# SERVICE RESERVOIR REFURBISHMENT


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**ABSTRACT**

Some steel reservoirs in Victoria are currently experiencing steel floor plate corrosion from the underside which has led to significant corrosion and even perforation. Furthermore some of the tanks have light gauge aluminium roofs that have experienced failing of the fixing screws and sheet damage due mainly to thermal movement.

The Water Supply Alliance (an alliance of SKM, MWC, UGI and Balderstone) was commissioned to investigate the condition of Melbourne Water Corporation's (MWC) Sydenham Service Reservoir (WR64) and to design and refurbish the floor and roof system. The design was used for a further three large steel tank refurbishments including the Cowies Hill 1 and 2 tanks and Yuroke tank. Compared to replacement, the refurbishment resulted in estimated cost savings of around $3-4m and a program reduction of around 12 months for each tank.

## 1.0 Introduction

The Sydenham Service Reservoir is a 46.5 ML, 11.1m high, 74m diameter steel tank owned by MWC. Refurbishment of the reservoir was seen as critical to MWC operations as leakage through perforations in the floor was predicted within the next few years. Although the floor had previously been repaired using epoxy glued 2mm thick steel patch plates, this repair method is not seen as a viable long-term solution and MWC initially required a new steel plate floor. Additionally, the condition of the aluminium alloy roof was of concern as extensive maintenance work would be required to repair vents, ridge capping, conduits, fixing screws, and sheet damage due to thermal movement. MWC therefore initially required the roof to be replaced with a heavy gauge steel roof.

A subjective investigation into the corrosion causes and an assessment of possible refurbishment / replacement options was undertaken resulting in an Options Report (Ref 2). The report included studies of previous reports and refurbishment methods, review of magnetic flux leakage (MFL) floor scanning, material corrosion investigations, a structural assessment of the tank, material replacement investigation and testing, and a risk and triple bottom line (TBL) assessment of the options.

The original Functional Requirement for replacement of the floor and roof with steel materials was challenged and ultimately the recommended floor refurbishment system, which included below floor cementitious grouting and a Polibrid 705E liner, and recommended roof replacement system, which included a stainless steel substructure and sliding aluminium roof, was approved. This system has not been used in Melbourne's service reservoirs before.

In addition the floor and roof repair, the tanks barrier coatings, Impressed Current Cathodic Protection (ICCP) system, ring road, drainage system and entrances were upgraded to comply to operational requirements, standards and regulations. These items are not addressed in this document.

The Sydenham Service Reservoir was designed in accordance with API-650 'Welded Steel Tanks for Oil Storage'.

Subsequent to the original design, Melbourne Water now prefers AWWA D100-05 'Welded Carbon Steel Tanks for Water Storage' as a design standard for steel tanks, this was therefore used as the design basis for all of Sydenham Tanks works where applicable.

The following items were found to have significant impact on the final recommended outcomes:

- MWC's previous experience with the option;
- Perceived structural and durability risk over the design life including maintenance requirements;
- Feasibility of the option to be a low risk, water tight technical solution;
- Ability to provide a cost effective outcome;
- Environmental and sustainability benefits of the option;
- Construction timeframe, an 8 month time constraint for the entire project; and
- Impacts on neighbours, MWC Ops and other stakeholders over the construction period.

## 2.0 FLOOR LINING SYSTEM

### 2.1 Corrosion source

Under floor corrosion and subsequent leakage of coated steel tanks in parts of Victoria has become a significant issue requiring repairs and refurbishments. The cause of the under floor corrosion has been attributed mainly to the use of crushed limestone contaminated with high levels of chlorides, in particular calcium chlorides (Ref. 1). Calcium chloride absorbs water at a min. of 30% relative humidity compared to 78% for sodium chloride. Thus in the presence of calcium chloride, the time of wetness is greater and hence corrosion rates can be greater to the uncoated underside of the steel floor plates (Refer Fig. 1).

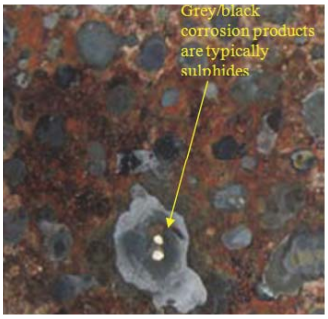


**Figure 1:** ***Under floor corrosion examples***

Furthermore, other processes were attributed to the underfloor steel pitting corrosion and may be present in addition to the increased chloride concentrations. These are:

1. A combination of moisture and oxygen cells can be created within void spaces below the steel floor which creates localised anode and cathode cells, inducing pitting corrosion. This is less likely to be seen where the steel floor is increasingly flush with the bedding of the tank.
2. Moisture movement to the underside of the floor plates is attributed mainly to poor drainage in the tank surrounds. It is typical to see these tanks surrounded by poorly drained gravel or grassed areas with pools of water present. Additionally, MWC has theorised (Ref 4) that the water can be drawn into the bedding layer from groundwater through soil pressure changes (much like a sponge) during filling and emptying of the tank, known as the 'pumping effect'.

3. Sulphate reducing bacteria (SRB) can create Microbiologically Induced Corrosion (MIC) under rust tubercles (Ref 3).

The combination of the above corrosion sources typically results in localised pitting which creates perforations and leakage over time.

A magnetic flux leakage (MFL) scan of the Sydenham Reservoir's steel floor was undertaken in November 2008 to assess the underfloor corrosion. A number of serious defects showing >70% deterioration (<3mm remaining) were found, the majority of which was concentrated towards the centre of the tank floor. The increase in defects towards the centre is attributed to voids which are created from the flexure in the steel floor plates that can occur during emptying of the tank and through roof uplift (the columns are welded to the floor for uplift resistance).

## 2.2 Tank Floor Remediation

Hypothesising the floor plate corrosion's contributing factors allowed for consideration of alternative and innovative refurbishment options as well as the business as usual full floor plate replacement. The remediation options considered are outlined below:

- Steel Plate Floor (replacement);
- Pre-Stressed Concrete Floor (replacement).
- Glass fibre reinforced polymer (GRP) lining – chopped and woven glass (refurbishment);
- Elastomeric polyurethane lining – Polibrid 705E lining (refurbishment);
- High Density Polyethylene (HDPE) lining (refurbishment);

Each option was assessed for material properties, durability and maintenance requirements over the required design life, merits and draw backs including fitness for purpose, sustainability, constructability, reliability, safety and compliance with the relevant design codes. Further comparison of the options was undertaken during workshops using MWC's Net Present Value (NPV) and Triple Bottom Line (TBL) assessment as well as a risk assessment, and involved WSA representatives including MWC operations and assets, design, construction, environmental and community liaisons representatives.

## 2.3 Results

Of all the options, the steel floor replacement option was the most well understood and could be expected to address most of the functional requirements; however the construction timeframe was unable to be achieved without staging.

The GRP and Polibrid 705E liners were generally preferred in most selection criteria areas especially construction time, sustainability and cost. The Polibrid 705E was found to be superior to GRP for flexibility and tensile strength properties in regards to spanning perforations in the floor without cracking or leaking (Ref 5), should corrosion persist. Cathodic disbondment and interface with the barrier coating was not considered a problem for either liner. The addition of a geotextile fabric within the Polibrid 705E allows for further distribution of pressure forces and resistance to tearing and was the final recommended product.

Injecting a cementitious grout below the steel floor was also recommended as it could provide a high pH environment for the steel underfloor, allows for continued underfloor ICCP use if required, provides a barrier and reduces voids between the steel floor and bedding material to remove corrosion sources, and provides a structural platform for the liner should corrosion of the steel persist. The injection locations were designed to be combined with the corrosion and column locations to reduce the number of patch plates.

A structural assessment of the tank using AWWA D100-05 inputs was undertaken to assess its condition should the floor continue to corrode. The tank was found to be sound, however there are indications that extreme environmental conditions may play a greater role in the structural condition of the tank. It's noted that API 653 (Ref 7) has a requirement for a min. remaining floor thickness of 1.25mm when combined with reinforced liners. However, the possibility of continued underside corrosion, combined with the above structural risks was considered and it was recommended that the AWWA D100-05 code for a min. 6mm floor thickness be achieved through welded patch plating.

## 2.4 Construction

Construction of the floor system was carried out with relatively few problems, although the Polibrid 705E liner application had some minor teething issues as it had not been laid on steel in such a large scale before. However with on site guidance from the supplier (International Paint Pty Ltd) and good QA (including holiday testing) the contractor (McElligotts Pty Ltd) was able to lay the liner successfully in just over 2 months (including injection grouting). After applying the lessons learned to a similar tank, Cowies Hill Tank 1 (62.5m diameter), the liner there was laid in 1 month.

**Figure 2:** ***Cementitious grout injection*** **Figure 3:** ***Polibrid 705E application***

## 3.0 ROOF REFURBISHMENT

The original Functional Requirements for the tank stipulated that the deteriorated light gauge aluminium roof was to be replaced with heavy gauge roof i.e. welded 6 mm steel plate. However due to advances in roofing products and construction methods there were other options considered with respect to benefits such as cost, maintenance, stakeholder impact, sustainability, safety and time. The two key options for replacement presented in the report were welded steel plates and a rollover single sheet light gauge roof with fixings that accommodate sliding, marketed under the name Kalzip® (Corus Pty Ltd). Both designs required redesign of the roof substructure to allow for differing construction techniques and loads. Replacement with a new screw down sheeting was not considered due to the required service life of 80 years and the previously noted corrosion issues.

Steel roofing generally shows benefits such as longevity, well defined maintenance program (general checks and re-coating around every 25 to 30 years), no moving parts, good loading resistance and increased security.

Kalzip has the advantage of being constructed quickly and having no fixing or fastening perforations thereby reducing corrosion and maintenance requirements previously noted for aluminium roofs. For greater corrosion resistance a stainless steel substructure was included for increased design life expectations.

## 3.1 Results

The use of Kalzip sliding aluminium sheeting with stainless steel substructure was recommended for this tank due mainly to time constraints, reduced construction impacts on surrounding residents and cost.

The Tank roof was designed to AS 1562.1:1992 *Design and Installation of Sheet Roof and Wall Cladding* for an eighty (80) year service life, fully trafficable for inspection and other purposes (1.2 mm thick) and accommodated thermal expansion of the roof structure and cladding. An FEA of the tank structure was completed to ensure that the existing roof was able to be taken off without support for the walls (there was no primary wind girder on the tank). The roof support structure comprised duplex 2101 L stainless steel rafters, beams, purlins and bracing/bridging and grade 304 stainless steel columns and safety mesh. Full corrosion protection and isolation between different metallic members was specified. Column pedestals were installed to avoid (uplift tearing) issues along any weakened floor points should corrosion of the floor continue. Roof appurtenances included two roof access hatches, an air monitoring hatch and four Turbine Ventilators.

**Figure 4:** ***Deconstruction of the roof***

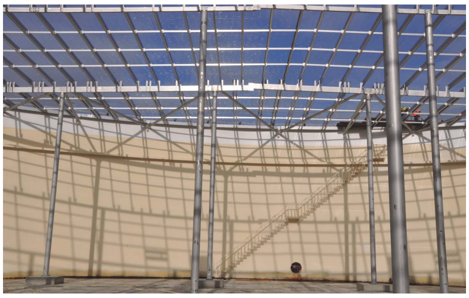

**Figure 5:** ***New stainless steel roof subsystem and safety mesh***

**Figure 6:** ***Scaffold ready for Kalzip installation***

**Figure 7:** ***Completed roof construction***

The ability of the roof sheeting to be constructed using single sheets fabricated on site at ground level allowed for a relatively quick (around 3 months) construction with low OHS&E risk. However, after construction it was found that the aluminium roof was not was not sufficiently isolated from the columns and walls, resulting in a large increase in CP load. This meant that an extensive program of inspection and testing would be required to find the source and instead MWC opted for the columns to be coated (Ref 7). Increased testing and QA throughout the subsequent tank construction works at Cowies Hill Tank 1 and 2 were implemented to ensure this did not occur again.

## 4.0 CONCLUSION

An innovative, low cost and environmentally beneficial means of refurbishing large diameter steel tanks was found for MWC's Sydenham Service Reservoir. Advances in roof and floor lining products and construction methods increasingly offer asset owners alternatives to costly floor and roof replacement or refurbishment options. However no two tanks are the same and rigorous analysis and consideration of in-situ conditions must be undertaken for each individual tank.

## 5.0 REFERENCES


Bartlett, D.J. (2002), *An Australian Perspective on Corrosion Protection of Steel Tanks, JPCL*, pp41-45

Claveria, S.J. (2009), *WR64 Sydenham Service Reservoir Refurbishment Options Report P32844-C-RP-001*, WSA

Moore, G. (2011), *Investigation of Rehabilitation Method and Contract Management of the 14ML Clear Water Storage Tank Located at Old Dookie Rd, Shepparton – Corrosion Protection Technical Note*, SKM report for GVW

Callant, R. (20008), *Steel Water Tank Strategic Asset Management Plan (SAMP)*, Melbourne Water Asset Management Division

Quick, D (2005), *Tank Floor Lining Test Results and Recommendations*, Email of testing results to Robert Callant (MWC) from Quick Thinking Pty Ltd

API (2009), *API Standard 653(Fourth edn) - Tank Inspection, Repair, Alteration and Reconstruction*, (Addendum 1 2010)