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Technical Memorandum No 1/81

HOME OFFICE

Aids to Underwater Searching

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SCIENTIFIC RESEARCH & DEVELOPMENT BRANCH

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AIDS TO UNDERWATER SEARCHING

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SUMMARY

At the recent request of the Association of Chief Police Officers Diving Committee, Police Scientific Development Branch has been examining the latest developments in depth sounders and short range sonars, and their applicability to police diving operations. Some limited trials have taken place and these are described.

1. INTRODUCTION

Police Scientific Development Branch has been examining the possibility of producing aids for police divers carrying out underwater searches ever since 1970. At that time a contract was awarded to Birmingham University to investigate the problem and to produce a high resolution sonar capable of imaging objects on the bottom of inland waterways. A high resolution sonar was produced, but in lengthy trials it was decided that this approach to the problem of searching turbid waters was not satisfactory, due to the poor quality of the images and the large number of false targets detected.

Subsequently a research contract was let to the Plessey Marine Research Unit aimed at developing an acoustic imaging device which would have sufficient sensitivity to detect low level diffusely scattered reflections from target objects on the bottom. Although a lot of progress was made, Plessey's inability at that time to make transducer arrays with sufficiently high performance caused us to terminate the contract. However, in the long term, this approach would seem to be the only one likely to achieve a practical searching aid, as will be seen from discussions later in this report.

Early in 1979 the ACPO Diving Committee, increasingly concerned about the problems of searching for objects in turbid, polluted waters and the danger to divers of such searches, asked PSDB if they could take a fresh look at the problem.

The typical problem presented by ACPO was the search for a body or a car in water depths up to thirty feet with near zero visibility. Of course, as the survey carried out by PSDB in 1972 showed, police divers are required to search for a large variety of objects in diverse underwater locations, but the ACPO diving committee emphasised bodies and cars because police are under some pressure when searching for missing persons.

The requirement was, therefore, for a device which could be boat-mounted and be capable of detecting objects over a wide area of the bottom, and in addition provide an approximate classification on that object without too many false alarms. Since most police searches take place in water of almost zero visibility, underwater television is ruled out as a general searching aid. The devices which we set out to examine were: short range sonar, depth sounders, magnetometers (for cars only), and the Thorn-EMI acoustic imaging system. Trials carried out in conjunction with

the Bedfordshire Police Diving Unit will be described in section 3, but first of all a brief discussion of the problems of searching in the typical inland underwater environment is given in Section 2.

2. THE PROBLEM OF UNDERWATER SEARCHING

The search for objects underwater in typical inland stretches in this country is considerably hampered by the high turbidity level. The presence of a high concentration of suspended particulate matter serves both to reduce the contrast and the resolution when visually searching for objects on the bottom. This effect is so marked that even with moderate turbidity levels having a particle concentration of a few times 10^7 particles/metre/cm^2, and particle size a few microns diameter (which gives a sighting range of a few feet) the optical resolution obtainable is no better than can be obtained with sonar equipment (about 0.20^o) (1). At ten times this turbidity level it has been shown that there is no reduction in the resolution of a high frequency sonar (2.5 MHz). This means that at the turbidity levels likely to be encountered in inland waters, the resolution achievable using sonar techniques will be higher than using optical techniques. The range will also be considerably greater.

Providing, therefore, that one can achieve a reasonable acoustical contrast between the object and its background (the bottom), it should be possible to make an efficient searching aid. This contrast level will depend on the acoustic impedance of the various objects sought compared with the acoustic impedance of typical river or canal beds and the manner in which acoustic energy is back-scattered. Since most objects appear acoustically smooth at the highest practical wavelength, scattering will in general be specular (mirror-like). This effect will tend to make a cylinder image as a straight line and a sphere as a dot. Recognition of objects may then be difficult unless the sonar is able to detect and display, in a satisfactory manner, signals which are reflected from parts of the object which are not at right angles to the incident beam (diffuse reflections). An alternative way in which recognition might be achieved is to look at the shadow cast by objects on the bottom when operating a sonar in the side scan mode.

This latter technique was the one adopted by Birmingham University for their sonar. However, it does require a uniform bottom,eg sandy sea bed, to work. Imaging on diffuse returns was the technique attempted by Plessey Marine Research Unit. Although satisfactory acoustic images were never obtained (because of their failure to make a satisfactory transducer array) images produced elsewhere by high frequency holographic techniques demonstrate that images of almost optical quality can be obtained (eg at Atomic Energy Authority, Harwell).

Various sophisticated optical techniques have been tried to improve the viewing range in turbid waters and viewing range increases of several times have been obtained (using range-gated laser techniques). However, since in most police searches the viewing range is less than 30 cm, increasing this by a few times would still not produce a useful searching aid able to cover large areas.

Optical techniques have been ruled out on the grounds of resolution and range, but one other technique has been tried for detecting cars, the fluxgate magnetometer. This device is largely unaffected by a depth of water between the car and the detecting head so large ranges are possible. However, all ferrous objects on the boat or operator have to be removed, and then cars may be detected at depths of 6 metres or so.

3. TRIALS

3.1 Depth sounders

Two depth sounders have been used in an attempt to assess their usefulness to police divers; the Raytheon DE 719B and the Lowrance LRG 1510B. The principle of operation of both is shown in figure 1. Both units have a paper chart readout which gives a continuous reading of the depth of the bottom or range to an object on the bottom. The Raytheon operates at a frequency of 200 KHz with a 10° beamwidth to the -3dB points whilst the Lowrance has a beamwidth of 22° and operates at 192 KHz. The other major difference between the two units is price, the Raytheon costs four times as much. Since the operating performance is similar, with the Lowrance having the edge on chart readability, all the remarks which follow apply equally to both units.

The site chosen for these trials was a leisure pool at Arlesey just north of Hitchin. The pool is about 1/10 square mile in area with a water depth varying from a metre to twenty metres. The pool is used for yachting and by the Bedfordshire Police diving unit for training. Our trials took place on various dates from March to October 1980.

A catamaran housed the depth sounder, battery supply and transducer head plus two or three personnel, and an outboard motor at the rear was used to drive the boat at uniform speed. (see figure 6).

Test objects were lowered onto the bottom at about 6 metres depth and their positions marked with floats. The catamaran was sailed over the test objects in an attempt to pick them up on the chart.

The narrow beamwidth of the Raytheon meant that very precise positioning of the boat was necessary to pick up even the largest test object.

The Lowrance was better in this respect because of its bigger beamwidth (twice), but even so positioning needed to be precise. This immediately highlighted the difficulty of searching for an object in an unknown position on the bottom. Unless the precise area covered by the boat can be recorded (within three feet) the chances of missing the object are very high.

The test objects used included a large metal equipment cupboard 1 metre x 0.5 x 1.5 metre, a small metal drawer, a car wheel (without tyre) and a diver.

All these objects could be detected under the right conditions, although detecting the drawer and car wheel was difficult. With the proviso mentioned above of precise positioning, depth sounders of this type could really only be used in deep water (greater than 3 metres) for cars. A police diver was detected mainly by bubbles from his aqua lung, and at 6 metres depth a dead body would be difficult to detect unless it was floating off the bottom. Typical results showing the chart readout are shown in figure 7.

3.2 Sonars

Two different types of sonar have been evaluated. One was a side scan sonar in which the transducer head is towed behind a boat, and the other was a mechanically scanned sonar. Both were high frequency types (500 KHz) and were thus expected to give a high resolution.

The side scan sonar was a Klein 500 KHz made by Hydroscan in the USA. The principle of operation is shown in figure 2. A beam, narrow in the vertical plane (0.2^{o}), is projected from each side of the transducer, covering a large area of the bottom, and the forward movement of the transducer head provides the scanning necessary in the direction of travel. Acoustic returns are displayed on a moving chart as a grey scale display and gross features on the bottom (eg ridges) are readily distinguishable.

The equipment is bulky and clearly not designed for use in an open boat, however for our trials it was mounted on a catamaran and a number of test objects were lowered onto the bottom as for the depth sounder trials.

It proved very difficult to detect even the largest test object and without knowing its whereabouts it would have been impossible to distinguish it from other similar sized objects on the bottom. The metres of wet chart paper which come out of the machine are a severe disadvantage in an open boat and it was concluded that a real time CRT display would have been useful as well. A chart recording obtained by sailing over the cupboard in 10 metres of water is shown in figure 8c.

The mechanically scanned sonar is made by UDI Ltd in Scotland and is based upon ideas developed by Birmingham University under the original PSDB contract. Its principle of operation is shown in figure 3. A beam, narrow in the vertical plane, is mechanically scanned around 360^{o} thus insonifying a large area of the bottom. The transducer head can be mounted on a stationary boat, on the shore, or on a platform on the bottom in shallow water.

The acoustic returns are stored in a 3 bit frame store and displayed as a flicker free 625 line picture with an 8 level grey scale - the picture remains on the screen and is altered as the circular scan picks up new objects.

As with the Klein it was extremely difficult to detect objects on the bottom and to distinguish them from other clutter. However, the progress of divers swimming about could be followed easily and it would be a relatively easy matter to guide a diver onto a target which had already been located. The photograph in figure 8 shows detection of three oil drums.

3.3 Thorn-EMI acoustic imager

The development of this device has been underway for several years and we have watched its progress with the Admiralty Underwater Weapon Establishment, the sponsoring authority.

Imaging is achieved with an acoustic image converter tube, a CRT with a front face of piezo electric quartz. The electrical charges generated when acoustic waves strike the quartz faceplate are read off with an electron beam, and converted into a conventional TV display. In this way an acoustical image formed on the quartz faceplate by the action of an acoustical lens is turned into a TV image. (see figures 4 and 5).

The system therefore, consists of a fixed focal length lens, whose distance from the front face of the CRT can be varied and a series of insonifying transducers fixed around the periphery of the faceplate, as shown in figure 9.

At various demonstrations in Thorn-EMI's test tank very convincing images of underwater objects have been demonstrated. So much so that it would appear to be the only device currently available which can even approach the task of classifying objects detected underwater. It still of course suffers from the same limitations as all acoustic imaging devices mentioned in section 2. Namely that because the wavelength is so much longer than light wavelengths, objects appear as a series of specular reflectors and the Thorn-EMI Imager is not sensitive enough to detect diffusely scattered returns. However, images obtained in a test tank full of turbid water can be very good. A revolver completely hidden under a thin layer of sediment is shown in figure 10.

Two trials have been carried out with this device, on both occasions the equipment was operated by Thorn-EMI engineers. The first was in 1979 when the first ruggedized (non-laboratory) model was announced. At that trial the sensitivity was very poor and it seemed extremely difficult to detect or image even objects suspended midwater a few feet from the system's lens. Imaging objects on the bottom was impossible.

The second trial took place in September 1980. The equipment was much improved but it was very difficult to detect objects on the bottom because of its small depth of field (10% of range). Even when an object was lowered down in a known position it was very difficult to detect and image it. However, a bicycle wheel was imaged when it was on the bottom and the spokes were easily identifiable.

The overall conclusion was that, whilst it was the only available device capable of producing recognisable acoustic pictures its small depth of field, narrow field of view (10^{o}) and short range combine to make detecting and imaging an object very difficult, and so it could not be recommended as a general searching aid. It might, however, have application to close inspection of objects in very turbid waters.

3.4 The fluxgate gradiometer

The fluxgate gradiometer is a very sensitive metal detector for ferrous objects (iron, steel) only. It works by detecting small local perturbations in the earth's magnetic field, and is an obvious contender for locating the position of submerged motor vehicles.

For the purpose of the trial the gradiometer and the operator were towed behind the catamaran in a rubber boat devoid of any ferrous metal. The gradiometer was found to detect oil drums readily at many metres depth, and the main problem encountered was in marking the position of the detected object.

This is by far the best way of detecting motor vehicles at several metres depth providing there is no other larger ferrous object as close to the detecting head (eg iron bridge, steel supports for a canal etc).

4. CONCLUSION

The results we obtained from the high resolution sonars were not very encouraging, although potentially useful for searching large areas of the bottom, in practice it proved to be extremely difficult to detect target objects in known positions.

Depth sounders were more successful at such detection but their narrow beamwidth makes it difficult to ensure the bottom of a wide stretch of water is adequately searched. However, they could be useful for searching canals for large objects, although a magnetometer would be a better choice for cars.

None of these devices were successful at classifying objects, even by size. The Thorn-EMI acoustic imager is able to produce recognisable images at close ranges,but because of its narrow field of view and short range is really only useful for inspection once a suspect object has been located.

We could not recommend purchase of any of these equipments except perhaps for the magnetometer (cost circa £1000) and the Lowrance depth sounder (cost circa £600). The Thorn-EMI acoustic imager costs in the region of £30,000 and the sonars cost between £10,000 to £15,000.

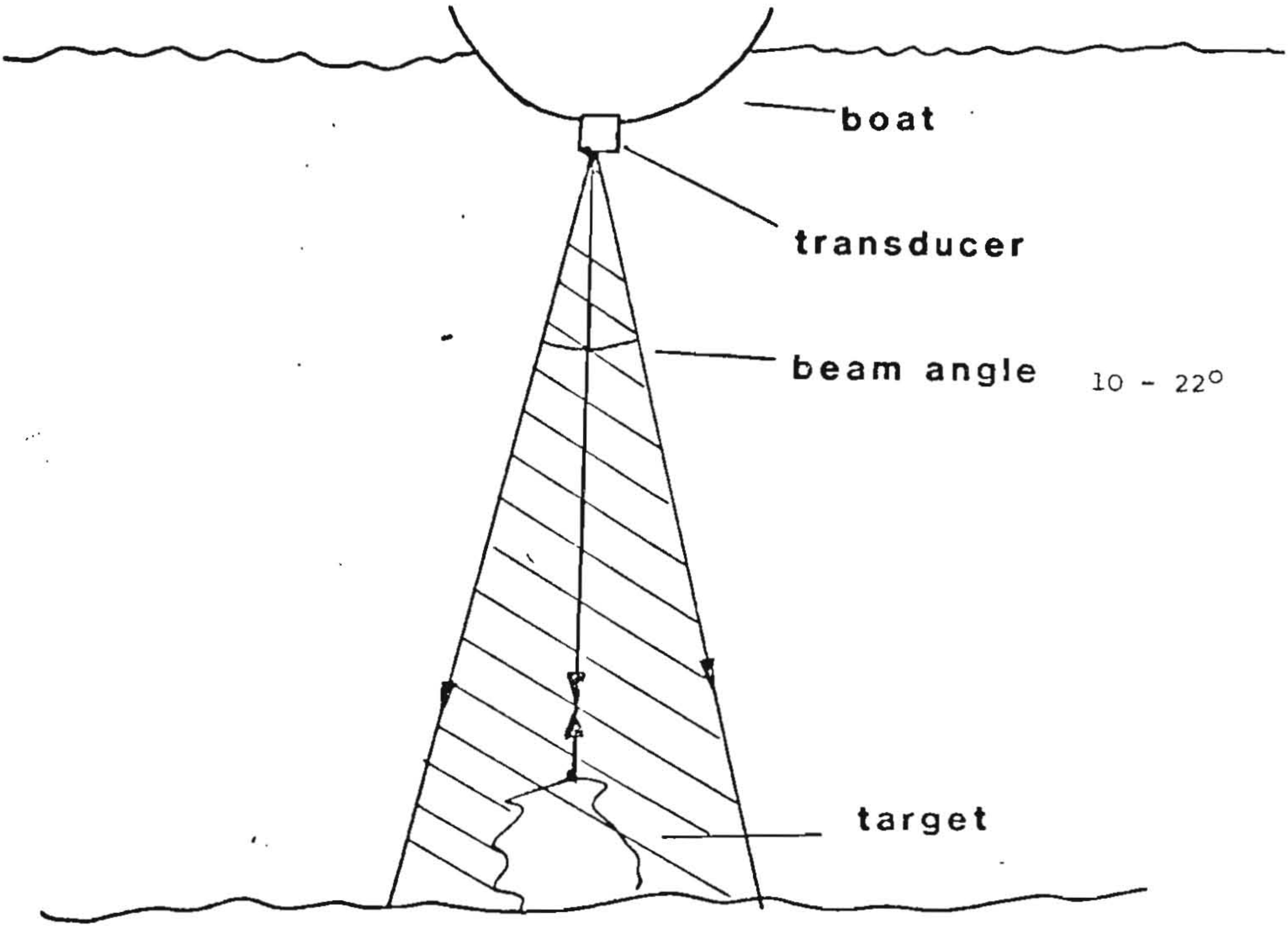
Both the magnetometer and the depth sounder are unlikely to be used intensively and are perhaps best held regionally by Technical Support Units.

PSDB will continue to monitor progress on the development of underwater imagers, and should Plessey solve the problem of producing transducers with the necessary performance we will consider further sponsorship of that work.

5. REFERENCES

1. Visibility and Resolution in Turbid Waters, B Gazey

2. Underwater Science and Technology Journal, June 1970

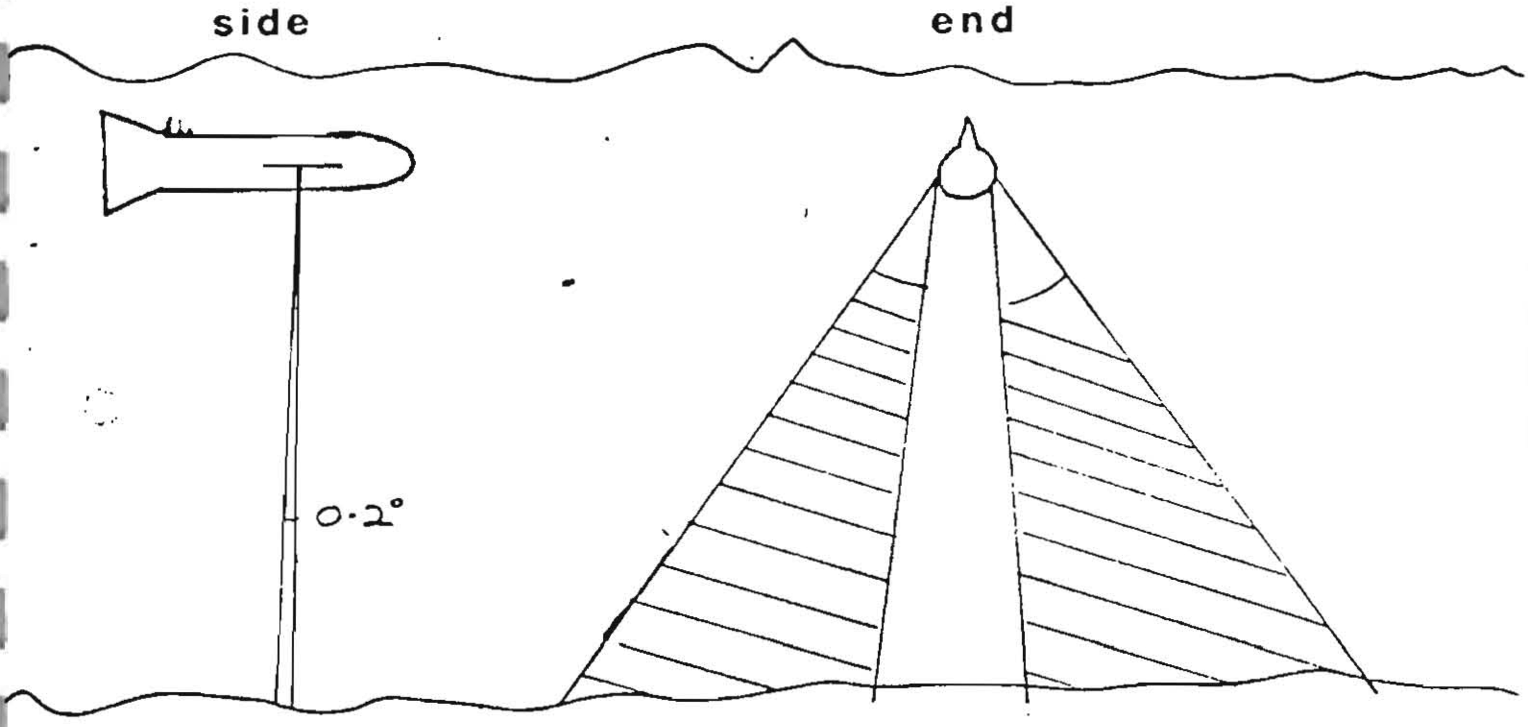


Depth sounder

figure 1.

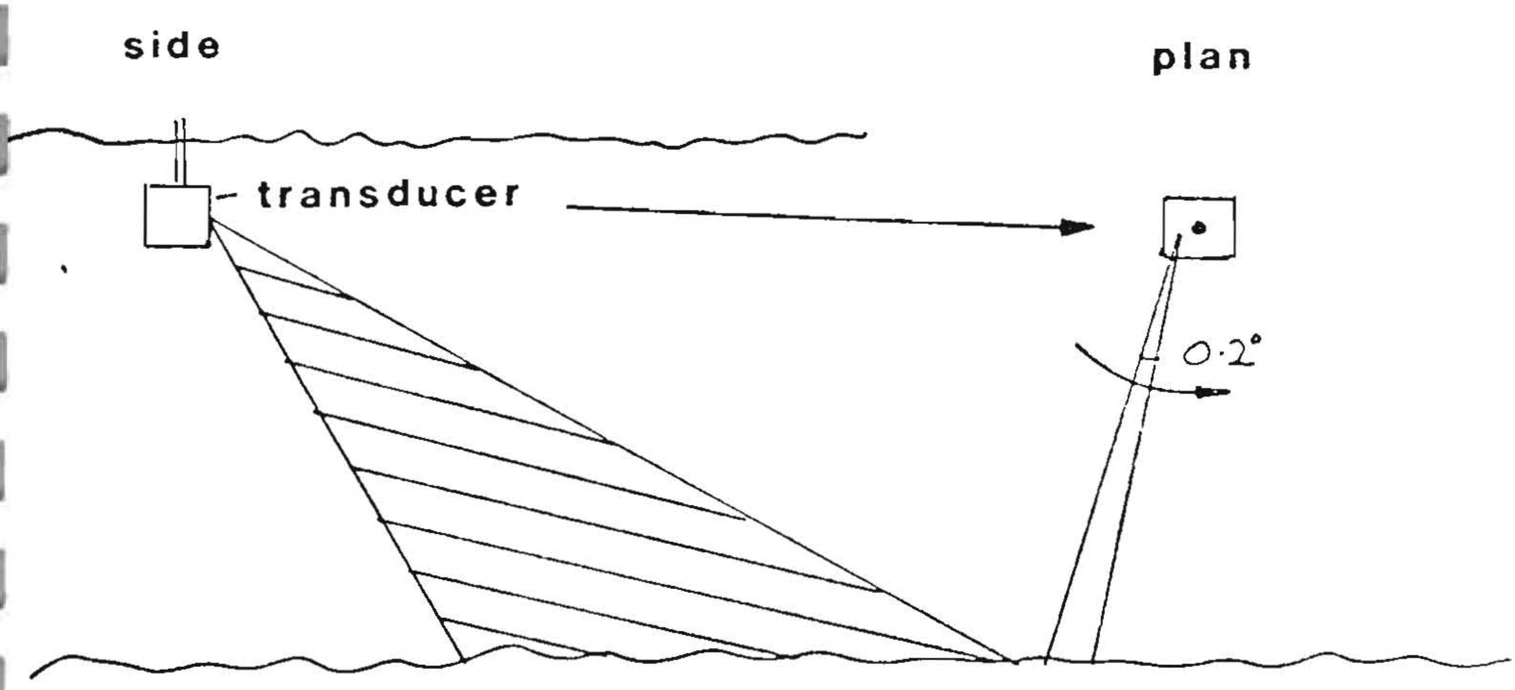
Towed fish side-scan sonar

figure 2.



Mechanically scanned sonar

figure 3.



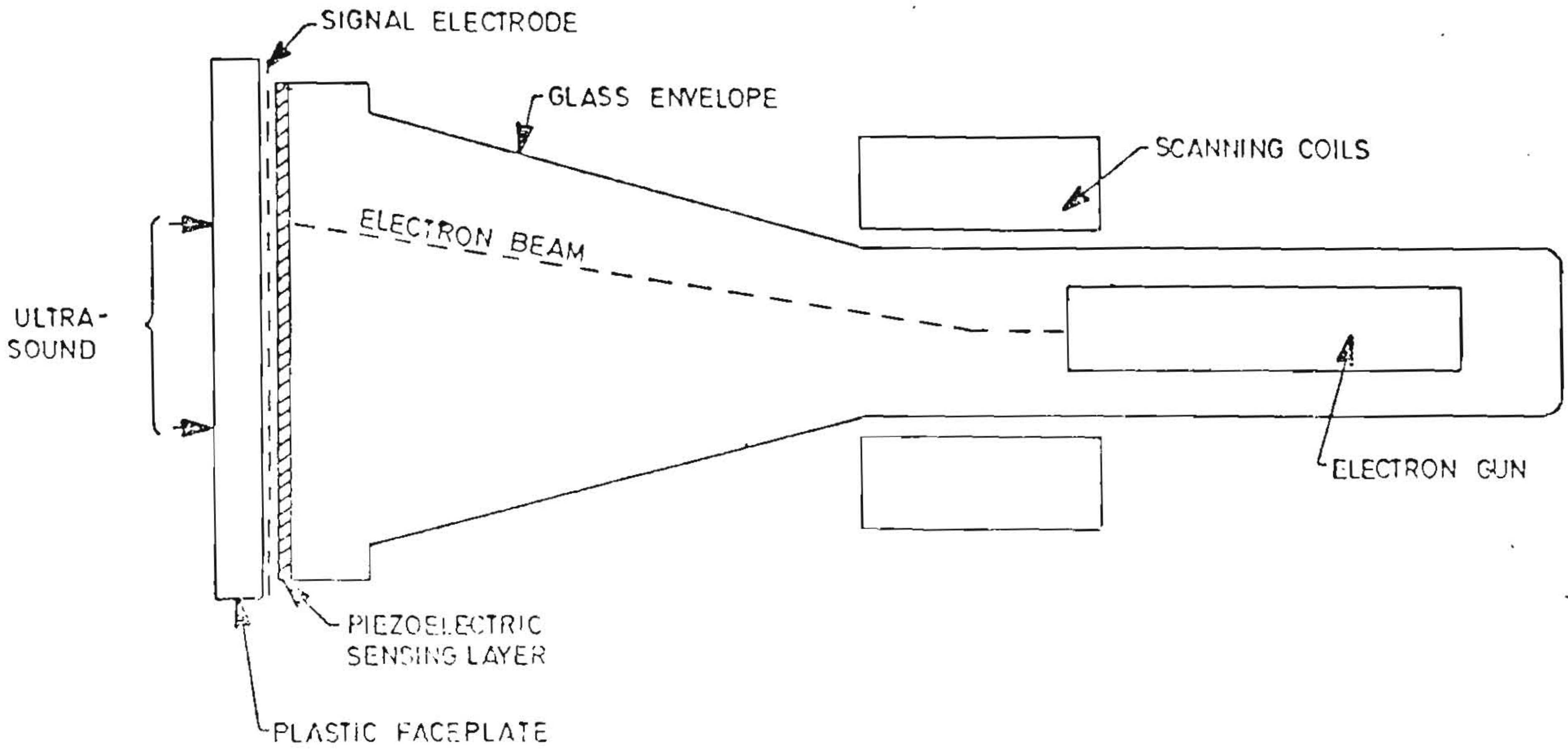


figure 4.

IMAGE CONVERSION TUBE

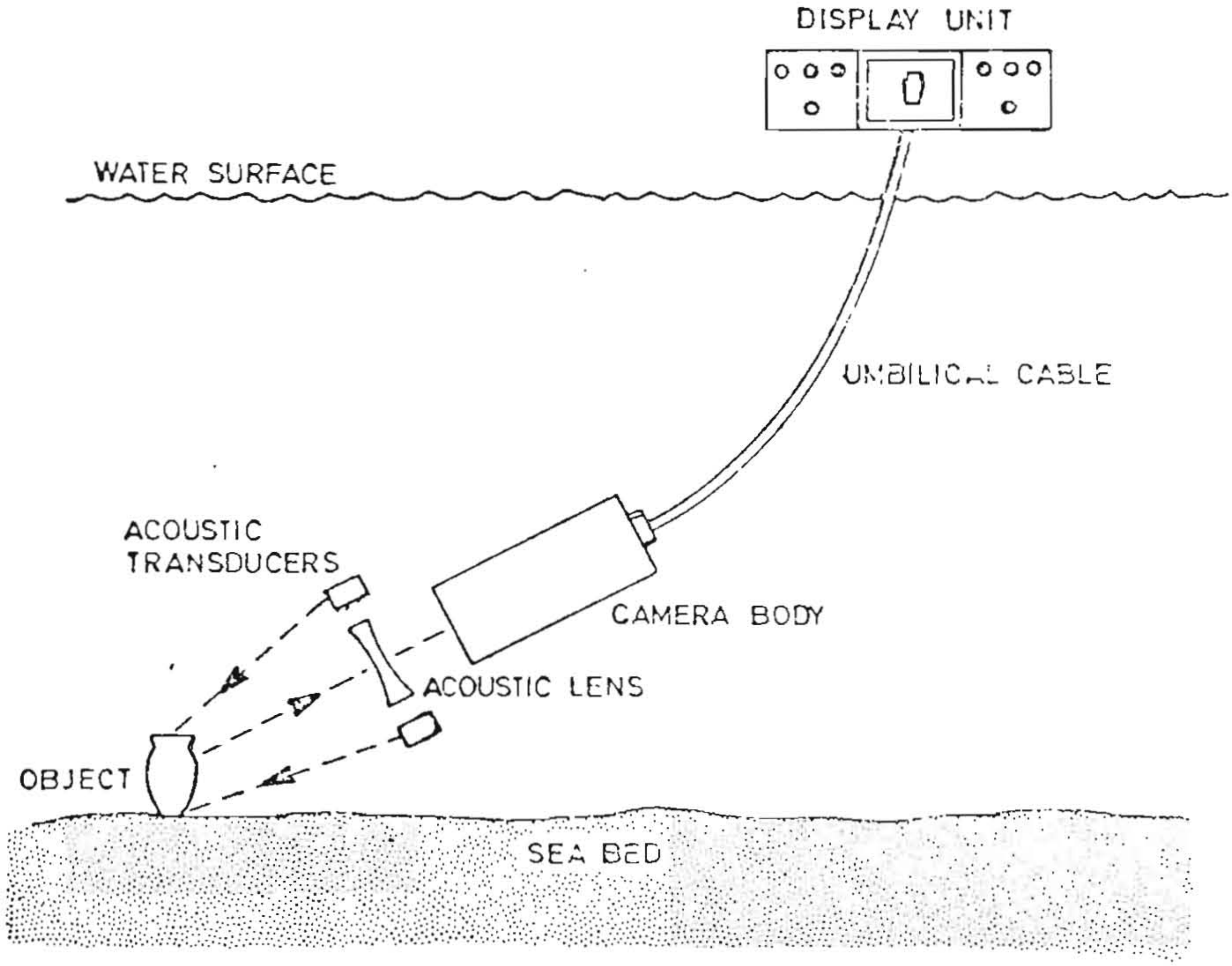
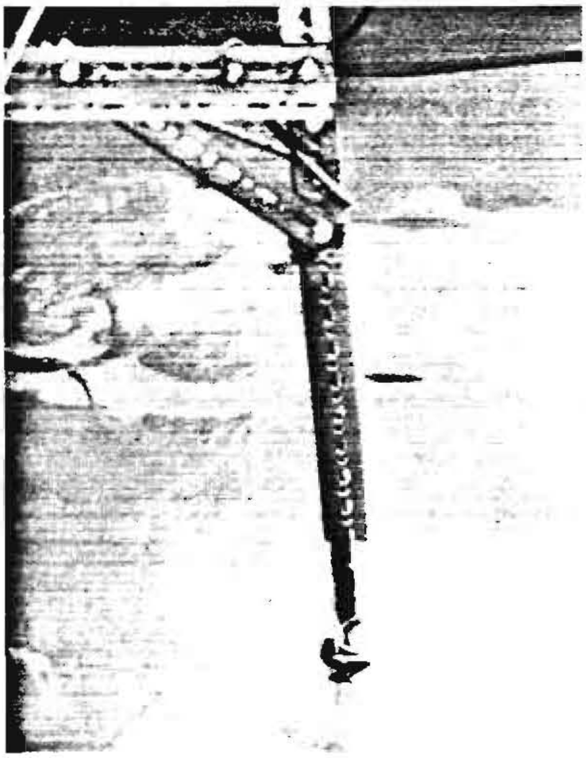
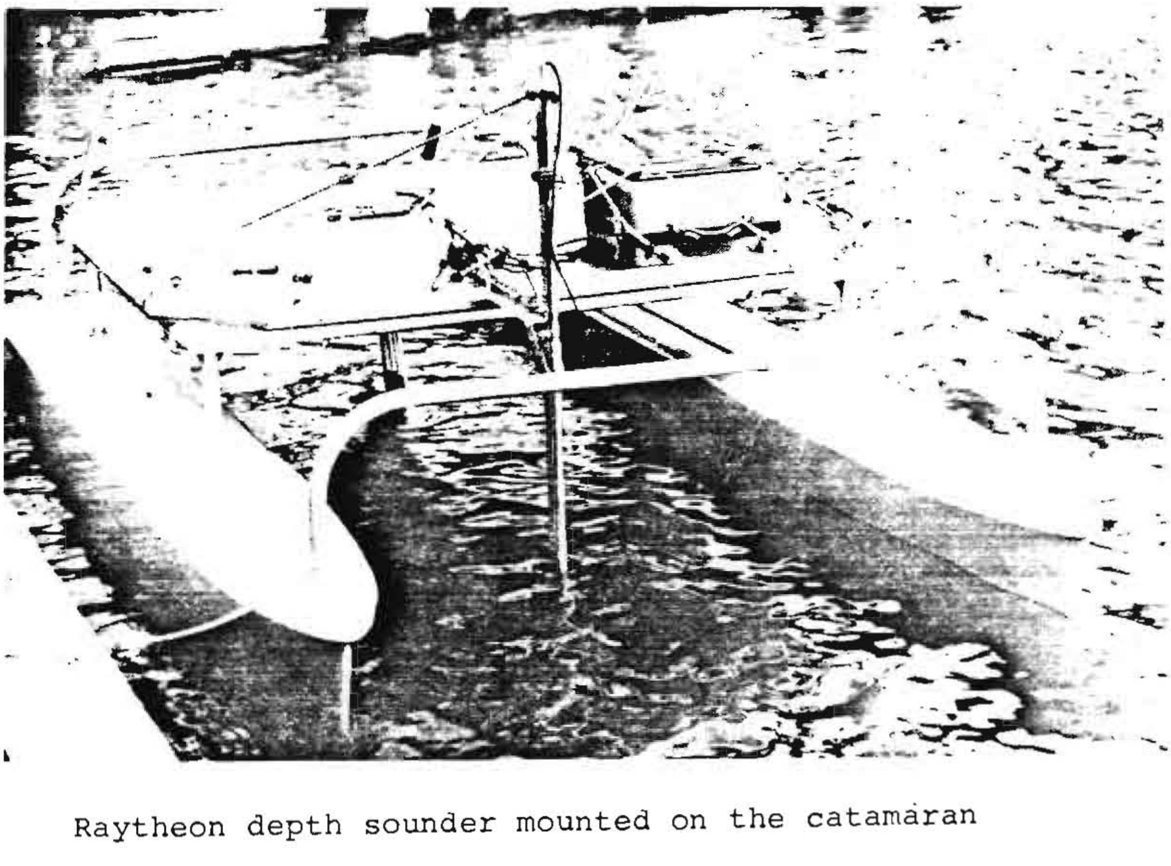


figure 5.
UNDERWATER ACOUSTIC TELEVISION SYSTEM

Raytheon chart recorder

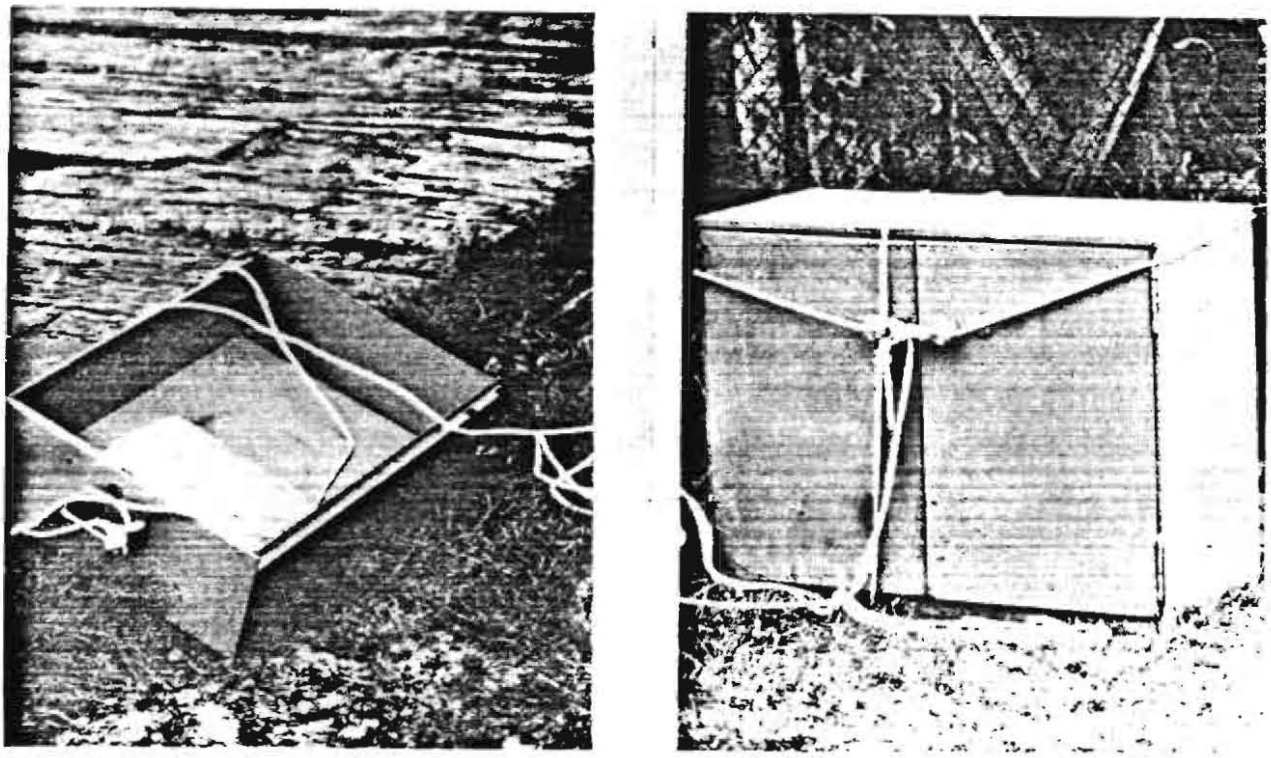


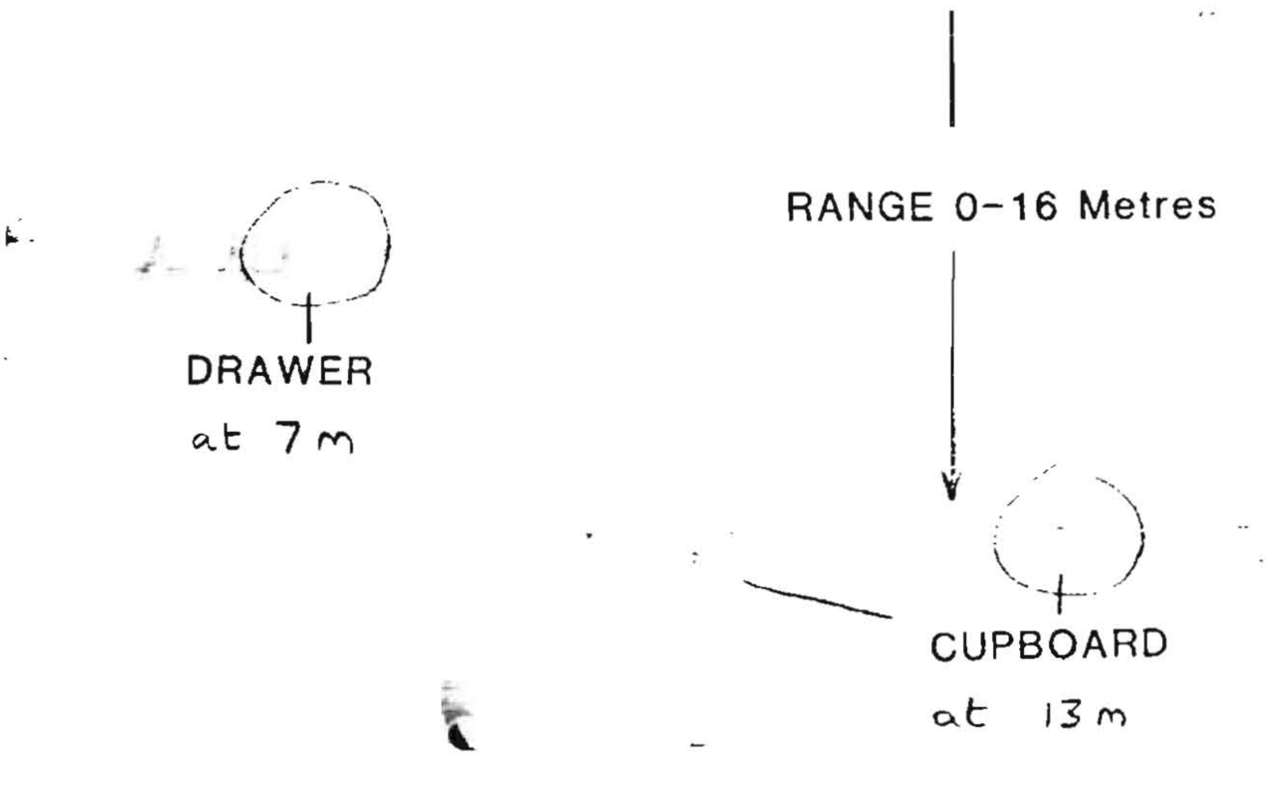
Raytheon transducer



Raytheon depth sounder mounted on the catamaran

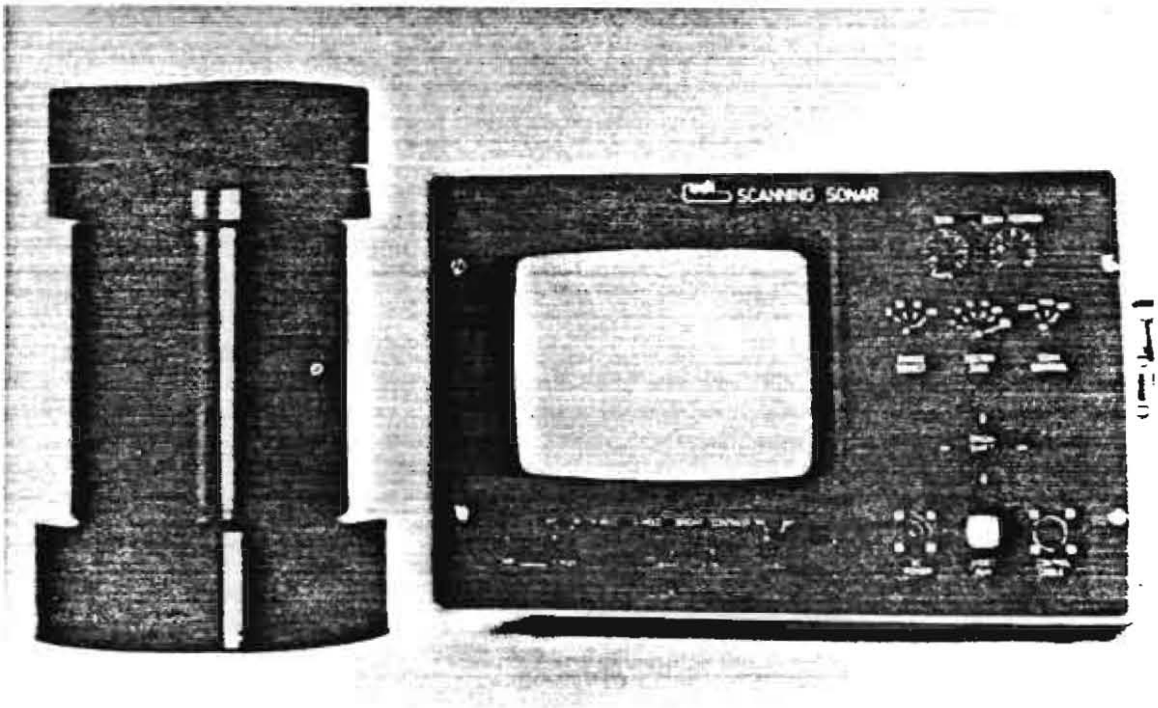
figure 6.





Depth sounder chart recordings

figure 7.

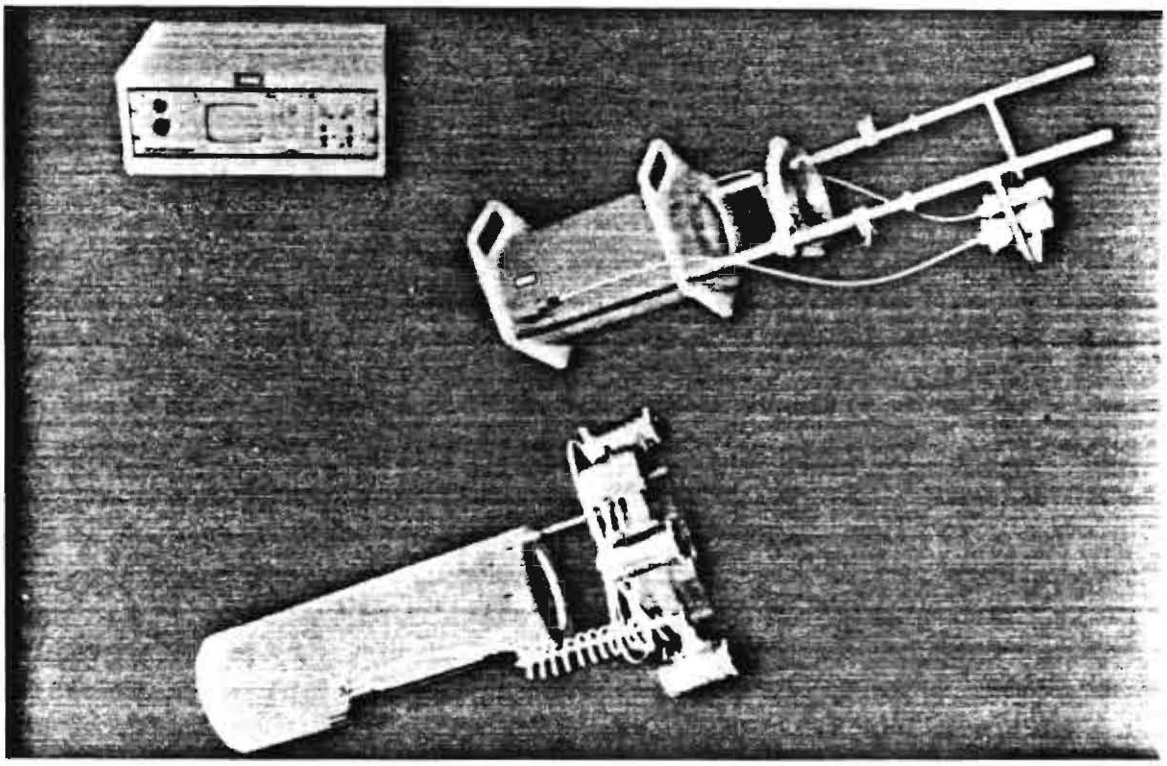


The UDI scanning sonar (a)

UDI sonar image (b)

Klein sonar image (c)

figure 8.



The Thorn-EMI acoustic imager

figure 9.

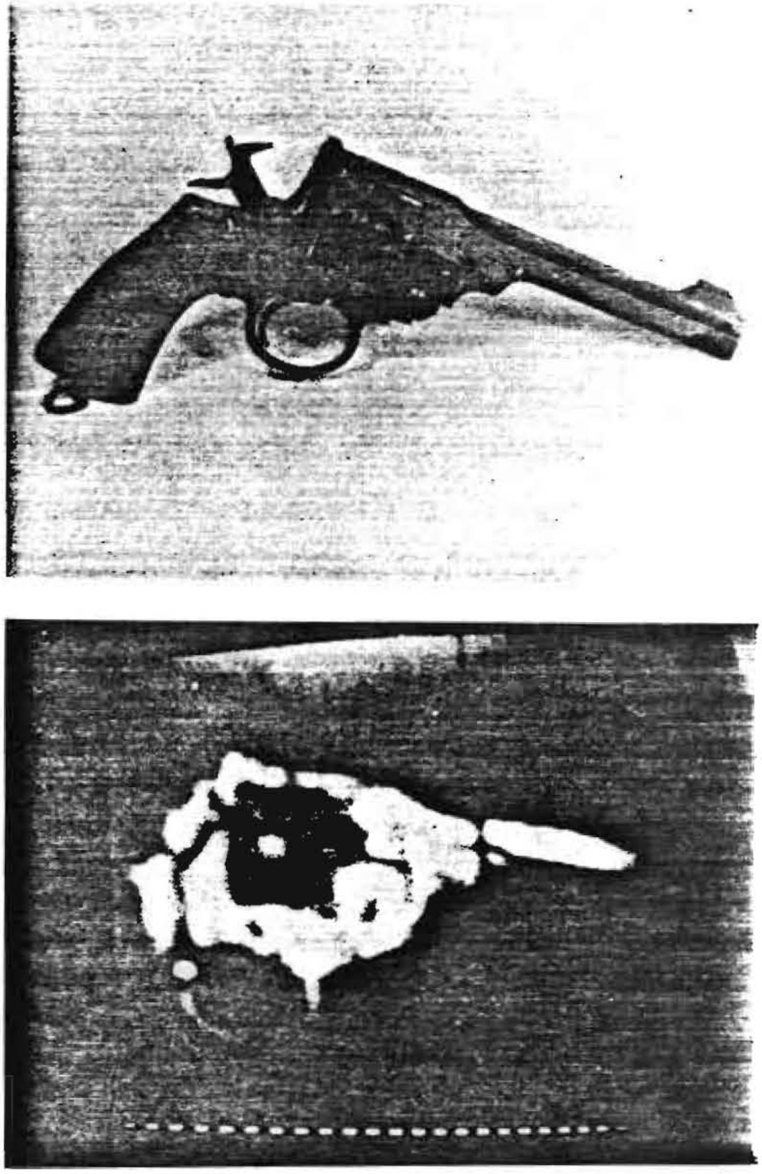


Image of a gun obtained by the Thorn-EMI acoustic imager

(The gun was in turbid water of a few centimetres visibility and completely submerged under a layer of mud).

figure 10.

CIRCULATION

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R Harvey	Asst to HM Chief Insp. of Constabulary

The Scientific and Technical Library
The Police Staff College Library, Bramshill
Information Service, PSDB, Sandridge

SCOTTISH HOME AND HEALTH DEPARTMENT

The Scottish Police College Library, Tulliallan Castle

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