

Role of Ocean Technology in Marine Archaeological Explorations — Perspectives and Prospects

(Keynote Address)

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Much of the material evidence of man's past, historical and cultural life, lies under water. The function of marine archaeologist is to draw conclusions about past societies and communities by discovering, recording, interpreting and preserving the material evidence they have left behind. The main source of evidence is sunken shipwrecks and submerged structures belonging to ancient townships. There has been very rapid development in the frontier field of ocean technology particularly during the last few decades. Better knowledge of marine science and advanced underwater techniques presently available can very well be utilized in the emerging area of marine archaeology. The paper while presenting a general description of various engineering techniques of relevance to marine archaeological explorations, describes some of the simple engineering tools and techniques employed in the underwater explorations carried out by the National Institute of Oceanography, Goa in Dwarka, an important historical and cultural centre on the north-west coast of India.

INTRODUCTION

Marine archaeology is an emerging frontier field of great importance to India. Ship building and other marine activities including overseas trade and commerce have flourished in the country since many centuries thereby contributing to the development of excellent maritime traditions. The main source of man's past historical and cultural life, in which a marine archaeologist would be interested is, the sunken shipwrecks and submerged townships. The remnants of ancient dock and harbour facilities, boat building and repair yards, warehouses, markets, raw materials and manufactured goods and the township created by such activities – all provide extremely useful evidence which a serious marine archaeologist must extract, process and evaluate.

Recent developments in underwater technology and marine surveying techniques have provided excellent means of locating, recovering and preserving the unique information and evidences which such sites contain. It is to be recognised that the tasks associated with the marine environment are many times more expensive than similar activities on land. The farther from the shore, the costlier would be any marine operation. This calls for the necessity of careful planning and execution of marine archaeological explorations.

Better knowledge of marine science, and improved engineering tools and technology presently available can very well be utilized in the emerging field of marine archaeology. In deeper waters, when proper justification can be worked out manned and/or unmanned submersibles could be employed. Sophisticated underwater cameras or television systems are presently available for examination of large number of possible targets as well as for proper documentation purposes.

The paper while giving a general description of relevant marine technology and engineering tools of importance to marine archaeological explorations, presents a brief discussion on the simple engineering tools adopted during Dwarka exploration on the north-west coast of India (Fig. 1).

During the investigations in Dwarka water, remnants of various structures indicating the past habitation and ancient township were discovered at the shore cliff, in the intertidal zone as well as in the nearshore zone of Bet Dwarka.

DIVING WORK FOR UNDERWATER EXPLORATIONS

Problems of Working in Underwater Environment

Due to the effect of weight-loss caused by buoyancy effect and as the diver has to carry with him the breathing apparatus, a wet or dry diving suit, a mask to allow clear vision, fins for propulsion, weight to ballast him, and a life jacket to afford him safely to the surface should he get into difficulties, man working in an underwater environment becomes less efficient than he would be on the surface. Diver will also, to some extent, feel the effects of heat loss (Hypothermia), and if he is working at a depth below 10 m, he may experience the effects of nitrogen absorption in his tissues which will impose limitation on his capacity to work underwater and requirement of costly de-compression facility. Breathing air under pressure can produce narcotic effect of nitrogen on the nervous system which will increase with depth. The physiological and psychological effects combine to decrease the efficiency of the diver significantly.

It would therefore, be necessary to devise simple engineering tools and techniques for divers to operate for underwater explorations and excavations in archaeological work. He can use an

adjustable frame to steady himself and use the condition of water at the site to work for him rather than against him.

Diving System

An adequate support facility on an anchored barge or boat will be required for diving operation. It is often convenient to use a low-pressure surface demand diving system in preference to the commonly used self-contained scuba diving system which involves the use of high-pressure air tanks strapped to the diver's back. Surface demand system requires a small compressor on the surface, say a boat for supplying necessary air to the diver through a flexible air pipe. It relieves the diver from the bulky encumbrance on his back. It also permits divers to complete long schedule underwater particularly in shallow depths without the worry of running short of air or inconvenience of changing tanks half-way.

The main disadvantage of a surface demand system is that it restricts the movement of the diver due to limited length of the supply air-hose. But in archaeological work which is generally

confined to a small and closely defined areas, this will not be a problem. The scuba diving, however, would, therefore, be indispensable for marine archaeological search operations where much greater freedom of movement is desirable than that can be provided by the surface demand system.

For explorations in Dwarka waters both the above systems of diving were employed successfully. Experience showed, however, that surface demand system is better suited for explorations connected with submerged township there and retrieval of building blocks. Locally available fishing boats were used to act as surface support platform for divers and archaeologists.

Underwater Equipment

The equipment needed for marine archaeological explorations should be thoroughly tested before being taken to the field so that avoidable wastage of time at the site should be avoided at all cost. Improvisation of techniques and tools may, however, become necessary at a given site depending upon the given situation.

Compressors, air-lifts, dredges and pumps, boats and engines, lifting gear, diving equipment, containers for storing the underwater finds, survey equipment, cameras, drawing boards, stationery, records etc. are some of the major items required for the underwater work connected with marine archaeology.

Drawing and Photography

Divers can carry out underwater drawings on a board with a grid ruled or etched on it on a suitable scale. An example of the stainless steel grid used in Dwarka explorations is shown in Fig. 2. Underwater cameras should be used for obtaining photographic records of various objects and underwater operations. Photogrammetric surveys can be extremely useful for documenting shipwrecks and submerged structures under *in situ* condition particularly in nearshore shallow waters. Aerial photographs can provide essential reference material. They facilitate target search and surveying as in the case of Dwarka exploration works where underwater camera was also extensively used.

Engineering Techniques for Search Operations

When an underwater search area of probability and likely characteristics of the target have been assessed, a suitable search technique has to be selected. An evaluation of the water depth, waves, currents, tides, degree of exposure to the open ocean conditions, sea bottom soil conditions, sediment suspension and movement, seaweeds, underwater visibility etc. which would have influenced the characteristics of the target is, therefore, very important. This is also important in planning and execution of the search operations.

Position Fixing Methods

Simple triangulation survey method can be used for fixing positions in the nearshore areas using surveyors transits or a plane table. A base-line of known length has to be fixed on a level ground on the shore and offshore positions can be identified by surface marker buoys. Relative position of these marker buoys with reference to the base-line can then be determined by triangulation and plotted. A nautical sextant generally used by marin-

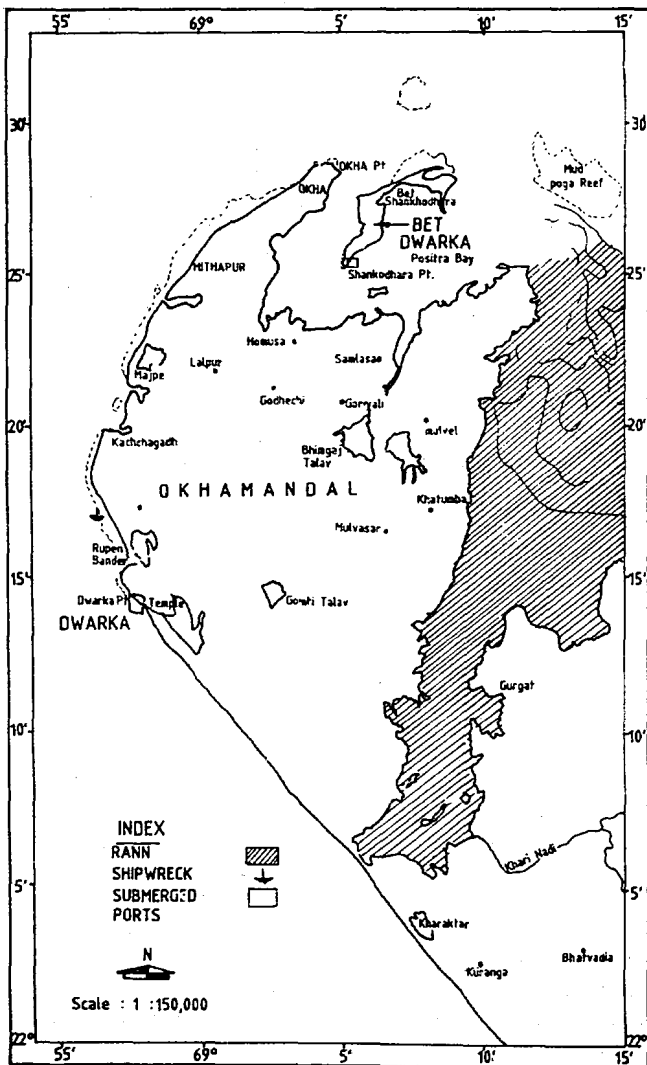


Fig. 1 Map indicating position of Dwarka and Bet Dwarka.

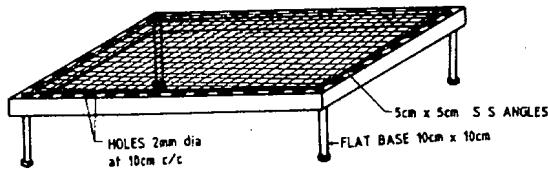


Fig. 2 Stainless steel underwater drawing grid used in Dwarka underwater explorations.

ers can also be used to fix the position of boat with reference to the known shore features or monuments such as light-house, buildings, chimney, TV or Radio towers etc. The above simple triangulation methods were extensively used in Dwarka site explorations.

When an accurate and efficient system of position fixing and plotting on a continuous basis is required for a sophisticated search system using geophysical techniques, an electronic position fixing system can be used. One such position fixing system which is portable and easily handled is Motorola Mini Ranger system. This system needs two or more transmitting stations at known points from which a continuous distance read-out is displayed and/or recorded from a receiver/recorder kept in the survey boat.

Search Techniques

When easily identifiable features such as the shoreline, a river bank or a reef are available at or near the search areas, visual prospecting by small groups of waders, swimmers or divers can be effective and useful as experienced in Bet Dwarka waters. Larger open areas can be covered by searches by divers using a suitable grid. Much large-scale search can now be carried out from a surface boat using a variety of electronic devices normally used by marine geologists and geophysicists. Brief description of these instrumentation systems are given below:

Proton Magnetometer

The simplest electronic device which can be of immense value to a marine archaeologist is the magnetometer which senses the strength of the magnetic field in its vicinity. Magnetic anomalies can be set up by wreck sites containing iron in the form of hull fastenings and fittings, ballast, ancient cannons, anchors etc. Systematic measurement of magnetic fields in the target area may yield one or more "high spots" which can then be checked visually by divers. Remote controlled video-cameras may be used as an alternative to divers in checking out protruding objects causing high magnetic anomalies particularly in deeper waters.

Side Scan Sonar

When wrecks or features protrude above the seabed, and the seabed otherwise is reasonably flat, side-scan sonar offers itself as the most efficient searching tool now available. Side scan sonar picks up and records an oblique sonar shadow of the features on the seabed thereby giving a plan-view of the seabed. This technique can be extremely sensitive and remarkable "pictures" of deepwater ship wrecks have been obtained in which details of hull, masts, and rigging could clearly be identified

(Rosencrantz, *et al.*, 1972).

Sub-Bottom Profiler

This is a bottom-penetrating vertical sonar system. Lower frequencies are used for obtaining better penetration of the acoustic signal in the sub-bottom soil layers. Sub-bottom profiling gives records of the stratification of subsoils below the seabed in which the varying densities of sediments and more dense features within them can be easily identified. This technique has a great potential for finding and surveying underwater buried sites of archaeological interest.

Various electronic search systems described above can be used singly or in combination depending upon the nature of the target and the resources available. They should however, have to be supported by an accurate and efficient system of position fixing and plotting as mentioned herein before.

PRE-DISTURBANCE SURVEYS

In marine archaeological explorations, it is important to document all information and data at the sites on the seabed or on the shore as observed in the undisturbed condition. Simple triangulation survey methods generally adopted on land can conveniently be used underwater also. Fixed base points can be set up by driving steel rods or by using natural sea-bed features when available. Fibreglass tapes can be used for measuring distances. Simple 3-4-5 rule can be used for setting right angles. Rough levels can be obtained using a shotline. Care must be taken to correct for tidal fluctuations. A datum point should be marked clearly and permanently on a firm base close to the site. This datum has to be tied to the Chart Datum.

Once the initial surveys by the divers are complete, magnetometer and/or side scan sonar and/or sub-bottom profiler can be used for more detailed surveys depending upon the requirements. Probing by divers can be a useful technique for obtaining useful information at a site. A 5 mm M.S. rod sharpened at one end and with a T-shaped handle at the other can be worked by hand into a metre or more of the sea-bed sediments.

Core sampling generally adopted by marine geologists and engineers is a useful technique for obtaining samples for studying soil stratification and other characteristics. Deeper soundings can be taken with a jet probe which consists of a thin-wall tube of about 2 cm internal diameter connected to a water pump at the surface by means of a flexible hose. The water-jet at the probe end displaces the sediments to facilitate movement of the pipe downward by displacing the loosened sediments upwards.

EXCAVATION AND RECOVERY TECHNIQUES

Excavation Tools

Excavation tools for marine archaeological studies have to perform two major functions namely, they must provide a means whereby archaeological deposits are properly revealed and they must transport the spoil efficiently to a suitable dump away from the site. Spoil can be transported from the excavation area using a water dredge as illustrated in Fig. 3 (Martin, 1981). This provides a light but effective suction at the excavation end and will carry the spoil to the exhaust pipe. Water dredge operates effi-

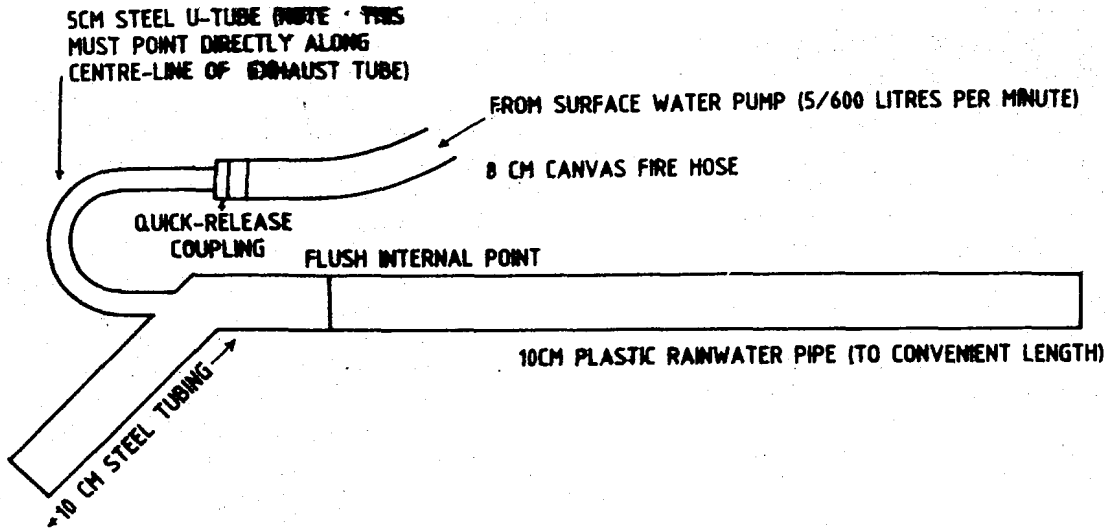


Fig. 3 Water dredge for disposal of excavated spoil.

ciently only in the horizontal position as it has very limited suction power.

Powerful suction can be provided by using an air lift as illustrated in Fig. 4 and 5. Airlifts type-A shown in Fig. 4 with 10 cm dia - one made of stainless steel and another of mild steel were extensively used to excavate sea-bed material at Dwarka site for revealing the building stones and submerged structures belonging to some ancient township. Soil water mixture was lifted to the surface by suction and then ejected into a large container with overflow arrangement installed on a suitable boat at the site. From the spoil it was possible to collect useful evidences in the form of pottery, shells, seal etc. An open-ended collapsible caisson as illustrated in Fig. 6 was placed on the seabed to support the sides of the pit being excavated using compressed air lift. The caisson was made of mild steel and the size used was 2 m X 1.5 m X 1 m.

Recovery Techniques

Small objects can be handled manually by divers and brought to the surface. Large boulders can be handled by slinging them and hauling them up by means of a suitable winch and derrick from the boat. Air-bags with compressed-air facility can also be used to lift the big objects using buoyancy effect under water. Small rocks and objects can be piled into a spread net and lifted up manually or handling gears on the boat. Big objects and ship wrecks can be lifted using specially designed pontoons and compressed air facility as illustrated in Fig. 7 (Frazen, 1972). Most of the building blocks found in Dwarka waters could be recovered using simple slinging and hauling method from a boat with the assistance of divers on the sea bed.

In the past few years progress in under water technology has been very rapid mainly due to the engineering activities connected with exploration and exploitation of offshore oil and gas. The day is not far off when marine archaeologists may be able to use much more advanced techniques and effective methods when they have to look for ancient ship wrecks with valuable materials in deeper and deeper waters.

Submersibles in Marine Exploration

Ships from every period of antiquity can be found in the shallow as well as deeper waters in the ocean. Here let us look into highly advanced search systems which could be very valuable for marine archaeological explorations, particularly when cost of such underwater work may not be a major consideration in view of the high value of the ship-wreck or the underwater object. The manned and unmanned submersibles have been playing a vital role in underwater exploration and exploitation tasks with particular reference to offshore oil and gas.

Manned Submersibles

The introduction of diver lock-out (DLO) manned submersible has heralded a new era in underwater technology. A DLO manned submersible has two separate crew compartments - one for the divers which can be pressurised like a diving bell and the other at atmospheric pressure for the pilot, observer and the diving supervisor. With this provision an underwater inspection engineer or marine archaeologist can be taken down to the work site in a warm, dry, atmospheric pressure environment to direct the underwater task to the divers. Fig. 8 shows a typical schematic layout of a manned DLO submersible. The archaeologist would be able to take on-the-spot decisions and guide divers properly. However, the manned submersibles are not suitable for long duration of underwater operations. They lack the power requirement to support the divers for long periods against Hypothermia. Handling and transportation of the manned submersible is difficult due to their bulky sizes. This needs special type of mother ship for handling and operation.

Unmanned submersibles

The unmanned submersibles are remotely operated vehicles (ROVs) and they rely on close circuit T.V. (CCTV) system for underwater inspection works. A survey on inspection can thus be recorded on video tapes for subsequent viewing. Thus, a decision on the work site is delayed. The subsequent operations

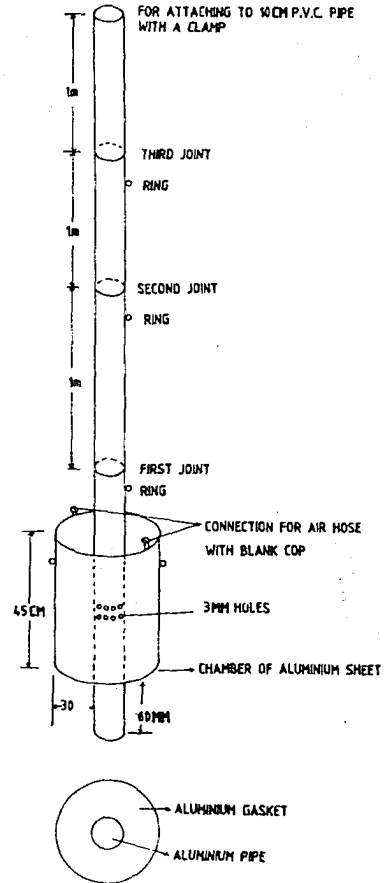
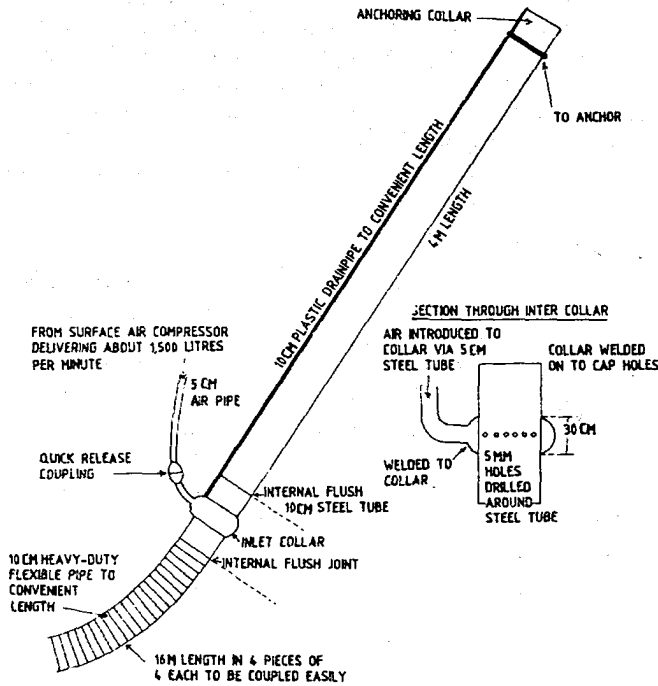


Fig. 4 Airlift Type-A employed in Dwarka archaeological explorations in India. Fig. 5 Airlift Type-B for lifting spoil vertically upwards.

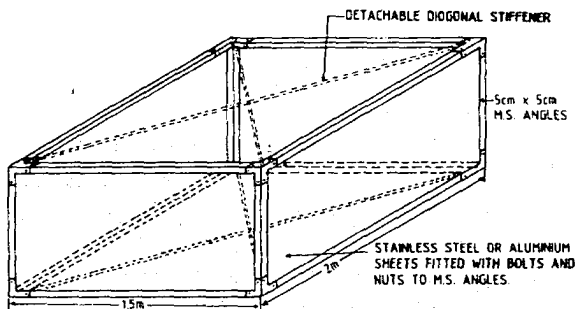


Fig. 6 Open ended collapsible box-type caisson used in Dwarka underwater explorations.

which are dependant upon CCTV recordings can be done only after viewing the video tapes.

The main advantage of an ROV is that it is easily transportable and can be deployed either from a medium size vessel or from a fixed platform. The most recent trend developed in ROVs is to reduce their physical dimension and weight by using two types of vehicles. The first is a small, light weight vehicle purely for observational and documentary purpose. This could be a handy and useful equipment for marine archaeological explorations. The second type is a larger, heavier and more powerful work vehicle equipped with manipulators.

Fig. 9 illustrates a schematic view of a typical low cost ROV. Most tethered ROVs weigh less than 550 kg. All tethered ROVs run on surface supplied AC power either from ship's power or from a dedicated diesel generator. Umbilical cables which carry power and communication links usually are single units with one or three co-axial conductors. Most of the ROVs have electric or hydraulic thrusters. Commonly, ROVs are equipped with B&W

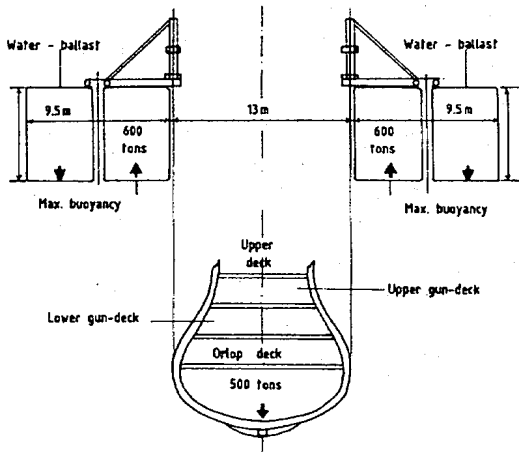


Fig. 7 Method adopted for lifting a wrecked Swedish warship using pontoons (Franzen, 1972)

television cameras, Quartz Iodide Malogen lights, 35 mm still cameras (some have stereo photography camera) and one or two manipulators. Standard gear includes echosounders, scanning sonars, sub-bottom profiler, directional hydrophones.

Simple low cost ROVs with closed circuit television camera

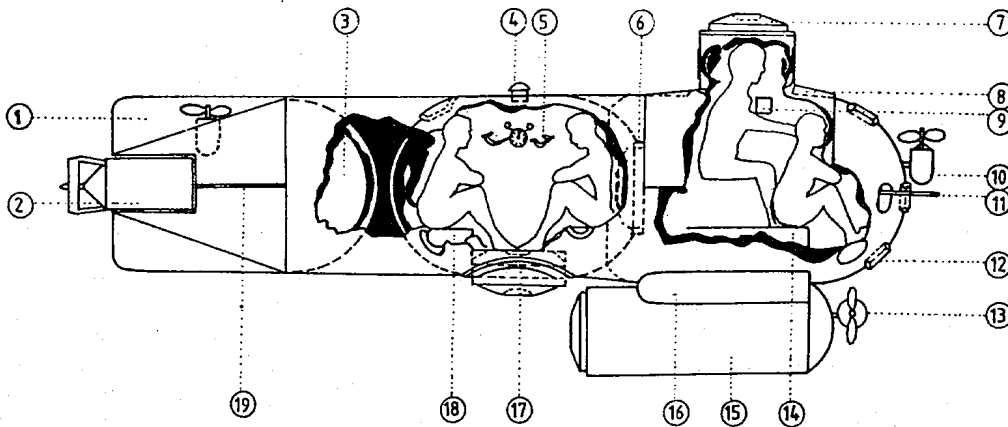
system with a television monitor on the surface boat would be very valuable equipment.

CONCLUSION

In this paper a general description of various ocean engineering techniques and tools that can be employed in the emerging area of marine archaeology have been presented. Marine archaeology can take advantage from the rapid advancement in marine science and technology which has taken place during the last couple of decades in regard to underwater search, excavation and retrieval of the objects. Special reference has been made in respect of the engineering techniques and tools employed in the marine archaeological explorations undertaken by the National Institute of Oceanography, Goa in Dwarka and Bet Dwarka waters on the northwest coast of India.

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| 1. VERTICAL STABILIZERS. | 6. INTER COMPARTMENT HATCH. | 11. BOW PLANES. | 16. HIGH PRESSURE AIR. |
| 2. 180° MAIN MOTOR | 7. HATCH. | 12. VIEW PORTS. | 17. DIVER EGRESS HATCHES. |
| 3. LIFE SUPPORT GAS STORAGE SPHERE | 8. MAIN BALLAST TANKS. | 13. HORIZONTAL BOW THRUSTER. | 18. VARIABLE BUOYANCY TANKS. |
| 4. MEDICAL LOCK. | 9. CONTROL BOX. | 14. TRIM TANK. | 19. HORIZONTAL STABILIZERS. |
| 5. EMERGENCY BREATHING APPARATUS. | 10. VERTICAL BOW THRUSTER. | 15. DROPPABLE BATTERY COMPARTMENT. | |

Fig. 8 A typical driver-lock-out manned submersible.

ROLE OF OCEAN TECHNOLOGY IN MARINE ARCHAEOLOGICAL EXPLORATIONS

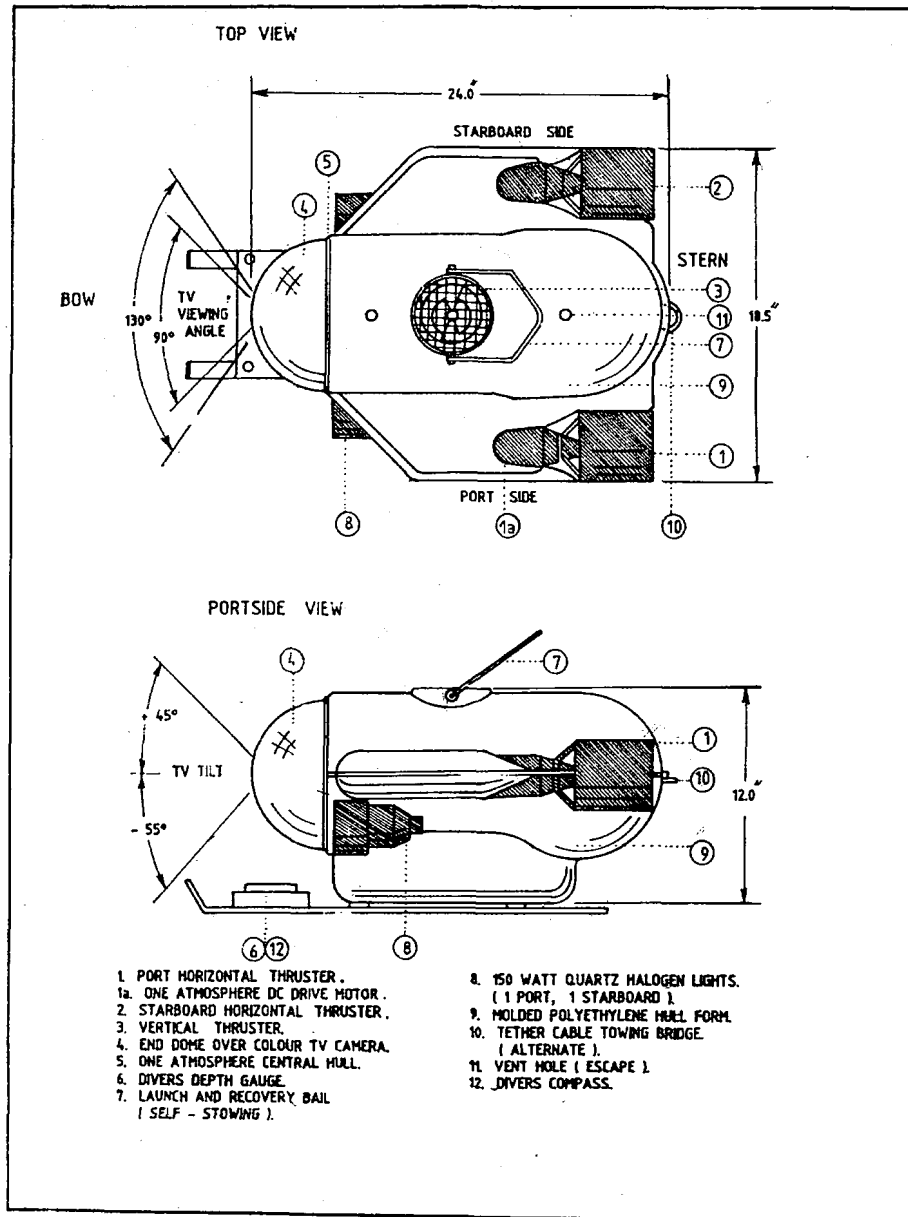


Fig. 9 A typical low cost ROV.

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