NATIONAL INSTITUTE OF OCEANOGRAPHY

WORMLEY, GODALMING, SURREY

The N.I.O. Depth Telemeter

by

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National Institute of Oceanography

C O N T E N T S

A.16

Summary

This instrument was designed initially for commercial mid-water trawling, but is equally applicable in any situation where the depth of equipment has to be measured. It is designed to give a continuous monitor of the depth of a net whilst in use. It consists of a self-contained unit attached to the towing warp at the net which sends out an acoustic signal towards the ship, the frequency of the signal being dependent on depth. This signal is picked up by a hydrophone towed behind the ship. The receiver unit which is situated on deck measures the incoming frequency by a simple heterodyne method. The present overall accuracy of the whole system is about 1·5% of full scale over a temperature range of 0°C to 20°C, with depth ranges of 0 to 200 metres and 0 to 600 metres, but it is hoped shortly to improve this by a factor of about 2.

1. Introduction

This equipment was initially designed to measure the depth of mid-water trawls. It can, however, be used in any application where the depth of equipment is to be measured. In this report we will consider its application in mid-water trawling. The original idea for this instrument was inspired by that described by Stephens, F.H. and Shea, F.J. (1956), which was itself based on one described by Dow (1955). The general conception of these instruments has much in common.

2. Principal of Operation

The equipment consists of three parts (see Fig. 1); a transmitter, a receiver, and a receiving hydrophone. The transmitter is attached to the trawl warp (see Fig. 2). The transmitter sends towards the ship an acoustic signal whose frequency depends on pressure and thus on its depth. This is received by a hydrophone towed astern of the ship. The receiving hydrophone feeds a receiver which amplifies the signal, beats it with a local oscillator and detects the resulting audio-frequency signal. This is then amplified and fed into a loudspeaker. The frequency of the local oscillator is adjusted until a zero beat note is obtained on the loudspeaker, and then the depth of the transmitter may be read directly from a dial which is coupled to the tuning circuit (as in a radio receiver).

3. The Transmitter

The transmitter measures depth by measuring hydrostatic pressure. The pressure measuring element is an encastre diaphragm attached to a parallel plate capacitor, the capacitance of which varies with pressure (see Fig. 3). This capacitor forms part of the capacitance of a resonant circuit in a transistor oscillator (see Fig. 4). Thus changes of pressure produce changes of frequency of the oscillator. The oscillator output is amplified by a power transistor which is transformer-coupled into a piezo-electric acoustic output transducer. This output transducer consists of four elements in parallel which are installed in an oil filled housing (see Fig. 3). Foam rubber is fitted behind the rear faces of the elements to stop backward radiation of energy. The acoustic output is transmitted through a fibreglass window; this window prevents the foam rubber pressure release material from being compressed by hydrostatic pressure and at the same time provides a reasonably good acoustic match between castor oil and water. The acoustic output is about one quarter of a watt and has a beam angle of about 30° between half power points.

In practice the resonant frequency (about 50 kc/s) of the piezo-

The coil is therefore a teroidal coil wound on a low temperature coefficient dust-core.

electric elements are measured and the oscillator frequency adjusted to give this frequency at the greatest depth, i.e. when the capacitance of the encastre plate is a maximum. The capacitance varies from 90 to 150 pF for full scale and this gives a change of frequency of about 6 kc/s.

The coil of the oscillator has to be very carefully constructed to reduce its temperature coefficient. Temperature coefficients are the main source of error in the system. To get an accuracy of 1% of full scale the transmitter and receiver must have a total temperature stability of 3 cycles/°C. * ~~Thexcoilxisxthereforexwaxexwoundxusingxxx bunchedxconductorxwirexonxxxceramicxformerxx~~ With this type of coil the oscillator has a temperature coefficient of about 2 cycles/°C. This is reduced by choosing a suitable temperature coefficient for the tuning capacitor which is in parallel with the pressure plate.

The transmitter is installed in a pressure case (see Fig. 5) with the fibre-glass window and encastre plate exposed to the sea. A separate compartment of the pressure case houses a 6 volt lantern battery which is switched on by a pressure switch at a depth of about 10 feet. This battery supplies power to the transmitter and lasts for 10 hours continuous running.

4. Receiving Hydrophone (see Fig. 6)

This picks up the acoustical signal from the transmitter with a piezo-electric transducer identical to that in the transmitter. It is towed astern on a strain-bearing co-axial cable which carries the received signal to the receiver. The hydrophone contains a single transistor amplifying stage whose collector load is in the receiver (see Fig. 8).

5. Receiver (see Fig. 7)

This receives the incoming signal, amplifies it, and passes it through a frequency changer which produces an audio-frequency signal equal to the difference between the incoming signal and the local oscillator frequency. The local oscillator covers the same frequency range as the transmitter oscillator, and in use is adjusted to be at the same frequency as the transmitter. This is achieved by feeding the difference frequency to a loudspeaker, and tuning the local oscillator until the frequency heard drops to zero. The difference frequency must be less than approximately 30 cycles/sec to obtain the necessary accuracy, and the loudspeaker is not capable of handling these low frequencies. The difference frequency signal is therefore amplified and limited so that it approaches a square wave, and at low frequencies a series of clicks are heard. Thus, to find the depth of the transmitter, the local oscillator is tuned until nothing is heard on the speaker. The depth is then read off a previously calibrated dial coupled to the tuning capacitor of the local oscillator.

At extreme range the signal to noise ratio may be poor. In these circumstances a slightly different procedure could be used. The ear acts as a very efficient filter and can detect a weak continuous tone superimposed on a much larger noise background, but the loudspeaker-ear combination is not efficient below about 200 c.p.s. In these circumstances the local oscillator is tuned to give a detectable tone on one side of balance, then to give the same tone on the other side of balance, and the mean of the readings is taken.

The receiver also is powered by a 6 volt lantern battery.

6. Performance

A 200 metre and a 600 metre unit have been tested at sea on an

Isaacs-Kidd Midwater Trawl. Both performed satisfactorarily and slant ranges of 1000 metres were obtained with no difficulty at a speed of 3 knots.

The desired overall accuracy of this system is 1% of full scale, i.e. ±2 metres or ±6 metres. This accuracy has to hold over a temperature range of 0 to 20°C.

Due to temperature compensation problems an overall accuracy of 1.5% has so far been obtained. It is hoped, however, to improve this shortly.

The whole equipment is transistorized and designed for ruggedness. The weight of the transmitter is 28 lb in air.

A P P E N D I X

Power Requirements of a Transmitter

In practice engineers would merely insert coefficients (usually in db's) into the relevant equations to find the power required to transmit a certain frequency over a given distance. Here we will consider it from a slightly simplified physical aspect.

Let W = Electrical power supplies to the transmitting transducer (watts)

P = Acoustical power transmitted into the water (watts)

E = Electrical transfer efficiency of the transducer

Then P = E x W.

If the beam is assumed to be conical with a beam angle of θ between half-power points, then S, the solid angle of the transmitter beam is given by:-

$$S = 2\pi(1 - \cos \theta/2) \text{ radians}$$

Then the transmitter (as seen from within the beam) appears to be an omni-directional transmitter with an acoustical power P′

$$\text{where } P' = P \times \frac{4\pi}{S} \text{ watts.}$$

Neglecting for the moment absorption of energy by the water, within the beam the acoustic intensity I in watts/cm^2 at a distance r cms from the transmitter is given by

$$I = \frac{P'}{4\pi r^2} = \frac{1}{Sr^2} \text{ watts/cm}^2.$$

$$\text{Now } I = \frac{p^2}{\rho c.10^7} \text{ watts/cm}^2$$

where p = sound pressure in dynes/cm^2

ρ = density of the medium in grams/cm^3

c = velocity of sound in the medium in cm/sec.

$$\therefore p = \sqrt{I\rho c.10^7}$$

$$= \sqrt{\frac{P\rho c.10^7}{Sr^2}}$$

$$= \sqrt{\frac{EW\rho c.10^7}{Sr^2}} \text{ dynes/cm}^2 \text{ at a distance r cms from the source.}$$

As well as a reduction in sound pressure due to dispersion, there is a further reduction due to absorption in the sea water. This absorption is dependent on frequency (N.I.O. Internal Report No. 13) and at 50 kc/s is approximately 12 db/kilometre.

This absorption is given by

$$I' = I.10^{-\alpha r}$$

where α is the absorption coefficient and is frequency dependent.

Including this effect the received sound pressure p′ is

$$\therefore p' = p.10^{-\frac{\alpha r}{2}} \text{ dynes/cm}^2$$

$$= 10^{-\frac{\alpha r}{2}} \sqrt{\frac{EW\rho c.10^7}{Sr^2}} \text{ dynes/cm}^2$$

at 50 kc/s $\alpha = 10^{-5}$.

This sound pressure when it reaches the hydrophone should be greater than the background noise level in the water. The background noise is dependent on the sea state, bandwidth of the receiving hydrophone, and the frequency range covered. The background noise in the sea decreases logarithmically with increase of frequency but to a first approximation it may be regarded as a linear decrease if the bandwidth is small.

At 50 kc/s the background noise energy in sea state 6 per unit bandwidth is 60 db down relative to $(1 \text{ dyne/cm}^2)^2$. This means that for a 1 cycle/sec. bandwidth the noise level is 1/1000 dyne/cm^2.

Since the total noise energy is proportional to bandwidth, the total noise pressure will be proportional to the square-root of the bandwidth. (Since Energy $\propto$ Pressure^2).

Since the depth telemeter has a bandwidth of 6000 cycles/sec. the total background noise pressure $= 1/1000 \times \sqrt{6000} = 0{\cdot}08$ dyne/cm^2 for an omni-directional hydrophone.

However, the receiving hydrophone is directional, and just as directionality increased the apparent output power of the transmitter, so it will reduce the power of the apparent background noise.

The hydrophone and transmitters have beam angles of 30° between half-power points. This gives a solid angle $S = 2\pi(1 - \cos 15) = 0{\cdot}24$.

Thus the power of the apparent background noise is reduced by a factor of $0{\cdot}24/4\pi$.

Therefore the pressure is reduced by a factor of $\sqrt{\dfrac{0{\cdot}24}{4\pi}}$

Therefore on the receiver the background noise will appear to be

$$\simeq 0{\cdot}08 \times \sqrt{\frac{0{\cdot}24}{4\pi}} = 0{\cdot}01 \text{ dyne/cm}^2.$$

Therefore if we require a signal to noise ratio of 1:1 we require a pressure of 0·01 dyne/cm^2 from the transmitter.

Let us specify a range of 1 kilometre, i.e. $r = 10^5$ cms.

$$\text{Then } p' = 10^{-\frac{\alpha r}{2}} \sqrt{\frac{EW\rho c.10^7}{Sr^2}} \text{ dynes/cm}^2.$$

Let $E = 75\%$, $\rho = 1$ gram/cc, $c = 1500.10^2$ cm/sec.

$$\therefore 0{\cdot}01 = 10^{-\frac{1}{2}} \sqrt{\frac{0{\cdot}75.W.1{\cdot}5.10^{12}}{0{\cdot}24.10^{10}}}$$

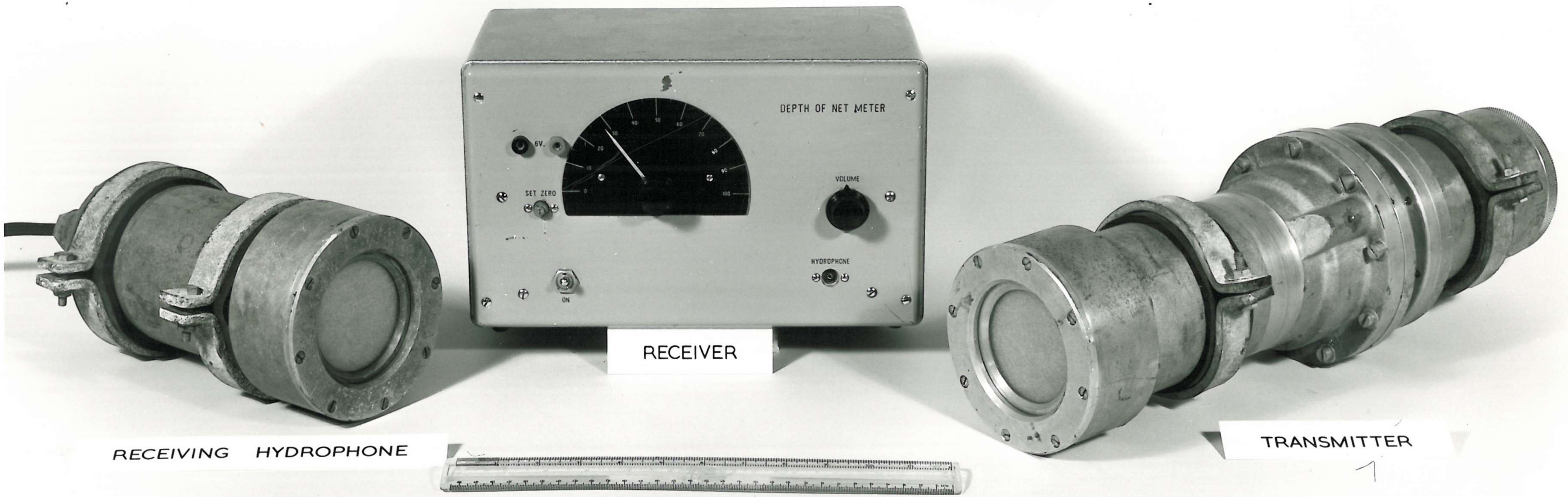
Giving W = 2·2 µW.

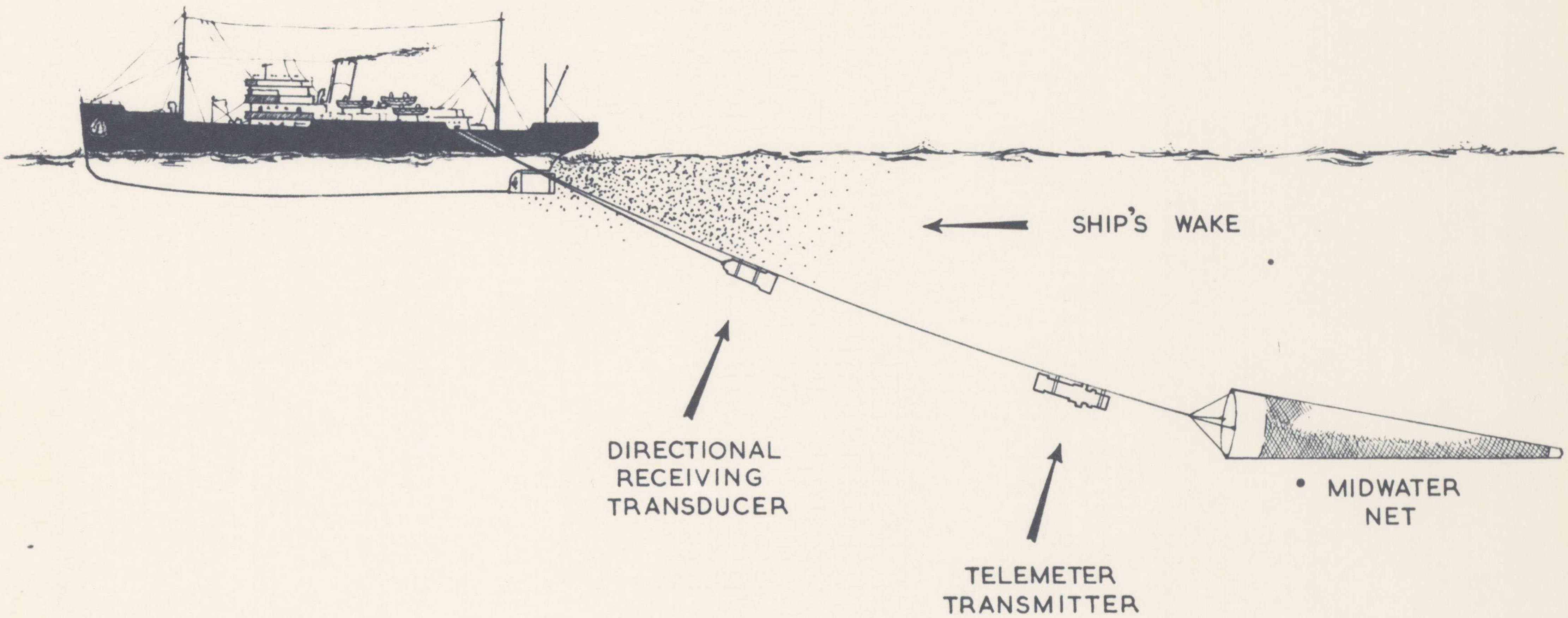
In practice W = 500 mW which gives at 1000 metres $p' = 4{\cdot}75$ dynes/cm^2, i.e. a signal to noise ratio of 475:1.

REFERENCES

DOW, W. (1955) Underwater telemetering. Deep Sea Research, 2, pp.145-151.

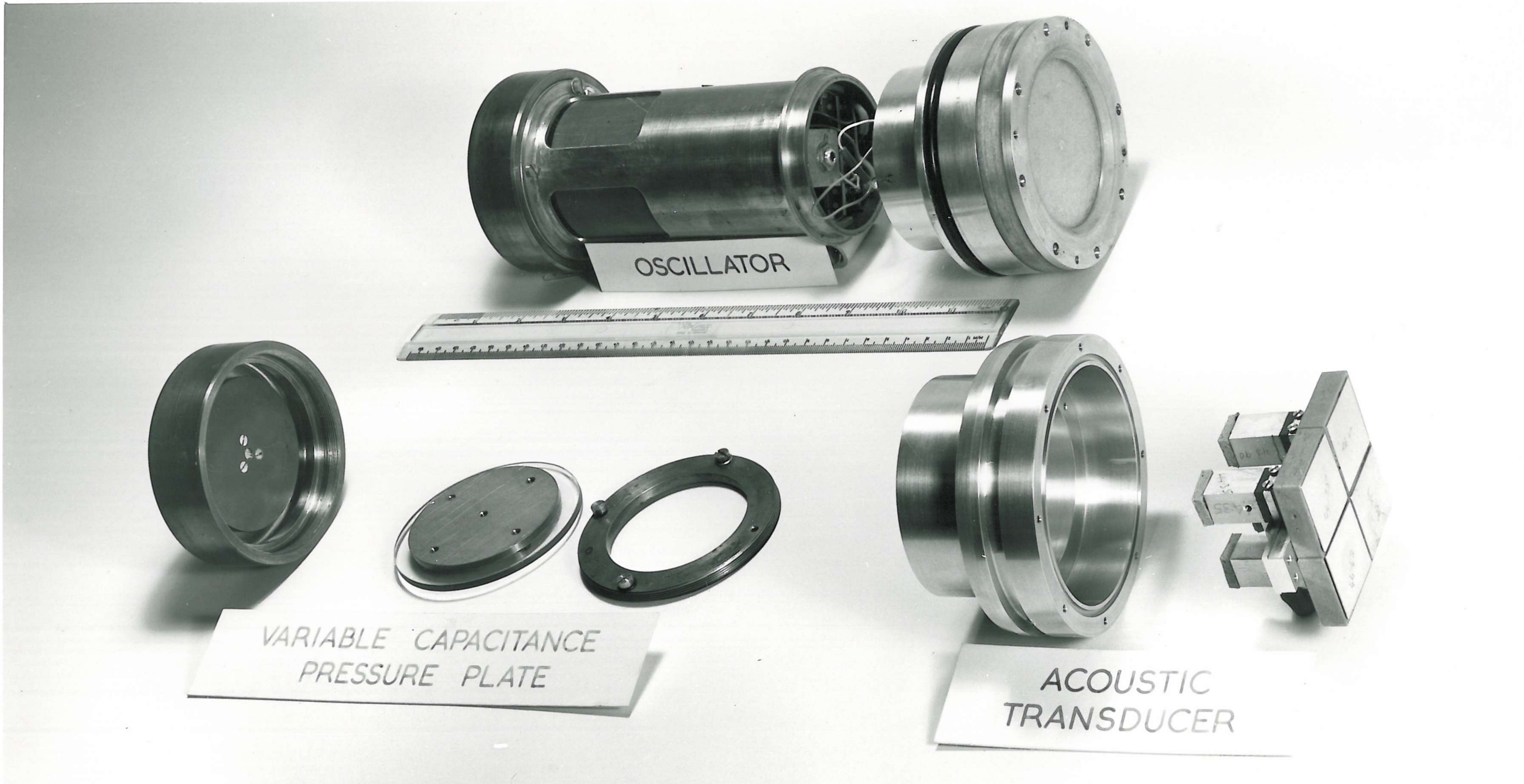
STEPHENS, F.H. and SHEA, F.J. (1956) Underwater telemeter for depth and temperature. U.S. Dept. of the Interior, Fish and Wildlife Service, Special Scientific Report No. Fisheries 181.

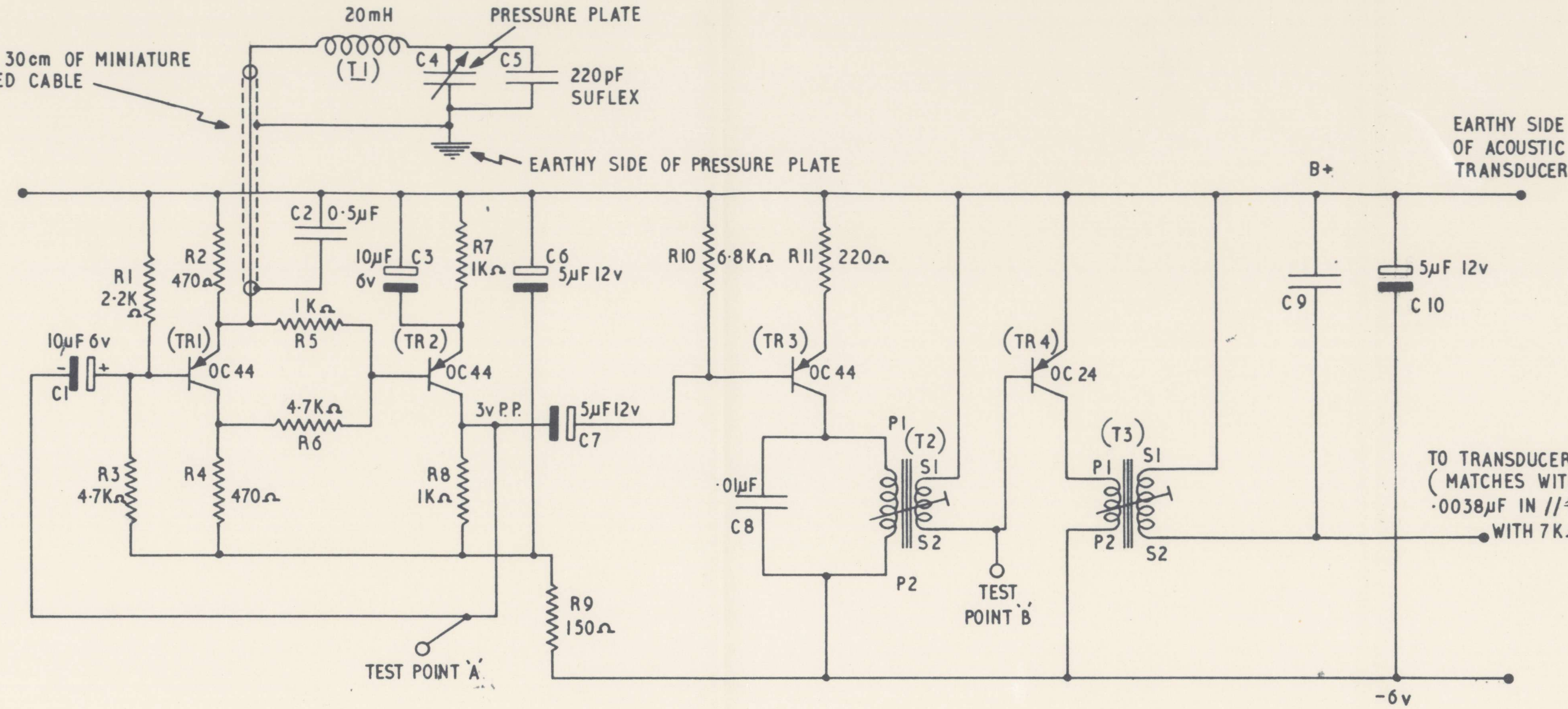

DEPTH OF NET METER
6V.
SET ZERO
VOLUME
HYDROPHONE
ON
RECEIVER
RECEIVING HYDROPHONE
TRANSMITTER



Depth Telemeter in Use

FIG. 2


OSCILLATOR
VARIABLE CAPACITANCE
PRESSURE PLATE
ACOUSTIC
TRANSDUCER



NB

20mH TORROIDAL CHOKE

DESCRIPTION

(1A) CHOKE PERMALLOY POWDER CORE
CORE CODE:- MM 73A
CORE WP 1067/EA
WINDING:- 10 SECTIONS APPROX. '135 T' OF
7/40 BE.S.S. BUNCHED CONDUCTOR
FINISH:- TAPED 1/2" LAP, 9/16" RAYON
INDUCTANCE TO BE 20mH ± 10%

(1B) THERE ARE NO LOOSE WIRES INSIDE IT'S HOUSING

(1C) THE RESISTANCE BETWEEN TERMINALS AFTER WIRING AND ASSEMBLING IS ≏ 30Ω

(2) THAT THERE IS GOOD INSULATION TO PLATE EARTH

(3) SCREEN OF LEAD FROM PRESSURE PLATE MUST NOT BE CONNECTED DIRECTLY TO EARTH OF MAIN CIRCUIT

(T2)	(T3)
CORE:- LA 2503	CORE:- LA 2503
Py. 48T 30 S.W.G.	Py. 5T. 32 S.W.G.
Sy. 8T 30 S.W.G.	Sy. 75 T 32 S.W.G.

N.I.O. DEPTH TELEMETER MK III

Transmitter Circuit

FIG 4.

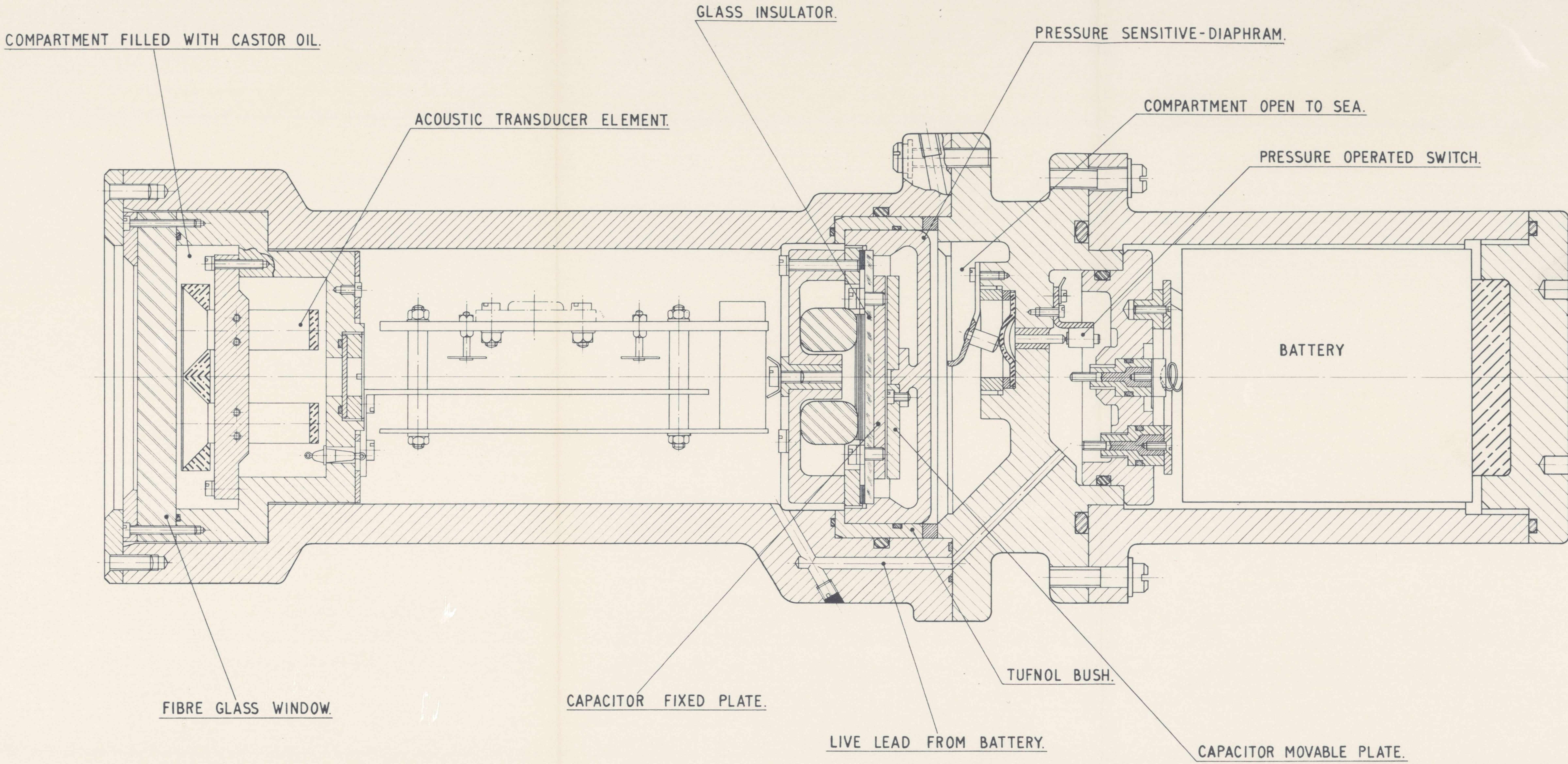


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FIG. 5.

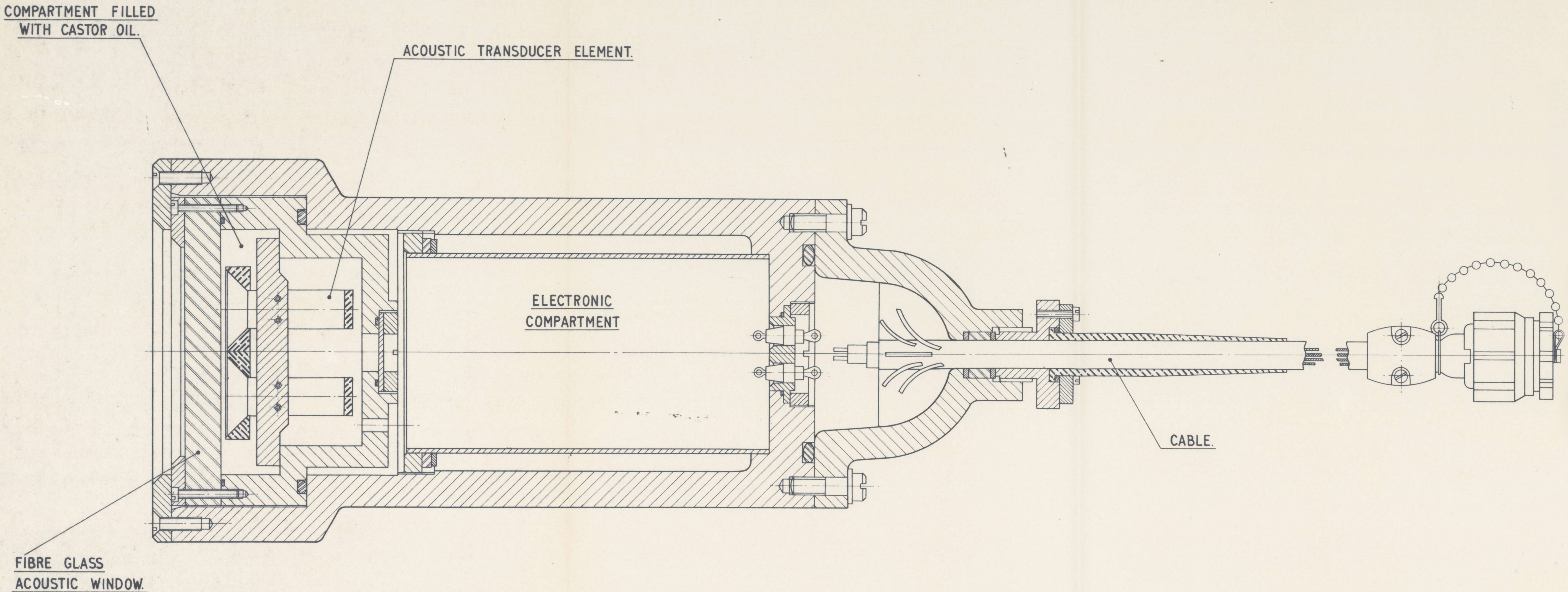

FIG. 6.

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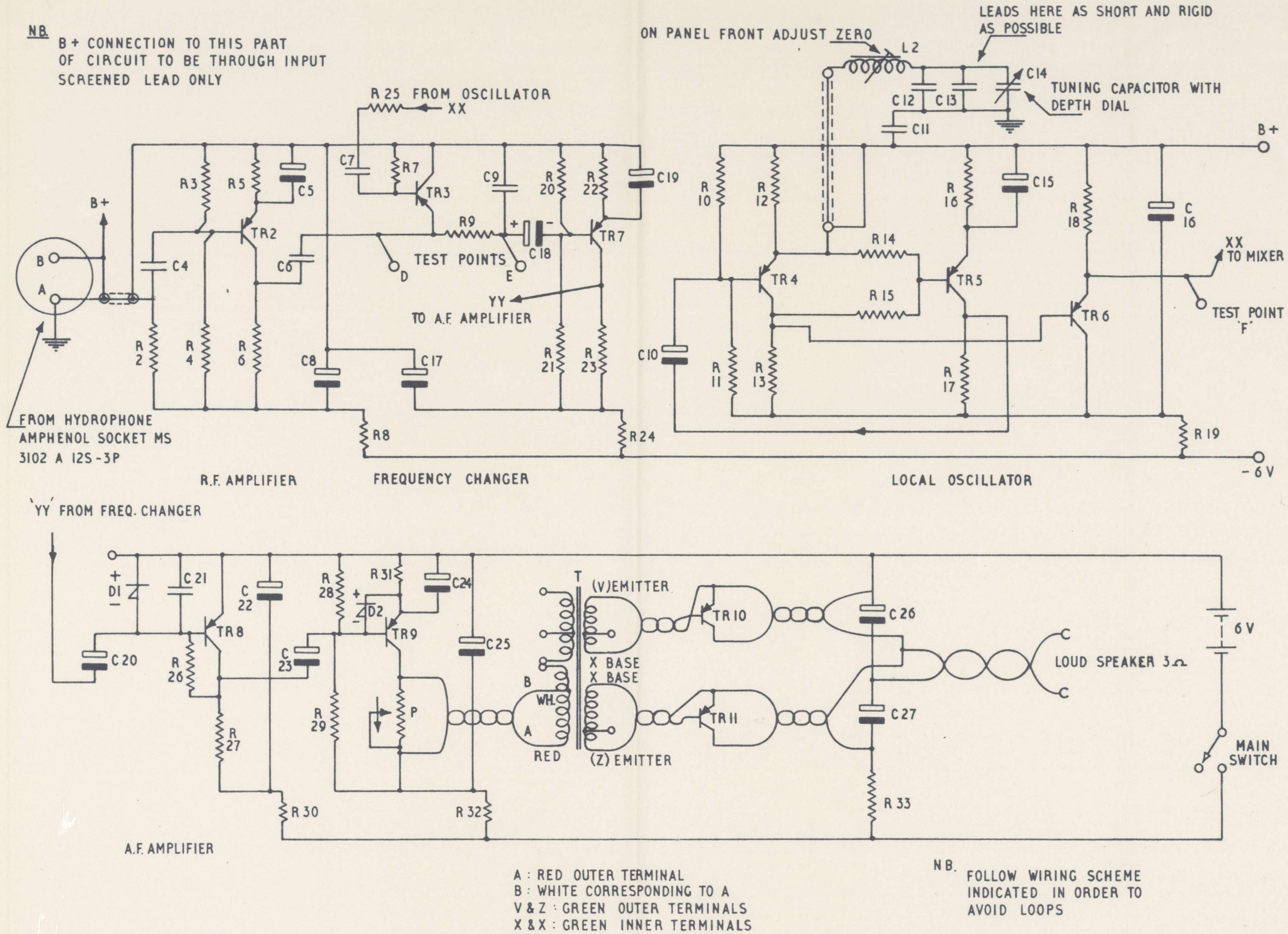

N.I.O. DEPTH TELEMETER
Receiver Electronics

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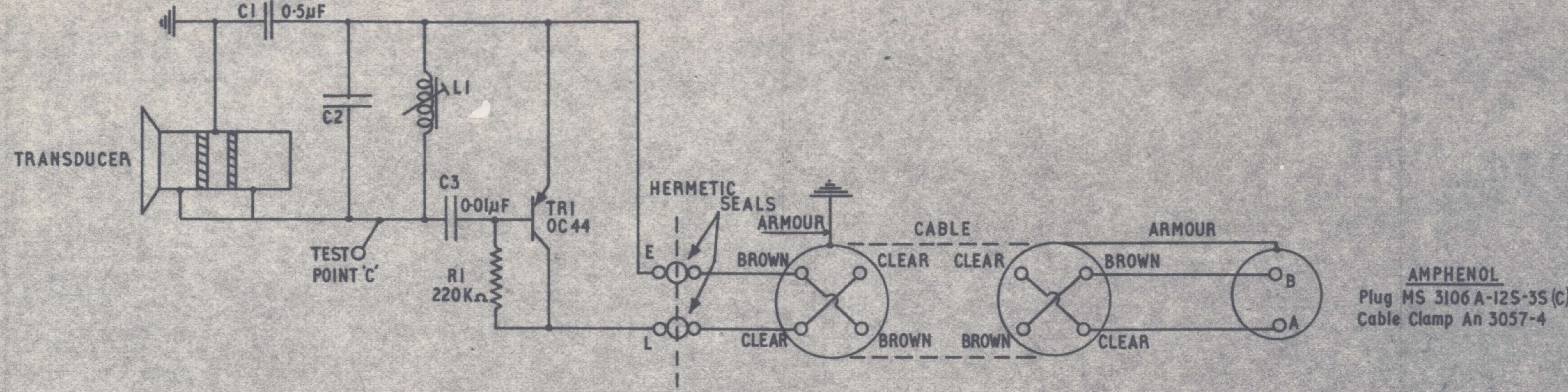
FIG 7



(C2) MAY BE NECESSARY TO BRING TUNING WITHIN RANGE OF L1 (=330pF)

(L1) 75 TURNS OF 30 S.W.G. LEWMEX 'M'

CABLE TELEPHONE CARRIER QUAD TYPE P MK 3. TO M.O.S. SPEC. I.E.M.E./L/4980 (MADE BY B.I.C.C. LTD.)

N.B. SOME EARLY MODELS HAD COAX CABLE

N.I.O. DEPTH TELEMETER.

Hydrophone Circuit Mk II

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FIG. 8.