HH/12 09 P.

Pure Polyurea
The Coating of Choice for China's Power Industry

S. Christopher Bean
Nukote Coating Systems International, LLC.

Summary: *With the dramatic advances of the coating industry, these polyureas, more than any other polymer coating, stand out in their versatility, strength and longevity. This article explains the reasons why pure polyurea is the best choice of the coating system in the Power Industry through the problems in the coating system and the advantages of pure polyurea's performance. And also elaborate the outstanding performance of purepolyurea in the coating system in the Power Industry.*
Key Words: *Pure Polyurea*

1. Introduction

Technological advances in the recent decade have resulted in a new breed of superior polymer coating formulations providing distinct advantages to both contractors and end-users. The development of this new breed of polymer products are the result of a combination of advances in both formulation and equipment technologies.

In a few years these new products will replace traditional coating, lining and membrane systems because they; eliminate common weaknesses of the older technologies, provide stronger physical properties, perform at higher levels of abuse and temperature extremes, last longer and can be applied quickly and easily.

Imagine, if you can, polymer products that; can be applied at a rate of 500-1000 square meters per day by a team of three-men without seams or layers, contain no volatile organic compounds, gel in seconds, can be put back in service within hours, use no catalysts or solvents in the curing process, are completely hydrophobic, exhibit physical properties much higher than traditional products, and can be used in coating, lining and membrane applications bonding and conforming to virtually any substrate.

This product is **pure polyurea**—the coating of choice for China's power industry.

Over the past 30 years the coating industry has made dramatic advances, chemical engineers have formulated innovative polymer resins that have a range of modulus, better fire retardancy, low VOCs and faster reaction times. Today's modern coatings, including polyurea, are among the most advanced resins developed. These polyureas, more than any other polymer coating, stand out in their versatility, strength and longevity. They are the next step in the coatings evolution.

Polyurea coatings combine extreme application properties such as rapid cure (even at temperatures well below 0 C°) and insensitivity to humidity to exceptional physical properties such as high hardness, flexibility, tear and tensile strength, and chemical and water resistance. The result is good weathering and abrasion resistance. The systems are 100%-solids, making them compliant with the strictest VOC regulations. Due to its specific curing profile and exceptional film properties, the polyurea spray coating technique developed into various areas, including corrosion protection, primary and secondary containment, membranes, linings and caulks.

When evaluating waterproofing, abrasion, primary or secondary containment, or any related coating application the following points in order of importance must be addressed thoroughly before a final decision regarding what coatings to use is made:

- The desired useful life of the coating application
- The acceptability and costs associated with service disruption or extended downtime (IE what does one day of downtime really cost?)
- The environmental conditions including effects of weather
- The level of chemical, corrosion, abrasion resistance required

- Cost of the application with respect to the expected useful life, the acceptability and costs associated with down time, the cost of the applied material including both material and application

The desired useful life of the coating application—Designers and specifiers, working with owners, determine he desired useful life of the power plant. Based on this expectation, designers specify products and equipment that will perform accordingly. Pure polyurea is frequently specified and warranted for 10, 20, and even 50 years. What's more is at the end of its desired useful life, the coating does not have to be removed, using a simple surface preparation technique a fresh coat can be applied adding decades to the original application and still maintaining a seamless, monolithiccoating.

Pure polyurea's tensile strength and elongation allow it to bridge small gaps and cracks that form in concrete due to ground movement ensuring the application is able to perform well for decades.

A qualified manufacturer of quality pure polyurea should be willing to warrant their product in power plant applications well beyond the warranties offered by any other competing product.

The acceptability and costs associated with service disruption or extended downtime—Coating applications can be a complicated process that requires a significant investment of resources. Therefore, an industrial coating should be expected to perform for a period long enough to justify that investment. Polyurea's resistance to corrosion, abrasion, chemicals, and other destructive attributes common to water collection, treatment, and distribution allow it to perform for years and even decades without risk of product failure.

Failures in coatings, especially those in the cooling systems, cause complete or partial plant shutdowns. Plant shutdows, either for scheduled maintenance or due to failures, directly translate to disruption of service, inconvenience and problems for customers, and lost revenues for the plant. Efforts spent to select and properly apply a suitable coating product that will prevent or minimize service disruption or extended downtime is essential.

Due to its physical properties and outstanding long-term performance, pure polyurea prevents service disruption or extended downtime due to product failure. Pure polyurea's ease of application, fast gel-time, and almost immediate return to service time ensure the least amount of downtime due to intitial application or scheduled maintenance. In fact, an experience application team can coat between 500 and 1,000 m^2 per day allowing tanks, pipes or any application to be fully operational the next day. When compared to other tank-lining options that require more than two weeks just for application, hours is amazing.

The environmental conditions including effects of weather—Pure polyurea can be applied in any temperature or humidity. This is especially helpful in many climates where application must continue regardless of season or temperature. Frequently, the waterproofing and other coating projects are some of the last steps in the completion of the project, and are consequently delayed until the project is already months behind schedule. Using a coating that can only be applied in certain temperatures or levels of humidity risks further delays to the operation of the plant. Pure polyurea can be applied in any of China's intense climates throughout the year with no risk of application failure.

Additionally, environmental impacts on other aspects including the freeze-thaw or expansion-contraction cycle is also extremely important. Concrete expands and contracts due to changes in temperature. Concrete is designed for this expansion and includes expansion joints to absorb it. However, many coatings, like epoxy coatings, are not able to expand and contract with the substrate and therefore will crack and fail when exposed to extreme temperature changes over the four seasons.

The level of chemical, corrosion, and abrasion resistance required—Polyurea's ability to resist damage due to chemicals, abrasion, and other sources of corrosion make it ideal for the rigorus application demands found in the power industry.

Laboratory and practical application results indicate that pure polyurea will perform well in the most abrasive environments (including lining of cement mixing trucks and the bed of a canal carrying rocks, sand, and other abrasive material). So, whether it is the lining on the material handling equipment, the wastewater containment, or any point in the water collection and transport system (IE dams, circulation lines, or headstocks) pure polyurea will perform exceptionally well.

Cost of the application with respect to the expected useful life, the acceptability and costs associated with down time, the cost of the applied material including both material and application—Power plants are the life-blood of China's economy. Without adequate power, China would be crippled. Currently, China's demands for power are growing faster than any economy in the world, and that continued demand growth is projected to continue exponentially for the next few decades. With that in mind, what is the actual cost of plant downtime including time spent at the end of the initial desired useful life for repair and restoration? How important is a two-week faster turnaround time on your concrete and steel tanks for your circulation system? How acceptable is a failure due to the presence of moisture in the substrate or due to natural freeze-thaw, expansion-contraction cycles? When calculating price or cost, you must perform a comprehensive calculation that includes answers to each of these questions and more.

Based on these comprehensive calculations, the decision to use a world-renowned pure polyurea is extremely easy. This is the case throughout China, Asia, and the world as power plants are using polyurea as their coating of choice over older options like epoxies and fiberglass. However, making the first decision alone, is not enough. Frequently, well-educated designers and specifiers will specify pure polyurea as the desired coating. However, at the last minute as the project is in its final stages and budgets for time, money, and other resources are exceeded, it is tempting for project manages to look for corners to cut. This is further complicated by a number of manufacturers, both locally and internationally, purport to sell pure polyurea, but rather supply a low-end, low-cost, low-performance polyurethane hybrid. Unfortunately, the two products look the same, but in actual performance where quality is essential to fast, trouble-free applications that will last well-beyond the designed usefull life the difference between a high-quality, pure polyurea and a low-quality hybrid is extremely important.

2. Polyurea is the coating of choice for China's power industry

2.1 The reasons of polyurea is the coating of choice for China's power industry

- Fast Reaction Time
- Moisture and Temperature Insensitivity
- Excellent Adhesion
- Superior Tensile Strength
- Low to No Volatile Content
- High Abrasion Resistance
- Heat and Fire Resistance
- Long-Term Stability
- Environmental Protection

Fast Reaction Time—Polyurea reacts immediately and is tack-free in less than ten seconds, making it the fastest reacting industrial coating product available. With the fast reaction time, polyureas do not easily react with humidity and moisture in substrates, so the material can be readily applied over cold or damp substrates, such as steel, concrete, wood or polyurethane foam. Fast reaction time is a great advantage to plant owners and general contractors alike in that it enables almost immediate return to service minimizing downtime, increasing uptime, and therefore increasing profits. In China's power industry demand is so great that every day of downtime translates into hundreds of thousands of RMB of missed profits.

Moisture and Temperature Insensitivity—Where moisture or humidity is a concern, polyureas outperform any product on the market today. Most coatings are sensitive to high humidity and moisture in a substrate. As a result, they will react with atmospheric moisture or high humidity to produce carbon dioxide gas and cause foaming or pinholing in the surface. In contrast, polyureas are not affected by moisture. Pure polyurea can also be applied at virtually any temperature without problem or complication.

Excellent Adhesion—If a substrate is moist or has condensation on it, polyurea will perform much better than competing products. A properly prepared surface will improve adhesion, especially for

critical applications such as moist concrete for containment lining and flooring, as well as adhesion protection for geotextile, wood and steel.

Superior Tensile Strength—In waterproofing applications, a low modulus and a high elongation elastomer are required to meet the challenge. Modern advances in the chemistry mean pure polyureas are formulated to feel as soft and elastic as polyurethane. Pure polyureas will stretch with much less force. And, more importantly, polyureas will vigorously resist punctures and tears.

Low to No Volatile Content—Unlike polyester fiberglass or epoxy, no fumes or styrene emission are associated with polyurea. Therefore, pure polyurea is ideal for applications such in potable water or other closed circulation systems where prevention against contamination is essential.

High Abrasion Resistance—In a highly abrasive environment, polyureas perform extremely well. In the rail and barge industry, polyureas are used because of their superior elongation and high impact resistance. Epoxies and other coating options will crack and delaminate when exposed to constant pounding.

Heat and Fire Resistance—When it comes to heat resistance and fire retardance, pure polyureas have the advantage over many other coating options. Because of its formulation, structural/rigid polyureas have excellent resistance to heat distortion and sagging. At the same time, polyurea maintains its flexibility and high impact resistance. Polyureas resist heat sag and maintain their shape. In the case of fire, polyureas will naturally outperform most other polymer resins. The resulting low smoke and flame spread is due to polyureas' molecular structure. Exposed to constant flame for 20-30 seconds, polyurea will self-extinguish.

Long-Term Stability—Many polyureas are based on aliphatic isocyanate prepolymers that are highly weather resistant and color stable. End-users could safely choose a polyurea for applications that would be constantly exposed to sunlight, without fear of discoloration or chalking. Regardless of whether an aliphatic, polyaspartic, or an aromatic pure polyurea does not lose physical properties due to exposure to weather or other natural forces including ultra-violet light.

Environmental Protection—Polyureas' fast cure times allow it to be rapidly applied to a prepared substrate with minimal downtime for the facility. This has made polyurea the choice of facility managers for walls around and floors under chemical storage of diluted acids, alkali, salt solution, organic solvents and oils. Polyurea provides a strong barrier to spills from reaching the environment. In this type of application, polyurea readily conforms to footings, pipes and protrusions to form a complete seal.

In a world of increasing environmental awareness, pure polyurea proves to be an effective and economical choice for governments and businesses for their elastomeric and structural needs.

2.2 Pure Polyurea—The Only Acceptable Option

Pure polyurea is defined as the result of a chemical reaction between an isocyanate and an amine, or the reaction between MDI and amine-terminated resins. This reaction is autocatalytic and does not require the presence of any solvents or catalysts. Pure polyurea is 100% solids and is potable water certified, which means it will not have any adverse affect on a wastewater or cooling water system.

Polyurethane is a product that is similar in name and appearance, but dramatically different in application and performance. Polyurethane is defined as the result of a chemical reaction between an isocyanate and a polyol. Unlike polyurea, polyurethane requires a catalyst and is not 100% solids, meaning there will be some contamination from the coating into the system.

Polyurethane has one primary advantage over polyurea in that the cost of the raw materials for polyurethane is lower than the cost of raw materials for polyurea. Therefore, many cost-sensitive suppliers of polymer coatings have created polyurea-polyurethane hybrid products in an effort to capture some of the strengths of polyurea at a lower cost. While these hybrids are very good coating options in application where neither long-term performance nor higher physical properties are needed, they are not a viable option for most power production and distribution systems where long-term performance is paramount.

While there are many reasons polyurethane or even a polyurea-polyurethane hybrid will not perform as well as pure polyurea in most applications, especially those on concrete or in water systems, one of the most basic is polyurethane's response to the presence of water or humidity. Products with any level of polyurethane will react with water causing pin holes, foam, and blisters in the coating leaving countless points of failure for the application. Additionally, the presence of any level of polyurethane will mean there is some contamination from the coating into the system. Finally, polyurethane products perform poorly in the presence of hydrogen sulfide gas, which can be found in many wastewater collection and treatment systems.

Therefore, when evaluating polymer coatings for use in China's power industry, pure polyurea is the only viable option. Owners, general contractors and anyone involved in the supply chain must require the product specified and supplied is pure polyurea. Product should be tested prior to order and periodically during the delivery and application process to ensure only pure polyurea is designed, sold, and delivered for a project. Otherwise, the owners, general contractors, and designers are ultimately playing roulette with the plants capability to produce and deliver power to China's public. Based on our research, the only failures of polymer coatings in China's power industry were a direct result of, typically the general contractor, trying to save money by changing the specification for pure polyurea to allow for the selection of a low-quality, lower-priced polyurethane hybrid. It is sad to think about the hundreds of thousands of dollars that were lost all because the general contract's budget was tight and he wanted to save ¥5.00 per square meter.

For applications where a long-desired useful life and outstanding physical properties are required, and where the acceptability for failures is none, as is the case in China's power industry, the only choice for coating applications is pure polyurea.

It should be noted that while many locally based producers of polymer coatings offer pure polyurea, the fact is while some are capable of producing a pure polyurea, they do not. The product manufactured and sold by local suppliers is a low-quality, lower-priced hybrid. Therefore all contracts for purchase and application of pure polyurea should include clauses for testing by a third-party testing facility to ensure the purity of the product being delivered to the job site. Randomly selecting a set of material and having the applicator spray it directly on water will accomplish the same thing. If the product cures without any problem then it is pure. If it bubbles and foams in the presence of water, then polyurethane is present.

2.3 Power Industry Applications

Pure polyurea has countless applications in the power production and distribution industry regardless of type of power generation facility. Industry experts were amazed when it was discovered pure polyurea functioned well as a liner for transportation and storage of nuclear waste from nuclear power plants. Hydroelectric plants have implemented polyurea as a protective coating for years for protecting concrete pen stocks, chutes, pipes, manifolds, floors, walls, steel turbines and other substrates. Natural gas power plants also have countless uses for pure polyurea, however, the most common power plants around the world, and especially in China, are coal-fire power generation facilities. Therefore, the remainder of this document focuses on applications and uses of pure polyurea in coal-fire power production facilities.

In addition to standard construction-related coating applications like roofs and floors some obvious ideal applications for pure polyurea include the more corrosive areas and systems including the material handling system and the water and cooling system.

2.3.1 Material Handling System

The material handling process in standard coal-fire power generation facilities has a number of opportunities for industrial coatings with the physical properties exhibited by pure polyurea.

A brief overview of these systems includes the loading equipment used to fill the transport cars, rail cars or trucks used to deliver the coal to the facility, the kilometers of belts used to transport the coal from the delivery point to the hoppers, the steel hoppers used to transport the coal to the feeder lines, and then the ceramic lined feeder lines used to transport the coal to the crushers. The crushers and the final exhaust pipe where the coal dust is transported to the burner are typically not coated and are not suited for coating with pure polyurea coatings.

Each of these steps can benefit from pure polyureas. What follows is a brief summary for applications in the material handling process. More detailed method statements for each process are prepared separately.

Loading Equipment—Loading equipment is subject to extremely abrasive applications on a daily basis. The blades and scoops on the material handling equipment handle millions of tons of coal each year. The blades and scoops expire much sooner than the equipment themselves leading to costly replacement. Coating the blades and scoops with Nukote polyurea dramatically extends the useful life of the blade and scoop thereby reducing both replacement costs and related down time.
Loading equipment is also subject to carry-back related issues. Any amount of coal that is left on the scoop or blade reduces the equipment's efficiency. Pure polyurea can reduce if not eliminate the carry back problem.

Rail Cars, Trucks, or other Vessels—Different power plants transport their coal to the plant in a number of manners, but the three most common are rail, truck, or boat. Each of these transportation methods suffer from the same problems and will be addressed in the same manner.
The largest problem associated with transporting coal is carry back. Carry back can be compounded by cold weather in some areas where the wet coal actually freezes to the steel. Another problem is damage caused by abrasion and other corrosive elements including water.
Pure polyurea reduces, if not eliminates, problems associate with carry back. It also improves resistance to freezing, abrasion and corrosion.
Pure polyurea not only extends the life of the rail cars, trucks, or other vessels used in transporting the coal to the site, but it also improves their efficiency.

Conveyor Belts—Each power production facility has kilometers of conveyor belts that cost millions annually to repair and maintain. While pure polyurea is not the ideal material for all conveyor belt repairs, it is an ideal product for use in preventative maintenance. Nukote polyurea's outstanding elongation, tensile strength, and abrasion resistance make it an ideal product in creating a protective skin for the conveyor belt that is easy to repair.

Hoppers—In most coal-fire facilities steel hoppers are used to transport the coal from the conveyor belts to the feeder lines. These hoppers suffer the same problems as the rail cars and other equipment used to transport the coal to the site—primarily carry back and damage caused by abrasion and corrosion.
As noted above, pure polyurea efficiently addresses these problems increasing the plant's efficiency and therefore output.

Feeder Lines—In most facilities the lines used to transport the coal from the hoppers to the crushers are ceramic lined pipes or tubes. They are ceramic lined due to the extremely intense abrasive environment. Pure polyurea would outperform many other coating in such an application, but would not be the ideal coating for this application. This application is best suited for Nukote's Metalshield, which is a unique ceramic-metal coating designed for high abrasion, high-temperature environments.

2.3.2 Water System

The water system in standard coal-fire power generation facilities has a number of opportunities for industrial coatings with the physical properties exhibited by Nukote polyurea. What follows is a generic outline of some of the coating applications that exist in typical coal-fired power generation facilities. It is not comprehensive, each power plant had unique conditions, designs, and circumstances.
A brief overview of these systems includes the feeder lines, the circulation lines, the water-softening tanks, cooling towers, other basins and tanks associated with the cooling tower and the waste water, and settling ponds (for non-once-through-systems).

Feeder Lines—The feeder lines bring the water in to the plant. The water usually comes from a river, lake, or reservoir in the close vicinity. Where the point of origin for this water is not man-made like a lake or river, there are a number of other coating opportunities including lining the reservoir and others. However, the feeder lines themselves require both internal and external coating to protect against corrosion for which pure polyurea is an ideal choice.

Water Softeners—The water softeners are large basins with agitators. Not only do the basins need to be coated, but the agitators and other pieces of equipment can also be coated with pure polyurea to dramatically extend their expected use life by protecting against corrosion and abrasion.

Circulation Lines—The circulation lines are typically lined pipes that transport the circulation water to the condensing tubes where the post-turbine steam is condensed into water. The water can be both abrasive and corrosive, which is why the circulation lines are prone to failure and also why pure polyurea is an ideal coating solution.
These lines are typically coated both internally and externally to protect against failure, which will bring the entire facility to a stop.

Cooling Towers—There are a number of applications in and around the cooling-tower section of the water system. Some of the most simple and logical is coating the decks that line the cooling tower. These decks, which in the United States are typically made with treated lumber. While the lumber does not necessarily need corrosion protection, it can, however, benefit from a skid resistant coating.
Other Basins and Tanks—In addition to the areas listed above, there are a number of other basins and tanks suitable for coating with pure polyurea.

Settling Ponds—For non-once-through systems, like those located right near a body of water where the water is used one time through the process and then returned to the body of water from which it came. The settling ponds require a primary, and in some cases secondary, water containment coating. The settling ponds are typically the largest surface area for coating applications. These ponds are ideal for geotextile-pure polyurea systems.

For applications where a long desired useful life and outstanding physical properties are required, and where the acceptability for failures is none, as is the case in the power production industry, the only choice for coating applications in the power production industry is pure polyurea.

Reference

[1] Coatings for pipelines, Sankara Papavinasam and R.Winston Revie,CANMET Materials Technology Laboratory Natural Resources Canada
[2] Exploiting the raw material/physical property relationship for the fine tuning of polyurea caulking systems, Jerry L.Reddinger ang Kenneth M. Hillman , Huntsman Corporation Austin Laboratories
[3] Introduction to Thick-Film Polyurethanes, Polyureas, and Blends, NACE International publication 6A198, NACE INTERNATIONAL THE CORROSION SOCIETY
[4] Polyurea Caulks/Sealants/Adhesives: A raw material perspective, Jerry L.Reddinger ang Kenneth M. Hillman , Huntsman Corporation Austin Texas USA
[5] Polyurea: Leading a Revolution in Coating Technology, John Henningsen, Simple Prose(st. Louis, Mo-USA)
[6] Polyurea spray coatings:The technology and latest developments, Marc Broekaert, Application and Product Development Manager, COATING HUNTSMAN Polyurethanes
[7] Polyurea : The slower dimension of a fast reaction, Kai Klockemann and Kennenth E. Hayden, Performance Chemical International Corp.
The influence of isomer composition and functionality on the final properties of aromatic polyurea spray coatings, Marc Broakaert and Wolfgang Pille-Wolf, Huntsman Polyurethanes