

PART I
GENERAL

INSTRUMENTATION IN FISHING GEAR RESEARCH

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INTRODUCTION

The general method of study of the performance of any dynamic system is to have an understanding of the various influencing factors. These include the dynamic parameters developed by the system as well as the external factors. In the case of a trawl net under operation there are many hydrodynamic forces acting on it. Since the trawl net is operated much below the water surface, visual observation is rather difficult. Model testing is an alternative method. However, as a model cannot be an exact replica of the original in all respects, model testing has only a limited application and an ultimate test with the actual gear in the true field conditions is necessary.

Since the advancement of physical sciences, the calculations and predictions of any hydrodynamic system by the direct measurement of their parameters have become more accurate and easy. The accuracy of these calculations ultimately depends on the knowledge of the various parameters of the system. Due to the mechanical imperfections of the components in the gear systems and the other various factors like the water current, uneven ground etc., theoretical estimations of these parameters are complicated.

Further, the theoretically calculated values of the fishing gear require direct measurements to ascertain whether they are in the expected ranges. Instrumentation is the best resort under such conditions and is invariably adopted in similar branches of science and technology. The surprising progress of physical sciences is attributed to the wide possibility of instrumentation in these fields. The various electronic techniques are widely used for the conversion of the signals and their easy transmission to the required place.

GENERAL TREND OF INSTRUMENTATION FOR UNDERWATER MEASUREMENT

Basically there are three methods for obtaining measurements underwater. They are (1) to record the signals in underwater units and read them after hauling in, (2) to convert these informations into electrical signals and transmit them to the vessel by means of electrical cables and (3) to convert them into ultrasonic signals and transmit to the vessel, where they will be received and translated into the corresponding values. In the first method the necessary instruments will be heavy and bulky. The use of heavy instruments in the fishing gear can disturb its natural functions and is also risky that such costly equipments may be damaged in the rough

conditions in the sea. Further, the measurements can be ascertained only after hauling in the gear and the time of operation is also limited to one rotation of the drum. The second method, does not in any way affect the natural performance of the gear, because, here, the necessary transducers required for converting the parameters into electrical signals can be made light and no recorders or such other heavy parts are required to be fixed on the gear. The third method possesses the combined merits of the first and second, i.e.; no wire is required for transmitting the signals and measurements are instantaneous and continuous. But such ultrasonic transmitters are also heavy, as they have to include the necessary electronic components and the heavy nickel or crystal transducer for converting the signals into ultrasonic waves, in addition to the batteries necessary for driving the whole mechanism.

MEASUREMENT OF THE OPERATING PARAMETERS OF THE FISHING GEAR

(1) Measurement of working depth:

Hamuro and Ishii (1964a) in Japan developed a heavy and large recording type instrument which records the depth of operation of the gear on a rotating paper drum. A hydrostatic pressure cell picks up the pressure and a pointer moves over a rotating drum. The measurement is obtained after the gear is hauled up. The whole system is attached to the otter board. Hamuro and Ishii (1964 b) also describe an ultrasonic transmitter for the same measurement. In this transmitter, the hydrostatic pressure cells pick up the pressure and a contactor is made to move over a rotating drum, where the stylus movement is made proportional to the length of electrical pulses. These pulses are further converted into ultrasonic waves of varying pulse lengths. The signals are received and displayed either in a recorder or in a microammeter. Mc Neely (1959)

describes a potentiometer type pressure sensing transducer. A potentiometer is actuated by the movement of a diaphragm in the presence of hydrostatic pressure which is proportional to the depth and the variations in resistance of the potentiometer are conveyed to the boat by means of three core electric cable. A wireless telemetering type depth indicator developed by National Institute of Oceanography, Surrey, is reported in World Fishing (1963). In this instrument the frequency of an ultrasonic oscillator is controlled by the hydrostatic pressure. These frequency-modulated ultrasonic waves are transmitted to the boat where they are received through a hydrophone. The depth is read in a calibrated dial by tuning the instrument to the received frequency. When it is off-tuned, a whistle is heard and the tuning position is indicated by the minimum pitch. Sivadas (1968 a) developed a mercury filled transducer for the above measurement. The transducer converts the hydrostatic pressure into variations in electrical resistance.



Fig. 1. Mercury - resistance type water depth transducer developed by Sivadas (1968 a)

These signals are conveyed to the boat by means of a two core cable. Sivadas (1969 c) has developed yet another

electronic type instrument using solid-state components. This instrument has got the additional advantage that the range of operation can be altered conveniently.

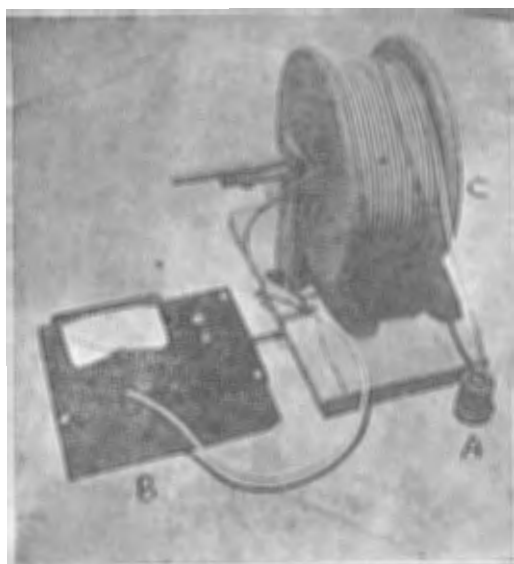


Fig. 2. Electronic operational depth measuring instrument developed by Sivadas 1969. A—transducer, B—Electronic indicating meter, C—Electric cable wound on a hand operated winch.

In all the above instruments, the basis of measurement is the hydrostatic pressure, which is proportional to the depth of the water. In the absence of instruments specially developed for the purpose some alternative methods are described by Mohr (1964) and Sharfe (1964) using echo-sounders. The transducer of the echo-sounder is tied on the head rope of the trawl net and kept facing vertically downwards. Another echosounder is operated from the boat for measuring the depth of the sea bottom. Both of them are recorded separately and the difference between these gives the depth of operation of the gear. This method has got the following defects:—

(1) If the sea bottom is uneven or is not parallel to the water surface, the difference in the sea bottom depths corresponding to the positions of the fishing gear and that of the boat will introduce error in the

measurement. The magnitude of this error is very often significant. (2) The transducer in the gear requires special hydrofoil or suitable arrangements for keeping it always directed exactly downwards. This makes the transducer and the assembly quite heavy and bulky. (3) The long insulated shielded and sheathed thick cable of the transducer makes the operation very difficult. Scharfe (1959 a) has measured this depth using two boats, the rear boat carrying an echo-sounder vertically above the trawl net which is towed by the other. The uncertainty of the exact position of the net produces errors in this measurement.

2) Measurement of warp tensions

Another important variable in the trawl net is the resistance offered by the gear system, which can be measured in terms of tension on the warps. This tension is a combination of resistances offered by the warp, the otter boards and the net which includes floats, sinkers etc. It has often been noted that the warp tension is unsteady due to many factors such as pitching and rolling of the boat, sliding of the otter board and the net over the muddy and rough ground, unsteady movement of the otter boards etc. Measurement of warp tensions helps one to judge the comparative efficiency of the nets so far as resistance to motion through water is concerned. A timely indication of the overloading, or entanglement of the gear at the bottom helps the skippers to control the situation and save the costly net. Many of the abnormal behaviours of the gear will be indicated in the instrument.

Basically there are two types of warp load meters. In one type, the full tension is applied along a hydraulic load cell or spring while in the second method, only portion of the actual load is given to the cell. The instruments developed hitherto have used one of the following three pro-

perties viz; hydrostatic pressure developed in a cell due to tension, mechanical compression of a helical spring and electrical resistance variations in a strain gauge due to the mechanical strain.

Scharfe (1959) used dial spring balances kept on board the vessel and measured the tension directly on the dial by connecting one end of the dial spring balance to the boat and the other end to the warp. Hamuro and Ishii (1964 a) applied the full tension on a spring and converted the compression of the spring into electrical variations and conveyed the signals to a convenient position when it is read in a microammeter. Carrothers (1968) describes a full load hydrostatic type of warp tension recorder consisting of hydraulic cylinder pressure cell and a strip chart pressure recorder.

Unlike the full load type tension meters, the partially loaded types possess the advantage that they can be easily fitted on the warp and used even while trawling. But they suffer from the main drawback that the responses from the respective transducers are not linear to the actual tensions, reducing the accuracy towards higher values of tensions. This is because, the tension which is effectively applied across the cell is $2 T \sin A$ where T is the actual tension and A is the deflection angle.

Satyanarayana and Nair (1965) have developed a deflection type, partially loaded portable tension meter, where the compression of a helical spring due to the partial tension across it is graduated in terms of full tension. Nicholls (1964) has converted the partial tension into electrical variations using strain gauges in a deflection type tension meter. The electrical variations conveyed to the wheel house were recorded in a continuous recorder. A partially loaded type electrical tension meter fitted in the winch developed by 'France Peche' is reported by Foster (1958).

The tension is converted to electrical variations which are conveyed to the wheel house and displayed in an electronic continuous recorder. White Fish Authority developed a deflection type "ship-installed" tension meter as reported by Driver and Ellis (1968). Here also the signals corresponding to tension are transmitted to the wheel house and recorded. The mechanical deflection type tension meter described in "World Fishing" (Anon. 1969) is worth mentioning in this context. The small bending produced in a bar of mechanical deflection type portable instrument is mechanically amplified and displayed in a dial type micrometer. The deflection angle is practically constant in this instrument since the strain produced in the system is small and does not affect the angle significantly.

In the deflection type tension meters using strain gauges, the tension displayed in meters will be linear, because the deflection angle is practically constant. A wide variation in the deflection angle makes the response curve more non-linear producing less sensitivity towards smaller values of the angle. The ship-installed deflection type warp load meters have overcome many of the disadvantages of the other types. Here the load cell is connected between the winch and the pulley in the gallows, so that it possesses a large deflection base and the variation in deflection angle is neglected. This can be a permanent fitting in the deck. A major error in this instrument is due to the unsteady deflection angle owing to the varying diameter of the winch drum.

3) *Underwater tension measurements*

There are different and contradicting opinions (de Boer 1959), among the research workers and technicians regarding the total resistance to motion of the gear system in relation to catch. It has not yet been established as to whether the total resist-

ance is increased or decreased. An increase in the resistance of the trawl net with catch is normally expected. But often times, the increase in tension due to catch is negligible compared to the decrease in tension due to the other factors, described below, contributing to it. As the catch increases, the tension contributed by the codend increases considerably with the result an extra pull is induced through the length of the net. This affects the geometry of the net and for establishing the equilibrium, the otterboards will have to come closer. Further, as the otterboards come closer, the angle of attack is also reduced. Consequently, the resistance to motion of the whole gear system is reduced. An exact and authoritative knowledge of the above performance can be obtained only by measuring the various parameters such as (1) the total warp tension, (2) the tension proportional to the catch, (3) the tension in between the otter board and the net (4) the horizontal opening and (5) the angle of attack. Underwater tension meters are intended for the measurement of the resistance to motion of various parts of a trawl net.

Basically, the underwater line tension meters are of the same principle as that of the warp tension meters. These instruments are to be operated underwater and the information should be either stored in water-tight and light cases or communicated to the boat either by electric cables or by ultrasonic waves.

The underwater line tension meters described by de Boer (*op cit*), Hamuro and Ishii (1964 a) and Nicholls (1964 a) are all based on hydrostatic principles, while the one developed by Carrothers (1966) is of electronic type using semi conductor strain gauges. Since all the above types are underwater recorders, naturally they are heavy and bulky and often times the use of such heavy instruments is undesir-

able since the natural performance of the gear system is affected by them. Further, required information can be obtained only after hauling up the gear. The electronic type underwater tension meter developed by Sivadas (1970) using solid state components is comparatively light and rugged and it communicates the information to the boat instantaneously.



Fig. 3. Underwater tension telemeter developed by Sivadas (1970).

4) *Angle of attack measurements*

Angle of attack is the angle between the plane of otterboards and their directions of motion. The resistance offered by the otterboard and its efficiency are related to the angle of attack. On theoretical calculations for the maximum efficiency the angle of attack has been estimated (Dale and Moller, 1964) to be in between 30° and 40° for a rectangular type otter-board. There are many limitations in the calculations of the required angle of attack, especially in the case of special otterboards such as curved, 'L' shaped etc. The whole hydrodynamic system will maintain equilibrium if the parameters are within a limited range. If they exceed the limits, the whole system is upset and does not function in the normal way. The measurement of the angle of attack is necessary to ascertain whether the otterboard is operating under the required optimum range and also to estimate the most suitable range of this parameter, wherever other methods such as theoretical calculations are impossible.

Basically there are two types of angle of attack meters in use. The one developed by de Boer (op. cit) is mechanical underwater recording type using curved board pasted with paper as the recording medium. The rigid recording part is fixed in the rear of the otterboard and an arm, capable of free movement in any plane is allowed to slide along the bottom. At the opposite end of the arm, a pen is attached, the point of which is in contact with the paper board. The paper board is semi-circular with its centre of curvature coinciding with the fulcrum of the arm. The clock-work-driven pen moves in the vertical direction. As the otterboard moves forward, the arm keeps itself as a reference direction to that of the movement of the otterboard. Here the major disadvantages are that (a) the reference rod is to be always in contact with the bottom, which indirectly means that its use is restricted to bottom trawling, (b) being an underwater recording type instrument, the time of operation is limited and the information can be obtained only after hauling the gear. Further, as a heavy instrument, its use is limited to large size trawlers only.

The second type belongs to the one developed by Sivadas (1969 a). A small circular coil fixed on a brass plate is mounted on the top edge of the otterboard. A plastic fin capable of free movement and fixed with a mild steel curved core is provided with its point of rotation coinciding with the centre of curvature of the arc of the coil. As the otterboard moves forward, the fin aligns itself in the direction of motion of the otterboard thereby establishing a reference to the direction of motion of otterboard. Any change in angle of otterboard is indicated in terms of the angle of attack with the help of the coil and mild steel core, the relative movement of which being proportional to the

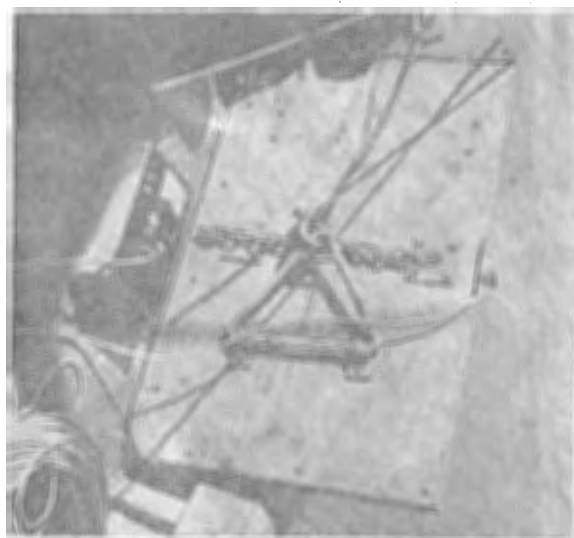


Fig. 1. Angle of attack meter developed by Sivadas (1969a) The transducer is shown fitted at the top of the otterboard

length of the latter. The signals are communicated to boat, where they are translated into angle of attack. This instrument is very light (400 g) and gives an instantaneous measurement quite accurately.

5) Tilt measurements

There are two possible tilts for an otterboard. The tilt in angle of the otterboard around a horizontal axis parallel to its plane is usually called *Tilt*. The tilt in angle of otterboard around a horizontal axis perpendicular to its plane is usually called *fore and aft tilt* of the otterboard.

The *tilt* of the otterboard is to be maintained within a limited range for the equilibrium of the gear system as well as for obtaining best results. The optimum value can be obtained by correlating the same with the other factors of the gear system such as horizontal opening, vertical opening, trawl resistance etc. Similarly, the *fore and aft tilt* also is important. *Fore and aft tilt* in the negative direction is very dangerous, as it causes the otterboards to plough into the mud result-

ing in the breaking of the warps and loss of the gear.



Fig. 5. Transducer of the *Tilt Meter* developed by Sivadas (1969b), fitted at the front edge of the otter-board

The mechanical underwater self recording "clinometer" developed by de Roer (1959 a) (*loc cit*) is too heavy and bulky for a medium sized trawl net. A suspended heavy weight keeps its position always vertical and a pen attached on it records the *tilt* on a moving paper board. The same clinometer is used for both the '*Tilt*' and '*fore and aft tilt*' by mounting them in two different ways.

The *tilt meter* developed by Sivadas (1969 b) is a telemetering type instrument with its very compact, light and rugged transducer. Another direct reading instrument based on the same principle has been made by Sivadas (1968 b) for the *fore and aft tilt* of otterboards. Even though they work on the same principle, they differ in

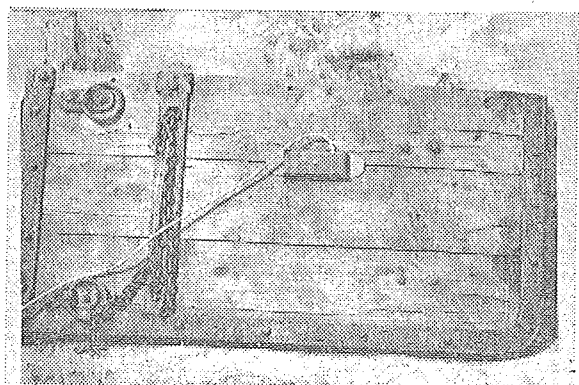


Fig. 6 Transducer of the *fore and aft tilt meter* developed by Sivadas (1968b), fitted at the side of the otterboard.

design and construction to suit the particular usage and ranges of measurement.

6) *Vertical opening measurements*

Vertical opening is one of the few important parameters of a trawl net.

Other things being the same, the catch is directly related to the mouth area. The number of floats and sinkers in a trawl net is estimated, quite often arbitrarily and it some times results in the use of inadequate numbers or too many of them. The measurement of this parameter of the net solves many of such problems and gives an easy and accurate way of estimating the performance of a trawl net. The basic principles used at present for this measurement are (1) the hydrostatic pressure difference between the points and (2) the time interval of an acoustic pulse to travel from the head rope to the foot rope or *vice versa*.

The differential manometer type self recording mechanical instruments described by de Boer, (1959) (*loc. cit*), Hamuro et al (1959) and Nicholls (1964) (*loc. cit*) are too heavy for an average trawl net and the information is obtained only after hauling out the gear. They measure the hydrostatic pressure difference between the foot rope and head rope which corresponds to the vertical mouth opening. In these instruments, two pressure capsules fixed on the head rope and the foot rope pick up the corresponding hydrostatic pressures and convey them to another bulky unit, where the pressures are made to oppose each other. A pen actuated by a force proportional to the difference in pressure, records the same on a moving paper. For reducing the bulkiness and obtaining instantaneous information, an alternative method is described by Leon (1968). The transducer of a low range fish finder is fixed on the head rope keeping its direction vertically downwards. The ultrasonic

pulses emitted by the transducer, after reflection from the special reflectors on the foot rope reach the transducer. The time interval between these two events communicated to the boat by cables is recorded in the echosounder. For obtaining sufficiently accurate measurements, the pulse length of the ultrasonic beam must be very short compared to the vertical opening. This is technically a difficult problem and in an ordinary fish finder, the pulse length itself covers a distance, say 2 to 3 meters and consequently, the vertical opening itself is submerged in the starting mark recorded in the instrument. With the help of special echosounders of very short pulses, the vertical opening can be measured fairly accurately. Holme and Mills (1969) describe trials taken with the cableless telemeter type depth recorder developed by M/S Furuno Electric Co., Japan. This is a recently introduced sophisticated instrument for obtaining informations of the area below the head rope of the trawl net. High frequency pulses are transmitted from a transmitter fixed on the head rope with its transducer directed downwards. Reflections from the fishes, foot rope and sea bottom reach the transducer and after amplification, ultrasonic waves of a different frequency modulated by the reflected signals are retransmitted to the boat. These signals are received and recorded in an ordinary echosounder whose working is synchronised with that of the one kept under water. M/S Kodan Electronics Co. Ltd., have also developed a similar equipment named "Net Monitor".

Sivadas (unpublished) has developed a prototype of a vertical opening meter based almost on the same principles as those of the differential types. Instead of recording the information there itself, they are converted into electrical signals and conveyed to the boat by means of electrical

cable. The size of the transducer has been brought down to 1/15th of that of the commercially available type, weighing below 2 kg.

7) *Horizontal opening measurement*

The horizontal opening is equally important as the vertical opening and is more significant in bottom trawling, because, bottom fishes, especially prawns, will be usually moving at the bottom within 2 meters range and a further widening of the net in the vertical direction is of little use while increasing it in the horizontal direction will proportionately increase the catch.

The horizontal opening is usually estimated by measuring the warp angle. The warp angle in radians, multiplied by the warp length gives the distance between the otterboards. This is very much approximate as it is based on the assumption that the warps are straight in water. But the curvature developed in the warps produces a substantial error in this measurement. Further, the angle subtended by the warp will be of the order of 10° to 15° and it is difficult to measure it within 2° accuracy with the present method which is quite improvised. The corresponding error in the estimated opening comes in the order of 20%. Nicholls (1964) (*loc. cit*) describes a potentiometer type 'divergence meter' for measuring the warp angle accurately. He has used two potentiometers with telescopic arrangements and graduated their relative variations in horizontal distance. de Boer (1959) (*loc cit*) describes a recording type instrument. By connecting a thin flexible cord between the two otterboards, the opening was measured with the help of a recorder fixed on one of the otterboards. The string is always kept taught by the help of the springs used in the unit. In addition to all the disadvantages of a self recording heavy instrument mentioned

earlier, this is very inconvenient to operate. With the help of two transducers of a fish finder fixed on both the otterboards and obtaining pulses transmitted from one transducer to the other, Leon (1958) (*loc. cit*) has measured the opening fairly accurately. Nicholls (1964) (*loc. cit*) describes a very sophisticated electronic underwater transmitter developed by electronic department of Saunders Roe. The pulses from the transmitter in one of the otterboards is received in the other and is retransmitted to the original one in a different frequency. The time interval is recorded there itself. Nicholls (1964) (*loc. cit*) describes another type also with two similar type transducers one for transmission and the other for reception both being connected by electric cables.

8) *Water current measurements*

The velocity of ocean currents vary from zero to several knots. The magnitude and direction of currents vary in oceans, seas and back waters. The performance of a fishing net depends very much on the currents and hence the measurement of water current is very important. The modern commercially available current meters generally use a light propeller as the transducer for picking up the magnitude of current. The propeller with the help of a magnetic field produces electrical pulses proportional to its r. p. m. The deviation of an energised coil from a similar one which has been set to the magnetic meridian of the earth, produces a signal giving an indication of the direction of the current with respect to magnetic meridian. Many producers like M/s Kelvin Hughes (London) and M/s Toho Dentan (Japan) have marketed such current meters. A different method using thermistors has been developed recently by Douglas (1968) for the accurate measurement of very low currents which are not detectable by other usual methods.

9) *Measurement of mesh size variations*

The meshes of the trawl net undergo stress and strain in operation. The strain produced affects the shape of the meshes and this variation in the shape will be different at different portions of the net. These changes in shape affect the normal functioning of the net. Too much elongation of the net reduces the gap and causes high resistance to motion of the net. Further, it affects the total length of the net considerably. The study of the mesh size variations helps the designer to foresee the changes the net undergoes while in operation and make necessary modifications.

No instrument is at present available for this measurement. The instrument must be very light and small in size so that its presence in the net should not in any way affect the functioning of the meshes. Sivadas (unpublished) has made a very light inductive type linear transducer to pick up the mesh shape variations. The variations are converted to electrical signals and conveyed to an electronic indicating meter on board the vessel where the signals are translated to lengths. Several numbers can be used at different positions at a time and simultaneous measurements can be obtained.

10) *Measurement of the water flow inside and outside the trawl net.*

The comparative variation of the water flow inside the net with respect to that outside, is a measure of the openings of the meshes as well as the resistance offered by the net.

Hamuro and Ishii (1964 a) (*loc. cit*) have made an underwater recording type mechanical instrument for the measurement of the magnitude of the water flow inside the net. Sivadas (unpublished) has made a prototype of a very light inductive type water flow transducer along with a solid state electronic indicating meter for this measurement.

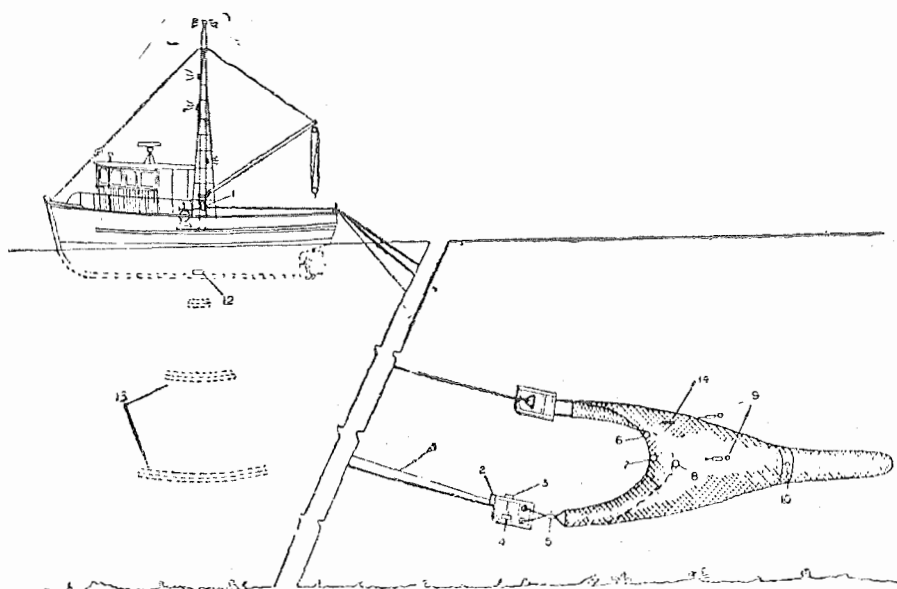


Fig. 7. Positions of the various telemetering instruments required for the study of the behaviour of the trawl.

1) Ship installed tension meter, 2) Tilt meter., 3) Angle of attack meter., 4) Fore and aft tilt meter, 5) Under water tension meter., 6) Net depth meter., 7-8) The pressure capsules of the net height meter., 9) Water flow meters., 10) Tension meter for cod end tension., 11) Electric cable., 12) Acoustic transducer., 13) the ultrasonic pulses, 14) Mesh size meter.

11) Other parameters

There are many other parameters such as warp declination, otterboard action on ground, ground rope curvature etc which are however not as significant as the ones mentioned earlier. The schematic diagram in Fig 7 shows the various instruments fitted in trawl net and boat for the measurement of the parameters described hither-to-fore.

THE SCOPE OF FURTHER INSTRUMENTATION.

The present trend in instrumentation is the adoption and application of various principles in electronics. A major handicap in instrumentation for underwater use is that miniaturisation is difficult and the wireless transmission of signals is also less efficient compared to that in air because, electro magnetic wave which is the medium of wireless transmission in space and air does not travel through water. The alternative is light which is also easily attenuated in water. Fortunately, sound travels in denser medium with less amount of

attenuation and greater speed compared to a rarer medium. Hence, the velocity of sound in water is about five times that in air and it can travel much more distance than in air without being weakened. Because of the above features, sound has been the most efficient agent for underwater communication and instrumentation.

As in any other advanced industry, automation has begun to play its role in fishing industry also. Instrumentation is the first step towards automation. Many underwater informations such as the different operating parameters of the net, the availability of fish shoals etc can be transmitted to the vessels where they are monitored and a computer with the help of servo mechanisms, can control the fishing operations very efficiently.

The major draw backs of the present instruments available are their bulkiness and weight. Many of the recorders cannot serve the purpose because, their very presence in the net adversely affects

its working. Handling of electrical cable is inconvenient in a vessel. However almost all the parameters of the trawl net which are measured by other methods can be converted to electrical signals and transmitted to the boat as ultrasonic waves modulated by the informations required. The receiver in the vessel can pick up the signals and translate them into the respective parameters. Signals from many transducers can be transmitted from a single transmitter one by one and the cost as well as number of instruments required can be reduced.

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