Assuring Quality When Applying 100 Percent Solids Polyurethanes

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One hundred percent solids plural component polyurethanes are protecting many different structures today, such as storage tanks, oil and gas piping, water and wastewater tank internals, bridges, ships, and other marine facilities. The products have been effective because of their outstanding life expectancy and performance, resistance to aggressively corrosive environments, high abrasion resistance, low temperature curing capability, strong adhesion, high film build, fast application, and compliance with the most rigorous regulations on volatile organic compound (VOC) emissions.

However, because application equipment for these coatings is complex, and application requirements are rigorous, quality assurance measures must be taken for their successful application.

This article describes these quality assurance measures. It begins with the implications of coating chemistry for application properties and requirements. It then describes management of quality assurance; quality assurance during surface preparation and application; equipment maintenance; and documentation. Common application problems and their resolution are also addressed.

How Chemistry Affects Application

One hundred percent solids polyurethanes usually consist of 2 components: 1 isocyanate-rich solution and 1 polyol-rich solution. Most coating manufacturers use "A" to designate the isocyanate component and "B" the polyol component. The polyol component usually contains pigments. A coating film is formed when the 2 components are combined; a rapid and exothermic chemical polymerization reaction takes place (Fig. 1).

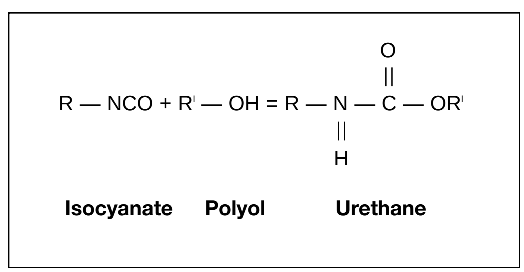


Fig. 1

The exothermic nature of this reaction enables application at almost any ambient temperature. The coatings' chemical resistance is directly related to the degree of cross linking of the polymer. A highly cross linked system generally results in good chemical and corrosion resistance.

Most 100 percent solids plural component polyurethane coatings cure rapidly. Typical pot life ranges from a few seconds to several minutes. Their rapid cure makes them ideal for shop coating work.

Because of the coating's very short pot life, however, the 2 components should be delivered through separate individual fluid lines to a mixing device, which is located within the spray gun or directly before the spray tip. The mixing ratio of the 2 components is normally 1:1. Manufacturers, therefore, tend to design the coating system so that each component has the same viscosity, requiring the same pressure to cause them to flow at the same rate.

If each component has a different viscosity, application setup is more complicated, and problems often occur. Mismetering of 1 or both of the components, often called an off ratio, can cause many application problems, as discussed below.

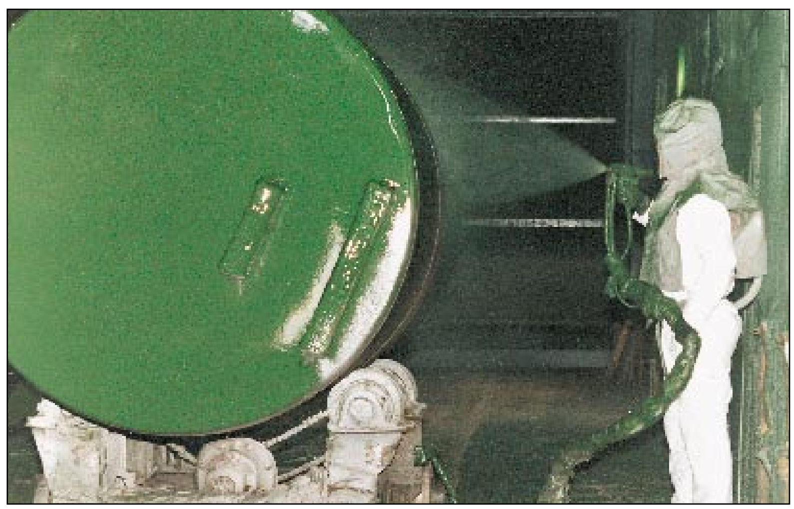
Another aspect of the coatings' chemistry that affects application is their sensitivity to moisture. If water is absorbed by the isocyanate component, it will react with the isocyanate, causing thickening and even gelation of the material. Water also reduces the reactivity of the isocyanate by reacting with a part of it. Because water is normally soluble in polyols, there is no apparent reaction when water is absorbed by the polyol component. However, when the water-contaminated polyol component meets with the isocyanate component, the reaction in Fig. 2 will occur, yielding disubstitute urea.

Carbon dioxide (CO_2) gas is evolved from the reaction in Fig. 2, generating bubbles within the coating during cure. If there are a significant number of bubbles in the coating, chemical and physical properties of the coating will be diminished. The finished surface of the coating may become dull and have the appearance of orange peel; foaming, blistering, and bubbling may also occur; and gloss will be reduced.

$$2R - NCO + H_2O \Rightarrow R - HN - \overset{\overset{\displaystyle O}{\|}}{C} - HN - R + CO_2 \uparrow$$

Fig. 2

Manufacturers often use molecular sieves or reactive isocyanates to remove moisture from coating raw materials and the manufacturing process. However, moisture will not be avoided if quality assurance measures are not taken during handling, storage, and application of these coatings.



Applying 100% solids polyurethane coating onto a steel tank. *Photos courtesy of Shiwei Guan.*

The recommended shelf life of 100 percent solids polyurethanes is relatively short, 6 months. Pure isocyanates (e.g., pure toluene diisocyanate and diphenyl methane diisocyanate) in the isocyanate component tend to crystallize while the material is getting old and freeze during very cold weather. Pigments may also settle at the bottom of the drum of very old polyol component. Manufacturers often put a production batch number on the label to help the applicator determine the age of the materials. If materials older than 6 months are to be used, they should be agitated thoroughly and applied in a test patch before full application is attempted.

As with conventional coatings, proper surface preparation is essential. Adhesion values of plural component coatings to a well prepared surface will vary from formulation to formulation. Without a primer, adhesion values in the range of 1,500-3,000 psi (10-20 MPa) have been measured. However, because of the rapid cure, intercoat adhesion can be a serious problem if the applicator misses the recoat window.

Managing Quality Assurance

Management support plays an important role in the successful application of 100 percent solids polyurethanes. Coating defects and failures are expensive, and avoiding them requires work, by all levels of personnel, not just the applicator. Quality assurance management can be improved with the following guidelines.

• Scheduling. Improve scheduling to reduce time pressure, to choose an experienced applicator, to avoid applying coatings under bad weather conditions, to ensure that the oldest materials are always used first, and to reduce material waste.

• Specifying. Do not specify 100 percent solids polyurethanes that have not been treated for moisture content. Also avoid specifying systems with very different viscosity values for each component.

• Verifying. Check the product label to ensure proper material has been delivered. Check the temperature of the coating material to ensure the material has not been frozen. Check all containers and ensure they are tightly sealed and have not been tampered with so that atmospheric moisture will not contaminate the material. Ensure that the material is stored off the ground on skids in a well ventilated area and protected from heat sources.

• Training. Adequately train application personnel on surface preparation, handling and storage of materials, application techniques, inspection, and reporting.

• Maintaining. Management should allocate funds to properly maintain application equipment and tools.

• Monitoring. Continuously monitor application conditions and equipment parameters. Document them daily in the Quality Assurance Report, discussed below. Troubleshoot problems immediately.

Quality Assurance during Surface Preparation

Most often, coating defects and failures occur because of improper surface preparation or coating application. Some quality assurance tests for avoiding surface preparation problems in the use of polyurethanes are listed below. They are similar to the surface preparation tests for other industrial maintenance coating systems.

• Moisture. Moisture (dew or frost) on a substrate will cause poor adhesion and other defects in 100 percent solids polyurethanes. Therefore, apply the coating only if the substrate temperature is 5 F (3 C) above the dew point. Before abrasive blasting, determine the dew point by using a sling psychrometer and a psychrometric chart. Be sure to use the temperature of the substrate (e.g., steel or concrete), rather than the atmospheric temperature, when applying the dew point criterion.

• Contamination. If steel grit is used, obtain a sample of it and place the sample into a bottle with clean water. Shake well. If oil appears on the surface of the water, the grit is contaminated, and new grit should be used. If dry blasting is used, be sure the air lines are free of moisture and oil before use. This can be done by air blasting into a clean, dry white rag to determine if the airlines are contaminated. If the rag stays white and dry, the air is clean. If the rag is dirty, oil is in the airstream, and the oil separator should be checked. If the rag is wet, moisture is escaping, and the moisture separator should be checked.

• Surface cleanliness. Abrasive blasting will not remove oil or grease. Blasting will simply drive contamination deeper into the profile being created. Before it is blasted, the surface must be cleaned with solvents or detergent solutions. To detect the presence of dust and other surface debris, apply a strip of scotch tape to the surface, remove it, and visually inspect the underside of the tape for dust or other contaminants. If it is dirty, repeat the cleaning and testing procedure until the tape comes off without debris.

• Blast profile. Use replica tape to determine the profile depth on steel. For immersion service of 100 percent solids polyurethanes, a Near White Blast (SSPC-SP 10, NACE #2) should be specified with an angular profile of at least 2.5 mils (65 micrometers). For atmospheric service a commercial blast (SSPC-SP 6, NACE #3) with a profile of at least 1.5 mils (38 micrometers) is desirable.

Application

Application equipment for plural component polyurethanes is much more complex than that for conventional solvent-borne systems.

The standard airless spray system (Fig. 3) can be divided into 3 parts: the low pressure part, the high pressure part, and the spray gun. The low pressure part provides clean product from individual drums of isocyanate and polyol components. A desiccant drier should be affixed to the air intake of each drum to avoid moisture contamination. The material is gravity fed or pumped by using a transfer pump, from the supply through an intake hose and "Y" strainer (low pressure filter) to the bottom of the displacement pump. Electric band heaters are strapped around the drums to warm and maintain the component feed temperatures at the required values.

The high pressure part supplies the spray gun with material in a 1:1 mixing ratio. The material is supplied evenly and consistently at the required temperature and sufficient pressure. The individual component is drawn in at the bottom of the displacement pump and pushed out at the top. It then passes through the secondary heater, high pressure relief valve, high pressure filter, and heated discharge hose leading to the gun. The secondary heaters further increase the temperatures of the separate materials, and the heated hoses maintain these temperatures to control fluid viscosities. The individual components are thoroughly combined into a mixing device located within the spray gun or directly before the spray tip and are then sprayed to the substrate. Materials remaining in the mixing device are purged by solvent flushing or mechanical motion, depending on the type of spray gun used. A solvent pump is used for a solvent flushing spray gun.

Additives are normally included in the coating formula to ensure homogeneity of the isocyanate-rich and polyol-rich components. Nevertheless, phase separation or settling may occur. It is essential that mate-

Fig. 4 - Holiday testing can be performed as soon as one hour after application of a 100% solids plural component polyurethane coating.

rials within the individual drums be recirculated or agitated before spray application to ensure a homogeneous mix. This can be achieved using drum mixers, but often a better solution is to use a recirculation kit as shown in Fig. 3. The kit is a by-pass system that allows the product to be pumped out of the individual drums through the plural component pump and back to the original drums. An hour or 2 of recirculation will provide adequate mixing in all but the oldest product. During recirculation, the materials are also preheated and filtered.

Quality Assurance Tests during Application

• Temperature check. The first quality assurance test during the application of plural

Common Problems and Resolutions

• Uneven coloring and uncured resins. Uneven coloring is mainly due to phase separation and pigment settling when the materials have not been recirculated or agitated before spray. It can also be attributed to clogged in-line filters or build-up on mixers and spray guns, particularly for the polyol component side that contains pigments and extenders. In addition, total or partial restrictions in the isocyanate component side may cause uneven coloring and uncured areas.

• Blistering. This is one of the most common failures in the application of plural component polyurethanes. The size of the blister usually depends on the degree of adhesion of the coating to the surface and the pressure of the gas or liquid within the blister. The usual causes of blistering are a contaminated substrate surface (e.g., moisture, oil, grease, sweat, dust) or an improper mismetering (off-ratio mixing) of the 2 components. Blistering can also be caused by gun ‘spits’. It can be avoided by making sure the surface is clean; by only triggering the spray gun off target before applying the coating to the substrate; by keeping the product supply warm; and by regularly cleaning filters, mixers, and spray guns to avoid cavitation and off-ratio spray.

• Overspray. Overspray is also common with 100 percent solids polyurethanes. It is caused by poor gun adjustment or coating at too great a distance from the substrate. Failure occurs when pinpoint rusting forms at an oversprayed area. Planning spray patterns along with proper gun control will eliminate this problem. Under normal conditions, the gun should be held perpendicular to the substrate with the tip 18 to 24 in. (0.5 to 0.6 m) away.

• Holidays. Holidays often occur when the applicator has missed coating the surface, or where thin spots exist in difficult-to-coat areas such as inside corners, along welds, around bolts and rivets, or wherever there are angles in the substrate surface. Attention to detail and spraying with a 50 percent overlap will help avoid holidays.

• Delamination. Delamination occurs when the coating fails to adhere to the surface. A closely related phenomenon is intercoat delamination, the loss of adhesion between coats. It occurs most often where surface preparation is poor, the substrate is contaminated, or repair or maintenance coatings are being applied over existing coatings. If the same type of coating is being applied over the existing coating, the failure is usually caused by missing the recoat window, or by the poor surface condition of the existing coating. (The original coating may be chalky or have embedded dirt.) Delamination may also be caused by an off-ratio spray. Around the off-ratio area, intercoat adhesion will be very poor.

• Fisheyes. Fisheyes or cratering can be an application problem, a material problem, or both. When they are a material problem, fisheyes occur when the material has a very high or very low surface tension; silicone or oil contamination is a possible cause. For the most part, however, fisheyes are an application problem caused by contaminants such as dirt on the surface or the wet coating. Often, oil in atomizing air contaminates the surface. Regular maintenance of the compressor and the use of airline dryers will ensure clean, dry air.

• Pinholing. Pinholes can result from overspray, surface contamination, or solvent entrapment. Pinholes may also be a result of moisture contamination of the B (polyol) component or of other types of contamination (e.g., silicone) in the coating. As with overspray, pinholing can be caused by improper gun adjustment. If the gun does not atomize properly, air becomes trapped in the coating. Pinholing can also be caused by applying the coating too close to the surface, creating an area in the center of the fan where too much material is applied and where air bubbles are trapped in the wet coating. ❍

component polyurethanes is the temperature check. The temperature should be checked in the supply drums at or near the point where the material is being drawn. This temperature should normally be between 110 F (43 C) and 130 F (55 C). Within this temperature range, the isocyanate and polyol components, which have, if any, a slight viscosity difference at room temperature, will tend to have the same viscosity. This is essential to properly metering and mixing the 2 components. The temperature can be increased by band heaters or by more recirculation. However, the material should not be heated above 140 F (60 C).

With the spray gun unattached, the temperature of the materials coming out the ends of the separately heated hoses should also be checked. This may be done by simply pumping a small amount of the materials into 2 separate containers like paper cups and then immersing a thermometer in them. The temperatures should be between 120 F (49 C) and 140 F (60 C), and the temperature of the 2 compounds should be the same.

• Off target test. In the off target test, one sprays the coating onto several square feet of wall, floor, or white cardboard to ensure that the fan is satisfactory and that the material is being mixed in a 1:1 ratio by volume and is thus setting up properly. For instance, an out-of-spec color may indicate phase separation or pigment settling within the supply drums. A long dry-to-touch time may indicate mismetering of the 2 components. Abnormal pressure gauge readings may indicate problems with the materials or equipment setup, as discussed below.

• Discharge pressure check. The discharge pressures of the liquid components—shown on their individual high pressure gauges—and their pressure differential should be monitored throughout application. The normal spray pressure range is from 1,700 to 2,500 psi (12 to 17 MPa) to ensure sufficient mixing of the 2 components. The 2 components are normally formulated to have the same viscosities. Theoretically, if the 2 components with the same viscosities are heated at the same rate, then the pressures required to force these materials through the same diameter hoses and into the mixing device should be the same.

A slight difference in pressures can be tolerated. A non-fluctuating pressure differential may not be a big problem if the material sprays well. Some equipment configurations will result in different pressures. For instance, the A side of 1 proprietary spray system is slightly more convoluted than the B side, resulting in a pressure difference of 500 psi (3 MPa) under normal operating conditions. This pressure differential will not generally hamper application. However, products with excessively different viscosities in the 2 components and equipment with a big pressure differential will cause problems during application. A constantly excessive pressure differential (over 500 psi or 3 MPa) indicates a more serious problem, such as complete block-

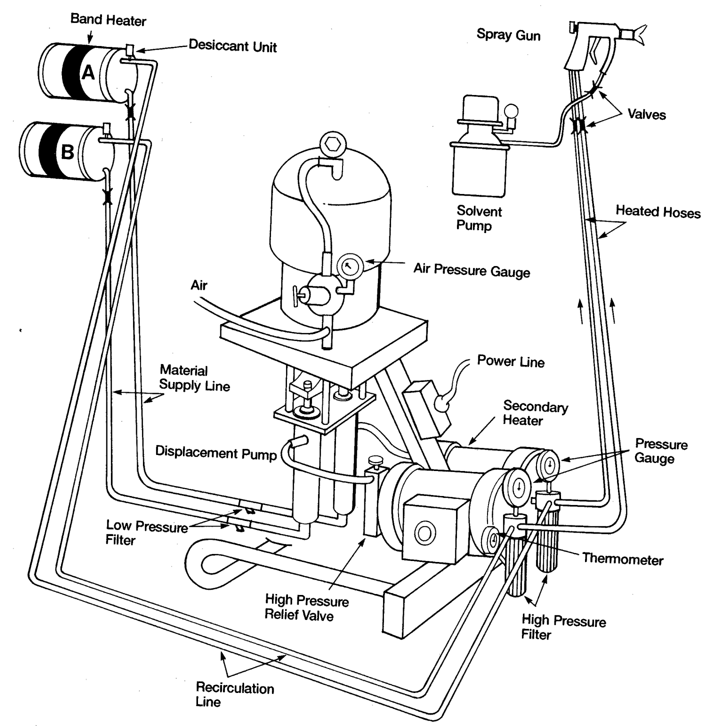


Fig. 3 - Typical airless spray set-up.
Figures courtesy of Shiwei Guan.

QUALITY ASSURANCE REPORT

Project Name: ______________________ Date: ____________________

Coating Supply:
Batch Number (A) __________________
Batch Number (B) __________________

Quantity (circle approx. amount)
Container A: 1/4 1/2 3/4 F
Container B: 1/4 1/2 3/4 F

Test Spray Observations
Pressure (A): _____ psi (MPa)
Pressure (B): _____ psi (MPa)
Temperature (A): _____ F (C)
Temperature (B): _____ F (C)

Spray Pattern: no fingers _____
no tails _____
no pulsing _____
Dry-To-Touch Time ________ minutes

Environmental Conditions
Ambient Temperature (outside): _____ F (C)
Ambient Temperature (inside): _____ F (C)
Substrate Temperature: _____ F (C)

Humidity (outside): _____ %
Humidity (inside): _____ %
Dew Point: _____ F (C)

Surface Preparation
Color: SSPC-SP 10 _____ SSPC-SP 6 _____
Profile: <2.0 mil angular _____ mils (µm) >2.0 mil angular _____ mils (µm)
Grit Type: ____________________

Coating Consumption
Number of Strokes Used: _____
Materials Consumed: _________ gal. (L)

Area Coated: _____ ft^2 (m^2)
Consumption Rate: _____ ft^2 (m^2/L)

Wet Film Thickness (WFT) and Dry Film Thickness (DFT)
Average WFT: ___mils (µm) Highest Reading:___ mils (µm) Lowest Reading: ___mils (µm)
Average DFT: ___mils (µm) Highest Reading:___ mils (µm) Lowest Reading: ___mils (µm)

Adhesion Test
Satisfactory _________
Unsatisfactory _______

Holiday Test
Area Checked ________ ft^2 (m^2)
\# Found ______ # Repaired _______

Completed by: ________________________ Checked by: ________________________

Fig. 5

age within the spray system, a defective heater, or an incorrect mixing ratio for the 2 components.

• Volume check. A volume check is used to verify that equal amounts of the 2 components are pumped through the system and provided to the spray gun. One simply removes the spray gun from the heated discharge hoses, points each hose into its own individual, same-size container (coffee cups, for example), and slowly cycles the pump until the containers are full. Both containers should, by visual inspection, have an equal amount of liquid, and both streams should be smooth and even with no bubbles or pulsing. Problems such as supply restriction, leg-packing leakage (associated with packing parts of displacement pumps illustrated in Fig. 3), full or partial high pressure blockage, and loose connections on the supply side can cause differential volumes, a pulsing stream of materials, or an uneven flow.

• Film thickness check. Film thickness must be checked. The coatings may be formulated to be applied to thicknesses above 100 mils (2.5 mm) per a multi-pass, single coat. This is totally different from spraying conventional, solvent-borne coating systems. Regularly checking the wet coating thickness with a wet film gauge can prevent wasting the materials. Placing a numerical counter in the displacement pumps can also help applicators manage the materials usage. The counter will record the number of strokes by the pump motion used during the application. As a point of reference, 0.046 gal. or about 6 fluid ounces (0.17 L) of the coating material is consumed per stroke if certain proprietary 3,000 psi (2.1 MPa) displacement pumps are used.

• Holiday detector test. Holiday detection should be carried out after or between coating applications (Fig. 4). The holiday test will find nicks, pinholes, and other film discontinuities. A low voltage holiday detector is often used. It consists of the detector, a ground cable, and a sponge electrode. High voltage holiday detectors are also being used for DFT above 10 mils (25 micrometers) on applications such as pipe lining and exterior coating projects.

• Adhesion tests. Adhesion tests should also be conducted after each coat. The adhesion test can be a modified version of ASTM D 3359, the cross hatch adhesion test. An X-cut is made in the coating film to the substrate to pull off the coating and measure adhesion. Instead of using pressure sensitive tapes, use a knife to pry off one of the corners that was created by scribing the X. Acceptance criterion will vary from specification to specification. A pull-off adhesion test (e.g., ASTM D 4541) is also very common. For exterior application, a minimum adhesion of 600 psi (4 MPa) is required; for immersion use such as tank lining, adhesion of 1000 psi (7 MPa) is usually desirable.

Equipment Maintenance

Proper maintenance can prevent many application problems with plural component polyurethanes. Most coating manufacturers have detailed setup, shutdown, and maintenance procedures. Typical examples are given here.

• Purging the pump. Flush the pump with di-octyl phthalate. Strong solvents such as xylene and methyl ethyl ketone are not recommended to flush the application equipment because coatings that have solidified on the inner walls of the equipment will absorb these solvents and become loose. Inevitably, these loosened solids will clog filters and mixing orifices downstream.

• Cleaning filters. In-line filters and high pressure filters should be cleaned daily. Apply a film of lithium grease to the threads of the filter housing to make future cleaning easier.

• Protecting the upper packing. Lubricate the displacements rods with throat seal to prevent isocyanate crystals from forming by reacting with atmospheric moisture. Isocyanate crystals will act much like sand paper and destroy the upper packings as the displacement piston extends and retracts. In addition, periodically tighten the packing nut so it is snug.

• Saving leftover materials. Wasting leftover materials by specifying the use of only filled drums is discouraged. Drums that have not been completely emptied should be filled with clean, dry nitrogen gas and tightly sealed to prevent the remaining materials from reacting with moisture.

Quality Assurance Report

A quality assurance report should be completed each day (Fig. 5). Record the date of the spray, and briefly describe the project. Note the batch numbers of both the A and B containers. Record the A and B operating pressures and the temperatures of the 2 components at the heater and supply drum. Note major variations during spray.

Record the ambient temperature, substrate temperature, relative humidity, and dew point. All these measurements should be taken where the coating will be applied.

Record the blast media and the color and profile of the blast. Record coating consumption and area coated to keep track of the material usage. These and other common problems are described in the box on p. 78.

Summary

Successful application of 100 percent solids plural component polyurethanes requires quality assurance measures ranging from management support to tests for proper surface preparation and application to equipment maintenance. Continuous training of application personnel is also important. It should cover the use of the plural component equipment, application properties and requirements, and common troubleshooting procedures for application problems. **JPCL**

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