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APPLICATION DETAILS AND SEA-TRIAL RESULTS OF AN ANTIFOULING AND ANTICORROSION SYSTEM

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Summary

A test area on a ship's hull was examined 22 months after a new antifouling/anticorrosion system, consisting of a solventless epoxy resin followed by multiple coats of soluble-matrix antifouling paint, had been applied to it. During the last 19 months of the period the ship operated continuously in Australian and Asian waters without docking.

Corrosion and fouling were not observed on the test area. The epoxy resin (three coats) was in excellent condition with no indication of loss of adhesion, blistering, or surface chalking. The antifouling paint (five coats) adhered satisfactorily during the sea trial. An attempt was made during the original application to utilize the adhesive properties of the recently applied epoxy resin to bond on the first coat of antifouling paint. This was only partially successful. Where a short time lag had been allowed (5–30 min), adhesion was not lost when the ship dried out in dock. Where the time lag was longer (30 min to 3 hr), drying out was accompanied by loss of adhesion at the epoxy/antifouling interface and resulted in the antifouling paint stripping off. Performance of the test area is compared with that of other systems on the remainder of the hull.

A section of the test area where adhesion was satisfactory has been left intact for further observations. The remainder was lightly sand-blasted to remove the rest of the antifouling paint and to roughen the glossy surface of the epoxy resin; it has since been recoated with antifouling paint so that observations can be made on the adhesion resulting from this alternative method of application.

I. Introduction

Wisely (1964) suggested that the combination of a solventless epoxy resin as an anticorrosive layer and a thick layer of soluble-matrix antifouling paint might extend anticorrosion and antifouling protection of steel hulls. The reasons for selecting this system were given and it was mentioned that a test area had already been applied to a ship. This paper gives more details on the formulations and application methods used and reports on performance during the first two years. Comparable data are given for a coal tar epoxy resin test area, and for a conventional antifouling/anticorrosion paint system applied to the remainder of the hull.

II. Materials and Methods

(*a*) *Surface Preparation*

During September 1963, the hull of the Royal Australian Navy destroyer H.M.A.S. *Vampire* was wet sand-blasted (by painters and dockers) at Captain Cook Dock, Sydney. A rust-inhibiting mixture of trisodium phosphate and potassium bichromate was included in the blasting jets to prevent rust from forming immediately

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after sand-blasting ceased. Just before the anticorrosive and antifouling systems were applied, the hull was washed down with fresh water containing a trace of the rust-inhibiting mixture. The amount added was sufficient, in the opinion of the painters and dockers doing this work, to prevent rust from developing during the interval of several hours between washing down and application.

(*b*) *Application of the Antifouling/Anticorrosion Systems*

The anticorrosive layer of the three systems consisted of solventless epoxy resin, coal tar epoxy resin, or anticorrosive paint (Table 1). These were overcoated with soluble-matrix-type antifouling paint.

TABLE 1

TYPES OF ANTIFOULING/ANTICORROSION SYSTEMS APPLIED

Anticorrosive				Antifouling		
Type	Area (sq ft)	No. of Coats	Thickness (in.)	Type	No. of Coats	Thickness (in.)
Solventless epoxy resin	250	3	0·025–0·035	Soluble-matrix	5	0·008–0·010
Coal tar epoxy resin	250	3	0·009–0·012	Soluble-matrix	2	0·003–0·004
Bituminous anticorrosive paint	Rest of hull	4	0·004–0·006	Soluble-matrix	2	0·003–0·004

The solventless epoxy resin was applied to an area of about 250 sq ft extending from the keel to the bilge keel on the starboard side below the main outlet. The resin selected was Araldite Resin 714 (now known as Resin MY752) supplied by CIBA Co. Pty. Ltd., Sydney, and it was mixed in the following proportions by weight: resin, 3·7 kg; hardener HY830, 2·3 kg; accelerator DY830, 66 g; thixotrophic agent Aerosil (SiO_2), 113 g. Araldite Colouring Pastes DWO3 (red) and DWO2 (yellow) were added to the second and third coats of the epoxy resin to provide colour contrast and so aid application. Components were weighed out in the laboratory and mixed except for the hardener; the latter was not added until the batch was about to be applied. This precaution gave a pot life (working time) of about an hour. The brushes used to apply the resin were cleaned with solvent (Eposolve 70) after about 30 minutes' use or immediately application ceased.

The dockyard application programme is given in Table 2 together with data on temperatures and humidities. Under laboratory conditions a thickness of about 0·005 in. was obtained with each coat of resin. The intention of the dockyard schedule was to apply three coats of resin to give a total thickness of 0·015–0·020 in. Measurements made after the first coat had been applied to the hull showed that the dockyard application was generally thicker but more variable than in the laboratory. Thickness measurements taken with a Tinsley gauge showed that the average thickness for 45 measurements was 0·011 in.; these ranged from 0·002 in. on pitted areas to 0·015 in. on areas where the epoxy had not been brushed out fully. Measurements made on these pitted areas after the second coat of epoxy had been applied showed that they were now covered by about 0·015 in. of resin. In other areas the thickness of the epoxy was beyond the limits of the gauge and could not be measured accurately. Presumably the thickness at this stage was about 0·022 in., which was considered sufficient. The proposed third coat was no longer necessary to build up thickness. Unfortunately, before the second coat measurements could be attempted it was necessary to allow the surface to cure to firmness; it was thus beyond the tacky stage when the time came to apply the first coat of antifouling paint. To meet this situation, a thin fast-curing third coat was prepared by halving the amount of thixotropic agent and doubling the amount of accelerator. This was applied and allowed to become tacky before the first coat of antifouling paint was applied.

TABLE 2

SOLVENTLESS EPOXY RESIN SYSTEM APPLICATION PROGRAMME

Weather fine and sunny with negligible rain. Temperature and humidity figures maxima and minima for day recorded at Observatory Hill, Sydney, by Bureau of Meteorology

Date	Coating Applied	Temperature (°F)	Relative Humidity (%)
Fri. 13.ix.63	Epoxy 1	49–68	25–50
Sat. 14.ix.63	—	53–74	26–54
Sun. 15.ix.63	—	55–77	26–57
Mon. 16.ix.63	Epoxy 2	53–82	16–49
Tues. 17.ix.63	Epoxy 3 + antifouling 1	54–65	36–70
Wed. 18.ix.63	Antifouling 2 + 3	48–66	34–74
Sat. 28.ix.63	Antifouling 4	45–68	64–89
Mon. 30.ix.63	Dock flooded		
Nov. 1963	Antifouling 5		

The first coat of antifouling paint was rolled onto the last coat of epoxy resin while the latter was still tacky, in an attempt to utilize the adhesive properties of the resin to bond in the antifouling paint. This procedure arose from earlier unpublished work in which steel plates were coated with epoxy resin and then allowed to cure for various intervals before being overcoated with antifouling paint. The plates were placed in the sea for a month and then removed and allowed to dry. These tests indicated that the best bond was obtained when the antifouling paint was applied as soon as practicable after the epoxy resin. When the epoxy resin was allowed to cure fully to a glossy hard surface before the antifouling paint was applied, the latter did not adhere well during immersion and flaked off readily on drying out. Similar adhesion problems were not encountered in earlier experiments when a vinylite antifouling paint was applied to a solventless epoxy resin (Wisely 1962).

The antifouling paint used for all three of the systems described here was Antifouling Red (Ref. No. 92027) supplied by International Majora Paints Pty. Ltd., Sydney. At the aft end of the solventless epoxy resin area a time lag of 5 min was allowed between application of the last epoxy and the first antifouling coats. The time lag was gradually increased along the test area to reach 3 hr at the forward end. The second and third coats of antifouling paint were rolled on the following day with a 5-hr interval between them; the fourth coat was applied 10 days later before the dock was flooded and the fifth was applied about 6 weeks later when the ship returned briefly to dock.

A 250-sq-ft area adjacent to the above was coated with a coal tar epoxy resin to see how it compared with the solventless type as an anticorrosive layer. Three coats of Luxol 5 supplied by British Paints (Aust.) Pty. Ltd., Sydney, were rolled on during consecutive days and then allowed to cure for 14 days when a single coat of the antifouling paint was applied. A second coat of antifouling paint was also applied about 6 weeks later when the ship returned to dock.

The remainder of the hull was roller-coated with a conventional antifouling/anticorrosive paint system supplied by International Majora Paints Pty. Ltd., Sydney. Four coats of Silver Primacon anticorrosive paint (Ref. No. 91014) were applied initially, followed by one coat of the antifouling paint and by a second coat about 6 weeks later.

(c) *Performance of the Systems during Sea Trials*

H.M.A.S. *Vampire* left dock at the end of September 1963 and cruised in Australian waters until mid November when she docked again. None of the three systems developed corrosion or fouling during this period. When the ship dried out, fine hair cracks developed in the thick layer of antifouling paint overlying the solventless epoxy resin but not in the thinner layer overlying the other anticorrosives. Just before *Vampire* left dock the entire underwater area was given its final coat of antifouling paint, bringing the total number of coats on the solventless epoxy resin to five and the total for the rest of the hull to two.

During the next 19 months *Vampire* remained at sea in Australian and Asian waters. She was not docked during this period but her underwater surfaces were inspected periodically by divers; the condition of the hull remained satisfactory and fouling growths and corrosion were not detected.

III. Results

(a) *Condition of Systems at July 1965 Docking*

When the ship docked the hull was remarkably free from corrosion and fouling. The only fouling growths noted consisted of small clumps of the tubeworm *Hydroides norvegica* Gunnerus bearing a few colonies of the erect bryozoan *Bugula avicularia* L. These occupied far less than 1% of the area and were confined almost entirely to areas difficult to paint properly (gratings, underwater outlets).

The condition of the solventless epoxy resin after 22 months' service was excellent. There was no indication of corrosion, loss of adhesion, or blisters. The attempt made to bond on the first coat of antifouling paint by applying it to the epoxy resin while the latter was still tacky was only partially successful. At the aft end of the test area, where the time lag was below 30 min, adhesion was maintained throughout the sea trial and during the drying-out period in dock. Further forward, where the time lag had been extended from 30 min to 3 hr, the antifouling paint adhered satisfactorily during the sea trial but began to flake off when the ship dried out in dock. After several days in dock extensive stripping of the antifouling paint took place in this area. The epoxy resin revealed by this flaking was pale green initially but changed rapidly to dark green on exposure to light; its surface was hard and glossy and not chalky. The antifouling paint had not become fouled during its 19 months' continuous exposure at sea; although it had been applied five times thicker than normal, delamination and flaking off of individual coats had not taken place to any great extent. Pieces of antifouling paint that had flaked off in the dock were broken up manually and did not delaminate into individual coats.

The antifouling, adhesion, and anticorrosion performance of the coal tar epoxy resin test area was generally satisfactory, except for the presence of isolated areas of small blisters that had developed at the epoxy/steel interface and had bulged out, cracking off the overlying antifouling paint on each blister. The conventional antifouling/anticorrosion paint system applied to the remainder of the hull was still in excellent condition at this stage and showed no indication of deteriorating in performance.

IV. Recoating

Part of the solventless epoxy resin area where the adhesion was satisfactory throughout the drying-out period was left intact so that further observations could be made. The remainder was lightly sand-blasted to remove the antifouling paint and to roughen the glossy surface of the epoxy resin in preparation for recoating. A coat of International Majora No. 1 Anti-corrosive (Ref. No. 91001) was then applied, followed by two coats of the antifouling paint. The same three-coat paint system was also applied to the coal tar epoxy resin area and to the conventional paint system on the remainder of the hull. It is understood that the No. 1 Anti-corrosive is mainly a bonding coat, supplying solvent to the old antifouling paint and facilitating the adhesion of the new antifouling paint to it.

V. Discussion

The solventless epoxy resin has given excellent anticorrosion protection during its first two years in service. It should be noted, however, that the hull was cathodically protected with an impressed current system during the sea trial and this would have reduced the possibility of corrosion developing over the entire hull.

It is already apparent that some rapid method of applying the solventless epoxy resin needs to be developed before large-scale hull applications could become a practical proposition. Brush application is tedious and slow; the application rate here was 22 man-hours to cover 1000 sq ft with one coat. The resin can be applied by roller, but air bubbles become trapped in the film during this process. These bubbles can be removed very easily by passing a flame rapidly over the surface shortly after the resin has been applied. In small-scale experiments a fish-tail gas burner has been used for this purpose. Modification of the resin so as to lower its viscosity might possibly aid brush, roller, or spray application. Mr. G. E. Knott, of the British Iron and Steel Federation, has kindly sent information (personal communication) that a number of British firms have been developing spray equipment for the application of this class of resin. The use of such equipment in dockyards could greatly facilitate application.

A reliable and less time-dependent method of bonding the antifouling paint onto the epoxy also needs to be developed. The *Vampire* trial showed that it was necessary to apply the particular antifouling paint used within 30 min after applying the epoxy to obtain good adhesion. A time lag as short and critical as this is not desirable in dockyards. The most obvious alternative seems to be to roughen the glossy surface of the epoxy resin and thus provide a more suitable physical surface for the antifouling paint to adhere to. This method has now been used on the test area but the results will not be known until *Vampire* returns to dock again. It may also be possible to develop primer coatings for use between the epoxy and antifouling layers.

The *Vampire* trial has indicated the possibility of using multiple coats of soluble-matrix paint to extend the interdocking period. A very thick layer (five coats) was put on the solventless epoxy resin area to see if the individual coats would adhere to one another during the sea trial, and to test the hypothesis that the effective life is proportional to the thickness. The adhesion of the individual coats within this layer seemed satisfactory, but the breakdown of the adhesion between the epoxy resin and the antifouling paint noted during the drying-out period after the sea trial precludes further observations on most of the test area. A small section of the area where adhesion at the epoxy/antifouling interface was satisfactory is, however, still suitable for future observations. The desirable thickness for multiple-coat systems is not yet known; at present ships must enter dock at 1–2-year intervals so that underwater area surveys and other maintenance can be carried out. There may be little advantage, at present, in having antifouling paint systems that last longer than this.

The application of a second coat of antifouling paint to the remainder of the hull in November 1963 was fortuitous. It is customary in the dockyard to apply a coat of antifouling paint just before a ship leaves dock, but the interval between this and the application of the previous coat of antifouling paint is not usually as short as 6 weeks. The result was that the antifouling paint was twice as thick as normal over most of the ship during the sea trial. The interdocking period for naval ships coated with one coat of antifouling paint is about a year. H.M.A.S. *Vampire*, with two coats, was practically free from fouling after 19 months and might well have remained so for a further 5 months had she not docked. While the economic implications of this are beyond the scope of this paper, it would seem that the cost of applying a second coat of antifouling paint while a ship is in dock would be more than compensated for if this resulted in a two-year, rather than an annual, docking cycle. If recoating maintenance is to be confined to antifouling paint application, then it is essential for the underlying anticorrosive layer to retain its integrity. The performance of the solventless epoxy resin as an anticorrosive layer has been excellent so far. No detrimental change has been observed since the July 1965 docking, and it has now completed two years in service. However, to date it has performed no better than the conventional anticorrosive system applied to the greater part of the hull; it will need to maintain its performance for many years yet before its potentiality can be assessed in economic terms.

VI. Acknowledgments

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