

Guidelines to Amateur Divers Working on Archaeological sites Reconnaissance and Excavation in water

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Working in a three dimensional fluid environment where you are virtually weightless and often in low visibility but still expected to carry out a range of skilled tasks, can often get tricky. This paper outlines a few basic techniques such as search patterns in different water conditions, the use of simple natural navigation and recovery techniques. Rigging and lifting of objects with lift bags along, bouyancy calculations to provide a successful lift are iterated. In archaeology it is important to emphasize that however scattered the contents of a site may appear the distribution is due to a logical sequence of events/forces that have acted on the material. It is also essential to know the relative positions of all objects. The need for good navigation and planned search activity and good communications are essential for a successful excavation.

INTRODUCTION

Ever since man first saw the sea he has been enthralled by it. He swam in it, he built boats, constructed ports from which to run foreign commerce. Eventually a large extent of his civilization revolved around the use of the sea. Today the most prosperous cities of the world are coastal cities. This great biomass of marine life feeds us. The endless reaches of the waves give us a cause to wonder. Yet in all this pre-history, we had no knowledge of what was below the thin layer of surface tension. Tidal waves, sea level rises and other natural phenomena devoured many a civilization and after man's attempts to breathe compressed air we are now in an age in which we can come in contact with the ocean floor and even explore our past. The paper is a series of facts that promote practical working knowledge and experience on search and recovery underwater.

DIVE PLANNING

Adequate dive planning involves two components

- Familiarization
- Assessment

Familiarization is collecting enough information about the diver and the dive site to make a valid assessment. For making an assessment you need to be familiar with your divers, their capacity, the dive site location and prevailing weather conditions. Dive site familiarity comes about with prior experience, on site orientation dives, making of maps with significant features above and below water including contours of underwater terrain. Entry and exit locations need to be marked and colour coded bouys which mark different locations, need to be put on so that relative positions can be plotted from land. Planning will probably allow a more con-

trolled tour and enable efficient management and search in the event of an emergency. It would also develop general awareness and navigational skills.

Assessment of the environment i.e. factors that constitute acceptable conditions are relative and dependent on the experience level of the group. It is firstly essential to get weather information from TV, radio and newspapers. Most weather conditions are due to the interaction of warm and cool air masses which are affected by the earth's rotation. At the sea surface the pressure is 29.92 inches of mercury (1013.2 millibars). The variations in this pressure are due to cold air sinking and creating high pressure areas and the warm air rising to create a low pressure region. As pressure rises it is able to hold large amounts of invisible moisture and as the pressure decreases the air condenses into moisture, clouds and fog. The point here is that high pressure areas are settled weather zones and low pressure areas signal unsettled weather.

The onshore winds develop as a result of temperature/pressure imbalances. As the land heats faster than the sea the hot air rises and the cool air from the sea is pulled in. This sea breeze intensifies into the late afternoon. As the land begins to cool this sea breeze will drop and dissipate at night. This phenomena is important for dive planning in mornings when calm wind conditions are encountered. Diving should not be attempted until weather, tides, currents, sea state, and visibility are studied. Currents which usually affect divers are localized and caused by tidal exchange. As a general rule high tide yields the best visibility. On days when there is a great variation between high tide and low tide, logically speaking, on these days vast amounts of water are exchanged and the local current will be stronger. Tidal changes in bays can cause significant current problems and poor visibility. Sediment is stirred up by an outgoing tide.

The best visibility is at slack tide – high or low – or an incoming tide. At the same time never assume that the current will go only in one direction, this is particularly true with longshore currents which interact with major oceanic currents. Like on the East Coast of the U.S. the Gulf stream flows from South to North it might seem logical to assume that all currents on the East Coast flow in this direction at all times but this is not true because major oceanic currents are not the only cause of localized currents, in fact localized eddies can develop in the direction opposite to major currents. Local physical features will also affect all this when diving in currents and emphasize working together. Also major patterns of oceanic circulation interact with wind driven waves and are further altered by local conditions. If local guidance can be sought it would help plan for the unexpected. Always have a safety line at the stern, for an incoming diver, specially when there is a current.

Take a high observation point and watch the floatsum and boats at anchor to determine the relative strength and direction of the current. Also the direction of the sub-surface current can be inconsistent with surface currents. The divers can usually sight a maximum current of one and a half knots and that too for a short distance. Therefore, it is important that the current be used as an aid, specially towards the end of the dive. This is an important consideration in selecting entry and exit points. Also if, for instance, a diver is caught in a strong current he must not try and swim against it but maintain positive buoyancy and float with it till help is signalled.

Like a lot of people I consider visibility to be the single most important factor in dive planning.

The factors which affect visibility are

- Weather
- Seasonal variation
- Bottom composition
- Wave action or surge and currents
- Time of day
- Location

Each of the above basically affects the amount of suspended particulate matter in the water column and therefore, light penetration. Rain can stir up the bottom and if it is made of fine silt this will remain in suspension; therefore, hard packed gravel bottoms are usually more desirable. Also run off from rivers contribute high nutrient levels specially in cold waters which would result in plankton blooms. Thermal stratification of water brought about by changes in air temperature can also affect visibility. Usually the interval between 10.00 hours and 14.00 hours offers the best visibility because at higher incidence angles the sun's rays have more penetration; generally angles less than 48° tend to deflect most of the light thereby reducing penetration.

The final thing about dive planning is, be practical about logistical considerations for remote areas; such as transport,

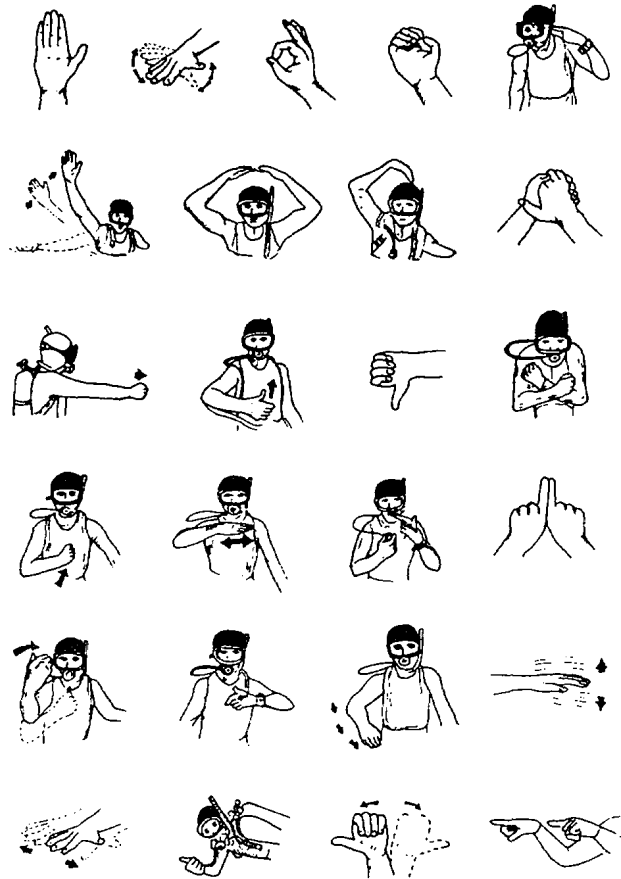


Fig. 1

total self sufficiency and contingency emergency procedure and medical first aid. A planned expedition always has a greater chance of success.

COMMUNICATIONS

Good simple reliable communications save time and add to security. Line signals i.e. number of pulls on the line can convey the status of the recovery operation. Other hand signals are as illustrated.

Signals are usually performed in an exaggerated manner to prevent confusion and all signals must be acknowledged by the receiver to indicate that a signal has been received and understood.

Whistles are also used sometimes, they are reliable and effective limited range devices for surface signalling. A diving whistle should be non-corrosive and attached to the diver in a readily accessible way and used only in an emergency. Whistles work really well when there is a fog or at night when surface visibility gets limited. The big advantage of a whistle is that a considerable amount of noise can be generated with very little energy, and sound carries well over water. Five short blasts is the international distress signal.

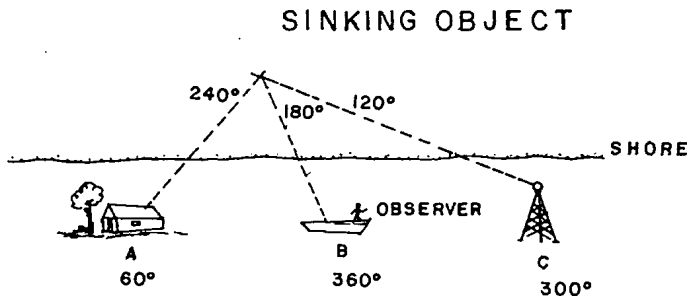


Fig. 2

Long range surface signalling devices are smoke emitters and flares. Flares and emitters don't light underwater but once they are lit they function well even if accidentally submerged.

Surface signalling devices such as strobes, flares, smoke emitters or mirrors are recommended whenever divers are diving in currents that could sweep them past the intended point of exit.

Audible signals have limited use under water. Frequently a rap on the tank with a dive knife is used to get attention. This is usually the signal to say that a diver is surfacing. Underwater slates are the best means of communication. A simple ordinary lead pencil and slate fit into the BCD pocket or on a instrument console. This is the best way of recording and conveying information to a group.

Tactile signals such as line pulls are useful if previously agreed upon.

There is no doubt that the most sophisticated method of underwater communication is by means of electronic transmitters and receivers. These devices use radio waves and allow complete conversations to take place between divers. When precise communication is required there is no better alternative than actual voice communication. Such gadgets are expensive and usually need to be housed within a casing. Whatever your methods of communications are, agree on them before hand. Talk to your buddy who may be from a different geographical location as to what signifies what for the particular dive and please, keep it simple.

PINPOINTING LOST AND FOUND OBJECTS

Shore Triangulation

Look straight ahead at the sinking object then turn your back and find a permanent object directly in front of you. Run down 100 yards to another object repeat the above procedure call this object 'b'. Go back to 'a' plus 50 yards in the opposite direction to 'c' Preferably the objects chosen have a more distinct object behind them. Bearings are taken 'a' 'b' 'c'. The diver needs to swim out from 'a' until 'b' and 'c' are reached. This would be a bearing directly opposite from the one taken from the shore. Now with the known reciprocals

the diver can swim directly out until two points on the shore cross. To double check when the diver sights over his compass along 120° and 240° the sunken object should be directly below him.

SEARCH PATTERNS AND NAVIGATION

Natural Navigation

It is important specially in a three dimensional fluid environment where you are weightless and in limited visibility references are seldom available and a certain amount of sensory deprivation also can contribute to disorientation. The use of natural surroundings for reference increases awareness and sense of direction. Proper navigation can avoid long surface swims, help buddies stay together and maintain a common course. Natural navigation techniques consist of

- (i) Dive Patterns
- (ii) Distance Estimation
- (iii) Use of Natural References

Dive Patterns allow the diver the freedom to explore but at the same time enable him to maintain an awareness of relative position. The basic concept here is to roughly follow a general heading and make distinct right hand turns and remember where each turn places 'you' relative to the end of the dive destination.

Some common patterns that work most efficiently and are simple are out and back techniques, go down one side of a rock ledge formation, reef. Turn back towards the starting point after crossing to the other side of the formation.

Other dive patterns are as outline in Fig. 3. The triangle pattern at 120° turns is recommended only when a compass is used. It is important to discuss the dive patterns with your buddy; visualize them in your mind. After this it is alright to wander of course as long as you know where you are in relation to your course; otherwise find something that you can reference so that you can return to your course heading. It is also important to know your distances for relocating sites or searching. The natural way for doing this is watching tank pressure. Your tank pressure times your dive segments and will give you the air used. Basic physics relationships of time

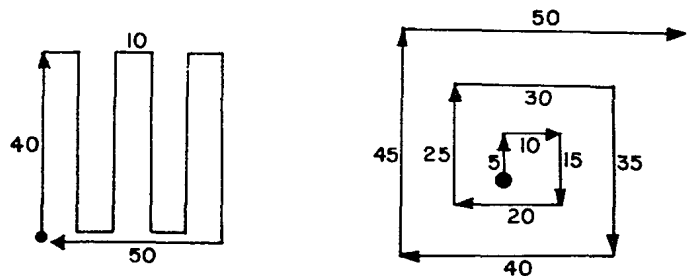


Fig. 3

distance and velocity ($d = vt$) can also be used. Counting kick cycles or arm spans is another basic method. As you move along it is important to note light shadows, the position of the sun at that time. Water movements surge. Surge intensity will always increase shorewards and surge is always perpendicular to the shore. If you watch sea fans they grow perpendicular to the current and sandollars are found parallel to the shoreline. Sand ripples which are a fascinating sight to watch are parallel to the shoreline. There is a lot of controversy how these are formed, basically it is from rip currents.

The divers begin their search pattern where the lost object is said to be. It is important to begin at a known point over a known area and end at a known point. The area must be marked by surface markers. They then begin swimming a series of U's either by timing each length or counting kick cycles. If time is used then usually I swim each leg of the pattern for 60 seconds. When counting kicks each leg is at least 40 kicks. The series of U's is also easier with a compass.

HOLDING ON TO A TOWED ANCHOR

One simple and efficient way of being towed underwater is simply to hold onto the flukes of the boats anchor. If the boat goes too fast there is a tendency for the anchor to float up, the diver would then have to swim it down. If the boat operator is a novice and goes too fast the anchor can be brought to the surface by inflating your BCD. If the boat moves too slow then the anchor will float along the bottom. If the boat moves faster than 2 knots it would be hard to keep your mask and regulator on. Sometimes it is easier to be towed by a line with a loop like shown below.

The U patterns mentioned earlier can be performed by the boat on the surface.

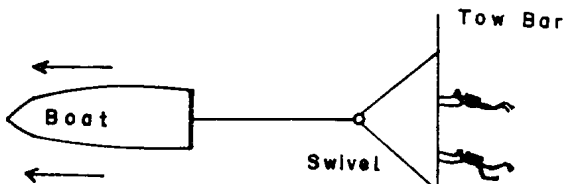
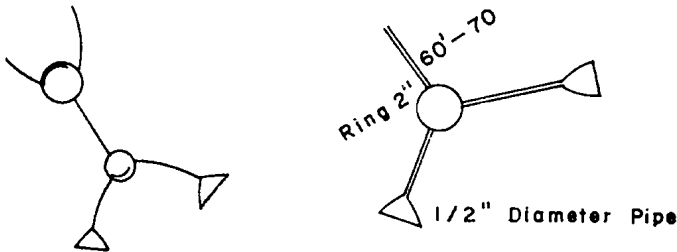


Fig. 4

Fig. 5

Whenever one is being towed a safety pick up zodiac must be operated on a course adjacent to the estimated position of the trawl. Also all the divers must be streamlined, no rescue valves, pressure gauges, fin straps left hanging. A good exposure suit will be handy due to rapid movement through thermoclines. The simplest yet most effective pattern is the circular search pattern. Two divers can descend to the bottom with a line. One diver holds the line while the second diver holds the other end, and swims in a circle. After each revolution the diver moves out another few feet and starts the circling process over again.



Fig. 6

Fig. 7

Sometimes it becomes necessary to control the search from the surface. Divers descend to depth and move out, all communications are through tugs.

In excessively murky water this could be modified to include a surface tender instead of surface divers. One diver is in direct contact with the shore by holding the line. The divers proceed towards the object; if they move away from the direction they are given a tug in the right direction from the surface tender.

BLACK WATER SEARCHES

In such waters the divers are diving blind and must rely on the tender and standby divers for guidance and safety. One must understand that divers are precision tools in the hands of a good tender. These tools never work needlessly and avoid being distracted by anything except what they are looking for. They never surface with items in hand. Hands are for stability and control.

Swinging Arc Pattern

Divers enter the water where the item is expected to be. The current is used in keeping the line taut. With the tender observing the divers' bubbles and watching the progress of the arc, he will turn the diver with a predetermined number of pulls. Some line is let out by the tender as the divers swim in the opposite direction. This procedure is repeated until the area is searched. If the item is located the divers give five

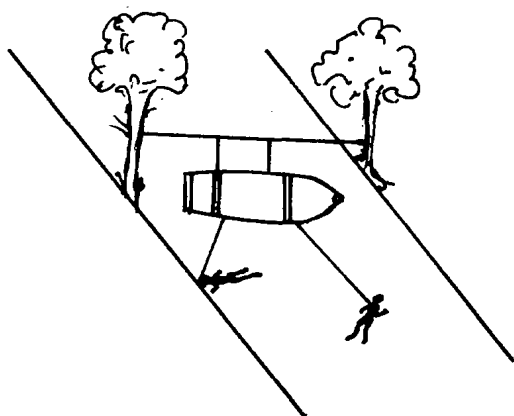


Fig. 8

tugs to signal this. The tender will allow slack so that a marker buoy can be attached. Sometimes a weighted bar is attached after the item is found so that the weighted bar can be used as a platform to achieve negative buoyancy.

A weighted line is used if the current is too strong; this allows negative buoyancy for the divers to stay on the bottom and move downstream at regulated rate. When the divers drift to the end of the line they signal and surface. The boat then transports them upstream to repeat the procedure.

ACOUSTIC SURVEYS AND PHASE MEASUREMENTS

This is a sophisticated method of underwater survey which is the direct equivalent of trilateration. In the simplest form three transponders are placed at known locations. They are interrogated regularly from within their established grid and the time delay for each response is measured and recorded. The velocity of sound in seawater is known accurately once temperature and salinity are measured. The time delays for the three responses are related to the distance between the interrogator and transponders by the formula ($\text{Dist} = \text{vel} \times \text{time}$). The interrogator gets a digital readout of the time delay. If the geodetic location is not important and only the relative position and motion within a site are to be measured, the acoustic grid is appropriate.

Phase Survey Measurement can be used when the area to be surveyed is large. Three receiving elements are precisely located on the underside of the craft. A diver places a transponder on the object where position is to be determined and an interrogator is located on the ship which queries the transponder. A phase analysis is performed on the receiver which displays as a deflection angle and line of range sight to the object with respect to the receiver element... Small transponders, if strapped to the divers tank, can also continuously monitor his position. If continuous communication is available the diver can be directed through a survey pattern that can be geodetically fixed knowing the ships position.

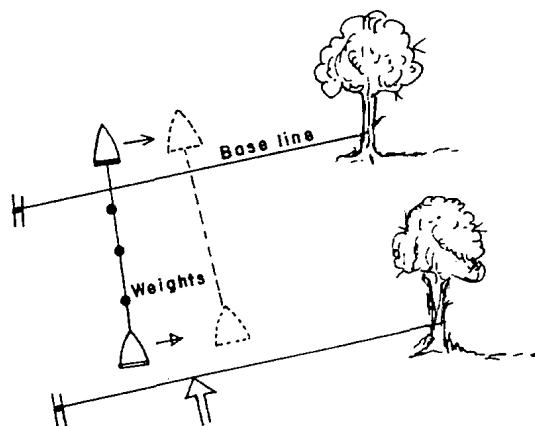


Fig. 9

These sophisticated survey patterns are obviously an indication of the strong interaction that is needed between marine engineers and archaeologists. The field of underwater bottom surveys and recording is moving into a technological era of sophistication and accuracy.

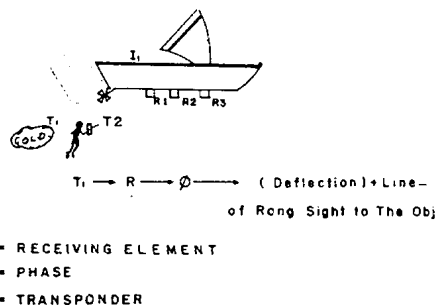


Fig. 10

EXCAVATION AND RECOVERY TECHNIQUES

Excavation is not just the process of recovering objects but deducing facts have to be seen in context with the environmental matrix and their association with neighbouring finds and existing facts. Recording during an excavation is important. Every detail, however trivial it may seem, could be a part of the puzzle. However scattered and random the sequence of events/objects may seem, unless these distributions are plotted we will not know if they represent a relevant pattern. Within the apparent chaos and disorder there is a logical sequence of events /forces that have acted on the material since its deposition. The relative positions and strata are more important than the absolute location of the objects.

Methods of search and triangulation have already been outlined. A baseline termini need to be fixed as securely as possible since these will be the primary points from which all subsequent site measurements will be taken. Often climbers or pistons are fixed into rock outcrops with Self locking eye bolts. In muddy bottoms steel rods are used and secured with ballast. The design of the baseline should be at least 10 m

Once your baseline is fixed and the distances between them are measured they can be used to establish the relative positions of other points by triangulation. Whenever rocks or outcrops are encountered a series of jumps or bypasses are done to triangulate further with new reference points established as required. Wherever possible, make measurements from the baseline because the more jumps you have a greater number of errors will accumulate. It is important not to transpose co-ordinate while plotting. While triangulation establishes a basic network of points, the detailed and complex features within this framework have to be recorded on a relatively flat and open site. This is done by a grid system. Since the grid is a purely arbitrary reference framework, it may be an advantage to place the point of origin well outside and below the actual origin of the grid, this allows possible extensions in these directions. Unless the site is flat, slopes and fissures need to be accounted for. If the slope is nearly flat ignore it and introduce corrective factors later. Sometimes rough levels can be taken using a depth gauge which has been calibrated against a suitably measured shot line. Levels are taken at a depth below mean low water tide. Sometimes water barometers are also used for more accurate levelling.

Once the initial survey is complete and the visible features and characteristics of the site have been mapped in detail, an attempt should be made to locate the extent of buried deposits. Since most wrecks contain metal in the form of fasteners, fittings and ballast, these can be used to locate the general trend of the wreck site. A systematic metal detector survey can usually be helpful. A metal detector is good when used as a prereconnaissance tool but every detected piece must not be dug out haphazardly without an assessment. Probing can of course damage buried objects. Surveys with probes must be carried out systematically with soundings made at fixed intervals. The advantage is that probing can often delineate large objects. Core sampling is a useful technique for obtaining stratified samples for analysis.

Excavation Tools

Excavation tools must perform two main functions.

(i) provide a means whereby archaeological deposits are revealed.

(ii) dump the spoil in a suitable damp area so that it will not spill back into the excavation site or further areas to be excavated. The best method is fanning sediment with one's hand; however, when it comes to transporting spoil by hand even the most vigorous fanning will not work. A suction pipe is needed. The water dredge provides light effective suction. The dredge is not used to dig directly into deposits but rather as a receptacle into which spill can be fed in. Care should be taken so that it has sufficient water to breathe. A much heavier excavation tool is the airlift. The

water depth must be at least 8 m for this to operate efficiently. The airlift consists of a partly rigid and partly flexible tube into which air is introduced through a manifold at the lower end. The manifold breaks air into small bubbles that mix with the water. The result is a gas liquid mixture of less density than that of the liquid outside the pipe. The air water mixture will rise until the pressure of the column of mixture equals the base pressure of water at the same level. The suction created at the lower end displaces the unconsolidated material.

High Pressure water jets are also another important tool; these are used to cut through unconsolidated overburden and force it away from the site. The system consists of a hose, pump and nozzle.

Recovery procedures are outlined in the buoyancy discussion but it is important to bag small finds. Large objects are stored in boxes individually with a label. Before extraction is attempted a suitable transfer container must be prepared.

Buoyancy

There are several methods of providing buoyancy to raise sunken objects ranging from the historical method of displacing water with air, either by filling the object with air held in a container or the filling of a vessel with plastic foam. The choice of method depends on several factors.

1. Location of the sunken objects, its attitude on the sea bed.
2. Identification of the object. In the case of a ship, the available plans can give an indication of the capacity fixtures, displacement weight and the centre of gravity.
3. Depth of water will give you an idea of bottom time and the amount of air needed to provide buoyancy.
4. Nature of the sea bed, its load bearing capacity, if the wreck has sunk, the contact area to the bottom and breakout force needed.
5. Sediment cover to be cleaned by necessary airlifting operations.
6. Structural integrity of the structure; whether its condition is compatible with the chosen method of lift.
7. Attachment points and their structural integrity.
8. Material of which the object is constructed and extent of biofouling on it.
9. A complete plan of action along with feasibility and availability of water communication.
10. Safety of divers in the area.
11. Tidal information and sea state.
12. Laws relating to the wreck, and arrangements for storing as well as disposing of the object when it is at the surface.

Salt water weighs 64 lb/ft³

Fresh water weighs 62.37 lb/ft³

Air weighs so little compared to an equal volume of water that it lifts virtually the same as it displaces.

AIRLIFT

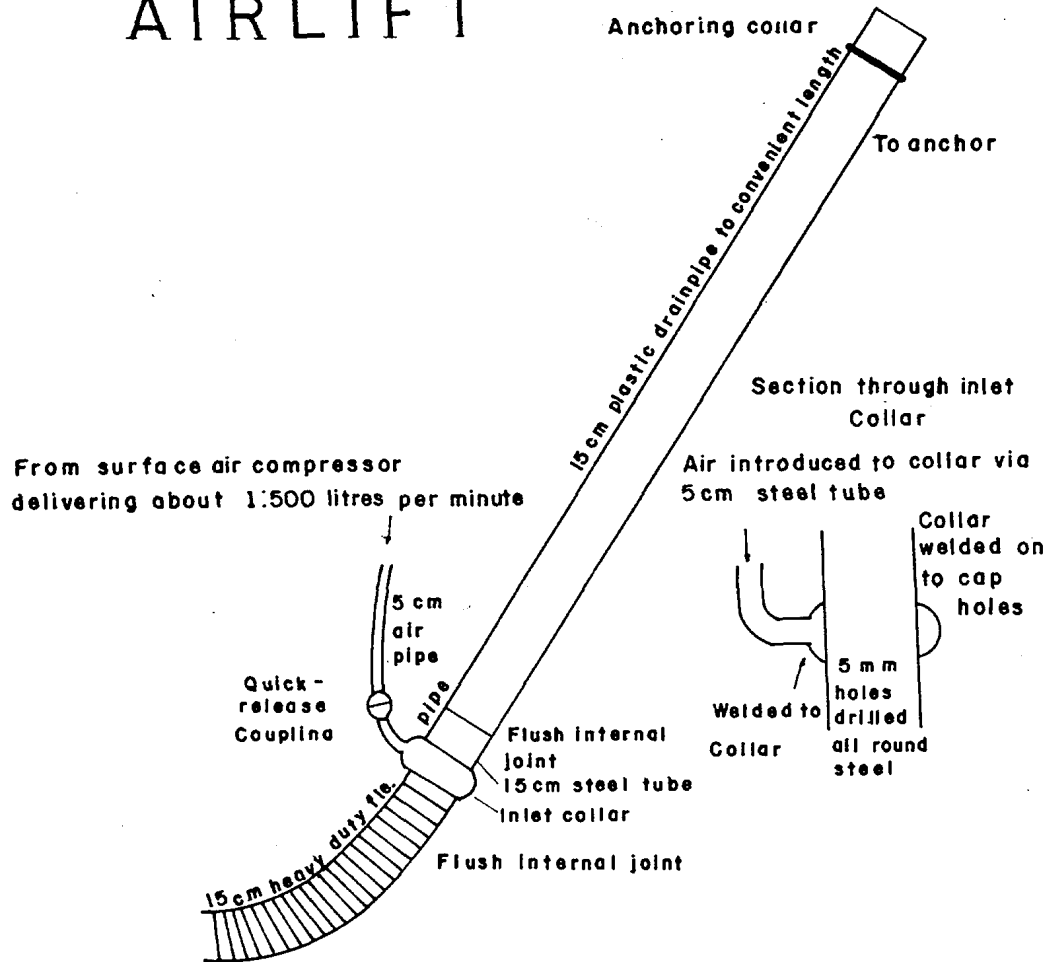


Fig. 11

As we all know that when we get into the water we weigh less, equipment that was once bulky and unrealistically heavy is suddenly maneuverable. The diver himself will loose almost 100% of his weight in water because the body's density is nearly the same as that of water. Then why is it that the lead weight this diver carries is still heavy and helps him sink? Lead does not become significantly lighter under-water because it is very dense (708 lb/ft³).

$$d = \text{mass/vol}$$

so mass = density × volume

Sunken objects are lifted off the bottom in many ways depending on sizes, weight and floatation capability.

Common methods are:

1. Lifting with a floating crane, or from salvage pontoons equipped with multiple winches: This method would require straps to be passed on either side of the object.
2. Air lift bags (see fig. Dive maker) which would then be inflated under water. Variations of this may be to place airbags within the structure or secure submersi-

ble salvage pontoons alongside the object which would then be pumped with air from the surface.

3. Sometimes the main compartments are pumped with a light floating material like 'Syntactic foam'. 'Eccofloat' is also used; it consists of hollow epoxy fiberglass spheres.

LIFTING CALCULATIONS

Archimedes principle is the backbone for salvage operations but theoretical figures on paper do not always reflect what happens in the field. On a research expedition off the Bahamas the following points had to be taken note of:

Location 26°57'N 76°06'W
 Memory rock in the Bahamas
 Boat anchor is set in hard rock
 Steel = 485 lb/ft³

Object thrown overboard was a geological sampling grab, water depth of about 30 ft.

Volume of grab = .25567 ft³
 Weight of grab in air = Vol of grab × density
 = .25567 × 485
 = 123.99 lbs

Due to slots and curves 128 lbs

Bouyant force = 64 × .25567
 = 16.36 lbs.

Wt. of grab in water = Weight in air –
 Weight in water
 = 128 lbs – 16.36
 = 111.64 lbs.

Density of S.W. = 64 lbs/ft³

64 lbs = 1 ft³

111.6 lbs = ? ft³

= 1.744 ft³

1 bottle = .135 ft³

? bottles = 1.744 ft³

12.91 13 bottles

The final lift took 14 bottles instead of 13. This could be attributed to bottom friction or what is more tangible is that the open ended list bottles have a tendency to dump air as they surface. The bottles were filled to one quarter their capacity because the air expands as it surfaces. All rigging was in good condition and divers were away from the grab as it rose. The object was controlled at the surface. The above calculation was a safety calculation to gauge a safe lift.

RIGGING AND LIFTING

- a) Never use personal buoyancy as a means to lift a heavy objective more than 15 lbs.
- b) When using a lift bag be sure the size is appropriate for the object.
- c) Be prepared to secure the bag to the object.
- d) Test Rigging before inflation.
- e) Inflate the bag
 - i) Use alternate air source.
 - ii) Be careful not to entangle the regulator in the rigging.
 - iii) Add a little air at a time.
 - iv) Be prepared to expel air from the bag at any time.

- f) Lift the object
 Remain clear.
 Be prepared to let go at anytime.
 At the surface be prepared to lift the object from water.

CONCLUSION

A systematic approach to uncovering the past requires a planned team effort. It is important to have as complete a background of existing knowledge about the find, plans, plots, previous trails and excavations; a trained team, and lots of painstaking hours towards deducing facts, not just recovering the 'objects' but testing the site. Often decisions which are very instinctive are taken in archaeology, though the underlying basis for these are from hard evidence and experience. Before any action is taken proper precautions and well thought procedures backed with the necessary support must be outlined. A lot of underwater work entails good positive immediate action.

Today underwater excavations are a delicate blend of marine archaeology, history, religion and the determination to pursue the excitement and revive the memories that have faded with time.

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