

POLYUREA SPRAY TECHNOLOGY IN COMMERCIAL APPLICATIONS

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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.

POLYUREA CONCEPT

At an SPI Technical Conference (Primeaux, 1989), the concept of 100% solids polyurea spray elastomer systems was introduced to the industry. This technology was

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characterized as being processed by plural component application equipment and having extremely fast system reactivities and cure properties. These polyurea spray elastomer systems were defined as having as one component the isocyanate quasi-prepolymer and the other component being the resin blend. For polyurea elastomer systems, the resin blend is composed of amine terminated resins and amine terminated chain extenders, no polyols. These systems are characterized as having extremely fast reactivities and cure properties. Typical elastomer physical properties are shown in TABLE I.

TABLE I: POLYUREA SPRAY TYPICAL ELASTOMER PROPERTIES

| | |
|-----------------------|--------------------------------|
| Tensile strength, psi | up to 4000 |
| Shore Hardness | A 30 to D 65 |
| Elongation, % | up to 1000 |
| Tear strength, pli | 250 to 600 |
| 100 % Modulus, psi | 500 to 2000 |
| CLTE, mm/mm/°C | 4.0 to 13.4 X 10 ⁻⁵ |
| Burst strength, psi | 250 to 500 |
| From a Sprayed Film | |

The technology has really matured since the initial introduction 8 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 catalyst 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.

The JEFFAMINE® Polyetheramines from Huntsman Corporation play a key role in the technology, Figure 1. These amine terminated resins have a polyoxypropylene backbone which is key to low moisture vapor transmission rates in the polymer. The primary amines react rapidly and consistently with the isocyanate component of the system without the use of a catalyst.

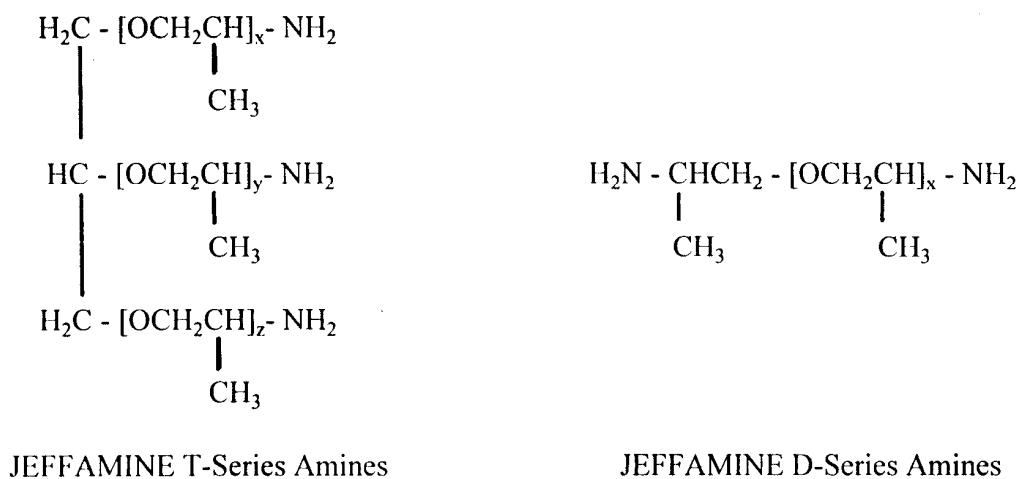


Figure 1 - The JEFFAMINE® Polyetheramines

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 (Primeaux and Anglin, 1992) was presented on the processing studies of aromatic and aliphatic polyurea spray elastomer systems. 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 recent years, it was found that by incorporating a common reactive diluent, propylene carbonate, in the isocyanate quasi-prepolymer portion (Primeaux, 1995), the polyurea system could be more readily applied and lower processing pressures could be used. By blending 5 to 10% by weight propylene carbonate into the isocyanate, the viscosities of the isocyanate and resin blend components would now be comparable. The propylene carbonate is stable in the isocyanate, but will react with the primary amines in the resin blend to form the β -hydroxy carbamate. This can then react with the isocyanate either by urethane linkage or biuret formation. The effect on elastomer physical properties can be found in TABLE II.

TABLE II: EFFECT of PROPYLENE CARBONATE

| | |
|---------------------------------|-----------------------------|
| Tensile strength, psi | Increase up to 20% |
| Shore Hardness | Remains relatively constant |
| Elongation, % | Increase up to 25% |
| Tear strength, pli | Increase up to 5% |
| 100 % Modulus, psi | Decrease of up to 10% |
| 10% pbw in Isocyanate Component | |

The propylene carbonate helps lower the initial mix viscosity of the system in the spray gun. This yields improved atomization and thinner elastomer film application capabilities. The propylene carbonate also helps guard the isocyanate component from freezing problems associated with low temperature storage conditions.

Traditionally, aromatic polyurea spray elastomer systems used isocyanate quasi-prepolymers based on MDI's of the high 2,2'- or 4,4'- isomer content. These gave very acceptable elastomer systems suited for a variety of applications. Recent work has shown that isocyanate quasi-prepolymers prepared from MDI's of the high 2,4'- isomer content provide significant improvements in elastomer processing characteristics due to slower reaction profiles. Elastomer physical properties are also greatly improved, as presented in TABLE III.

TABLE III: EFFECT of HIGH 2,4- ISOMER MDI QUASI-PREPOLYMER

| | |
|-----------------------|-----------------------------|
| Tensile strength, psi | Increase up to 20% |
| Shore Hardness | Remains relatively constant |
| Elongation, % | Increase up to 25% |
| Tear strength, pli | Increase up to 5% |
| 100 % Modulus, psi | Decrease of up to 10% |

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 IV gives some typical adhesion values to select substrates for a basic aliphatic and aromatic polyurea spray elastomer system. For adhesion testing, an Elcometer Adhesion Tester was used according to ASTM D-4541. 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 (psi) 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 IV: ELCOMETER ADHESION STUDIES

| SUBSTRATE | ELCOMETER ADHESION, psi |
|----------------------------|-------------------------|
| Concrete, dry | 400, SF |
| Concrete, primed | 1000, SF |
| Steel, 2-mil blast profile | > 2000 |
| Aluminum, cleaned | > 2000 |
| Wood | 250, 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). For this study, two aromatic 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 V). 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

| | | System Reactivity, sec | |
|---|-----------------|------------------------|--------|
| | | 2.5 | 3.5 |
| 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, psi | Bare steel | > 2000 | > 2000 |
| | Urethane primer | 500 | 800 |
| | Epoxy primer | 1200 | 1100 |
| 1000 hours ASTM B-117 Salt Fog Exposure | | | |

These evaluations of the 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

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.

RAILCAR/HOPPER CAR LININGS

In the railcar lining industry, it is quite common to see high solids epoxy based coating systems being used to line the interior of hopper cars used for plastic pellet and grain transportation. One of the main problems with these coating systems is flexibility inside the hopper car at the seams and corners as the cars move down the tracks. The use of outside impact devices on the sides of the car during unloading also causes cracking of the coating inside the car. Repeated heavy loading of the plastic pellets and grain tends to show severe abrasion problems. Once the coating is breached, the load can then be contaminated and no longer useful for the application.

In a joint effort within the Huntsman Organization and using the expertise of Specialty Lining Inc. railcar shop, several test cars were lined with an experimental aromatic polyurea spray elastomer system. The elastomer was applied directly to the blast steel substrate at an average film thickness of 0.012 inches. Adhesion, measured by direct pull-off strength, was greater than 2000 psi.

Repeated loading and unloading of highly abrasive polystyrene pellets had little effect on the polyurea coating. The loading process could actually be increased for faster turnaround time in the hopper cars. No cracking in the polyurea lining was noted at the joints and weld seams after repeated transportation runs.

Application of the polyurea spray elastomer system inside the cars also allowed for faster in-shop turnaround. The cars could be lined and inspected the same day as compared to the 24-hour wait period for epoxy systems. Also, the polyurea system is 100% solids.

This process has been commercial now for over 2 years. There are approximately 200 hopper cars with the polyurea spray lining that are used for polyethylene, polypropylene and polystyrene transport. No problems have been noted with respect to adhesion, cracking or abrasion.

CONCRETE COATINGS

The largest use of the polyurea spray technology is in concrete coating applications. 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 downtime 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 seen in Figure 2 for an existing area with piping and tankage and Figure 3 for a new construction area.

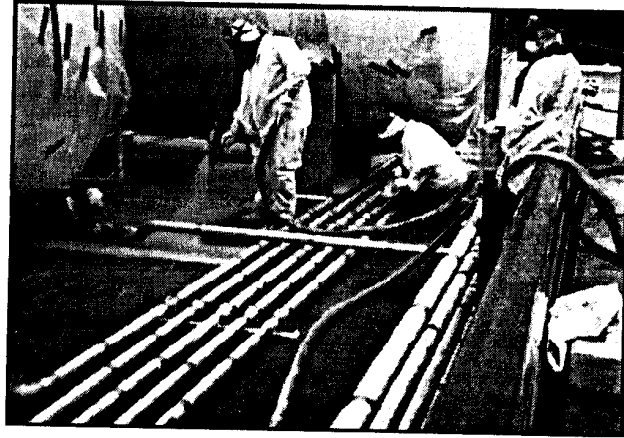


Figure 2: Secondary Containment Area



Figure 3: Secondary Containment Area, New Construction

Polyurea spray elastomer systems are also being touted as a new system for parking decks, 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. They are applied by means of 2-part caulk tubes or proportioning equipment. Examples can be seen in Figure 4.

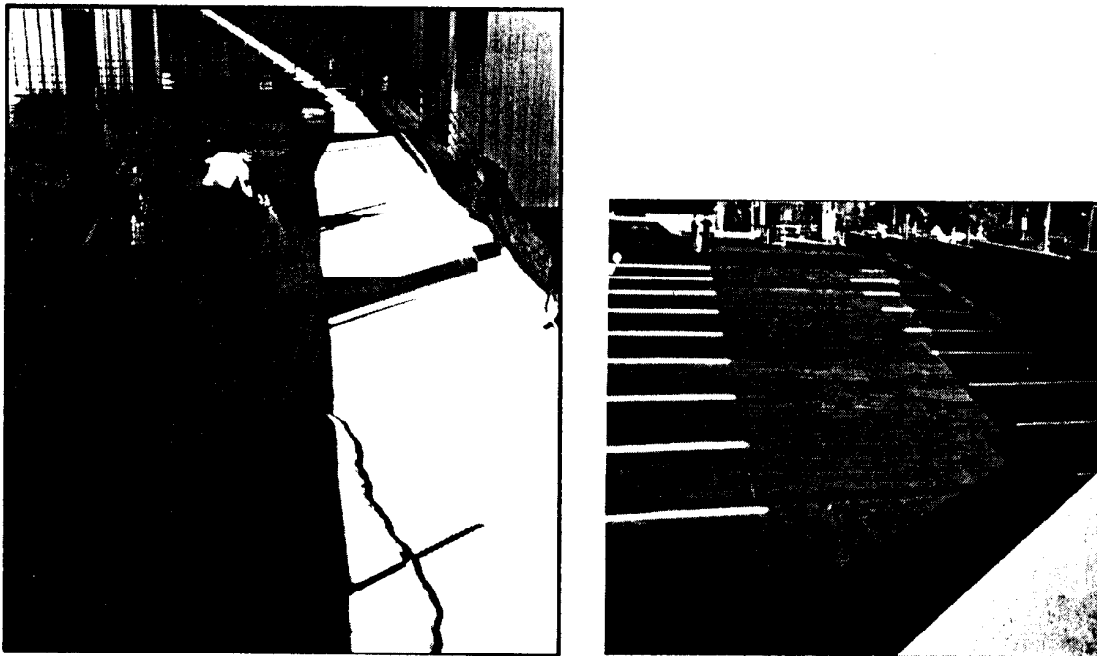


Figure 4: Deck Coating Applications Using Aggregate

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. Figure 5 shows an example of this.



Figure 5: Flooring Application Using Texture Technique

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. Figure 6 shows an example of shower room facility where the polyurea base coat was overcoated with an epoxy system.



Figure 6: Shower Room Coating Application with Epoxy Top Coat

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. In Figure 7, an example of a primed concrete bridge wall is being coated with an aromatic polyurea spray elastomer system to protect from salt corrosion.

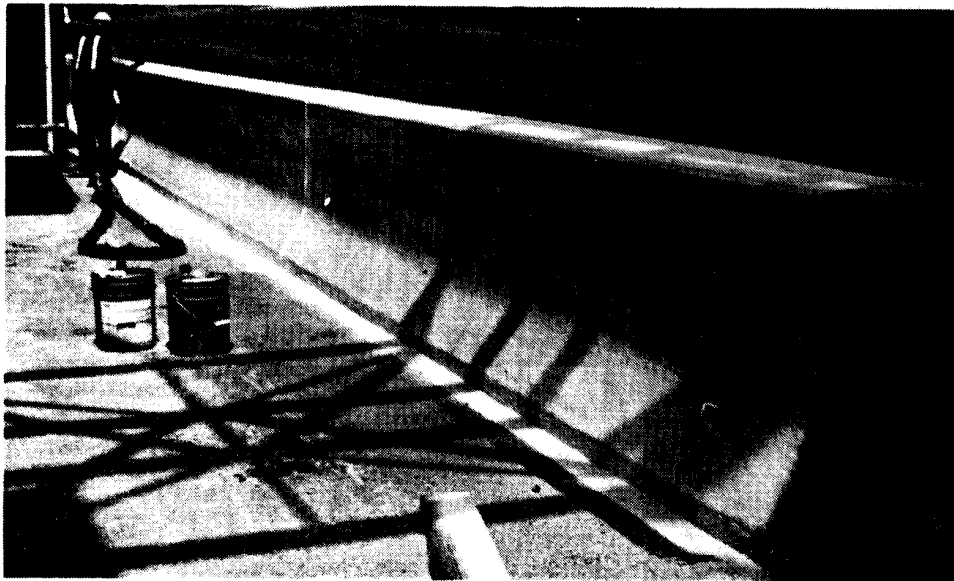
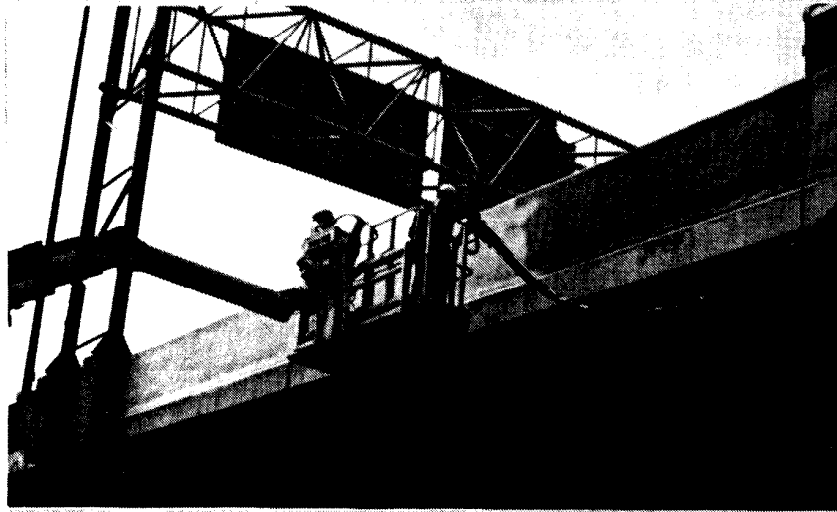


Figure 7: Concrete Bridge Wall Coating

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 waste water / process water industry. For concrete tankage, the surface is prepared in a manner much similar to that as in the secondary containment, Figure 8.

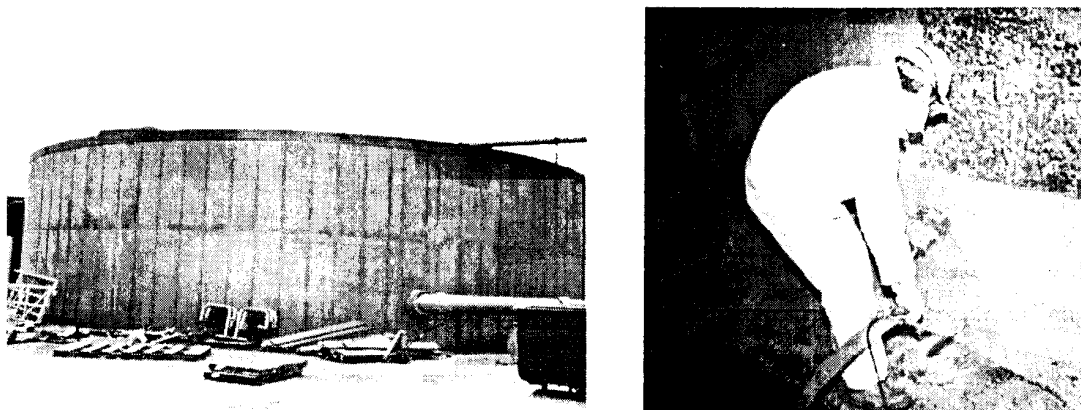


Figure 8: Concrete Waste Water Tank Lining

In another concrete tank lining application, polyurea system have been found to show no adverse effect on aquatic marine life. Properly formulated system 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, Figure 9.



Figure 9: Concrete Fish Hatchery Tank Lining

Polyurea system 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, Figure 10.

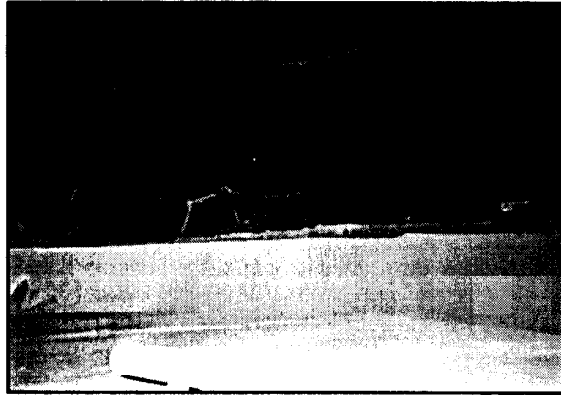


Figure 10: Fuel Oil Tank Lining

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.

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 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 system are used to replace the unsaturated vinyl esters for open mold spray part production. Faster manufacturing times are noted with no emissions.

PROFESSIONAL ORGANIZATIONAL ACTIVITIES

The polyurea spray elastomer technology has also begun to see acceptance and recognition in a variety of professional organization. Numerous technical papers and editorials have appeared in *The Journal of Protective Coatings & Linings*, *Modern Paint and Coatings*, *Paint & Coatings Industry*, *Concrete Repair Digest*, *Concrete Repair Bulletin*, and *Electric Light & Power*. These articles highlight applications from secondary containment to pipecoatings to pondliners to flooring.

The National Association of Corrosion Engineers (NACE) conducts technical meetings twice a year where committees are represented which cover broad areas of corrosion associated issues. In these groups, Technical Reports, State-of-the-Art Papers, Recommended Procedures of Practice as well as Standards are prepared on corrosion protection issues. Noted experts in a variety of fields get together to prepare these documents.

Under the T-6 Group Committee on Protective Coatings and Linings, the Polyurea Technology Sub-committee (T-6A-67a) has been formed to prepare a state of the art paper on this rising technology. The NACE/SSPC (The Society for Protective Coatings) have joint task groups dealing with corrosion applications where polyureas have been identified alongside polyurethanes.

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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Visuron Technologies, Inc. 3650 Patterson Road, Bay City, Michigan, 48706. Figures 3, 7.

BIOGRAPHY

Dudley J. Primeaux II received an M.S. Degree in Organic Chemistry from Lamar University in Beaumont, Texas in 1984. He joined Texaco USA that same year in the Environmental and Customer Service Section. In 1985, he transferred to 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 the 100 % solids polyurea spray elastomer technology was demonstrated. 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 is a Research Chemist in the Thermoset Applications Group devoting his efforts to the applications development of the polyurea spray elastomer technology. He is active in the National Association of Corrosion Engineers (NACE) and SSPC: The Society for Protective Coatings. He holds numerous US patents on polyurethane and polyurea foam applications as well as polyurea spray elastomer systems/applications. He also has 15 technical publications on the polyurea elastomer technology.