STRAY CURRENT CORROSION OF COPPER SHEATHING AND KEEL COOLING PIPE OF A 36' TRAWLER

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The results of investigations into the cause of an accelerated corrosion of copper sheathing and keel cooling pipe of a 36' wooden trawler are reported. The corrosion is attributed to the stray electric currents originating from the electrical wiring system. The sources of stray currents and the remedial measures have been suggested.

INTRODUCTION

Copper and its alloys are widely used as marine materials because of their resistance to corrosion by sea water. However, instances are not lacking where the copper sheathing has undergone pitting corrosion due to diverse reasons. This paper deals with an accelerated corrosion of copper sheathing and keel cooling pipe due to stray electric current.

THE PROBLEM

In a 36' wooden trawler whose hull was sheathed with copper sheets and having an underwater copper keel cooling pipe installation, unusual and accelerated corrosion of the copper sheets and copper pipe was observed. The vessel was lying idle at the wharf for about four months excepting for a few fishing operations off Cochin. Even on non-fishing days the engine and the generator were working for some hours daily and repair works were going on. When the vessel was hauled up it was observed that some of the copper sheets and cooling pipe were severely corroded. Corrosion was noticed at the bilge and stern area. The keel cooling pipe had undergone severe corrosion from outside. The hull repairs were completed by replacing the corroded copper sheets and keel cooling pipe and the trawler was operated for about seven months. At the end of this period the vessel was examined and was found to have suffered similar type of corrosion observed earlier. An investigation was undertaken to find out the cause of observed rapid corrosion.

The arrangement of starter motor, engine, dynamo and battery in the vessel is schematically shown in Fig. 1 and the electrical wiring circuit in Fig. 2.

The problem was investigated under the following premises:

i) Corrosion might be due to poor quality of copper sheets.
ii) Corrosion might be initiated by organic deposits during the idle period.
iii) Corrosion might be due to stray electric current.

EXPERIMENTAL

1. *Total Immersion Tests*

Samples were cut from the corroded and non-corroded copper sheets and put to total immersion corrosion tests in natural sea water for a period of 60 days. The same experiment was repeated by aerating the medium using an aquarium aerator. Samples of keel cooling pipe were also put to same tests.

II *Corrosion Behaviour of Copper in Sea Water at low Velocity.*

The rate of corrosion of copper specimens at a velocity of about 0.12 metre/sec. was determined. Aerated sea water was pumped through a 4 cm. diameter polythene pipe containing the test coupons. The tests were conducted for a period of 8 hours. The results of experiments I & II are given in table I.

III *Corrosion Initiated by Organic Deposit*

Organic deposits can be expected where the water current is low. As the vessel was lying idle at the wharf for some time, the possibilities of deposits of weeds or any other foreign matter were expected. Hence a few corrosion experiments were performed in a sea water medium containing organic matter. Agar agar was dispersed in the medium to act as organic deposit. Results of the experiments are given in Table II. Direct bacterial attack on copper may not be operative as amount of copper passing into solution may act as poison to bacteria. The sulphate reducing bacteria on the mud bank can produce hydrogen sulphide which might corrode copper. An analysis of water sample at the wharf has recorded a concentration of 1–1·5 ppm. of hydrogen sulphide.

IV *Corrosion due to stray current*

Stray currents cause localised corrosion at points where these currents leave the immersed metal structures. The technique adopted by Pomfret and Mosher (1948) with slight modification was followed to establish the presence of stray electric current.

Corrosion coupons were attached to the hull of the trawler to experience similar operation conditions. Only one set of the coupons was electrically connected to the hull, whereas the electrically unconnected coupons served as the controls. After a period of 13 days corrosion coupons were detached and corrosion rates determined. Results are given in table III.

DISCUSSION:

In sea water moving less than 30 cm/sec. copper corrodes at rates of 0.3 to 3.3 mils per year with an average of about 1.6 mpy (May and Weldon, 1964). Corrosion rates of 2·2 mils and 2·4 mils in case of copper sheets and 2·1 mils and 2·5 mils in case of keel cooler pipe in tropical marine environment under non-aerated and aerated conditions indicate the normal corrosion behaviour of copper. Similarly the corrosion rate of copper sheets and keel cooler pipe in low velocity water flow is also comparable (Table I).

As the vessel was at the wharf for some period, where the water velocity is mainly due to tidal movements debris or some foreign body such as mud and / or sea weed might have settled. Flow of sea

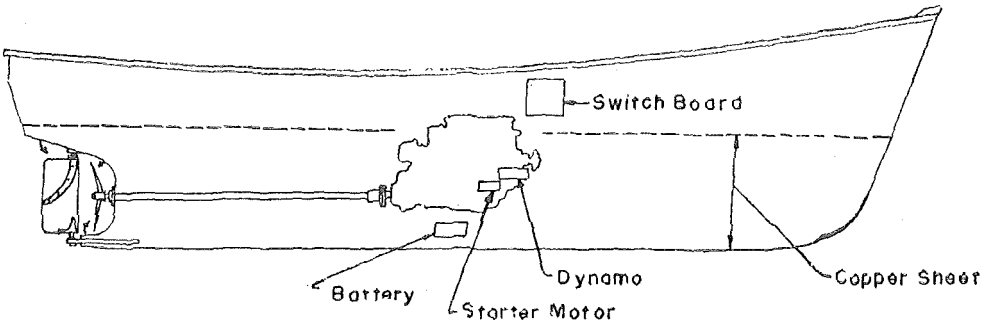

Fig:1 SCHEMATIC ARRANGEMENT OF ENGINE, DYNAMO ETC; IN THE VESSEL

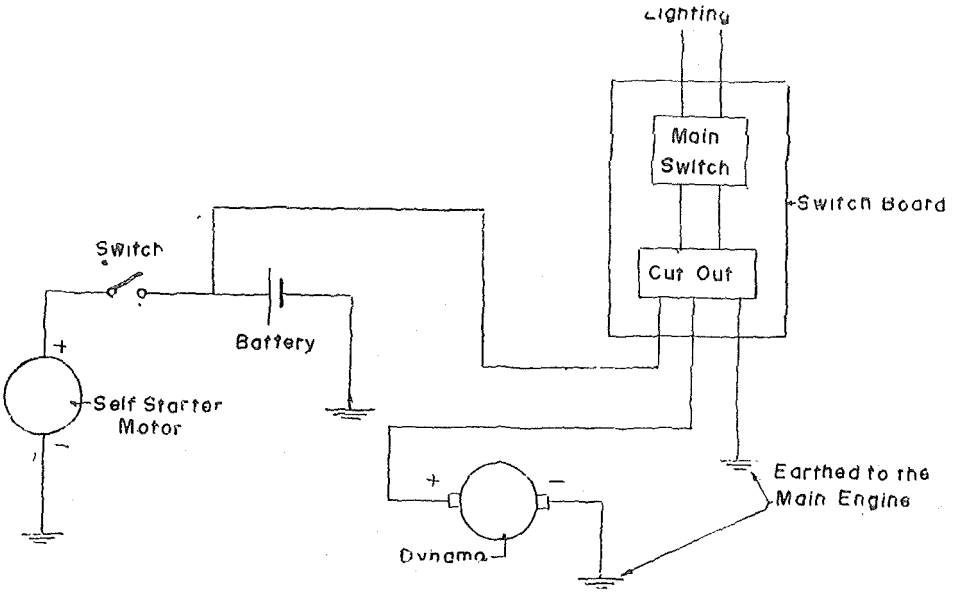

Fig. 2 CIRCUIT DIAGRAM

TABLE I CORROSION OF COPPER SHEET AND KEEL COOLER TUBE

Period of testing : 60 days
Medium : Sea water

Test specimen	Corrosion rate (inch penetration per year)		
	Stagnant condition	Aerated condition	Sea water at 0.12m / sec.
Copper sheet	0.0022	0.0024	0.0032
Keel cooler tube	0.0021	0.0025	0.0032

TABLE II CORROSION OF COPPER SHEETS IN PRESENCE OF ORGANIC DEPOSITS

Test specimen	Corrosion rate (inch penetration per year)
Copper sheet	0.0025
Keel cooler tube	0.0025

TABLE III CORROSION OF COPPER TEST SAMPLES ON THE HULL OF THE TRAWLER

Nature of bonding to the hull	Corrosion rate (inch penetration per year)
Electrically insulated	0.0032
Electrically coupled	0.048

water in general facilitates the supply of corrosives at the metal surface at a faster rate and hence accounts for the increased corrosion rate of 3·2 mils at a water velocity of 0·12 metres/sec. Deposits create differential aeration cells with a small anode screened from oxygen with a large cathode, favouring pitting corrosion. A corrosion rate of 2·5 mils under deposit attack cannot obviously account for the observed damage of the hull sheathing. An analysis of water sample at the jetty indicated the presence of hydrogen sulphide. As the hydrogen sulphide concentration is well below 10 ppm., the corrosion of copper cannot be attributed to it Hence any of these factors was not responsible to account for the severe corrosion.

Some of the metallic components present on the wooden hull of the vessel are not in direct electrical contact. The propeller shaft, for example, is separated from the hull metallic components by wooden stern bearing offering high electrical resistance. A wooden structure damp with sea water (which is having a low electrical resistance of about one ohm per

foot cubed) conducts electricity. When a bare wire or a cable with broken insulation is in contact with a damp wood, electricity flows through the wood to the metallic skin fittings. In such cases metals which form anode will be seriously attacked. The presence of stray electric current is indicated by the results in Table III and the path of current leakage is shown by arrows in Fig. 1. An increase in corrosion rate by about 15 times when the metal coupons were in electrical contact with the hull establishes this fact. Serious localized pitting results especially at discontinueities. For each ampere of current leaving from the hull about 10 kg. of copper will be wasted in a year. The electrical systems in the trawler were checked, repaired and the vessel despatched to Veraval. No such complaints were noticed after that.

A two wire system of electric wiring is to be adopted. The cables should be able to withstand salt spray. Especially at bends, insulation breaks and the bare wire comes in contact with moist wood. Insulation faults particularly in the earth return, cause stray currents, which flow through sea water between isolated metal structures. Intense leakages usually occur when junction boxes are placed in a damp place. Faulty electrical earthing of echo-sounders and other equipments also causes serious troubles.

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