) is usually adequate for new galvanizing. This will remove oil applied to the galvanizing to protect it during exterior storage. If loose zinc corrosion products or coating are present on either galvanized or inorganic-zinc primed steel, they should be removed by bristle or wire brushing (SSPC SP 2 or SSPC SP 3) or water blasting. The method chosen must successfully remove the contaminants. Uniform corrosion of unpainted galvanizing may expose the brownish iron-zinc alloy. If this occurs, the surface should be painted as soon as possible. If rusting is present on older galvanized or on inorganic-zinc primed steel, remove the rust by sweep abrasive blasting (SSPC SP 7) or using power tools, such as wire brushing (SSPC SP 2, SSPC SP 3). Abrasive blasting is usually more appropriate when large areas are corroded, while the use of hand or power tools may be more appropriate when rusting is localized. For either method, the procedure should be done to minimize removal of intact galvanizing or of the inorganic zinc primer. Deteriorated coatings should also be removed using abrasive blasting or hand or power tools. When leaded-coatings are present, special worker safety and environmental precautions must be taken. Refer to Sections 3 and 13.

6.3.5 Aluminum and Other Soft Metals. New, clean aluminum and other soft metals may be adequately cleaned for coating by solvent cleaning (SSPC SP 1). The use of detergents may be required for removal of dirt or loose corrosion products. Abrasive blasting with plastic beads or other soft abrasives may be necessary to remove old coatings. Leaded coatings will require special worker safety and environmental precautions.

6.4 Standards for Condition of Substrates

6.4.1 Unpainted Steel. Verbal descriptions and photographic standards have been developed for stating the condition of existing steel substrates. SSPC VIS 1, Abrasive Blast Cleaned Steel (Standard Reference Photographs) illustrates and describes four conditions of uncoated structural steel. They are:

<u>Title</u>	<u>Grade</u>
Adherent mill scale	A
Rusting mill scale	B
Rusted	C
Pitted and rusted	D

Since the condition of the surface to be cleaned affects the appearance of steel after cleaning, these conditions are used in the SSPC VIS 1 cleanliness standards described below.

6.4.2 Nonferrous Unpainted Substrates. There are no standards describing the condition of other building material substrates.

6.5 Standards for Cleanliness of Substrates

6.5.1 Standards for Cleaned Steel Surfaces

6.5.1.1 SSPC and NACE Definitions and Standards. The SSPC and the NACE Standards are used most frequently for specifying degree of cleanliness of steel surfaces. SSPC has standard definitions and photographs for common methods of cleaning (SSPC VIS 1 and SSPC VIS 3, Power- and Hand-Tool Cleaned Steel). NACE TM0170, Surfaces of New Steel Air Blast Cleaned With Sand Abrasive; definitions and metal coupons) covers only abrasive blasting. Volume 2 of SSPC Steel Structures Painting Manual contains all the SSPC standards, as well as other useful information. For both types of standards, the definition, rather than the photograph or coupon, is legally binding. The SSPC and NACE surface preparation standards are summarized in Table 7.

To use the SSPC or NACE standards, first determine the condition of steel that is to be blasted (e.g., Grade A, B, C, or D), since different grades of steel blasted to the same level do not look the same. After determining the condition of steel, compare the cleaned steel with the pictorial standards for that condition. The appearance of blasted steel may also depend upon the type of abrasive that is used. NACE metal coupons represent four degrees of cleanliness obtained using one of three types of abrasives - grit, sand, or shot.

6.5.1.2 Job-Prepared Standard. A job-specific standard can be prepared by blasting or otherwise cleaning a portion of the structure to a level acceptable to both contractor and contracting officer, and covering it with a clear lacquer material to protect it for the duration of the blasting. A 12-inch steel test plate can also be cleaned to an acceptable level and sealed in a water- and grease-proof bag or wrapper conforming to MIL-B-131, Barrier Materials, Water Vaporproof, Greaseproof, Flexible, Heat-Sealable.

6.5.1.3 Pictorial Standards for Previously Painted Steel. Photographic standards for painted steel are available in the Society for Naval Architects and Engineers Abrasive Blasting Guide for Aged or Coated Steel Surfaces. Pictures representing paint in an original condition and after each degree of blasting are included.

Table 7
SSPC and NACE Standards for Cleaned Steel Surfaces

Method	SSPC No.	NACE No.	Intended Use
Solvent Cleaning	SSPC SP 1		Removal of oil and grease prior to further cleaning by another method
Hand Tool	SSPC SP 2		Removal of loose mill scale, rust, and paint
Power Tool	SSPC SP 3		Faster removal of loose mill scale, rust, and coatings than hand tool cleaning
White Metal Blast	SSPC SP 5	NACE 1	Removal of visible contaminants on steel surfaces; highest level of cleaning for steel
Commercial Blast	SSPC SP 6	NACE 3	Removal of all visible contaminants except that one third of a steel surface may have shadows, streaks, or stains
Brush-Off Blast	SSPC SP 7	NACE 4	Removal of loose mill scale, rust, and paint (loose paint can be removed with dull putty knife)
Pickling	SSPC SP 8		Removal of mill scale and rust from steel
Near-White Blast	SSPC SP 10	NACE 2	Removal of visible contaminants except that 5 percent of steel surfaces may have shadows, streaks, or stains
Power Tool Cleaning	SSPC SP 11		Removal of visible contaminants (surface is comparable to SSPC SP 6, also provides profile)

6.5.2 Standards for Cleaned Nonferrous Metals. No industry standards describe the degree of cleaning of nonferrous metals, and previously painted non-steel substrates.

6.5.3 Previously Coated Surfaces. When the surface to be painted is an old weathered coating film (that is, surface preparation will not include removal of the old coating), ASTM visual standards should be used for chalk, mildew, and dirt removal. In general, a minimum chalk rating (ASTM D 4214, Evaluating Degree of Chalking of Exterior Paint Films) of 8 should be required for chalk removal, a minimum mildew removal rating (ASTM D 3274, Evaluating Degree of Surface Disfigurement of Paint) of 8 (preferably 10) should be required for mildew removal, and an ASTM D 3274 rating of 10 should be required for dirt removal. Consideration should be given to requiring preparation of a job-specific standard (as described in par. 6.5.1.2) when large jobs are contracted. This standard should cover removal of loose material, chalk, and mildew, as well as feathering of edges, and other requirements of the contract specification.

6.6 Recommendations for Paint Removal. It is often necessary to remove old coatings that are peeling, checking, cracking, or the like. General recommendations for removal of paint from a variety of substrates are made in Table 8. More specific information is provided in par. 6.7.

Table 8
Procedures for Coating Removal
(IMPORTANT NOTE - Presence of Leaded Paint Will Require
Environmental and Worker Safety Controls)

Substrate	Methods
Wood	Chemical removers; heat guns or hot plates along with scraping; power sanding (must be done with caution to avoid damaging wood).
Masonry	Careful water blasting to avoid substrate damage; brush-off blasting and power tools, used with caution.
Steel	Abrasive blasting; water blasting.
Miscellaneous metals	Chemicals; brush-off blast; water blast

6.7 Methods of Surface Preparation. Information on surface preparation methods and procedures are presented to help select appropriate general procedures and to inspect surface preparation jobs. It is not intended to be a complete source of information for those doing the work.

6.7.1 Abrasive Blasting. Abrasive blast cleaning is most often associated with cleaning painted and unpainted steel. It may also be used with care to prepare concrete and masonry surfaces and to clean and roughen existing coatings for painting. Abrasive blasting is an impact cleaning method. High-velocity abrasive particles driven by air, water, or centrifugal force impact the surface to remove rust, mill scale, and old paint from the surfaces. Abrasive cleaning does not remove oil or grease. If the surface to be abrasive blasted is painted with leaded paint, additional controls must be employed to minimize hazards to workers and the surrounding environment. Leaded paint issues are discussed in more detail in Section 3.

There are four degrees of cleanliness of blast cleaning designated by the SSPC and the NACE for steel substrates. These designations are white metal, near-white metal, commercial, and brush-off. They are described in detail in par. 6.5.1.1. The

degree of cleanliness obtained in abrasive blasting depends on the type of abrasive, the force with which the abrasive particles hits the surface, and the dwell time.

6.7.1.1 Types of Abrasive Blasting

a) Air (Conventional). In conventional abrasive blasting (Figure 1), dry abrasive is propelled against the surface to be cleaned so that rust, contaminants, and old paint are removed by the impact of the abrasive particles. The surface must be cleaned of blasting residue before painting. This is usually done by blowing clean air across the surfaces. Special care must be taken to ensure that horizontal or other obstructed areas are thoroughly cleaned. Uncontrolled abrasive blasting is restricted in most locations because of environmental regulations. Consult the local industrial hygiene or environmental office for regulations governing local actions. Procedures for containment of blasting debris are being used for paint removal from industrial and other structures. The SSPC has developed a guide (SSPC Guide 6I) for selecting containment procedures depending upon the degree of containment desired. The amount of debris generated can be reduced by recycling the abrasive. Recycling systems separate the paint waste from the abrasive.

b) Wet. Wet-abrasive blasting is used to control the amount of airborne dust. There are two general types of wet abrasive blasting. In one, water is injected near the nozzle exit into the stream of abrasive (Figure 2). In the other, water is added to the abrasive at the control unit upstream of the nozzle and the mixture of air, water, and sand is propelled through the hose to the nozzle. For both types of wet-blasting, the water may contain a corrosion inhibitor. Inhibitors are generally sodium, potassium, or ammonium nitrites, phosphates or dichromates. Inhibitors must be chosen to be compatible with the primer that will be used. After wet blasting, the surface must be rinsed free of spent abrasive. (The rinse water should also contain a rust inhibitor when the blasting water does.) Rinsing can be a problem if the structure contains a large number of ledges formed by upturned angles or horizontal girders since water, abrasives, and debris tend to collect in these areas. The surface must be completely dry before coating. When leaded paint is present, the water and other debris must be contained and disposed of properly. This waste may be classified as a hazardous waste under Federal and local regulations, and must be handled properly.

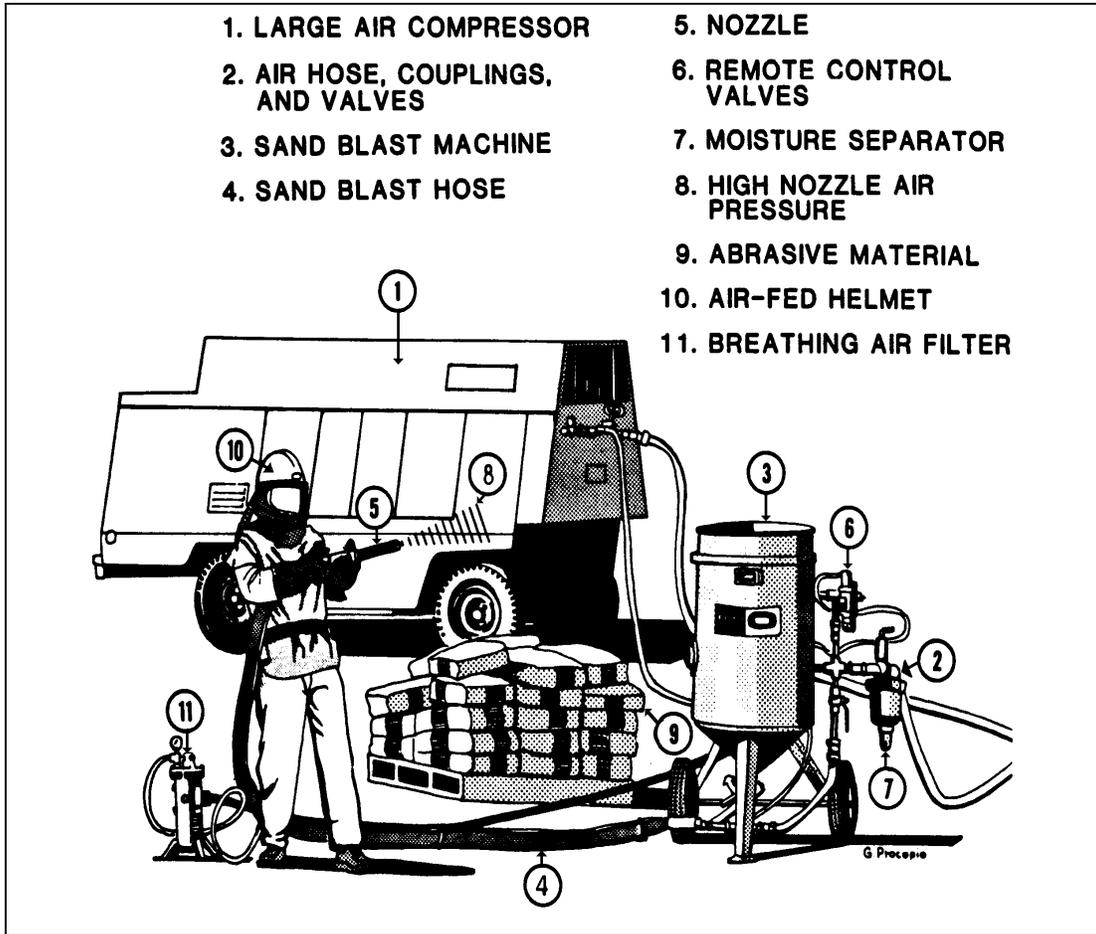


Figure 1
Schematic Drawing Illustrating Components of Conventional
Abrasive Blasting Equipment

c) Vacuum. Vacuum blasting systems collect the spent abrasives and removed material, immediately adjacent to the point of impact by means of a vacuum line and shroud surrounding the blasting nozzle. Abrasives are usually recycled. Production is slower than open blasting and may be difficult on irregularly shaped surfaces, although shrouds are available for non-flat surfaces. The amount of debris entering the air and the amount of cleanup is kept to a minimum if the work is done properly (e.g., the shroud is kept against the surface). This procedure is often used in areas where debris from open air blasting or wet blasting cannot be tolerated.

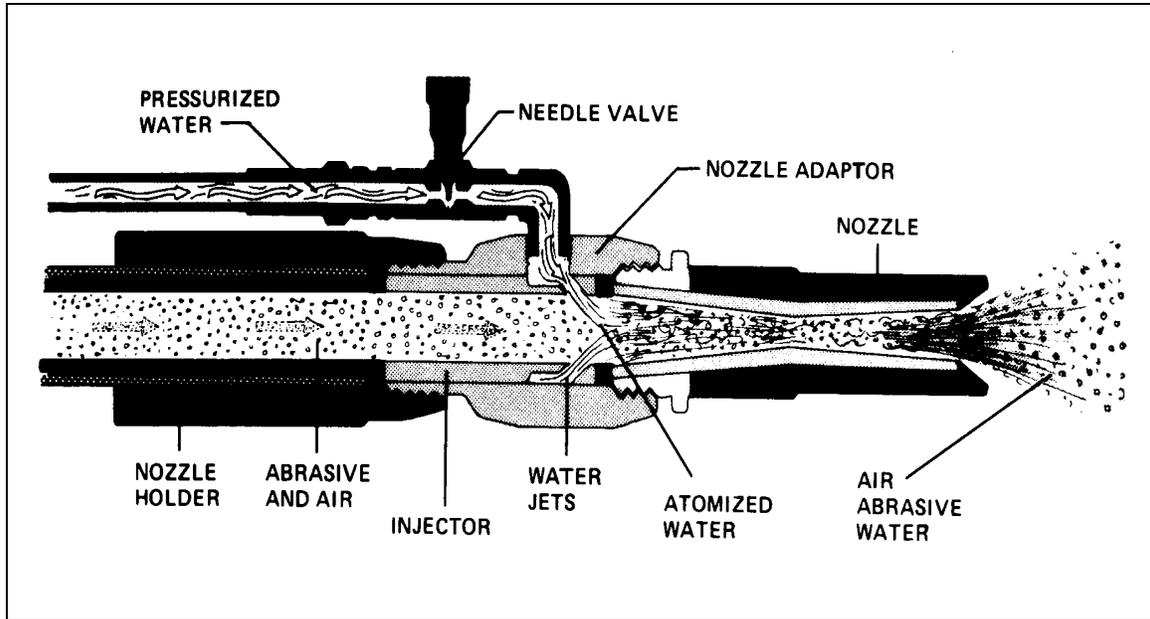


Figure 2
Schematic Drawing of Cross Section of Typical Water-Injected
Wet Abrasive Blasting Nozzle

d) Centrifugal. Cleaning by centrifugal blasting is achieved by using machines with motor-driven bladed wheels to hurl abrasives at a high speed against the surface to be cleaned. Advantages over conventional blasting include savings in time, labor, energy, and abrasive; achieving a cleaner, more uniform surface; and better environmental control. Disadvantages of centrifugal blasting include the difficulty of using it in the field, especially over uneven surfaces, although portable systems have been developed for cleaning structures such as ship hulls and storage tanks. Robots may be used to guide the equipment. In many cases, the abrasive used is reclaimed and used again.

6.7.1.2 Conventional Abrasive Blasting Equipment. Components of dry abrasive blasting equipment are air supply, air hose and couplings, abrasive blast machines, abrasive blast hose and couplings, nozzles, operator equipment, and oil and moisture separators. A brief description of each component follows:

a) Air Supply. The continuous and constant supply of an airstream of high pressure and volume is one of the most critical parts of efficient blasting operations. Thus, the air supply (compressor) must be of sufficient capacity. Insufficient air supply results in excessive abrasive use and slower cleaning

rates. The compressor works by taking in, filtering, and compressing a large volume of air by rotary or piston action and then releasing it via the air hose into the blasting machine. The capacity of a compressor is expressed in volume of air moved per unit time (e.g., cubic feet per minute (cfm)) and is directly related to its horsepower. The capacity required depends upon the size of the nozzle orifice and the air pressure at the nozzle. For example, a flow of 170 to 250 cfm at a nozzle pressure of 90 to 100 psi is necessary when using a nozzle with a 3/8 to 7/16 inch orifice. This typically can be achieved with a 45 to 60 horsepower engine.

b) Air-Supply Hose. The air-supply hose delivers air from the compressor to the blasting machine. Usually the internal diameter should be three to four times the size of the nozzle orifice. The length of the hose should be as short as practical because airflow through a hose creates friction and causes a pressure drop. For this reason, lines over 100 feet long generally have internal diameters four times that of the nozzle orifice.

c) Blasting Machine. Blasting machines or "sand pots" are the containers which hold the abrasives. The capacity of blasting machines varies from 50 pounds to several tons of abrasive material. The blasting machine should be sized to maintain an adequate volume of abrasive for the nozzles.

d) Abrasive Blasting Hose. The abrasive blasting hose carries the air and abrasive from the pot to the nozzle. It must be sturdy, flexible, and constructed or treated to prevent electrical shock. It should also be three to four times the size of the nozzle orifice, except near the nozzle end where a smaller diameter hose is attached.

e) Nozzles. Nozzles are available in a great variety of shapes, sizes, and designs. The choice is made on the basis of the surface to be cleaned and the size of the compressor. The Venturi design (that is, large throat converging to the orifice and then diverging to the outlet, Figure 3) provides increased speed of abrasive particles through the nozzle as compared with a straight bore nozzle. Thus, the rate of cleaning is also increased. Nozzles are available with a variety of lengths, orifice sizes, and lining materials. The life of a nozzle depends on factors such as the lining material and the abrasives and varies from 2 to 1500 hours. Nozzles should be inspected regularly for orifice size and wear. Worn nozzles result in poor cleaning patterns and efficiency.

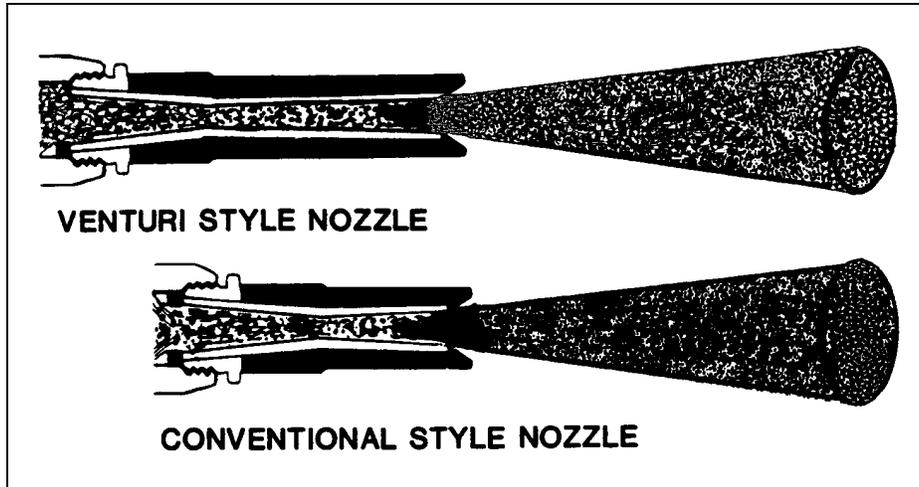


Figure 3
Cross-Sectional Drawing of Nozzles

f) Oil/Moisture Separators. Oils used in the compressor could contaminate the air supply to the nozzles. To combat this, oil/moisture separators are installed at the blast machine. The separators require periodic draining and routine replacement of filters. Contamination of the air supply can be detected by a simple blotter test. In this test, a plain, white blotter is held 24 inches in front of the nozzle with only the air flowing (i.e., the abrasive flow is turned off) for 1 to 2 minutes. If stains appear on the blotter, the air supply is contaminated and corrective action is required. ASTM D 4285, Indicating Oil or Water in Compressed Air describes the testing procedure in more detail.

g) Operators Equipment. The operators equipment includes a protective helmet and suit. The helmet must be air-fed when blasting is done in confined or congested areas. To be effective it must furnish respirable air to the operator at a low noise level, protect the operator from rebounding abrasive particles, provide clear vision to the operator, and be comfortable and not restrictive. Air-fed helmets must have National Institute of Safety and Hygiene (NIOSH) approval. Refer to Section 13 for additional information.

h) Wet Blasting. In addition to equipment needed for dry abrasive blasting, metering, delivery, and monitoring devices for water are needed.

i) Vacuum Blasting. Although there are many designs for vacuum blasting equipment, all systems have a head containing a blast nozzle, surrounded by a shroud connected to a vacuum system, and a collection chamber for debris.

j) Centrifugal Blasting. In centrifugal blasting, abrasive is hurled by wheels instead of being air-driven. This type of blasting is often used in shop work. Portable devices have been developed for use on flat surfaces. Abrasive is contained and usually recycled.

6.7.1.3 Abrasive Properties. The SSPC has a specification for mineral and slag abrasive, SSPC AB 1, Mineral and Slag Abrasives. Abrasives covered by the specification are intended primarily for one-time use without recycling. The specification has requirements for specific gravity, hardness, weight change on ignition, water soluble contaminant, moisture content and oil content. MIL-A-22262, Abrasive Blasting Media, Ship Hull Blast Cleaning, a Navy Sea Systems specification for abrasives, also limits the heavy metal content of abrasives. These and other properties of abrasives are discussed below:

a) Size. Abrasive size is a dominant factor in determining the rate of cleaning and the profile obtained. A large abrasive particle will cut deeper than a small one of the same shape and composition, however, a greater cleaning rate is generally achieved with smaller-sized particles. Thus, a mix is generally used.

b) Shape. The shape and size of abrasive particles determine the surface profile obtained from blasting (Figure 4). Round particles, such as shot, produce a shallow, wavy profile. Grit, which is angular, produces a jagged finish. Usually a jagged finish is preferred for coating adhesion. Round particles are well suited for removal of brittle contaminants like mill scale and are also used when little or no change in surface configuration is permitted. Sand and slag, which are semi-angular, produce a profile that is somewhere between that of shot and grit. Currently, sand is used much less than other abrasives because of health and breakdown factors.

c) Hardness. Hard abrasives usually cut deeper and faster than soft abrasives. Hence, hard abrasives are best suited for blast cleaning jobs where the objective is to remove surface coatings. Soft abrasives, such as walnut hulls, can remove light contaminants without disturbing a metal substrate or, in some cases, the existing coating system.

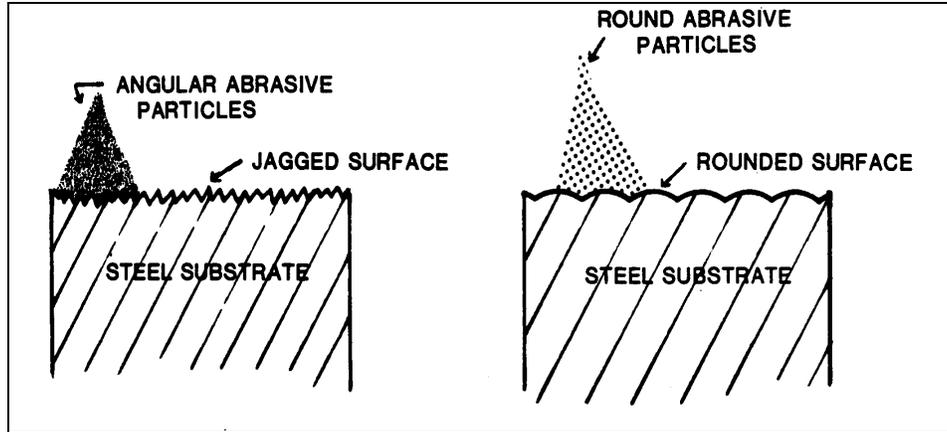


Figure 4

Drawing Illustrating Effect of Shape of Abrasive Particle on Contour of Blast-Cleaned Metallic Substrate

d) Specific Gravity. Generally the more dense a particle, the more effective it is as an abrasive. This is because it takes a certain amount of kinetic energy to remove contaminants from the surface and the kinetic energy of an abrasive particle is directly related to its density (specific gravity).

e) Breakdown Characteristics. Abrasive particles striking the surface at high speeds are themselves damaged. The way in which they fracture (breakdown) and/or in which they change their shape and size is called their breakdown characteristic. An excessive breakdown rate results in a significant increase in dusting, requires extra surface cleaning for removal of breakdown deposits, and limits the number of times the abrasive can be reused.

f) Water-Soluble Contaminants. ASTM D 4940, Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives describes a conductivity test for determining the level of contamination of metallic, oxide, slags, and synthetic abrasives by water-soluble salts. SSPC AB 1 requires that the conductivity of the test solution be below 100 microsiemens.

6.7.1.4 Abrasive Types. Abrasives fall into seven general categories: metallic, natural oxides, synthetic, slags, cellulose (such as walnut hulls), dry ice pellets (carbon dioxide), sodium bicarbonate, and sponge. A summary of typical properties of some of these abrasives is found in Table 9.

Table 9
Typical Physical Characteristics of Abrasives (1)

	Hardness	Shape	Specific Gravity	Bulk Density (pounds per cubic foot)	Color	Free Silica Wt Percent	Degree of Dusting
Naturally Occurring Abrasives							
	(Mohs Scale)						
Sands:							
Silica	5	Rounded	2 to 3	100	White	90 +	High
Mineral	5 to 7	Rounded	3 to 4	123	Variable	< 5	Medium
Flint	6.7 to 7	Angular	2 to 3	80	Lt. Grey	90 +	Medium
Garnet	7 to 8	Angular	4	145	Pink	Nil	Medium
Zircon	7.5	Cubic	4.5	185	White	Nil	Low
Novaculite	4	Angular	2.5	100	White	90 +	Low
By-Product Abrasives							
	(Mohs Scale)						
Slags:							
Boiler	7	Angular	2.8	85	Black	Nil	High
Copper	8	Angular	3.3	110	Black	Nil	Low
Nickel	8	Angular	2.7	85	Green	Nil	High
Walnut Shells	3	Cubic	1.3	45	Brown	Nil	Low
Corn Cobs	4.5	Angular	1.3	30	Tan	Nil	Low
Manufactured Abrasives							
	(Mohs Scale)						
Silicon Carbide	9	Angular	3.2	105	Black	Nil	Low
Aluminum Oxide	8	Blocky	4.0	120	Brown	Nil	Low
Glass Beads	5.5	Spherical	2.5	100	Clear	67	Low
Metallic Abrasives							
	(Rockwell C)						
Cast Steel (2) Shot & Grit	as spec. or range 35-65 RC	Spherical or Angular	3 to 10		Grey	Nil	
Malleable Iron Shot or Grit	range: 28-40 RC	Spherical or Angular	3 to 10		Grey	Nil	
Chilled Cast Iron Shot or Grit	range: 57-65 RC	Spherical or Angular	3 to 10		Grey	Nil	

- NOTES: (1) Taken from SSPC SP COM, Steel Structures Painting Manual, Systems and Specifications, Vol. 2, p. 17, and Vol. 1 of Good Painting Practice, p. 34.
- (2) Represents 85 percent of the metallic abrasives used.

a) Metallic. Steel shot and grit are the most commonly used metallic abrasives. Metallic abrasives are used to remove mill scale, rust, and old paint and provide a suitable anchor pattern. The advantages of metallic abrasives include longer useful life (can be recycled many times), greater impact energy for given particle size, reduced dust formation during blasting, and minimal embedment of abrasive particles. The disadvantages include blast cleaning equipment must be capable of recycling, abrasives must be kept dry to prevent corrosion, and the impact of steel shot on metal surfaces may cause formation of hackles on the surface. These hackles are relatively long slivers of metal and must be removed mechanically by sanding or grinding before coating to prevent pinpoint corrosion through the paint film.

b) Natural Oxides. Silica is the most widely used natural oxide because it is readily available, low in cost, and effective. Sand particles range from sharply angular to almost spherical, depending on the source. OSHA and EPA regulations have restricted the use of sand in many areas. Nonsilica sands (generally termed "heavy mineral" sands) are also being used for blast cleaning. However, they are generally of finer particle size than silica sand and are usually more effectively used for cleaning new steel than for maintenance applications.

c) Synthetics. Aluminum oxide and silicon carbide are nonmetallic abrasives with cleaning properties similar to the metallics and without the problem of rusting. They are very hard, fast-cutting and low-dusting, but they are costly and must be recycled for economical use. They are often used to clean hard, high tensile strength metals.

d) Slags. The most commonly used slags for abrasives are by-products from metal smelting (metal slags) and electric power generation (boiler slags). Slags are generally hard, glassy, homogeneous mixtures of various oxides. They usually have an angular shape, a high breakdown rate, and are not suitable for recycling.

e) Cellulose Type. Cellulose type abrasives, such as walnut shells and corncobs, are soft, low density materials used for cleaning of complex shaped parts and removing dirt, loose paint, or other deposits on paint films. Cellulose type abrasives will not produce a profile on a metal surface.

f) Dry Ice. Special equipment is used to convert liquid carbon dioxide into small pellets which are propelled against the surface. Since the dry ice sublimates, the abrasive leaves no residue. The method can be used to remove paint from

some substrates, but not mill scale and will not produce a profile. Paint removal is slow (and very difficult from wood) and the equipment needed to carry out the blasting is expensive.

g) Sponge. Specially manufactured sponge particles, with or without impregnated hard abrasive, are propelled against the surface. Less dust is created when sponge abrasive is used as compared to expendable or recyclable abrasives. The sponge is typically recycled several times. If sponge particles with impregnated hard abrasive are used, a profile on a metal can be produced. Sponge blasting is typically slower than with conventional mineral or steel abrasives.

h) Sodium Bicarbonate. Sodium bicarbonate particles are propelled against the surface, often in conjunction with high-pressure water. This method provides a way to reduce waste if the paint chips can be separated from the water after cleaning since sodium bicarbonate is soluble in water. These particles can be used to remove paint, but not mill scale or heavy corrosion.

6.7.1.5 Selection. Selection of the proper abrasive is a critical part of achieving the desired surface preparation. Factors that influence the selection include: desired degree of cleanliness; desired profile; degree of rusting; deep pits; and kind and amount of coating present. Since obtaining the desired degree of cleanliness and profile are the main reasons for impact cleaning, they must be given priority over all other factors except environmental ones in abrasive selection.

6.7.1.6 Inspection. Abrasives must be dry and clean. It is most important that they are free of inorganic salts, oils, and other contaminants. There are only limited standard procedures for inspecting abrasives. The following general procedure is suggested:

a) Visually inspect the abrasive to ensure that it is dry,

b) Test for presence of water soluble salts by following ASTM D 4940 in which equal volumes of water and abrasive are mixed and allowed to stand for several minutes and the conductivity of the supernatant is measured using a conductivity cell and bridge,

c) Examine the supernatant of the ASTM D 4940 test for presence of an oil film.

6.7.1.7 Procedures/General Information. Good blasting procedures result in efficient and proper surface preparation. Adequate pressure at the nozzle is required for effective blasting. Other factors, such as flow of abrasive, nozzle wear, position of the nozzle with respect to the surface, and comfort of operator are also important. A well trained operator is essential to obtaining an acceptable job.

a) Handling the Nozzle. The angle between the nozzle and the surface and the distance between the nozzle and surface are important factors in determining the degree and rate of cleaning (Figure 5). The working angle will vary from 45 to 90 degrees depending upon the job. To remove rust and mill scale, the nozzle is usually held at an angle of between 80 and 90 degrees to the surface. This is also the preferred configuration for cleaning pitted surfaces. A slight downward angle will direct the dust away from the operator and ensure better visibility. A larger angle between nozzle and surface allows the operator to peel away heavy coats of old paint and layers of rust by forcing the blast under them. Other surface contaminants may be better removed with a cleaning angle of from 60 to 70 degrees. By varying the distance between the nozzle and the surface, the type and rate of cleaning can also be varied. The closer the nozzle is to the surface, the smaller the blast pattern and the more abrasive strikes it. Thus, a greater amount of energy impacts the surface per unit area than if the nozzle were held further away. A close distance may be required when removing tight scale, for example. However, a greater distance may more effectively remove old paint. Once an effective angle and distance have been determined, each pass of the nozzle should occur in a straight line to keep the angle and distance between the nozzle and the surface the same (Figure 6). Arcing or varying the distance from the surface will result in a nonuniform surface.

b) Rates. The rate of cleaning depends on all of the factors discussed above. Abrasive blasting of steel to a commercial degree of cleanliness (SSPC SP 6 or better) is much slower than painting. No more steel surface area should be blast cleaned at one time than can be primed the same day, since significant rusting can occur overnight. If rusting does occur, the surface must be reblasted before painting.

6.7.2 Acid Cleaning. Acid cleaning is used for cleaning efflorescence and laitance from concrete.

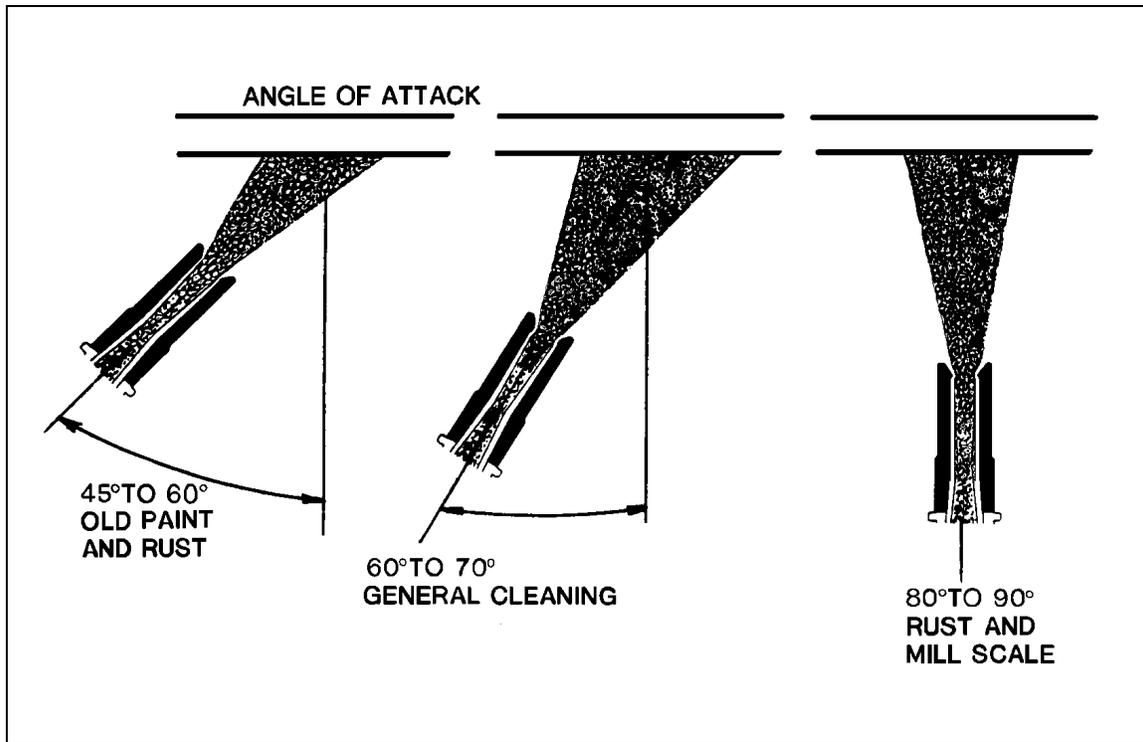


Figure 5
Schematic Illustrating Typical Cleaning Angles
for Various Surface Conditions

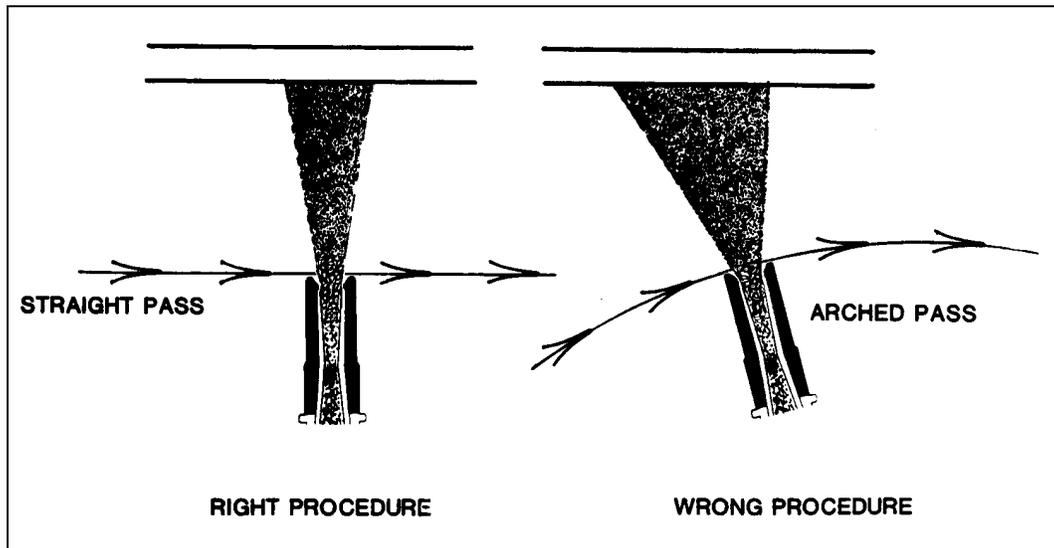


Figure 6
Illustration of Proper Stroke Pattern for Blast Cleaning

6.7.2.1 Concrete. Heavy efflorescence and laitance should be removed from concrete surfaces by dry brushing or cleaning prior to acid cleaning. This is to prevent dissolution of the efflorescence and subsequent movement of the salts into the concrete. Prior to application of an acid solution, heavy oil, grease, and soil deposits must also be removed. Oily dirty deposits can be removed by solvent or detergent washing. The commonly used procedure to acid clean these surfaces is to thoroughly wet the surface with clean water; uniformly apply acid solution (often a 5 to 10 percent solution of hydrochloric (muriatic) acid solution or a solution of phosphoric acid); scrub the surface with a stiff bristle brush; and immediately rinse the surface thoroughly with clean water. Measure the pH of the surface and rinse water using pH paper (ASTM D 4262, pH of Chemically Cleaned or Etched Concrete Surfaces). In general, the pH should be within one pH unit of fresh rinse water. It is essential for good paint performance that the acid be neutralized before painting. Work should be done on small areas, not greater than 4 square feet in size. This procedure or light abrasive blasting can also be used to etch the surface of very smooth concrete prior to coating. Coating adhesion on slightly rough concrete surfaces is usually much better than on smooth and (e.g., troweled) surfaces. An acid etched surface is usually roughened to a degree similar in appearance to a medium grade sandpaper. This cleaning method is described in detail in ASTM D 4260.

6.7.3 Chemical Removal of Paint. Paint strippers can be used when complete paint removal is necessary and other methods, such as abrasive blasting, cannot be used due to environmental restraints or potential damage to the substrate. Removers are selected according to the type and condition of the old coating as well as the nature of the substrate. They are available as flammable or nonflammable types and in liquid or semi-paste types. While most paint removers require scraping or other mechanical means to physically remove the softened paint, types are available that allow the loosened coating to be flushed away with steam or hot water. If paint being removed contains lead, additional environmental and worker safety precautions will be needed. Many removers contain paraffin wax to retard evaporation and this residue must be removed prior to recoating. Always follow manufacturer's recommendations. In addition, surrounding areas (including shrubs, grass, etc.) should be protected from exposure to the remover, collection of the residue will probably be required by environmental regulations. Removers are usually toxic and may cause fire hazards. Management of the waste associated with the procedure will also be necessary. Consult the local environmental and safety offices for further information.

6.7.4 Detergent Washing. Detergent washing or scrubbing is an effective way to remove soil, chalk and mildew. Detergent cleaning solutions may be applied by brush, rags, or spray. An effective solution for removal of soil and chalk is 4 ounces of trisodium phosphate, 1 ounce household detergent, and 4 quarts of water. For mildew removal, 1 part of 5 percent sodium hypochlorite solution (household bleach) is added to 3 parts of the cleaning solution used for chalk and soil removal. Of course, if there is little or no existing chalk on the surface, the cleaning solution should not contain the trisodium phosphate. Note, that sodium hypochlorite solution (household bleach) must not be added to cleaning solutions containing ammonia or other similar chemicals. Toxic fumes will be produced. Thorough rinsing with water is absolutely necessary to remove the soapy alkaline residues before recoating. To test the effectiveness of the rinse, place pH paper against the wet substrate and in the rinse water and compare the pH of the two. (Refer to ASTM D 4262 for complete description of the procedure.) The pH of the substrate should be no more than one pH unit greater than that of the rinse water.

6.7.5 Hand Tool Cleaning. Hand cleaning is usually used only for removing loosely adhering paint or rust. Any grease or oil must be removed prior to hand cleaning by solvent washing. Hand cleaning is not considered an appropriate procedure for removing tight mill scale or all traces of rust and paint. It is slow and, as such, is primarily recommended for spot cleaning in areas where deterioration is not a serious factor or in areas inaccessible to power tools. Hand tools include wire brushes, scrapers, abrasive pads, chisels, knives, and chipping hammers. SSPC SP 2 describes standard industrial hand-tool cleaning practices for steel. Since hand cleaning removes only the loosest contaminants, primers applied over hand-tool cleaned surfaces must be chosen that are capable of thoroughly wetting the surface. Paint performance applied to hand-cleaned steel surfaces is not as good as that applied over blast cleaned surfaces.

6.7.6 Heat. Electric heat guns and heat plates are used to remove heavy deposits of coatings on wood and other substrates. The gun or plate is positioned so that the coating is softened and can be removed by scraping. Production rates depend upon the thickness of the old coating and the smoothness of the substrate. There is a possibility of creating toxic fumes, or conditions in which burns are possible. The use of torches is not recommended, although they have been used to remove greasy contaminants and paints from surfaces prior to painting. This is an extremely dangerous procedure. The SSPC no longer has a surface preparation standard for flame cleaning because of the danger involved.

6.7.7 Organic Solvent Washing. Solvent cleaning is used for removing oil, grease, waxes, and other solvent-soluble matter from surfaces. VOC rules may prohibit or limit the use of solvent cleaning. The local environmental and safety office should be consulted before using or specifying solvent cleaning. Inorganic compounds, such as chlorides, sulfates, rust, and mill scale are not removed by solvent cleaning. Solvent cleaning or detergent or steam washing must precede mechanical cleaning when oil and grease are present on the surface because mechanical and blast cleaning methods do not adequately remove organic contaminants and may spread them over the surface. Before solvent washing, any soil, cement splatter, or other dry contaminants must first be removed. The procedure for solvent washing is to: wet the surface with solvent by spraying or wiping with rags wet with solvent; wipe the surface with rags; and make a final rinse with fresh solvent. Fresh solvent must be used continuously and the rags must be turned and replaced continuously. Solvents rapidly become contaminated with oils and grease since they clean by dissolving and diluting contaminants. Mineral spirits is effective in most solvent cleaning operations. SSPC SP 1 describes recommended industry practices for cleaning steel using solvents.

Organic solvents pose health and safety threats and should not come into contact with the eyes or skin or be used near sparks or open flames. Table 3-5 lists the flash points (the lowest temperature at which an ignitable mixture of vapor and air can form near the surface of the solvent) and relative toxicity of common solvents. Disposal of solvent must be done in accordance with governing regulations. Rags must be placed in fireproof containers after use. Additional safety information is contained in Section 13.

6.7.8 Power Tool Cleaning. Power tool cleaning can be used to remove more tightly adhering contaminants and existing paint than hand tool cleaning. Either electrical or pneumatic power is used as the energy source. Power tool cleaning is recommended when deterioration is localized, deterioration is not a serious problem, or when abrasive blasting is not possible. SSPC SP 3 and SSPC SP 11 describe the use of some of these tools for steel. In general, power tool cleaning is less economical and more time consuming than blasting for cleaning large areas. However, power tools do not leave as much residue or produce as much dust as abrasive blasting. Also, some power tools are equipped with vacuum collection devices. Power tools include sanders, grinders, wire brushes, chipping hammers, scalers, needle guns, and rotary peelers. Power tools clean by impact or abrasion or both. Near-white (i.e., rust and paint removed) steel surfaces with anchor patterns (although different than those achieved in blast cleaning) can be obtained with some power tools, as

described in SSPC SP 11. Care must be taken when using wire brushes to avoid burnishing the surface and thus causing a reduced adhesion level of the primer coating. Grease and oil must be removed prior to power tool cleaning. Danger from sparks and flying particles must always be anticipated. The operator and adjacent workers must wear goggles or helmets and wear protective clothing. No flammable solvents should be used or stored in the area. Refer to Section 13 for further safety details.

6.7.9 Steam Cleaning. A high-pressure jet of steam (about 300 degrees F, 150 psi), usually with an added alkaline cleaning compound, will remove grease, oil, and heavy dirt from surfaces by a combination of detergent action, water, heat and impact (refer to SSPC SP 1). The steam is directed through a cleaning gun against the surface to be cleaned. The pressure is adjusted to minimize spraying time. Any alkaline residue remaining on the surface after the cleaning operation must be removed by thorough rinsing with fresh water. Alkali cleaners used in steam cleaning may attack aluminum and zinc alloys and should not be used on these substrates. Steam cleaning may cause old paints to swell and blister. Thus, when steam cleaning previously painted surfaces, the cleaning procedure should first be tested in a small area to assess the effect on the old paint.

Steam cleaning equipment is usually portable and is one of two designs. With one type of equipment, concentrated cleaning solution is mixed with water, fed through a heating unit so that it is partially vaporized, pressurized, and forced through a nozzle. With another type of equipment, sometimes called a hydro-steam unit, steam from an external source is mixed with the cleaning solution in the equipment or in the nozzle of the cleaning gun. The shape of the nozzle is chosen according to the contour of the surface being cleaned. Steam cleaning is dangerous and extreme caution should be exercised with the equipment. A dead man valve must be included in the equipment and the operator must have sound, safe footing. Workers engaged in steam cleaning operations must be protected from possible burns and chemical injury to the eyes and skin by protective clothing, face shields, and the like. Refer to Section 13 for safety details.

6.7.10 Water Blast Cleaning. Water blast cleaning uses a high-pressure water stream to remove lightly adhering surface contaminants. Selection of water pressure and temperature and addition of a detergent depend on the type of cleaning desired. Low pressure - up to 2000 psi - (sometimes called "power washing") is effective in removing dirt, mildew, loose paint, and chalk from surfaces. It is commonly used on metal substrates and generally does little or no damage to wood, masonry, or concrete

substrates. For removing loose flaky rust and mill scale from steel, water pressures as high as 10,000 psi or more and volumes of water to 10 gallons per minute are used. However, water blasting without an added abrasive does not provide a profile. By introducing abrasives into the water stream, the cleaning process becomes faster and an anchor pattern is produced. Hydroblasting at high pressures can be dangerous and extreme caution should be exercised with the equipment. A dead man valve must be included in the equipment and the operator must have sound, safe footing. He should wear a rain suit, face shield, hearing protection, and gloves. Additional safety equipment may be needed. Further safety procedures are described in Section 13.

6.7.10.1 Equipment. The basic water blasting unit (without injection of an abrasive) consists of an engine-driven pump, inlet water filter, pressure gauge, hydraulic hose, gun, and nozzle combination. As with the equipment for abrasive blasting, the gun must be equipped with a "fail-safe" valve so that the pressure is relieved when the operator releases the trigger. Nozzle orifices are either round or flat. The selection depends on the shape of the surface to be cleaned. Flat orifices are usually used on large flat surfaces. Nozzles should be held about 3 inches from the surface for most effective cleaning.