Drinking Down Under:
Great Idea, Second Thoughts, The Right Path

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Key learning points: *Learn about the importance of having a proper specification for a concrete tank lining project. Have an understanding of the industry standards related to surface preparation of a concrete surface. Selection of the proper materials for successfully completing a concrete potable water tank lining project. Learn the importance of training related application of thick-film polyurea spray elastomer systems in demanding application areas.*

Abstract: Thick-film elastomeric coating / lining systems have excellent performance characteristics in a variety of potable water lining work; including the polyurea spray elastomer technology. While some have cast doubt on the suitability of a polyurea system for immersion applications, there are a variety of commercial products with the NSF/ASNI-61 certification for potable water use that are performing quite well. Much of the myth around failures can be identified by improper specification work and incorrect material selection for the specific application. Even though a proper system is selected and applied, improper surface preparation and / or spray application techniques can lead to application failures. The same is true for other coating / lining technologies as well. Having the proper training, material selection and proper guidance can lead to a successful application. This paper will discuss a recent major concrete potable water storage tank lining application, the challenges faced; and, the solution that led to success in Australia.

INTRODUCTION:

Due to drought condition in Queensland, Australia in the mid 2000's, numerous water treatment facilities were planned and built to handle future water shortage issues. In Bundamba, QLD, Veolia Water contracted with Thiess / Black & Veatch JV and Construction Australia to construct a facility just west of Brisbane. This new facility, Bundamba Advanced Water Treatment Plant (AWTP), incorporated some of the state of art technology of the time in the Koch Micro Filtration / Reverse Osmosis (MF/RO) system.

The Bundamba AWTP, delivered by the Thiess / Black & Veatch joint venture, was in partnership with Western Corridor Recycled Water Pty Ltd and the Queensland Government's Department of Planning and Infrastructure, and part of the Australian Western Corridor Recycled Water (WCRW) Project. This was the third-largest recycled water project in the world. Featuring a network of 200 kilometers (124 miles) of underground pipelines and three new advanced water treatment plants, the WCRW Project was to ensure a secure water supply for the rapidly growing yet drought-stricken south-east Queensland region for years to come.

The Bundamba AWTP uses the latest membrane and advanced oxidation technologies to provide purified recycled water for cooling and other purposes at the power station. The main treatment steps employed at the plant comprise, ultra-filtration membranes, reverse osmosis membranes followed by advanced oxidation using ultraviolet irradiation and hydrogen peroxide, is the first large-scale indirect potable reuse scheme in Australia. The Bundamba AWTP at completion supplies up to 233 million liters / day (61.5 million gallons / day) of purified recycled water (1).

As part of the construction specification, an aromatic polyurea spray elastomer system was specified to line the two new concrete MF/RO process tanks. This polyurea system had both ANSI/NSF 61.5 certification as well as Australian Water Quality Centre certification. The two concrete MF/RO tanks were approximately 1.9 million liter (0.5 million gallon) in size. The approximate lining surface area of the concrete was 900 m^2 (9700 ft^2) for each tanks.

The polyurea spray lining system was applied by a certified Brisbane applicator, and completed in December, 2007. The installation procedure involved first abrasively blasting the cast-in-place concrete tank walls and floor (SSPC-SP 7: Brush-Off Blast Cleaning) to remove laitance, open the bugholes and create a profile. This was followed by High Pressure Water Cleaning (HPWC) to removes dust, contaminants and any loose concrete (4 – 8). Parging the concrete walls was accomplished with application of an acrylic-based cementicious fairing coat, followed by complete priming with a moisture cured urethane was installed via roller / brush. The primer was applied at a coverage rate of 2.63 m^2/l (~100 ft^2/gal), within the guidelines of installation procedure.

The polyurea spray elastomer system was applied using a GRACO® Reactor® E-XP 2 high pressure, high temperature plural component proportioning unit. This was fitted with a GRACO Fusion® AP high pressure spray gun. Approximately 2130 liters (~560 gallons) were applied to the walls and floors of both tanks, giving a coverage rate of 0.42 m^2/l (~17 ft^2/gal). This coverage rate yielded approximately 2 mm (80 mils) applied dry film thickness, thus meeting the requirements of the specification.

After the lining work, the tanks were filled and some leakage was noted, being identified as occurring from reported pinholes in the liner system. Subsequent spray patch work was done in early 2008 using an unpigmented version of the same polyurea spray elastomer system, though it is not clear why this was used. Some of the patches and overspray / feather edges over areas of pinholing in the original applied liner, were coming loose, as well as dry spray around patches, and causing plugging issues in the pumps and (MF/RO) filter system.

For the patch work, the applicator reportedly followed the advice of the material supplier in surface preparation of the pervious installed liner. This procedure involved scrubbing the surface with NMP (n-methylpyrrolidone). Once this area dried, additional spray application of the unpigmented polyurea spray was done to cover the pinholed area, i.e. cow-patty application. No abrading was done prior to cleaning with the NMP solvent.



Figure 1: Google® Map View of Site, date unknown

Lining Installation Inspection:

As the disbonding and plugging issues in the MF/RO filter system were becoming more problematic, and inspection was called in mid 2009. Visual inspection of the applied liner system showed that the blue applied polyurea spray had undergone some fading in color. For the application of the patch material (there were numerous patches) with the patches turning a dark brown due to non-pigmentation of the system. The original blue color could be seen in areas where the patches had peeled from the initial installation of liner system. This discoloration is not uncommon for an aromatic polyurea system and can not be considered as any type of failure or product degradation from these visual observations (9).

In areas where concrete had been exposed due to blister or delamination cut-out, the concrete surface was very smooth. This was noted as a Concrete Surface Profile (CSP) of about 1 (10). Most lining applications over concrete for thick film systems require a CSP 3 minimum. This may be similar to the min 550 µm profile from the specification. While review of the specification noted abrasive blasting to be performed, review of application procedures during installation work showed only the use of low pressure water cleaning.

In the patch repair areas, the removed patches exposed the surface of the initial applied polyurea spray, and that surface was relatively smooth / glossy. This indicated that no abrading had been performed prior to treatment with the NMP and re-spray patch. It is also noted that the patch areas are feathered out. The lack of direction of first abrading the surface prior to treatment / re-spray, is the main cause of the delamination of the patch areas, especially in the feathered area around the patch.

In cut-out areas (very minimal) it was also noted the applied polyurea was greater than 2 mm dry film thickness. Visual observation shows no indication that the polyurea spray was applied off ratio, or any deterioration of the liner.

Shore D Hardness:

Also observed was the Shore D Hardness for the applied polyurea system (11). The hardness measurement gives an indication of proper set and mix ratio. The tested Shore D Hardness for the applied polyurea system in numerous areas was found to be 45 - 50. The values noted are well within the reported range of 50 ± 5 and indicate that the system was applied on ratio and mix.

UV Light Testing for Contaminants:

In order to determine a possible cause of the noted blister areas of the applied lining system from the concrete, a UV LED light was used to check for possible fluorescent penetrants; and, or contaminants (12). Fluorescent penetrants would be materials such as oils, un-reacted components, etc., that would inhibit bonding to the substrate, thus forming a blister in the lining system. Using an INOVA X5MT-UVT LED Light, a safe alternative to Black Light, the exposed concrete areas from blister removal were evaluated. Observation gave no contaminants.

Elcometer Adhesion Testing:

Adhesion tests were conducted in the MF/RO tanks to confirm bonding of the applied liner system to the substrate, as well as some patch areas for adhesion confirmation. For this testing, ASTM D 7234 was used with a Positest AT hydraulic gauge and 20 mm diameter dollies (13).

The dollies were adhered to the applied lining system and patch areas, following scuffing of the lining surface, using a gel methylmethacrylate adhesive. Data collected is reported in the following Table 1:

Table 1
Adhesion Values from MF/RO Tank

MF/RO 2102 Area	Value, MPa	Failure mode
AD #1 (floor)	No Test / sheared	100% Cohesive within surfacer
AD #2 (floor)	3.28 MPa	80% Primer, 20% Cohesive surfacer
AD #3 (S wall)	No Test/ sheared	100% Cohesive within surfacer
AD #4 (S wall / patch)	1.7 MPa	100% Cohesive within surfacer
AD #5 (E wall / patch)	2.0 MPa	100% Cohesive within surfacer
AD #6 (E wall)	3.36 MPa	100% Cohesive within surfacer
AD #7 (W wall	3.10 MPa	100% Cohesive within surfacer
AD #8 (N wall)	2.95 MPa	100% Cohesive within surfacer

Based upon the mode of failure in this representative sample, no additional adhesion testing was performed. In observation of the exposed concrete surface at the dolly pulls, as well as the blister cut-out areas, the concrete surface was very smooth.

It should be noted that these values observed are on average lower than that noted in the project specification, section 3-5.03 Adhesion, where a value of >3.4 MPa (> 500 psi) is recorded. Testing by the applicator during the project work provided for similar results. However, no adhesion failure of the liner system was noted. Failure was primarily cohesive in the surfacer / concrete.



Figure 2: Dolly Adhesion Test Samples

Once the adhesion testing was performed, a discussion was held with other inspectors to address concerns on testing procedure used. It was noted that an Australian Standard

would have been more applicable. A comparison was then made between the two ASTM Methods and the Australian Standard, though the specification notes the use of ASTM D 4541. The main issues with testing seemed to be the adhesive used and the coring around the dollies (14, 15).

With respect to adhesive used, ASTM D 4541 Section 5.4, D 7234 Section 6.5 and AS 1580-408.5 Section 5.2, all note that two-part epoxy systems are usually used, but primarily the adhesive should not affect the coating properties. Therefore, the use of methylmethacrylate would be an acceptable adhesive for securing the loading fixtures / dollies. A provision is made in ASTM D 4541, D 7234 and AS 1580.408.5 to record type of adhesive used.

In respect to the size of the dollies for testing, ASTM D 4541 notes that 12.5 mm to 50 mm diameter dollies are used depending on the Type test unit used. ASTM D 7234, Section 6.1.1, notes that usually 20 mm diameter dollies are used, but may range from 20 mm to 75 mm diameter. Interestingly, in AS 1580.408.5, no information is provided as to dolly size / diameter.

As far as scoring around the loading fixture / dolly, ASTM D 4541 Section 6.7, cautions against this as it may violate the fundamental in-situ test criteria that an unaltered coating be used. However, we are dealing with elastomeric materials that have high elongation and tensile strength values so that scoring is required to provide for accurate values. ASTM D 7234 Section 7.2 and AS 1580.408.5 Section 8 (d) notes that scoring is required. ASTM D 7234 goes further to specify scoring on coating greater than 0.5 mm 20 mils) thickness.

In applying the test load, ASTM D 4541 and AS 1580.408.5 note that 1 MPa/sec (145 psi/sec) should be used so that testing is complete in 100 seconds or less. ASTM D 7234 notes that 0.2 MPa/sec (30 psi/sec) should be applied so that testing is complete in less than 30 seconds.

Based upon review of all three test methods, they all appear to be very similar, with much more detail given in ASTM D 4541 and D 7234. ASTM D 4541 and AS 1580.408.5 are very similar, and more applicable to steel / metallic substrates. And for ASTM D 7234, this is suited for concrete substrates, and is very appropriate / applicable to this project.

Polyurea Applied Film Thickness:

Records reviewed from the applicator indicated that the polyurea was applied at the minimum average 2 mm (80 mils) dry film thickness. This is based upon material consumption, area of applied coating and ultrasonic thickness check performed during installation work.

Since this adhesion testing is destructive in nature, a "plug" of material is removed from the test area. The removed plugs of material could be then checked for applied thickness using a micrometer (16). These values are noted below:

Table 2
Applied Polyurea Film Thickness

Sample Location	Noted Polyurea thickness
AD #1	2.3 mm (90.5 mils)
AD #2	3.0 mm (118 mils)
AD #3	1.3 mm (51.2 mils)
AD #4	2.8 mm (110 mils)
AD #5	3.0 mm (118 mils)
AD #6	1.8 mm (70.9 mils)
AD #7	1.9 mm (74.8 mils)
AD #8	2.5 mm (98.4 mils)

Proposed Repair Procedure:

Based upon inspection of the application work, the spray polyurea spray elastomer system was installed at the proper mix ratio / processing conditions and at the minimum average required dry film thickness of 2 mm in the MF/RO tanks. Adhesion testing shows that the applied patch materials, though minimal preparation was done, have greater adhesive strength than the lining system to the concrete substrate. The polyurea has a significantly higher tensile strength / elongation than the concrete and/or surfacer and adhesion test failure would be expected within the overall substrate (cohesive), not adhesion failure.

The primary cause for the repair patch areas being removed from the initial applied liner work is due to incomplete surface preparation of the liner surface. The common procedure is first abrading the surface to remove the gloss / shine, followed by wiping down with the NMP solvent for reactivation. The feathered edges of the patch area came off easily; possibly because the application of the patch spray exceeded the confines of the prepared areas.

Based upon evaluation of the applied membrane and adhesion, a valid option for repair would have been to continue the patch repair procedure. This should have been performed by first abrading the surface area of the patch locations to remove any contaminants and surface gloss. These areas would then be wiped with the NMP solvent prior to re-application of the polyurea at a minimum average 1 mm (40 mils) dry film thickness. However; this would still be a patch and concerns were still present.

If the observed adhesion values / failure mode was found to be acceptable by the owner, then based upon observations and adhesion testing at the site, an alternative suggested

repair would be to re-spray the complete surface area of the tank with a minimum average 1 mm (40 mils) polyurea. This would seal the lining system and the already applied patches. The surface area would require complete abrading to remove any contaminants and surface gloss (17). The area would then be wiped with the NMP solvent prior to re-application of the polyurea. For the patch areas and cut-outs, the existing polyurea should be ground to create a feather / sloped edge (18).

Should the observed adhesion values / failure mode not be acceptable, then the applied lining system would require complete removal. This would then be followed by abrasive blasting to a CSP 3 profile minimum. Any exposed bugholes would require filing, as performed during the initial installation. This would be followed by primer application, with the suggested that the primer be applied in 2 thin coats such to reduced the possibility of pinholing in the subsequently applied polyurea system. The polyurea system should then be applied at the minimum average 2 mm (80 mils) dry film thickness.

After considerable discussions and cost analysis, it was opted to ground the complete surface area of the applied polyurea, remove any loose materials, prepare and respray. Once this was started though, the adhesion problems became much worse. Large sections of applied liner could easily be removed by hand, thus exposing concrete that was smooth and still had paint line.

The following figures show the details:





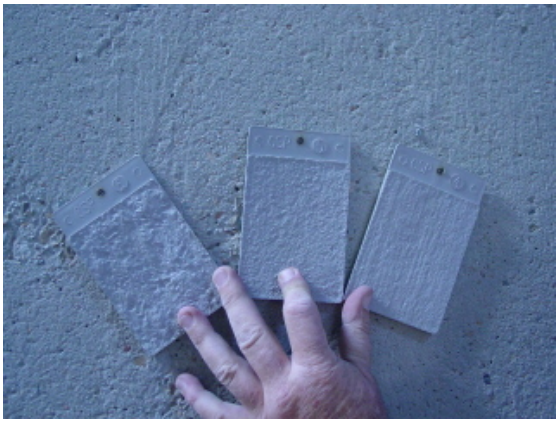
Figures 3 and 4: Preparation for Repair and Over-coating

COMPLETE RE-LINING:

Based upon the observed results of grinding the surface of the existing applied polyurea system and overcoating, a critical decision was made to completely remove the liner and start at the beginning. As difficult as this may seem, removal was actually quite easy due to the low strength of the surfacing material to the incompletely prepared concrete surface.

After the liner was removed from both tanks, abrasive blasting was done to create the required CSP 3 to CSP 6 surface profile for the concrete surface. This also removed the poorly attached surfacing material, primer, and paint and opened the small bughole areas in the concrete walls. After abrasive blasting, the complete surface was vacuumed. See figures below:





Figures 5 and 6: Concrete Surface Profile after Blasting

After confirming the moisture content of the concrete substrate was at <3%, an initial coat of a potable water approved epoxy primer was applied using roller application (19). A second coat was then applied with 800 µm (16 – 18 grit) quartz aggregate seeding. This process assisted in filling the bughole areas and provided a texture finish for bonding of the subsequent application of the polyurea spray elastomer system.





Figures 7 and 8: Application of Aggregate Filled Epoxy System

The polyurea system was then applied as in previous work, with ultrasonic thickness measurements showing 2 – 3 mm (80 – 118 mils) dry film thickness. Following installation of the liner system, random pull-off adhesion measurements gave values > 4 MPa (> 550 psi) with failure mode being cohesive within the concrete. These adhesion test areas were then repaired using an approved procedure with the polyurea spray elastomer system.

The polyurea lined tanks were then washed using LP WC cleaning to remove any dust, contaminants or un-bonded overspray from installation. The tanks were then put back into service in September 2009 with no reported leaks to date.





Figures 9 and 10: Application of the Polyurea Spray Lining System

CONCLUSION:

While the use of the approved polyurea system was an excellent choice for this potable water lining project, that did not mean shortcuts could be taken and expect a successful project. The polyurea systems are in a way similar to other coating / lining technologies, proper surface preparation and application are a must. The specification must also be properly prepared in a manner that all aspect of the work are understood and followed.

Several items contributed to the initial "failure" of the application included: incomplete surface preparation; use of inappropriate surfacer system; incorrect primer for immersion application; and, inconsistent application of the polyurea system. This resulted in a complete re-lining; at a very valuable and costly lesson to the applicator. Following proper installation techniques, the lining system is now performing as designed.

Also note that the Bundamba AWTP received numerous national and international accolades from the global engineering community. These included: Water Project of the Year at the 2008 Global Water Awards; International Project of the Year by the Construction Management Association of America; Global Honour award for Design Category at the 2008 International Water Association (IWA) Project Innovation Awards; and winner of the Environmental Engineering Award at the 2008 Engineerís Australian Engineering Excellence Awards. In November 2009 the plant was named as one of the top ten engineering wonders in Queensland. It is great to know that polyurea played a role in this successful project.

References:

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(5) SSPC-SP 13: Surface Preparation of Concrete
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(7) SSPC-TR 5: Design, Installation, and Maintenance Protective Polymer Flooring Systems for Concrete
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(11) ASTM D 2240 (latest version): Standard Test Method for Rubber Properties – Durometer Hardness
(12) ASTM E 1135 (latest version): Standard Test Method for Comparing the Brightness of Fluorescent Penetrants
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(14) ASTM D 4541 (latest version): Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
(15) Australian Standard® AS 1580.408.5-2006, Paints and related materials – Method of test, Method 408.5: Adhesion – Pull-off Test.
(16) ASTM D 1005 (latest version): Test Methods for Measurement of Dry Film Thickness of Organic Coatings Using Micrometers
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(18) SSPC-TU 3: Overcoating
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