STRUCTURAL CORROSION ISSUES ON COLLINS CLASS SUBMARINES

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Summary: This paper is a modified summary from a study conducted by the Submarine Branch to identify and quantify the impact of corrosion on the Collins Class platforms during major maintenance activities. The results of the study led to prioritising and targeting the strategies needed to minimise corrosion and hence reduce the cost of ownership and increase platform availability.

The paper has been modified because of the restricted nature of information releasable in the public domain, but its purpose is to highlight that, like many other marine platforms, the Collins Class Submarines operate in an extremely harsh environment.

Keywords: Collins Class platforms and submarines, Full Cycle Docking (FCD), platform availability, Electrical Hull Penetrations, Pressure Hull Penetrations

1 EXECUTIVE SUMMARY

The cost of repairing protective coatings and corrosion damage (metal loss) is estimated at approx $8.9 million per COLLINS Class Submarine during a Full Cycle Docking (FCD), which occurs at approximately 72 monthly intervals. Corrosion repairs are often unplanned growth work resulting from survey inspections or other maintenance activities and can account for up to 50% of the duration of all Docking periods. This is not uncommon for submarines and surface ships in the global environment, the challenge is to identify the cost drivers that impact on submarine availability and the cost of ownership.

The cost and time to repair corrosion damaged steel structures (grinding and welding) can be significantly higher than repairing protective coatings.

Over four FCDs (assuming >28 years life), the entire Class major corrosion repair expenditure in today's money could be as high as $200 million.

Submarine platforms generally have minimal allowances for corrosion, due to the required operational performance against weight issues that occur during the design phase. Therefore the protection of the hull structures from corrosion damage is critical from a safety, longevity and cost point of view. For the Collins Class, identifying the causes of corrosion is fundamental for mitigation. These causes can be categorised into the following broad groups;

- Corrosion that is influenced by Design/material selection;
- Corrosion that is influenced by normal degradation;
- Corrosion influenced by inadequate maintenance routines and ship's husbandry;
- Corrosion influenced by inadequate Quality Control
- Corrosion influenced by a combination of the above.

From analysis of cost and technical data it was estimated that the corrosion repair costs could be reduced by up to 50% per Submarine per FCD by implementing design/material solutions at a minimal outlay in comparison to the total life cycle cost in each case. In particular the corrosion on the Hull Valve Forgings, Electrical Penetrations & Body end Valves were identified, the potential cost benefit identified for a solution to the class over four FCDs was estimated to be $84.0m.

The importance of design/material selection is that the cost of changing material/design can be difficult and expensive. In the case of the Collins Class, the procurement phase allowed the designer to select the materials within a specified framework.

This framework did not necessarily apply to detail design, the focus was on achieving optimum platform operational performance and technological edge.

In hindsight a balanced approach could have included a deeper analysis of maintainability costs, which would have meant analysis of some detail design aspects.

This was one of many issues that influenced the formation of the DMO, where the cost of ownership and platform availability are essential elements that DMO uses to manage projects.

2 INTRODUCTION

A cost study was undertaken in 2003 into the effects of corrosion on the cost of ownership and platform availability during the first two Full Cycle Dockings (FCDs) on the Collins Class Submarines.

FCDs are undertaken at approximately 72 monthly intervals and are the major maintenance activities for the Collins Class Submarines. The duration of FCDs is between 18 months and 2 years.

3 MAIN CORROSION ISSUES

The study estimated that up to $8.9m were expended on each Submarine for both maintenance and repair of structures in relation to corrosion during the two FCDs. The following areas have shown to impact significantly on costs and schedule due to corrosion (see annexe A);

- Electrical Hull Penetrations PHPs- (photo 1 Annex D)-bolted joint-galvanic and crevice corrosion.
- Bilges (photo 4 Annex D)- severe pitting corrosion due to localised coating damage.
- Battery Compartments (photo 5 Annex D)-severe pitting corrosion due to localised coating damage.
- Body end Valves- (photo 3 Annex D)-bolted joint-galvanic and crevice corrosion.
- Seawater flood areas- Stern Tube, SSEs (photo 6 Annex D-galvanic corrosion), Torpedo Tubes, Free Flood Spaces.
- Hatches
- Tanks
- Shaft seal
- Mechanical Hull Penetration Forgings (photo 2 Annex D-galvanic corrosion)-design change already completed, changed from a Nickel coating to Inconel cladding.

Photographed examples of some of the main problem areas are attached in Annex D.

4 ANALYSIS

1. An overview of the corrosion issues show that the above areas are constantly in contact with fluids, and are primarily protected by coating systems with the exception of the Potable Water, Lube Oil Tanks and the Shaft Seal.
2. Over 50% of the total corrosion repair and maintenance costs are directly related to design/material selection factors, in these cases galvanic and crevice corrosion mechanisms feature highly with less than ideal physical configurations;
   - Hull Valve Forgings -(Material/Design)
   - Pressure Hull Penetrators (PHPs)-(Material/Design)
   - Bilges- (Design, maintenance/ husbandry)
   - Battery Compartments (Design, maintenance)
   - Body end Valves (Material/Design)
   - Seawater flood areas- Stern Tube, SSEs, Torpedo Tubes, Free Flood Space (Design).
   - Hatches-(Materials, maintenance)
   - Tanks (Design, maintenance, normal degradation, workmanship)
3. The expected platform life is >28 years, and in today's money, the total cost of corrosion could be as high as $200million for the class. The other major issue found during the study was that significant unplanned growth work to repair corrosion damage at FCDs could add up to 50% of the duration of FCD's. Not surprisingly the major corrosion problems were on the primary or critical structures that needed urgent attention due the safety implications of not repairing them.

4. A cost benefit analysis with estimates to reduce/control corrosion helped to prioritise the problem areas. This gained necessary funding to reduce the cost of ownership and improve Submarine Availability. The top priorities allocated for detailed technical studies were;

   - Electrical Penetrations
   - Bilges
   - Battery Compartments
   - Body end Valves

   Based on Pareto analysis the above problem areas accounted for approximately 60% of known structural corrosion costs of the Collins Class. The solutions are currently being implemented

5. Protective coatings emerged as a potential across the board savings and analysis of the repair coasts are shown in Annex A. The analysis showed that monitoring of the overall condition of the coating system would be helpful in predicting economical life and preventing structural damage. Data in Annex B shows Boat A as having some significant coating system problems.

6. Annex C shows some life data of various surface preparation schemes, in particular power tool cleaning preparation in immersed areas used for touch up repairs performed consistently with the published graph.

5 CONCLUSIONS

1. The cost of repairing and maintaining the structural condition of Collins Class Submarines will decrease on a significant scale due to the implementation of Design/Material changes. Maintenance refinement, improved protective coating systems and improved Quality Control will underpin the maintenance reduction.

2. Data collection of costs, performance and history are essential elements in managing corrosion effectively and a help prioritise problematic areas when using Pareto analysis.

3. Design/material selection influences on the major corrosion issues need to be separately identified and analysed for Life Cycle Costing. This is particularly so during the early stages of a project definition phase when significant capital expenditure is undertaken.

4. Undertaking of survey inspections and prompt coating repairs soon after new-build or major maintenance will significantly reduce major corrosion damage and hence the associated costs and schedule impact during Dockings.

5. High quality Survey Inspections and quantitative reporting systems will provide the necessary technical data for through life assessments and optimise; survey inspection intervals, repair methods, priority surveys and effective cost management.

6. Historical data of coating and structural corrosion repairs are necessary to understand the state of the Submarine structures today and identify potential problem areas in the future.

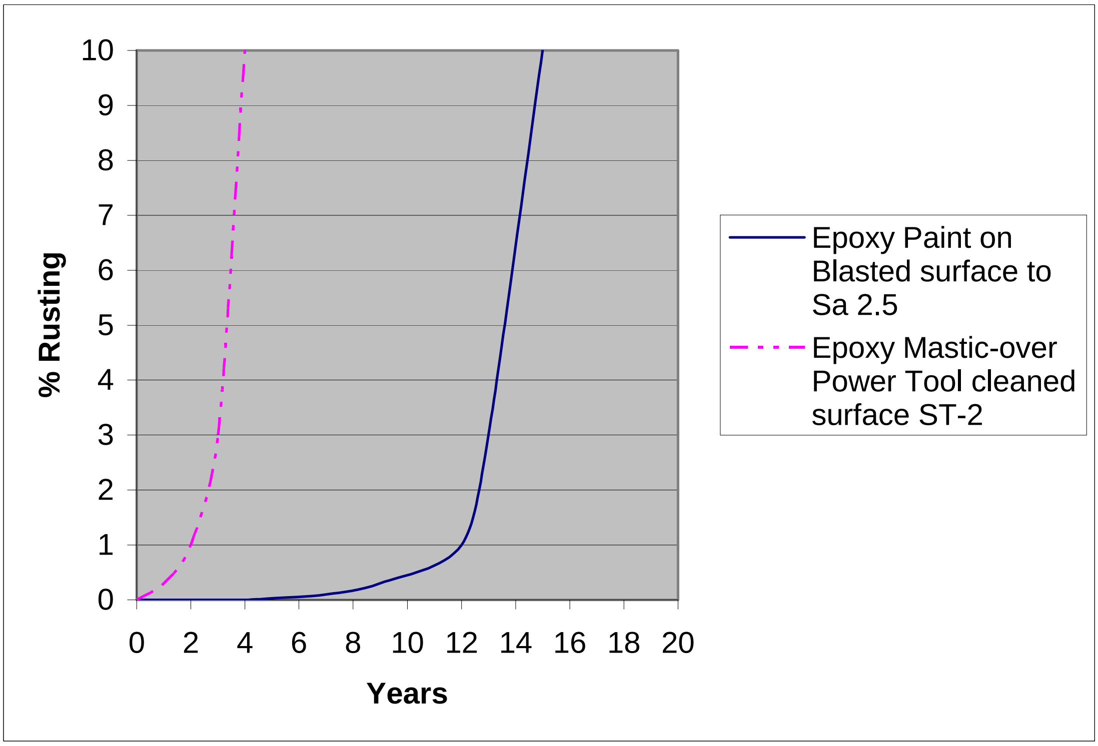
6 ANNEX A - OVERVIEW OF THE MAJOR CORROSION ISSUES AT FULL CYCLE DOCKINGS (FCD)

Corrosion Issue(s)	**Structural Integrity or Safety impact?**	**Corrosion Mechanism(s)**	**Cause of Corrosion**	***Estimated Cost of Corrosion Repairs at FCD's $m**
General corrosion in Tanks (48 of)	YES	-Galvanic corrosion -Differential aeration	-Coating defects - sharp edges -mechanical damage -Previous coating repairs breaking down (power tool preparation)	2.0
Marconi PHP's, up to 3mm metal loss on the pressure hull and tanks	YES	-Galvanic corrosion -Crevice Corrosion	-Detail design not suited for paint adhesion on the hull/stud interface	2.0

Bilge Plating up to 10mm metal loss on hull plating in the 4 Bilges	YES	-Galvanic Corrosion -Differential aeration -Coating damage -Suspected Biological corrosion	-Design does not factor in damage to coatings during maintenance -Design does not factor in access for inspection and ease of coating repairs -Bilges not cleaned regularly	1.2
Flood Areas Several millimetres metal loss on the Stern Tube, SSE's and Torpedo Tubes	YES	-Galvanic Corrosion -Differential aeration -Coating detachment	Complex geometries and sharp edges Poor choice of protective schemes (SSE's)	0.8
Body End Valves- up to 3mm metal loss on plating	YES	-Galvanic Corrosion	Detail design is not suitable for protection using coatings	1.5
Battery Compartments -Corrosion of Deck and sump over 10mm deep	YES	-Galvanic Corrosion -Pitting corrosion	-Detail design does not allow battery acid to drain freely -Maintenance routines need refinement -Mechanical damage of protective coatings	0.5
Hatches	YES	-Galvanic Corrosion -Mechanical damage to sealing face	-Detail Design uses low corrosion resistant materials -Hatches not greased and protected with covers	0.5
Shaft Seal	YES	Galvanic Corrosion	UNDER REVIEW	0.4 is renewed every 36 months
TOTALS				**8.9M**

***Corrosion repairs include; paint and structural repairs, mobilisation, removal and reinstatement of equipment**

7 ANNEX B- AVERAGE PERFORMANCE COMPARISON OF COATINGS WITH DIFFERENT PREPARATION METHODS.



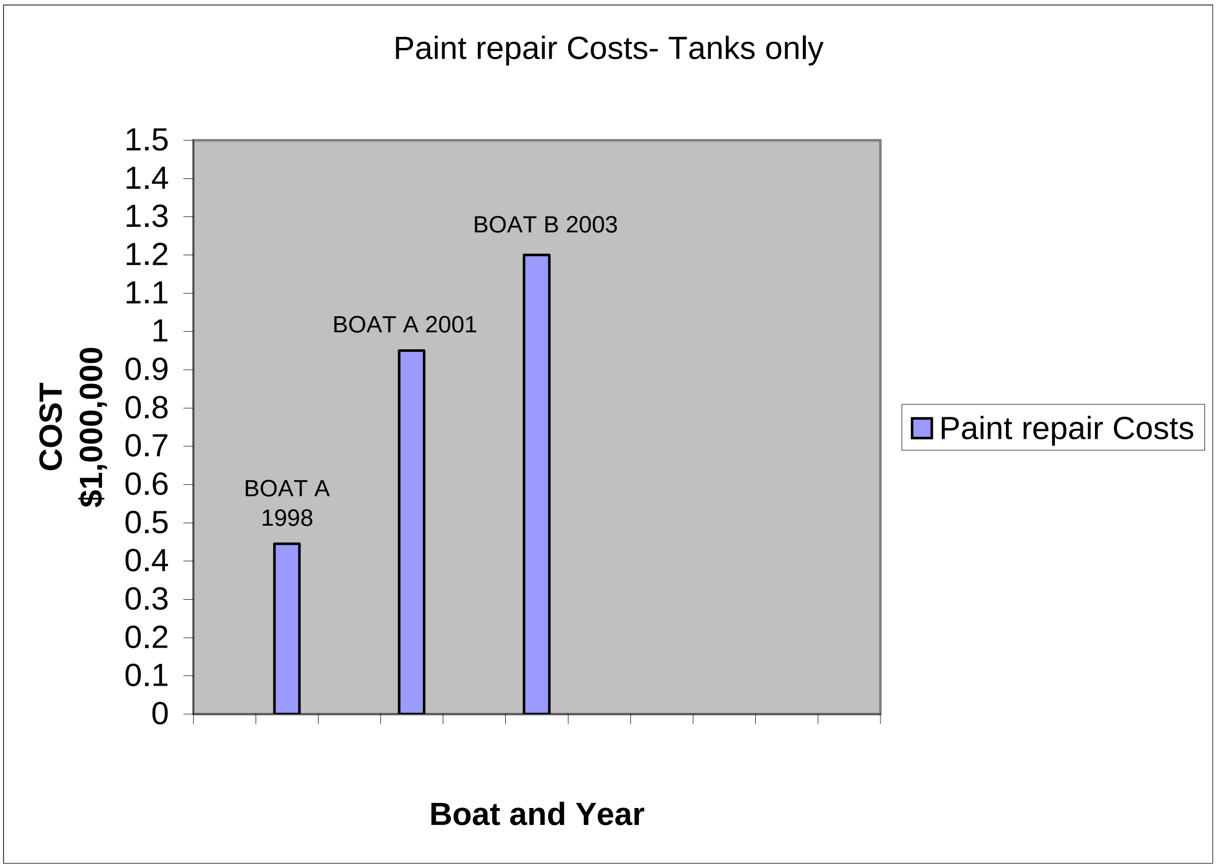
Source Data- Journal of Protective Coatings and Linings (JPCL) - Performance of Coating Systems Using Numerical Life Prediction, July 1998-Neil .P.Adamson, BE, CBIP-Coatings, Altex Coatings Limited,

HMAS 'A' and HMAS 'B' survey data.

Note!- Rust levels at 0.1% is considered the point to begin coating maintenance[L] , however at >1% scattered there is significant risk of metal loss corrosion ocurring. The cost of repairing coatings by blasting on a 1% rusted surface, compared to a 5% rusted surface is a cost multiple of approx 3 times[K].

Power Tool Cleaning has an approximate cost multiple of 2.2 times[K] for 1% and 5% rusted surfaces respectively.

8 ANNEX C- ESTIMATES OF TANK COATING REPAIR COSTS-HMAS 'A' AND 'B'



9 ANNEX D- SAMPLE PHOTO IMAGES OF THE CORROSION FOUND DURING FCD MAINTENANCE.

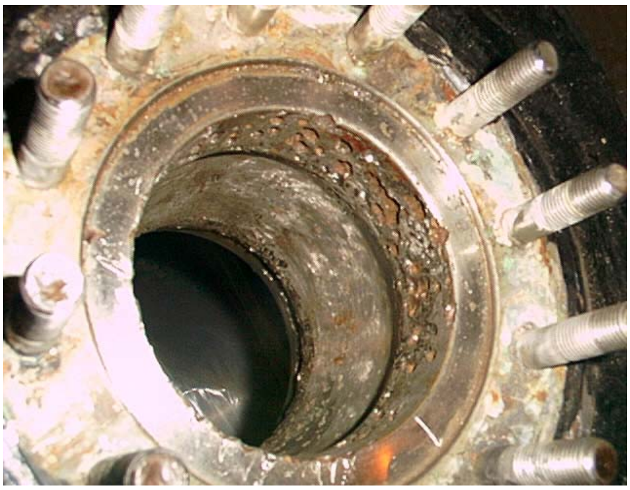


Photo1- Electrical Hull Penetration -bolted joint **Photo 2- Mechanical Hull Penetration**

Photo3- Body End Valve- bolted joint

Photo 4- Bilge Plating-pitting corrosion

Photo 5- Battery Compartment- pitting corrosion

Photo 6-SSE Forging-galvanic corrosion

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