Pre-Coating Surface Preparation

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Gilbert Gedeon, P.E.

Continuing Education and Development, Inc.

P: (877) 322-5800
info@cedengineering.com

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Chapter 7
Surface Preparation

7-1. Introduction

a. Surface preparation is the key factor in determining the success of a protective coating system. The equipment and techniques that can be used to achieve the desired surface cleanliness and roughness (profile) vary considerably. Traditional methods of surface preparation are now accompanied by new, innovative methods that have evolved mainly because of the issues surrounding the safe removal of lead-containing coatings from industrial structures.

b. The ultimate objective of surface preparation is to create proper adhesion of a coating over an underlying substrate. Adhesion is the key to coating effectiveness. It determines whether the coating is merely a thin film lying on the surface or if it becomes an actual part of the substrate. Adhesion is even more critical for coatings subjected to corrosive or immersion environments. Proper surface preparation is vital to the service life and overall effectiveness of a coating for protection of the substrate. The purpose of surface preparation is twofold.

c. The surface must be roughened, providing an increased surface area for a mechanical bonding of the coating to the substrate. This roughening is commonly referred to as anchor pattern or profile, and it is essentially a pattern of peaks and valleys etched into the surface. This pattern is most commonly obtained by abrasive blast cleaning, although it can be obtained by the use of certain power tools which simultaneously clean and roughen the surface.

d. Cleanliness is essential for adhesion of the coating to the substrate. Coatings applied over rust, dirt, or oil bond poorly to the substrate. Early coating failure usually will result unless the substrate is free from these contaminants.

7-2. Common Methods of Surface Preparation

A wide variety of surface preparation methods exist. Those discussed in this chapter include: solvent cleaning, hand-tool cleaning, power-tool cleaning, water jetting (low and high pressure), chemical stripping, abrasive blast cleaning (wet and dry), vacuum blast cleaning, centrifugal blast cleaning, sodium bicarbonate blast cleaning, sponge jetting, carbon dioxide blast cleaning, and laser removal.

a. Solvent cleaning (SSPC-SP 1). Solvent cleaning (SSPC-SP 1) is a procedure for removing detrimental foreign matter such as oil, grease, soil, drawing and cutting compounds, and other contaminants from steel surfaces by the use of solvents, emulsions, cleaning compounds, steam cleaning, or similar methods that involve solvent or cleaning action. Solvent cleaning is a form of surface preparation used specifically for the removal of oils and greases. It does not remove rust, rust scale, mill scale, or old coating residues from the surface. Poor solvent cleaning technique spreads contamination to an otherwise clean surface because the oil or grease becomes dissolved in the solvent. Immediately on solvent evaporation, the grease remains as a thin film over the entire wiped surface. The bonding of the coating to the steel will be inhibited if a thin film of oil remains on the surface. Oil and grease contamination is extremely common, however, and must be removed before the application of any coating. Solvent degreasing is a practical removal process and is used in conjunction with all the various methods of surface preparation. Three common methods are water washing, steam cleaning, and the use of hydrocarbon solvents.

(1) Water washing. Low pressure water washing is an effective method of solvent cleaning. If alkaline or emulsion cleaners are used, the surface (following washing) must be thoroughly rinsed with clean water to remove any residual film of the alkaline or emulsion cleaners. If not removed, these soap/oil films will adversely affect the adhesion of the subsequently applied coating. If alkaline cleaners are used, the pH of the surface should be checked after the final rinse. The pH should be no greater than that of the rinse water (typically, a pH of 6 to 7 is neutral).

(2) Steam cleaning. Steam cleaning effectively removes grease, oil, and dirt by a combination of detergent action, high pressure heated water (138 °C [280 °F] to 149 °C [300 °F] at 0.189 to 0.315 liters/sec [3 to 5 gal/min]), and impact; and it is used on both coated and uncoated surfaces. The equipment consists mainly of a pressure jet steam cleaner. A separate solution tank or drum frequently is required for preparation of the cleaning solution. One type of steam cleaner stores the concentrated cleaning solution and mixes it with water at a constant rate to generate a uniform cleaning solution. The solution is fed through a heating unit that partially vaporizes the solution and creates pressure. The hot solution and steam are forced through nozzles onto the surfaces to be cleaned. The same equipment can be used for cleaning with super-heated vapor (dry steam) or with cold water under high pressure, and it may be either portable or stationary.

(3) Hydrocarbon solvents. Hydrocarbon solvents are petroleum-based mineral spirits (aliphatics) with a minimum flash point of 38 °C (100 °F), or “Stoddard Solvents” (ASTM D235), and are commonly used as the general

purpose solvent for cleaning under normal conditions. When the temperature is 27 °C (80 °F) to 35 °C (95 °F), high flash aliphatic mineral spirits with a minimum flash point of 54 °C (130 °F) should be used. Heavy mineral spirits with a flash point over 60 °C (140 °F) should be used when the temperature is over 35 °C (95° F). Aromatic solvents may be used if greater solvency is required; however, they generally are more toxic and have lower flash points. Commonly used aromatic solvents include toluol, xylol, benzol, and high flash naphtha. Benzol (benzene) is highly toxic and explosive, and it should not be used. Because of the relatively low flash points of these solvents, fire and explosion hazards are inherent, and extreme care should be taken to ensure safe working conditions.

b. Hand-tool cleaning (SSPC-SP 2). Hand-tool cleaning is a method of preparing the substrate by the use of nonpower hand tools to remove all loose mill scale, loose rust, loose paint, and other loose detrimental foreign matter. Hand-tool cleaning generally is used only when power-operated equipment is not available, if the job is inaccessible to power tools, or when the job is too small to justify mobilization of power-tool or abrasive-blast-cleaning equipment (e.g., maintenance spot touchup). Hand-tool cleaning is slow and tedious, it is not intended for preparation of large surfaces, and it will not generate the surface roughness required for most industrial protective coatings. Care must be taken so surface contaminants such as oil or grease are not distributed over the entire surface through cleaning operations. Solvent cleaning in accordance with SSPC-SP 1 should be performed prior to hand-tool cleaning. Common hand tools include wire brushes, nonwoven abrasive pads, scrapers, chisels, knives, and chipping hammers.

c. Power-tool cleaning (SSPC-SP 3). Power-tool cleaning, similar to hand-tool cleaning, requires removal of all loosely adherent rust, paint, mill scale, etc. using pneumatic and/or electrically operated tools rather than hand tools. Through careful selection and use, many cleaning operations can be accomplished rapidly and produce satisfactory surface cleanliness by using power-tool cleaning. Impact cleaning tools, rotary cleaning tools, and rotary impact cleaning tools are three common categories of power tools, each with unique characteristics that make them adaptable to different cleaning operations and requirements. Power-tool cleaning equipment may or may not generate sufficient surface roughness (profile), depending on the type of tool selected.

(1) Impact cleaning tools. The design of impact cleaning tools involves a piston-driven chisel which strikes the surface. Chisels can be adapted for both scraping and chipping and are useful when heavy deposits of rust scale, mill scale, thick old paint, weld flux, slag, and other brittle products must be removed from the surface. Chisels are available in a variety of different shapes and are made of various materials. Impact cleaning tools are available with various handle and throttle styles and should be carefully selected for the specific operations for which they will be used, with consideration for operator safety, convenience, and preference. This minimizes worker fatigue and improves operator productivity. Great care must be exercised when using impact tools. Excessive cutting into the surface will remove sound metal, create sharp burrs, and result in premature coating failure. Also, these tools must be sharp; otherwise, they may drive rust and scale into the surface rather than remove it. Impact cleaning tools typically include chipping and scaling hammers.

(a) A needle scaler (needle gun) is essentially a scaling hammer comprised of a bundle of 2-mm (0.08-in.) steel needles housed and positioned forward of the striking piston. The piston strikes all needles simultaneously, propelling them individually against the surface. Needle scalers adapt to irregular surfaces and are most effective in removing brittle and loosely adherent surface contaminants.

(b) Piston scalers are similar to scaling hammers, except that the piston is also the chisel. This minimizes the axial dimension and permits use in applications with limited access. Piston scalers are available in single- and multiple-piston types; some can be mounted in groups for cleaning larger surface areas.

(2) Rotary cleaning tools. It is difficult, if not impossible, to achieve sufficient surface roughness for most industrial coatings using rotary power tools. Commonly, a polished, glossy surface prevails. Rotary power tools are notorious for spreading oil and grease over the surface; however, solvent cleaning, prior to power-tool cleaning, is required by the SSPC-SP 3 protocol. Rotary cleaning tools are comprised of two basic types of cleaning media: nonwoven fiber wheels with abrasives and cup wire brushes. Both can be used to remove old coating, light mill scale, rust, weld flux, slag, and dirt deposits.

(a) Nonwoven fiber wheels can be composed of various grades of abrasive and densities. Fresh working abrasive provides a constant rate of surface cleaning. Nonwoven fiber wheels containing a resin-mounted abrasive are recommended when base metal should not be removed but when wire brushes are not aggressive enough.

(b) Rotary wire brushes are composed of various shapes and sizes of wire bristles with crimped or knotted bristles. Selection of style and type of bristle abrasive composition is based on manufacturer's recommendations and personal trial. Wire brushes and nonwoven fiber wheels are manufactured in both cup and radial form.

(3) Rotary impact tools. Rotary impact tools operate on the same basic principle as other impact tools, through cutting or chipping action. However, rotary impact tools use a centrifugal principle in which cutters or hammers are rotated at high speed and thrown against the surface. On pneumatic or electric powered tools, rotary impact tools consist of three major types: heavy duty rotary flaps, cutter bundles (or stars), and rotary hammers.

(a) Heavy duty rotary flaps are uniquely portable tools that use tungsten carbide shot attached to the ends of flexible leather flaps. These flaps are loaded onto a hub, and its rotation impacts the shot against the surface. This fractures old coatings or mill scale and can provide a cleanliness equivalent to “white metal.” The process generates a nominal 2.0-mil profile, and it is generally more rapid and thorough than other types of rotary chipping tools. Rotary flaps, while yielding white metal cleanliness and 2-mil profile, do not produce a texture equivalent to abrasive blast cleaning and may not be suitable for some coatings.

(b) Cutter bundles, or stars, consist of hardened steel star-shaped washers that are free to rotate individually on spindles that orbit a powered axis. The scraping is suited for grinding concrete, surface preparation, coating removal, and generation of nonslip surfaces.

(c) Rotary hammers are a series of free-swinging hammers that, through impact on a surface, are used for removal of most industrial coatings and heavy layers of rust and mill scale.

d. Power-tool cleaning to bare metal (SSPC-SP 11). Power-tool cleaning to bare metal requires a greater degree of cleaning than that required by SSPC-SP 3 and has a surface profile minimum of 0.0254 mm (1 mil). Surfaces prepared by this method should be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products, and other foreign matter. The tools used to prepare the surface to SP 11 are similar to those used for SP 3. The availability of SSPC-SP 11 provides an opportunity to select a method of cleaning suitable for certain coatings in areas where abrasive blast cleaning is prohibited or not feasible, yet a greater degree of cleaning is necessary than can be produced by hand and power tool methods. Applications include: touchup of welds or damaged areas created during shipping or erection, reduction of the volume of hazardous waste produced by abrasive blast cleaning, and cleaning around equipment or machinery that is sensitive to airborne aggregate and debris.

e. Low pressure (6,890 to 20,670 kPa [1,000 to 3,000 psi]) water jetting. Low pressure water jetting can be used with or without detergents to remove grease, oil, or other loose foreign debris from the surface. Low pressure water jetting can also be used to meet the requirements of SSPC-SP 1. This method will not remove adherent coatings and, at lower pressures, may not remove loosely adherent paint unless the water stream is directed under the loose edges. This application is best suited for general overall cleaning operations on various items, structures, and substrates. It can be used effectively on wood and concrete/masonry surfaces without creating any damage.

f. High pressure (34,450 to 68,900 kPa [5,000 to 10,000 psi]) water jetting. High pressure water jetting will effectively accomplish all that low pressure water jetting will, as well as the removal of many tightly adherent materials. This method is, perhaps, the most commonly used of water jetting. It provides not only a higher pressure normally required to remove more material from the surface, but also requires water at only approximately 0.63 liters/sec (10 gal/min) to provide maximum cleaning rates and maximum endurance of the operator’s physical ability, compared to ultra high pressure water blasting.

g. Ultra high pressure (≥103,350 kPa [15,000 psi]) water blasting. Ultra high water blasting will effectively remove intact coatings, but it will not remove tight rust or mill scale. This method is capable of cutting through concrete/masonry surfaces and can be more effective compared to abrasive blasting in the removal of coatings similar to coal tar enamels.

h. Chemical stripping. Chemical stripping involves the application of an alkali, acid, or methylene chloride solution to a painted surface by spray, brush, or trowel. The solution remains on the surface for a few hours or overnight to allow the chemical reaction to take place and soften the coating. The stripper and coating are then scraped off, and the surface is scrubbed and washed to remove residual stripper and coating. Following removal, neutralization of the surface is required, depending on the specific product used to provide a surface with a neutral pH. Many of these formulations, because of the chemical used, may cause burn and toxic effects; therefore, protective clothing and respiratory protection should be used as recommended by the product manufacturer. For more detailed information on proper safety practices, see Chapter 10. Recent developments include strippers that are more user friendly and do not contain alkalis, acids, or methylene chloride. Instead, they involve the use of various solvents; but the manufacturer's safety precautions for product use should be followed. These products should not be permitted to contaminate the soil after use, and they should be properly contained and disposed of. Additionally, concerns are necessary if the coating removal contains lead-based paint (see Chapter 6).

i. Conventional methods of abrasive blast cleaning—expendable abrasive. Abrasive blast cleaning is perhaps the most productive method of surface preparation for coatings that require both an anchor pattern and a high degree of surface cleanliness. Blast cleaning is the only method that can completely remove intact rust and mill scale and produce an even roughness with a controlled anchor pattern. Abrasive blast cleaning is the propelling of abrasive materials at speeds of up to 724 kilometers perhour (km/hr) (450 miles per hour [mph]) against a surface. The mass of abrasive, combined with velocity created by the compressed air (620 to 689 kPa [90 to 100 psi]) used to propel the abrasive, creates kinetic energy. This kinetic energy is transferred to the surface and results in efficient removal of rust, mill scale, paint debris, and other surface materials. Simultaneously, a controlled anchor pattern (surface profile) is generated. The SSPC has published reference cleanliness standards for abrasive blast cleaning (SSPC Painting Manual, Volume 2). The National Association of Corrosion Engineers (NACE) has established similar standards that will be discussed later in this chapter (paragraph 7-4*a*). Each degree of cleaning stipulates a percentage of the surface that must be free of all materials and a percentage of the surface permitted to contain stains, streaks, or discoloration. Conventional blast cleaning generally falls into five categories: open nozzle, water blast with abrasive injection, open nozzle with a water collar, automated blast cleaning, and vacuum blast cleaning. Perhaps the most common method of abrasive blast cleaning is the use of an “open nozzle,” by which abrasive media are fed from a hopper through a hose using compressed air.

(1) Equipment. An open nozzle abrasive blast-cleaning operation consists of: the air compressor, air hose (compressor to abrasive pot), moisture and oil separator/air coolers and driers, blast pot, blast hose (abrasive and air), nozzle, and safety-related equipment.

(a) Air compressor. The air compressor is the source of energy for open nozzle blast cleaning. The amount of work accomplished (production) is in direct proportion to the volume of air pressure (cubic feet per minute) at the nozzle. The larger the compressor, the larger the orifice size of the nozzle it can support. The larger the orifice of the nozzle, the more productive the operation can be.

(b) Air hose. The air hose connects the compressor to the blast pot. For efficient blast cleaning, the air hose should have as large an inside diameter as practical to reduce friction and avoid air pressure loss (a minimum 31.75-mm (1-1/4-in.) inside diameter (i.d.) air hose is recommended; however, air hoses with a 50.8- to 101.6-mm (2- to 4-in.) i.d. are commonly used). If the hose size is too small for the volume of air passing through, frictional losses will cause a loss of pressure and poor blast cleaning efficiency. The air hose should be as short as practical to reduce pressure drop, and contain as few couplings as possible. Because many projects utilize two or more blasters, the air hose must be adequately sized so proper nozzle pressures can be maintained.

(c) Moisture and oil separators/air coolers and driers. Moisture (especially in humid areas) and oil mists (from the lubricating oils in the air compressors) become problems when large amounts of compressed air are used in an abrasive blast-cleaning operation. To combat this, adequately sized oil/moisture separators should be installed at the blast pot (the most distant point from the compressor) to eliminate oil and moisture contamination. Separators are usually of the cyclone type with expansion chambers and small micron filters. Air coolers/driers also commonly are used to treat the air generated by the compressor.

(d) Blast pot. The blast pot (direct pressure machine) is the high production blast machine used in shipyards, refineries, chemical plants, and other facilities for large-scale blast-cleaning operations. The size of the blast pot is generally determined by its abrasive capacity. Therefore, the smaller the pot capacity, the more frequent filling is required. Generally, when blast cleaning extensive square foot areas, a pot that will allow 30 to 40 minutes of blasting without refilling is recommended. Blast machines are available as: portable, mounted on wheels, and in various capacities (number of bags or pounds); or semiportable, with or without wheels, for high production in ton capacities that, in addition, can be equipped with an abrasive hopper for efficient abrasive refilling. The majority of blast pots used on large blasting projects are the gravity-flow type that have equal pressure on top and beneath the abrasive. A typical blast machine consists of air inlet and outlet valves, filling head, metering valve for regulating abrasive flow, and an easily opened hand hole that allows easy access to inspect for wear and removal of any foreign objects that may have fallen into the chamber. If the abrasive used is bulk or recycled, the pot should be equipped with a screen to prevent foreign objects (e.g., cigarette butts, paper, stones, etc.) from entering. When continuous blasting is required, a high-production-type machine, which allows blasting to continue while being refilled, can be used. This type of unit consists of two pressure pots, one mounted over the other. All blasting is done from the lower pot. While blasting from the lower pot, the upper pot is depressurized and refilled. Once the pot is again pressurized, the abrasive is automatically transferred to the lower pot.

(e) Blast hose. The blast hose connects the blast pot to the nozzle and carries both compressed air and abrasive. A sturdily constructed multi-ply hose with a minimum of 31.75-mm (1-1/4-in.) i.d. is common. A short length of lighter, more flexible hose is sometimes formed at the end. These sections, called whips, are easier to handle than the multi-ply hose and are effective for work in areas with many angles, pipes, and stiffeners. Productivity may be affected because whips have a smaller diameter than the blast hose. Maximum blast efficiency is attained when the length of hose between the blast pot and the nozzle is kept as short and straight as possible. Only externally fitted, quick connect couplings should be used. Internal-type fittings will reduce the inside diameter of the hose, thereby reducing air volume at the nozzle. These fittings also cause air turbulence inside the hose, resulting in an abrasive action where the air and abrasive strike the edge of the internal coupling. The screws that attach the external quick couplings to the blast hoses must not penetrate through the tube because air leaks can occur around these screws. The quick couplings have universal jaws and replaceable gaskets to ensure a good air seal. Quick couplings are available in brass, aluminum, or nylon. Brass has a considerably longer life; however, nylon and aluminum couplings are commonly used because of their light weight.

(f) Blast nozzle. The blast nozzle is a major element in the blast-cleaning operation. Nozzle sizes are identified by the inside diameter of the orifice. Diameters are measured in sixteenths of an inch. For example, a 4.76-mm (3/16-in.) diameter orifice is designated No. 3, a 7.94-mm (5/16-in.) diameter orifice is designated a No. 5, and so forth. Nozzles are commonly available up to 15.9 mm (5/8 in.) in diameter. However, the nozzle can be too large for the air volume being supplied and cause air pressure and production to decrease. Therefore, nozzle size should be as large as permitted by the volume of the air supply to maintain a 620- to 689-kPa (90- to 100-psi) air pressure at the nozzle. Nozzles are available in an assortment of lengths, orifice sizes, lining materials, and configurations. Nozzles may be lined with tungsten carbide, boron carbide, ceramic, or cast iron. Ceramic and cast iron are considered short-life nozzles; tungsten and boron carbide nozzles are long life. The average life of tungsten carbide nozzles is 200 hours; ceramic and cast iron nozzle life averages 2 to 4 hours. Boron carbide nozzles can have a 1,500-hour life if properly handled to prevent cracking of the brittle carbide material. For difficult to reach areas, nozzles are available in right angle configurations, enabling the blaster to propel abrasive around corners. Venturi designed nozzles have a tapered interior shape that increases the abrasive exit speed up to 724 km/hr (450 mph) to create a larger, more even blast pattern. Production cleaning rates can be increased by as much as 30 to 50 percent with the use of a venturi nozzle over a conventional “straight bore” nozzle. Longer nozzles, from 127 to 203 mm (5 to 8 in.), will more easily remove tightly adherent deposits and increase cleaning rates. However, short nozzles (76 mm [3 in.] or less) may have to be used behind beams or in otherwise relatively inaccessible areas. As the abrasive material flows through the nozzle, the lining wears away and the cleaning effectiveness is reduced. Nozzles should be replaced when wear increases the opening of the original orifice size to the next larger size. Use of worn nozzles will result in increased compressor wear, increased abrasive consumption, and reduced productivity. Nozzle diameter, air pressure, and air volume are all critical. At 620 kPa (90 psi), a 9.5-mm(3/8-in.) nozzle will consume 81.66 liters/sec (173 cubic feetper minute [cfm]) of air, and a 12.7-mm (1/2-in.) nozzlewill consume 145.85 liters/sec (309 cfm) of air. Because production is in direct proportion to the volume and pressure of air at the nozzle, a 12.7-mm (1/2-in.) nozzle is capable of generating almost 179 percent of the cleaning accomplished with a 9.5-mm (3/8-in.) nozzle if there is sufficient air available to maintain the nozzle air volume pressure at 620 kPa (90 psi). If the nozzle air pressure with a 12.7-mm (1/2-in.) nozzle drops to 482 kPa (70 psi) because of an inadequate air supply, air consumption drops from 145.85 to 118.95 liters/sec (309 to 252 cfm). Therefore, a 137.8-kPa (20-psi) drop in nozzle pressure causes a loss of 26.9 liters/sec (57 cfm), or 18.4 percent in the cleaning rate (57 divided by 309, multiplied by 100 percent).

(g) Safety. Manually operated air inlet and outlet valves were used in the past to shut down the blast-cleaning operations. Today this has been replaced by the remote-controlled deadman. These remote-controlled devices have been designed to fit any existing blast pot setup, and they are operated at the blast nozzle. They eliminate the need for a pot tender and provide a high degree of safety to the worker because, with the remote control deadman valves, the moment the grip on the nozzle is relaxed, the abrasive pot shuts down. Blasters frequently consider the deadman a nuisance because they must constantly hold down the lever while blasting, and they tend to override the safety feature of the deadman by inserting wedges or tying down the lever. This can be extremely dangerous, especially if the blaster trips and drops the blast hose because the abrasive flow will continue until the wedge or wire is removed or the pot tender shuts the operation down. Other safety and health practices related to abrasive blast-cleaning operations include: respiratory protection, skin protection, eye protection, ear protection, and fire/explosion prevention. A more in-depth discussion of safety during blast-cleaning operations is provided in Chapter 10.

(2) Blast cleaning techniques.

(a) Blast-cleaning techniques are essential for an effective, efficient blast-cleaning operation. The blaster must maintain the proper abrasive flow, angle of attack, and distance between the nozzle and the surface. Experimentation with different angles and distances when starting a new job will determine what is most effective for the surface condition.

(b) The proper balance of abrasive and air is achieved when the abrasive airstream from the nozzle is “bluish” in color. Experience is ultimately the best indicator. Many operators tend to use too much abrasive, reducing speed and increasing airborne dust and cleanup cost. The air/abrasive mixture is adjusted using the metering valve, or carburetor, at the base of the abrasive pot.

(c) The angle of the nozzle to the surface can range from 45 to 90 degrees. To remove rust and mill scale, an 80- to 90-degree angle to the surface is preferred. This angle also is suitable for dislodging contaminants from pitted surfaces. A slight downward angle also directs the dust away from the operator. To peel old paint and layers of rust from the surface, a 45- to 70-degree angle to the surface is most productive.

(d) The closer the nozzle is to the surface, the smaller the blast pattern. With a small pattern, the abrasive is concentrated in a smaller surface area, resulting in an impact at greater speed and more force. In a small surface area, the operator can blast more area for the energy spent but will cover less area in a given time. A distance of only 152.4 mm (6 in.) may be required to remove tight mill scale and heavy rust, but a 457.2-mm (18-in.) nozzle-to-surface distance may be most effective for removal of old coating. Each pass should be straight and at the same distance to produce a uniform pattern.

(3) Quality control.

(a) Air pressure. Reading the pressure gage on the compressor or on the blast pot reveals the air pressure at those points only. Friction losses and pressure drops through the pot, hoses, etc. all reduce nozzle pressure. Nozzle pressures of 620 to 689 kPa (90 to 100 psi) are considered optimum. Lower pressures reduce blast-cleaning efficiency. Although higher pressures do not greatly increase efficiency, they do lead to operator fatigue. The air pressure at the nozzle is measured using a hypodermic needle pressure gage. The gage needle is inserted into the blast hose as near to the nozzle as possible. The needle must point in the direction of the abrasive flow, and the measurement is made while the abrasive and air are flowing. The gage reading indicates air pressure at the nozzle.

(b) Air cleanliness. Compressed air cleanliness can be determined in accordance with ASTM D4285 by exhausting the compressed air (downstream of moisture and oil separators) onto a clean white cloth or blotter paper. Air cleanliness should be evaluated each day prior to commencing blast cleaning work, and as required thereafter to help ensure a clean, dry air source.

(c) Nozzle orifice. The orifice size of a blast-cleaning nozzle can be monitored for wear using a nozzle orifice gage. Similar in appearance to a ring sizer, the gage measures the inside diameter of a nozzle internally. A china marker (grease crayon) is used to mark the side of the cone. The gage is then inserted into the blast nozzle, twisted slightly, then removed. The nozzle opening will etch the grease crayon marking, which coincides with scale divisions (inches and cfm at 100 psi) to reveal the interior diameter.

(d) Abrasive cleanliness. Abrasive materials contaminated with oil or chemical residue can lead to surface contamination. Abrasives should be monitored for cleanliness using either of the following techniques. The first method, the “vial test,” is referenced in SSPC Painting Manual Volume 2 Abrasive Specification No. 1, “Mineral and Slag Abrasives” (SSPC-AB 1). With this test, if the abrasive is contaminated, the top of the water in the vial will reveal a film of grease or oil. The abrasive also can be tested for chemical contamination by performing a conductivity test, per ASTM D4940. However, water-soluble contaminants such as salt will not be detected using these tests. If water-soluble contaminants are present, a litmus paper test of the water in the vial will tell if they are acid or alkaline. If neutral, a drop of 5 percent silver nitrate solution should be added to the water. The formation of a white precipitate will indicate the presence of chlorides. Alternatively, after the water has evaporated, if these contaminants are present, salt crystals would be detectable.

(e) Ambient conditions. Ambient conditions typically do not affect rough blast cleaning; however, for final blast-cleaning operations, ambient conditions must be monitored, and work should be halted if temperature, relative humidity, dew point, and surface temperature conditions are outside of the contract requirements. Most importantly, the surface temperature should be at least 3 °C (5 °F) higher than the dew point for final blast-cleaning operations. This precautionary step will preclude moisture formation on the surface. A more in-depth discussion on measurement of ambient conditions is in Chapter 9.

j. Abrasive blast cleaning with recyclable abrasives. Abrasive blast cleaning with recyclable abrasives can be performed using compressed air to propel the abrasive similar to blast cleaning with expendable (nonrecyclable) abrasives, or without compressed air using centrifugal force to propel the abrasive.

(1) Centrifugal blast cleaning. Centrifugal blast cleaning is widely used in steel fabrication shops for several reasons: it is relatively fast, consumes less energy and blasting abrasive, and allows for recycling abrasive. The principles of operation for centrifugal wheel blasting equipment are fairly simple. The steel to be cleaned is conveyed through a cabinet or enclosure where blast-cleaning abrasive is hurled at the steel surface from various directions by rotating wheels with blades. The bladed wheels rotate rapidly enough to propel the abrasive at speeds of up to 322 km/hr (200 mph). The spent abrasive, rust, mill scale, etc. fall to the bottom of the cabinet where a separator removes the fines, rust, and mill scale from the abrasive so the abrasive can be reused. The bladed wheels are motor driven and are typically capable of hurling approximately 362.4 kilograms (kg) (800 pounds [lb]) of abrasive per minute; an airblaster with a 9.5-mm (3/8-in.) diameter nozzle delivers only approximately 31.7 kg (70 lb) of abrasive per minute. The degree of blast cleanliness obtained can be altered by a number of methods. Generally speaking, the requirements of SSPC-SP 10 can be met by conveying the steel to be cleaned at the rate of 1.2 to 1.8 meters/min (4 to 6 linear feet per minute). Greater or lesser degrees of surface preparation can be achieved by regulating the speed of the conveyor or the velocity at which the abrasive is hurled toward the steel. In some cases, it may be necessary to convey a piece of steel through more than once to attain a high degree of surface cleanliness or to assure that all of the surfaces have been exposed to the cleaning action of the abrasive.

(2) Airblast cleaning. Airblast cleaning with recyclable abrasives can involve a permanent shop-type setup, including a blast room. The floor generally consists of steel grating to allow the passage of spent abrasive to be recycled into the system for reuse. Similar to centrifugal blast cleaning, during the abrasive recycling, dust fines, mill scale, rust, and other contaminants are filtered out. Airblast cleaning with recyclable abrasive also can involve the same equipment previously discussed using expendable abrasives. The only difference is the abrasive is recycled manually and sifted through screens to eliminate foreign debris.

(3) Vacuum blast cleaning. Vacuum blast cleaning uses compressed air to propel abrasive particles against the surface to be cleaned. The blast nozzle is fitted into a localized containment assembly (surrounding the nozzle only), which is equipped with a vacuum. As a result, dust, abrasive, and coating debris are vacuumed simultaneously with the blast-cleaning operation. Debris is separated for disposal, and the abrasive is returned for reuse. Metallic abrasives are commonly used. When properly used, vacuum blast cleaning can significantly minimize, or eliminate, airborne dust and debris, which is of major importance when removing lead paint. The volume of debris also is significantly reduced compared to open abrasive blast cleaning with disposable abrasives because it is composed of only abrasive fines and pulverized paint. Vacuum blast cleaning is capable of producing the highest degree of surface preparation on large, open surfaces, but it does not have the same capability in areas of difficult accessibility. In fact, the greatest limitation of vacuum blast cleaning is that, to eliminate dust and to recycle all of the abrasive, the mask or brush surrounding the blast nozzle must be held tightly to the surface at all times. This is not possible on irregular surfaces. Even on flat surfaces, productivity is limited by a small blast pattern and the need to maintain a seal between the head and the surface, which also adds to operator fatigue.

(4) Recyclable abrasives. Recyclable abrasives generally are not used in the field unless a reclaiming and recycling system is used primarily because of the higher costs of recyclable abrasives (e.g., steel shot and steel grit). By using a recycling system, the abrasive can be reused numerous times before replacement with new abrasive becomes necessary. For projects in which the generation of dust emissions and spent abrasive must be contained and controlled, steel grit is the preferred choice of a recyclable abrasive.

(5) Monitoring abrasive size and methods. Control of the work mix (size) is vital in maintaining a consistent production rate and surface profile. Representative samples of the work mix, which actually performs the cleaning and provides the finish (anchor pattern), should be subjected frequently to careful sieve analysis to be certain that the size distribution of the work mix is in balance, i.e., not predominantly coarse or fine. The larger pellets in the work mix impart the greatest impact energy per pellet, cause cracking or fragmenting of heavy surface contaminant on the area being cleaned, and impart indentations of maximum peak-to-valley values. Medium and smaller pellets in the work mix provide greater coverage for scouring and complete removal of cracked or fragmented surface contaminant. Because of the decreased impact energy of the smaller abrasive particles, the peak-to-valley value is decreased. Also, because of the small size, a greater number of impacts occur on a given area of the work piece and greater peak population results. Each abrasive type, size, and shape has its own inherent impact life cycle, generally measured in pounds used per blasting hour. Theoretically, new abrasive should be added to the system every blasting hour in amounts equal to the rate of withdrawal, or loss, from the system. In practice, however,

making additions once a shift, or every 8 hours, is acceptable. A continuous, automatic system of abrasive replenishment is the preferred and most reliable method of maintaining a uniform work mix in a production operation. Delay in making new abrasive additions tends to decrease the percentage of coarser sizes in the work mix; the result will likely be poorer quality cleaning and reduction of anchor pattern depth. Conversely, adding a large quantity of new abrasive at one time increases the percentage of coarser sizes; this results in a coarsening of surface profile and, for a given period, insufficient coverage and poorer cleaning. Maintaining a uniform and stabilized operating mix also requires the abrasive particles removed from the blast machine to be of uniform size. To realize the greatest economic benefits of using metallic abrasives, the particle size removed should be smaller than the smallest size that is effective in the cleaning operation. Control of removal size requires careful attention to the adjustment of the separator system and of the airflow through the separator.

(6) Abrasive cleanliness and methods. Although there is no inspection apparatus for determining the cleanliness of the abrasive to be used, a visual inspection must be made to assure that it is not damp or contaminated. When abrasive recycling systems are used, tests for contamination should be conducted as discussed under paragraph 7-2*i*(3)(d).

k. Wet/water abrasive blast cleaning.

(1) Wet abrasive blast cleaning involves the incorporation of a small amount of water into a dry abrasive blast-cleaning operation. Methods, equipment, and techniques are similar to dry abrasive blast cleaning, except that a modified nozzle is used in which water is either injected into the blast stream or introduced to the abrasive as a “collar” around the exit stream.

(2) Water abrasive blast cleaning uses high pressure water and abrasive to provide a cleaned and roughened surface. Basically, a small amount of abrasive is fed into the water stream. The equipment, methods, and technique are similar to wet blast cleaning, except an abrasive supply is provided for injection into the water stream. The advantages of wet abrasive blast cleaning include the control of dust emissions and aid in the removal of chemical contamination by the introduction of water. The advantages of water abrasive blast cleaning include providing a surface profile when compared to the water blast-cleaning method without abrasive. The limitations of wet abrasive blast cleaning include the accumulation of considerable amounts of abrasive on the surface because of a lesser amount of water in and around the abrasive stream, which requires an extra step of cleaning (washing) to remove the spent abrasive. A limitation of both wet and water abrasive blast cleaning is that the prepared steel surfaces will oxidize quickly because of the presence of water. Therefore, rust inhibitors must be used to prevent the oxidation process.

(3) Flash rusting can occur within minutes after blasting with water. To prevent oxidation or flash rusting, a suitable inhibitor usually is injected into the blast hose or applied after blast cleaning. A rust inhibitor with a solution strong enough to retard rust after the final rinsing of the contaminants and spent abrasives has been completed should be used. Inhibitors include soluble chromates, phosphates, nitrates, and molybdates. When dry, certain inhibitors leave salts that could produce adhesion problems for protective coatings. Therefore, the inhibitor must be compatible with the paint system to be applied. Inhibitors also must meet USEPA requirements and be nonpollutants. It may be preferable to apply the inhibitor solution after the water blast operation to minimize operator exposure, save inhibitor, reduce problems of liquid pollution, and reduce the risk of excessive flash rust. The air-drying feature of the air-water-sand method is highly beneficial in minimizing flash rusting.

l. Sodium bicarbonate blast cleaning.

(1) Sodium bicarbonate blast cleaning is an innovative method for coating removal. Compressed air or high pressure water is used to propel abrasive particles of sodium bicarbonate (baking soda) against the surface to be cleaned. Sodium bicarbonate is water-soluble; therefore, the coating chips can be separated from the water (and dissolved sodium bicarbonate) to reduce the total volume of waste material.

(2) The equipment is specialized and consists of an air compressor, water, sodium bicarbonate abrasive, a means of collecting the coating debris and water, and a system for separating the coating chips from the water and dissolved bicarbonate. A blast pot, blast hose, and specialized nozzle are required for airblast systems. The nozzle is equipped with a means of introducing water to the abrasive immediately prior to exiting the nozzle. For water systems, a specialized pump is used (typically less than 41,340 kPa [6,000 psi]) to convey high pressure water to the nozzle. A special nozzle assembly is used to inject the sodium bicarbonate (from a blast pot) into the water stream at the nozzle.

(3) Sodium bicarbonate blast cleaning has inherent advantages and limitations. This method will remove coatings, dirt, grease, machine oil, and various process residues; but it leaves mill scale and rust unaffected. If mill scale and rust are present, some degree of mechanical removal may be required prior to coating. The addition

of a small percentage of expendable abrasive can assist in the cleaning and enhance the removal of mill scale and rust. If the original surface was blast cleaned, the profile is often “restored” after the coating is removed, and the surface becomes suitable for painting.

(4) The residual sodium bicarbonate left on the surface provides a slight passivation to the surface (pH 10), which prevents most of the flash rusting potential common when using wet abrasive blasting methods. Sodium bicarbonate blast cleaning is relatively slow compared to the productivity of open nozzle abrasive blast cleaning. Sodium bicarbonate blast cleaning can be effectively used by many industries such as pulp and paper, food processing, petrochemical, and others when plant shutdowns are undesirable.

m. Sponge jetting.

(1) Sponge jetting or sponge blasting is an innovative method of preparing a surface for painting. Compressed air is used to propel particles of manufactured polyurethane sponge against the surface to be cleaned. The sponge particles can be impregnated with abrasive for the removal of coatings, rust, and mill scale. After use, the sponge and debris are collected, loaded into a vibrating screen and/or wet separation system, and the reusable portion of the sponge is returned for additional blast cleaning. The inception of sponge jetting began with a simple urethane foam sponge designed solely as a degreasing media. Similar urethane sponge particles were then impregnated with a nonsilica-containing mineral abrasive and garnet (both identified, respectively, as mildly aggressive and aggressive blast media when combined with sponge material). These materials permitted simultaneous degreasing and rust/coating removal operations and surface profile generation. Aluminum oxide and steel grit have also been incorporated with the sponge jet material.

(2) The specialized equipment required for sponge jetting includes an air compressor, blast hoses and special blast nozzle, specialized blast pot, abrasive collection equipment (e.g., vacuums), and vibrating screen abrasive reclaiming equipment. Screens or tarps to isolate the work area along the ground are typically sufficient to capture the abrasive and debris for return to the separation system. Fine dust particulate, typically associated with open abrasive blast cleaning using expendable abrasives, is not visually apparent with this method.

(3) Sponge jetting, as with all removal methods, has inherent advantages and limitations. The visible dust created when using sponge jetting is substantially reduced compared to open blasting with expendable or recyclable abrasives. The volume of debris also is reduced substantially because the sponge abrasive is typically reused from 5 to 15 times. The method offers the same advantages as abrasive blast cleaning with regard to the superior degree of cleaning and the ability to clean areas of difficult accessibility, but the productivity is 25 to 50 percent that of open nozzle blast cleaning, depending on the condition of the surface to be cleaned. When compared with other dry methods of abrasive blast cleaning, some form of containment is still required to capture rebounding sponge abrasive and debris. The costs of the equipment and sponge media are high. Although sponge jetting is a relatively new method of preparation, it is similar enough to open nozzle abrasive blast cleaning that operators can easily adjust to the process. In addition, this process minimizes waste generated as in conventional surface preparation methods and provides increased worker and public safety by minimizing adverse effects to the environment during surface preparation activities.

n. Carbon dioxide (dry ice) blast cleaning.

(1) Dry ice pellets can be used as an abrasive media to remove coating materials from a surface. Basically, compressed air is used to propel rice-sized pellets of carbon dioxide (dry ice) against the surface to be cleaned. The abrasive dissipates, leaving only coating debris for disposal. Liquid carbon dioxide is converted to pellets with specialized equipment and conveyed through a blast hose and special nozzle assembly. This method is capable of removing coatings, but it leaves mill scale and rust unaffected. If the original surface was blast cleaned, the profile is “restored” after the old coating is removed. Carbon dioxide blast cleaning is a remarkable concept, and it may represent trends in removal methods of the future. Carbon dioxide will not create a spark or conduct electricity; therefore, it can be considered for use in areas where the possibility of sparking is unacceptable. The abrasive dissipates and reduces the volume of waste to only the coating being removed. In addition to the reduction in the volume of waste generated, containment requirements also are reduced because of the low dusting created during removal.

(2) Carbon dioxide blast cleaning is not without limitations. The equipment is expensive, and a large supply of liquid carbon dioxide (e.g., tank truck) is required in addition to other specialized equipment for producing the carbon dioxide pellets and dispensing them through a blast nozzle. The pellets will not productively remove mill scale or heavy rust, and coating removal also is slow. One advantage of using this method, particularly in a confined space, is that it does not produce the dust generated with abrasive blast cleaning.

o. Laser removal. Research studies have shown that mill scale and other adhering deposits can be removed, at least to some degree, when subjected to thermal shock of chemical decomposition using laser beams. The testing of this process revealed that, when rusted steel was exposed to laser beams of several kilowatts, the hydrated oxides were changed to a dense, hard scale of magnetite that then could be removed. Laser cleaning probably will not have much impact on the cleaning of structural steel in the near future because of significant energy input and equipment development requirements.

7-3. Abrasive Type and Selection

a. Abrasive selection. The surface effects produced with various abrasives can range from deep cutting to gentle scouring of the surface. Important factors to consider in selecting an abrasive include: type of surface to be cleaned, shape of the structure, type of material to be removed, surface finish desired, profile, breakdown rate of the abrasive, reclamation of the abrasive, hazards associated with the use of the abrasive, and the area in which the abrasive will be used and its danger to surrounding equipment.

b. Abrasive types. The types of available abrasives vary from one part of the country or the world to another. The general categories are: steel shot, metal grit, and mineral abrasives. Each type of abrasive cleans in a different way and leaves a slightly different surface texture. There is a recommended physical and chemical property reference for mineral and slag abrasives as defined by SSPC-AB 1. In addition, several ASTM test methods exist that deal with all abrasives and include the following: C128, C566, C702, D1125, D4417, D4940, and E1132.

(1) Natural oxides. Natural oxides such as silica sand were perhaps the most widely used natural oxides because of their availability, low cost, and effectiveness. The hazards of silica have been elucidated by both USEPA and OSHA, and the use of silica abrasive has been restricted in many areas. Another natural abrasive, also a silica material, consists of a blend of coarse and fine staurolite sands mined from mineral deposits in Florida. It is characterized as an efficient cutting abrasive and has less dusting and a lower breakdown rate than silica sand.

(2) Metallic abrasives. Metallic abrasives such as steel shot and grit abrasives are efficient, hard, and create less dust; but care must be taken to properly store the abrasive to prevent rusting. The initial cost is higher than most other abrasive types, but these abrasives may be recycled many times to make them more cost effective. A combination operating mix of both steel shot and steel grit abrasives is common.

(3) Slag abrasives. Slag abrasives (ore smelting by-products) are fast cutting, but they have a high breakdown rate and generally are not recycled. These abrasives are the most likely to exhibit a pH on the acidic side.

(4) Synthetic abrasives. Synthetic abrasives (aluminum oxide and silicon carbide) exhibit cleaning properties similar to the metallics, without the problem of rusting. They are extremely hard, fast cutting, and low dusting; but they are costly and must be recycled for economic use.

c. Characteristics. Proper abrasive size and hardness are essential to produce the necessary cleanliness and profile. The characteristics of an abrasive related to performance include size, hardness, and abrasive shape.

(1) Size. A large-sized abrasive particle will cut deeper than a smaller size of the same composition and shape to provide a deeper surface profile. However, the greatest cleaning rate is achieved with the smaller abrasive because of a larger number of impacts per unit area. Abrasive particles larger than 16 or 18 mesh may gouge the metal surface, resulting in a slower cleaning rate. Fine particles (80 mesh size or finer) cannot achieve the 0.038 to 0.063 mm (1.5 to 2.5 mil) profile usually desired for industrial coatings. Particles in the 40- to 50-mesh range commonly are used.

(2) Hardness. Hard abrasives generally cut deeper and faster than soft or brittle abrasives. A hard, brittle abrasive will shatter on impact, reducing its cleaning power.

(3) Abrasive shape. The shape and size of abrasive grains determine the type of surface profile achieved. Because steel shot is round, it peens the surface. Therefore, shot is particularly effective in removing brittle deposits such as mill scale. Grit is angular in shape and produces a jagged finish by cutting rather than peening, which generally is preferred for coating adhesion. A wide variety of surface patterns are available from different grits.

d. Recyclable versus nonrecyclable. Abrasives are categorized into various classifications; some can be recycled effectively but others cannot because of their breakdown characteristics. Nonrecyclable abrasives are not as expensive as recyclable abrasives and should be used for economic reasons if recycling is not to be performed. Generally, abrasives should not be recycled if the breakdown rate is greater than 10 percent; as increased airborne dust, insufficient surface profile, and decreased blast cleaning productivity will likely result. Recyclable abrasives are harder and do not break down as quickly as nonrecyclable abrasives, and they can be reused.

e. Cleaning/consumption rates. As with all cleaning operations, differences in surface condition, type of steel, corrosion, etc. affect the production rates of cleaning. Conditions are listed in Table 7-1 for open air blast cleaning rates and abrasive consumption on newly fabricated steel using a 9.5-mm (3/8-in.) blast nozzle and 689-kPa (100-psi) nozzle air pressure prepared to an SSPC-SP 10 requirement.

f. Embedment. Some abrasives, particularly softer abrasives, tend to break down and embed particles into the surface profile, which makes it extremely difficult to obtain a specified blast cleanliness (e.g., SSPC-SP 5). In addition, their embedded particles frequently are extremely difficult to remove by brushing and vacuuming.

g. Chemical cleanliness. The pH of an abrasive should be nearly neutral when the abrasive is mixed with water. Most suppliers note the pH on the technical data sheet accompanying the abrasive. The pH value is easily checked and should be routinely monitored. An abrasive with an acid pH would cause premature corrosion of steel and could cause coating failure. pH can be verified using litmus paper. Soluble chloride is important because chlorides in an abrasive will leave a chloride residue on the blasted substrate that could be detrimental to the substrate and subsequent coating systems. Most chemical laboratories can routinely analyze for soluble chlorides. If the abrasive source is near seawater, routine checking for soluble chlorides is a must.

h. Dust generation. Dust generation is described as the amount of dust generated by an abrasive on impact. Excessive dust can create visibility problems during blasting and cause environmental problems at the jobsite. Generally speaking, the silica sands, boiler, and nickel slag abrasives have the highest degree of dust generation. On the other hand, manufactured abrasive such as silicon carbide steel shot and aluminum oxide have the lowest dust generation.

i. Profile yield. Selection of the proper abrasive depends on the desired surface profile heights, which in turn assures good coating adhesion and performance. Thicker coating films require deeper surface profiles. Steel shot has been found to be adequate for profiles less than 0.076 mm (3 mil). Boiler slag or coarse steel grit may be required to attain profiles of greater depth. The mass and hardness of

Table 7-1
Examples of Cleaning Rates with Typical Abrasives

Abrasive	Abrasive Consumption	Production Rate	Comments
Silica sand 16/40 mesh	12.69 kg/sq m (2.6 lb/sq ft)	0.44 sq m/min (4.75 sq ft/min)	0.038 mm (1-1/2 mil) etch dusty
*Garnet 36 grit	*17.58 kg/sq m (3.6 lb/sq ft)	0.33 sq m/min (3.55 sq ft/min)	0.038 mm (1-1/2 mil) etch - very little dust-reusable
*Aluminum oxide 36 grit	*15.13 kg/sq m (3.1 lb/sq ft)	0.42 sq m/min (4.58 sq ft/min)	0.038 mm (1-1/2 mil) etch - very little dust-reusable
*G-40 steel grit	*26.85 kg/sq m (5.5 lb/sq ft)	0.28 sq m/min (3.06 sq ft/min)	0.063 mm (2-1/2 mil) etch - no dust gray metal-reusable
Crushed flint 12/30 mesh	17.58 kg/sq m (3.6 lb/sq ft)	0.25 sq m/min (2.69 sq ft/min)	0.076 mm (3 mils)-reusable
Staurolite 50/100	15.13 kg/sq m (3.1 lb/sq ft)	0.45 sq m/min (4.85 sq ft/min)	0.013 mm (1/2 mil) etch smooth surface
Coal slag 16/40 mesh	15.62 kg/sq m (3.2 lb/sq ft)	0.36 sq m/min (3.83 sq ft/min)	0.063 mm (2-1/2 mil) etch reusable-imbedding
Copper slag 16/40 mesh	15.13 kg/sq m (3.1 lb/sq ft)	0.40 sq m/min (4.36 sq ft/min)	0.05 mm (2 mil) etch reusable-imbedding

* These abrasives are normally reused.

an abrasive will dictate the depth of the profile on the steel it strikes. The size of the abrasive selected also will affect the number of peaks per square inch. Although abrasives can be recycled, they break down over time. Each abrasive type has its particular rate of breakdown expressed in pounds consumed per hour. To maintain the same degree of blast cleaning, new abrasive media should be added to the working mix at roughly the same rate as the abrasive disintegrates. And new blast material should be added on a daily basis to maintain the working mix.

j. SSPC-AB 1. The SSPC-AB 1 is a specification for evaluation of mineral and slag abrasive blast-cleaning media. It contains specifications and criteria for abrasive properties including: specific gravity, hardness, weight change on ignition, water-soluble contaminants, moisture content, oil content, and crystalline silica content.

7-4. Surface Preparation Standards and Specifications

a. Steel surfaces. The SSPC and NACE have developed surface preparation standards and specifications for steel surfaces. Blast-cleaning standards and specifications will be discussed in this paragraph. SSPC Painting Manual Volume 2 provides more detailed information for these standards. The written standards are supplemented by SSPC VIS 1-89, which photographically depicts the appearance of four grades of blast cleaning over four initial mill scale and rust grades. The standards are visually compared with the prepared surface to determine the degree of cleanliness achieved. The final two pages of VIS-1 illustrate a white metal blast cleanliness using three metallic and three nonmetallic abrasives. The resulting surfaces have slight color and hue differences caused by the type of abrasive media used. In contrast, NACE encapsulates metal test coupons in a plastic media rather than relying on photographic representation. Each encapsulated plate contains representative surfaces blast cleaned to the four grades of cleanliness. NACE standards are prepared for sand, steel grit, slag, and steel shot abrasives. The blast cleanliness specifications are:

(1) SSPC-SP 7 or NACE #4. Removal of all loose materials; tight materials may remain if they cannot be loosened by a dull putty knife.

(2) SSPC-SP 6 or NACE #3. Two-thirds of every square inch (surface area) is cleaned to white metal; one-third of every square inch (surface area) may have stains, streaks, discolorations only; pitted steel may have traces of rust/paint in pits.

(3) SSPC-SP 10 or NACE #2. Ninety-five percent of every square inch (surface area) is cleaned to white metal; 5 percent of every square inch (surface area) may have stains, streaks, or discoloration only.

(4) SSPC-SP 5 or NACE #1. One hundred percent of every square inch (surface area) must be clean and have a gray-white appearance.

b. Concrete surfaces.

(1) Sweep blasting. Concrete can be prepared by “sweep blasting.” The nozzle is held further from the surface than when blasting steel, and the blasting rate is much faster. Sweep blasting will remove any weak surface layers of concrete (laitance), open bug holes, and provide a sound, slightly roughened surface for coating adhesion. Abrasive blast cleaning of concrete can be performed, but lower nozzle pressures (275.6 to 344.5 kPa [40 to 50 psi]) should be used to avoid damaging the concrete by exposing heavy aggregate or reinforcement steel. ASTM D4259 covers three specific methods of surface preparation: mechanical cleaning using rotary impact, vertical impact, and circular grinding tools; water blast cleaning using high pressure water blasting equipment; abrasive blast cleaning using either dry abrasive blast equipment or dry abrasive blast equipment with water injection.

(2) Acid etching. ASTM D4260 provides the procedures for acid etching. Two purposes of acid etching are to neutralize the surface to be coated and to etch the surface to remove the glaze. The surface must be rinsed immediately after acid etching is performed to avoid formation of salts on the surface, which are difficult to remove. The surface should be re-etched if the texture is not of medium sandpaper texture after the first etching treatment. Acid etching will not remove grease or oil; therefore, if these substances are suspected to be present, the concrete should be scrubbed with detergent, soap, or a trisodium phosphate solution prior to acid etching. Steam cleaning also may be required. When concrete surfaces are steel troweled, they may become dense, smooth, and glazed and the paint will not adhere to the surface. In this situation, it may be desirable to etch the surface. A simple method to determine whether etching is required is to pour a few drops of water on the surface. Etching is not necessary if the water is quickly absorbed. Glaze may be removed by rubbing with an abrasive stone, lightly sandblasting, or allowing the surface to weather for 6 to 12 months. The glaze also may be removed by treatment with a solution of 3 percent zinc chloride plus 2 percent phosphoric acid to etch the surface. This solution is not flushed off but is allowed to dry to produce a paintable surface. Acid cleaning methods may be necessary in certain instances to neutralize concrete and masonry surfaces before applying a coating that is

sensitive to alkali. Detection of free alkali should be performed using pH paper, especially if acid washing or etching has been performed, in accordance with ASTM D4262.

(3) Problems with form release agents. Waxes or various resins are often used to prevent possible problems during stripping operations. These compounds vary considerably in their composition and their ability to support adhesion at a later date when an organic coating is applied. Subsequent adhesion testing always is required to determine whether or not form releases were used.

(4) Concrete curing agents. Concrete curing agents frequently are sprayed onto architectural and engineered concrete walls unless their use is specifically prohibited in the specification. However, if these agents are not used and if some form of moist-curing is not used on the concrete, crazing and/or shrinkage cracking probably will occur because of the rapid volume changes that act to create internal stresses within the hydrating matrix of the concrete. Blasting with an approved abrasive solves the problem of removing light contaminants and curing compounds from most concrete surfaces. Sometimes a second pass is required to remove the weak layer of laitance and to open any voids or larger honeycombs.

(5) Moisture content. Underground below grade concrete surfaces and concrete slabs or exterior walls subject to moisture may be subjected to excessive capillary moisture or hydrostatic pressure. This condition may be determined easily by a portable moisture meter instrument as well as by following the test method in ASTM D4263. This method involves taping a segment of plastic sheet to the concrete and allowing the sheet to remain in place for at least 16 hours; the sheet then is removed and the concrete surface as well as the sheet are visually examined for the presence of moisture.

c. Galvanized surfaces. Galvanized steel has a very smooth, comparatively hard surface; consequently, the lack of profile results in potential adhesion problems. The zinc may have a mill-applied surface treatment to prevent wet storage stain; this usually is a chromate passivation treatment. Unsuitable pretreatments can lead to delamination of applied paints. The methods of galvanized surface treatments follow.

(1) Solvent cleaning. When coating galvanized surfaces, certain procedures need to be considered to assure adequate coating adhesion. Oil or grease should be removed by wiping or scrubbing the surface with proper types of rags or brushes wetted with a suitable solvent. The final wiping should be done with clean solvent and clean rags or brushes so oil and other contaminants will be dispersed in a thin film over the entire surface. Suitable cleaning solvents include mineral spirits, turpentine, and high-flash naphtha. The manufacturer's recommendations for the use of solvents always should be followed. In certain instances, alkaline detergents such as trisodium phosphate may be used to remove residual oils. Surfaces cleaned with detergents must be thoroughly rinsed with water to remove alkaline residue. The water should be hot or under pressure, preferably both. Some materials may not be easily removed by these solvents and detergents, and stronger solvents such as acetone or methyl ethyl ketone may be required.

(2) Weathered galvanized steel.

(a) During the first few months of weathering, the layer of zinc corrosion products normally present on a weathered surface may be incomplete, depending on atmospheric conditions. During this period, the weathered substrate should be rinsed with clean water to remove soluble zinc salts, and the surface should be treated as newly galvanized material.

(b) When galvanized steel is completely weathered and all the bright zinc surface has changed to a dull surface layer, some paints will perform satisfactorily. The time needed for weathering varies with the local exposure conditions, and it can differ for different parts of a structure. A weathered surface may be difficult to clean completely; therefore, it may be more satisfactory to paint galvanized steel when it is new. Normal weathering produces a finely etched surface that will provide sufficient roughness for painting. Suitable paint will adhere quite satisfactorily to this type of surface, even though the reaction products generally are considered to cause some loss of adhesion. The slight etching of the weathered surface may be the controlling factor.

(c) Just how effective this weathering can be depends on the microstructure of the zinc surface and on stresses in the metal. Careful inspection is necessary to ensure that weathering has produced a dense, uniform, adherent coating. The surface zinc is expected to have under normal conditions contains a mixture of the zinc oxide, zinc carbonate, and basic zinc carbonate hydrates. Some indications suggest that optimum painting results can be obtained if weathering can be continued until iron-zinc alloy layers are exposed.

(d) Weathering will remove entrapped oil and chromates applied for wet storage stain control and allow the patina of adherent corrosion products to form.

(e) For a subsequent paint application, there should be some concern about the effect of temperature on this system. Some spalling has occurred at low temperatures, possibly because of incomplete weathering. This condition has been found even in conjunction with a zinc dust/zinc oxide primer that has given excellent results in two-coat systems in a wide variety of tests and services. Careful inspection ensures that weathering has been uniformly effective.

(f) The deliberate use of weathering as a pretreatment method of new zinc surfaces prior to painting is not a preferred practice because the minimum time needed for full weathering cannot be easily assessed and because it is difficult to clean a weathered surface completely (for example, to wash off soluble sulphates). In addition, the recognized pretreatments for painting permit more positive quality control, and the barrier effects of a weathered surface are indeterminate. However, in practice, paint on a weathered galvanized structure has a longer life than a comparable system on black steel.

(3) Brush-off blast cleaning. Galvanized surfaces can be prepared by brush-off blast cleaning. This procedure will etch the surface to enhance adhesion, but it also may remove the galvanizing and thereby defeat its purpose.

(4) Phosphatizing treatments.

(a) Currently, the most common chemical paint pretreatments for zinc-coated steel convert the surface to a nonreactive zinc phosphate. Most effective phosphatizing baths for zinc surfaces are mildly acidic. They contain orthophosphoric acid; zinc phosphate; oxidizing agents such as nitrates or chlorates; and a metallic ion accelerator such as iron, nickel, cobalt copper, or other metals below zinc in the electromotive series. One additional chemical constituent may be necessary to phosphatizing zinc-coated steel. The presence of aluminum in quantities of 0.1 to 0.5 percent in hot dip zinc coatings necessitates the use of an additional "accelerator" in the phosphatizing solution. The most common chemical ion for promoting phosphatizing on aluminum-bearing zinc is fluoride or other soluble metal fluorides.

(b) A typical liquid zinc phosphate treatment can be applied by brush, spray, or immersion, preferably after the zinc surface has been exposed by abrasion or etching. After 3 to 6 minutes, the surface should be washed with clean water and allowed to dry before application of the paint. This need for washing down after application makes it difficult to treat large structures, and this treatment should not be used if there is a danger of acid entrapment in joints because of poor rinsing. In this situation, a wash primer is indicated. One gallon of zinc phosphating solution will cover approximately 93 sq m (1,000 sq ft) of zinc surface. This treatment gives a strongly adherent coating under most conditions because it is formed by a reaction with the zinc surface. It also provides a good mechanical tooth for the paint because of the etching and fine capillary nature of the crystals that are formed. However, painting must take place soon after treatment to avoid pick up of surface contaminants.

(5) Wash primers.

(a) A variation of phosphate conversion coating is available in the form of wash primers. These primers consist of polyvinyl butyral resins to which are added zinc tetroxy chromate pigment and phosphoric acid, as well as certain phenolformaldehyde, cresolformaldehyde, or melamine resins to stabilize the primer or to obtain other film properties. Originally, wash primers came only in two containers that had to be mixed before using. Now, one-container wash primers have been developed. These primers are useful for large structures that will not fit into spray washers or tanks used for phosphate or chromate treatments. They are applied by spray application.

(b) The reactions involved are complex, but the net result is a passivation of the zinc surface, the formation of some zinc phosphate, and conversion of the resin into a relatively insoluble film. Although the range of paints that will adhere well to such films is somewhat smaller than for phosphatizing, a system based on wash primers can give satisfactory service. Their major advantage is that no rinsing is required. The mechanism of bonding is similar to that of the phosphate coating. The presence of pigment and a film-forming vehicle immobilize the zinc phosphate coating as it forms while the film is drying. In this respect, the wash primers are a combination pretreatment and primer.

(c) Wash primers must be applied in a thin coat to achieve good adhesion. The dry film thickness should not exceed 0.013 mm (0.5 mil). This is a potential source of failure, and the fact that the thickness should not exceed 0.013 mm (0.5 mil) should be especially emphasized.

(d) The wash primer should not be applied to a wet surface nor to a previously chromated or phosphatized surface because the reaction will be impeded and the adhesion affected. These wash primers must be primed and topcoated promptly because inherent resistance of wash primer films to moisture is low.

d. Aluminum surfaces.

(1) Maintenance of shop-applied coatings. Coated aluminum usually is covered with a factory-applied coating that has been applied under controlled conditions and baked

to obtain maximum adhesion. These coatings usually are rather thin. However, they are primarily an acrylic or vinyl acrylic, which have excellent weathering resistance. For the most part, aluminum surfaces with this type of coating are recoated or repaired where damage has occurred or when the coating has weathered to the point that a general recoating of the surface is necessary. There is little or no corrosion of the aluminum on these surfaces. Thus, maintenance and repair usually only involve the application of an additional coat (or coats) of a compatible topcoat over the previous coating. In this situation, the required surface preparation primarily involves a thorough washing to remove any chalk, dirt, grease, or other impurity; this step is followed by the recoating procedure.

(2) Aluminum corrosion. Occasionally, coated aluminum surfaces become corroded. The corrosion usually has the appearance of a white aluminum oxide that may form in small pinpoints in and around the break in the coating. On aluminum surfaces—such as those on the aluminum deck houses on ships, particularly where such structures are joined to a steel hull—aluminum corrosion can be extensive and there may be undercutting and considerable pitting of the aluminum surface. When aluminum is corroded, the surface should be abraded, and the abrasion should be light. If blasted, the abrasive used should be very fine, and the nozzle should be held a considerable distance from the surface. Aluminum is a soft metal that both cuts and warps easily.

e. Wood surfaces.

(1) Finish removal. The removal of paint and other film finishes is time consuming and may be a difficult process. However, removal may be necessary when a new surface must be prepared if, for example, the old surface is covered with severely peeled or blistered paint and cross-grain cracking has occurred from excessive paint buildup. This process is also necessary when a penetrating stain or water-repellent finish applied to a previously painted surface is desirable. There are several options for paint removal including sanding, using electrically heated paint removers and blow torches, chemical strippers, and sandblasting or spraying with pressurized water.

(a) Sanding. Disk or siding sanders equipped with a tungsten carbide abrasive disk of medium grit are effective in removing old paint. The method is faster than the others discussed here, and the tungsten carbide disk is less likely to clog than conventional sanding disks. The depth of cut for the sander can be set with the siding guide, but experienced operators often work freehand without the guide. The operator should be careful to remove only paint and not excess wood. After finishing with the disk sander, the surface should be smoothed somewhat by light hand sanding or with a straight-line power sander using 120-grit sandpaper in the direction of the wood grain.

(b) Heat. Electrically heated paint removers can be used to strip paint. The remover simply heats the paint, which causes it to separate from the wood. Although effective, this method is slower than sanding and requires at least a 1,000-watt heater to be effective. An open-flame blowtorch also may be used. A blowtorch is effective and inexpensive, but there is a constant danger of starting a fire within the walls of the building from flames that penetrate cracks in the siding.

(c) Chemical. Liquid paint and varnish removers—such as commercially prepared chemical mixtures, lye, or trisodium phosphate—also will remove paint from wood surfaces. However, the surface sometimes must be neutralized after removing the paint with chemical removers. Before repainting, the wood surface should be sanded in the direction of the grain. Strong caustic solutions, such as lye and trisodium phosphate, leave the wood surface extremely porous.

(d) Sandblasting and pressurized water spray. Blasting with sand or high pressure water also can be used to remove paint; however, these methods usually require the services of a professional. The sand particles or water can erode the wood as well as strip the paint. The softer earlywood is eroded faster than the latewood; this results in an uneven, rough surface that may not be suitable for painting. Approximately 4,134 to 13,780 kPa (600 to 2,000 psi) of pressure is used with water.