Polyurea Spray Elastomer Technology: Commercial Application Update

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ABSTRACT

Several years ago, the concept of a polyurea spray elastomer technology was introduced. Since that introduction, numerous developments and presentations have boosted the market interest. The use of amine terminated polyether resins is still the basis for this technology. The polyurea spray elastomer systems require no catalyst and are extremely fast in reactivity and cure. Changes in humidity and ambient temperature have little effect on this fast, consistent reactivity. Aromatic and aliphatic polyurea spray elastomer systems are easily achieved by changes in formulation composition, and they are still 100% solids.

These spray systems have excellent mechanical properties and extended durability when subjected to extreme environmental conditions. Coating applications show excellent adhesion to a variety of substrates, including sand blasted or primed steel, aluminum and concrete. Polyurea spray coated steel panels exhibit good corrosion resistance when subjected to salt fog exposure and salt water immersion at elevated temperatures. Variable moisture permeability rates in the elastomer system can also be obtained while the excellent performance characteristics. Recent studies and developments have shown that polyurea spray elastomer systems can be applied at much lower processing pressures. This allows for thinner film applications as well as broader processing equipment use.

With these new developments, both the aromatic and aliphatic polyurea spray elastomer technologies are finding wide acceptance in a variety of large commercial applications. These applications include a variety of concrete, fabric, metal, wood and foam coatings as well as open mold spray work.

INTRODUCTION

For decades, coating and lining systems have been used for a variety of applications. These initial systems, though complex in preparation at the time, were fairly simple to install. The common installation technique mainly involved brush / hand application. Newer system developments and the evolution of spray application soon realized enhanced coating and lining performance. This spray technique was mainly single component applied. Excellent atomization could be easily achieved in these systems by introduction of various solvents, which also extended the system "pot life".

With new regulations and the move to higher solids content coating and lining systems, new means of application technique and equipment were required. This gave rise to the plural component application equipment. In the late 1980's, a new coating and lining technology was introduced to the industry, plural component polyurea spray elastomers. The basis of this technology was aromatic systems, which are very fast in reactivity and cure. Following suit in the early 1990's, 100% solids, plural component aliphatic polyurea spray elastomers were introduced. Having similar fast reactivities to the aromatic based systems; aliphatic polyurea systems provide optimum performance and color stability.

Due to the extremely fast reactivity and cure of this 100% solids technology, plural component equipment is required. The system must also be heated during processing, not for reactivity control, but for the ability to atomize and spray correctly. High-pressure proportioners are used to properly deliver product to the impingement mix spray gun.

POLYUREA CONCEPT

At an SPI Technical Conference[1,2], the concept of 100% solids polyurea spray elastomer systems was introduced to the industry. In order to fully understand the application requirements, we must first define what a polyurea spray elastomer system is. The National Association of Corrosion Engineers has recently published a Technical Committee Report[3], "Introduction to Thick-Film Polyurethanes, Polyureas and Blends", which gives a basic summary of the technologies. The polyurea spray elastomer systems are defined as having one component, the aliphatic isocyanate quasi-prepolymer and the other component being the resin blend. For polyurea elastomer systems, the resin blend is composed of primary amine terminated resins and amine terminated chain extenders, no polyols or catalysts. Additional additives and fillers may be used so as to enhance performance. This is the basis for the definition adopted by the newly formed Polyurea Development Association.

This technology was characterized as being processed by plural component application equipment and having extremely fast system reactivities and cure properties. Typical elastomer physical properties are shown in TABLE I.

TABLE I: POLYUREA SPRAY TYPICAL ELASTOMER PROPERTIES

Tensile strength, mPa	up to 27.6
Shore Hardness	A 30 to D 65
Elongation, %	up to 1000
Tear strength, N/m	19 to 58 (x 1000)
100 % Modulus, mPa	6.2 to 13.8
CLTE, mm/mm/°C	4.0 to 13.4 X 10^{-5}
Burst strength, mPa	1.8 to 3.5
Flexibility / Crack Bridging (-26°C)	3 mm, pass

*From a Sprayed Film

The technology has really matured since the initial introduction 12 years ago and use in a broad range of application areas is growing. Specific attributes of the polyurea spray elastomer technology, which allows for a wide range of application uses, include:

- Excellent mechanical properties and extended durability, even in extreme environmental conditions.

- Fast, consistent reactivity that is relatively unaffected by changes in humidity and temperature. No catalysts are required.

- Excellent adhesion to a wide variety of substrates for properly formulated systems, even with the fast system reactivity.

- Readily compliant with regulations limiting the levels of volatile organic compounds. Polyurea spray elastomer systems are able to meet stringent environmental standards due to the 100% solids formulations.

- Excellent color stability for aliphatic based formulations.[4,5]

Another mechanical property that is sometimes overlooked is low temperature flexibility. The polyurea spray technology, including the aliphatic-based systems, has excellent low temperature flexibility, even down to -40°C. This is due to the highly amorphous nature of the polymer backbone, unlike the crystalline nature of polyurethane systems. Information on the low temperature characteristics can be found in Table II.

Table II: Low Temperature Properties

Low Temperature T_g	-50°C
3 mm Mandrel bend, -20°C	Pass
Gardner Impact, -20°C,	160 in-lbs
Direct*	Pass
Indirect*	Pass

*Applied to 1/32 inch metal coupon

PROCESSING DEVELOPMENT

One of the keys to the success, or failure, of the polyurea spray technology is in application and equipment used. In 1992, a detailed paper was presented on the processing studies of aromatic and aliphatic polyurea spray elastomer systems, with an update in 1998.[6,7] It was shown that high pressure, high temperature impingement mix spray equipment was required to achieve proper atomization and mixing of this highly reactive technology. The equipment found to give the optimum performance is the GUSMER line of proportioners and spray guns.

In processing these 100 % solids polyurea spray elastomer systems, one must overcome the viscosity of the individual components as well as the initial mix viscosity of the system inside the mixing chamber of the spray gun. The use of the high temperature and pressure helps to reduce this initial viscosity build in the system and allows for atomization of the mixed components achieving a spray pattern. In addition, volume flow of material into the mixing chamber of the spray gun is important.

In order to process this exciting new technology, considerations must be given to the processing equipment. The key to processing is within the proportioning pump and the spray gun. This is the “life support” system for proper installation and application. There are 2 types of proportioning pumps, vertical and opposed horizontal. These can either be air operated or hydraulically driven. For the spray guns, only the impingement mix types are appropriate for the fast cure, 100% solids aliphatic polyurea spray systems.

Ideally, one would like to see comparable viscosities between each component. This aids in the mechanical delivery of equal volumes of material to the spray gun. Most systems are processed at a 1:1 volume ratio. For proper proportioning and application of polyurea spray elastomer systems, you must have the following:

- Pressure,
- Temperature,
- and Volume material flow.

EnviroLine Technologies has taken steps in the preparation of their polyurea elastomer systems so as to match viscosities of each component. This aids in the ease of application and overall performance of the coating systems.

ADHESION STUDIES

Polyurea spray elastomer systems exhibit excellent adhesion to a variety of substrates. By careful formulation development and selection, elastomer substrate adhesion values can be achieved which exceed the cohesive strength of the elastomer system or substrate. Even with the rapid system reactivity of the polyurea elastomer technology, adhesion values are quite good.

Many factors affect the adhesion of polyurea spray elastomer systems, including the substrate surface condition/preparation; elastomer system formulation; elastomer system reactivity (surface wetting effect); and service and exposure of the coated substrate. All of these factors should be considered in the development of a system for specific applications.

TABLE III gives some typical adhesion values to select substrates for a basic EnviroLine aromatic polyurea spray elastomer system. For adhesion testing, an Elcometer Adhesion Tester was used according to ASTM D-4541[8]. This test evaluates the pull-off strength (commonly referred to as "adhesion") of a coating by determining the greatest perpendicular force that a surface can bear before a plug of material is detached. The adhesion values are reported as the perpendicular force (mPa) needed to remove the polyurea elastomer coating from the substrate. In some cases, failure of the substrate or cohesive elastomer failure is noted before adhesion is lost.

TABLE III: ELCOMETER ADHESION STUDIES

SUBSTRATE	ELCOMETER ADHESION, mPa
Concrete, dry	2.8, SF
Concrete, primed	6.9, SF
Steel, 2-mil blast profile	> 13.8
Aluminum, cleaned	> 13.8
Wood	1.7, SF

SF = Substrate Failure

CORROSION STUDIES

To further illustrate the excellent adhesion characteristics of the polyurea spray elastomer technology, standardized metal panels were coated and subjected to salt fog evaluation (ASTM B-117)[9]. For this study, two aromatic EnviroLine polyurea spray elastomer systems were used. The main difference in the two formulations was system reactivity. It was presumed that the system with the slower reactivity should wet the substrate better, an attribute that would impart adhesion properties superior to those possessed by the faster formulation. The systems, which were applied to KTA-Tator 2 mil blast profile panels (with and without the use of a primer), were subjected to 1000 hours of salt fog exposure.

It is very interesting to note that both the highly reactive system and the slower system gave comparable performance in the salt fog evaluations (TABLE IV). The polyurea systems actually performed better when applied directly to the steel panels as opposed to using a primer. The unprimed, polyurea coated panels maintained this performance out to 3000 hours of exposure.

TABLE V: SALT SPRAY / CORROSION STUDIES

		EnviroLine	
		HD	GP
Blistering	Bare steel	None	None
	Urethane primer	None	None
	Epoxy primer	F, #2	F, #2
Corrosion from scribe, mm	Bare steel	4.0	7.0
	Urethane primer	> 10	> 10
	Epoxy primer	9.5	8.0
Elcometer adhesion, mPa	Bare steel	> 13.8	> 13.8
	Urethane primer	3.4	5.5
	Epoxy primer	8.3	7.6

1000 hours ASTM B-117 Salt Fog Exposure

These evaluations of the EnviroLine polyurea spray elastomer systems have given consistent, reproducible results and should stand as a reliable indication of various performance properties for the polyurea spray elastomer systems, including adhesion, moisture vapor transmission and hydrolytic stability.

TECHNOLOGY APPLICATIONS

The prospects of landing a major coating application loomed before the contractor who could meet the requirements of the job. But how could these areas be efficiently coated/repaired in a seven-day-a-week, 10 - 14 hour-a-day, setting without closing some portion of the area use or daily traffic? It was clear that by preparing and installing repairs on a limited area during each work cycle, partial openings could be accomplished. The problem however was in finding a repair material that could be installed during off-hours and would be cured with minimum downtime. The needs of the customer required that the installations be not only tack free, but also have the ability to return the area to normal service.

It was early 1993 and the selection of coating materials, which could meet the needed specifications, was exceedingly meager. Polymer systems based on modified polyurethanes, epoxies, methyacrylates, polysufides or silicones might be products to consider except that curing times, which at best, ranged into the 12 hour time zones with many in the 24+ hour zones. None of these products could fully meet the restraints for the projects

During this time, a handful of products were being developed based on a polymer chemistry referred to as polyurea. Cure times of 1 to 3 hours were being touted with product properties for installation and repair that met or exceeded most polyurethane, epoxy and silicone based technologies.

Based on the variety of application and performance advantages of the polyurea elastomer technology, numerous applications area can be targeted. This would include areas commonly served by polyurethane, epoxy, and polyester technologies as well as polyethylene and polypropylene sheet goods.

For many coating applications, the desire to return the facility back into service shortly after the application is complete is extremely advantageous. Polymer systems based on polyurethane, epoxy and acrylics usually require at least a 12-hour cure period, and in some case 24 hours, before the coated area can be put into service. Due to the fast, consistent reactivity and cure times of polyurea systems, coating applications can easily be returned to service in a 1- to 3-hour time period. This technology can even be applied at -20°C ambient temperature and reach service cure within 1 hour.

Another very important feature of the polyurea technology is the 100% solids nature with no volatile organic compounds (VOC's). During and after application, no vapors, fumes or chemicals are released when properly processed. This makes the polyurea technology attractive for confined space application as well as for use in food processing/handling applications.

CONCRETE COATINGS

The largest use of the polyurea spray technology is in concrete coating applications.[10] This ranges from secondary containment to flooring to water proofing methods. The fast reactivity and cure of the polyurea spray technology allows for rapid application and minimum downtown for the facility where the coating is being applied. For the application work, the concrete surface is shotblasted, cleaned and vacuumed followed by application of a primer system.

The most prominent concrete coating application is secondary containment. Here the polyurea system can be easily applied around protrusion and adheres well to tank footings and pipes through the concrete. For highly chemical resistant application, a topcoating can be applied. An example can be see in Figure 1.

Polyurea elastomer base coat

with chemical resistant topcoat

Figure 1: Secondary Containment Area

Polyurea spray elastomer systems are also being touted as a new system for parking deck, traffic areas and flooring. The application technique is the same as that for secondary containment except that a slower system may be required. This will allow the introduction of a non-skid type aggregate material for traction purposes. Types of aggregate commonly used would be metal slag and quartz or sand. In addition, slow cure polyurea plural component caulk/sealant systems are used for the expansion joints. These are applied by means of 2-part caulk tubes or proportioning equipment.

In addition to introduction of aggregate into the spray, the non-skid appearance can be done by spray technique. The fast reactivity of the polyurea technology will give a uniform stipple effect to the surface of the coating. This texture is acceptable for normal foot traffic type flooring applications.

For either highly corrosive environments or a more aesthetic appeal, the polyurea technology can be used as a base coat system and then top coated with an epoxy or aliphatic polyurethane system. The polyurea system has the flexibility to absorb normal movements in the substrate that would typically crack the more rigid top coating system. An example can be seen in Figure 1.

Concrete surfaces can also be coated for corrosion protection, not necessarily secondary containment applications. This would be areas where salt spray or road film has had a detrimental affect on the concrete causing spalling and deterioration. Normal thermal expansion and contraction has also played a key role in the failures of the concrete.

TANK LININGS

Another major use for the polyurea spray technology is in direct immersion application such as tank and pond linings. Here, the performance of the polyurea elastomer system must be optimum so as to hold up to these environments. The largest application area would be the wastewater / process water industry. For concrete tankage, the surface is prepared in a manner much similar to that as in the secondary containment. Figure 2 is an example of a concrete wastewater storage tank lining application.

Figure 2: Concrete tank lining

In another concrete tank lining application, polyurea systems have been found to show no adverse effect on aquatic marine life. The properly formulated EnviroLine systems have no off-gassing. The US Fish & Wildlife Service has specified a polyurea system to re-line all of the concrete tanks used in fish hatcheries. The polyurea is used due to the fast processing time of the system and the durable, flexible properties of the film. This allows for expansion and contraction of the tanks during extreme temperature variations and loading and unloading without cracking of the lining.

Polyurea systems also perform well as lining systems for non-aqueous environments. In the case of steel tankage used for fuel type storage application, a 2-mil blast profile is specified and a high solids epoxy primer is used to insure optimum performance. Speed of application and being able to return the tank back into service was the main reason for using polyurea. The elastomer system also performs well in the application.

While not a direct concrete coating tank lining application, applying the polyurea spray elastomer system to geotextile has been used in secondary containment applications as well as primary containment / pond liners. The geotextile fabric, both woven and non-woven, provides a nice uniform surface for application of the polyurea elastomer system. The fabric also enhances the tear and puncture resistance of the system.

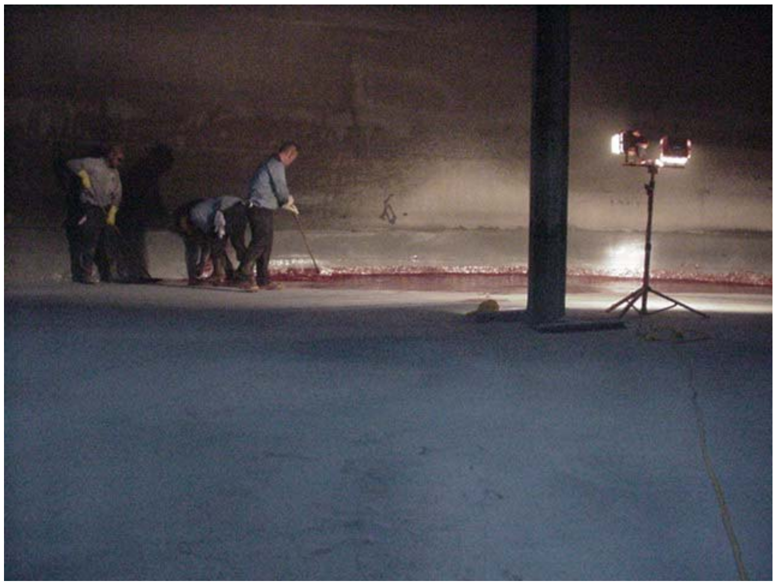

Figure 3: Steel Tank Lining, Chemical Resistant Topcoat

In Figure 3, a steel tank used to contain a corrosive condensate byproduct from oil refining that was having a floor corrosion problem. A concrete sub-floor had been poured but severe cracking was noted. A light weigh geotextile fabric was adhered to the floor using the spray polyurea system. Approximately 3 mm of polyurea was then applied to the geotextile and then top-coated the same day using a modified epoxy system at 0.4 mm. The application is performing extremely well to date.

While these applications highlight the most significant application areas for the polyurea spray technology, there are several other interesting uses. Exterior coating to metal pipe for corrosion protection is a growing area. The polyurea technology allows for pipe to be re-coated in field environments without the use of expensive coating cure equipment. It has been reported that a polyurea system has been approved for use on the Alaska pipeline for repair applications. There are also several in-house new pipe-coating applications involving polyurea spray elastomer systems.

Polyurea spray elastomer systems are also finding significant use in truck bed lining applications. Here the adhesion to the substrate, durability of the system, high thermal properties, rapid application and the ability to produce uniform textured surfaces are the advantages over polyurethane based systems.

Another area is the use in roof coating systems. The fast cure of the system at low ambient temperatures has allowed for roof repair applications well into winter months. The composite industry is also seeing some application of polyurea elastomer systems. Here, the systems are used to replace the unsaturated vinyl esters for open mold spray part production. Faster manufacturing times are noted with no emissions.

CONCLUSION

The development of the polyurea spray elastomer technology now provides for an extremely good cost and time-effective solution to a variety of coating problems. The fast, consistent reactivity, coupled with a good performance record, is pushing the polyurea technology to levels like that of polyurethane and epoxy systems. With the extreme efforts for industrial rehabilitation and increasing need to comply with environmental, economic and time constraints, the speed and durability of the polyurea elastomer technology holds great promise.

Well, what does the future hold for the polyurea spray technology? Efforts will continue with the aromatic polyurea technology to fine-tune the formulations for specific end use application areas. This may mean designing a formulation specifically for coating fresh impacted mortar concrete pipe, or a system that would be applied by way of a centrifugal spinner for lining the interior of pipe.

Work is currently in progress to modify the aliphatic polyurea systems such that reaction rates will allow application of an aesthetically smooth film yet maintain the fast processing characteristics. The possibility also exists for development of a single-component applied polyurea elastomer system that is not moisture cured.

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BIOGRAPHY

Dudley received an M.S. Degree in Organic Chemistry from Lamar University in Beaumont, Texas in 1984. He then joined Texaco Chemical Company - Austin Research Labs where he was involved in the development of rigid and flexible polyurethane foam systems and applications. It was under this area where he developed and first demonstrated the 100 % solids polyurea spray elastomer technology. In 1987 he joined the Performance Polymers Group where he has been involved in polyurea RIM and spray elastomer development and applications development of amine catalyst in polyurethane foam systems.

In 1994, Dudley became part of Huntsman Corporation following the sale of Texaco Chemical Company. Here, he was a Research Chemist in the Thermoset Applications Group devoting his efforts to marketing and applications development of the polyurea spray elastomer technology.

In October 1998, Dudley became Managing Partner / Chief Chemist with EnviroChem Technologies. Dudley was responsible for all formulation development for the *EnviroLastic*® polyurea product line and marketing of those systems and applications. He also interacted with the Certified Contractor Network on products and application techniques. Application equipment setup, training and servicing also fell under his responsibilities.

In November 2000, Dudley left the association with EnviroChem Technologies to pursue a personal consulting business, Primeaux Associates LLC. This work relates to the polyurea industry, equipment, application and training. He is currently working with EnviroLine Technologies to assist in development of their polyurea elastomer technology, both from a chemistry standpoint and market / application perspective.

Dudley is active in the National Association of Corrosion Engineers (NACE), SSPC: The Society for Protective Coatings and President-elect of the Polyurea Development Association (PDA). He is named inventor of 22 US Patents and 6 European Patents on polyurethane and polyurea foam applications as well as polyurea spray elastomer systems/applications. He also has 22 technical publications on the polyurea elastomer technology.