

BIOFOULING AND CORROSION ON WAVERIDER BUOY SYSTEMS

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ABSTRACT

During the wave data collection programme being carried out by the National Institute of Oceanography, Goa severe corrosion on the 316 stainless steel hull of the waverider buoy as well as on its metallic mooring components was noticed. The pitting on the buoy hull due to the effect of marine growth and possible causes of corrosion have been discussed. Methods adopted to counteract the corrosion processes on the stainless steel waverider buoy hull resulting in increase in the life of the buoy etc have also been presented. Cathodic protection measures adopted for the steel shackles, waverider hull including its stabilizing chain etc. to prevent corrosion, have also been highlighted in the paper.

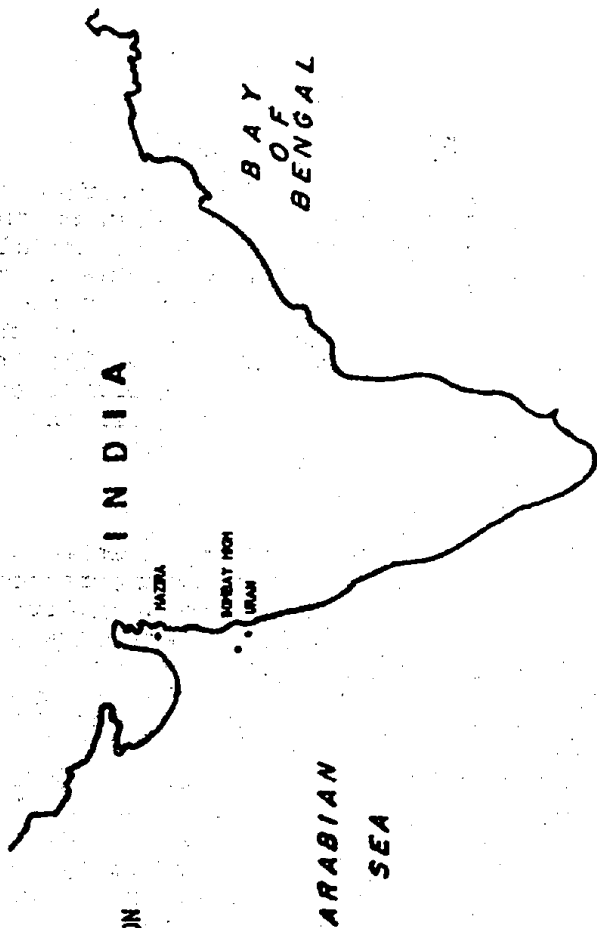
INTRODUCTION

National Institute of Oceanography, Goa has been using Datawell waverider buoys since 1980 for the wave data collection programmes in India. Severe corrosion problems were faced on the hull of the waverider buoy and its mooring hardwares. This necessitated retrieval of the waverider buoys and its mooring for periodic inspection and preventive maintenance. Fig. 1 gives the locations where severe marine fouling and corrosion problems encountered on the moored buoy systems.

The hull of the waverider buoy used was made either of the AISI Austenitic grade type 316 stainless steel or of 90/10 Copper-Nickel alloy (CUNIFER). Type 316 stainless steel cannot be heat-treated and as a result has to attain its strength through a combination of alloying and work hardening processes. Crevice corrosion is an electrochemical process that occurs on the stainless steel when the crevice formed prevents the formation of a protective passive metal oxide film on the surfaces. The crevice corrosion leads to severe pits on the stainless steel surfaces.

WAVERIDER BUOY MOORING SYSTEM

Figure 2 shows a typical waverider buoy mooring system adopted by NIO. Various metallic connectors used in the mooring were made either of type 316 stainless steel or of galvanised steel. Measures were taken to



LEGEND

• WAYERIDER BUOY LOCATION

S. NO.	LOCATION OF WAYERIDER BUOY.	WAYERIDER BUOY HULL MATERIAL.	PERIOD OF STUDY.	REMARKS.
1.	AT BOMBAY HIGH.	TYPE 316 S.S STEEL AND 90/10 COPPER NICKEL ALLOY.	22nd MAY to 12th DEC. 1984.	MODERATE CREVICE AND PITTING CORROSION ON TYPE 316 S. STEEL BUOY HULL AND HARDWARES.
2.	OFF URAN.	TYPE 316 S. STEEL.	26th JUNE to 16th OCT. 1984.	SEVERE CREVICE AND PITTING CORROSION ON BUOY HULL AND HARDWARES.
3.	OFF HAZIRA.	TYPE 316 S. STEEL.	22nd JUNE to 30th DEC. 1985.	REMEDIAL MEASURES ADOPTED PREVENTED FURTHER CORROSION ON BUOY HULL.

FIG. 1. WAYERIDER BUOY LOCATIONS.

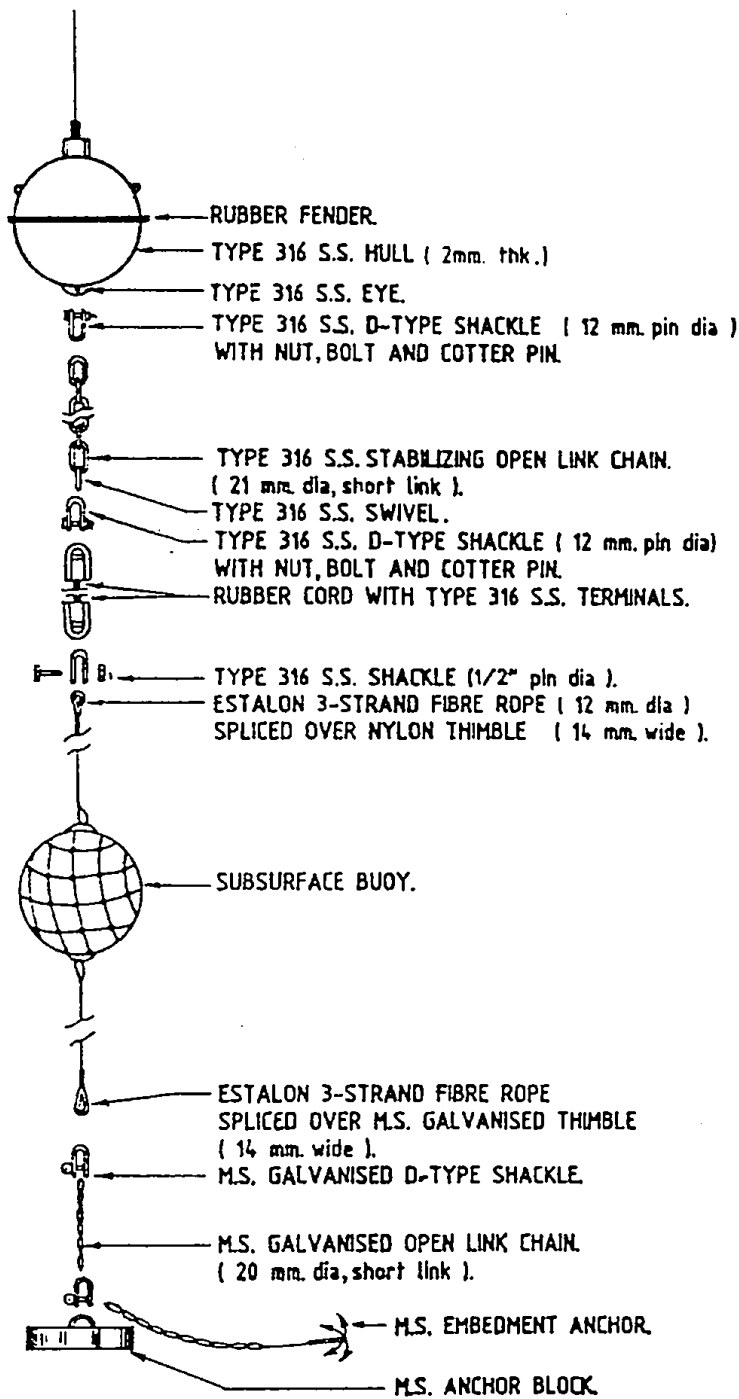


FIG. 2 A TYPICAL WAVERIDER BUOY MOORING SYSTEM. (Disassembled View).

alleviate the galvanic corrosion between the dissimilar metals connected together in the mooring system. All directly inter connected metallic hardwares in the mooring system were of identical metals.

MARINE FOULING AND CORROSION

Waverider buoys deployed at Bombay High:

A new unused 90 cms diameter waverider buoy made of type 316 stainless steel hull was operated continuously for a period of eight months covering the 1984 monsoon and the post-monsoon period. The lower hull of the 90 cm diameter waverider buoy was left unpainted as per the recommendations of the manufacturer (M/s Datawell, Netherlands), While the upper hull was painted in deep orange colour by using ordinary synthetic enamel paint for improving the visibility of the buoy from a distance. The localised crevice and pitting corrosion at two locations was noticed on the waverider buoy. They were at the O-ring groove of the hull (Fig. 3) and on the lower hull as well as at the rubber fender on the upper hull of the waverider buoy.

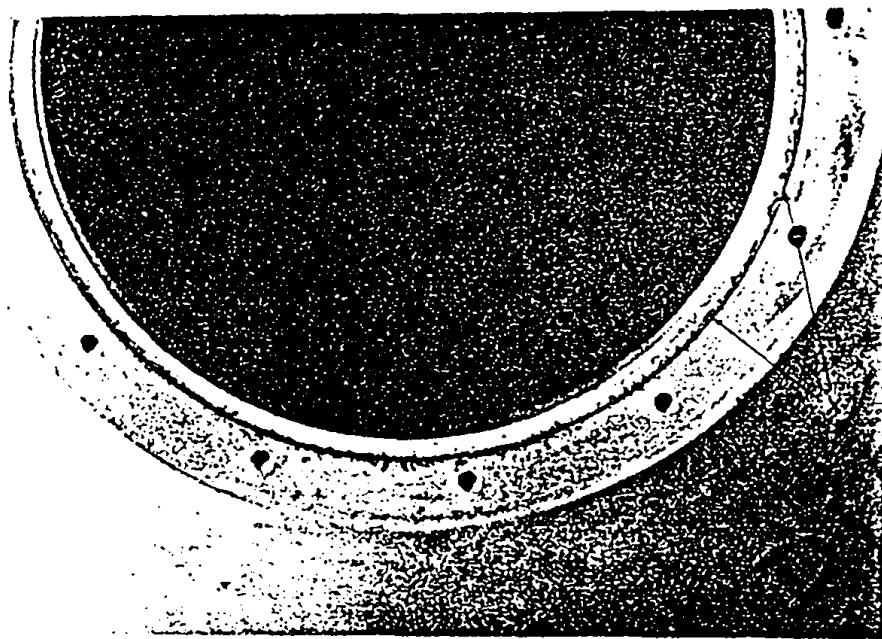


FIG.3. X CORROSION PITS ON O-RING GROOVE.

The first type of marine corrosion was probably as a result of the trapping of the seawater in the O-ring grooves. Application of sealants like silicon grease did not prove to be effective to prevent the seawater seepage through the fine cracks of O-ring. The second type of marine corrosion was noted to be more dominant on the lower un-painted hull of the waverider buoy. On recovery, a fairly large growth of marine foulers (Fig. 4) on the lower hull of the buoy was observed. Crevice corrosion initiated in these numerous interstices caused by the marine foulers probably has led to severe pits on the hull. These pits were of scallop shape with penetration into the hull varying from 40% - 50% of the buoy hull thickness. The protective coating of paint on the upper hull was not found to adhere on to the smooth stainless steel surfaces. The trapped



FIG. 4. A TYPICAL GROWTH OF MARINE FOULERS ON WAVERIDER BUOY.

Seawater in the pin holes formed under the paint coat initiated crevice corrosion on the upper hull. However, the depth of penetration and number of pits formed were less compared to that on the lower hull. Practically no corrosion was seen on 70 cm diameter 90/10 Copper-Nickel alloy (CUNIFER) buoy hull even after its extended duration of exposure to the same marine environment covering the 1985 monsoon and post-monsoon.

Waverider system deployed off Uran:

A new unused 90 cm diameter type 316 stainless steel buoy was operated off Uran continuously for a period of four months covering the 1984 southwest monsoon. The entire buoy hull was left un-painted. On retrieval it was found that the lower hull of the buoy was coated with a layer of fine silty sediment. Very few marine foulders were found attached to the hull of the buoy. The localised attack of corrosion was found to be very severe both on the waverider buoy hull and mooring connectors.

Deep scallop shaped pits were found to develop on the lower hull of the waverider buoy. Among these four pits were quite severely pitted and found to penetrate upto 50%-60% of the thickness of the hull (Fig. 5). This localised corrosion on the lower hull of the buoy was apparently as a result of the micro-crevices formed in the sediment coating on the buoy surface.

The D-type shackles made of 316 stainless steel used for connecting the rubber cord to the waverider buoy was also found to be severely pitted (Figs. 6 & 7) in the crevice formed between the locking bolt head and its mating U-body area of the shackle, in the crevices formed between the locking nut and its mating U-body area of the shackle as well as in the crevices formed between the threaded contact surfaces between the locking nut and bolt. The depths of the pits formed varied between 3 to 5 mm.

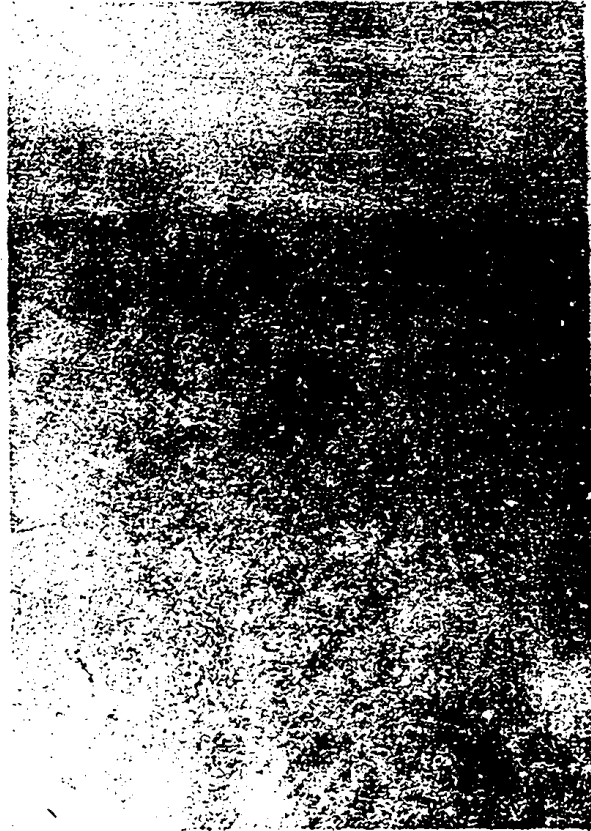


FIG. 5. X A TYPICAL CORROSION PIT
ON WAVERIDER HULL.

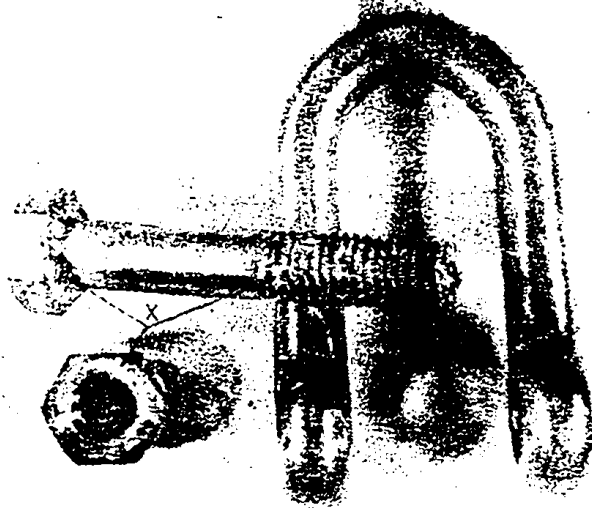


FIG. 6: X CORROSION OF 316 S.S. SHACKLE.

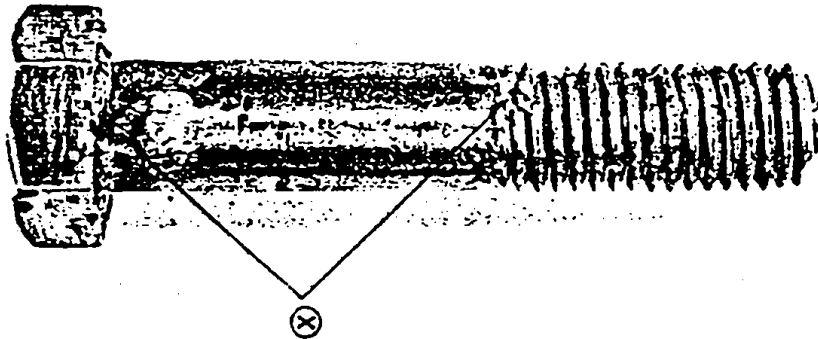


FIG. 7. X CORROSION ON 316 S.S. SHALKLE BOLT

Waverider system deployed off Hazira:

The 90 cm diameter waverider buoy retrieved from Uran was reused off Hazira during the 1985 southwest monsoon as no other spare 90 cm diameter buoy was available. The major pits on the waverider buoy were filled with industrial resin-hardner (Araldite) manually mixed in 1:1 ratio and were air-dried for 48 hours prior to deployment. The buoy location was known for strong tidal currents and heavy suspended sediment load. Periodic retrieval was planned and undertaken for inspection of the behaviour of the protected buoy hull. Some of the observations have been listed below:

First retrieval:

The buoy was recovered during the monsoon after its one and half months continuous operation at sea. The lower hull surface of the buoy was found coated with a layer of fine sediment. The performance of the resin-hardner as filler material was quite satisfactory. The filler material was found to adhere very well in the pits thereby giving very good protective cover to the hull. However a few additional small pits were found to occur on the lower hull as a result of micro-crevices formed due to the formation of a sediment coating on the hull surface. Corrosion of weld material was observed particularly severe around the welded bottom eye of the buoy (Fig. 8). A standby safety line passing through the stabilizing chain link, was provided as shown in Fig. 9. This line was meant to keep the buoy attached securely to its mooring in the event of the welded eye detaches from the buoy hull. The attack of corrosion on the other mooring hardwares was not very severe.

Before the next deployment the entire buoy hull was coated with zinc chromate paint which acts as a sacrificial anode. Proper care was, however, taken to clean and wash the waverider buoy thoroughly with fresh water and acetone. As described earlier, all the pits were filled with resin-hardner and air-dried for 48 hours before applying the zinc rich zinc chromate primer paint. Three coats were applied after air-drying

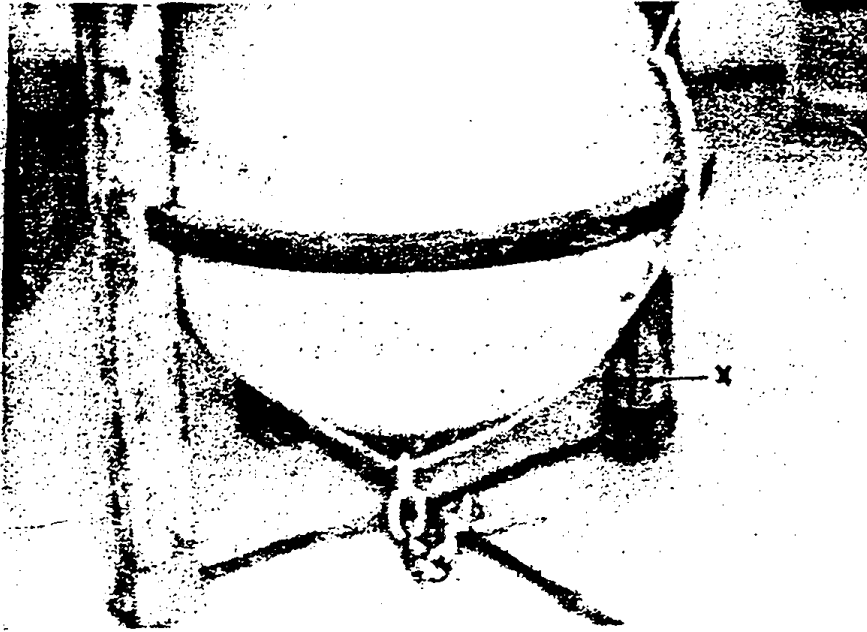


FIG. 8. X CORROSION OF WELD DEPOSITS AROUND EYE.

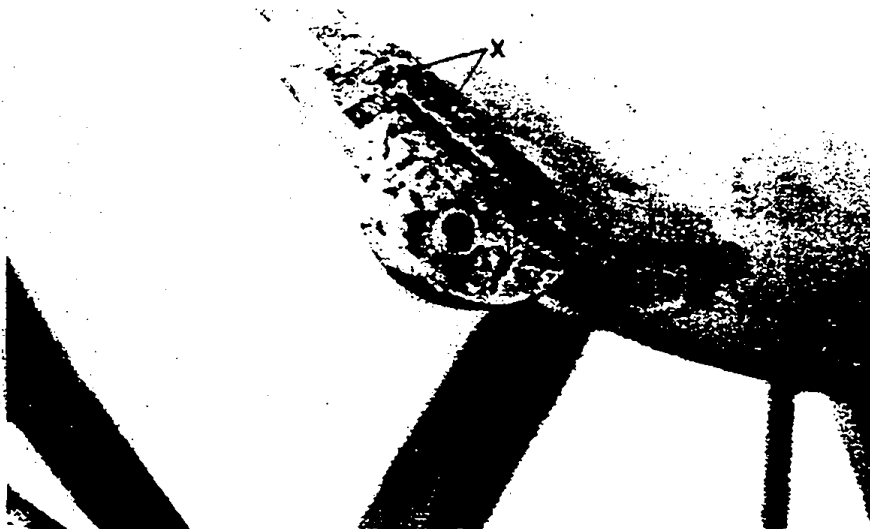


FIG. 9. STANDBY SAFETY LINE (X) PASSING THROUGH THE STABILIZING CHAIN.

each layer of paint. The dry film thickness of the paint varied between 150 to 200 microns.

Second retrieval:

The buoy was recovered after another one and half months of continuous operation at sea. The buoy hull was found to be free from fresh corrosion attacks. The entire protective sacrificial paint coat was found to be free from deficiencies such as pin holes, peeling off due to poor adherability and localised corrosion attacks etc. The buoy hull was found good enough for another 2 - 3 months. The same buoy was re-deployed by opening and refilling the pits with the same filler material and repainting the hull after removing the earlier paint coat as a precautionary measure.

Third retrieval:

The third retrieval during the end of monsoon was the last retrieval at the end of the wave measurement programme. The sacrificial paint coat on the hull surface was found still strong enough for further exposure to marine environment. But the unpainted hardwares and stabilising chain were subjected to moderate attack of corrosion.

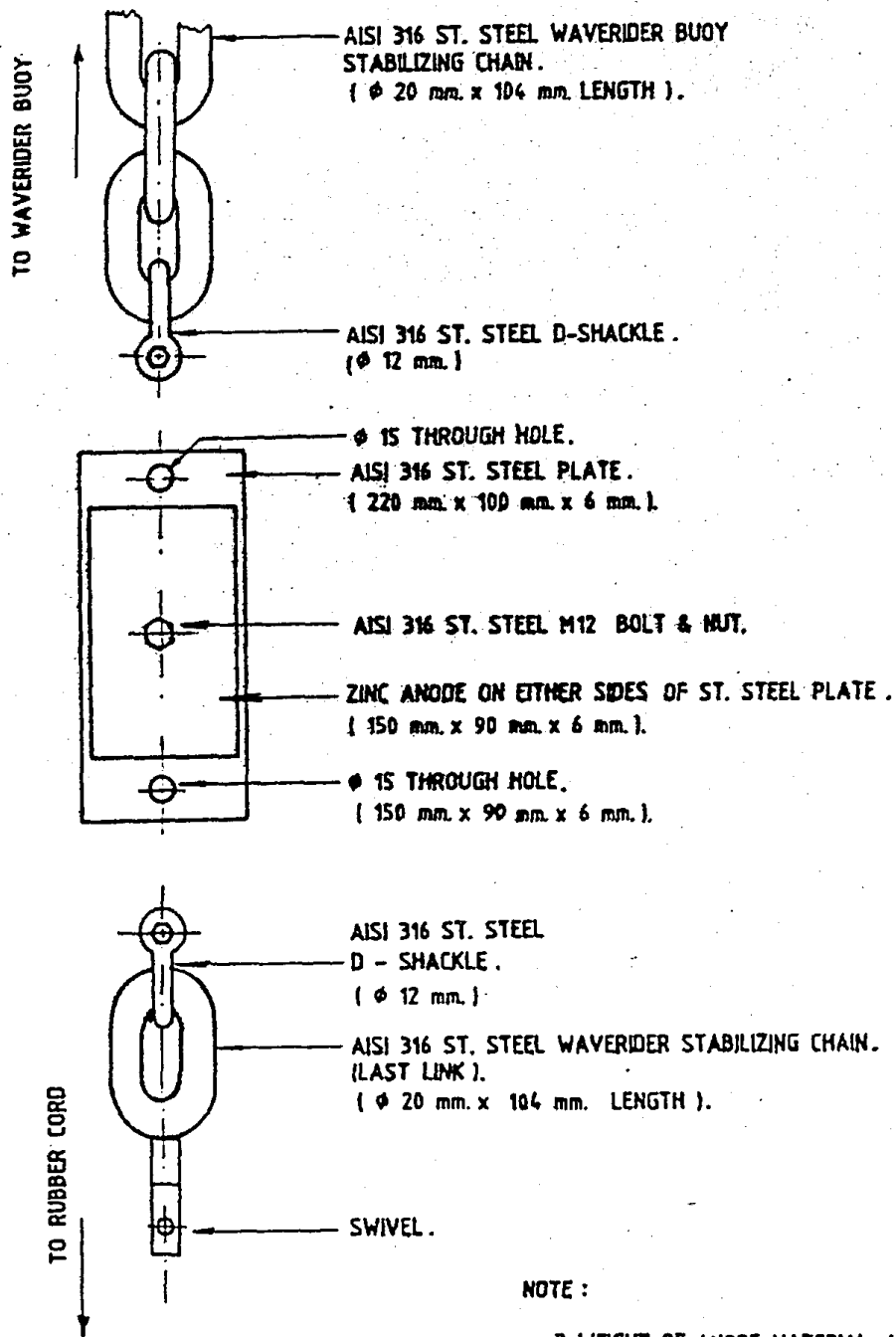
CONCLUSIONS

Long-term continuous wave data can be collected by increasing the life of waverider buoy and its mooring system by taking suitable protective measures against corrosion.

The zinc rich primer was found to give good protection against corrosion of the stainless steel surfaces and components by acting as an effective sacrificial anode for about 4 to 5 months. A coat of anti-fouling paint over this is recommended to prevent marine growth on the buoy hull. The cathodic protection using sacrificial zinc anode is recommended for long-term operation of the waverider buoy at sea. Fig. 10 shows the recommended cathodic protection system for type 316 stainless steel waverider buoy painted with sacrificial paint on its entire surface. A sacrificial anode of zinc weighing about 1.2 kg is suggested for operation of the buoy for one year. The performance of 90/10 Copper-Nickel alloy buoys were found to be excellent under identical marine environment.

Previous attempts by the Institute of Oceanographic Sciences, U. K (Humphery, 1982) to fill these pits by type 316L stainless steel electrodes by welding process resulted in rupturing of the accelerometer sphere due to welding heat. As the welding temperature with 316L electrode falls in the range of 500-700 °C, special care has to be taken while welding the individual pits on the hull around the accelerometer sensor. In order to prevent damage to the accelerometer sensor caused by welding heat, it is necessary to dismantle the accelerometer sensor by removing the foam around it and isolate the accelerometer sensor from the welding zone. After completion of the welding, the accelerometer sensor can be refixed again in position.

It is recommended to use type 316 stainless steel hardwares in the mooring. If galvanised steel components are used in the mooring necessary allowance to cover the corrosion losses has to be provided. Fig. 11 shows cathodic protection used at N.I.O. on type 316 stainless steel D-shackles by clamping a zinc sacrificial anode.



NOTE :

$$\frac{\text{WEIGHT OF ANODE MATERIAL (KG)}}{\text{CURRENT (A) \cdot DESIGN LIFE (yrs) \cdot 8760}} = \text{CAPACITY OF ANODE MATERIAL (A hrs/kg)}$$

1) REDUCE FEW LINKS FROM THE STABILIZING CHAIN EQUAL TO THE ADDITIONAL WEIGHT INTRODUCED DUE TO THE ATTACHMENT OF CATHODIC PROTECTION SYSTEM.

FIG. 10 CATHODIC PROTECTION SYSTEM FOR TYPE 316 ST. STEEL HULL WAVERIDER BUOY. (Disassembled View).



FIG. 11. X SACRIFICIAL ZINC ANODE
PROVIDED ON 316 S.S. SHACKLE.

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