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100% SOLIDS POLYURETHANE PROTECTIVE COATINGS FOR PIPELINE INTERNALS AND EXTERNALS

Howard Kennedy B.Sc., MBA
Business Development Manager
Madison Chemical Industries Inc.
Milton, ON, L9T 3Y5
905-878-8863 (ph) 905-878-1449 (fx)

ABSTRACT

The 100% solids polyurethane coating technology is an excellent system for the internal and external corrosion protection of pipelines. Applications include standard external corrosion protection for oil and gas transmission lines as well as internal and external coatings for water and wastewater piping. The technology is well suited for use in bell hole and line travel rehabilitation as well as girth welds These field applied systems can provide the same, if not improved, performance and longevity as the conventional factory applied systems such as fusion bonded epoxies, coal tars and tape. The 100% solids polyurethanes are available in a wide variety of setting times ranging from very fast systems that allow rapid factory application to conventional brush and roller application to simple field castings.

This paper covers the basic definition and history of polyurethane as well as the wide range of applications in a variety of industries. The paper covers the specific advantages of the 100% solids polyurethane coating systems for pipeline work in terms of applicator safety, application and performance. The paper covers some recent developments in the technology and covers some case histories as well.

Key Terms: 100% solids, polyurethane, pipe, pipeline, rehabilitation, corrosion protection, protective coating

EXECUTIVE SUMMARY

100% solids polyurethanes are excellent systems for the coating of pipeline internals and externals. This simple chemistry, the reaction product between an isocyanate and a polyol, plays a vital role in many industries and in our every day activities. Polyurethane foams are used as thermal insulation in buildings and refrigerators. Mattresses and sofas use polyurethane foams as well. Shoe soles, elastic thread, car body panels and even heart pacemakers are all different forms of polyurethanes.

This coating technology has been in use for almost 20 years in other industries such as underground fuel storage tanks with excellent results. The need for pipeline owners to economically coat their lines with materials that are safe, easy to apply and that offer long lasting corrosion protection has led many to consider the advantages that 100% solids polyurethane technology offers.

WHAT IS A 100% SOLIDS POLYURETHANE?

Polyurethane is a very versatile thermoset plastic that was originally developed for military use by Otto Bayer in the late 1930's[1]. It is simply the reaction product of an isocyanate and a polyol (fig.1).

Today a wide variety of polyurethanes are used for many diverse applications. Flexible polyurethane foams are used to make bedding, sofas, cushions, carpet backs and car seats. Rigid foams are used for insulation in freezers, refrigerators and roofs. Many running shoe manufacturers use the tough elastomeric polyurethanes for shoe soles. The auto industry makes dashboards, bumper covers, moldings and fenders out of polyurethane. Several American auto producers make vehicles with fenders and door panels that are all molded out of polyurethane. There are many types of polyurethane coatings as well, ranging from bridge coatings to floor sealers to tank linings.

It is virtually impossible for anyone in the 20th century world *not* to come in contact with a variety of polyurethanes several times a day. It is estimated that the average family probably owns somewhere between 25 and 100 pounds of polyurethane[2]. When the application demands a material with toughness and longevity, polyurethane is the most common answer.

By definition, the term ‘100% solids’ means the coating system does not use any solvent to dissolve, carry or reduce any of the coating resins. Further, the resins normally in a liquid state, will convert , 100%, to a solid film after application. The viscosity of the coating system is determined by the selection of the resin components and not by the addition of solvent. In fact, the reduction of a 100% solids polyurethane coating with a solvent (or thinner) is normally not recommended by the manufacturers because the solvent may react with some of the system components. Some systems that are classified as 100% solids may contain a small amount of solvent (up to approximately 5-10%) that acts as carriers for pigments and catalysts.

Figure 1

POLYURETHANE REACTION

Iso + Polyol = Polyurethane

$$R-NCO + R'-OH = R-\underset{}{\overset{\displaystyle H}{\overset{|}{N}}}-\overset{\displaystyle O}{\overset{||}{C}}-O-R'$$

TYPES OF 100% SOLIDS POLYURETHANES

Unlike conventional coatings, such as epoxies, where there is only a very narrow range of raw materials to select from, polyurethanes come in an extremely wide variety of shapes and forms. The term 'polyurethane coating' is actually very generic because it covers everything from wood sealers to floor paint to underground tank coatings. The most common polyurethanes (such as aliphatic top coats, moisture cures and automotive paint) are solvent based systems.

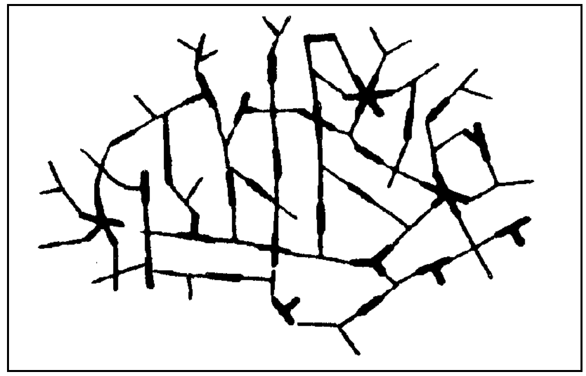
The inclusion of the terminology, '100% solids' only narrows the field slightly. There are literally hundreds of different isocyanates and thousands of polyols available for a polyurethane formulator to choose from resulting in millions of permutations and combinations. In terms of comparison, if a common soda can (12 oz, 355 ml) was filled with all the possible formulations for epoxies, it would take a 10 million gallon reservoir to hold all the 100% solids polyurethane formulations.

One further distinction of the 100% solids polyurethanes is the type of isocyanate used. The most common isos are known as 'aromatic'. These systems are economical and good performers but tend to chalk and darken when exposed to ultra violet radiation (sunlight). The corrosion resistance and other physical properties are not affected by the sunlight but the aromatic systems need to be topcoated if they are to be used in an aesthetic application where color is important. Aliphatic isocyanates, are used in the formulation of polyurethanes to give them excellent color and gloss retention. Automotive paints are the most visible form of aliphatic polyurethanes on the market today. Virtually every vehicle is painted with an aliphatic polyurethane coating. The primary drawback of aliphatic iso is its high cost. It is typically three to four times that of an aromatic.

Systems can be further defined by the amount and type of fillers or extenders used. In some cases, certain fillers can improve the properties of a coating but they are usually used to reduce the cost. The general rule, "you get what you pay for", is true when fillers are used in most coating systems; things that reduce cost, reduce performance as well; 100% solids polyurethanes are no exception. Typically, the addition of 10% to 20% filler (typically tar) has a significant positive effect on the cost but only a slightly negative effect on the performance properties of the coating system. The addition of more than 40% fillers will definitely reduce the cost but the reduction in coating performance and handling characteristics is very dramatic. The most common fillers used in 100% solids polyurethanes are tar materials. Petroleum, asphalt or coal tars are normally used. It should be noted that coal tar is a known carcinogen[3].

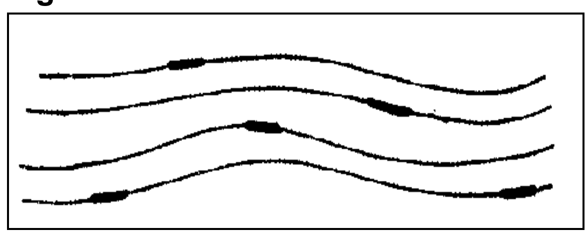
The properties of 100% solids polyurethanes vary from very soft, rubbery elastomers (like running shoe soles) to hard, ceramic like systems. The chemical bonds in the more rigid systems are highly cross-linked to each other to create hard, dense systems that have very good chemical and moisture resistance. The systems usually have very good adhesion and are the best choice for the corrosion protection of metals (fig. 2). On the other hand, the elastomers have a more linear structure with much less cross linking that allows them to be very stretchy and elastic (fig. 3). These systems normally have great impact strength and flexibility but poor adhesion.

Figure 2[1]



rigid, highly cross-linked polymer

Figure 3[1]



linear, flexible elastomer

However, the linear nature of the elastomer's chemical bonds tends to allow water and chemicals easier entry and passage through the polymer. As such, the elastomers are better suited to protecting substrates that tend to move and flex like concrete but do not work as well on steel. The chemical and corrosion resistance of the elastomers can be improved if the systems are applied relatively thickly (> 60 mils, 1.5 mm).

Figure 4 shows some of the typical applications for 100% solids polyurethanes in the areas of pipe and pipelines. Note that, as mentioned above, it is possible to formulate the 100% solids polyurethanes to do almost anything. Figure 4 shows only the typical systems and applications that are being used in the market today.

Figure 4[3]

100% SOLIDS POLYURETHANE TYPES (for pipe)

System	Cross Link Density	Filler Content	Notable Properties	Typical End Uses
Aromatic - Fast Set, Spray Grade	rigid	0%	• excellent adhesion • excellent corrosion resistance • very good abrasion, impact resistance and flexibility • excellent chemical resistance • good high temperature resistance • best performing PUR for corrosion resistance	• oil and gas pipe externals high temperature and normal service • girth welds • slipbore, river crossing, rockshield • line travel rehabilitation • bell hole rehabilitation • potable water internals • jet fuel, chemical internals
Aromatic - Fast Set, Spray Grade	rigid	10%-20%	• very good adhesion • very good corrosion resistance • very good abrasion, impact resistance and flexibility • good chemical resistance	• oil and gas pipe externals • municipal pipe externals (concrete, steel, ductile, concrete cylinder) • slipbore, river crossing, rockshield • girth welds • line travel rehabilitation • bell hole rehabilitation

Figure 4[3] **(continued)**

System	Cross Link Density	Filler Content	Notable Properties	Typical End Uses
Aromatic - Fast Set, Spray Grade	rigid	20%-40%	• good adhesion • very good corrosion resistance • very good abrasion,	• wastewater pipe internals (concrete, steel, ductile, concrete cylinder pipe)

			impact resistance and flexibility • good chemical resistance	• replacement for coal tar epoxy
Aromatic - Fast Set, Spray Grade	elastomer	0%	• excellent abrasion resistance • excellent impact resistance and flexibility • adequate corrosion and chemical resistance if applied thickly (>60 mils, 1.5mm)	• slurry line internals, abrasive flow • coating of moving concrete
Aliphatic - Fast Set, Spray Grade	varies	0%	• excellent color and gloss retention	• aboveground piping externals, severe to moderate atmospheric service
Aromatic - Slow Set, Thick Mastic	rigid	0-10%	• similar to fast set • applied with brush, roller	• touch up and repair of fast set systems • coating of small areas • girth welds
Aromatic - Slow Set, Spray Grade	rigid	0-10%	• similar to fast set • applied with conventional airless, brush, roller	• touch up and repair of fast set systems • coating of small/medium sized areas

SAFETY

100% solids polyurethanes offer substantial advantages over many coating technologies in terms of applicator safety. The hazards of polyurethane application are easily recognized and controlled. The isocyanates are formulated and blended to reduce the handling risks to almost nil. Also, the 100% solids systems are, by definition, solvent free thus eliminating solvent health hazards and flammability concerns.

Most 100% solids polyurethane coatings contain none of the dangerous ingredients that are common in many coatings (fig. 5). Some 100% solids polyurethanes do use coal tar extenders, others use asphalt or petroleum tar. Coal tar is considered to be a carcinogen[4].

The main hazardous pre-cursor of polyurethane is isocyanate. Contrary to popular beliefs isocyanate is *not* carcinogenic[6,7]. The only problems are allergic reactions. A very small percentage (<1%) of the population will exhibit immediate allergic reactions when exposed to isocyanate and should avoid all contact with the material. The average individual however, will only exhibit temporary irritation of the respiratory system, skin and eyes when over-exposed. This isocyanate hazard is easily recognized.

Most applicators will know they are being over exposed because they get runny noses, itchy eyes and irritated throats. Once the over-exposure is stopped, the allergic reactions end. These 'early-warning' discomforts are very effective ways to avoid over exposure. Only prolonged unprotected exposure to isocyanate can cause irreversible sensitization problems. Over exposure to isocyanates is controlled simply by wearing respirators, gloves and other protective clothing as per standard good painting practices[7].

Figure 5 [5,6,7,8]

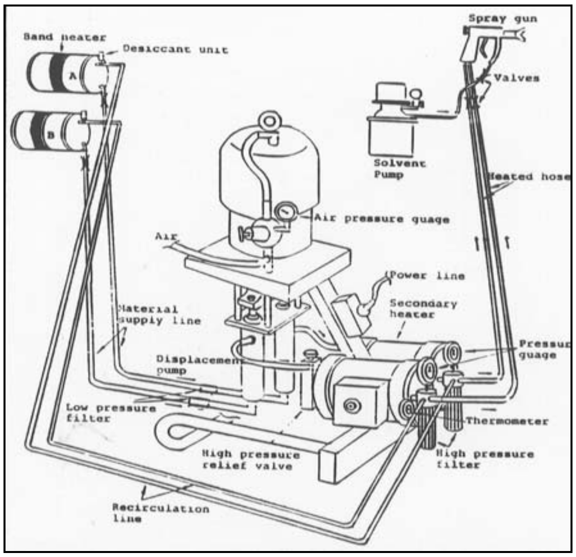
100% SOLIDS POLYURETHANE SAFETY FEATURES

- **NO Solvents**
- **NO Flammables**
- **NO Amines**
- **NO Styrenes**
- **NO Carcinogens**
- **NO Monomeric Isocyanate**
- **"Early Warning"**

APPLICATION

100% solids polyurethane technology is available in a variety of setting times to allow application techniques including 'brush and roller', 'hand spray', 'automatic line travel' and 'casting'. 'Factory' results can be achieved in the field. Typically, the setting (or cured-to-touch) time for these polyurethane systems ranges from less than one minute to several hours. Slower setting systems are typically applied with conventional airless spray equipment or by a brush or roller. Brush or roller applied systems are normally good for doing touch ups or coating small areas (<10 ft^2 / 1 m^2). Conventional airless applied systems are better for the coating of larger surface areas or where plural component equipment is not feasible.

Figure 6



Plural Component Spray Machine

Fast setting plural systems (with setting times of under 20 minutes) are usually applied with plural component equipment. The pot life is effectively zero minutes. Two component airless spray pumps meter the components (iso and polyol) in the correct ratio (fig. 6).

The components are kept apart until they meet at (or just before) the spray gun. Equipment is available from a number of manufacturers.

Fast setting systems can also be applied using a casting method to areas such as girth welds (fig. 4). It is this fast setting time that provides many advantages (fig. 5). First, the coating can be applied to virtually any required thickness in one coat. Using the hand spray technique, the applicator will spray on five to ten mils (125 to 250 microns) in one pass. Within one to two minutes (for most systems, seconds for others), this first pass has cured enough so a second pass can be applied. This multi-pass process is continued until the required thickness is achieved. Line travel machines use a variety of techniques to accomplish the same results in an automatic fashion[10].

A girth weld coating can be hand cast with a fast setting polyurethane in less than 5 minutes. The 100% solids polyurethanes can cure at a very fast rate. The fast setting systems allow a pipe to be inspected and buried within minutes of its application. The slower setting hand applied systems may take several hours. The rapid cure of the 100% solids polyurethanes and the nature of the reaction makes the systems very easy to inspect. Within minutes (for the faster systems) and within hours (for the hand applied systems), the coatings can be tested for thickness and holidays.

If the coatings are not mixed in the proper ratio, they will simply not react to form a hard, solid coating. The applicator and/or inspector knows something is wrong. If there is any water or other contamination on the substrate surface, the polyurethane will typically react very quickly (within hours) to form a blister or bubble that is easily identified. With a minimal amount of inspection, it would be very rare for an improperly applied coating to go undiscovered. This 'instant-failure/inspecting' characteristic helps the applicator, inspector and owner easily recognize and correct application problems before the pipe is buried[12].

There is no question that fusion bond epoxy one of the most economical and most commonly used pipeline coatings in the oil and gas industry. Also, the laboratory performance testing of the FBE coating indicates the coating should perform very well...when applied properly. However, recent failures in New Mexico[13] have raised concerns about the ability to inspect FBE to know whether or not it has been applied properly. The 'self-inspecting' feature of polyurethane can be extremely valuable.

It should be noted that the same fast setting 100% solids polyurethane systems used for automatic line travel applications and for manual spraying can be applied in the factory as well, with little or no modifications. In this sense, the same system can be used on new or rehabilitated pipes. Finally, the nature of the iso/polyol reaction is exothermic. Because it generates its own heat, it can be applied at almost any ambient temperature. It is not uncommon for the 100% solids polyurethanes to be applied down to temperatures of -40°F (-40°C) without any additional heat.

All of these factors add up to a coating technology that is extremely versatile for everything from doing small touchups to 100 mile (160 kilometer) coating projects.

Figure 7[3]

POLYURETHANE APPLICATION FEATURES (typical)

Features	Slow Set - Mastic	Slow Set - Spray Grade	Fast Set - Spray Grade	Fast Set - Castable
INITIAL SET TIME	2-4 hours	1-4 hours	15 seconds to 15 minutes	5 - 10 minutes
CURE TO INSPECT OR HANDLE TIME (@70°F/ 20°C)	4-8 hours	2-8 hours	30 seconds - 30 minutes	5 - 20 minutes
MINIMUM APPLICATION TEMPERATURE	32°F/0°C	0°F/-18°C	-40°F /-40°C	-40°F / -40°C
MAXIMUM THICKNESS PER COAT (vertical surface)	20 mils, 500 microns	8-10 mils, 200-250 microns	unlimited	unlimited
SELF-INSPECTING?	NO	YES	YES	YES
APPLICATION METHOD	Brush, roller	Brush, roller, conventional airless spray	Plural component heated airless	Hand mix and cast
APPLICATOR SKILL LEVEL	NIL	STANDARD	SPECIAL TRAINING	NIL

PERFORMANCE, HOW LONG WILL IT LAST?

The question (how long will it last?) is a very difficult one to answer because it depends on so many variables. Factors such as surface preparation, film thickness, water temperature, frequency of ice, cathodic protection and so on, all effect the longevity of a coating. The true cost of a coating is not the cost per square foot (or square meter). It is the cost per area coated per year of life.

100% solids polyurethanes are available on the market today that will perform as well as (or even better than) conventional pipe coating systems. However, due to the great diversity possible in the formulation of 100% solids polyurethanes, the end user must take great care in specifying the right material for the right job.

Figure 8 shows typical performance numbers of some 100% solids polyurethanes. The elastomer system should not be used for underground corrosion protection on steel given its very poor adhesion and cathodic disbondment numbers. The other three systems would be much more suitable for underground corrosion protection with the non-extended material performing the best. If the coating was to be used in a higher temperature service, clearly, the non-extended polyurethane would be the only suitable alternative.

RECENT PRODUCT DEVELOPMENTS

The raw material suppliers of the isocyanates and polyols up until recently (last 5 years) had been focusing much of their research and development efforts in the foam markets. However, as the foam industry has become more and more commodity-like, these suppliers have spent more resources in developing new isocyanates and polyols for the coatings industry.

High Temperature Resistance[14]

The oil and gas pipeline industry has shown a trend to operating lines at greater pressures and temperatures in order to transport more material through the line. Until recently, there were no commercially available polyurethane resins that allowed continual service much beyond 140°F/60°C[8]. Performance properties, especially cathodic disbondment, became very erratic at the elevated temperatures[13]. Figure 8 shows the typical performance properties of an ‘extender free’ 100% solids polyurethane that incorporates the newly developed resins for higher temperature applications.

Figure 8[3]

100% Solids Polyurethane Coating Performance

Test	15% Tar Extended	30% Tar Extended	0% Extended	Elastomer	Castable (Girth Welds)
Applied Thickness (on steel)	15 mils /375 microns	15 mils /375 microns	15 mils /375 microns	60 mils /1500 microns	200 mils /5000 microns
Abrasion Resistance CS17 wheel, 1000 rpm ASTM D4060	<80 mg loss	<100 mg loss	<60 mg loss	<5 mg loss	<60 mg loss
Flexibility 1" mandril ASTM D4145	120°	130°	100°	180°	60°
Impact Resistance ASTM D2749	>45 in lbs	>50 in lbs	>40 in lbs	>80 in lbs	>150 in lbs
Hardness ASTM D2240	60 Shore D	70 Shore D	80 Shore D	60 Shore A (Soft)	80 Shore D
Adhesion ASTM D4541	3000 psi	2500 psi	3500 psi	800 psi	3500 psi
Cathodic Disbondment @ 20°C ASTM G42	10 mm	12 mm	8 mm	30 mm	<1mm
Cathodic Disbondment @ 65°C ASTM G42	30 mm	40 mm	15 mm	>50mm	5mm

Low Cost / High Performance Wastewater Internal[15]

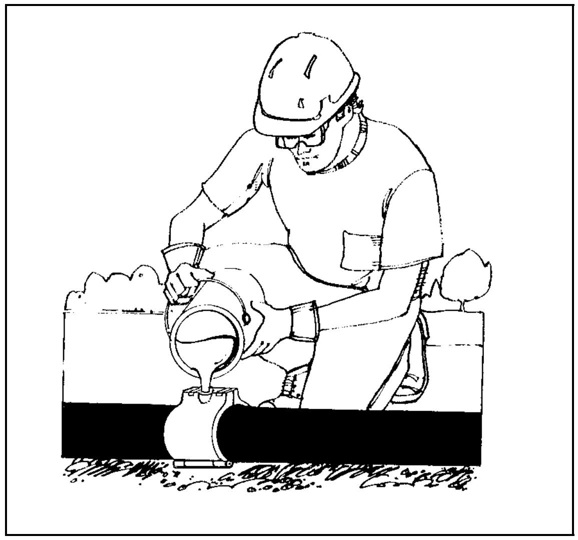
Ductile iron, concrete and other municipal pipe suppliers have been faced with the challenge of supplying a product to the wastewater industry that will last 50 to 100 years at the lowest cost possible. Competition from mainly the plastic pipe industry has forced them to find materials that will perform adequately but at a minimum cost. The polyurethane coating industry has responded by developing systems that use slightly more tar filler (thus reducing the cost) while maintaining the properties that are necessary for corrosion protection. The material used to coat the internal of a sewer pipe is slightly softer and more susceptible to damage than the system for the external of the pipe. However, because the coating's primary function is to protect the inside of the pipe from chemical attack, its reduced impact strength is still very acceptable. The cost is 40% lower than the less extended system for the pipe externals.

Girth Weld Casting Coating[16]

100% solids polyurethanes have been used as girth weld coatings for many years very successfully. Traditionally, high performance coatings for girth welds involve field applying fusion bonded epoxy or polypropylene and FBE. These systems require expensive, sophisticated equipment and highly trained operators. Recently, a new concept using a castable 100% solids system has been introduced to the market.

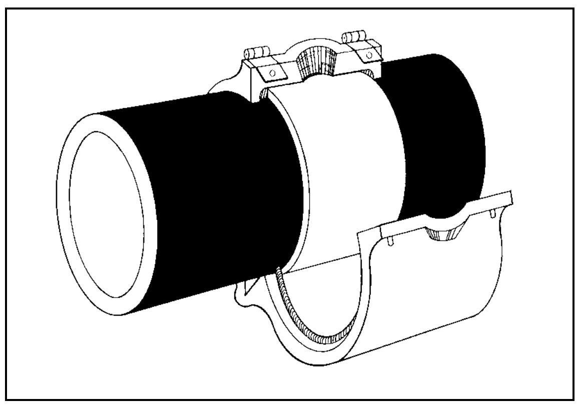
The resins used are very similar to the rigid, aromatic, non extended systems discussed above except for several notable characteristics. First, the systems use resins with low viscosities. This makes the materials very easy to mix and to pour so they will easily travel around the largest, roughest girth weld to completely fill the whole cavity and wet out the entire surface. Figures 9 and 10 show a typical mold and casting process.

Figure 9[16]



Hand Casting a Girth Weld

Figure 10[16]



Girth Weld Tool

The equipment and skill level required to apply or to install the girth weld coating is rather minimal. The pot life of the system can be varied from about 5 minutes to 15 or 20 minutes depending on the size of the girth weld. The only equipment needed to do even a 48" girth weld (in addition to that of surface preparation) is a mixing bucket, mixing stick and the tool (or mold). The container sizes can not only be matched to the size of the girth weld to minimize waste but they can also be sized so that one pail can be poured into the other for 'no measure' mixing. With the low viscosity resins and two components of different colors, the applicator can mix the system easily and accurately and repeatedly in an almost 'idiot-proof' manner.

The mold or tool can be made from a variety of materials depending on the life and number of joint castings requires. Common materials are aluminum and fiberglass reinforced plastic (FRP or GRP). The exact size and profile of the pipe and girth weld must be known ahead of time so that the mold-maker can make the tool properly. The tool should allow for easy assembly and demolding as well as for good resin flow throughout the mold.

The performance of a girth weld casting as a system is usually quite outstanding and significantly better that even the 'best' sprayed on system as shown in figure 8. Simply, the system is applied much thicker to somewhere between 0.125" to 0.250" (3mm to 6mm). High temperature resistance to cathodic disbondment and impact resistance increase dramatically.

CASE HISTORIES

Underground Fuel Tanks[17, 18, 19]

Since 1975 there have been over 300,000 cathodically protected, underground steel fuel storage tanks installed in the United States and Canada. The tanks in Canada were designed according to the Underwriter Laboratories of Canada standard S603.1. The majority of the American tanks were built according to the STI-P3 standard of the Steel Tank Institute of Lake Zurich, IL or the Underwriters Laboratories UL1746.

Virtually all of these tanks have been coated with 100% solids polyurethane coating. The amount of steel coated is in excess of over 150,000 million square feet. The design of the system has been so effective that, to date, there have been ***zero failures*** reported as a result of external corrosion of the tanks. The simple design involves a dielectric coating (usually 100% solids polyurethane), nylon bushings (to electrically isolate the tank from the piping) and sacrificial anodes.

The fabricators of the STI-P3 tanks continue to use 100% solids polyurethane coatings and offer a 30 year warranty against external corrosion. Although an underground fuel tank is not quite the same as an underground pipeline, the similar service conditions show that pipeline owners should experience similar success when coating new or rehabilitating old pipelines.

Ductile Iron Pipe[20, 21]

In June of 1993 a San Diego corrosion engineering firm, tested the corrosion protection system installed in 1991 on the 12", 6 mile, ductile iron pipeline known as Fiesta Island Replacement Project (Phase 1) in San Diego, California. The system uses 25 mils (625 microns) of a 100% solids polyurethane coating and sacrificial magnesium anodes. The consultant's analysis[15] showed that the coating system had an installed efficiency of 99.66% and the pipe had an actual current requirement (for corrosion protection) three times less than the design value.

The inspector said that, in his opinion, *"this is outstanding performance for a coating on bell and spigot ductile iron pipe".* The analysis goes further to report that, given the excellent condition of the polyurethane coating and the corresponding low rate of consumption of the anodes, the system will last 111 years.

In 1991, a start was made towards meeting the San Diego Clean Water Program's water reclamation goals by building Phase 1 of the Fiesta Island Project. The line conveys digested sludge at high pressure from the Point Loma Wastewater Treatment to a new biosolids processing plant 19 miles away. The balance of the pipeline is to be completed by 1997.

Success of this first pipeline was (and still is) very critical. The pipeline route goes through a military base, a popular park and an affluent neighborhood. It also goes through an earthquake fault line and several heavily traveled business corridors. Corrosion survey reports indicated that the soil was very corrosive. Any sort of premature failure could mean political and functional disaster. The 100% solids polyurethane successfully met this challenge on all counts as the external corrosion resistant coating.

The applicator prefers to use the polyurethane system about conventional coal tar epoxies due to the many handling advantages of the technology. First, there is no concern over carcinogenic coal tar in the polyurethane system because the safer petroleum tar is used as an extender instead of coal tar. Secondly, the polyurethane is applied in one coat (no primer), directly to the blasted metal using an automatic spray gun and pipe conveyor at a rate of 20 feet of pipe per minute (6 meters/min). These production rates are at least 5 to 10 times of what is possible with coal tar epoxy.

The pipe installers and on-site inspectors reported that the pipe survived the installation and a 2000 mile trip from Birmingham, Alabama (where the pipe was made and coated) to San Diego with little or no coating damage; an 'unheard-of' feat when dealing with coal tar epoxy or tape coatings.

Maljamar Gas Line[22]

In 1988 a 100% solids polyurethane coating was used to protect a 4.5 mile line of 6" steel pipe carrying gas through the Maljamar, New Mexico gas field for major pipeline company. The engineers at the facility monitor the cathodic protection system on a continual basis. They report that there is nothing to report. The cathodic protection levels have remained constant since the day the pipeline was installed.

The pipes were coated to a thickness of 18 mils (450 microns) at an average rate of 35 feet per minute (10 meters per minute) at a pipe coating facility in Odessa, TX. The coated pipe was then transported by truck to Maljamar where it was buried to a depth of approximately 40 inches (1 meter).

The polyurethane's high degree of impact and abrasion resistance minimized the amount of wear, tear and damage sustained during the transport and installation. Unlike conventional coal tars and tape coatings, exposure to the hot New Mexico sun for several weeks during the installation did not affect the polyurethane's properties. Sometimes, no news is good news. In this case, the engineers estimate that 7 years of solid initial coating performance will result in a further 30-40 years of coating life at least.

Submarine Base Pilings[23]

A 100% solids polyurethane coating dramatically outperformed a coal tar epoxy system in protecting steel pilings at the Trident submarine base in King's Bay, Georgia over a 5 year period. This case history does not involve tanks but does involve a direct comparison between 100% solids polyurethane and epoxy over an extended period under rather severe service.

During the spring of 1986, the U.S. Navy commenced the construction of its new Trident submarine base. The program involved 200,000 square feet of steel pilings and a similar quantity of pipe pilings. The pilings were coated with a 100% solids polyurethane and the pipe pilings were protected with coal tar epoxy. Both coating systems met the Navy specification 68-81-3020 Sec. 098505. No cathodic protection was used. The pilings were coated by Pennsylvania applicator in the spring of 1986 and installed by South Carolina construction company that fall.

Forty per cent of the pilings supported a permanent infrastructure of docks and piers. The remaining pilings were used to construct a temporary drydock facility for use over 5 year period for the rehabilitation of submarines. As part of the Navy's plan, these pilings were removed during the summer of 1990 and scheduled for disposal. During the removal it was discovered that the pilings coated with the polyurethane were in such pristine condition that they could be re-used or sold for a future project. Further inspection of the permanent pilings protected with the 100% solids polyurethane showed that they too were in excellent condition.

The polyurethane exhibited no flaking, brittleness, cracking or delamination after 5 years of abrasion, salt spray and tidal activity. Large sections of the pilings had little or no barnacle growth and where barnacles were located, they were easily removed. There was some spot corrosion where the coating had been gouged as a result of severe abrasion. However, the rust did not extend beyond the damaged areas.

The epoxy pilings coated at approximately the same time with the same surface preparation and exposed to the same service conditions did not fair nearly as well. The epoxy blistered and delaminated in many spots. There were also large areas where the steel had rusted through the coating. The barnacle growth was extensive and difficult to remove.

CONCLUSION

The 100% solids polyurethanes offer an extremely wide ranges of coatings for a wide variety of pipe coating and linings requirements that offer significant performance and handling advantages. Specifiers, end users and applicators should be aware of all of the different polyurethane technologies available so they can ensure that the right coating is selected for the right job.

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