Section 7: APPLICATION

7.1 Introduction. This section provides general information on paint application and on activities associated with application such as paint storage and mixing. Application procedures discussed include brushing, rolling, and spraying (conventional air, airless, air-assisted airless, high-volume low-pressure, electrostatic, plural component, thermal, and powder).

7.2 Paint Storage Prior to Application. The installation industrial hygienist should be consulted about local regulations for paint storage, since storage of paint may be subject to hazardous product regulations. To prevent premature failure of paint material and to minimize fire hazard, paints must be stored in warm, dry, well ventilated areas. They should not be stored outdoors, exposed to the weather. The storage room or building should be isolated from other work areas. The best temperature range for storage is 50 to 85 degrees F. High temperatures may cause loss of organic solvent or premature spoilage of water-based paints. Low temperature storage causes solvent-borne coatings to increase in viscosity, and freezing can damage latex paints and may cause containers to bulge or burst. (When paint is cold, a 24-hour conditioning at higher temperatures is recommended prior to use.) Poor ventilation of the storage area may cause excessive accumulation of toxic and/or combustible vapors. Excessive dampness in the storage area can cause labels to deteriorate and cans to corrode. Can labels should be kept intact before use and free of paint after opening so that the contents can readily be identified.

The paint should never be allowed to exceed its shelf life (normally 1 year from manufacture) before use. The stock should be arranged, so that the first paint received is the first paint used. Paint that has been stored for a long period of time should be checked for quality and dry time before use. Quality inspection procedures are described in par. 9.5.5.

7.3 Preparing Paint for Application

7.3.1 Mixing. During storage, heavy pigments tend to settle to the bottom of a paint can. Prior to application, the paint must be thoroughly mixed to obtain a uniform composition. Pigment lumps or caked pigment must be broken up and completely redispersed in the vehicle. Incomplete mixing results in a change of the formulation that may cause incomplete curing and inferior film properties. However, caution must be used not to overmix waterborne paints since excessive foam can be created. Constant mixing may be required during application for paints with heavy pigments, such as inorganic zincs.

Mixing can be done either manually or mechanically. Two types of mechanical mixers are commonly used: ones which vibrate and ones which stir with a propeller. Since manual mixing is usually less efficient than mechanical mixing, paints should only be manually mixed when little mixing is needed because there is limited pigment settling or when mechanical mixing is not possible. Vibrator-type mixers should not be used with partly full cans of paint. This can cause air to become entrained in the paint which, if applied, may lead to pinholes in the dry film.

When pigments form a rather hard layer on the bottom of the can, the upper portion of the settled paint can be poured into a clean container (Figure 7), so that the settled pigment can more easily be broken up and redispersed to form a smooth uniform thin paste. When mixing manually, lumps may be broken up by pressing them against the wall of the can. It is essential that settled pigments be lifted from the bottom of the can and redispersed into the liquid. Once the material is uniform, the thin upper portion of the container is slowly poured into the uniform paste while the paint is stirred. Stirring is continued until the entire contents is uniform in appearance. No more paint should be mixed than can be applied in the same day. Paint should not be allowed to remain in open containers overnight.

7.3.1.1 Mixing Two-Component Coatings. Epoxies and polyurethanes are commonly used two-component coatings. The base component, A, contains the pigment, if any. The B component contains the curing agent. The two components must be mixed in the ratio specified by the coating manufacturer on the technical data sheet, unless the coating is being applied using a plural component gun (refer to par. 7.5.4.5). Usually the materials are supplied so that the contents of one can of component A is mixed with the contents of one can of component B. Failure to mix the components in the proper ratio will likely result in poor film formation. Binder molecules are cross-linked in a chemical reaction upon mixing of the two components. Unless the two components are mixed together, there will be no chemical reaction and no curing of the paint.

a) Mixing. Two-component coatings are preferably mixed with a mechanical stirrer as follows:

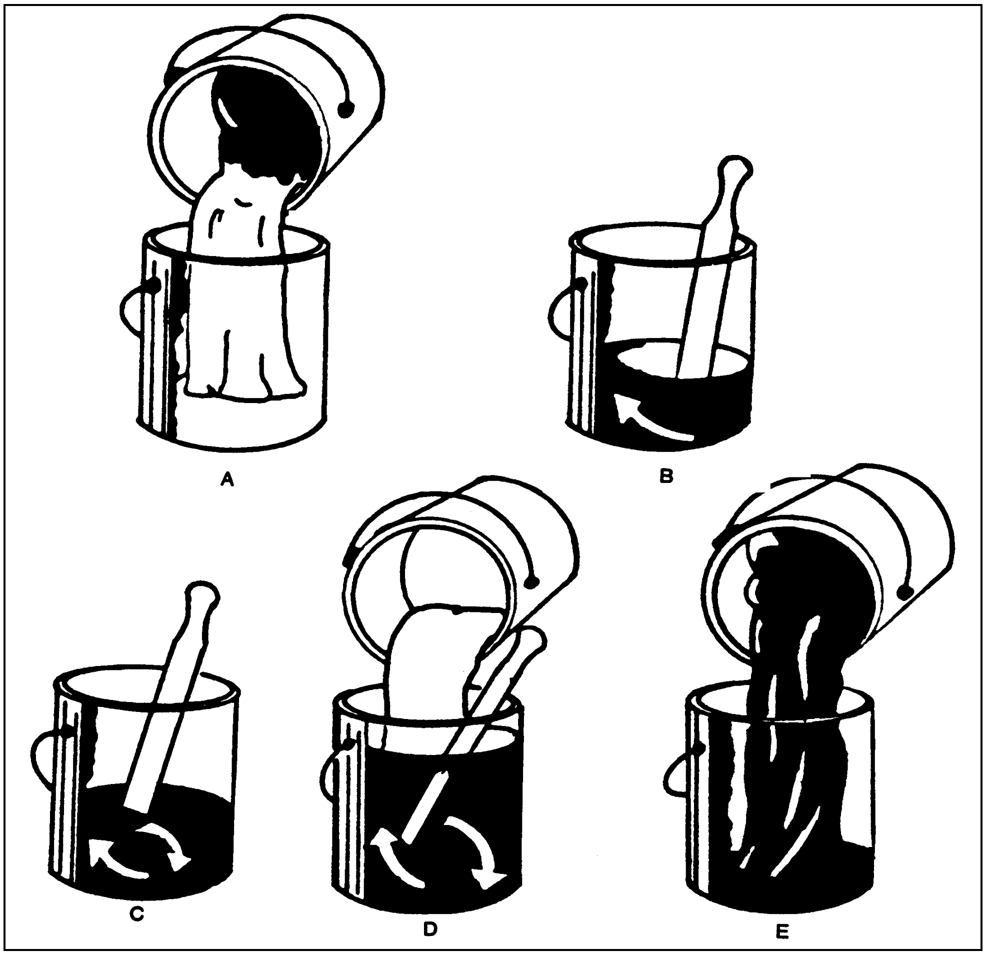


Figure 7
Illustration of Mixing and "Boxing" One-Component Paint: A - Pouring Off Pigment-Poor Vehicle, B and C - Mixing Pigment to Form Smooth Paste, D - Pouring in Vehicle and Mixing, E - Boxing Paint

(1) The base component is mixed to disperse settled pigment. If necessary, some of the thin, upper portion may be poured off before stirring to make it easier to disperse the pigment. When the upper portion is poured off, it must be mixed back with the bottom portion before the two components are mixed together.

(2) While continuing to stir, the two components are slowly mixed together. No more than a few gallons should be mixed at a time, or no more than that specified by the coating manufacturer, since heat is usually generated upon mixing because of the chemical cross-linking reaction. Excessive heat may lead to premature curing of the coating, reducing the pot life.

(3) The two combined parts are agitated until they are of smooth consistency and of uniform color. (Often the color of the two components is different.)

b) Induction. Some two-component paints must stand for approximately 30 minutes after mixing before application. This time is called the induction time. During induction, the chemical reaction proceeds to such an extent that the paint can be successfully applied. However, some formulations of two-component paints do not require any induction time and can be applied immediately after mixing the two components. Material specifications and manufacturer's recommendations must be followed carefully. Induction time will depend on temperature of the paint.

c) Pot Life. Pot life is the time interval after mixing in which a two-component paint can be satisfactorily applied. Paints low in VOC content often have a reduced pot life. The chemical reaction that occurs when two component paints are mixed accelerates with increasing temperature. Thus, a paint's pot life decreases as the temperature increases. Above 90 degrees F, the pot life can be very short. (Curing time of the applied coating is also faster at higher temperatures.) Pot life is also affected by the size of the batch mixed, because the chemical reaction produces heat. The larger the batch, the more the heat produced and the faster the curing reaction proceeds. Thus, the shorter the pot life. Paint must be applied within the pot life. The coating manufacturer's recommendations must be followed carefully. Mixed two-component paint remaining at the end of a shift cannot be reused and must be discarded. Lines, spray pots, and spray guns must be cleaned during the pot life of the paint.

7.3.2 Thinning. Usually thinning to change the viscosity of liquid paint should not be necessary. A manufacturer formulates paint to have the proper viscosity for application. If thinning is necessary, it must be done using a thinner recommended by the coating manufacturer. Also, the amount used should not exceed that recommended by the coating manufacturer. Prior to adding the thinner, the temperature of the coating and the thinner should be about the same. The thinner must be thoroughly mixed into the paint to form a homogeneous material. Some "false-bodied" or "thixotropic" paints are formulated to reach the proper application viscosity after stirring or during brush or roller application. Undisturbed in the can, they appear gel like, but upon stirring or under the high shear of brush or roller application, these materials flow readily to form smooth films. Upon standing, the coating in the can will again become gel-like. Because of this property, thixotropic coatings may require constant agitation during spray application.

7.3.3 Tinting. Tinting should be avoided as a general practice. If materials are tinted, the appropriate tint base (e.g., light and deep tones) must be used. Addition of excessive tinting material may cause a mottled appearance or degrade the film properties (e.g., adhesion). Also, tinting should only be done with colorants (tints) known to be compatible with the base paint. No more than 4 ounces of tint should be added per gallon of paint.

7.3.4 Straining. Usually, paint in freshly opened containers should not require straining. However, mixed paint having large particles or lumps must be strained to prevent the film from having an unacceptable appearance or clogging spray equipment. Straining is especially important for inorganic zinc coatings. Straining is done after mixing, thinning, and tinting is completed by putting the paint through a fine sieve (80 mesh) or a commercial paint strainer.

7.4 Weather Conditions Affecting Application of Paints. Paint application is a critical part of a complete paint system. Many of the newer paints are more sensitive to poor application procedures and environmental conditions than oil paints. Four main weather conditions must be taken into account before applying coatings: temperature, humidity, wind, and rain or moisture. The paint manufacturer's technical data sheets should be consulted to determine the limits for these conditions as well as other constraints on application of the paint. Applying paints outside the limits is likely to lead to premature coating failure.

7.4.1 Temperature. Most paints should be applied when the ambient and surface temperature is between 45 degrees F and 90 degrees F. Lacquer coatings such as vinyls and chlorinated rubbers, can be applied at temperatures as low as 35 degrees F. There are other special coatings that can be applied at temperatures below 32 degrees F but only in strict compliance with manufacturer's instructions. Application of paints in hot weather may also cause unacceptable films. For example, vinyls may have excessive dry spray and latex paints may dry before proper coalescence, resulting in mud-cracking. In all cases painting must be done within the manufacturer's acceptable range. Also, the temperature of the paint material should be at least as high as the surface being painted. Paint should not be applied when the temperature is expected to drop below 40 degrees F before the paint has dried (except when allowed in the manufacturer's instructions).

7.4.2 Humidity. Ensuring the proper relative humidity during application and cure can be essential for good film performance. However, different types of coatings require different relative humidities. The coating manufacturer's technical data sheet should be consulted. Some coatings cure by reacting with moisture from the air (e.g., moisture-curing polyurethanes, silicones, and inorganic zincs). These coatings require a minimum humidity to cure. However, too high a humidity may cause moisture-curing coatings to cure too quickly resulting in a poorer film. In addition, too high a humidity may cause blushing (whitish cast on surface of dry film) of some solvent-borne coatings. Blushing is caused when the surface of a coating film is cooled by evaporation of a solvent to such an extent that water condenses on the still wet film. Excessive humidity may also cause poor coalescence of latex coatings since the coalescing agent may evaporate before enough water evaporates to cause coalescence of the film.

7.4.3 Wind. Wind can cause a number of problems during spray application. These include uncontrollable and undesirable overspray and dry spray caused by too fast evaporation of the solvents. The wind velocity at which these undesirable effects occur depends upon the material being applied and the application parameters. Wind can also blow dust and dirt onto a wet surface which could lead to future paint breakdown.

7.4.4 Moisture. Paint should not be applied in rain, wind, snow, fog, or mist, or when the surface temperature is less than 5 degrees F above the dew point. Water on the surface being painted will prevent good adhesion.

7.5 Methods of Application. The most common methods of application are brush, roller, and spray. They are discussed in detail below. Paint mitts are recommended only for hard to reach or odd-shaped objects such as pipes and railings when spraying is not feasible. This is because it is not possible to obtain a uniform film that is free of thin spots with mitt application. Foam applicators are useful for touch-up or trim work. Dip and flow coat methods are beyond the scope of this handbook. Of the three primary methods, brushing is the slowest, rolling is faster, and spraying is usually the fastest of all. A comparison of approximate rates of application by one painter of the same paint to flat areas is listed in Table 10.

Table 10
Approximate Rates of Paint Application
(From SSPC Good Painting Practice)

Method	Square Feet Applied in 8 Hour Day
Brush	800 - 1400
Roller	2000 - 4000
Air Spray	4000 - 8000
Airless Spray	8000 - 12,000

7.5.1 Selection of Application Method. The choice of an application method depends on the type of coating, the type of surface, environmental factors, and cleanup. Alkyd coatings can easily be applied by brush, but fast drying coatings, such as vinyls, are difficult to apply by brush or roller. Brushing is the preferred method for small areas and uneven or porous surfaces, while rolling is practical on large flat areas. Also, brushing of primers over rusted steel and dusty concrete is preferred over spraying. (Note that applying paint over these substrates should be avoided, if possible.) Spraying is usually preferred on large areas and is not limited to flat surfaces. Spraying may not be feasible is some locations and in some environments because of the accumulation of toxic and flammable fumes or overspray.

7.5.2 Brush Application. Brushing is an effective method of paint application for small areas, edges, corners, and for applying primers. Brush application of primers works the paint into pores and surface irregularities, providing good penetration and coverage. Because brushing is slow, usually it is used only for small areas or where overspray may be a serious problem. Brush application of paint may leave brush marks with paints that do not level well, thus creating areas of low film thickness.

Even a second coat of paint may leave the total coating system with thin and uneven areas that may lead to premature failure.

Brushes are made with either natural or synthetic bristles. A drawing of a typical paint brush is shown in Figure 8. Chinese hog bristles represent the finest of the natural bristles because of their durability and resiliency. Hog bristles are also naturally "flagged" or split at the ends. This permits more paint to be carried on the brush and leaves finer brush marks on the applied coating. Horsehair bristles are used in cheaper brushes but are an unsatisfactory substitute for hog hair. Nylon and polyester are used in synthetic bristles or filaments. The ends are flagged by splitting the filament tips. Synthetic bristles absorb less water than natural bristles and are preferred for applying latex paints. However, synthetic bristles may be softened by strong solvents in some paints. Thus, natural bristles are preferred for application of paints with strong solvents.

Brushes are available in many types, sizes, and qualities to meet the needs for different substrates. These types include wall, sash and trim (may be chisel or slash-shaped), and enamel (bristles are shorter). It is important to use high quality brushes and keep them clean. Brushes with horsehair or with filaments that are not flagged should be avoided. The brush should be tapered from side to center (see Figure 8).

7.5.2.1 Procedure for Brush Application

a) Shake loose any unattached brush bristles by spinning the brush between the palms of the hand and remove the loose bristles.

b) Dip the brush to cover one-half of the bristle length with paint. Remove excess paint on the brush by gently tapping it against the side of the can.

c) Hold the brush at an angle of about 75 degrees to the surface. Make several light strokes to transfer the paint to the surface. Spread the paint evenly and uniformly. Do not press down hard but use a light touch to minimize brush marks. If there is time before the paint sets up, cross-brush lightly to eliminate excessive brush marks.

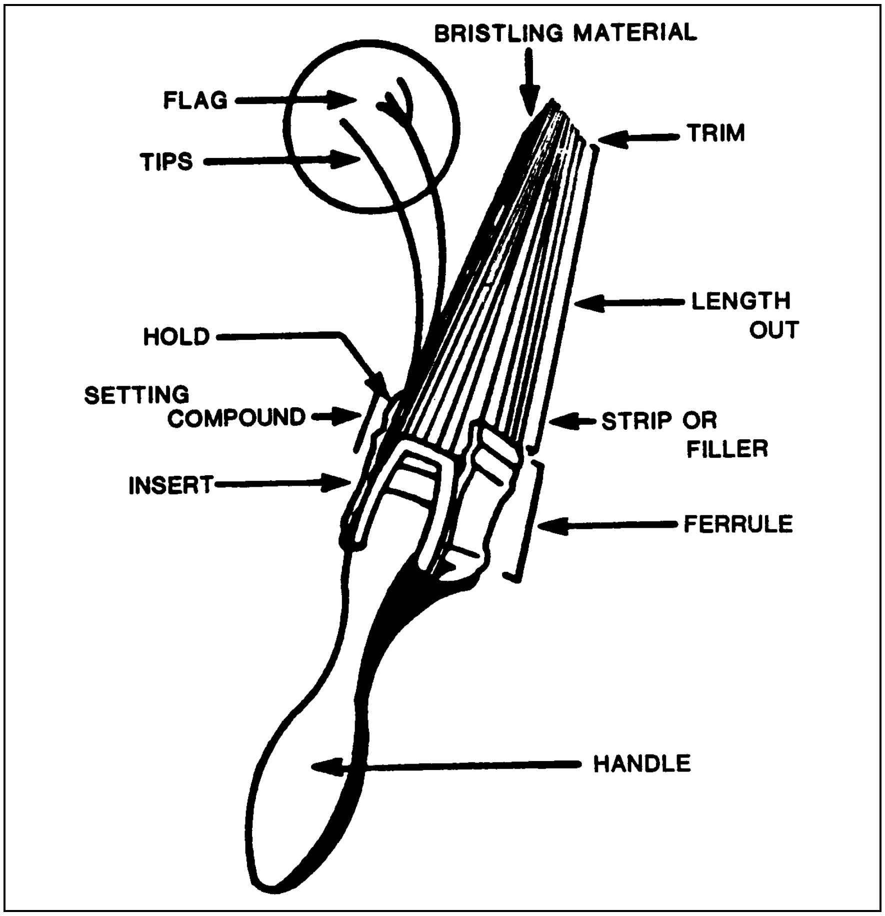


Figure 8
Illustration of Parts of Paint Brush

d) Confine painting to one area so that a "wet edge" is always maintained. Apply paint to a surface adjacent to the freshly painted surface sweeping the brush into the wet edge of the painted surface. This helps to eliminate lap marks and provides a more even coating film.

7.5.3 Roller Application. Roller application is an efficient method for flat areas where the stippled appearance of the dry film is acceptable. However, paint penetration and wetting of difficult surfaces is better accomplished by brush than roller application. Thus, brush application of primers is preferred over roller application.

A paint roller consists of a cylindrical sleeve or cover which slips onto a rotatable cage to which a handle is attached. The covers vary in length from 1 to 18 inches and the diameter from 1.5 to 2.25 inches. A 9-inch length, 1.5-inch diameter roller, is common. The covers are usually made of lamb's wool, mohair, or synthetic fibers. The nap (length of fiber) can vary from 0.25 to 1.25 inches. Longer fibers hold more paint but do not give as smooth a finish. Thus, they are used on rougher surfaces and chain link fence, while the shorter fibers are used on smooth surfaces. Use of extension handles makes the application of paint to higher surfaces easier. However, use of a long extension handle usually results in a less uniform film. Use a natural fiber roller (for example, wool-mohair) for solvent base paints and a synthetic fiber roller for latex paints.

7.5.3.1 Procedures for Roller Application. Rollers are used with a tray which holds the coating or a grid placed in a 5-gallon can (Figure 9). Application procedure is described below.

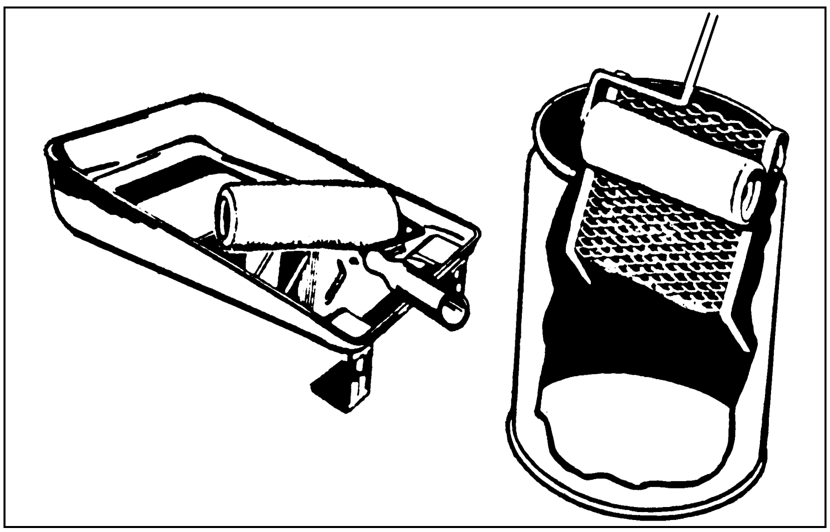


Figure 9
Equipment Used in Applying Paint by Roller

a) If a tray is being used, fill it half full with premixed paint. If a grid or screen is being used, place it at an angle in the can containing premixed paint.

b) Immerse the roller completely in the paint and remove the excess by moving the roller back on the tray or grid. Skidding or tracking may occur if the roller is loaded with too much paint.

c) Apply the paint to the surface by placing the roller against the surface forming a "V" or "W" of a size that will define the boundaries of the area that can be covered with the paint on a loaded roller. Then roll out the paint to fill in the square area. Roll with a light touch and medium speed. Avoid letting the roller spin at the end of a stroke. Always work from a dry adjacent surface to a wet surface. The wet edge should be prevented from drying to minimize lap marks.

d) Use a brush or foam applicator to apply paint in corners, edges, and moldings before rolling paint on the adjacent areas.

7.5.4 Spray Application. Spray application is the fastest technique for applying paint to large areas. Spray application also results in a smoother, more uniform surface than brushing or rolling. There are several types of equipment: conventional air, airless, air-assisted airless, high-volume, low-pressure (HVLP), electrostatic, multi-component, thermal, and powder. Conventional air and airless were most commonly used. However, with changing VOC requirements the other methods are being used more. Air or air-assisted methods of spraying, including HVLP, rely on air for paint atomization. Jets of compressed air are introduced into the stream of paint at the nozzle. The air jets break the paint stream into tiny particles that are carried to the surface on a current of air. The delivery of the paint to the nozzle may be assisted using hydraulic pressure. In airless spray, paint is forced through a very small nozzle opening at very high pressure to break the exiting paint into tiny droplets. A general comparison of properties of conventional air and airless spray are given in Table 11. Note that specific application rates, the amount of overspray, and other properties depend to a great extent upon the type of paint, and may vary from those listed in the table. Air methods other than conventional have been developed to overcome some of the environmental and other concerns of air and airless spray. These differences are discussed separately for each method below.

7.5.4.1 Conventional or Air Spray Equipment. The conventional method of spray application is based on air atomization of the paint. The basic equipment (air compressor, paint tank, hoses for air and paint, spray gun) is shown in Figure 10. The coating material is placed in a closed tank (sometimes called a pot) connected to the nozzle by a hose and put under regulated pressure using air from the compressor. A hose from the air compressor to the nozzle supplies the air required for atomization of the paint. The tank may be equipped with an agitator for continuously mixing paints with heavy pigments. The air compressor must have sufficient capacity to maintain adequate and constant air pressure and airflow for paint atomization at the nozzle, for paint flow from the tank to the nozzle, for powering the agitator and other job-site requirements. A constant flow of air from the compressor is required for proper painting. Loss of pressure at the nozzle can cause pulsating delivery of the paint as opposed to the desired constant flow. (Data sheets from paint manufacturers give recommended air pressures for spraying.)

a) Air Hose. The air hose connecting the compressor to the tank must be of sufficient diameter to maintain adequate air pressure. Required diameter of the fluid hose connecting the gun and tank depends on volume and pressure of paint required at the gun. The hose should be kept as short as possible, especially when spraying coatings with heavy pigments, to avoid settling of pigments within the supply hose. Also, the fluid hose must be resistant to paints and solvents that flow through it. As with blasting equipment, the air supply must be free of moisture, oil, and other impurities. Oil and water should be removed by separator or extractor attachments to the compressor.

Table 11
Comparison of Conventional Air and Airless Spray

Property	Conventional Air	Airless
Coverage, sq ft/day	4-8000	6-10,000
Overspray	Considerable	Some
Transfer efficiency	Poor (about 30	Fair (35-50)
"Bounce back"	percent)	Minor
Hoses	Significant	1 (fluid)
Penetration of corners,	2 (air and fluid)	
crevices and cracks		Moderate
Film build per coat	Fair	Good
Versatility	Fair	Fair
Paint clogging problems	Good	More
Operator control	Few	Poor
Safety during painting	Good	Poor
Safety during cleanup	Fair	Poor
	Fair	

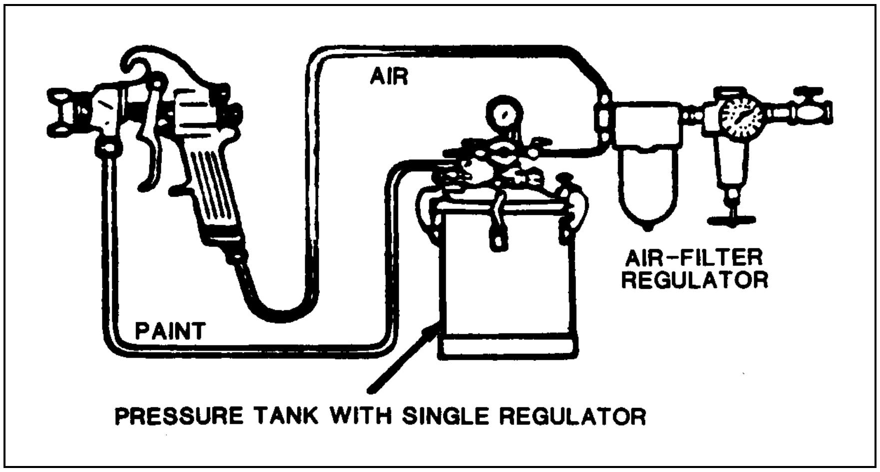


Figure 10
Schematic Drawing Illustrating Basic Parts of Conventional Air Spray Application Equipment

b) Gun or Nozzle. The gun or nozzle is a relatively complex device (Figure 11). It consists basically of 10 parts:

(1) Air nozzle or cap that directs the compressed air into the stream of paint to atomize it and carry it to the surface.

(2) Fluid nozzle that regulates the amount of paint released and directs it into the stream of compressed air.

(3) Fluid needle that controls the flow of fluid through the nozzle.

(4) Trigger that operates the air valve and fluid needle.

(5) Fluid adjustment screw that controls the fluid needle and adjusts the volume of paint that reaches the fluid tip.

(6) Air valve that controls the rate of airflow through the gun.

(7) Side port control that regulates the supply of air to the air nozzle and determines the size and shape of the spray pattern.

(8) Gun body and handle designed for easy handling.

(9) Air inlet from the air hose.

(10) Fluid inlet from fluid hose.

c) Air Nozzle. Two general types of air nozzles are available: external atomization and internal atomization. In both types, outer jets of air atomize the wet paint (see Figure 12). In the external type, paint is atomized outside the nozzle, while in the internal type paint is atomized just inside the nozzle opening. The type selected depends on the type of paint to be sprayed and the volume of air available. The external type is the more widely used. It can be used with paints and most production work. The spray pattern can be adjusted. A fine mist can be obtained which can result in a smooth even finish. Nozzle wear and buildup of dry material are not major problems. The internal-mix air nozzle requires a smaller volume of air and produces less overspray and rebound than the external type. The size and shape of the spray pattern of the internal-mix nozzle cannot be adjusted. Catalyzed and fast drying paints tend to clog the openings of internal-air nozzles. These coatings should be sprayed with an external-mix nozzle.

d) Setting-Up, Adjusting Equipment, and Shutting-Down Procedures. Both the pressure on the paint and the air pressure at the gun must be properly regulated to obtain the optimum in film performance. A properly adjusted nozzle will produce a fan that is about 8 inches wide, 10 inches from the gun. The shape of the spray pattern produced may vary from round to oval. The pattern must have well defined edges with no dry spray at the ends or heavy film buildup in the middle (Figure 13). Coating manufacturers provide guidance on appropriate equipment and pressures for application of their coatings. Additional job-site adjustments may be necessary. The aim is to obtain a wet looking film that is properly atomized with as little overspray as possible. To minimize bounce back and dry spray, the atomizing air pressure should be kept as low as possible. Common spray pattern problems and their cause and remedy are listed in Table 12. The gun should be taken apart and cleaned at the end of each day and the air cap and fluid tip should be cleaned with solvent. Pivot points and packing should be lubricated with lightweight oil. Leaving a gun in a bucket of solvent overnight will likely cause the gun to become plugged and lead to premature failure of the gun. The shutting-down procedure is detailed in the instructions supplied by the manufacturer of the spray equipment and these instructions should be followed. Other worker safety issues are discussed in the section on safety.

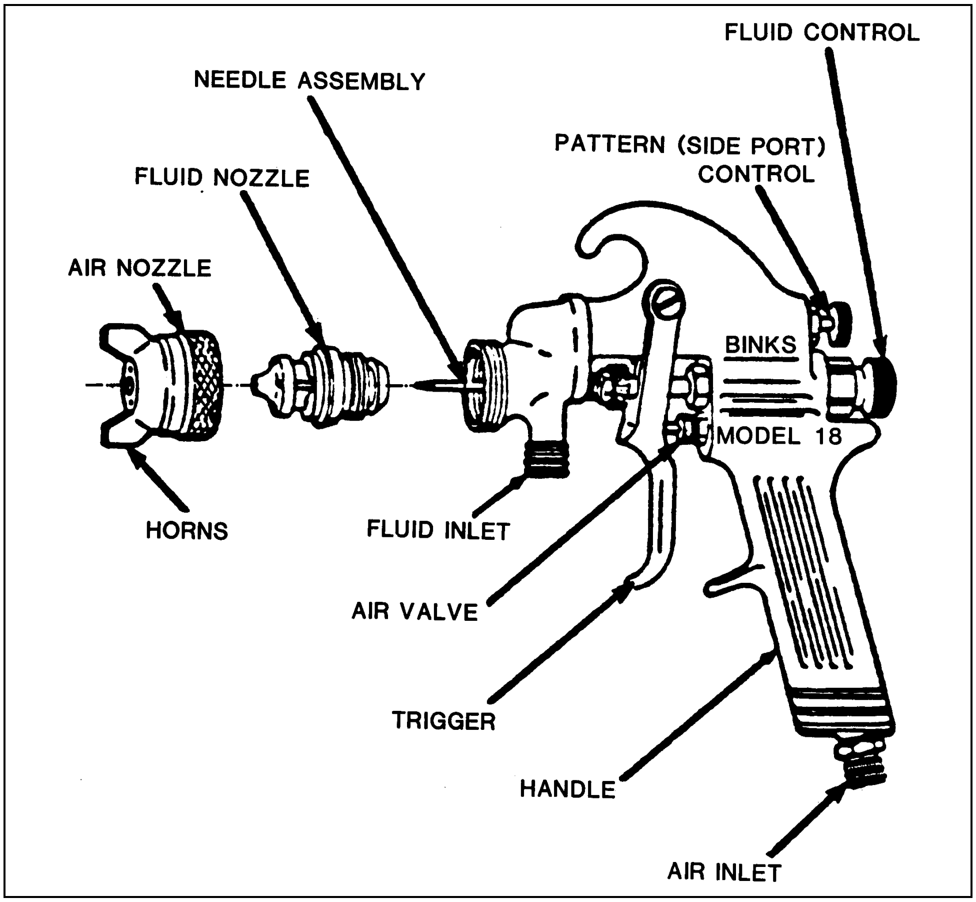


Figure 11
Drawing of Air-Spray Gun

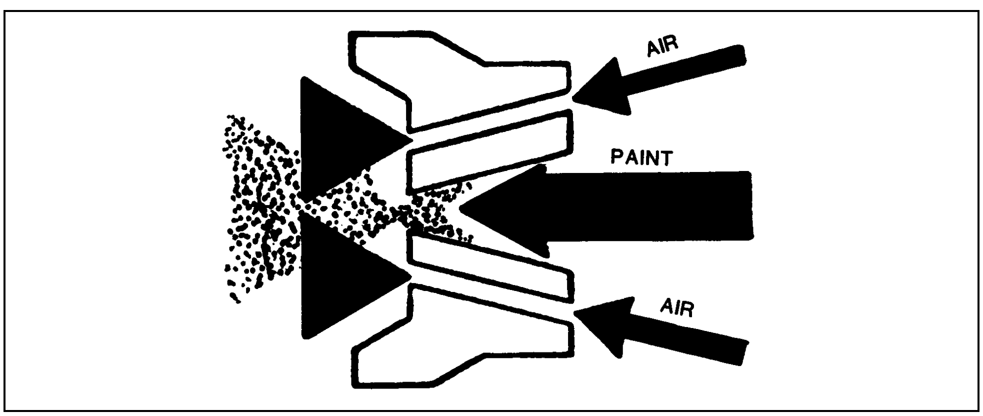


Figure 12
Cross-Sectional Drawing of Nozzle of Air-Spray Gun

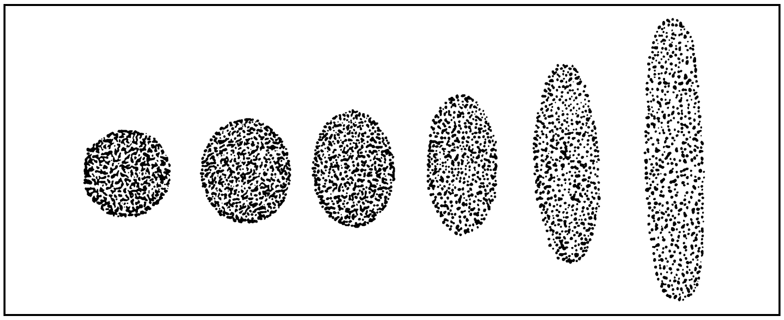
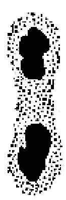
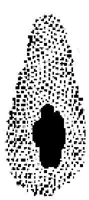
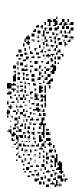


Figure 13
Illustration of Proper Spray Patterns
(Note that the patterns are uniform throughout.)

Table 12
Common Conventional Air-Spray Problems and Their Causes and Remedies

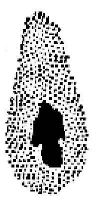
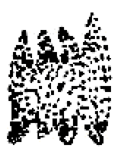
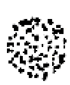
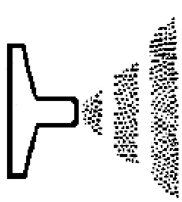
	Description	Cause	Remedy
	Thick center; thin ends; pinholes	Atomizing air pressure too low; too much fluid to gun	Increase air pressure; decrease fluid pressure or use smaller nozzle
	Hourglass shape; dry spray on ends	Fluid pressure low; air pressure too high; too wide a spray pattern	Increase fluid pressure; reduce air pressure; adjust pattern control; reduce paint viscosity
	Teardrop shape; thicker at bottom	Problem with gun - nick in needle seat; partially clogged orifice or slightly bent needle or loose nozzle	Remove and clean air nozzle; replace any bent parts or tighten air nozzle
	"Boomerang"	Dried paint has clogged one of the side port holes of the air nozzle	Dissolve dried paint with thinner; do not probe into nozzle with metal devices

7.5.4.2 Airless Spray

a) Equipment. Airless spray relies on hydraulic pressure alone. Atomization of paint is accomplished by forcing the material through a specially shaped orifice at pressures between 1000 and 3000 psi. Because of the high pressures, extreme care must be taken to prevent worker injury. The spray manufacturer's instructions must be followed carefully. The basic parts of airless spray equipment are a high-pressure paint pump, a fluid hose, and an airless spray gun. The high-pressure pump must deliver sufficient pressure and material flow to produce a continuous spray of paint. The fluid hose must be able to withstand the very high pressures required to deliver the paint to the gun and atomize it. A filter screens out particles that might clog the tip. Since atomization is controlled by the size and shape of the orifice of the tip, a different tip is used to obtain different patterns and atomization rates. The tip angle controls the fan width. Tips having the same orifice size but different angles deliver the same amount of paint, but the area covered with one pass is different. Viscous materials require a larger tip than less viscous materials. Coating manufacturers recommend tip sizes on their data sheets. The larger the orifice, the greater the production rate. But, if too large an orifice is used for a thin coating, the rate of delivery may be such that the operator cannot keep up with the flow. This will result in sagging and running of wet paint. Airless spray is available with heaters to reduce paint viscosity, permitting spraying of coatings having higher ambient viscosities at a faster production rate.

b) Setting-Up, Adjusting Equipment, and Shutting-Down Procedures. The manufacturer's instructions should be followed for setting up the spray equipment. To minimize tip clogging problems, airless spray equipment must be scrupulously clean before setting-up for a spray application and the coating must be free of lumps. The manufacturer's recommendations should be followed rigorously for the setting-up, using, and shutting-down procedures. Since the pressures used are high, two safety features are required for guns: a tip guard and a trigger lock. The tip guard prevents the operator from placing a finger close to the tip and injecting paint into the skin. The trigger lock prevents the trigger from accidentally being depressed. Other safety measures include never pointing the gun at any part of the body; not making adjustments without first shutting off the pump and releasing the pressure; making sure the fluid hose is in good condition, free of kinks, and bent into a tight radius; and using only high-pressure hose fittings. Also, never clean systems containing aluminum with chlorinated solvents. Explosions may occur. Causes of and remedies for faulty patterns are described in Table 13. Additional problems that may occur with airless spraying may be associated with excessive pressure, undersized equipment, and too long or too small paint hoses. Undersized spray equipment, including hoses, may result in lower production rates, a pebbly-appearing film caused by poor atomization (nozzle tip too large), and thin films. Air supply hoses that are too long or too small may cause instability of the pump, poor atomization of the paint, or a pulsating spray pattern.

Table 13
Common Airless-Spray Problems and Their Causes and Remedies

	Remedy	Description	Cause
	Thick center, pressure, thin ends, pinholes and hour-glass shape	Inadequate fluid delivery or improper atomization	Increase fluid decrease paint viscosity, choose larger tip orifice, or reduce number of guns using one pump
	Teardrop replace shape coating thicker	Clogged or worn nozzle tip if necessary	Clean nozzle tip,
	Rippling, uneven pattern	Pulsating fluid delivery or suction leak	Increase supply to air motor, reduce number of guns using one pump, choose smaller tip orifice, clean tip screen and filter, or look for hose leak
	Round pattern	Worn nozzle tip or fluid too viscous for tip size	Replace worn tip, decrease fluid viscosity increase pressure, or choose correct tip orifice
	Fluid spitting	Air entering system, dirty gun, or wrong cartridge adjustment	Check for hose leak, clean gun, or adjust cartridge and replace if necessary

7.5.4.3 Air-Assisted Airless Spray. Air-assisted airless spray uses air to help atomize paint as compared with only fluid pressure in the airless system. Thus, a lower hydraulic pressure (typically 500 to 1000 psi) can be used. Air pressure is typically 10 to 15 psi. Air-assisted airless spray provides a finer spray than airless spray, and the lower hydraulic pressure provides improved operator control. Consequently, finishes tend to be smoother with fewer runs and sags. Transfer efficiency is about the same as airless spray, but air-assisted airless spray is more expensive to maintain.

7.5.4.4 High-Volume, Low-Pressure Spray. HVLP spray is an air spray technique that uses low pressure and large volumes of air to atomize the paint. It has much better transfer efficiency that conventional air spray and some systems have been found to meet the 65 percent transfer efficiency requirement of California's South Coast Air Quality District. Because of the lower air pressures, there is also less bounce back than with conventional systems. Turbine air-supply systems, along with large (1-inch diameter) hoses are commonly supplied with the systems. Since the air supply is not turned off when the trigger is released, air flows continuously through a bleeder valve in the gun. An HVLP gun can be equipped with different fluid and air tips depending upon several variables: the desired spray pattern (wide fan to narrow jet), viscosity of the finish, and output of the turbine. Although some special training of painters may be required because of differences between conventional air systems and HVLP, such as less recoil, higher delivery volumes and continuous flow of air, an experienced operator has good control.

Conversion kits for air compressor systems are available which allow the use of them with HVLP systems. Spray techniques may be slightly different depending upon the source of pressurized air.

7.5.4.5 Multi-Component Spray. Multi-component (or plural-component) spray equipment combines components of multi-component paints in the nozzle. The equipment is more complicated than other spray equipment, and its use is usually confined to large or specialized coating applications. The components are metered to the gun in the proper relative volumes, mixed and then atomized by one of the previously described techniques. Thus, pot life is not a factor in application of multi-component coatings. However, it is essential that the metering be done in accordance with the coating manufacturer's instructions. Volume mixing ratios are usually from 1:1 to 1:4. Heating of the components before mixing is also provided with some equipment. By heating the components, both the viscosity during application and the cure time can be altered. The equipment is cleaned by purging with solvent. Because of the complicated nature of the equipment, specialized operator training and skilled operators are required. Initial and maintenance costs are also greater than for other spray techniques.

7.5.4.6 Electrostatic Spray. In hand-held electrostatic spray systems, a special protruding part of the gun is given a high, negative voltage which places a negative charge on the spray droplets as they come from the gun. The surface being painted is grounded. This causes the paint droplets to be attracted to the grounded surface to be painted. Because there is an electrical attraction between the paint droplets and the object being painted, a very high percentage of droplets lands on the surface. That is, the transfer efficiency is high and there is minimal overspray. Also, some droplets will be attracted to the edges and the back of the surface, if they are accessible. This is called the wraparound effect. Specially formulated paints are required for electrostatic spraying. Also, painting is restricted to use on conductive substrates, such as steel or galvanized steel. Only one coat of paint may be applied to the base metal by electrostatic spraying since a painted surface is not conductive. Electrostatic spray is an ideal spraying method for piping, fencing, channels, and cables because of the wraparound effect and minimal overspray. However, because of high voltage, special safety requirements must be met, including grounding the power supply and the operator.

7.5.4.7 Powder Spraying. Powder coatings, usually epoxies, are specially prepared polymeric coatings. They are applied to preheated conductive surfaces, such as steel, by special electrostatic spray equipment or in a fluidized bed. Once applied, the coated component is heated to fuse the powder into a continuous coating film. This technique is commonly used in shop applications because heating can be done in an oven, there are no volatile solvents to control and material that did not stick to the surface can be collected and reused. Portable systems are also available and can be used in special situations.

7.5.4.8 Thermal Spraying. Thermal spraying, sometimes called metallizing, is a process in which finely divided metals are deposited in a molten or nearly molten condition to form a coating, usually on steel. Equipment and techniques are available for flame or electric arc spraying of pure zinc, pure aluminum, or an 85 percent zinc, 15 percent aluminum alloy. The coating material is available in the form of a powder or wire, with wire used more frequently. Once the metal becomes molten, it is delivered to the surface with air or gas pressure. It forms a porous coating that protects steel by cathodic protection in a variety of environments. For more severe service such as very acid or alkaline conditions, or fresh or salt water spray, splash, or immersion, the coating may be sealed with a thin conventional organic coating or silicone. A white-metal blasted surface is required. Metal spray coatings are normally very abrasion resistant and provide excellent corrosion control.

Thermal spraying of metals is best accomplished in a shop environment, but can also be done in the field. DOD-STD-2138(SH) describes the wire flame spraying of aluminum using oxygen-fuel gas. SSPC Guide 23, Coating Systems describes thermal spray metallic coating systems.

7.5.4.9 Application Technique. Proper application technique is essential for obtaining quality films. Poor technique can result in variations in paint thickness, holidays (small holes), and other film defects, and wasted time and materials. The same basic techniques described below are used for both conventional and airless spraying:

a) Stroking. With the spray gun at a right angle to the work, the wrist, arm, and shoulder are moved at a constant speed parallel to the surface. Holding the gun at an upward or downward angle to the surface will result in a non-uniform coating thickness and may increase the problem with dry spray or overspray. Also, changing the distance between the gun and the surface, arcing, as illustrated in Figure 14, will result in a non-uniform coating thickness. For large flat surfaces, each stroke should overlap the previous one by 50 percent as shown in Figure 15. This produces a relatively uniform coating thickness. The stroke length should be from 18 to 36 inches, depending upon the sprayer's arm length and comfort. Surfaces of greater length should be divided into smaller sections of appropriate length (Figure 16). Each section should slightly overlap the previous one along the lines where they are joined.

b) Triggering. The spray gun should be in motion before triggering and continue briefly after releasing at the end of a stroke. This is illustrated in Figure 17. Proper triggering also keeps the fluid nozzle clean, reduces paint loss, prevents heavy buildup of paint at corners and edges, and prevents runs and sags at the start and end of each stroke.

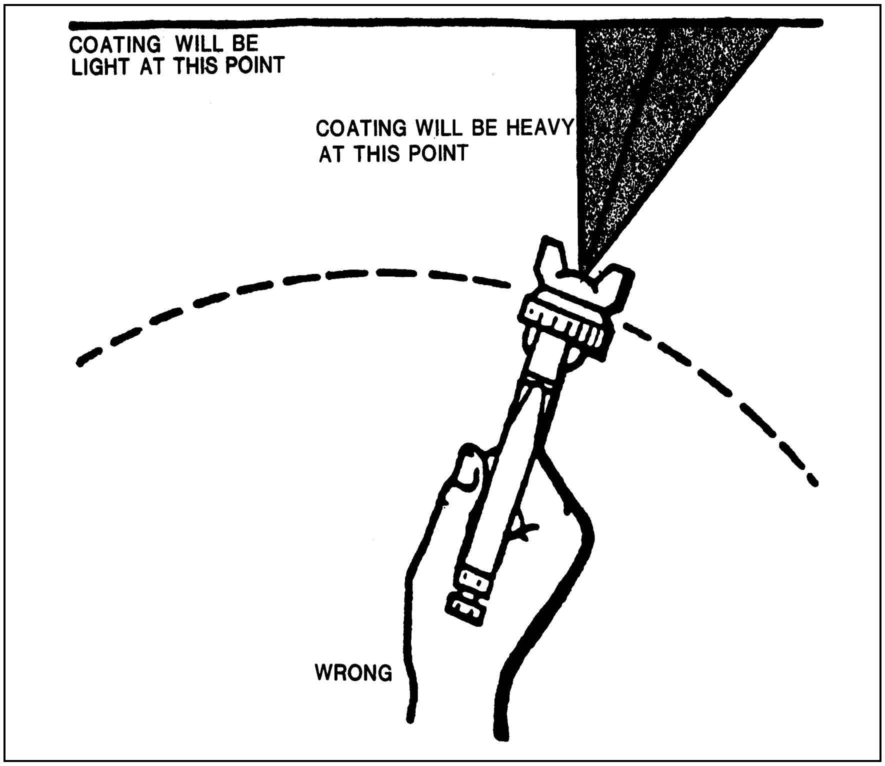


Figure 14
Illustration of Improper Movement of Spray Gun
When Applying Paint

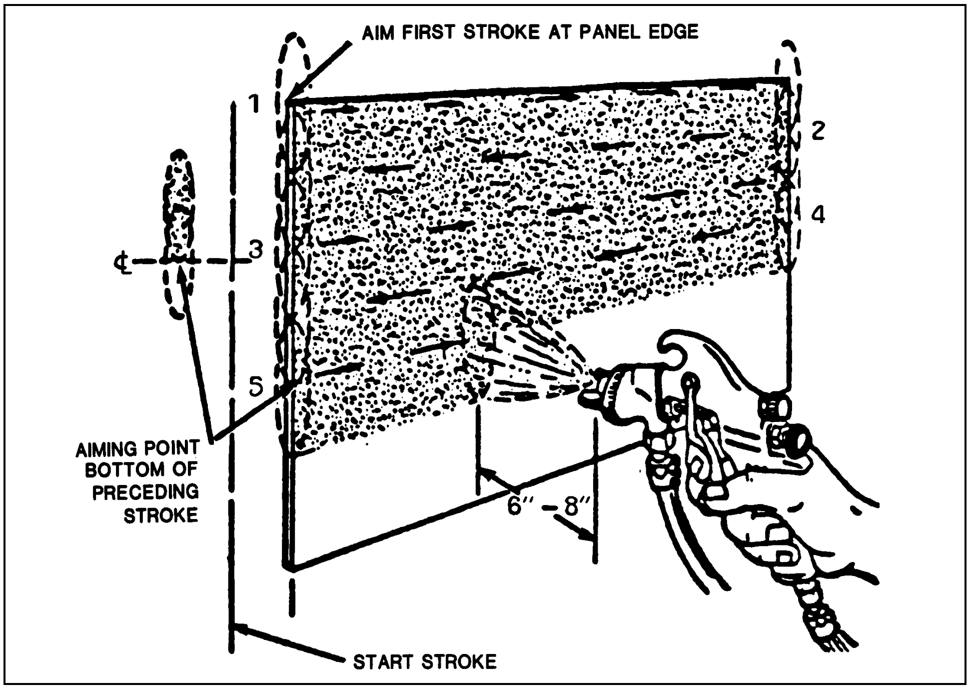


Figure 15
Illustration of Proper Procedure for Spray Painting
Large Flat Surfaces

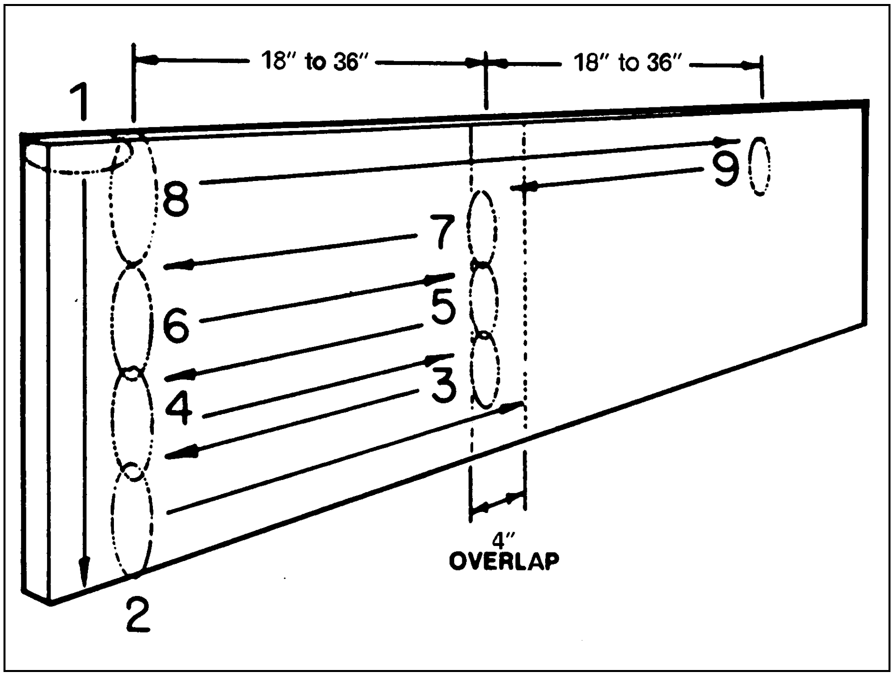


Figure 16
Schematic to Illustrate Proper Painting of Large Vertical Surfaces

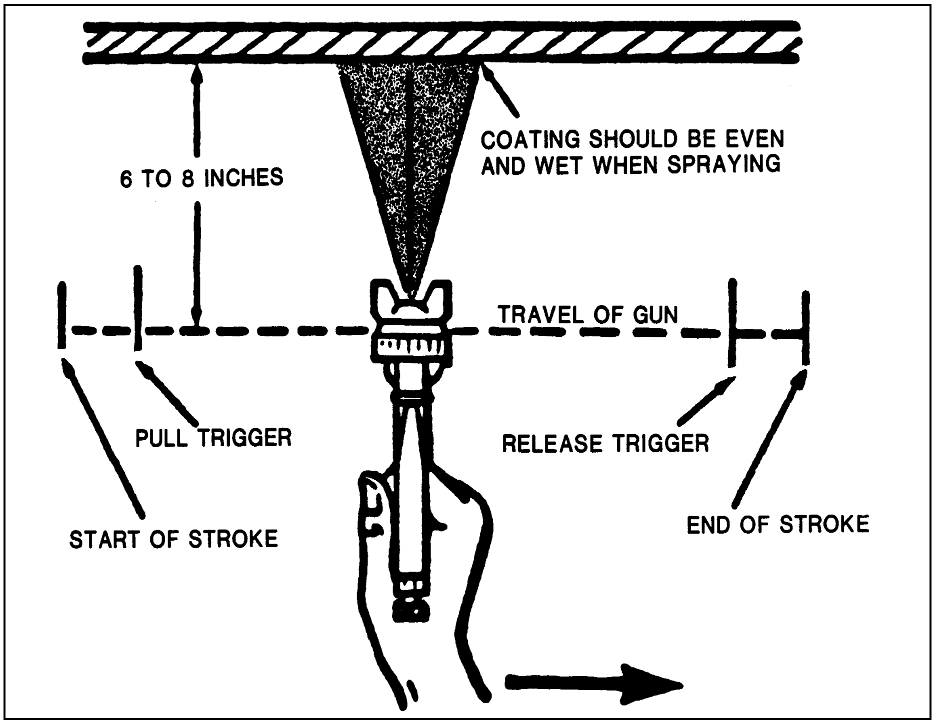


Figure 17
Illustration of Proper "Triggering" of Spray Guns

c) Distance. Distance between the nozzle and the surface being painted depends on atomization pressure and the amount of material delivered. This distance usually varies from 6 to 12 inches for conventional spraying and from 12 to 15 inches for airless spraying. If spray gun is held too close to the surface, heavy paint application and sagging or running may occur. If the gun is held too far away from the surface, a dry spray with a sandy finish may result. Such paint films usually contain holidays (small holes) and provide an unacceptable surface.

d) Corners. Both inside and outside corners require special techniques for uniform film thickness. Each side of an inside corner should be sprayed separately as shown in Figure 18. Too thick a layer of paint can easily be applied to an inside corner. But when too thick a layer is applied, the coating may shrink or pull away from the inside corner causing a void underneath the coating. This will lead to premature failure. An outside corner is first sprayed directly, as shown in Figure 19, and then each side is coated separately. On an outside corner, the coating tends to pull away from the corner. Thus, the coating on the corner tends to be too thin. Outside edges should be ground so that the edge is rounded before painting.

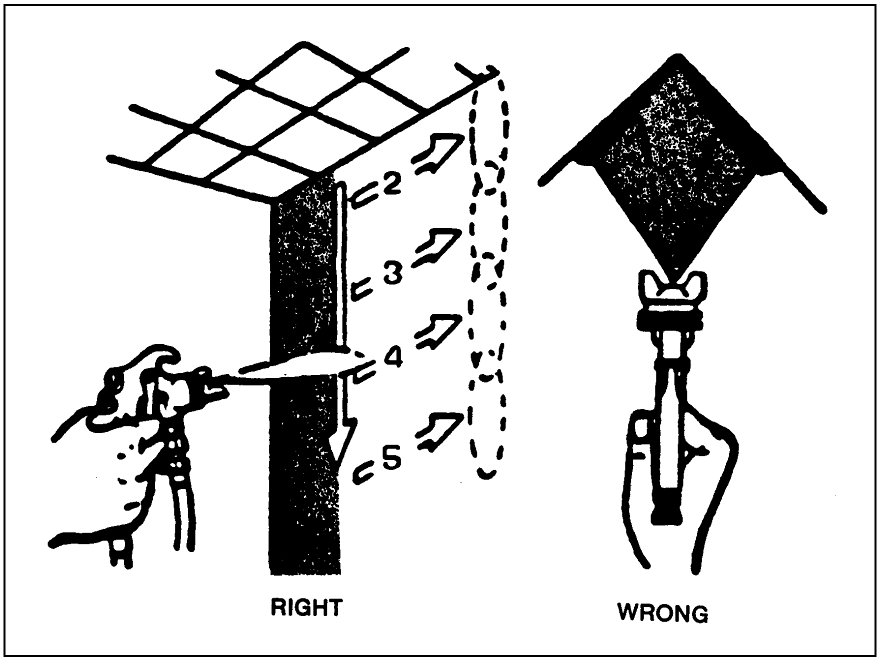


Figure 18
Proper Spray Painting of Inside Corners

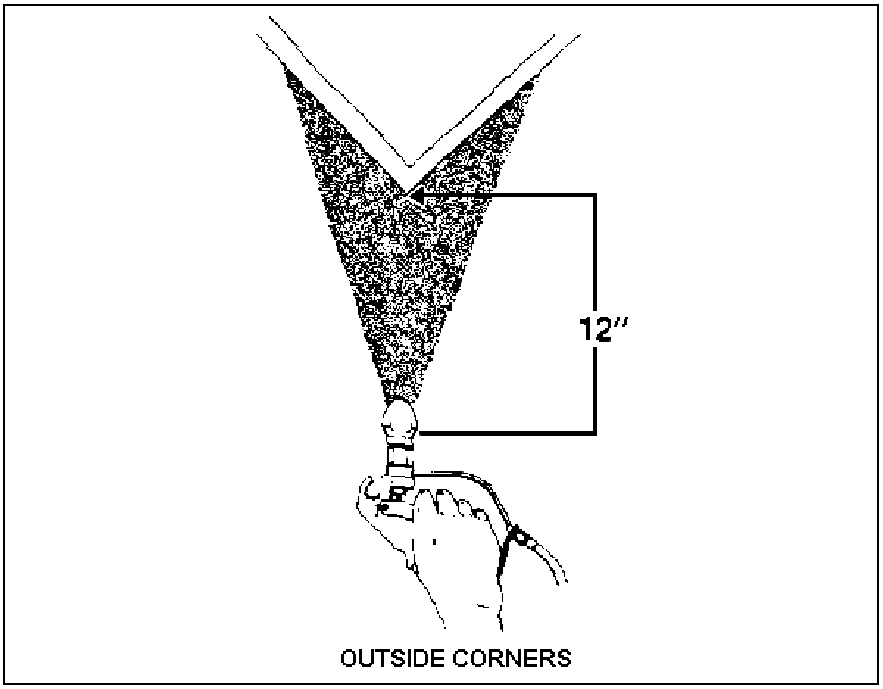


Figure 19
Proper Spray Painting of Outside Corners

e) Welds. Welds are usually rougher than the adjacent steel and a uniform coating is more difficult to achieve. Failure often occurs first over welded areas. Thus, after grinding the welds to smooth them, a coat of paint should be brushed over the welds. Then the entire surface can be painted by spray. With this extra coating over the welds, paint often lasts as long over welds as on the adjacent flat areas.

f) Nuts, Bolts, and Rivets. It is a good coating practice to brush-coat these areas before spraying the flat areas. Paint can be worked into crevice and corner areas. Nuts, rivets, and bolts should be sprayed from at least four different angles to prevent thin coatings caused by shadowing effects (Figure 20).

g) Common Errors. Some common errors and the results that are produced in spray painting are summarized in Table 14.

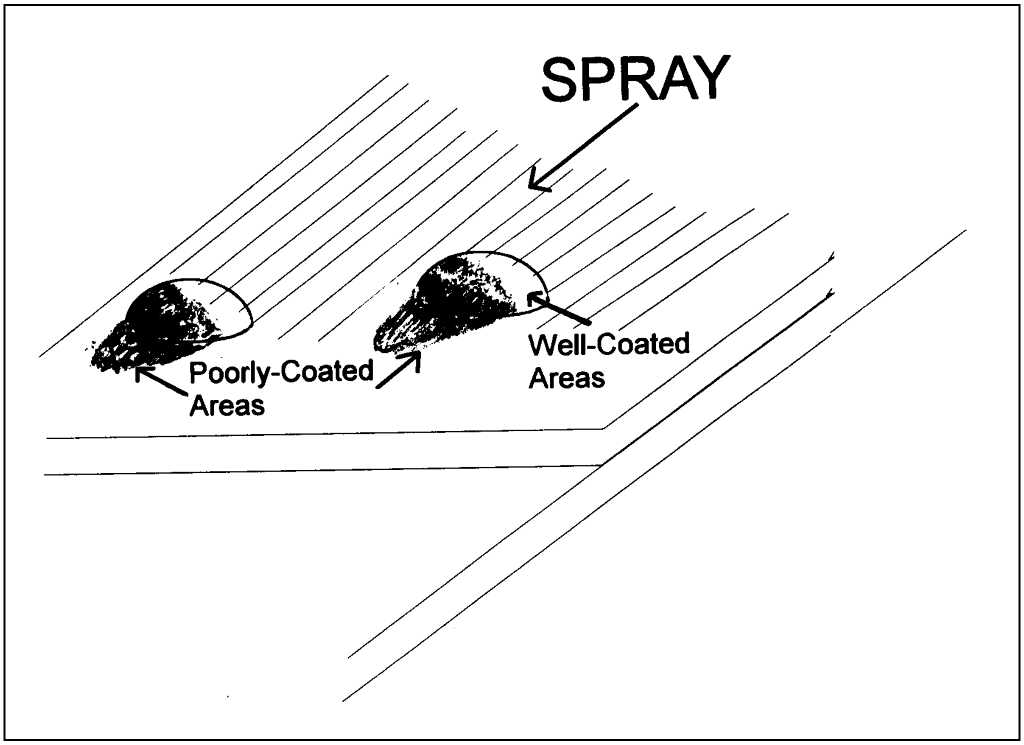


Figure 20
Schematic Illustrating Importance of Spraying Surfaces With Protruding Parts From All Directions to Avoid "Shadowing Effect"

Table 14
Spray Painting Errors

Error	Result
Improper spraying technique (e.g., arcing, tilting gun)	Spray pattern varied from narrow to wide Variation of sheen from overspray Uneven film thickness
Improper fan width	Inadequate or excessive film build on complex substrate shapes, such as "I" or "H" beams
Spray gun too close to surface	Excessive film build Runs, curtains, sags Poor paint adhesion from improper curing Wrinkling during and after surface curing Excessive paint used Orange peel pattern or blow holes
Spray gun too far from surface	Film build too thin Non-uniform film thickness Dry spray Uneven angular sheen from overspray earlier work

Section 8: PREPARATION OF A PAINTING CONTRACT SPECIFICATION

8.1 General. A contract specification is a written detailed, precise description of the work to be done; it constitutes a part of the overall contract to describe the quality of materials, mode of construction, and the amount of work. The purposes of the specification are:

a) To obtain a specific desired product

b) To ensure quality materials and workmanship

c) To ensure completion of work

d) To avoid delays and disputes

e) To obtain minimum or reasonable costs

f) To make the contract available to as many qualified bidders as possible

g) To avoid costly change orders and claims

h) To meet safety, environmental, and legal requirements

Construction specifications provide a description of the desired work in such detail that a product other than that desired may not result. Because painting frequently comprises only a small part of construction work, it frequently receives only limited attention so that it is inadequate to fill the desired goals.

Construction specifications are further complicated by the fact that they comprise legal documents and thus must meet legal as well as technical requirements. Deficiencies in paint or other construction specifications permit bidders to interpret incompletely described requirements to their advantage, and to provide lesser work or cheaper materials. These in turn, give rise to disputes and litigation. Thus, it is extremely important that specifications be prepared systematically, thoroughly, and legally.

8.2 Background. At one time, it was a common practice to use old painting specifications over and over again without attempting to update them. Changes to meet new needs frequently were made by "cutting and pasting." This did not permit the use of new technology, address new requirements, or correct errors in earlier documents.

Another common practice was to have coating suppliers prepare specifications for painting, particularly for small jobs. As might be expected, the supplier's products were required by the document. Today, specifications are usually prepared by architect-engineers who specialize in this work. They have the background, and the standards and other criteria documents at their disposal, to prepare an engineering document for a specific job in a professional manner that is technically correct (complete and without error), clear (unambiguous), and concise (no longer than absolutely necessary).

The specification writer must be able to describe the important details while visualizing the desired final products of the work. The different requirements and phases of the work must be presented in logical, sequential steps to permit the work to be accomplished efficiently. Poorly or incompletely written specifications can result in the following bidding problems: bids from unqualified contractors, fewer bids from qualified contractors, or unrealistically high or low bids.

8.3 The CSI Format. A systematic format for construction specifications is necessary to include important items. It also makes it easier for those preparing bids or executing the contract to accomplish their work, because the requirements can be found in the same part of the document, as in previous documents from the firm. The format of the Construction Specification Institute (CSI) is used by the Federal and many State governments, as well as private industry. It divides construction work into 16 divisions by the building trade involved with the work. Finishes are always in Division 9 and paints and protective coatings in Section 09900 of Division 9. Sections have five digit numbers. Each CSI section is divided into three basic parts:

a) Part 1. General

b) Part 2. Products

c) Part 3. Execution

8.3.1 General Information Part. The general information part of the CSI format includes the following sections:

a) Summary or Introduction

b) References

c) Definitions

d) Submittals

e) Quality Assurance

f) Delivery, Storage, and Handling

g) Site Conditions

8.3.1.1 Summary Section. A Summary or Introduction section at the start may present the scope and purpose of the work. Care must be taken here to avoid any repetition of work described elsewhere in the document, because any variations in description can result in problems of interpretation. Thus, many specification writers prefer to use only the title of the specification to introduce the document.

8.3.1.2 Reference Section. The reference section, sometimes called "Applicable Documents," includes a listing of documents used in the specification and no others. Others included only for general information may be interpreted as requirements. Listed references form a part of the specification to the extent indicated.

a) Industry specifications and standards, such as those of the SSPC, are preferred to Government standards for equivalent products or processes. Their issuing organization, number, and latest issue are normally listed. Unless otherwise indicated, the issue in effect on the day of invitation for bids applies. Where alternative standards occur, the normal order of precedence is:

(1) Industry documents

(2) Commercial item descriptions (CIDs)

(3) Federal documents

(4) Military documents

b) This should not be confused with the order in which they are normally sequenced in the specification reference listing - alphabetically, by organization name, or by document category name. For example:

(1) American Society for Testing and Materials (ASTM)

(2) Commercial item descriptions

(3) Federal specifications

(4) Steel Structures Painting Council (SSPC)

c) Within each of the above categories, individual documents are listed numerically. As with other items, references should be used as little as possible in the body of the specification to minimize error. Where alternative standards or practices are available, only one of them should be used.

8.3.1.3 Definition Section. An understanding of terms used in painting operations may vary widely in different geographical locations and even between different people in the same location. Definitions for such words may prevent costly disputes over different interpretations.

8.3.1.4 Submittals Section. Specification submittals are documents or samples to be provided by the contractor to the contracting officer. They are provided to ensure that specific requirements will be met.

a) Submittals on painting contracts may include:

(1) Wet samples of coatings

(2) Drawdown films of coatings

(3) Blast-cleaned reference panels

(4) Laboratory test results

(5) Certificates of conformance

(6) Product data sheets

(7) Supplier's instructions

(8) Supplier's field reports

(9) Shop drawings

(10) Warranties

b) Complete laboratory testing of paint for conformance to specification can be very expensive and thus is not often done except where very large areas are coated or where the coating provides a critical function. More often, the contracting officer accepts certificates of conformance. These are basically statements that a previous representative batch of the same formulation have met specification requirements, and a few quick laboratory tests (standard quality control (QC) tests) by the supplier indicate that the present batch does also. Sometimes, analytical results from an earlier batch are required along with the certificate. When qualified products lists, for Federal or military specifications, or suggested supplier lists, for commercial item descriptions, are available, the listed suppliers should be utilized.

c) For large or critical batches of paint, factory-witnessed manufacture or testing is sometimes done. These and first article tests can be very expensive and so should be used only where the expense is justified.

d) Sometimes, authenticated wet samples of coating are retained for later testing, should early failure occur. They are normally retained for only 1 year, the normal warranty period. The specification should also permit field sampling of coatings being applied. This may prevent unnecessary thinning or substitution of products.

e) The data sheets and instructions of suppliers may be used to define under what conditions and under what acceptable procedures the product can be successfully applied to produce a quality film. If SSPC PA 1, Shop, Field, and Maintenance Painting, or a written description of the work requirements are included in the specification, the order of priority of these documents should be stated, should some differences occur.

f) At one time, many specifications stated that an undercoat should be allowed to thoroughly cure before topcoating. However, complete curing of thermosetting undercoats may present problems of adhesion of finish coats.

g) Warranties should also be received as a submittal. Some products such as textured coatings for masonry structures are commonly warranted for 15 years. Such warranties are normally limited to such conditions as flaking, blistering, or peeling. They do not usually include fading or chalking in sunlight.

h) Inspection, safety, or work sequence and scheduling plans may be required in order to obtain information on how each of these aspects will be handled. An inspection plan will show how each of the inspection requirements will be met. SSPC has examples of these plans and reporting forms. Information of the sequencing and execution of the work will be important where they affect other operations.

8.3.1.5 Quality Assurance Section. The quality assurance section includes those items not covered elsewhere in the general information or execution parts that are necessary to ensure that quality work will be obtained from the contractor.

a) They may include the following:

(1) Qualifications

(2) Certifications

(3) Field sampling

(4) Regulatory requirements

(5) Preconstruction conference

b) Qualification or certification statements may be requested to establish the capabilities of the contractors and his employees. This is particularly necessary, if capabilities with high pressures from airless spray or other safety hazards require special certification. The SSPC Painting Contractor Certification Program will ensure the capability of completing the work in a satisfactory manner and time. Additional certification may be required if asbestos fibers or lead-based paint complicate the work. It is desirable to include a clause permitting the contracting officer to procure at any time a sample of the paint being applied. Local air pollution personnel usually have this authority.

c) The contractor must be familiar with prevailing regulations. Material safety data sheets (MSDS) for paints, solvents, and other materials to be used should also be submitted and kept available on-site. In addition, coating manufacturer's technical data sheets should also be on-site and available.

d) A preconstruction conference and site visit of contracting officer and contractor personnel should be held before the work begins. At this time, any differences of opinion or uncertainties should be resolved. Any agreements reached that affect the specification should be written down and signed by both parties so that it becomes a part of the contract. Any differences not resolved may result in costly change orders.

8.3.1.6 Delivery, Storage, Handling, and Disposal. Information must be provided on acceptable methods of delivery, storage, and handling. Packaging and shipping procedures must be in accordance with prevailing regulations. There must also be suitable arrangements for acceptance and storage of materials on the job site. Storage must provide for protection of materials from deterioration, as well as conformance to prevailing safety and environmental regulations. Spill kits must be present and procedures established to clean up spills, and any hazardous waste generated must be stored and disposed of in accordance with local regulations.

8.3.1.7 Site Conditions. The site conditions must be completely and correctly defined. Variations from the description of the site conditions generally cause costly changes in the specification. They may concern the size or scope of the work, the extent of corrosion or coating deterioration, the construction or coating materials, or other things that affect the work to be done. Some specification writers do not examine the job site but rely on drawings on file that may not be current. Additions significantly increasing the level of effort may have occurred since the drawing was made. The Federal Government does not require inspection of the job site before bidding, because it might be unduly costly to bidders located in other geographical areas. Thus, bidding may not be as precise as if the site were inspected. In fact, some bidders deliberately do not inspect the work site in hope of finding variations that would bring additional money to them.

Another common error is to underestimate the amount of loose, deteriorated coating that must be removed in maintenance painting. Loose paint is generally not well defined. The best definition is probably paint that can be removed with a dull putty knife.

Recently, a number of contracts have been awarded that involve the removal of paint containing lead, chromium, asbestos, or some other toxic material. Such paints must be identified as containing hazardous material before the contract is advertised.

8.3.2 Products Part. The products part of a specification includes requirements for materials to be used. This may include abrasives and other cleaning materials and thinners, as well as coating materials. Historically, materials with proven performance and low life-cycle costs were usually chosen. Now, most heavily populated areas require lead- and chromate-free coatings that are low in VOCs. These are frequently more difficult to apply than earlier formulations, have had very little field testing, and thus may provide shorter term protection.

Paint products are always best procured using a specification or a specific brand name, if this is permitted and if the product has data showing good field performance. Many

Government agencies cannot purchase a sole source product, unless it can be shown to be uniquely differentiated from other products. Sometimes, a qualified products list can be used or suggested suppliers of coatings for a particular specification, for which good performance data are available. Specifying "Brand X or equal" is dangerous, because there is no specific definition of "equal" or procedure to determine such equality. Also dangerous is to describe a product by its composition and/or performance. These are sometimes done to procure a particular product without calling out its name. Standard colors available in the particular specification or commercial product should be specified. FED-STD-595 provides a large number of color chips for which many specification coatings are available. A fandeck of these chips is also available from the General Services Administration (GSA). It is better to use these standards than to refer to a particular supplier's color code or name.

Whatever the method of specifying products, it is always best to require that products for a multiple-coat system be procured from the same supplier, who recommends their use together. This will avoid compatibility problems and limit any liability to one supplier.

8.3.3 Execution Part. The execution part of the specification describes the use of the materials in the products part. Because painting may be only a small part of a construction project, it must be coordinated with the other sections. This will permit surface preparation and coating application under suitable conditions and without delays or other interference.

Much information of the execution of a specification may be found in drawings that form a part of the specification. To prevent problems resulting from variations between descriptions in the drawings and the body of the specification, requirements in the body should be stated as preempting those in drawings. They should not repeat requirements in the body of the contract to avoid differences.

8.3.3.1 Work Conditions. This portion of the execution part describes the weather conditions under which work is permitted. If priming of steel is delayed by the weather or other reason, it will be necessary to reblast the steel to remove any flash rusting that has occurred during the delay.

The air temperature at the time of coating application should be in the supplier's listed acceptable range. The temperature should be at least 5 degrees above the dew point, and rising, to prevent moisture from condensing on the surface of the wet paint film. The specification should state how frequently temperature and dew point measurements should be taken.

Spray painting should also be restricted during times of moderate to heavy winds. Painting at such times may not only produce unsatisfactory films of coating but also result in overspray onto automobiles or other structures in the area.

8.3.3.2 Surface Preparation. It is always best to describe the desired prepared surface condition, using standards such as SSPC SP 6, if available, rather than telling the contractor how to prepare the surface. It is inappropriate to specify both the desired condition and how to achieve it. These requirements may cause legal problems if the surface cannot be obtained using the directions specified. For example, it is much more effective to require a "SSPC SP 10, Near-White Blast Cleaning" without specifying how the blaster achieves it. However, if the specification calls for abrasive blasting of steel at 90 to 100 psi using a venturi nozzle held 8 inches from the surface, then there can be no requirement for a particular degree of cleanliness other than that which is achieved when the specific directions are followed.

Care must also be taken to use only standard terms such as "brush-off blast cleaning" which is defined in SSPC SP 7 rather than "brush blast," "sweep blast," "shower blast," or some other undefined term. Also avoid other vague terms such as "heavy abrasive blasting" that are subject to interpretation.

8.3.3.3 Coating Application. Normally, painters are permitted to apply their materials by brush, roller, or spray, unless the material can only be applied satisfactorily by one or two of these methods. Thus, zinc-rich coatings should be applied by spray using an agitated pot and following the instructions of the coating supplier. SSPC PA 1 may be referenced as an industrial standard for shop and field painting. Local transfer efficiency requirements may prevent the use of some types of spray application (e.g., airless or conventional air spray). Currently, requirements for transfer-efficient methods of application are limited to shop work. Any thinning of paints should be limited to thinner and the amount recommended by the supplier. It should also be within the limits set by local air pollution authorities.

8.3.3.4 Inspection. In the inspection section, inspection requirements should be listed. By referring to standard test procedures, details of both the procedures and their requirements can be found. Thus, SSPC PA 2, Measurement of Dry Paint Thicknesses With Magnetic Gages, will indicate how many thickness measurements must be made on each 100 square feet of coated steel surface. If referencing SSPC PA 2, then do not reference ASTM D 1186, Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base. Slight differences in these standards can cause problems.

Occasionally, the contractor and the representative of the contracting officer informally agree on a surface preparation standard for inspection. Often, this is a protected area of steel, or a reference panel, that has been blast cleaned to an acceptable level. Such agreements should be put down in writing and signed by both parties. It then becomes an amendment to the specification and can resolve any disputes that may arise concerning the agreement.

8.4 Language to be Used in Specification. In order to meet the goal of preparing a correct, clear, and concise specification, the language of the document must be such as to describe exactly what is desired. The contractor is required to provide the product described in the specification, not necessarily what is desired. In order to do this, the specification writer must be very precise with his language. This following recommendations will help:

a) Use short, specific words (avoid vague terms)

b) Use short sentences

c) Put the action words up front

d) Use strong verbs

e) Use the imperative mood

f) Do not repeat descriptions or requirements

8.4.1 Concise Words. Words in the specification should be relatively short, specific, and readily understood. Avoid words that are ambiguous, vague, or otherwise not readily understood. Such expressions as "high-performance coatings" and "quality workmanship" are too vague to be used.

a) Short sentences are more readily understood than longer ones. Also, the action words (subject and verb) should go up front. Thus, don't write, "After the steel has been properly cleaned and after the weather conditions have been verified to be acceptable, apply one coat of the specified primer." Instead, write, "Apply one coat of the specified primer after . . ."

b) Strong verbs such as "blast," "clean," and "prime" are more precise than weaker verbs such as "make," "build," and "establish." They are also more easily understood. Use of the imperative mood is preferred, because it is more concise and more easily understood. Thus, "Blast clean to an SSPC SP 10 surface" is better than, "The surface shall be blast cleaned to an SSPC SP 10," or, "The contractor shall clean the surface to an SSPC SP 10."

c) No information in the specification should be repeated in a second place because of the greater possibility of errors or because slight differences in description may receive different interpretations.

8.5 Construction Criteria Base. The Construction Criteria Base (CCB) is a compact disc system containing the complete texts of thousands of documents needed for the design and construction of buildings and civil works, together with built-in software for automatic accessing and processing the information. The CCB can be obtained from the National Institute of Building Sciences, 1201 L Street, N.W., Washington, DC 20005.

Section 9: INSPECTION OF PAINTING OPERATIONS

9.1 Scope of Section. This section describes the duties of an inspector, general inspection procedures, and specific inspection methods used in inspecting painting operations. Depending upon the job and the contract requirements, quality-control inspectors may be contractor-supplied (that is, contractor quality control - CQC) or Government personnel. In either case, the contracting officer is responsible for ensuring the quality of the job. The intent of this section is to describe proper inspection procedures so that Government personnel will know either how to inspect a painting operation or to ensure that someone else has done it correctly.

9.2 Importance of Inspection. The success of a painting job depends upon the specification requirements being met for surface preparation, application and materials. Most coating failures are the result of contract requirements not being met. Inspection procedures are designed to detect situations when the requirements of the contract are not being met. Thus, inspection is a key factor in obtaining the performance and durability built into the specification.

9.3 Contractor Quality Control Inspection. In Government painting, quality control inspection is often provided by the contractor. For large jobs, a contractor usually hires an inspector. For smaller jobs (less than $200,000), a contractor's superintendent may carry out the quality control inspection. If deemed necessary because of the size or difficulty of a job, or because of the crucial function of a structure, the contract specification can require the contractor to hire a certified inspector (e.g., NACE has a certification program). In this way, the contractor's inspector may be more independent of the contractor and may have better inspection skills. Although this requirement may increase inspection costs, the increased cost of proper inspection as opposed to none or poor inspection has been found by the private sector to be cost effective. Quality control inspectors should report deviances from the contract specification in writing to the contracting officer. Appropriate governmental action in response to these reports is essential in obtaining the quality of the job built into the specification.

9.4 Duties of an Inspector. The duties of an inspector include understanding the contract specification requirements, making sure that the specification requirements are met by the contractor, and keeping good records. Record keeping is a very important part of inspection. It should occur during all phases of the job. Records form an important part of the permanent record on each building, and provide key information in the case of contract disputes.

9.4.1 Record Keeping. Inspectors should keep records in a bound book (logbook). Each page should be initialed by the inspector and dated. The record book should contain:

a) Written records of verbal agreements made between the contracting officer or the inspector and the contractor.

b) Daily descriptions of the type of equipment and number of workers on the job site.

c) Descriptions of the coating materials that are on site.

d) Records of the rate of work progression.

e) Measurements of ambient conditions.

f) Results and observations of the surface preparation inspection.

g) Measurements and observations of coating application, including time between surface preparation and coating application, and times between coats.

h) Results of the final and warranty acceptance inspections.

It is especially important that agreements between the contracting officer (or designee) and the contractor that modify the contract specification be in writing and be signed to minimize future disputes.

9.5 Inspection Equipment. A description of equipment used in typical inspections is summarized in Table 15. Instructions on its use are provided in Section 10 and in the equipment manufacturer's literature. Some of the equipment is readily available from local hardware or variety stores but some is specialized equipment for painting operations. Suppliers of specialized equipment are listed in:

a) ASTM, 1916 Race Street, Philadelphia, PA 19103.

b) NACE, P.O. Box 218340, Houston, TX 77218.

c) SSPC, 516 Henry Street, Suit 301, Pittsburgh, PA 15213-3738.

d) Paul N. Gardner Company, Inc., Gardner Building, P.O. Box 10688, Pompano Beach, FL 33060-6688.

e) KTA-TATOR, Inc., 115 Technology Drive, Pittsburgh, PA 15275.

f) ZORELCO, P.O. Box 25500, Cleveland, OH 44125.

g) Pacific Scientific, 2431 Linden Lane, Silver Spring, MD 20910.

h) S. G. Pinney & Associates, 2500 S.E. Midport Road, P.O. Box 9220, Port St. Luice, FL 34952.

9.6 Inspection Steps. The inspector's tasks can be divided into eight general steps, which are summarized in Table 16 and discussed in more detail below. Special equipment required in each of these steps is also listed in the table. A form that may be useful in reviewing the contract is provided in Figure 21, and one for organizing inspection data is provided in Figure 22.

9.6.1 Review Specification and Correct Deficiencies, If Any. The first part of any inspector's job is to read and understand the contract specification. If deficiencies are found, resolution of the deficiencies between the contracting officer and the contractor is needed prior to start of work. Any changes in the contract specification must be documented in writing and signed by the two parties or their representatives. Copies of these agreements should be kept in the inspector's records. In addition to reviewing the specification, the inspector must also review the contract submittal. The form shown in Figure 21 may help an inspector to identify key specification requirements and essential information from the submittals, and to prepare for the preconstruction conference. Note that at this time, all the information needed to complete the form may not be available. However, the information should be available before the start of the job.

9.6.2 Visit Job Site. It is important for the contractor to visit the job site with an inspector prior to the preconstruction conference so that the scope of the job and any constraints are understood. Potential problems that are found, such as difficulty with access to the job site, can then be resolved at the preconstruction conference. Such visits have been shown to be effective in reducing problems during the job.

Table 15
Equipment for Inspecting Painting Operations

Tool	Typical Use	Description	Source
SSPC VIS 1 and VIS 3 visual standards	Surface preparation of steel	Colored prints illustrating the degrees of blast, hand or power-tool cleaning	SSPC
NACE TM0170 and TM0175 standards	Surface Preparation of steel	Abrasive blasted steel panels illustrating 4 degrees of cleaning	NACE
ASTM standards	Surface preparation, application, and approval	Test methods for measuring profile, film thickness and comparing quality	ASTM
Comparator gage	Determine surface profile of blast cleaned steel	Field instrument consisting of comparator discs and lighted magnifying glass	Supplier
Replica tape	Determine surface profile of blast cleaned steel	Plastic backed foam-like material used to make a reverse image of blasted surface	Supplier
Micrometer	Surface preparation, dry film thickness	Instrument with adjustable opening to measure small thicknesses	Supplier
Inspection mirror	Surface preparation, application	Instrument with mirror on end of handle	Supplier
Moisture meter	Application	Instrument to measure moisture content of substrate	Supplier
Camera	Throughout job		
Sling psychrometer/ psychrometric tables	Ambient conditions	Instrument consisting of wet and dry-bulb thermometers used with a table to determine relative humidity and dew point	U.S. Government Printing Office
Surface thermometer	Application	Special thermometer to measure temperature of substrate	Supplier
Clean cloth or blotter	Application	Use to detect oil in compressed air lines	Supplier
Wet film thickness gage	Application, approval	Flat metal panel with notches of various depths corresponding to expected thicknesses	Supplier
Dry film thickness gage	Application, approval	Magnetic or other gages to measure dry film thickness	Supplier
Magnifying lens	Application, approval	Illuminated microscope, 5x and higher	Supplier
Holiday detector	Application, approval	Portable, low voltage noise detector for detecting coating flaws or discontinuities on metal substrates	Supplier
Adhesion testers	Application, approval	Field instruments to measure either tensile or peel adhesion	Supplier

Table 16
Inspection Steps

Action	Brief Description	Tools (Not all may be needed for any particular job)
Review contract specification and submittals	Determine specified coating, surface preparation, application procedure and final appearance	Contract specification, material technical data sheets, Figure 21
Visit job site	Ensure that the contractor understands the scope and difficulties of the job	
Conduct preconstruction conference	Discuss painting job with contractor	Contract specification, visual standards, material technical data sheets
Carry out presurface preparation inspection	Ensure that repairs are complete, oil, grease, weld splatter are removed, surrounding area is protected from potential damage	
Inspect coating material	Ensure adequate material is on the job site; examine age and condition of coatings and storage facilities	Paddle for stirring
Assess ambient conditions	Throughout the painting job, measure air and surface temperature, relative humidity and dew point, and wind velocity	Psychrometer and chart, surface thermometer, and weather data
Inspect surface preparation	As required, inspect surfaces for cleanliness, profile, removal of loose paint, chalk, mildew, soil and grease	Comparator, surface preparation standards (SSPC VIS 1 and VIS 3, NACE TM-01), felt for chalk measurement, visual standards for chalk and mildew assessment, instrument for measuring profile
Inspect coating application	Ensure specified materials are used; check thinner and amount of thinning; measure dry film thickness and determine that one layer has dried/cured properly before another is applied	Material technical data sheets, wet and dry film thickness gages
Final approval of complete system	Examine film for thickness, appearance, uniformity, and defects	Camera, dry film thickness gage, holiday detector (if needed), magnifying glass, adhesion tester

Project No. ____ Project Title _______________ Inspector __________________ Contractor ___________________

Buildings in Contract, Nos. ____

Coating Materials

Primer: Manufacturer ________________________ Product Designation ________________ Color _______________

Batch _______ Volume Solids ______% Number of Components ______ Storage Temp. Requir. ______

Recommended Thinner ______________________________ Maximum Thinning Recommended ______________

For multi-component paints: Mixing Ratio _________ Induction Time ________ Pot Life ________

Midcoat: Manufacturer ________________________ Product Designation _________________ Color _______________

Batch _______ Volume Solids ______% Number of Components ______ Storage Temp. Requir. ______

Recommended Thinner ______________________________ Maximum Thinning Recommended ______________

For multi-component paints: Mixing Ratio _________ Induction Time ________ Pot Life ________

Topcoat: Manufacturer ________________________ Product Designation _________________ Color __________

Batch _______ Volume Solids ______% Number of Components ______ Storage Temp. Requir. ______

Recommended Thinner ______________________________ Maximum Thinning Recommended ______________

For multi-component paints: Mixing Ratio _________ Induction Time ________ Pot Life ________

Surface Preparation:

Method _____________________ Standard for Cleanliness __________________ Profile: min ___ max ______

Special Instructions ____

Application:

Ambient Conditions Limitations: Minimum Temperature __________ Maximum Temperature __________

Minimum % Relative Humidity __________ Maximum % Relative Humidity __________

Minimum Difference Between Dew Point and Surface Temperature __________

Equipment Requirements ____

Special Instructions ____

Figure 21
Sample Inspector's Contract Summary Form

Date ______________ Project No. _________ Project Title ___________________________ Inspector ___________

Time	Location	Wet Bulb	Dry Bulb	Rel. Hum.	Dew Point	Surface Weather			Material Temp.	
						Temp	Condition	Wind Vel.	At Applic.	Storage

Painting Operation Report

Bldg No.	Location	Operation (# people on site, activity type)	Surface Preparation			Moisture Content	Color		Application			Dry Film		
			Type	Cleanliness Level	Profile		Spec No.	Color No.	Method	Wet Film Thick	Cure Time	Spec Thick	Actual Thick	Meas. Method

Figure 22
Sample Daily Project Reports for Painting Inspectors

9.6.3 Conduct Pre-Construction Conference. At the beginning of each new contract or work order before the start of any surface preparation or coating application, a meeting should be held with the contractor, contracting officer, inspector, and other key people. Figure 21 may be helpful in this discussion. During this conference, agreement should be reached on details of the specification and the procedures and expectations of the inspector. For example, the number and locations for inspecting surface preparation and coating thickness should be determined. Scheduling, job sequencing, job stops for inspection, and other job-related issues should be discussed. Differences between contractor and contracting officer should be resolved at this time to avoid future misunderstandings and job delays. Agreements that result in a change of the contract should be made in writing, signed and included in the record book.

9.6.4 Inspect Job Site After Pre-Surface Preparation. Prior to surface preparation or coating application, it is necessary to be certain that requirements in the specification relating to readying a surface or area for painting are carried out. These may include protecting adjoining surfaces, removing weld splatter, ensuring that surfaces are free of oil and grease, grinding sharp metal edges, protecting plants and other shrubbery, replacing rotted wood, caulking joints, and the like.

9.6.5 Inspect Coating Materials. Coating materials must be inspected at the job site to identify deficiencies that could result in failure of the paint film. The following checklist can be used:

a) Read labels on the coatings to verify that the coatings are the ones specified or approved.

b) Take one representative 1-quart sample in accordance with the specification. Retain the sample for a period of 1 year from the date of final approval of the contract work in case of coating film failures or contract disputes.

c) Ensure that coating materials are in sealed, unbroken containers that plainly show that the date of manufacture is within 1 year. The label should display the manufacturer's name, specification number/or designated name, batch number, and FED-STD-595 color.

d) Inspect the paint after stirring for homogeneity, weight, viscosity, color, and smell. If deficiencies are suspected from these tests, the paint should be sent to a laboratory for testing. A kit developed by the Army Construction

Engineering Research Laboratory (Champaign, IL 61802, 1-800-USA-CERL) is available that will assist the inspector in field inspection of latex and oil-based paints.

e) Count the cans of paint on the job site to determine that a sufficient quantity is available to complete the job as specified. For multi-component paints, confirm that the proper ratio of materials for each specific coating is present. To estimate the paint required for a job, use the nomograph reproduced from a Naval Facilities Engineering Service Center (Port Hueneme, CA 93043) Techdata Sheet shown in Figure 23.

f) Ensure that the paint is stored on site in an approved building or area.

g) Record number of cans and paint condition in record book.

9.6.6 Measure Ambient Conditions. Most coating systems will not dry or cure properly under extremes of temperature or humidity, nor will they adhere well if applied over damp surfaces. For example, specifications often require that the substrate surface temperature be 5 degrees F above the dew point and rising. For these reasons painting contracts have requirements for air and surface temperature, dew point, and, perhaps, additional environmental conditions. The paint manufacturer's technical data sheet will also have limits for acceptable environmental conditions. (If the limits are in conflict, agreement on the limits should be reached during the preconstruction conference.) Because temperature and dew point may vary considerably within a small area, temperature and dew point should be measured in the immediate vicinity of the work being done. Surfaces being painted may be colder than the atmospheric temperature and their temperatures should be measured in addition to atmospheric temperatures. Dew point at the surface being painted may also be different from that in the air away from the surface. Thus, dew point should be measured near the surface. Ambient condition measurements should be made about every 4 hours. These times should include before start of job, after breaks, and after sudden changes in environmental conditions. Sudden changes in environmental conditions should also be recorded in the logbook. In addition, do not paint in rain, snow, fog, or mist, or when the surface is covered with frost.

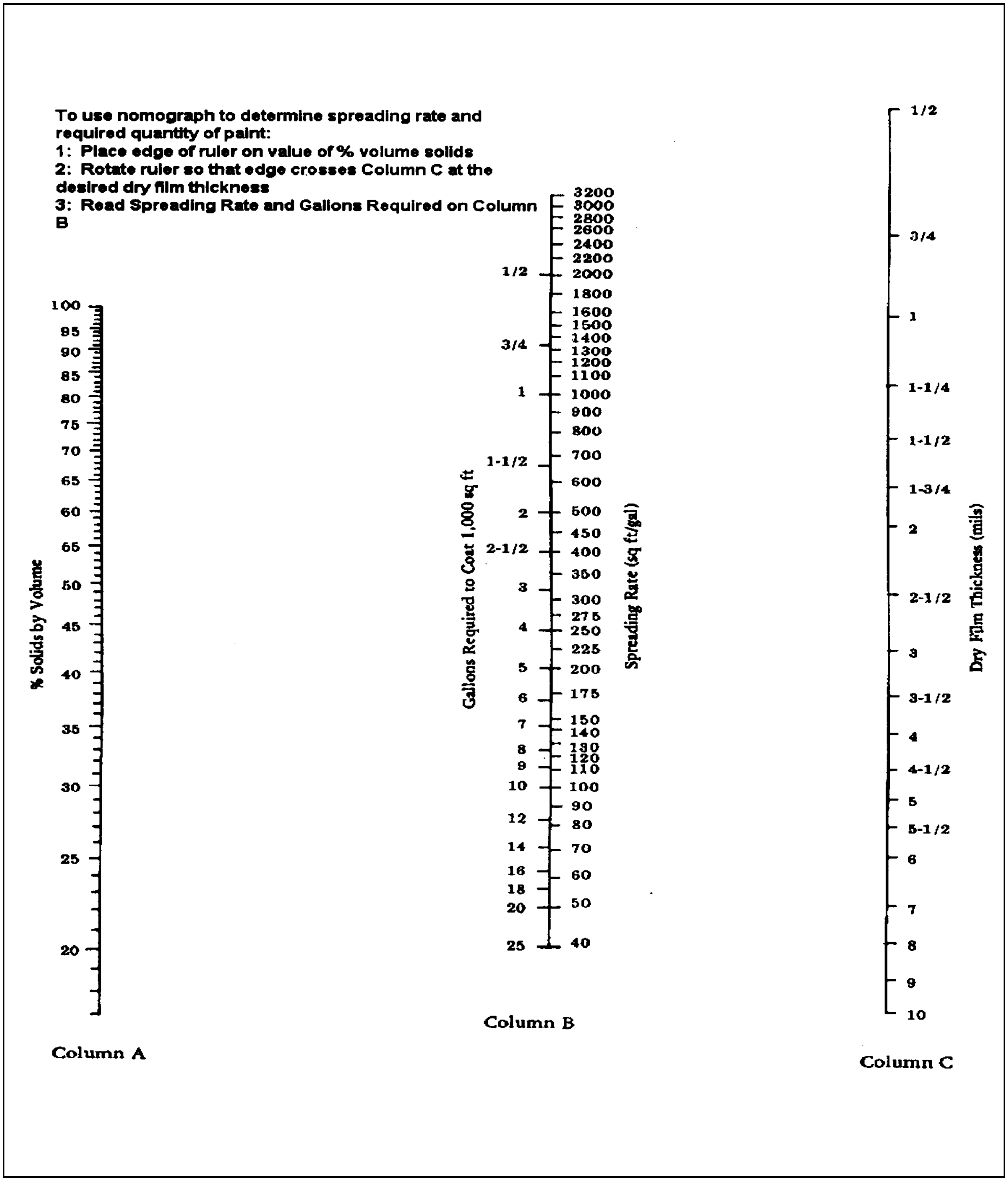


Figure 23
Nomograph for Estimating Quantities of Paint Required for a Job

9.6.6.1 Relative Humidity and Dew Point. These conditions are measured using a psychrometer. Most psychrometers consist of a wet bulb thermometer, a dry bulb thermometer, and a standard psychometric table. Using the table, the relative humidity is obtained from the two temperature readings. More detailed information is provided in Section 10.

9.6.6.2 Surface Temperature. Surface temperature is measured using a special thermometer in which the temperature sensing element is designed to come into intimate contact with the surface and to be shielded from the surrounding air. The surface temperature of the coldest and warmest surfaces should be within the limits of the specification. The location, temperature and time of the measurement should be recorded in the record book.

9.6.7 Inspect Surface Preparation. Surface preparation inspection procedures include inspecting equipment, and associated materials (e.g., blasting medium and chemicals), as well as the cleaned surface itself. Proper surface preparation, as described in the specification, must be completed to obtain a durable coating film. Additional information on surface preparation is presented in Section 6. Many of the surface preparation requirements involve visual inspection of the surface, and some are subjective. For example, the specification may require removal of loose paint (for example, paint that can be removed by a dull putty knife), removal of surface chalk to some specified level and feathering of edges on the remaining paint film. To help avoid conflicts between the contractor and the inspector, it may be useful to have the contractor prepare a test surface about 4 by 4 feet that can then be used as a standard for surface preparation. Photographs of the test surface could be part of the inspection record. For steel, the test surface should be protected by a clear coating.

When blast cleaning is part of the surface preparation, it should be performed in a manner so that no damage is done to partially or entirely completed portions of the work, adjacent surfaces, or equipment. Usually blast cleaning should progress from the top towards the bottom of a structure, should be carried on downwind from any recently painted structures, and should not scatter abrasive on or into surrounding buildings or equipment. All dust from blasting operations must be removed by brushing, blowing, or vacuuming before painting.

9.6.7.1 Abrasive-Blasting Surface Preparation Equipment and Supplies

a) Air Cleanliness. Routinely (at least two times a day or every 4 hours) inspect air supply lines for both blast cleaning or paint spray application to ensure that the air supply is clean and dry. A blotter test as described in ASTM D 4285 can be used to determine whether the air supply is free of oil and moisture. In this test, a clean white blotter is held downstream about 19 inches from the nozzle for 2 minutes. It should remain clean and dry.

b) Abrasive. Each batch or shipment of abrasive should be checked for oil contamination and, if required, soluble salts. Either can contaminate a cleaned surface and reduce the service life of the coating. A commonly used test to check for oil contamination is to take a small random sample of the abrasive, place it together with clean water in a small bottle or vial, shake the bottle for a minute and examine the surface of the water. There should be no sheen of oil on the surface of the water. Soluble ionic contaminants can be detected using the electrical conductivity test described in ASTM D 4940. In addition, the abrasive should feel dry to the touch when it is placed in the abrasive blasting machine. Recycled abrasives break down after several cycles, and the number of cycles depend upon the type of the abrasive. The abrasive should be replaced when it no longer meets the requirements of the specification.

c) Blast Hoses and Nozzles. Blast hoses should be in good condition and kept as short as possible. The nozzle pressure and diameter of the nozzle orifice both affect the cleaning rate. A nozzle orifice gage is used to determine the orifice size. Air pressure at the nozzle is measured using a hypodermic needle air pressure gage and should be from 90 to 100 psi for optimum efficiency. Usually these parameters are measured at the start of a job and when production rates are decreasing. An increase of nozzle size of more than 1/8-inch causes loss of cleaning efficiency because of the increased pressure drop. Increased nozzle size also causes increased use of abrasive. Profile should be inspected when major changes in cleaning efficiency are noted.

d) Safety. Special safety precautions are required during abrasive blasting. Refer to Section 13 for more information. These precautions include use of external couplings on blast hoses and dead man controls, and electrical grounding of equipment.

9.6.7.2 Water Blasting. Since contaminants, such as salts and oils, in the blasting water will be left behind on the blast-cleaned surface and may adversely affect the adhesion of the coating to be applied, water should be essentially free of contaminants. If cleaning agents are added to the water used for blasting and cleaning, the surfaces must be thoroughly rinsed with clear water. An exception is the use of flash-rusting control agents when cleaning steel. These agents should only be used in accordance with the contract specification and the coating manufacturer's recommendations. As for abrasive blasting, hoses should be in good condition and kept as short as possible. Special safety precautions, similar to those used in abrasive-blast cleaning, also need to be taken. In addition, consideration should be given to the slipperiness of wet surfaces. More information on safety is provided in Section 13.

9.6.7.3 Frequency of Inspecting Cleaned Surfaces. The objective of the inspection is to ensure that the entire surface was prepared in accordance with the specification. The inspection report should provide a representative description of the cleaned surface. The specific number and location of places at which surfaces should be inspected must be in accordance with the contract specification. If not detailed in the specification, SSPC PA 2 can be used as a guide. Additional inspection sites that should be considered include those where the existing paint was failing, in hard-to-reach areas where surface preparation is difficult, and where major changes in equipment were made.

9.6.7.4 Inspecting Prepared Steel Surfaces

a) Cleanliness. If a small representative sample of surface was not prepared to use as the standard for surface preparation, the degree of blast or tool cleaning should be compared to the description given in the SSPC or NACE specification referred to in the contract specification. The appearance should correspond with the specified pictorial standards of SSPC VIS 1, SSPC VIS 3, or a NACE panel. Complete descriptions of the degrees of cleanliness are found in Section 6. After blasting, blast-cleaned surfaces must be cleaned (e.g., vacuum, air blast, or brushing) to remove traces of blast products from the surface or pitted areas. One of two tests for cleanliness can be used. In one, a white glove or other clean cloth is rubbed over the surface and examined for soiling or debris, and in the other, a piece of clear adhesive tape is applied to the surface, removed and the adhesive side examined for debris.

b) Profile. Profile is measured using one of three pieces of equipment: comparator, depth micrometer, or replica tape. It should be noted that the three techniques may give slightly different results. Complete descriptions of standard methods for each of these techniques are described in ASTM D 4417, Field Measurement of Surface Profile of Blast Cleaned Steel and in Section 10.

9.6.7.5 Inspecting Concrete, Masonry, Wood, Plaster, Wallboard, Old Paint. On these surfaces, specifications may have requirements for measurements of moisture content and residual chalk, as well as visual condition. The specification should state how moisture is to be measured, since the different methods provide different types of data. Moisture content can be measured either using a plastic sheet test (ASTM D 4263) or an electric moisture meter. In the plastic sheet test, a piece of plastic film is taped (all edges) to the surface. After 24 hours, the film is removed and the underside is examined for the presence of condensed water. Prior to application of most coatings, the sheet should be free of condensed water. This is because accumulation of water at the concrete/primer interface will usually lead to delamination of the primer. To use a moisture meter on hard surfaces, small holes must drilled for the electrodes. These holes should be repaired after the measurements are completed. The contract should state a moisture requirement. Residual chalk is usually measured using a piece of cloth of contrasting color, in accordance with ASTM D 4214. Other procedures are also described in ASTM D 4214. In the cloth method, a piece of cloth is wrapped around the index finger, placed against the surface and then rotated 180 degrees. The spot of chalk on the fabric is compared with a photographic reference standard. Chalk readings of 8 or more indicate adequate chalk removal providing reasonable assurance that the new coating should not fail because of application to a chalky surface.

9.6.8 Inspect Coating Application. Proper application is another essential factor in determining paint performance, and the requirements of the specification must be followed. General guidance on paint application is presented in Section 7 and SSPC PA-1. Inspectors should assess ambient conditions, application equipment, ventilation, mixing, film thickness, and drying and curing conditions to ensure that they are within the limits of the specification and the technical data sheets for the paints. It is especially important that the paints be applied and cure within the temperature and relative humidity limits of the specification, since these conditions affect film formation. A properly dried and cured film is essential for satisfactory paint performance, and deviations from these limits may prevent proper film formation. For two-component systems, the inspector should ensure that the materials were mixed together and in the proper ratio. For all materials, thinning should only be allowed in accordance with the manufacturer's data sheet.

9.6.8.1 Application Equipment. Equipment to apply the coating must be in acceptable working condition. When spraying, the spray pattern should be oval and uniform, the gun should be held at the proper angle and distance from the surface, and each spray pass should overlap the previous one by 50 percent. Proper techniques should also be used for brushing, rolling, or other application procedures. Refer to Section 6. Special safety requirements for paint application are described in Section 13.

9.6.8.2 Ventilation. The ventilation of tanks and other enclosed areas where paint is to be applied and cured must meet the requirements of OSHA's Confined Space Regulation, and the contractor's safety plan required by contract specification. Good ventilation is also necessary for proper coating cure.

9.6.8.3 Mixing/Thinning. Paints must be properly mixed as described in Section 7. Paint solids often settle out during storage and must be completely blended into the paint vehicle, resulting in homogeneous mixture. For multi-component paints, the inspector should ensure that all components have been mixed in the proper proportion, that the mixing is thorough and that the resulting paint is uniform in appearance. Required induction times must also be met to obtain satisfactory application and film properties. Although the paint manufacturer prepares paint to produce a consistency for brushing, rolling, or spraying, sometimes additional thinning is permitted in the specification. Thinning of the paint must follow manufacturer's instructions for both type and amount of solvent. A thinned paint will cover more surface area but the dry film thickness will be less and may not meet the requirements of the specification.

9.6.8.4 Film Thickness. Contract specifications may require a minimum and/or a maximum dry film thickness for each coating application. Wet film thickness measurements made at the time of paint application are used to estimate dry film thickness so that appropriate adjustments in the application procedure can be made to meet the specification. Wet film thicknesses are not used in meeting contract requirements because of the many factors (solvent evaporation, wetting energies) that affect the measurement. Procedures for making wet film thickness are described in ASTM D 4414, Wet Film Thickness by Notch Gages and in Section 10. The dry film thickness is estimated from the wet film thickness according to:

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

The percent volume solids is available from the coating manufacturer's data and should be part of the inspector's records. Dry film measurements are made after the coating has hardened. For steel surfaces, thickness measurements can be made according to SSPC PA 2 or ASTM D 1186 or ASTM D 1400, Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base. (There are some differences in calibration procedures between SSPC PA 2 and the ASTM standards. If the contract specification does not specify the exact procedures to be used, the procedures should be agreed upon, and the agreement documented, during the preconstruction conference.) ASTM D 4128, Identification of Organic Compounds in Water by Combined Gas Chromatography and Electron Impact Mass Spectrometry describes a destructive procedure for measuring coating thickness on non-metallic substrates using a Tooke gage (refer to Section 10). If the contract specification requires minimum film thicknesses for each layer, the measurements must be made after each layer has cured, taking care not to depress soft coatings during measurements.

9.6.8.5 Drying. The inspector should ensure that a previous coat has dried or cured as required by the contract specification before another coat is applied. For most thermosetting coatings, manufacturers specify a maximum, as well as a minimum, curing time before application of the next coat. In some situations, a coating manufacturer may require use of a methyl ethyl ketone (MEK) rub test to assess curing prior to application of another layer. The inspector's record should provide information so that the dry/cure time for each layer can be determined.

9.6.9 Final Approval Procedures. The final approval inspection is very important since it determines whether the contract requirements have been met, and whether identified deficiencies have been corrected. Since most coatings function as a barrier and since the protection of a surface is usually directly related to coating thickness and continuity, inspection of coating thickness and film continuity are essential. The following checklist can be used to inspect the final job:

a) Examine, as required by the specification, the cured coating system for visual defects, such as runs, sags, blistering, orange peel, spray contaminants, mechanical damage, color and gloss uniformity, and incomplete coverage. Note any areas of rusting, or other evidence of premature failure of the coating system.

b) If defects are observed, bring them to the attention of the contractor for correction. If resolution of the corrective action cannot be reached with the contractor, bring the matter to the attention of the contracting officer. Dated photographs of the defects could become part of the inspector's records, if deemed appropriate.

c) Measure and record the total dry film thickness using appropriate gages. When the Tooke gage is used, the coating must later be repaired.

d) Measure adhesion as required in the contract specification. Adhesion measurements vary from those made with a knife (ASTM D 3359, Measuring Adhesion by Tape) to those that determine the amount of force needed to remove a dolly (Section 10 and ASTM D 4541, Pull-Off Strength of Coatings Using Portable Adhesion Testers) that has been cemented to the surface.

e) Examine the coatings on steel structures for pinholes using a holiday detector as described in NACE RP0188 and Section 10, if required in the contract specification.

f) Record the results of observations in the record book. Document photographs taken and retain in the record book.

9.6.10 Year Warranty Inspection. The warranty inspection includes a visual inspection of the film, and may involve a chalk, film thickness, and adhesion measurements. Since the film was found to be essentially free of defects upon completion of the job, a goal of the inspection is to identify contractually unacceptable defects that have formed during the course of the year. Resolution of film deficiencies should follow the same steps as for the final inspection. Deficiencies should be recorded in the logbook. Documented photographs (date, location, and photographer) should be included if deemed necessary to resolve contract disputes.