12.9. SURFACE PREPARATION

Surface preparation is a critical part of coating projects and must provide a surface that is compatible with the coating material to be applied. The main concerns in this aspect of protective coatings are the cleanliness of the surface required and the surface roughness or profile that essentially provide anchorage to the coating. It is believed that, of the cost of a coating job, as much as one-half to two-thirds goes for surface preparation and labor.

In some cases, it is impossible to provide the best prepared surface because there is insufficient money or time to do the job and/or it is not permitted because of possible product contamination, fire hazard, or some other reason. It must however be recognized that when there is a lesser surface preparation, the longevity of a coating system will likely be compromised.

The surface properties of the substrate to which a coating is applied will influence its performance. Surfaces in compression often increase coating performance because they tend to be attacked less than surfaces that are less stressed; on the other hand, surfaces in tension may cause coatings to fail earlier than they would otherwise. Differences in expansion rates between a coating and a substrate impose stresses on the coating which may lead to cracking and failure. Additionally, both inadequate and excessive coating thickness may lead to failure.

12.9.1. Principles of Coating Adhesion

Of the cleaning methods available to provide the cleanest and largest effective surface per unit area, the use of abrasive blasting produces a surface closest to the ideal surface profile. However, the best of blasted surfaces can still be badly contaminated with residual metal oxides, extraneous dirt, particles of the abrasive materials, and adsorbed gases on the metal. As a consequence, it is necessary to construct coating formulations with the maximum capacity to compete for and lock into the available bonding sites. For this reason, coating materials containing polar functionalities such as OH, and others, particularly C=O functional groups provide the best adhesion to a metal substrate.

Good wetting of the surface by liquid coatings is obviously a requisite for good adhesion. The coating material must remain stable to maintain adequate adhesion. If embrittlement occurs through oxidation, cross-linking, or volatilization of a portion of the coating, the resultant shrinkage stresses in the coating can pull it from the surface. Any loss of adhesion from such sources is obviously undesirable.

12.9.2. Abrasive Cleaning

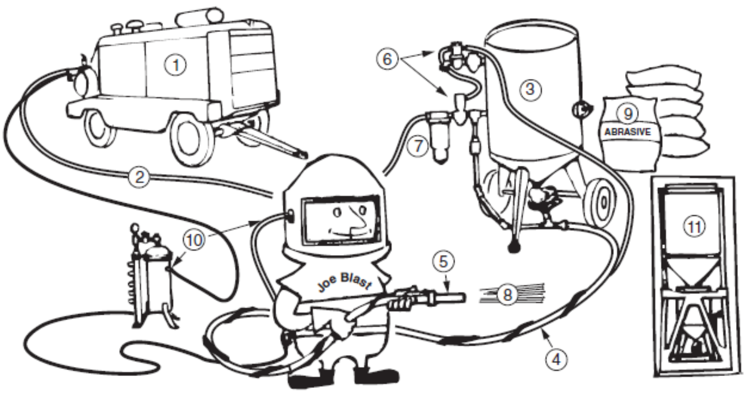
The two main methods of abrasive cleaning before application of coatings are centrifugal blasting and air pressure blasting. Centrifugal blasting is accomplished by machines that propel abrasives against the surface to be cleaned by imparting velocity to the particles by means of a rapidly rotating wheel. The abrasive material (commonly grit, and/or shot, but also specialized abrasives such as cut wire, various hard oxides, or carbides) impinges against the surface, removing both the surface contamination and making a pattern of indentations, such as shown in Fig. 12.16. This pattern, consisting of peaks and valleys, serves as anchors to the chemical bonding forces of materials applied to the surface. The total surface area exposed in a profile of this type is obviously much greater than that exposed by a smooth surface.

Centrifugal blasting machines are of most economical when continuous or intermittent shipments of steel are cleaned by the wheel machine, such as in a steel fabrication shop. All steel, as it is received, can be run through the blasting machine and immediately primed with a preconstruction primer to provide an advantageous start on the coating system. Without this initial treatment of the steel, a more tedious, expensive, and difficult blast cleaning operation may be required after erection. Even then, overlapping surfaces and many recesses in the erected structure cannot be properly cleaned and primed, and must be touched-up by air pressure blast cleaning.

Field blasting involves injecting a supply of abrasive into a rapidly moving air stream and expelling it through a nozzle of the proper configuration so that the solid particles impinge against the surface to be cleaned (Fig. 12.30). A standard commercial setup for pressure blasting is illustrated in Fig. 12.31.[5]

Figure 12.30 Dry abrasive blasting of (a) a ship hull and (b) a pipeline. (Courtesy of Barton Mines Co.)

Figure 12.31 Typical rig for compressed air abrasive blasting: (1) an adequate and efficient air supply (compressor); (2) air hose, couplings, and valves of ample size; (3) a portable, high-production blast machine; (4) the correct size of antistatic pressure hose with externally fitted quick couplings; (5) high-production venturi nozzle; (6) pneumatic remote control valves for safety and cost savings; (7) an effective moisture separator; (8) high nozzle air pressure; (9) the proper blasting abrasive; (10) a safe air-fed helmet and air purifier; (11) inset showing bulk abrasive storage hopper over pressure blast vessel equipped with remote control valves—when pop-up filling valve opens, abrasive from the hopper fills the machine.



For smaller items, or for touch-up, venturi-abrasive blast cleaning cup guns may be used. The abrasive in this equipment is stored in a small container fastened beneath the blasting gun and educted into the air stream. This equipment is used by hobbyists, by automotive repainting shops, and for small areas or inside shops for work on small pieces.

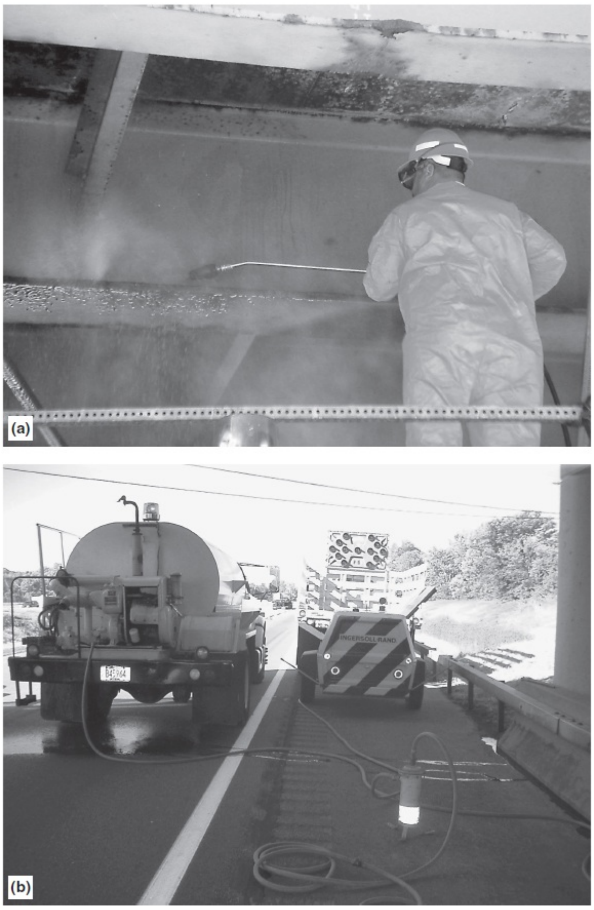
The skill of the workman in keeping the blast stream at the right angle and at proper distance to the work while making sure that all areas are properly cleaned are a prerequisite to a good job. NACE International and the SSPC have jointly adopted a schedule of five degrees of cleaning steel by blasting operations. These are described briefly as follows:

1. *NACE 1/SSPC 5:* White metal blast cleaned: Produces a gray-white, uniform, metallic color with no obvious foreign material remaining.
2. *NACE 2/SSPC 10:* Near-white blast cleaned: Foreign matter is removed, but with differing shades of metallic gray surface allowable.
3. *NACE 3/SSPC 6:* Commercial blast cleaned: Rust and foreign matter is removed, except for tight specks of oxide or paint uniformly distributed over a minor portion of the surface; some residues in pits.
4. *NACE 8/SSPC 14:* Industrial blast cleaned: Similar to NACE 3/SSPC 6, except that evenly disbursed small islands of mill scale are also allowed to remain on the cleaned surface.
5. *NACE 4/SSPC 7:* Brush-off blast cleaned: Light mill scale and tightly adhered rust are allowed if distributed over the surface.

12.9.3. Water Jetting

Water jetting involves playing a stream of water moving at a high velocity (ca. 35–275 MPa) against a surface to be cleaned (Fig. 12.32). The energy imparted to the water dislodges the scale or contamination from the surface to reveal the substrate profile underneath existing coatings. This method is especially effective in removing resilient materials which may not be removed efficiently by abrasives, or in cleaning surfaces of complex cross section such as gratings or sieves. Water also can be used when grit blasting is a fire or environmental hazard. Water jetting excels at removing water soluble salts from a surface. The coatings industry uses water jetting primarily for recoating or relining projects where there is an adequate preexisting profile.

Figure 12.32 Water-jetting operation (a) and pressurizing equipment (b). (Courtesy of Termarust Technologies.)



NACE International and the SSPC have jointly adopted a schedule of four degrees of cleaning steel with water jetting to parallel the degrees of cleaning with abrasives. NACE No. 5: SSPC SP-12 describes the degrees briefly as follows:

WJ-1: "Clean to Bare Substrate" surface is free of all visible rust, dirt, previous coatings, mill scale, and foreign matter.

WJ-2: "Very Thorough or Substantial Cleaning" allows for randomly dispersed stains of rust, tightly adherent thin coatings, and other tightly adherent foreign matter. The staining or tightly adherent matter is limited to a maximum of 5% of each unit area of the surface.

WJ-3: "Thorough Cleaning" allows staining or tightly adherent matter to a maximum of 33% of each unit area of the surface.

WJ-4: "Light Cleaning" provides a lesser degree of cleaning than thorough cleaning (WJ-3). The objective of light cleaning is to allow as much of an existing coating or foreign matter to remain as possible and to roughen the surface prior to coating application.

12.9.4. Wet Abrasive Blasting

Abrasive wet blasting is variation of abrasive particle air blasting that involves introducing abrasives into a rapidly moving stream of water and air. The combination obviously cuts down on the atmospheric pollution experienced when using the dry abrasive alone. Inhibitors are often added to the water to reduce rusting of the “clean” steel before the prime coat is applied.

Wet abrasive blast cleaning systems commonly encountered include: air/water/abrasive blast cleaning, which uses compressed air to propel the abrasive, pressurized water/abrasive blast cleaning, which uses water to propel the abrasive; and a combination of pressurized water/pressurized air with abrasives. The abrasive defines the profile.

12.9.5. Other Surface Preparation Methods

Although abrasive blasting and water jetting are widely used for plants, ships, bridges, and other large systems, there is a great variety of other methods that can be used to prepare a surface for the final coating application.

For certain surfaces, it is only necessary to wipe the surface with a selected solvent to remove oil, grease, and loose dirt. The use of detergent solutions, isopropanol, ketones, and aliphatic and aromatic hydrocarbons for this purpose can be effective. The major requirement for the process is that the wipe shall not leave a residual contaminant, but rather a clean, dry metal surface. Such a cleaning procedure is used on previously cleaned steel, stainless steel surfaces, and old paint films before overcoating, or on dirty steel prior to abrasive blasting.

A surface that is dry and free from oily residues can be obtained by suspending the item in a closed booth in which the vapors of a solvent are condensing. The vapors condense on the part, coalesce, dissolve the contaminant, and drip from the surface. 1,1,1 Trichloroethane (Trichlor) and perchloroethylene have been widely used solvents for this purpose. However, these otherwise excellent solvents are being phased out due to their high health and environmental risk. Many production line items are cleaned in this manner before coating. Baths of cleaning solvents may also be prepared to remove oily or loose contaminants. Aqueous detergent systems, emulsion systems, and alkali baths are also used with good mechanical or ultrasonic agitation to ensure scouring of the surface by the liquid.

Hot water heaters or steam generators (“gennys” or “gensets”) are available for use in the field to clean metals, coatings, or concrete surfaces. Strong detergents or alkalies are added to the water to emulsify oils and similar organic contaminants on contact. Impingement of the hot, strong emulsifying agent on the surface removes even heavy soil at a rapid rate. This method can often be used with good results prior to abrasive blasting.

The process of flame cleaning has found greater favor in Europe than in America. A wide oxy-acetylene flame is played on the surface of steel parts to produce two effects. First, the heavier portions of rust scale or mill scale will pop from the surface because of the thermal expansion difference between the scale and the substrate. Second, the surface is freed of moisture if sufficient heat is applied to the substrate. Removal of loose rust particles after the treatment, followed by prompt coating can produce an adequate coating procedure for certain applications. When using an open flame for cleaning, extreme caution must be used to prevent fires and explosions.

Manual or power tool cleaning of an oxidized surface is sometimes the least thorough and slowest means of surface preparation. However, cost, location of the part, or the availability of tools often dictates the use of such a technique. Normally, only the top loose layers of rust on a piece of steel are removed through this method. Moisture and other contaminants remain in the residual scale. It is important to consider the compatibility of the tool with the substrate when using brushes or grinding wheels. For instance, the use of steel or bronze brushes to clean aluminum can leave sufficient heavy metal (Cu or Fe) contamination on the surface to initiate severe pitting of the metal. An air-actuated needle gun is also available to clean small areas by mechanical action. Barrel cleaning, where parts are placed in a rotating drum containing an abrasive, is also used for small parts.

Great quantities of sheet, plate, coil stock, and other forms of metal are pickled in production mills or by metal recyclers. On steel products, the goal is the removal of the mill scale formed on the surface during hot processing (>575°C). The bath is an aqueous hot hydrochloric, sulfuric, or less frequently phosphoric acid solution containing an inhibitor. The inhibitor must allow uniform attack on the metal, as little metal loss as possible, and when pickling steel, must leave a clean surface free of carbon smut.

The pickling process is conducted in large vats and does not lend itself readily to use in the field. Acid gels or washes based on phosphoric acid can be prepared which will lightly etch a steel surface when held on the surface once the heavy scale has been removed. This type of “pickling” is restricted to smaller articles where the acid can be managed properly.