

defects, particularly the tiny holes, could serve as sites for the commencement of the localized corrosive attack. This is because the defects could set up the anodic and cathodic reaction processes within the test environment which would, invariably, enhance the corrosion of the steel by anodic dissolution and paint stripping by underfilm corrosion.

4.2. Potential measurements

From the above-described results, it could be explained that the immediate decrease in potential after immersion might be due to the chemical reactions occurring at the specimen/solution (cassava juice) interface. The reacting species in the juice, by diffusion process, seems to have set up a chemical reaction with the epoxy paints and penetrated through pores to the metal surface immediately after the immersion of the specimens. This probably caused some of the paint stripping from the specimen's surface by underfilm corrosion. The unpainted specimens were immersed immediately after grinding or machining. This meant that an almost bare fresh surface had been exposed to the test environment. The effect then was that of immediate anodic dissolution reaction at the specimen/solution interface. The observed trend for all the specimens mentioned above at this initial stage was that of active corrosion, though it was more pronounced with the unpainted specimens, as expected.

As indicated in Figs 3-5, the overall corrosion behaviour profile was that of increasing negative potential with some repassivating potential fluctuations probably caused by unstable corrosion

deposits. The acidic nature of the test environment, with a pH of 3.90, appeared to have prevented the passivation of the test specimens' surface by corrosion deposits or hydroxyl-formed film.

4.3. Effect of number of coats of paint

It is very difficult to say precisely why there has been loss of adhesion and consequent coating failure on the specimen surface in contact with the cassava juice, despite the varied number of applied paint coatings. However, some of the explanation given earlier in sections 4.1 and 4.2 are considered to be reasonable explanations of this phenomenon.

Conclusion

1. The cassava juice, with its hydrocyanic acid content, is very corrosive to the mild steel. The CN⁻ ion reacting species could penetrate the air/hydroxyl-formed oxide film and/or penetrate through defects in the painted surfaces by a diffusion process to initiate corrosion reactions.
2. The zinc-rich epoxy paint is more protective on the steel's surface than the red Dulux paint. This is believed to be due to the zinc content of the paint that protects the steel cathodically.
3. In this investigation, the overall protective effect of the paints on the steel's surface in the cassava juice environment was minimal, particularly from the red Dulux paint which was less protective.

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A device to study biofouling and corrosion from fixed offshore platforms

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METHODS TO STUDY biofouling and corrosion in shallow coastal waters cannot be used in deep offshore waters because of the greater depths and more hazardous conditions. In this paper, a method is described using which test panels can be exposed in such environments and retrieved with minimum time and effort. The method has been successfully tried and confirmed reliable at an offshore location in the Arabian Sea.

Introduction

Exposure of test panels is a simple and effective way of providing data and monitoring biofouling and corrosion in marine waters (Richards, 1977). For the prediction and effective control of marine growth, reliable information on the reproduction

and growth of the organisms concerned is an essential prerequisite. The use of experimental panels is one of the practical means of collecting this information (Hillman, 1977). Different techniques have been used by various workers in different parts of the world (Cory, 1967;

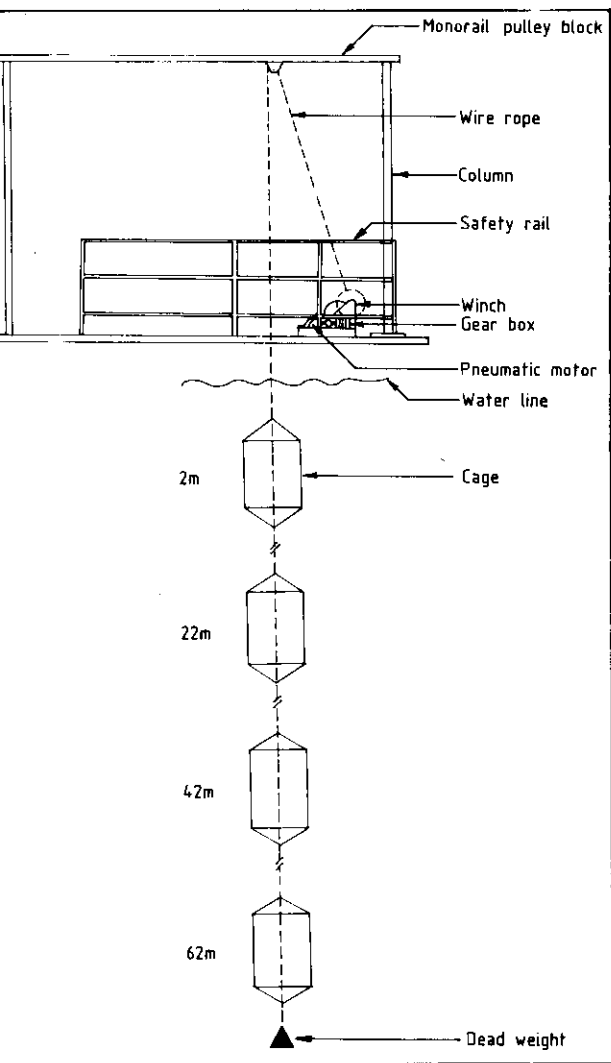


Fig. 1. Schematic diagram depicting the working platform including the winch, gear box, motor, cages, etc.

Balasubramanyan et al., 1968; De et al., 1968; Haderlie, 1968; Nauman and Cory, 1969; Frame and McCann, 1971; Hillman, 1975; Grovhoug and Rastetter, 1980 and Dahlem et al., 1984). Most of these studies have been conducted in the coastal localities (where the water depth does not exceed a few metres) and the techniques used are quite sufficient to serve the purpose. For deeper offshore waters, buoyed arrays containing floats of different sizes have been made use of (DePalma, 1972; Pequegnat and Pequegnat, 1972). The inherent drawback of this system is that retrieval and changing of panels is difficult and time consuming.

Studies of fouling of far offshore localities became a necessity with the advent of offshore oil and gas production platforms. These platforms, which have a life span of about 20 to 25 years, accumulate biofouling subsequent to their installation. The marine growth is detrimental to the integrity and safety of the platforms (Heaf, 1981; Kingsbury 1981) and therefore requires detailed studies with respect to its qualitative and

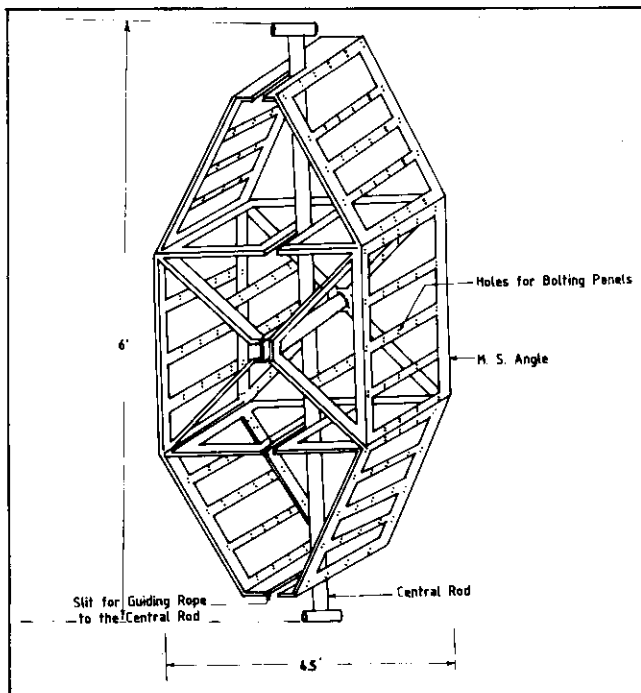


Fig. 2. Schematic diagram of a single steel cage.

quantitative aspects. Most of the studies conducted on the fouling of offshore platforms have been done by scraping the fouling material that has developed on the underwater structures of the platform since its installation or blast cleaning, and drawing conclusions based on the material thus collected. This kind of data collection does not give any information on the variations occurring on a shorter time scale or the yearly buildup of biomass, for which the classical test panel exposure is best suited. However, techniques used to study biofouling in shallow waters cannot be used here because of greater depth and more hazardous conditions. An ideal method should be safe, easy to use and must not require more than 2-3 people to operate.

We had an opportunity to study the various aspects of an offshore oil production platform situated in the Bombay High area of the Arabian Sea, where the water depth was about 80m. A technique which could be used to deploy and retrieve panels with minimum time and effort has been developed and successfully tried in these waters for a period of three years. In this paper, we describe the technical aspects of the device and its practical application.

Details of the technique

The investigations were carried out in the Bombay High area of the Arabian Sea, about 170km WNW of Bombay. An oil producing and processing platform was used as the station. A suitable place on the lower-most deck of the platform (boat landing) was selected as the work

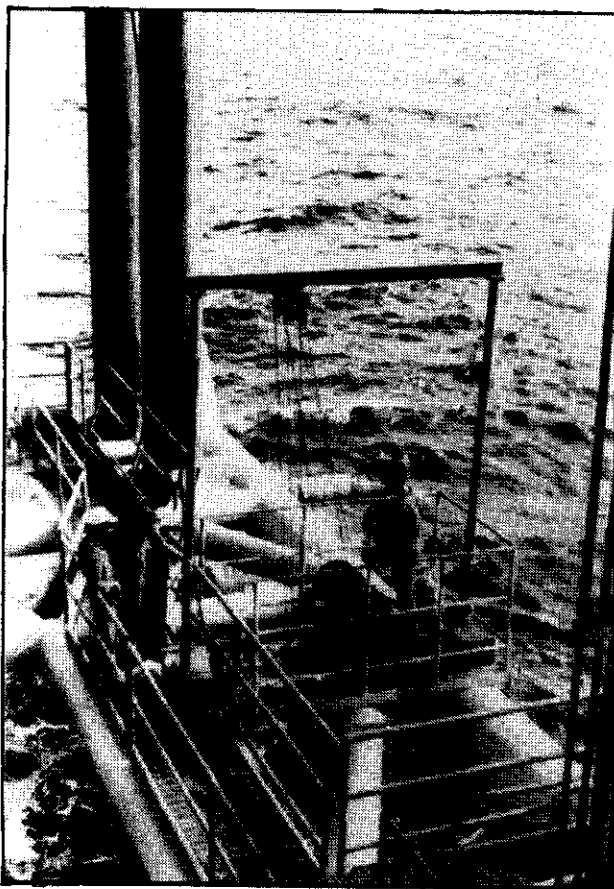


Fig. 3. Study site showing the working platform.

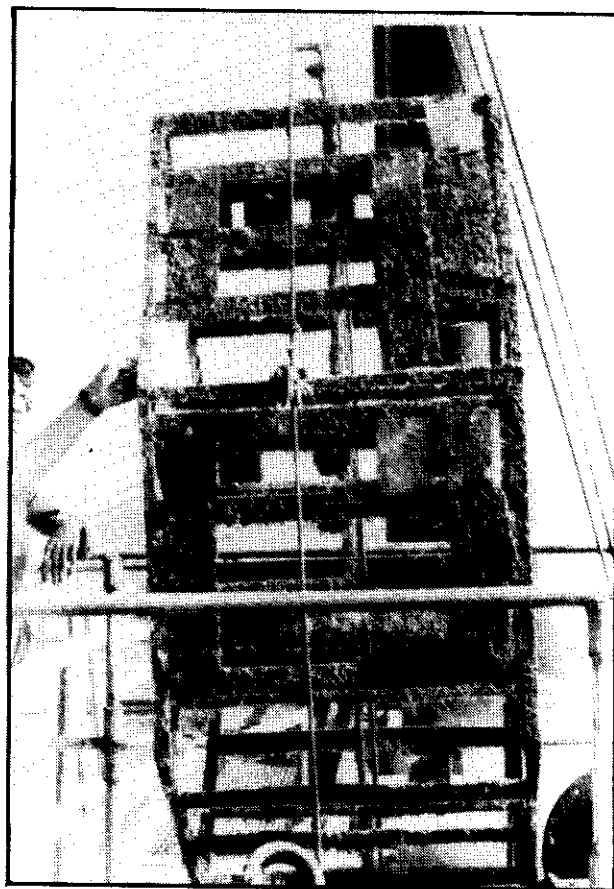


Fig. 4. Steel cage with the test panel.

site. Since the work envisaged lowering of racks containing the experimental panels down to a depth of more than 60m, an unobstructed column of water which was well within the physical structure of the platform had to be found. This was done by consulting the architectural design of the given platform. Here a small working platform was constructed with safety rails all round (Figs 1 and 3). The floor of this working platform was secured with chequered plates with a rectangular opening (3.5ft \times 3ft) in the centre. Two steel columns of about 10ft height were bolted to the two narrow ends of the working platform. To these columns was attached a horizontal beam (monorail pulley block) with a brass pulley in the middle in such a way that the pulley, was located exactly above the middle of the opening of the working platform.

Four massive steel cages, further details of which are given below, were suspended for exposing the test panels at the four depths, i.e. 2, 22, 42 and 62m. The cages were suspended from the horizontal beam using 8-mm wire rope. The wire rope, after passing through the pulley was wound to the drum of a winch which was securely bolted to the chequered plates on the floor of the working platform. The winch was connected to a custom-built two-way pneumatic motor (the use of an electric motor was ruled out as it involves fire

hazards on an oil platform) through worm reduction gears. The motor was operated with the help of compressed air at 1000 psi available on the platform. The motor was detachable from the shaft of the reduction gear, where a handle could be connected for manual operation.

The steel cages, which have a side view similar to that of an elongated hexagon (see Figs 2 and 4), were designed in such a way that test panels could be exposed in different orientations with respect to the sea surface, such as horizontal, vertical and angular (30°, 45°, 60°, etc.). Such angles had been provided to simulate the crossmembers of the platform jacket which were angular in orientation. Steel was selected as it adds to the weight of the

Table 1. Biomass of fouling on panels immersed for one year (expressed as kg-m⁻²).

Depth (m)	Mean biomass	S.D.
<i>Mild Steel</i>		
2	9.25	3.71
22	8.17	1.79
42	1.10	0.53
62	0.34	0.23
<i>Aluminium</i>		
2	7.09	1.44
22	10.29	4.43
42	1.18	0.25
62	0.59	0.49

structure; other materials such as aluminium would have caused excessive and undesirable swinging of the cages underwater due to their lightness. The whole structure was built around a central rod, which could be attached along its length to the wire rope with the help of two 2.5-in clamps. For this purpose, an access slit was left on one side of the cage, through which the central rod could be brought into contact with the wire rope for clamping. Each of the cages weighed about 150kg in air (unladen weight).

Test panels (15 × 10 × 0.3cm) made of mild steel (MS), aluminium and fibre-reinforced plastic (FRP) were attached to the cages using nuts and bolts. MS nuts and bolts were used for MS and FRP panels. In case of aluminium panels, polypropylene nuts and bolts were used to avoid bimetallic contact with the steel frame of the cage.

Lowering and lifting of the cages was a simple operation because of the pneumatic motor. While lowering, the cages were attached, one after the other, to the wire rope and lowered in such a way that each one was exposed at the proper depth. While lifting, the cages were sequentially removed from the wire rope and put aside on the rails of an adjacent catwalk, where the removal and replacement of the test panels could be easily done.

Performance and reliability

The above-mentioned technique was tried and successfully used for the collection of data for a period of about three years (May 1983 to April 1986). The yearly buildup of biomass recorded on the MS panels and aluminium panels is given in Table 1. The data indicated that at the upper two depths, the biomass of the fouling may be as much as 10kg/m² or more.

The technique did have slight problems on two occasions. In May 1985, one of the submerged cages got stuck between the crossmembers of the platform jacket during the process of lifting, resulting in the bending of the horizontal beam. This happened because of strong currents pushing the cage sideways. In January 1986, the wire rope on which the cages were suspended snapped due to corrosion, and the cages fell to the sea bottom. On both occasions the help of divers was sought for the recovery of the cages.

The submerged cages were sometimes seen to be rotating under the influence of currents and waves. We used two side ropes (made of nylon), in addition to the central steel rope, to check the rotation of the cages. This led to problems such as entanglement of the ropes to each other, and therefore their use was subsequently discarded. A single wire rope was sufficient to hold the cages properly, though they did rotate underwater.

The system can be reliably used for the collection of fouling and corrosion data, provided a few points are taken care of. Firstly, the selection of the site on the platform has to be done by taking sufficient precautions. In areas of strong currents, ample space should be available for the cages to swing sideways, but still travel up and down without getting stuck anywhere on the complex underwater structure of the platform. Secondly, the wire rope has to be properly inspected periodically for corrosion breakages. If found defective, it should be removed and replaced with a new one. We found that a good-quality wire rope could be used in Bombay High for a period of 6 to 8 months, after which it had to be replaced.

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