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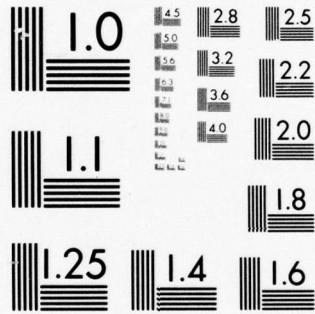
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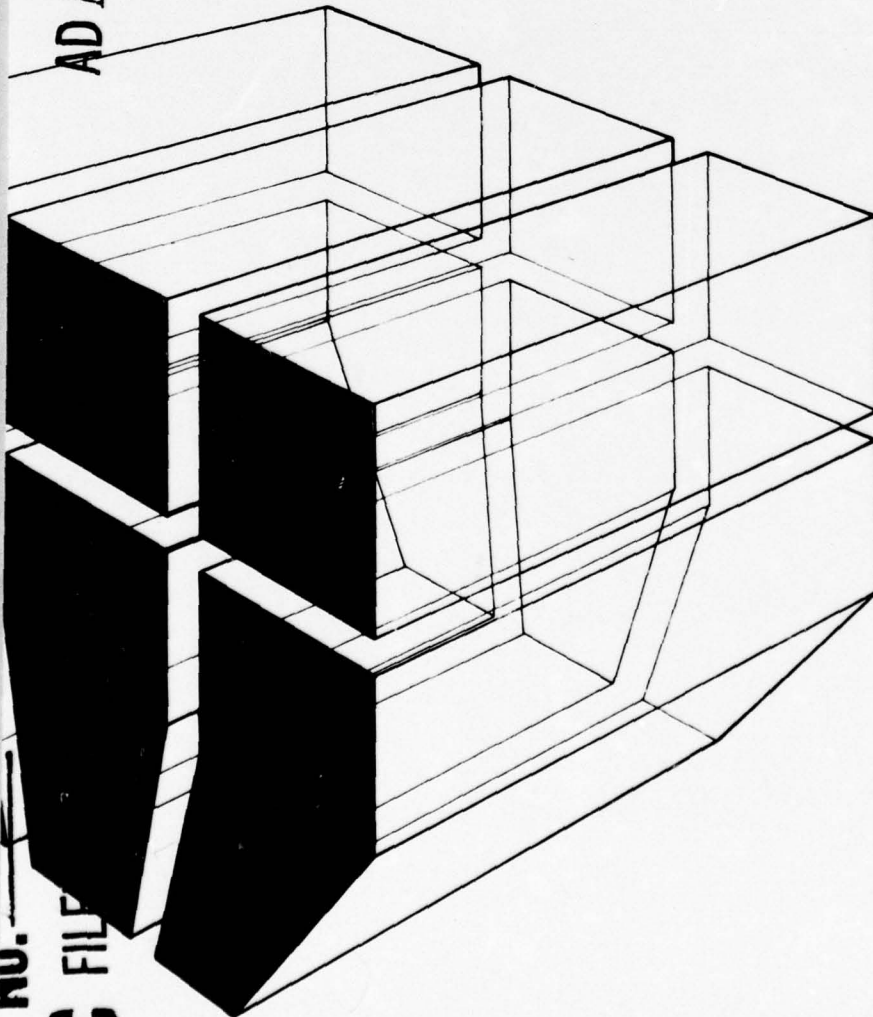
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SPRAY PAINTING: EQUIPMENT AND TECHNIQUE
FOR APPLICATION OF VINYL PAINTS

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by
A. Beitleman



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This paper is intended to assist those involved with spray painting to better understand both the equipment and techniques used in the application of vinyl paints. The basic components of both conventional atomization and airless atomization systems are discussed (including heated systems). Guidance is given on the application techniques found to be most effective when applying Corps of Engineers' vinyl paints. The causes of some unsatisfactory painting results are given along with methods for correcting the problem.		

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FOREWORD

This paper was prepared for presentation at the Civil Works Paint School, conducted annually at the U.S. Army Construction Engineering Research Laboratory (CERL). Background work was conducted as part of Civil Works Research Work Unit 31205. The school is funded under reimbursable order CWE-D-77-4, and the research under reimbursable order WES RF-77-11. The technical monitor of both projects is Mr. L. G. Guthrie of the Directorate of Civil Works, Office of the Chief of Engineers.

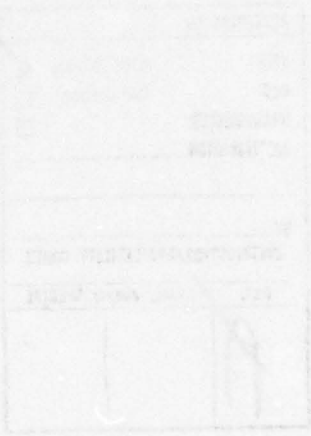
The paint school is conducted by members of the Construction Materials Branch (Mr. P. A. Howdysshell, Chief), Materials and Science Division (Dr. G. R. Williamson, Chief).

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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SPRAY PAINTING: EQUIPMENT AND TECHNIQUES FOR
APPLICATION OF VINYL PAINTS

1. Introduction

The subject of spray painting, even when confined to the construction and maintenance of steel structures, has become quite complex due to the introduction of new types of coatings and new types of spray-painting equipment. Prior to about 1950, exterior coatings in this field were preponderantly oil and oleoresinous types. While these coatings had application shortcomings, they were comparatively simple to spray apply. They had inherently good leveling properties and were low to moderately low in volatile content, which provided for excellent dry-film build per coat.

The new coatings are not considered difficult to apply, but they do require better spraying techniques and therefore place greater demands on the painter's proficiency and knowledge. To do even a passable job, he* must know their spraying and drying characteristics and how to select, adjust, and properly operate the spraying equipment. The major variable adding to the complexity of the subject is the weather. The painter may be called upon to apply vinyl paints in temperatures ranging from 40°F to 100°F, with surface temperatures running up to 125°F. If he does not know how to compensate for differences in spraying conditions, his results will be far from satisfactory. The relatively new two-component chemically curing type coatings such as the coal-tar epoxies, epoxies, urethanes, and zinc-rich paints add to the complexity of the subject. Furthermore, the application properties of each type of paint vary from formula to formula.

Spraying equipment, which changed little except for refinements in 50 years, is now undergoing some rather radical changes. The employment of paint heaters and paint pumps is largely responsible for the changes. The inconsistency in names given to the several painting processes and equipment by the industry leads to an appreciable amount of confusion. Currently, when someone refers to airless spray, it is unclear whether the process includes heating the paint or spraying it without heat. When

*"He" is used throughout this paper to represent both masculine and feminine genders.

the term "hot spray" is used, it is not known whether it is conventional hot spray or airless hot spray. To avoid this confusion, this paper classifies the four processes as follows:

a. Conventional Spray (Air Spray). This is the oldest and most widely used process. In this method, the paint is atomized by direct contact with compressed air. The atomization may take place either inside the paint gun or just outside the gun at the tip. The paint is at normal temperatures when sprayed.

b. Conventional Hot Spray. As implied by the name, in this process the paint is heated before it is atomized by conventional methods, i.e., by direct contact with compressed air. The equipment might be strictly conventional, modified only by the insertion of a heating unit in the paint line near the gun. It might, however, be considerably more complex in nature and operation. A more detailed description of the equipment and the process in general is provided in Section 2b below.

c. Airless Spray. In this process the paint is atomized by placing it under very high hydraulic pressure and forcing it through a small orifice. The normal hydraulic pressures employed range from about 1200 psi to above 3000 psi. One manufacturer has adopted the trade name of "Hydra-Spray" for his equipment.

d. Airless Hot Spray. This classification includes systems which employ both heated paint and high hydraulic pressures to atomize the paint. The original so-called airless equipment introduced in the early 1950's was of this type but only used pressures up to about 600 psi. The more modern airless hot spray simply attaches an electric heater to a recirculating fluid line on a standard airless unit.

2. Equipment

a. Conventional Spray Equipment. Conventional spray equipment consists essentially of an air compressor, material and air hoses, a paint tank often referred to as "paint pot," air-regulating devices, and a spray gun. A material or paint pump can be used in place of the tank. A suction cup gun, standard equipment to the automotive refinishing industry, is also considered conventional but could be used on only very small field painting jobs.

(1) *Air Compressor.* The important consideration regarding the air compressor is that it have adequate capacity to supply the demands of the equipment. A high production spray gun needs from 10-20 cubic feet of air a minute at normal spraying pressures. While this is a substantial amount, it is only a fraction of that required for operation of a 3/8 in. or 1/2 in. sand-blasting nozzle. If the spray gun is starved for lack of suitable air pressure, the paint will not be atomized as it should be. Where air-fed respirators and hoods are worn by the painters, some consideration should be given to carbon monoxide contamination of the air. This could occur if the compressor is driven by a gasoline or diesel engine or if the compressor's air intake is too close to other engines.

(2) *Air Hose.* The air hose to the gun should have a minimum inside diameter of 5/16 in. and preferably 3/8 in. The pressure drop due to friction losses is excessive when smaller air hoses are used. Table 1, published by a leading equipment company, shows the comparative drop in line pressures of 50 ft lengths of 1/4 in. and 5/16 in. hose at various operating pressures.

Table 1
Pressure Loss in Air Lines

<u>Entering Pressure</u> <u>psi</u>	<u>1/4 in. Hose</u> <u>psi Drop</u>	<u>5/16 in. Hose</u> <u>psi Drop</u>
50	24	10
60	31	11-1/4
70	34	13
80	37	14-1/4

To properly atomize vinyl paints applied at high production rates, i.e., upwards of 35 ounces a minute, the pressure at the gun should be about 60 psi. Table 1 shows that the pressure at the compressor would have to be over 100 psi to do this with a 50 ft length of 1/4 in. hose. If hoses longer than 50 ft are being employed, or if high-viscosity materials such as coal-tar epoxies are being sprayed, the diameter of the hose should be not less than 3/8 in. The air hoses are not made to resist paint solvents and should not be used as material hoses. Moreover, they should be kept clean. The small air holes and passages in a spray gun and cap are very easily plugged. A dirty or defective air hose can cause troublesome delays and poor workmanship.

(3) *Material or Paint Hoses.* Material or paint hoses should have a solvent-resistant inner liner. While short lengths of 5/16 in. diameter hose may be used for paints of normal viscosity, hoses of 3/8 in. diameter are preferred and are required if long lengths are used or if the material is somewhat viscous. Daily cleaning after use is highly recommended but often not done. With the chemical-setting two-component paints, the cleaning should be very thorough. With some of these, the hose should be cleaned out if the painting is interrupted for as little as an hour. Hose cleaners designed especially for this purpose are very efficient and effective and offer a substantial savings in labor and cleaning fluids.

(4) *Paint Tanks.* Paint tanks come in a variety of sizes and types. In the more commonly used type, the regulated air pressure forces the paint out of the tank via a pipe which extends from the tank lid down to near the bottom of the tank. A second type, called "bottom withdrawal," has an outlet in the bottom through which the paint is forced. The latter type should be used if viscous paints such as mastics and coal-tar epoxies are being sprayed.

The tank should be equipped with at least one air regulator and a pressure gauge. They are often equipped with two regulators and gauges, one set to regulate and gauge the tank pressure and the second to control atomization air pressure to the spray gun. The two sets work

entirely independently of each other, since the air requirements are rarely the same. The paint flow (called fluid flow) to and through the gun is controlled by regulating the tank pressure. Naturally this pressure is not the same for all paints for all sizes and lengths of fluid hose. Even the height relationship between the tank and the gun is a consideration.

Tanks equipped with air-driven agitators are necessary for special types of paint such as those containing zinc dust pigment.

(5) *Air-Driven Material Pumps*. Air-driven material pumps are often used in place of tanks to deliver the paint from the container to the spray gun. There are many types and sizes of these being marketed. If they are properly designed to provide a continuous flow of paint free of pulsations, are of adequate size, and are equipped with the proper regulators, they perform quite satisfactorily.

(6) *Air Transformer*. An air transformer has three important functions:

- (a) Removes dust, oil, water, and other contaminants from the air.
- (b) Provides a regulator and gauge to control the atomization air.
- (c) Provides multiple air outlets and shutoff valves to supply the spray gun, tank, and other equipment.

This piece of equipment is very helpful in getting good spray-painting results, especially when the compressed air supply contains large quantities of water due to high humidity. If other regulators are used for controlling the atomization air pressure and the air supply is not contaminated, the use of a transformer is not mandatory for successful results.

(7) *Spray Guns*. There are many types and sizes of spray guns which are classified as conventional. High-production guns are designed to spray paints of normal viscosities at rates up to approximately 45 ounces a minute. Many of these can be used for spraying any type of coating materials, including mastics, by selecting the proper gun components -- head, fluid tip and needle, air cap, and in the case of mastics, stronger needle spring.

The operating principle of the spray gun is relatively simple. It consists essentially of the body, trigger, fluid tip and needle assembly, and air cap. With some guns, the head assembly is removable so that heads of different types and sizes may be used. The needle seats into the fluid tip, and is held in place by a guide and spring. This assembly is in essence a variable valve to control the flow of paint. An air valve is also built into the hand grip of the body of the gun. Both of these valves are controlled by the trigger and operate semi-independently. As the trigger is partially depressed, the air valve is opened, permitting air to pass out through the holes in the air cap. Further depression of the trigger withdraws the needle from its seat in the fluid tip. The paint, under pressure exerted by pressure in the tank, is forced out of the tip orifice into the air streams coming out of the air cap, where it is atomized and shaped into a pattern.

The gun has two regulating screws located on the back just above the grip. The upper screw controls the amount of air to the holes located in the two horns of the air cap. If the air to these horn holes is shut off, the atomized paint particles are deposited in a round pattern. As more and more air is forced through the horn holes, the pattern is flattened. When this valve is completely open, the pattern is fan shaped. The second screw provides a secondary or supplementary means of controlling the paint flow. This screw, together with a spring, controls the distance that the needle can be withdrawn from its fluid tip seat. By and large, the flow of paint should be controlled by regulating the tank pressure and not at the gun.

The selection and use of the proper fluid tip and needle assembly and air cap are very important to good results. These components affect the fluid flow, effectiveness of the atomization air, degree of atomization, and type, size, and shape of the fan or pattern. Fluid tips have orifices ranging in size from .040 to .140 in. inside diameter. One with an orifice of .070 in. (DeVillbiss "E") is quite satisfactory for most paints encountered, including conventional epoxy resin and vinyl coatings. An .086-in. tip (DeVillbiss "D") has provided excellent results

with coal-tar epoxy resin coatings. Larger orifices may be required for mastic coatings. Tips with orifices larger than .070 in. should not be used with vinyl coatings, since the atomization air becomes progressively less effective as the diameter of the orifice and paint stream is increased.

Air caps are classified by the width of the fan they produce and the number and location of the air holes. Eleven-hole caps which produce an 11-12 in. fan at a spraying distance of 8 in. (DeVillbiss Cap No. 765) are well suited for vinyl and other standard types of paints. An eight-hole cap which produces a 9-10 in. fan has also been found satisfactory for vinyl paint spraying. These caps are the external type; i.e., the paint is atomized outside the air cap. With internal caps, the paint and atomizing air meet within the tip where the atomization takes place. These are satisfactory for slow-drying paints and preferred if the air supply is limited. Internal caps are seldom used for lacquer coatings, primarily because these fast drying paints tend to build up on and close the slot in the tip, resulting in distorted, uneven fan shapes.

b. Conventional Hot Spray Equipment. Conventional hot spray equipment in general use is of three types -- modified conventional, circulating paint hot spray units, and circulating hot water units.

(1) *Modified Conventional.* The simplest form consists of merely inserting a small heating unit in the paint hose of conventional spray equipment. The heater is usually located only a few feet from the gun. Generally, these heaters are powered by 110V and are carried in an insulated sling. The capacity of a 1 kW heater is limited to around 20 ounces of 150°F paint per minute; this falls far short of being enough for normal field painting.

(2) *Circulating Paint Hot Spray Units.* Circulating paint hot spray units are probably the most popular. These units consist of a conventional spray gun and air hose, an electric-powered cast aluminum heating unit assembly, two fluid hoses, and a duo-purpose material pump to supply the paint to and circulate it through the system. The smaller units

may have either an electric-powered centrifugal pump or an air-driven piston pump. If more than one gun is being operated off the unit or if the material hose is over 40 ft in length, a piston pump is generally recommended. The heating unit assembly consists of one or more 1 to 2 1/2 kW heating units; they may be 110V or 220V, depending upon their size. Each heater has a built-in thermostat which limits the metal temperature of the heater to avoid local overheating. The final temperature of the paint is controlled by another thermostat located in the paint line between the last heating unit and the gun. This thermostat assembly also has a thermometer which registers the paint temperature at that point. One paint hose runs from the heating unit to the gun and a second from the gun back to the pump. The speed of the air-driven pump and thus the flow of material is controlled by the air regulator and gauge.

The equipment operates automatically once the system is filled with paint and the gauges are set for the desired temperature and delivery of paint. The pump takes paint out of the paint tank or can and circulates it through the heating units to the gun. When the gun is closed, all of the paint is circulated back to the pump and again goes through the heaters. The flow of paint through the hose is always slightly greater than that needed by the gun so that the paint in the return line is never stagnant. If the unit is properly designed, the temperature of the paint at the gun will not vary significantly. The flow of paint in the hose to the gun and the pressure remains fairly constant at all times. When paint is sprayed, the pump maintains the pressure by taking in more paint. While the gun is closed, it merely circulates the paint.

Some of the smaller units depend upon a pressure paint tank or a paint pump for their paint supply. The pumps in these units are designed to merely circulate the paint once it is in the system.

As indicated above, units are made in many sizes. The capacity of the equipment is governed primarily by the size of heating units. However, the circulating capacity of the pump and the size and length of the paint hose are factors. For a one-gun operation, the heating unit assembly should be rated at not less than 2 kW. An efficient 5 kW unit will

supply a three-gun operation when ambient temperatures are above 40°F.

(3) *Circulating Hot Water Units.* A third type of unit employs circulating hot water to supply heated paint. The unit consists of a combined electric water heater, electric-powered water circulating pump, and a heat exchanger. Additionally, it employs a three-passage material hose, a conventional spray gun, various valves, gauges, temperature and air regulating devices, and a conventional paint tank or paint pump to force the paint through the unit to the spray gun. The paint is heated in the hot water heat exchanger. This temperature is maintained all the way to the spray gun by circulating hot water through the two outer passages of the three-passage material hose. The paint is heated only once and does not recirculate through the heater.

c. Airless Equipment. Airless equipment is essentially of one type of several sizes. A unit generally consists of an air or electric-powered hydraulic pump mounted over a 5 to 10 gallon paint container, high-pressure fluid hose, spray gun, valves, gauges, regulators, and screens. Some units have an air-driven paint agitator, surge tank, and special filters.

(1) *Pumps.* The pumps are rated according to the amount of fluid (hydraulic) pressure they create on the paint and amount of paint they pump. Some pumps are now rated at 45:1. This rating means that each psi of compressed air used to power the pump creates 45 psi of hydraulic pressure on the paint. Theoretically, it is possible to have an hydraulic pressure of 4500 psi at the gun with compressed air having a pressure of 100 psi.

(2) *Hoses.* Paint hoses having an inside diameter of 1/4 in. or 3/8 in. are generally used, and are constructed to withstand around 10,000 psi pressure. Steel-braid-covered hoses lined with solvent-resistant teflon are often used, although nylon hoses have also been found satisfactory.

(3) *Spray Guns.* Spray guns are constructed with removable tips so that tips with orifices of various sizes can be used. The fluid tip is

largely responsible for controlling the amount of paint flow, degree of atomization, and the size and shape of the spray fan. While the amount of hydraulic pressure also affects these somewhat, it is normally advisable to regulate the fluid pressure to near its maximum and change the tips until the desired results are obtained.

d. Hot Airless Spray Equipment. Hot airless spray equipment, in addition to having paint heaters, may differ substantially from airless equipment. Essentially, it consists of an air or electrically powered pump designed to create hydraulic pressure, a paint-heating component, a spray gun, a paint hose to the gun, and a return hose from the gun to the unit. The equipment is controlled by air regulators, valves, and thermostats.

The equipment operates similarly to conventional hot spray in some respects, except that paint is atomized by the high-fluid pressure small-orifice principle. The pump serves the dual role of keeping the system filled with paint at the desired hydraulic pressure and circulating the paint through the system.

The gun is constructed similarly to the airless gun and employs the same type of interchangeable tips.

The fluid hoses used are or may be of substantially the same size and type as used for airless. A "Y" connection at the gun may permit the paint to bypass it and circulate back to the heater, or the bypass may be built into the gun.

3. Application of Vinyl Paints by Conventional Spray

The application properties of vinyl resin paints specified for Corps of Engineers structures have much in common with the lacquers used in the automotive industry. Poor spraying techniques with either can cause many types of defects in the applied film, such as pinholes, orange peel, curtains and sags, surface bubbles and craters, honeycombed films, rough, sandy finishes, and uneven film thicknesses. Moreover, if proper procedures are not used, the coating may be thin in spots with corners, edges,

rivet heads, and welds poorly covered. These defects are discussed in Section 3c. Additionally, poor technique can easily result in the loss of half of all paint sprayed. A good painter can effect a savings of several cents per square foot in paint usage to say nothing of the added durability of the better film which he obtains.

a. Preparation of Paint. The first step toward good painting results is the proper preparation of the paint for spraying.

(1) *Temperature.* The viscosities of all paints and particularly vinyl paints are greatly affected by the temperature. In many cases, they gel when subjected to low temperatures and must then be heated to above 100°F to return them to near normal viscosity. If at all possible, the temperature of the paint should be above 60°F and preferably above 70°F at the time of spraying. Paints at these temperatures require appreciably less thinning to atomize than cold paints, thus giving more film thickness per coat.

(2) *Mixing.* With few exceptions, the pigments in paint tend to settle to the bottom. This settling may vary from traces in freshly made paints to a substantial portion of the pigment in others which have been stored for a long period. For obvious reasons, therefore, paints should be well mixed before application. This mixing should include boxing of the paint between two pails and inspecting the bottom of the pails to insure that all of the pigment has been redispersed. On occasion, a minor amount of lumpiness still exists after thorough mixing. Where this condition exists, the paint should be strained before it is put into the paint tank.

(3) *Thinning.* The third step in preparation is thinning. The amount of thinner required varies from paint to paint and from day to day. It might even vary from morning to afternoon. Thinner is added for two reasons: (1) to lower the paint's viscosity so that it can be atomized properly by the spray gun, and (2) to insure that the paint does not dry out too much as it travels in an atomized state from the spray gun to the surface. It is not desirable to thin the paint so that

it atomizes into a mist; instead, the atomized particles should be about the size of fine sand when they are deposited on the surface. In terms of a No. 4 Ford Cup, good atomization can be obtained if the viscosity is about 35 seconds. As a matter of comparison, most Corps of Engineers' vinyl paints have a viscosity between 75 and 90 seconds at the time of manufacture. They require 15% to 25% thinning to lower their viscosity to 35 seconds at normal temperatures; 20% thinning, i.e., 1 gallon of thinner to 5 gallons of paint, is a very good starting point when ambient temperatures are around 70°F. After a trial pass, the painter may find that excessive air pressure is required to break it up and more thinning is needed.

During warm weather, the solvents tend to volatilize out of the atomized paint very rapidly after it leaves the gun. The paint also dries faster when applied to warm surfaces. These factors must be compensated for either by adding more thinner or by starting out with a slower evaporating thinner. Methyl isobutyl ketone (MIBK) thinner is recommended for low and normal temperatures. When ambient temperatures are high, above 70°F, thinning with methyl isoamyl ketone (MIAK) produces much better results than MIBK. MIAK has a higher boiling point and does not volatilize out of the paint as fast.

It is important that thinning be the optimum amount for several reasons. In addition to the cost of the thinner, overthinning may make it impossible to get the normal film thickness per coat without runs and sags. In many cases, additional coats may be required to get the desired film thickness. Underthinning, resulting in poor atomization, can cause the paint to have an orange peel texture. If the paint is too dry as it comes out of the spray gun, much of the paint will never reach the intended surface but will float away in the form of spray dust and even webs. The paint that is deposited will not have enough solvent to permit it to flow out, and it will be rough and contain pinholes. In extreme cases, it will have a rough, sandy finish.

b. Spray Painting Techniques. Spray-painting techniques include the

spray pattern, gun distance, lapping, triggering the gun, the stroke, atomization pressures, and the double spray coat.

(1) *Pattern and Gun Distance.* Under normal conditions, the gun should be held so that the tip is 6 to 8 in. from the surface being painted. The painter should get accustomed to spraying at a set distance and not vary this distance more than an inch except in special cases*. Fluctuating the distance between the surface and gun between 5 and 10 in. can have several consequences. As the gun moves closer, the pattern becomes narrower and the same volume of paint is applied over a smaller area unless the gun is moved faster. The paint loses less solvent and is deposited wetter because it does not have as far to travel. Either of these conditions can cause the paint to sag and bubble. The atomization air may even distort the wet paint film. As the gun is moved farther away, the pattern becomes wider and the paint goes on thinner and drier. Orange peeling, pin holes, and a sandy finish may result. Fluctuating the distance causes the applied film to have a nonuniform thickness.

If wind or air currents are a factor, it may be desirable to hold the gun closer than 5 in. so that the fan will be less affected and less paint will be blown away.

The proper shape of a spray pattern can be described as a flat oval. The pattern tapers some at the ends but not drastically. The distribution of the atomized paint is quite uniform throughout the entire width of the pattern. If the fan is distorted in any manner, the paint cannot be applied uniformly. It may be normal on one end but light on the other or it may be distorted to a half-moon shape. These defects are usually caused by plugged air holes in the cap or dirt, dried paint, or skins in the orifice or on the fluid tip. If the fluid flow and the atomization air are not in proper balance, the pattern may be very broad in the middle and taper sharply at the ends, or it may be split, i.e., be heavy on

* The painter can easily measure this distance by placing his thumb at the tip of the gun; with the hand spread, the distance from the thumb to the little finger is about 8 in.

the ends and thin in the center.

(2) *The Stroke.* The gun should be moved at a uniform speed across the surface and held perpendicular to the surface being painted. "Fanning" or "arcing" the gun is a very common practice with many painters. Here the gun is swung in an arc. The only time the gun is truly pointed at the surface is in the middle of the stroke. The distance the paint travels may vary from 6 in. in the middle of the stroke to as high as 24 in. on each end. Much of the paint is dry before it ever reaches the surface, and a substantial amount flies off into the air. "Tilting" the gun either up or down produces equally poor results. In tilting, part of the paint travels a short distance, while the other part travels farther and covers a broader area. The deposited film is not uniform in any respect.

Considerable concentration and practice are required before the painter automatically maintains the gun perpendicular to the surface at all times. In a natural movement, the wrist flexes outward at the end of each stroke. If the stroke is proper, the wrist gradually flexes in on both ends of the stroke.

(3) *Lapping.* To produce a coating having uniform thickness, it is necessary to lap each pass 50% over the preceding pass. This is done by aiming the gun at the bottom of wet paint film just deposited in the previous pass. This produces a shingling effect and promotes uniformity. Pinholes occur in paint film which has not been lapped, primarily because the wet paint is not thick enough or wet enough to flow out properly.

(4) *Triggering.* As previously stated, the first depression of the gun's trigger opens the air valve to let air pass through the cap; further depression allows the paint to flow. The gun should be triggered at the end of each stroke by letting up on the trigger just enough to shut off the paint but not the air. As the stroke is reversed, the trigger is again depressed to start the paint. In shutting off only the paint flow at the ends of the stroke, the paint is feathered out over the end a few inches; i.e., the thickness is tapered off. This eliminates a heavy streak at the lap when the adjacent area is painted, provided it too is

"feathered." In changing directions at the end of each stroke, the momentary pause causes heavy deposits of paint if the gun is not triggered. Poor painters who do not trigger avoid sags by flipping the gun and shooting the paint into the air. This wastes paint and causes sandy finishes.

(5) *Fluid Flow and Atomization Pressure.* When painting flat surfaces, a proficient painter can use a fluid flow of 45 ounces a minute. Less proficient painters cannot manipulate the gun fast enough to use more than about 32 ounces of paint a minute. If the paint is thinned properly and an efficient air cap is used, 60 lbs of air pressure at the gun is sufficient. Air pressures higher than 60 psi at the gun are considered excessive for spraying vinyl paints. If too much air pressure is employed, the paint is overatomized and in extreme cases will be mist-like. This tends to dry the paint out too much and causes it to be deposited in a semidry condition. Moreover, excessive pressure and volumes of air increase the loss of paint through fogging and overspray. The optimum amount of air pressure is the minimum required to break up the paint into particles, approximately 80% of which are the size of fine sand.

(6) *Double Spray Pass.* A double spray coat consists of applying paint to a working area of several hundred square feet at a coverage rate of 225-275 square feet per gallon in a single, half-lapped spray pass, followed after drying to a near tack-free condition by another spray pass applied at the same coverage rate and at right angles to the first. The drying time required between passes of a double spray coat varies from about 5 minutes on warm days to more than 15 minutes depending on the ambient and metal temperatures. Before applying a double spray coat to an area, edges, corners, interior angles, seams, crevices, junctions of joining members, rivets, weld lines, and similar surface irregularities must be given a preliminary spray to insure adequate coverage. In spraying such surfaces, the spray gun must be pointed directly at the area being painted. Cross lapping of succeeding passes is not necessary when spraying members less than about 24 in. wide. In spraying these, both spray passes should be applied with the stroke parallel to the longer dimension. In spraying an edge or exterior angle, the gun is held about

3-4 in. from the edge so that the paint reaches the adjacent flat surfaces before drying out. When spraying an interior angle, it is helpful to turn the gun so that the pattern is at about a 45° angle to the direction of the angle.

(7) *Film Build.* The dry film build obtained with a double spray coat should average approximately 1.5 mils (.0015 in.). If too much paint is applied during a pass, the paint may run and sag. Also, heavily applied films tend to entrap air in the form of bubbles causing the film to have a honeycombed texture. To hold these defects to tolerable limits, not more than 2 mils of dry film should be applied per double spray coat.

c. Unsatisfactory Painting Results, Their Causes, and Methods of Correction. This discussion of unsatisfactory painting results assumes that the paint is properly formulated.

(1) *Orange Peel Surface Texture.* Orange peel surface texture may be caused by:

(a) Gun being held so close that wet film is rippled by atomizing air.

(b) Paint not being sufficiently atomized. Paint is too viscous due to being cold or not properly thinned; higher atomization air pressure is needed.

(c) Paint being too dry when deposited. Gun distance is too great or the gun is being arced and/or tilted; atomization air is excessive, causing over volatilization.

(2) *Pinholes in Film.* Pinholes may result from passes not being lapped properly or for the reasons given under (1)(b) and (1)(c) above.

(3) *Sandy Finish.* A sandy finish results from:

(a) Air currents distorting fan, carrying dry and semidry paint to freshly painted surfaces.

(b) Overspray from painting an edge or corner. (This is very difficult to control but can be held to tolerable limits with the proper gun angle, distance, and stroke.)

(c) Paint being too dry when deposited, due to lack of thinning, ex-

cessive air pressure, too great a gun distance, or arcing and tilting of the gun.

(4) *Sags and Curtains.* Sags and curtains result from:

- (a) Too much thinning.
- (b) Gun being held too close.
- (c) Paint being put on too heavily.
- (d) Stroke speed not uniform.
- (e) Gun not being triggered properly.
- (f) Defective spray pattern.

(5) *Surface Bubbles and Honeycombed Films.* These problems result when paint is applied so heavily that air is entrapped either at the surface or within the film. This is aggravated by extremely warm or extremely cold surfaces. In both instances, the deposited paint becomes viscous quite rapidly due to rapid loss of solvent in one case and rapid lowering of the temperature and loss of solvent in the other.

(6) *Low Film Build per Coat.* Low film build per coat is caused by:

- (a) Excessive thinning.
- (b) Cold paint being sprayed, requiring additional thinning to atomize.

(c) Not enough drying time between sprays or coats.

(d) Paint not being applied heavily enough during each spray pass.

(e) Improper lapping.

(7) *Thickness of Film Not Uniform.* This problem is due to:

(a) Stroke speed not being constant.

(b) Gun distance being varied.

(c) Arcing and tilting of the gun.

(d) Poor pattern.

(e) Passes not being lapped 50%.

(f) Succeeding passes not being applied at right angles to preceding pass.

(8) *Paint Thin on Edges and Other Irregular Surfaces.* This problem is caused by:

- (a) The surface not being given preliminary pass coat before adja-

cent flat areas are coated.

- (b) Gun being held at wrong angle and distance.
- (c) Improper fan width.

4. Conventional Hot Spraying of Vinyl Paints

The hot spray process offers several advantages over conventional spraying in the application of vinyl paints, especially when ambient temperatures are normal or below. In many cases, the viscosity of a vinyl paint can be lowered sufficiently to atomize without thinner by raising its temperature to about 150°F at the gun. Thus, the paint, as applied, has much less solvent and can be applied heavier without sagging. Regrettably, atomization is not the only reason for thinning. Generally, thinning is required to obtain a wet spray. Normally, the amount of thinner needed is about half the amount required for conventional spraying; but when ambient temperatures are above 80°, the thinning requirements are about the same. Atomization air requirements are low, which cuts down on overspray.

Under ideal conditions, 50 to 100% more paint film thickness can be obtained per pass of the spray gun. However, these ideal conditions rarely exist. Generally, if the paint is laid down too heavily, the film will contain too much air and be honeycombed. It is therefore not advisable to permit the paint to be applied heavier than slightly over 1 mil (dry film) per pass of the spray gun.

The hot spray process shows to best advantage when ambient temperatures are below normal, since little or no thinner need be used at these temperatures. One of the largest variables in field painting is eliminated by having the paint temperature the same every day regardless of the ambient temperature.

There is a common misconception that the heated paint reaches the surface while still hot and that the paint therefore dries much faster. It has been established that the paint temperature at the time of deposit is practically the same as with conventional spray. The spraying technique is substantially the same as with conventional spray.

Good hot spray equipment, properly used, can effect savings in thinner, paint, and labor at no sacrifice in film quality. These savings can be substantial when ambient temperatures are low.

5. Application of Vinyl Paints by Airless Spray

In recent years airless equipment has gained in popularity with contractors for several reasons: (1) the initial cost of a complete airless unit is somewhat less than that of a conventional unit of equivalent capacity; (2) electrically operated airless units are much smaller, and thus more portable, than conventional units of similar capacity; and (3) the basic principle of airless equipment allows heavier films per spray with less overspray, providing both time and labor savings to the contractor. These all appear to be valid reasons for purchasing and using airless equipment, provided all other characteristics are at least equal to those of conventional equipment.

a. Paint and Its Preparation. Airless equipment appears to have been designed for conventional and high solids paints. Its use with lacquers such as the Corps of Engineers' vinyl paints often creates peculiar problems.

(1) *Paint.* In an effort to find the optimum equipment and procedures for good airless application, a sample of Corps of Engineers' vinyl paint was submitted to a leading manufacturer of airless equipment for his recommendations. The manufacturer's report stated that the material was not successfully sprayed due to severe solvent popping and that it "was evident that the material was not formulated for airless spray." This conclusion is valid--the material was not formulated for airless spray; however, this does not mean it cannot be successfully applied. Lacquer paints formulated for airless application are usually based on lower molecular weight resins and much slower solvents. Lower molecular weight resins produce a weaker film, and slower solvents usually plasticize the film for an extended period of time, making it more susceptible to mechanical damage. Neither of these shortcomings can be

tolerated in the applications for which the Corps of Engineers' vinyls were designed. Therefore, until these formulation barriers can be overcome, the basic procedures of airless application must be reassessed and adapted if existing formulations are to be applied successfully.

(2) *Temperature.* As discussed in section 3a, temperature has a major effect on the paint viscosity and therefore on the amount of thinning required. Excessive thinner, as discussed below, creates additional problems. Thus, it is important that the paint to be applied with airless equipment be as warm as possible. The 60°F to 70°F minimum temperatures recommended for conventional application become a necessity, and higher temperatures such as those produced with hot airless equipment are very desirable.

(3) *Mixing.* In section 3a it was stated that paints should be well mixed and that if a minor amount of lumpiness exists, they should be strained before use. This is of added importance when using airless equipment. All well-designed airless units have screens and/or filters to remove lumps and coarse particles from the paint. These filters can become plugged quite rapidly if lumpy material is not eliminated during the mixing operation.

(4) *Thinning.* The addition of thinner to the paint must be considered for one basic reason: thinning lowers the paint's viscosity, thereby allowing atomization at lower pressures and cutting down on the pressure loss as the paint passes through the hose. Thus, more thinning will probably be necessary at lower ambient temperatures. The necessity of thinning to insure that the paint is deposited on the receiving surface in a fluid condition is not usually encountered with airless as it is with conventional atomization.

The amount of thinning varies greatly depending on other factors within the airless system. Factors such as the temperature of the paint, pressure limitations of the pump, diameter and length of the hose, type and condition of screens or filters used, and the efficiency of the orifice all have a direct effect on the amount of thinning required. In most well-designed systems, it can be assumed that a

material having a No. 4 Ford Cup viscosity of 55 to 65 seconds can be atomized sufficiently well when the proper orifices are used. Corps of Engineers' vinyls will usually require 5% to 10% thinning to bring them into this viscosity range. Thus it can be noted that less thinner is required with airless atomization. When excessive thinner is used, film build must be reduced or solvent entrapment and honeycombed films will result.

b. Spray Painting Techniques. Some of the basic techniques encouraged by the manufacturers of airless spray equipment have not been found to produce acceptable results when applying Corps of Engineers' vinyl paints. Alternate techniques have been evaluated and will be discussed in the following paragraphs.

(1) *Pattern, Gun Distance, and Gun Handling*. Most manufacturers of airless equipment suggest that the spray gun be held at a working distance of from 10 to 15 in. However, this is usually not practical when applying vinyl paints to hydraulic structures, since air currents will distort the spray pattern badly at these gun distances. As with conventional spray, about 8 in. should be considered the normal gun distance for most applications.

The spray pattern, stroke, and the advantage of using a double spray pass are essentially the same as discussed for conventional spray. Triggering the gun at the end of each stroke is also similar; however, with airless equipment there is no atomization air to feather out the last few inches of the spray pass. Painters often attempt to flip the gun at each end of the pass, thereby increasing gun distance and obtaining a partial feathering effect. Although this minimizes sags at the ends of the pass, it requires additional effort and wastes materials. The proficient painter can avoid sags without using this procedure.

Lapping each pass 50% over the preceding pass (half lapping) tends to produce the most uniform coating thickness. Manufacturers of airless equipment often recommend lapping succeeding passes only enough to provide a continuous film. This may be satisfactory where appearance is

the only important factor; however, where coating thickness is critical, half lapping is more desirable.

(2) *Fluid Flow and Atomization.* Both fluid flow and atomization are largely controlled by selection of the proper tip. It is true, especially with the more conventional paints, that increasing the pressure at the pump will produce better atomization and a slightly greater fluid flow. However, when applying the Corps of Engineers' vinyls it is suggested that the pressure be adjusted to about 3000 psi (at or near the maximum for most units) and the fluid flow and atomization be controlled by tip selection and the addition of thinner, if necessary.

Tips are manufactured with two design parameters: (1) the size of the orifice which controls the volume of paint, and (2) the shape of the orifice which controls the angle or size of the fan. All too often the inexperienced applicator will select a tip with both parameters larger than he can handle. This is particularly true when one of the Corps of Engineers' vinyl formulations is to be applied. With these formulations and an 8-in. spraying distance, it is not practical to have a fan width of more than approximately 8 in. on flat or simply configured structures. When more complex structures are to be coated, the fan width may need to be reduced to as little as 4 or 5 in. With these fan widths in mind and assuming a dry film thickness of 1 1/2 mils per spray, it is physically impossible for anyone to exercise control with orifices having flow rates in excess of about 1/2 gallon per minute. On complex structures, where the fan angle is decreased and the degree of control is of added importance, it may be desirable to reduce the flow rate to as little as 1/10 gallon per minute.

(3) *Film Build.* The dry film build obtained with a double spray coat should average about 2 to 2 1/2 mils. (It may be necessary for the initial spray coat of paint applied to a surface to be somewhat thinner.) If an attempt is made to apply thicker films per spray, the coating will probably be honeycombed and may contain pinholes. Contrary to conventional equipment, where the initial effect of excessive coating thickness is sags or runs, honeycombed films are not readily noticeable

by the applicator. The honeycomb may not even develop for as much as a minute after the film has been applied. By that time the applicator may have moved to another area, not realizing the problem he has created.

c. Unsatisfactory Painting Results. Many of the unsatisfactory painting results discussed in section 3c are common to conventional and airless application. They will not be discussed again in this section. Only problems peculiar to airless application will be discussed.

(1) *Tails or Fingers.* This is a defective spray pattern which is caused by inadequate fluid delivery or fluid not atomizing properly. Remedies may include the following:

(a) Increase the fluid pressure.

(b) Insure that the system is properly designed and free of restrictions; i.e., clean filters and gun, check that hoses are of proper diameter and length, and make sure pump is capable of supplying number and size of orifices used.

(c) Reduce the viscosity of the paint either by heating the paint or by adding thinner.

(d) Using a larger tip orifice size will alleviate the problem, but may create other problems.

(2) *Distorted Spray Patterns.* This frustrating problem is caused by plugged tip orifices. Because of their extremely small size, these orifices can become plugged with a grain of sand, a particle of poorly dispersed pigment, or even a slug of paint of unusually high viscosity caused by poor mixing. The only remedy is cleaning or replacing the tip; however, the following preventive measures should be observed:

(a) Insure that paint is mixed adequately and that all settled pigment is uniformly dispersed.

(b) Insure that the system has filters of the proper size and that they are clean and in good repair.

(c) Whenever the system is to be shut down, insure that the pump and lines are properly cleaned with a suitable solvent.

(d) Using a larger orifice size will alleviate the problem, but may create additional problems.

(e) Some companies manufacture tips which can be rotated, allowing fluid to pass through the orifice in the reverse direction. Although these tips do not solve the basic problem, they do reduce downtime when the problem is encountered.

(3) *Surface Bubbles and Honeycombed Films.* These are the most often encountered film defects when vinyl paints are applied with airless spray. The basic cause is that the paint is applied so heavily per spray that air or solvent is trapped within the rapidly drying film. The frequency with which these problems are encountered is reduced as the applicator gains experience in applying the material. Selection of a smaller orifice will give the inexperienced applicator better control of the quality of the coating which he is applying.

6. Airless Hot Spray

The principle of atomization is the same in this process as in airless. However, the paint is heated to around 150°F to lower its viscosity. Except for somewhat better results during cool weather, hot airless application does not appear to offer advantages over regular airless. The film build per spray is substantially the same; it is rarely safe to apply more than 1 to 1 1/2 mils of paint (dry film thickness) per pass, because heavier films tend to entrap objectionable amounts of air. Claims by airless spray and airless hot spray equipment companies that 4 or 5 mils of vinyl paint (dry film) can be applied in a single coat do not apply to the more durable types of vinyls used by the Corps of Engineers. These claims refer to weaker mastic-type vinyls which have much poorer water resistance due to high pigmentation, and to vinyls modified with other resins such as alkyd resins or the vinyl acetate resins.

The technique used with airless hot spray equipment is substantially the same as for airless. The degree of atomization is largely controlled by thinning, although the amount of hydraulic pressure is a consideration.

In spraying vinyl paints, it is usually best to set the hydraulic pressure close to maximum and, after selecting a fluid tip of about the desired size, adjust the thinning until good atomization and a uniform fan are obtained. However, it must be remembered that as thinner is added, the rate of fluid flow out of the tip increases. If less paint flow is desired, a smaller tip must be selected. The tips are easily plugged by small particles of sand, pigment, and paint skins. This causes work stoppages unless the proper screens are installed in the equipment.

7. Conclusions

Airless spray offers both advantages and disadvantages over conventional spray. The biggest point in its favor is the elimination of atomization air. As a result, less paint is carried away from the surface, substantially reducing paint waste caused by overspray. Also, less volatilization occurs in the atomized paint, allowing it to reach the surface in a wetter condition, producing better flow-out. Paints of higher viscosity can be atomized, thereby cutting the volume of thinner required. Film build per spray is somewhat greater than for conventional spray and compares very favorably with conventional hot spray. Here again, sagging and air entrapment limit the amount of paint that can be applied per pass, irrespective of the method of application.

Hot spray, whether conventional or airless, provides distinct advantages over its non-heated counterpart, especially when ambient temperatures are lower than 60°F. Advantages include both a savings in the amount of thinner required and the inherent benefits of providing a uniform material irrespective of changes in ambient temperatures.

Manufacturers' recommendations for airless spraying techniques are often quite different from those recommended for conventional spray. Recommendations often include the use of tips having large orifices with wide fan angles; the use of long spray distances, and slight lapping of passes. However, when spraying Corps of Engineers' vinyls, best results

have been obtained by using essentially the same fan angle, gun distance, and spraying techniques that are used with conventional spray equipment.

The principal disadvantages of the airless process are the inflexibility of the controls and work stoppages caused by the tiny orifices becoming plugged. The plugging problem can be controlled by installing effective screens or filters, but the lack of controls proves very troublesome at times. For all practical purposes, the only control over atomization is through thinning and the only control over fluid flow and the width of the pattern is tip selection. These disadvantages far outweigh many of inherent advantages of airless spray application, especially when highly volatile lacquer coatings are being applied to complex structures such as the locks and dams maintained by the Corps of Engineers.

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