



Coatings - Surface Preparation

An Online Continuing Education Course for Engineers

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Introduction

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.

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.

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.

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.

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.

Solvent Cleaning (SSPC-SP 1)

Solvent cleaning 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.

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.

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.

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.

(1) 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.

(2) 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.

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.

(1) 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.

(2) 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.

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.

(1) 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.

(2) 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.

(3) 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.

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.

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.

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.

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.

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. 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.

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 per hour (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 course. 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.

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.

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.

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.

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.

Blast pot. The blast pot (or pot) is used in high-production blast machines at chemical plants, and other industrial cleaning operations. The pot capacity is determined by its abrasive capacity, the pot capacity, the moisture. Generally, when blast cleaning a pot that will allow 30 to 60 minutes of refilling is recommended. Either portable, mounted on wheels, or fixed (number of bags or pounds of abrasive without wheels, for high production addition, can be equipped with an efficient abrasive refilling. This is used on large blasting projects are treated at equal pressure on top and bottom. The blast machine consists of air inlet head, metering valve for regular refilling, easily opened hand hole that allows inspection 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.

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 the air volume at the nozzle. These fittings also cause wear inside the hose, resulting in an abrasive and air strike the edge of the hose. The screws that attach the external quick connect hoses must not penetrate through the hose. Leaks can occur around these screws. The universal jaws and replaceable gaskets provide a good seal. Quick couplings are available in brass, nylon. Brass has a considerably longer life than nylon and aluminum couplings are preferred because of their light weight.

The nozzle is a major element in the blasting process. Nozzle sizes are identified by the orifice. Diameters are measured in millimeters. For example, a 4.76-mm (3/16-in.) nozzle is designated No. 3, a 7.94-mm (5/16-in.) nozzle is designated a No. 5, and so forth. Nozzles are available to 15.9 mm (5/8 in.) in diameter. A 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

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