DEVELOPMENT OF A PORTABLE COMPOSITE EQUIPMENT FOR COASTAL FISHERY AND HYDROGRAPHIC INVESTIGATIONS

Thesis submitted to The University of Cochin
in partial fulfilment of the requirements for the award of degree of
DOCTOR OF PHILOSOPHY

By

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OCTOBER 1983

DECLARATION

I hereby declare that this thesis is a record of bonafide research carried out by me under the supervision of Dr. C.T.Samuel, Dean, Faculty of Marine Sciences, University of Cochin and that it has not previously been formed the basis for award of any degree, diploma, associateship, fellowship or other similar titles from this or any other University or Society.

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This is to certify that this thesis is an authentic record of the research carried out by Shri T.K.Sivadas under my supervision and guidance in the Central Institute of Fisheries Technology, Cochin-682029, in partial fulfilment of the requirements for the award of the Ph.D. degree of the University of Cochin and that no part thereof has been presented earlier for any other degree in any University.

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FOREWORD

The author started his career solving problems connected with marine engineering in Central Institute of Fisheries Technology. He soon realised the vast scope of electronics and instrumentation for solving the numerous problems in marine sciences particularly fisheries, and started research and development in this field with the blessings and encouragement from the then Director, Dr. A.N.Bose, which later led to the formation of a Division in Electronics and Instrumentation, and developed more than 3 dozens of electronic instruments and systems many of which were commercialised and three of them fetched National Invention Awards. During his service in National Institute of Oceanography he enjoyed great encouragement and guidance from Dr. S.Z.Qasim, the then Director of N.I.O., present Secretary of Department of Ocean Development, which helped him to expand his activities and contributions to wider areas in marine sciences. The author could further expand the activities and make contributions with parallel applications of his findings to a variety of other fields namely, agricultural meteorology, water resources management etc. with the encouragement from Late Shri G.K.Kurian and the present Director, Dr. C.C.Panduranga Rao, to whom he is much indebted.

The author encountered many hurdles in getting registration for Ph.D. as he insisted to continue his research work in instrumentation applied to fisheries and marine sciences. The formation of the Faculty of Marine Sciences in the University of Cochin and the able guidance and encouragement rendered by Dr. C.T.Samuel as guide to his research, enabled him to carry out the work and submit this thesis. The author wishes to express his heartiest thanks for the broad outlook and help of Dr. C.T.Samuel. He is much grateful to the Scientists of C.I.F.T. and those of many departments in the country who used the instruments and systems which formed parts of the equipment under report and gave constructive suggestions and encouragements.

The author is much thankful to his colleagues Shri K.Ramakrishnan, Smt. K.Vijayabharathy and Shri P.S. Alias for their sincere assistance during the various tests and collection of data from the field.

T.K.SIVADAS

INTRODUCTION

1. INTRODUCTION

Ocean is a potential source of living and non living resources capable of fulfilling our ever increasing demands. Our dependance on ocean has increased enormously during the recent decades and the developments in these lines are expected to be much higher in the coming years. For effective utilisation of the resources, sufficient knowledge on the environment is essential. The fast developments in electronics and instrumentation have made impacts in marine fields also. The developments in semiconductor technology, integrated circuits, data processing, data transmission, micro processing etc. have been suitably utilised in marine instrumentation problems as well.

There are specific and unique problems associated with the marine instrumentation. Some of the problems are regional and hence the design of the instrumentation systems are to be done to a great extend considering the regional problems. For example, marine biological growth is a problem encountered mostly in tropical waters while it is insignificant in cold waters. The submerged sensors of instruments to be operated in tropical waters should be designed to overcome this problem. Many instruments now popular are not suitable for our waters. Corrosion of metals on the sensors and other submerged objects is another serious problem which is universally existing. Marine environment is highly corrosive and the onboard instruments are also seriously affected by this. The switching contacts electrical coils etc. undergo changes in values in the presence of high humidity and salt spray.

Many sophisticated techniques available for instrumentation in equivalent other fields cannot be adopted as such in marine fields under the above circumstances.

In earlier works each environmental parameter is measured independantly. Most parameters are independent and their simultaneous measurement is essentially needed for better interpretation of the results.

1.1 HISTORICAL BACKGROUND

All the present equipment available for fishery hydrography are the result of its parallel applications in oceanography. Instrumentation efforts in oceanography intensified as early as 1930^{s}. One of the earliest contribution is echo sounder used by United States Coast and Geodetic Survey and described by Rude (1938). The Reversing Thermometers introduced by Negretti & Zambra (London) in 1874 was modified later to obtain an accuracy of .01°C. Moshy (1940) devised one of the most needed instrument called Thermosounder for measurement of temperature against depth. A series of current meters were introduced by several firms along with the classical one developed by Ekman (1905, 1932). Some of the earlier mechanical instruments such as bathy thermograph and reversing thermometer are still popular because of their versatility and rugged design features. Most of the equipment used for collection of samples such as water samplers, grabs, corers etc. are still popular as such.

Naval Physical and Oceanographic Laboratory, Cochin had been engaged in marine electronics with their attention primarily on applications of ultrasonics for naval purposes. National Institute of Oceanography, Goa started R & D activities in Marine Instrumentation since 1973 and have contributed to marine measuring instruments. Central Institute of Fisheries Technology started working in this line with special emphasis given to the explorations and exploitations on living resources and the associated gear technological investigation. A few instruments developed indigenously have been commercialised through National Research Development Corporation of India and made available in the country.

1.2 MODERN ELECTRONIC INSTRUMENTS

The developments in electronics especially in semiconductor technology and integrated circuits made fast changes in the design of instruments. The following few pages give a brief and classified account of the various principles adopted and instruments developed in the relevant fields connected with the project under report.

1.2.1 MEASUREMENT OF WATER CURRENT

In most instruments water current is sensed with mechanical sensors like impeller and rotor. The impeller is directed towards the water flow. The rotation rate of the impeller is

$R = K. |\bar{V}| \cos\Theta$ where K is a constant, $\bar{V}$ is the velocity of the current being measured, and Θ is the angle between the axis of the impeller and the water flow. At very low velocities, the system is likely to fail to align to the water flow and makes errors proportional to cos Θ The rotor operates in vertical axis and responses fully to all directions and is free from the above error. Impellers and rotors use different methods for converting the rotations into pulses. In earlier models, make and break contacts in a water tight chamber was made for producing pulses. Usually magnetic coupling was done for making water protection easier. Later reed switches were used for making the 'make and break' easier. Reed switches were activated by permanent magnets mounted on the rotor/impeller. 'Hall chips' were also used in the place of reed switches. In general impellers and rotors are most popular because of the simple design, high reliability and minimum electronics.

Gaul, R.D. et al. (1963) have made a detailed study on the performance of savanius rotor. Tests have shown that the relation between water current and rotor rotation is fairly linear above .1 knot.

Chalupnik, J.D. & Gree, P.S. (1962) describe a doppler shift ocean current meter using a frequency of 10MHz producing a frequency shift of 13 to 130,000 Hz corresponding to 1 mm/sec to 10m/sc. However the signal to noise ratio was very low. Lester (1962) describes acoustic type current meter using 4 Nos. transducers. The fluid velocity in such a system is given by $V = \frac{\Delta t \; C^2}{2L}$ where C = velocity of sound in water, t = difference in time delays and L distance the sound travels. The attractive features of the acoustic flow meter are (1) there are no moving parts, (2) it is a digital system basically (3) very high accuracy is possible.

Ultrasonic waves are used in different ways for water flow measurement in open ocean. Doppler shift of acoustic waves is used to measure the velocity of water mass. An ultrasonic beam projected to the water undergoes volume reverberation and gets reflected to a receiver after undergoing a frequency shift due to Doppler effect. Koczy, F.F., Kronengold, M. & Loevenstein, J.M. (1963) describe a doppler current meter with an ultrasonic beam of 5 MHz. Super hetrodyne principle is used for effective noise suppression. It is reported that this method is suitable for streamlined constant flows.

Acoustic travel time sensing is a very effective method for achieving higher accuracy. The travel time between the transmission and reception of an acoustic beam is measured as a function of the velocity of the water flow. If a current U exists between two transducers, such that U makes an angle with e, the vector connecting sensor 1 and sensor 2, the travel time required of a wave emanating from 1 to reach 2 is

$$T_{12} = \frac{|\vec{e}|}{C + |U| \cos\theta}$$ and the travel time from 2 to 1 is

$$T_{21} = \frac{|\vec{e}|}{C - |\vec{U}| \cos\theta}$$

The obvious algetradc manipulations yield:

$$|\vec{U}| \cos\theta = \frac{|\vec{e}|}{2}\left(\frac{1}{T_{12}} - \frac{1}{T_{21}}\right)$$

$$C = \frac{|\vec{e}|}{2}\left(\frac{1}{T_{12}} + \frac{1}{T_{21}}\right)$$

$$\therefore T_{12} - T_{21} = 2|\vec{e}| \frac{|\vec{U}| \cos\theta}{C^2}$$

Clinlon D. Winant (1978) gives an account of the laboratory test results of an acounstic travel time sensor.

Electro magnetic sensors utilise Faraday's Law which states that a conductor (sea water) moving with velocity $\vec{U}$ through a magnetic field $\vec{H}$ generates a voltage U

$$\vec{V} = \vec{H} \times \vec{U}$$

The sensors geneate an magnetic field $\vec{H}$ and sense voltage difference between pairs of a electrodes. Two pairs of electrodes can be used for resolving the vector average of the current. Clinton D.Winant (1978) gives the curve of the combined linearity and angular response of electronic velocity meter. He have also reported the results of a mechanical current meter consisting of two orthogonal flow sensors developed at scripps Institutions of Oceanography. Each sensor consists of a pair of fans and the rotation rate of the common shaft is given by

$$R = \alpha /\bar{U}/ \cos\theta$$

where $\bar{U}$ is the velocity of the current being measured, θ is the angle between the flow sensor axis and $\bar{U}$. There are provision to identify the rotations in clockwise and anticlockwise.

The author (Sivadas, 1981a) has developed savanious rotor type current meter for oceanographic purposes with very small rotor and compact underwater probe.

Oceanographic current meters are manufactured by several firms all over the world. Ogawa Seiki Co., Ltd., Japan has marketed current meters with impellers model O.S,K. 1805, O.S.K. 891-B, O.S.L. 891-A, O.S.K. 891-C, O.S.K. 891-D and O.S.K. 900 with direct measurements in their on-board meters. The model O.S.K. 1801 with impeller uses a built-in recorder for making continuous measurements up to 20 days. These current meters need heavy fish weights to bring the sensing probes to vertical. Because they do not have the facility for self alignment to horizontal.

Marsh Mc Birney, Inc. has manufactured electromagnetic current meters for oceanographic purposes, based on Faraday's law. Sensor of the instrument consists of a sphere which contains an electromagnet, two pairs of external electrodes in contact with water. One significant speciality of this instrument is that it gives vector velocity of the current components X and Y as $V = \sqrt{X^2 + Y^2}$ and the velocity direction is $\Theta = \tan^{-1} Y/X$. Model 5, 2, 4 has got insitu measurement with its read out meters, for X and Y components separately in 2 meters. Model 551 has got a self contained electronics housed in pressure proof chamber rendering the measurements up to 3500 ft. Model 555B gives both currents and its directions with its self contained electronics extending the operation up to 6000 ft. depth.

Inter ocean systems Inc. has manufactured electromagnetic current meters with almost the same design features of Mash-Mc-Birney Inc. as explained above using spherical electro-magnet. The model 135 and 135m current meters of the same firm use balanced savonious rotor with self contained electronics for recording the data.

Endeco U.S.A. has got current meters with impeller type 110, 132 with remote read out facilities. Types 717 and 720 are electromagnetic types with vector averaging facilities.

Aanderaa Instruments, Norway uses savanious rotor alongwith self contained electronics and magnetic tape for recording current in deep waters. Tsurumi Seaki, Japan has got current meter with direction using savanious rotor (model MTCM-4A) with self contained recording facilities. Their another model MTCM-6 uses electromagnetic sensor with vector averaging facilities. Plessey Environmental systems, U.S.A. has got the current meter with impeller in their model 9021 alongwith facility for internal recording. General Oceanic, U.S.A. has marketed a current meter with self contained recording facilities for deep water measurements. One unique novelty of their current meter (model 6011) is that the current magnitude is measured as a function of tilt from vertical of a floating system, due to water current. Though the accuracy of this method is quite low, it is more rugged and can operate safely under bio and sediment ladded waters. Acoustic current meters have been manufactured by Simrad, Norway and Neil Brown International systems, U.S.A. Deep ocean work systems, U.S.A. has marketed very inexpensive type vector measuring current meter using 3 nos. of impellers.

Lawrence & Mayo, Bombay has marketed current meter using impeller. Saraf Electroceanic Appliances has marketed the know how of National Institute of Oceanography and developed by the author.

Unesco (1967) has made an intercomparison of some of of the current meters in the field conditions. Current meters of rotor and impeller types of different manufacturing firms were used in the study. The study has revealed the fact that all the current meters have worked reasonably well and the performance of rotors/impellers are better than what claimed by the firms.

Unesco (1970) has made a much more detailed field tests of 6 current meters belonging to rotor, impeller and two Russian types with cups and paddle wheels. The study conducted has revealed several practical failures of instruments.

1.2.2 MEASUREMENT OF CURRENT DIRECTION

Oceanographic current meters essentially need the measurement of current direction also. The direction of current in ocean vary at different depths due to several changes. The basic features needed for measurement of water current are (1) The under water probe fully or partially should align to the direction of water flow thereby making a reference to the flow direction (2) There must be a constant and fixed reference with which this reference should be compared. Usually this is done with the magnetic north with the help of a built in magnetic compass (3) The sensing probe should be well stabilized free from the tilt due to hydrodynamic drag. Many current meters are not stabilized by virtue of their design. In such cases, they are brought to fairly steady and stable condition by adding heavy fish weights even up to 50 to 100 kgs. In the absence of such heavy weights, the under water probes are too much tilted and the direction sensing compass will not work properly. But the sensing probes can be kept at stabilized condition by designing the system with streamligned condition wherein the system will offer comparatively very low drag force, will remain stabilised in the horizontal plane even though the cable is tilted. The weight of fish weight needed in such cases is comparatively low.

The under water probe is designed for minimum area exposed to water flow. This is achieved when the body is made horizontal as well as aligned to the direction of water flow. Once the system is aligned to water flow free from tilt, the direction is sensed with respect to the magnetic north by means of magnetic compass. Basically there are two types of compasses used at present. The simplest type senses the direction by means of a built in magnetic compass and a potentiometer. The difference in directions is converted to the variation in resistance of a potentiometer. The accuracy of such sensors are comparatively less around 2° to 5°. The current meters of Aanderaa, Norway, Plessey, U.S.A., Toho Dentan, Japan etc. use these types.

Another method namely, 'flux gate' has come into operation with much higher accuracy. The compass consists of a toroidal coil with dual pick up windings mounted on gimbals in a fluid filled enclosure. A separate electronic circuit provides the excitation, control and output signal conditioning functions. These type sensors are used by aircrafts and ships for precise navigation. It is not available in compact sizes unlike the other equivalent types for accommodating in small current meters. Neil Pollock (1982) gives a detailed account of the design of the complete system including its toroidal coils and the electronics. Digicourse is manufacturing different types of these for various applications. Endeco has manufactured similar type sensor for under water uses.

1.2.3 MEASUREMENT OF SALINITY

Salinity of sea water is a defined valve. Owing to the complexity of sea water it is rather impossible by direct chemical analysis to determine the total quantity of dissolved solids in a given sample and it is difficult to get reproducible results. Therefore a technique was adopted for estimation of salinity by The International Commission for the Exploration of the sea in 1902 (Sverdrup, 1942a) based in the works done by Knudsen (1901) and accordingly salinity is defined as the total amount of solid material in grams contained in one kilogram of sea water when all the carbonate has been converted to oxide, the bromide and iodine replaced by chlorine, and all organic matter completely oxidized. Here chloride ions make up approximately 55 percent of the dissolved solids. The empirical relationship between salinity and chlorinity, as established by the International commission, is Salinity = 0.03 + 1.806 x chlorinity. The chlorinity that appears in this equation is also a defined quantity (Sverdrup, 1942b) and des not represent the actual amount of chlorine in a sample of sea water. Both chlorinity and salinity are expressed in grams per kilogram. In the titration with silver nitrate, bromides and iodides are precipitated together with the chlorides, but in the computation it is assumed that they are chlorides. Chlorinity was originally defined as the total amount of chlorine, bromine and iodine in grams contained in one kilogram of sea water, assuming that the bromine and iodine had been replaced by chlorine. The various stages of development in the definition of chlorinity and its estimations are described in detail by Klaus Grasshoff (1976). The primary standard used in the determination of chlorinity is so called 'Normal water' prepared by the Hydrographic Laboratories in copenhagen.

Salinity expressed conventionally as parts per thousand and written, say 35.7‰. But this has recently been amended by Unesco (1981). The practical salinity adopted is 1000 times more than the conventional one. Then the figure 35.7‰ becomes 35.7 only.

The other methods for estimating salinity are based on its relation with (1) density at constant temperature (2) electrical conductivity at constant temperature and (3) refractive index at constant temperature. The first and third methods are not very popular because of the difficulties involved in the measurements. The second method of measuring electrical conductivity is the most popular one giving maximum accuracy. It is available for instant and remote measurements. The possibility of using conductivity for determining salinity became practicable with the successful introduction of an electronic equipment (Brown & Hamon, 1961) and the consecutive efforts done by UNESCO, SCOR and IAPSO finally led to the relation (Wooster et al. 1969)

$$S\ \text{‰} = -0.08996 + 28.29720\ R_{15} + 12.80823\ R_{15}^{2} - 10.67869\ R_{15}^{3} + 5.98624\ R_{15}^{4} - 1.32311\ R_{15}^{5}$$

where R_{15} is the conductivity ratio at 15°C relative to the conductivity of 'standard sea water' having a salinity of 35.00 ‰ and chlorinity 19.375 ‰.

The conductivity factor sensed with electrode cell or electrodeless induction cell is measured mostly by a bridge network where the electrical resistance of the sensitive arm is balanced by a potetiometric resistance variation of the opposite arm. Aagaard, E.E. & Van Haagen, R.H. (1963) describe a null method for measuring conductivity. He shows how the balancing signal can be used for activating a servomotor which in turn balances the null. Null methods have the unique advantages that they are largely free from the errors due to transformer magentising reactance and core loss, power supply variations, frequency variations etc. Brown N.L. (1963) uses a more sophisticated signal conditioning system wherein he describes the effects to temperature and pressure on conductivity and introduces compensation methods for them using thermistor and pressure operated potentiometer. He has studied the effects with double wheatstone bridge compesnation circuit and a double transformer compensation circuit. Jacobsen, A.W. (1948), Hamen, B.V. et al (1956) have used conductivity cells with suitable signal conditioners for insitu measurements. Skinner, D.D. (1963) proposes a slight alteration in the conventional method by detecting the phase difference caused in conductivity bridge due to the conductivity of the water. The D.C. voltage derived from the phase detector is used to operate a servomechanism. Tucker M.J. (1966) describes the complications involved in the temperature conductivity relationship which makes it much impracticable for automatic temperature compensation.

Measurement of conductivity in laboratory conditions is fairly easy and practicable as a high amount of accuracy can be achieved.

Jones, G. & Bollinger, G.M. (1931), Hamon, B.V. (1956) Wenner, F., Smith, E.H. & Soule, F.M. (1930) have used conductivity cells for sensing salinity in laboratory conditions.

Sivadas, T.K. (1978) has used conductivity cell with platinum electrodes for sensing salinity as a function of water conductivity. Attempts have been made for using capacitively coupled cells for salinity measurements, as mentioned by Brown N.L. (1963) in his review of various techniques. But because of the numerous problems in dealing with high frequency, this has never came into practice.

Brown, N.L. (1966) describes a laboratory type instrument using 2 sets of inductive type cells which are maintained at constant temperature bath.

Sivadas, T.K. (1981b) has developed a field operated type instrument for the measurement of salinity, temperature and depth. Salinity is sensed using a 2-electrode conductivity cell.

Both laboratory and field instruments have been commercialised by several manufacturing firms all over the world. Inter Ocean Systems, U.S.A., Grundy Environmental systems Inc. U.S.A., Sea Bird Electronics, U.S.A., Beckman Instruments, U.S.A. and Applied Micro systems U.S.A. have marketed salinometers and conductivity meters. Recently Beckmen Instruments, Inc. have introduced a mini computer attached with their model RS9 induction salino meter for computing salinity from the conductivity eliminating the effect of temperature. Guidline Instruments Inc. have marketed a portable type instrument attached with a micro-processor for computing salinity from conductivity and temperature.

1.2.4 MEASUREMENT OF WATER TEMPERATURE

Temperature is sensed based on thermocouples, bimetallic expansion, liquid expansion, mercury expansion, electrical resistance variations of metal wires, resistance variation of thermistor, voltage variation across the base emitter junction of a silicon transistor etc. Here many methods are not suitable for remote measurements needed for oceanography. Thermistors and resistance wires are commonly used as the basic elements for sensing temperature. Measurement of base-emitter junction voltage has not become popular in oceanography because of the long response time. Thermistor is most popular because of its high signal level and simple circuit design. But the response is non-linear and special efforts are needed to linearise the output. Special thermistors with higher consistencies and identical features have been marketed by Fenwal Electronics, U.S.A., specificcally for oceanographic measurements.

Apart from the usual devices mentioned above, there are special devices also developed for specific purposes. Gfil, F.G. & Thompson, J.H. (1963) gives an account of a very sensitive type temperature sensing device based on the principle of a high Q mechanical resonator whose frequency is temperature dependant. High accuracies of the order of ± 0.02°C has been achieved in the laboratory model reported. The expression for a thin disc with no post and vibrating flexurally with two modal diameters is

$$f = \frac{0.238\ t}{R^2}\sqrt{\frac{Y}{e(1 - \sigma^2)}} \quad \text{where}$$

f is resonator frequency, R is the radius of the disc in cms, t is the thickness in cm, Y is the young's modulus in dymes/cm^2, σ is the poisson's ratio and e is the mass density in gm/cm^3.

Rapid measurements of temperature is needed when the sensor cannot be kept in a position. Many conventional sensors fail here because of their long response times. Hoover, H.M. (1963) describes a precise platinum resistance element enclosed in a very thin stainless steel tube. He could achieve a time constant less than 1 sec with an accuracy of .05°C. The pressure effect of the stainless steel tube was determined using lane's empirical approximation for the crushing strength of long tubes given by

$$P = 80,000 \times \left[\frac{t}{D} - \left(\frac{t}{D}\right)^2\right] \quad \text{where}$$

t is the wall thickness in inches, D is tube diameter in inches and P is the crushing pressure in psi. The unbalanced bridge has an output computed as follows from Thevenin's principle.

$$Eo = \frac{E\ (AS-BX)}{RE(A+B+S+X) + (A+B)\ (X+S)}$$

Where Eo is open circuit voltage across detector, E is source voltage, A,B and S are fixed bridge resistors, X is the platinum resistor and RE is the sourse impedance. The current, Id, passing through is

$$Id = \frac{Eo}{Rd + RB}$$

where RB is the bridge resistance seen by the detector and Rd the detector impedance. Higher linearity is achieved by keeping the bridge resistance variation relatively low and a high impedance detector. Hudimac, A.A. et al. describe a thermistor suitably designed to give a temperature response of .5 sec and an accuracy of .005°C. The base-emitter voltage of silicon transistors is reported to be inversely proportional to the temperature in a wide temperature range of -60°C to 200°C. Ramakrishnan, K. et al. (1982) have developed remote operated thermometers in the range -40°C to +40°C with an accurancy of $\pm$.1°C.

In commercial models thermistor is the most popular temperature sensing element because of the simplicity of the instrumentation associated with it. The well known

Oceanographic firms namely Inter ocean, U.S.A. and Aanderaa Instruments Norway use thermistors in their equipment for temperature measurements. Temperature measurements are invariably done alongwith conductivity and salinity measurements, because temperature is needed for computing salinity from the conductivity of sea water.

1.2.5 MEASUREMENT OF DEPTH OF OPERATION

Depth is measured in oceanographic operations based on two principles namely, 'acoustic echo sounding' and 'hydrostatic pressure'. The former method is popular for measurement of total water depth at a place. But the depth at which the under water probe is operated is not very popular though it can also be done by means of acoustic echo sounding method by getting reflections from the probe or the water surface. The latter method of sensing the hydrostatic pressure as a measure of depth is most popular. The hydrostatic pressure is related to depth as $P = h\rho g$ where h is the height of water column (ie. depth), ρ is the density of water and g is the acceleration due to gravity. The variation of ρ and g being very insignificant, P is directly proportional to h.

There are different methods used to measure the hydrostatic pressure. In early models, the pressure is recorded mechanically by means of the mechanical recorder.

The pressure converted to the movement of the recorder pen. In general, in all cases, the pressure is first converted to mechanical movement. This conversion is done by means of 1) bellows 2) diaphragms and 3) buordon tubes. The mechanical movement is further converted to electrical signal by means of potentiometer, LVDT (Linear Voltage Differential Transformer), capacitance variation etc. Electrical and semiconductor strain gauges are also used for producing electrical signals proportional to hydrostatic pressure after convertion of the pressure into mechanical strains on metal diaphragms. Lovett (1962) describes a vibratron type pressure sensor used in the SVTP instrument for depth measurement. It gives a repeatability of .25%, linearity with in ±3% of a straight line between end points and temperature sensitivity is less than .1% of band width per °C of zero frequency. Fox, G.P. (1966) used a buorden tube as the basic element for sensing the depth as hydrostatic pressure. The movement of buorden tube is mechanically connected to a potentiometer for producing electrical resistance variations which in turn alters the frequency of a wein bridge oscillator.

Hydrolab, U.S.A. has manufactured depth sensors using buordon tube and potentiometer. Aanderaa Instruments, Norway also use much similar types for depth measurements in their instruments. Data Instruments Inc. have made depth sensors with strain gauges.

A recent significant development in pressure measurement is the works done by National Semi conductor corporation, U.S.A. They have introduced for the first time pressure transducers using integrated circuit technology. These I.C. pressure transducers available up to a range of 5000 PSI in the series L x 14 xxA, L x 14 xxAF, L x 14 xxAS and L x 14 xxAFS are very compact.

Pressure transducers belonged to many of the types mentioned are being used in commercial equipment. The selection of the types are dependant mostly on their adaptibility to the type of instrumentation. In most cases mentioned above the electronic signal conditioners also should be attached to the transducer. This is a major limitation of using these transducers for oceanographic purposes.

1.2.6 UNDER WATER DATA ACQUISITION METHODS

The under water data was acquired in earlier models using under water mechanical recorders. Later when instrumentation techniques improved with electronics, magnetic data recording became popular. Wire telemetering and wireless acoustic type data acquisition are two other advanced forms.

1.2.6.1 UNDER WATER MECHANICAL RECORDING

This earlier type under water data acquisition method has become unpopular because of its bulkness, and poor accuracy of measurements. Wherever the parameter can be converted to mechanical movements recording is possible. The recording media in earlier models were clock work driven circular paper drum and smoke coated glass plate. The bathy thermo graph which has not lost popularity even now is a classical oceanographic equipment under this group and manufactured by several firms namely Ogawa Seiki Co., Japan and Oceanographic, Denmakk. The depth meter developed by Chikamasha Hamuro and Kenji Ishi (1964) and the depth meter manufactured by Ogawa Seiki Co., Japan record the depth on a paper drum. De Boer (1959) describes a series of under water recording instruments needed for the acquisition of data from a trawl system under water. Dickson, W. (1959) describes similar type instruments for fishing gear investigatinns. The data from these instruments can be obtained only after opening them.

1.2.6.2 UNDER WATER PHOTOGRAPHY

Another recent method is taking photographs of the data. Here the data has to be converted to a form suitable for taking photographs. Temperature rise in a mercury thermometer, tilt of a lever due to water current etc. are a few cases. EG & G, U.S.A. has marketed current meters based on this principle. The water current tilts one free arm and the camera takes photographs of a ball which indicates the relative movement due to current, alongwith the direction and an electronic watch indicating the time.

Jay W.Harford (1962) describes the modified version of a standard EG & G under water camera with necessary circuitry to use as lapse-time data cameras. The dual chamber data camera will take 4000 data pictures sequentially in six pairs to handle up to 12 sensing instruments. The data camera can act as a versatile nucleus of an under water instrument package for the recording of various oceanographic variables.

1.2.6.3 UNDER WATER MAGNETIC RECORDING

Magnetic recording became possible when the data could be conditioned to the required d.c. level, and converted to frequency variations. Most of the data can be recorded in this way. The system should have electronics for conditioning the data, conversion to frequency, multiplexing, magnetic tape system, power supply etc. Usually the data can be deducted only later after playing back the cassette with the help of translator, paper punch, and computer for conversion to engineering units. Aanderaa Instruments, Norway and Plessey Environmental systems have manufactured similar equipment for acquisition of data on current, current direction, salinity, temperature and depth. These equipment are meant for continuous operation for long durations.

Hadgen, G.F. (1966) describes the engineering aspects of a current meter where signals are stored in magnetic tape after conversion to BCD form.

1.2.6.4 WIRE TELEMETRY

The data can be transmitted to the electronic unit on board the vessel by means of long multi-cored cable. The unique advantagee of this method is that proper functioning of the under water system can be ascertained always and the information is instantaneously obtained. The advantage of wire telemetry is much more significant for instrumentation in warm tropical waters. Continuous operation of under water instruments is not practicable in tropical warm waters, since the submerged objects are affected by marine biological growth in very short duration of one or two weeks. The wire telemetry instruments enable short time operations at required times.

Hudimac, A.A. et al. (1963) describe a wire telemetering system consisting of 26 Nos. thermistors and one pressure transducers. All the sensors are separately conditioned using wheatstone bridges. A multichannel data logging system was used.

Temperature from different depths is acquired by mounting several sensors on a long wire. Bowers, R. & Bishop, D.G. (1966) describe a towed thermistor chain. The resistance variations of the thermistor is converted to frequency variations of an oscillator by means of a 4-layer diode. Accuracies of the order of .01°C is achieved from the non-linear temperature-period curves of different thermistors. Bathy thermographs are obtained by means of air-dropped capsules and radio beacons. The capsules which sink at definite rates send acoustic transmissions to the surface buoy which in turn retransmit the same as electromagnetic waves to the air craft. Castelliz, H. (1966) describes such a system with 5.5 K.Hz. acoustic waves.

Frassetto, R. (1966) uses a single basic signal conditioner for all his five sensors for temperature, salinity, depth, current and current direction. The information is first converted to electrical resistances which are further used for producing frequency by means of a R-C time network used along with a unijunction transistor.

1.3 OBJECTIVES OF THE RESEARCH PROJECT

The fishery resources are highly dependant on the marine environment and hence better understanding of the marine environment is needed for our effective interaction with it. Much works have already been done in correlating the behaviour of different species of marine life with the changing marine environmental parameters such as temperature, salinity, depth, current, current direction etc. The works done by Taivo Laevastu et al. (1962, 1970) on compiling such works done for the past several decades have helped the research workers in the fields. These works have made only a begining of this large subject. The exploratory and commercial utility of such works depend how fast, accurately and instantaneously we can gather the information from the field. Here comes the importance of portable and accurate instruments which can be operated especially from smaller fishing crafts enabling such efforts within the reach of individual research workers with minimum facilities. The unique coastal fishery phenomenon namely, 'chakara' observed occassionally in the Kerala coast can be studied much more easily and effectively enabling us even to predict its occurence. Indigenous development and later the availability of such an equipment can be fruitfully utilised for obtaining enormous data from the large fishing fleet operated in the coast and off-shore. Such data will help us to correlate the behaviour of the marine life including its migration and abundance with the catch efforts done simultaneously. One of the promising fishery forecasting methods that is being followed and practised in advanced countries is based on the correlation of the marine environmental parameters and the behaviour of the marine life. Instantaneous acquisition of the relevant data is the prime necessity here.

This project under report is aimed at developing a portable, self contained instrument for instantaneous measurement of the important fishery hydrographic parameters namely, water current, current direction, salinity,

temperature and depth. It is designed with a single under water probe and a single on-board console unit, both being connected by a single 3-core cable, utilising the materials and components available indigenously as far as possible. Such an equipment is expected to help much the related investigations thus improving our knowledge of the marine life and their dependance on the environment.
Other requisite features of the equipment are low power consumption from its self contained power supply thus rendering it to be very portable and convenient for operation. The field operated instruments should have facilities for testing their reliability and performance using simulators wherever possible. The equipment is designed with facilities for feeding simulated signals and thus ensuring its proper operations.

1.4 RESEARCH AND DEVELOPMENT VALUE OF THE PROJECT

The fast development in electronics during the last 2 decades is mostly concentrated on digital electronics and integrated circuits with their applications mainly, in signal processing and computer technology. There has not been a proportional development in transducers and signal conditioners for obtaining data from the field. Further, the instrumentation problems of marine electronics have unique features which are not shared by other electronic fields. Therefore special attention is needed in the field of data collection from the marine environment to strengthen the comparatively week field of transducers and appropriate signal conditioners with special attention given to portable,rugged and accurate systems for easy operation.

The performance and success of field instruments mostly depend on the reliability of the transducers which sense the information directly from the place. Apart from the required features to sense the information, they should also have additional facilities to protect from the environmental hazards also. Such problems are unique and hence they need special attention and should be taken as independant cases.

Some of the important research and development values of the project are listed below:

1) Development of new transducers or alterations of existing types for producing strong signals.
2) Development of signal conditioners with low power consumption, working on low and single power supply with features needed for engaging more transducers, one by one, in order to reduce the complexities and number of signal conditioners otherwise needed.
3) Development of multiplexers suitable for this integrated and composite system design.

4) Development of methods to solve the problems associated with long cables, ambient temperatures effect on transducers and electronics, marine growth on transducers etc.

5) Development of methods to replace the rotor of the under water probe which may undergo wear and tear along with facilities to simulate signals so as to avoid occassional calibration.

6. Design of a suitable under water probe mounted with all the transducers and pressure proof chamber for encasing the essential controls and multiplexer so that it remains hydrodynamically stabilized and is free from heavy eddy current formations.

7) Design of a digital data display system with a single LCD unit for the display of the parameters in their respective units.

The above tasks are specific problems which have to be solved in an integrated manner in order to make the equipment quite portable, rigged and sea worthy. None of the transducers except temperature is available indigenously. Moreover, the conventional transducers are not suitable to this composite system, as they need certain uniform features needed for accomodating into this composite system design. Therefore every stage need special attention and almost all mechanical accessoreies have to be specially designed and fabricated.

THE SYSTEM DESIGN

2. THE SYSTEM DESIGN

The various components, circuits, controls, displays and sensors are designed for maximum ruggedness, reliability, portability, easiness of operation, very low power consumptioon, low voltage single supply and very low weight and bulk using the latest state of art in electronics and instrumentation. Rugged and sea worthy sensors with strong signals and facility for remote operation is the most important factor for achieving the above goal. This point has been given top priority throughout the design and development of the system.

2.1 WATER CURRENT SENSOR

Water current sensor forms one of the important parts of the system. The design of the under water system is done mostly to cater the needs of the current measurement.

2.1.1 THE ESSENTIAL FEATURES OF WATER CURRENT TRANSDUCER

For a sound, reliable, accurate and easy method of measurement of water current the transducer should have the following features.

1. Strong signals at low impedance so that they are immune to noise and hence can be conveyed through ordinary long cable.
2. The signal should be free from environmental effects.

3. Simple design.

4. Low power requirements.

5. Operation independant of other factors.

6. Minimum wear and tear, so that occasional calibration can be eliminated.

7. Easy replacement of the rotor to eliminate the need for occasional calibration.

8. Easy method to check the accuracy and performance.

9. Streamlined design with facilities for auto stabilization to avoid errors due to the drag and tilt of sensor.

Considering the above features and the various techniques available at present, rotor with vertical axis is found to have maximum advantages. Rotor and impeller have almost same basic operational features. Rotor has an additional plus point over the impeller that it works independent of the current direction. The impeller responds to the current magnitude fully only when its horizontal axis is aligned to the water flow. This system has got the required tail and swivel joints for aligning it to the water flow. But when the flow is very low, the hydrodynamic force on the tail is too low that it fails to align to the direction of water flow. Under this conditions the impeller responds to only a component of the water flow depending in its alignment angle (see Fig.1-A). But this

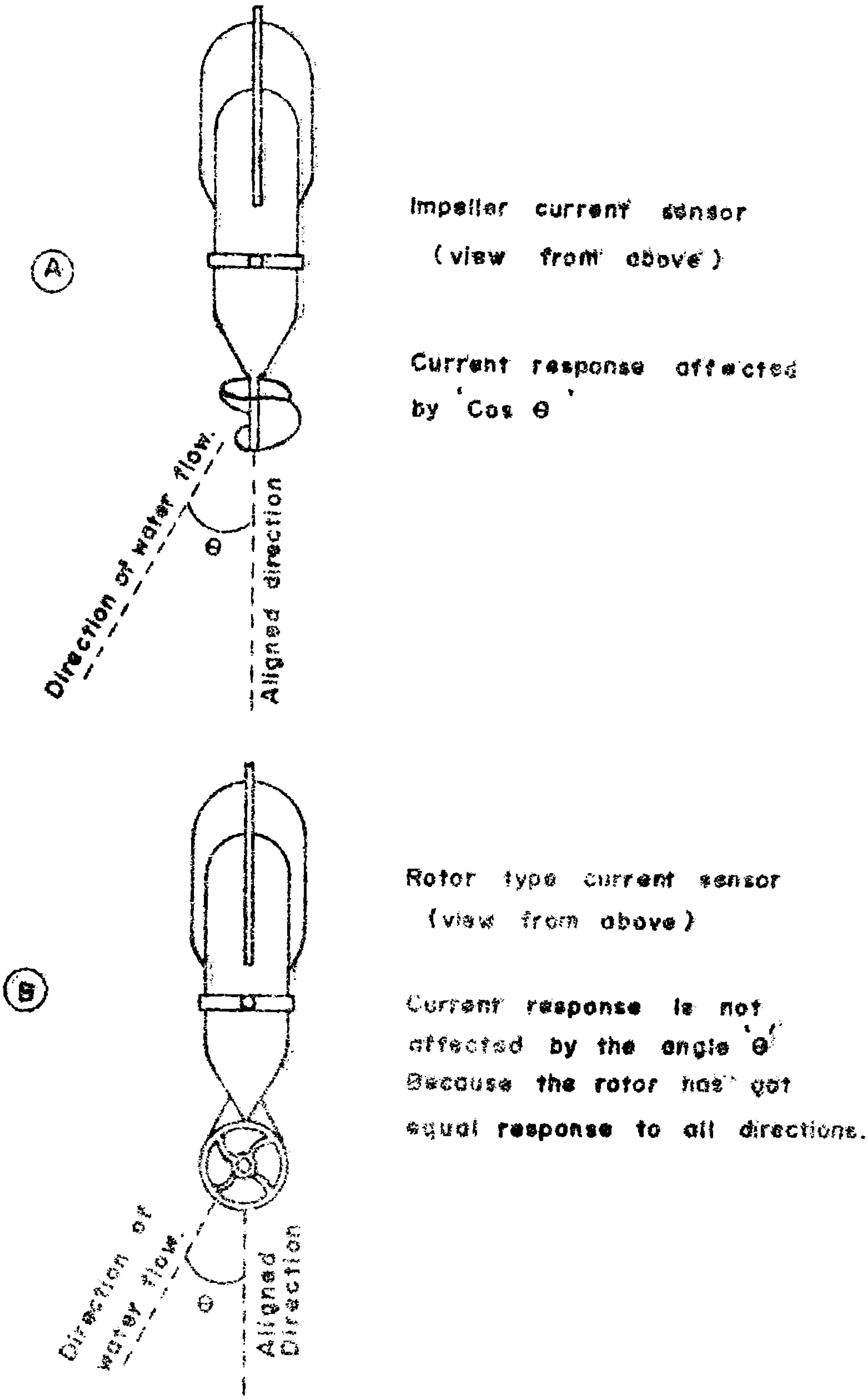


Fig.1.

THE DRAWINGS SHOW HOW THE MISALIGNMENT AFFECTS THE CURRENT RESPONSE.

problem does not affect the rotor type sensor. Because the rotor is unidirectional. It has got equal responce to all directions in the horizontal plane (see Fig.1-B). Hence savanious rotor was selected for water current measurements because of its unique advantages and simple design.

2.1.2 ROTOR WITH ELECTRIC INDUCTION

Though savanious rotor has got several advantages as mentioned above, its biggest problem is that it is subjected to mechanical or magnetic loads while producing electrical pulses. The rotor sensor can be made more reliable with better threshold features, and repeatability if its mechanical or magnetic load could be eliminated. The solution of this problem resulted in the development of the new technique called 'rotor-induction' as explained below. It is a fact that rotor or impeller alongwith 'hall diode' does not cause the magnetic or mechanical load as reviewed in the introduction. But it requires fairly large impeller/rotor for accommodating the powerful magnet used for activating the hall diode.

The basic principle used in the 'rotor-induction' method is that the inductance of an electric coil is altered as the value of the permeability of its core is altered. Here a coil is used in the stator and a very thin (about .5mm) ferrous piece of approx. 1.5 cm. dia mounted on the rotor used to change the inductance of the

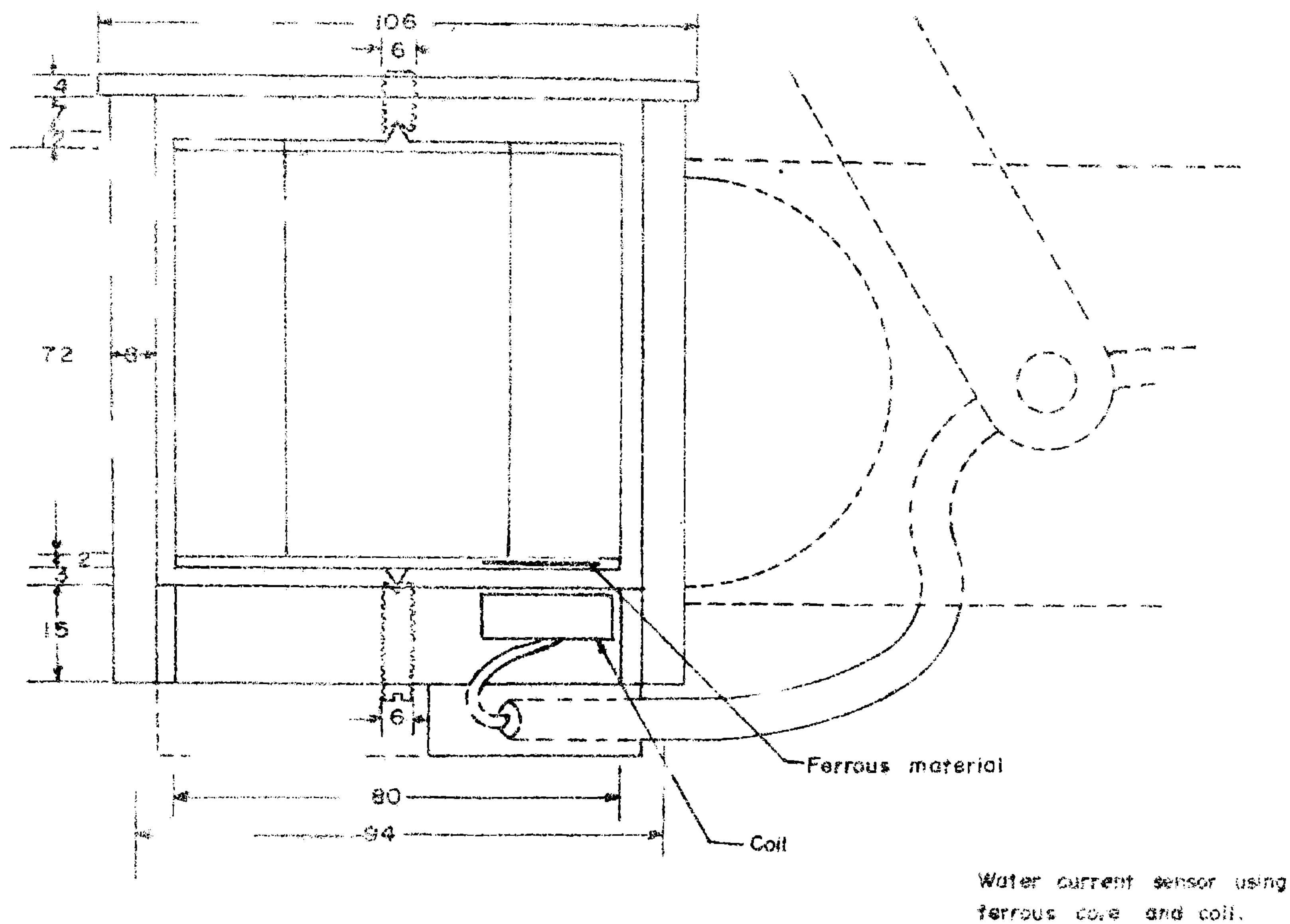


FIG. 2 ROTOR (ELECTRIC) PART OF THE INSTRUMENT

former when the latter passes near, alongwith the rotation of the rotor. The ferrous piece could be moulded in plastic and concealed on the rotor plate. Though the signal is low, it is at very low impedance and hence could be made immune to noise. This signal could be conveyed through ordinary 2-core cable without any noise problem. The details of the assembly of the system are given in Fig.2. It is obvious that minimum distance is needed between the coil and the core for achieving maximum signal output. But as a practical case, at least 2-3mm gap is needed between the stator and rotor. Considering other practical limitations the distance between the core and coil could be fixed between 4-6mm. The ferrous piece alters the inductance of the coil once in every rotation of the rotor. The above signals in the form of changes in inductance of an electrical coil is conveyed through ordinary unshielded cable to the display meter on board the vessel without any problem of noise penitration which is obvious from the clear signals available at the output of the amplifier, as given in the Fig.3. The figure shows the graphs plotted by a high speed recorder with the pulses against time. The pulse frequency is altered from almost zero to approx. 18 corresponding to speeds 0 and 440 cms/sec. respectively. The graph shows that the amplitude is not at all affected by the wide range of frequency variation. The shapes of pulses is

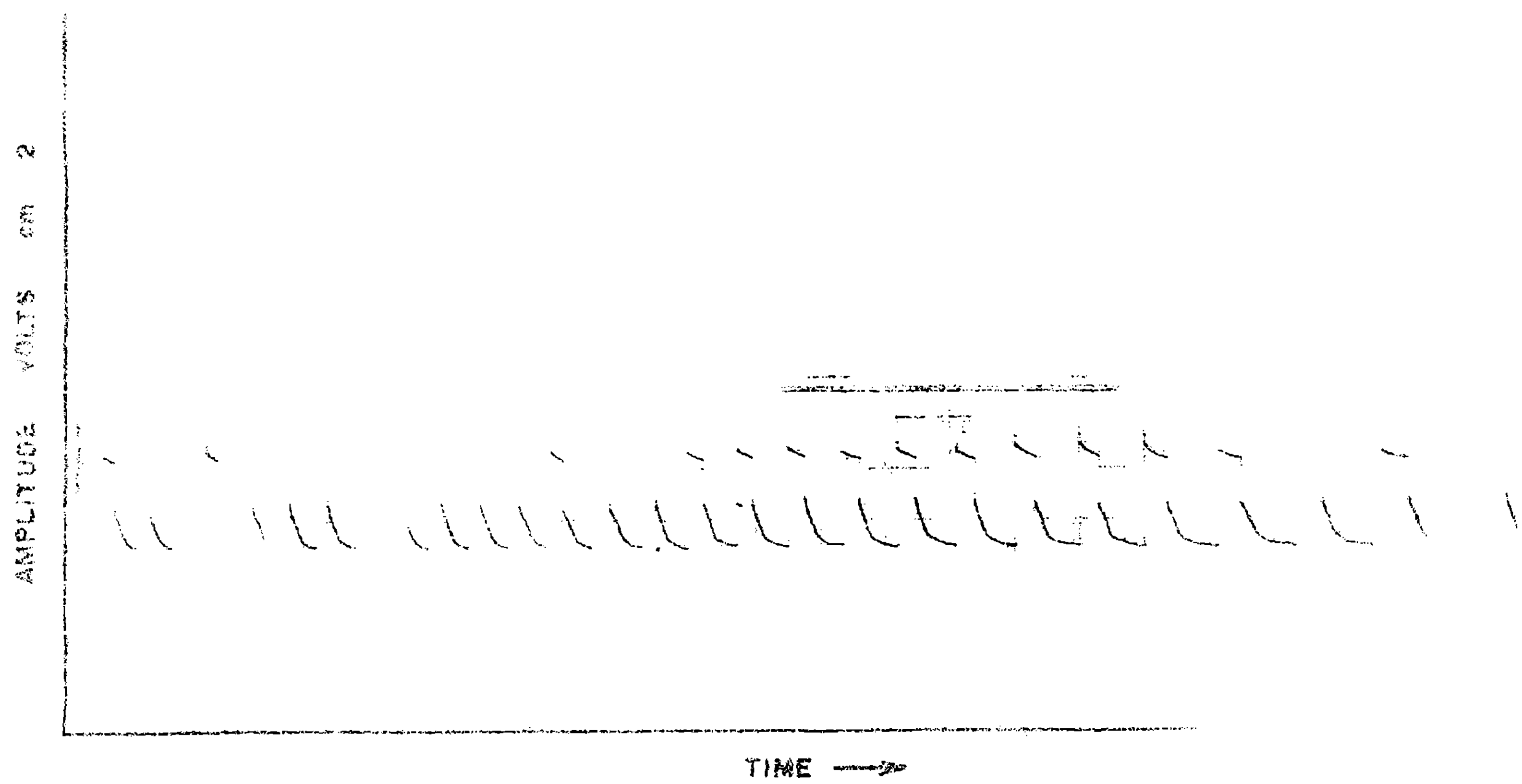


Fig 3. THE PULSES CORRESPONDING TO THE ROTATION OF ROTO
(ELECTRIC INDUCTION) AND PRODUCED AT TH OUTP

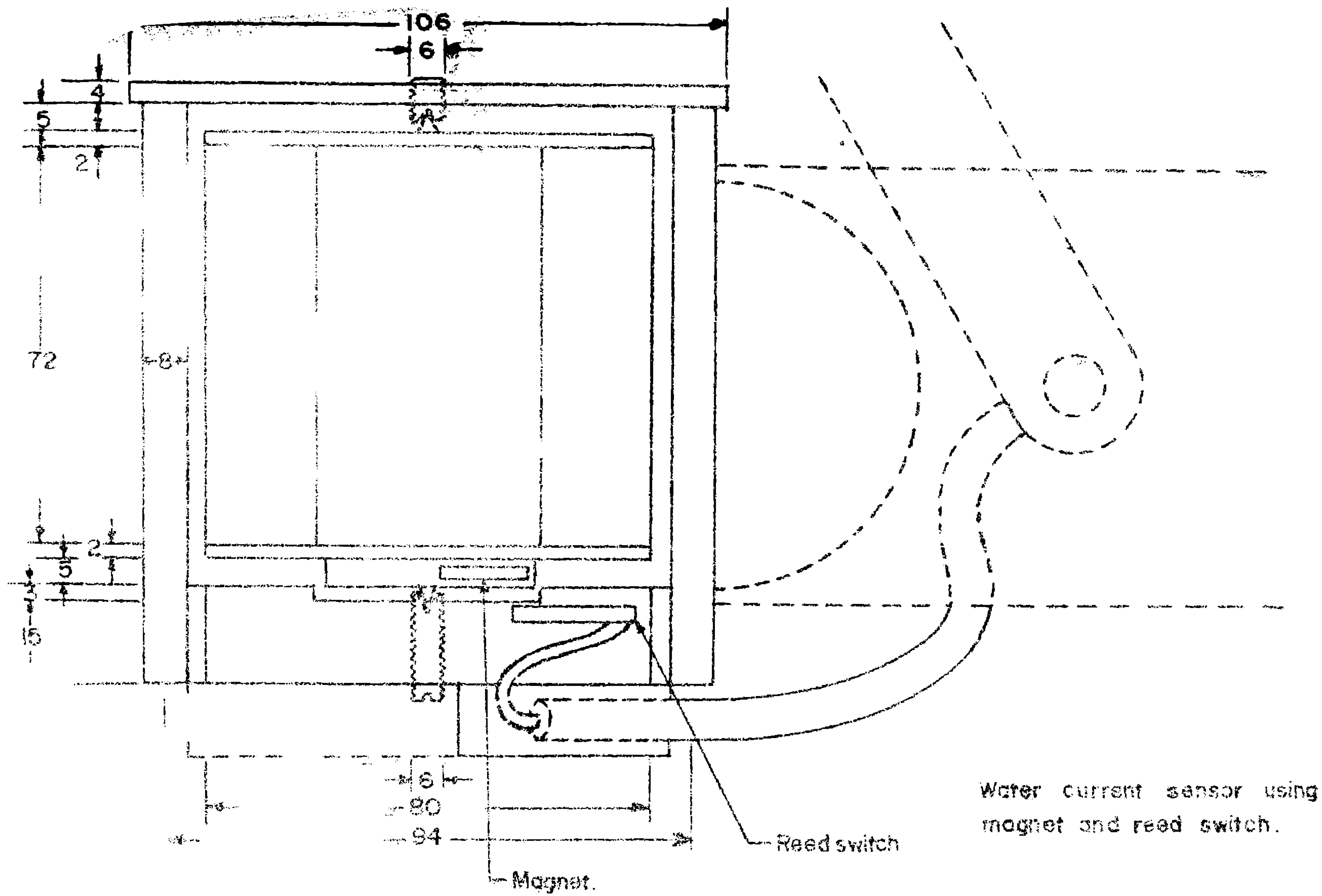


FIG 4 ROTOR (Magnetic) PT OF THE INSTRUM NT

maintained sufficiently uniform. No traces of noice is found in the graph.

2.1.3 ROTOR WITH MAGNETIC INDUCTION

Rotor with magnetic induction is already existing in some of the current meters, eg. the current meter manufactured by Aanderaa Instruments, Norway. It has got advantage that its associated electronics is very simple. Wherever a larger rotor can be accommodated, this method is much inexpensive. Its rotor has to be slightly larger than the 'electric induction' type as it has to carry one magnet for activating the reed switch mounted on the stator, as shown in Fig.4. Rotor with magnetic induction was designed and fabricated with the following features.

1. Dimensions of rotor	..	80 mm dia x 78 mm length
2. Thickness of material	..	1 mm
3. Material	..	high density polypropylene
4. Dimensions of magnet	..	4 mm dia x 25 mm length
5. Size of reed relay	..	3 mm dia x 20 mm length, gold plated contacts
6. Maximum distance allowed between magnet and reed switch to make a contact	..	9 mm
7. Weight of rotor without magnet	..	35 gms

8. Weight of rotor with magnet .. 47 gms

9. Nountings of rotor .. Stainless steel pins with brass sockets

As the magnet passes near the reed switch once in every rotation, the switch is activated making a switching contact from its normally opened condition. The switch remains 'on' in the presence of the magnet until the magnet moves sufficiently away from the reed switch.

The pluses from the reed switch were examined and found to have the required perfection free from transients and external noices, which is obvious from the recordings on paper chart as given in Fig.5.

2.1.4 SPECIFIC ADVANTAGES OF ELECTRIC ROTOR-INDUCTION METHOD

The following are specific advantages gained by this method.

1. No wear and tear while producing the required pulses. This increases the longivity of the associated parts.
2. No additional load is caused while producing the pulses. This has reduced the threshold value of the detected current.
3. The rotor could be made much smaller compared to the conventional types. This has resulted in much compact and convenient type current-meter.

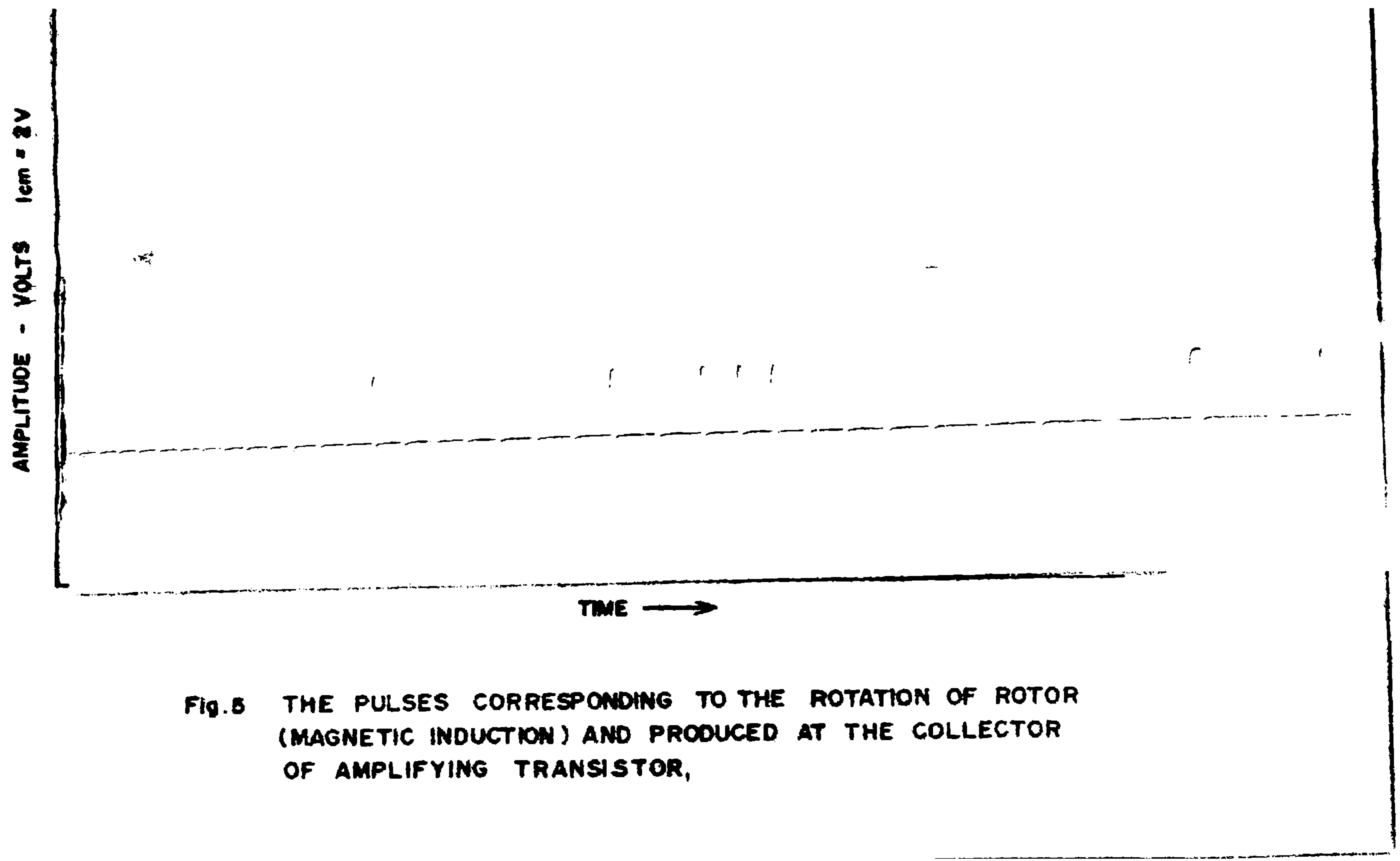


Fig. 5 THE PULSES CORRESPONDING TO THE ROTATION OF ROTOR (MAGNETIC INDUCTION) AND PRODUCED AT THE COLLECTOR OF AMPLIFYING TRANSISTOR,

4. The sensing elements can withstand any reasonable hydrostatic pressure. This has eliminated the need for a pressure chamber which usually makes current meter probes bulky and heavy.

5. As the rotor is quite small and light, it could be mounted on two pins thereby making the design simpler. It is independant of other parts and electronics of the equipment. Hence the maintenance and checking are easy. The rotor can be replaced easily.

The physical features of the rotor are:

1. dimensions	..	55 mm dia x 78 mm length, 5 Nos. blades
2. material	..	high density polypropellene
3. mountings	..	stainless steel pins with brass sockets as shown in figure.
4. dimensions of ferrous piece	..	15 mm dia, 0.5 mm thick
5. weight of rotor	..	29 gms in air
6. Relative permeability of material	..	above 500

2.2 DIRECTION SENSOR

The direction of water current is sensed as changes in electrical resistance of a potentiometer. The following are the features and components related to the process.

1. The shape of the complete under water unit along with the vertical and horizontal fins and the swivel suspension system which allows the under water probe to be aligned in the direction of water flow.
2. Potentiometer resistance fixed in the under water system moves alongwith the complete system.
3. Magnetic compass piyoted for free motion and mounted inside the potentiometer, alighnes to earth's magnetic north.
4. Potentiometer stylus which makes a contact on the potentiometer resistance whenever needed so. This stylus mounted on the magnet makes always a reference to the earth's magnetic north as it is mounted on the compass. Thus the stylus position on potentiometer makes a signal in relation to the relative positions of the potentiometer (which refers to the current direction) and the earth's magnetic north. The electrical signal is obtained as changes in electric resistance from 0 to 2000 ohm corresponding to the direction 0 to 360°.

5. Energising coil. Normally the stylus is free from making a contact so that the magnet can freely align to Earth's magnetic north. When a current is passed through the energising coil which surrounds the compas and potentio meter, the magnet is pulled perpendicular to its direction of motion so that the stylus mounted on it makes a contact on the potentiometer. After making measurements, the coil is deenergised enabling the compass to align to the new direction.

A commercially available direction sensor was used with the features as given below and drawing as per Fig.6.

2.2.1 FEATURES OF MAGNETIC DIRECTION COMPASS

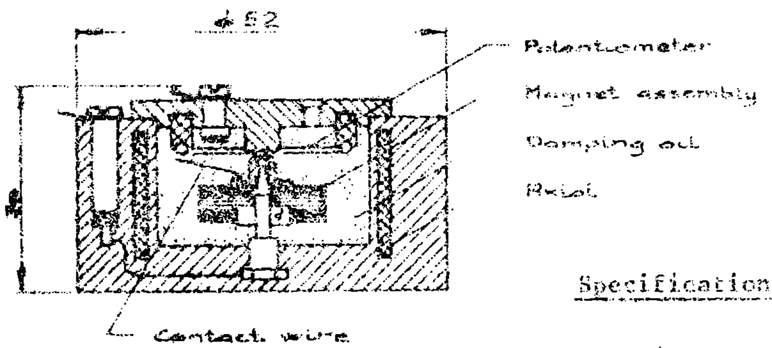
1.	Manufactured by	..	M/s. Aanderaa Instruments, Norway
2.	Dimensions		53 mm dia x 33 mm height
3.	Exciting voltage		6 V
4.	Required current	..	15mA
5.	Allowable tilt	..	12°
6.	Weight in air	..	92 gms
7.	Potentio meter resistance	..	2000 ohms
8.	Damping		oil damped
9.	Response time		less than 5 sec for 90° angle
10.	Accuracy	..	±2°

Aanderaa Instruments
Østtun Norway

Technical Note No.
April 1972.

COMPASS

Th compass was for ording current meter application nstrument, can many other purpose this compas. potentiomete When is to be read, magnet assembly, normally to Clamping by the effect of clamping current axially wound coi the lamped t the assembly will make with a wirewound potentiometer reading the clamping must be interrupted for few allow the magnet semb to swing towards north, have been altered dur ng the reading



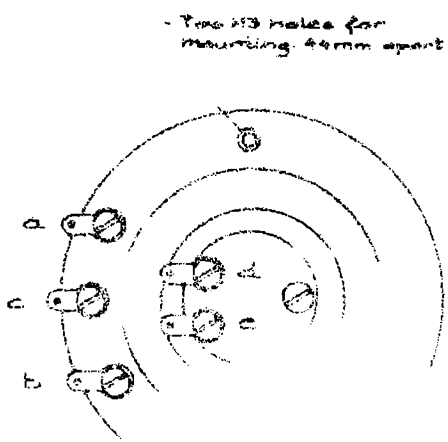


FIG. 6

Specifications:

amping vo'tage, 6 Volts.
Clamping current, mA.
Potentiometer resistanc
Allowable tilt, 12°
Accuracy, better
true
suddenly
seconds, ading

Clamping coil.
Potentiometer,

2.3 TEMPERATURE SENSOR

Thermistor was used as the basic sensing element Thermistor is a semi conductor material which undergoes resistance variation inversely proportional to temperature. This variation in resistance is given by

$$R = Ro \exp \left(B \left(\frac{1}{T} - \frac{1}{To}\right)\right)$$

where Ro = resistance at reference temperature

To = (°k); R = resistance at temperature

T (°k); B = material parameter describing the slope of resistivity Vs temperature.

Thermistors are available with different resistance ranges from almost as low as 10 ohm to several thousands of ohms. They are available as discs, pointed glass encased probes, with different current capacities. Normally termistors do operate in the temperature range of -40° to +150°C. There are termistors with wider temperature ranges also.

2.3.1 LINEARISATION OF THERMISTOR

Linearisation of thermistor is needed for (1) making the calibration easier and (2) making direct measurements in their final engineering units from LCD/LED digital meters.

The thermistor response can be linearised within certain limitations of range by shunting the thermistor with an appropriate resistance based on the characteristics of the thermistor as well as the required range of measurement.

If R_1, R_2, R_3 ...... are the resistance of the thermistor at temperatures t_1, t_2, t_3 ..... respectively, the effective resistance after shunting with a resistance R are obtained as r_1, r_2, r_3...... etc. as given by the relation

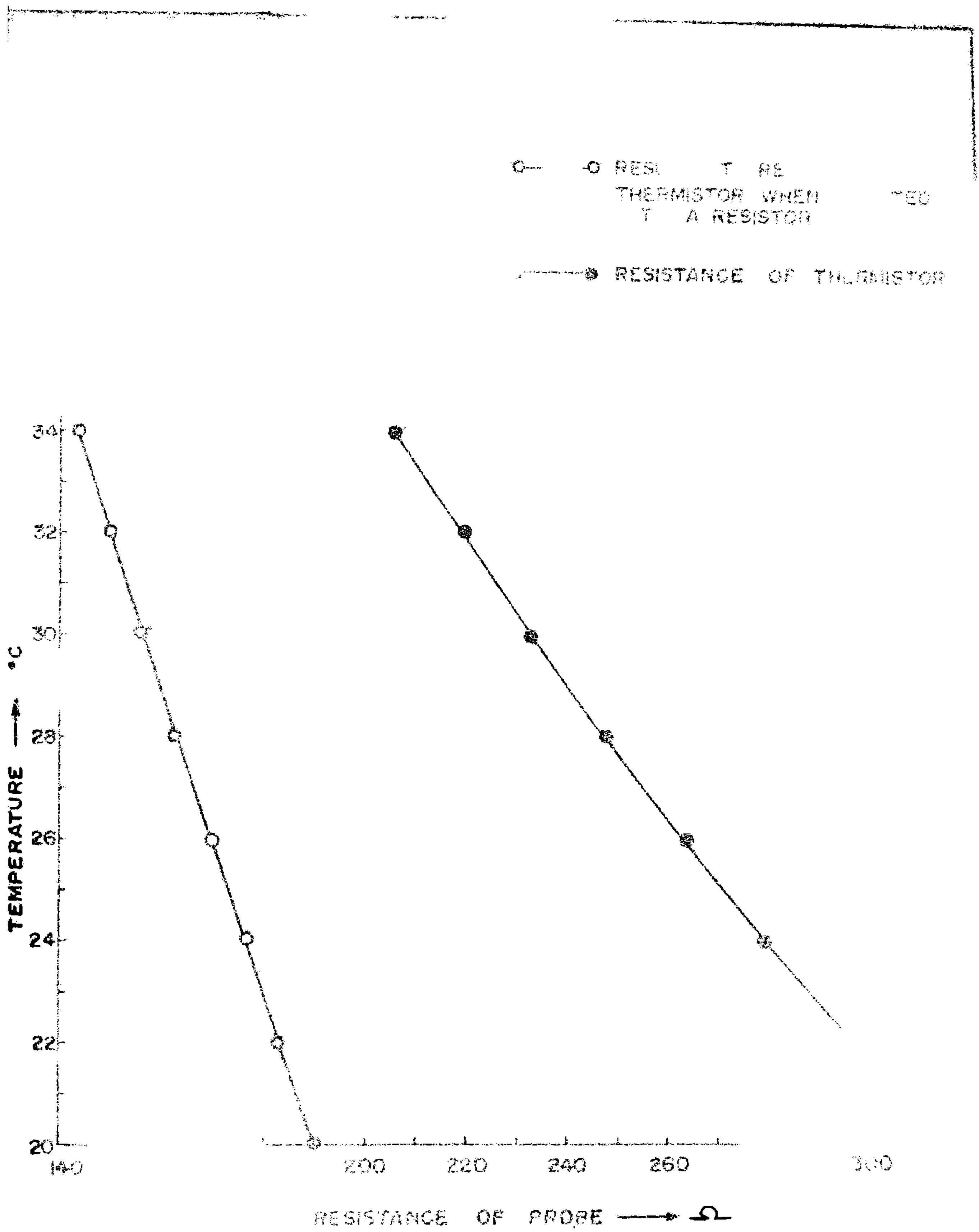
$$\frac{1}{R_1} + \frac{1}{R} = \frac{1}{r_1}$$

i.e $$r_1 = \frac{R\ R_1}{R + R_1}$$ and

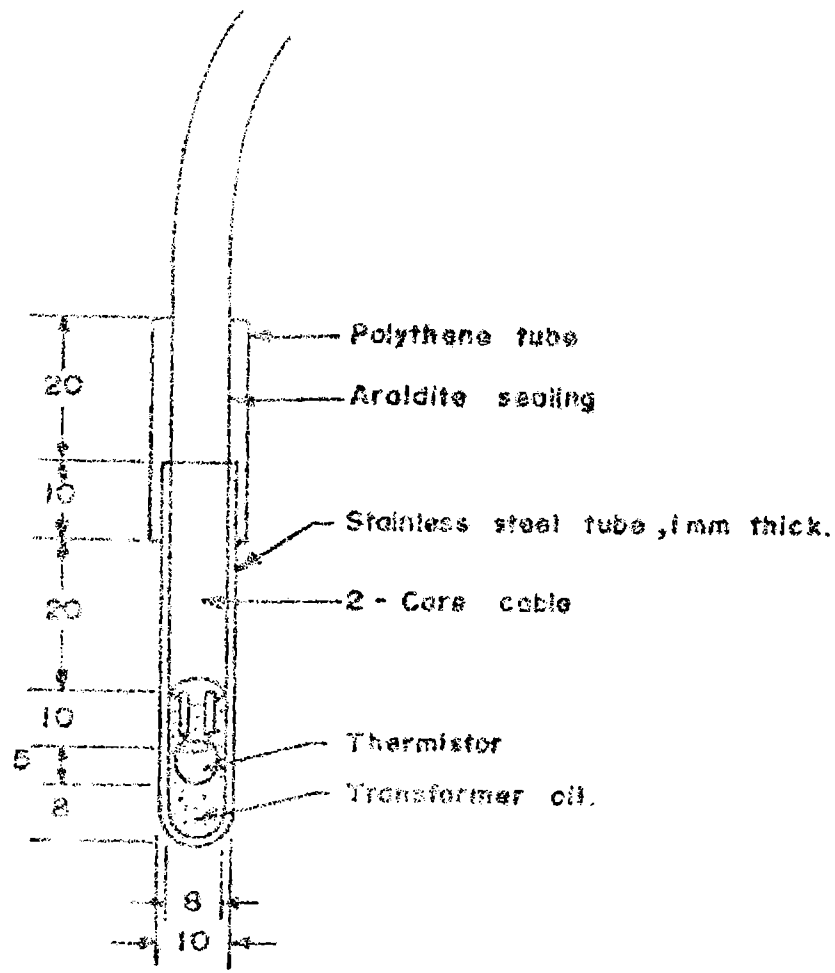
$$r_2 = \frac{R.\ R_2}{R + R_2}$$

The value of R is so chosen that r_1, r_2, r_3 .... are linearly inversely proportional to temperature. It can be seen that the percentage of non-linearity increases for larger ranges of temperatures. But for oceanographic purposes, large ranges are not needed and the linearity is obtained quite satisfactorily in the range of 20°C to 35°C with an accuracy of $\pm$.05°C.

The Fig.7 gives curves with and without shunt resistors. The lower values of shunt resistors lowers the effective resistance also. Suitable series resistors are added to them so that they come within the required ranges



FIG·7 THERMISTOR CHARACTERISTICS



Dimer

THERMISTOR [illegible] IN CASE.

of electrical resistances needed by the associated electronic circuits.

The thermistor is selected such that its resistance alongwith the shunt resistance and series resistance comes within the required range already decided, i.e approximately 50 ohms for a temperature variation of 20°C to 35°C and an effective resistance below 470 ohms. As shown in Fig.8 the thermistor was encased in stainless steel case for enabling it to withstand the hydrostalic pressure and the contact with sea water.

2.3.2 RESPONSE TIME

Maximum response is obtained by using very thin walled chamber for encashing the thermistor and filling the inner space with transformer oil. The response time of the thermistor probe was studied in laboratory by noting the time needed for attaining the temperature when the termistor probe is transfered from a high temperature bath to a low temperature bath and vice versa. The graphs given in the Fig.9 were plotted automatically by a recorder, thus eliminating all the manual errors. The Fig.9 shows 2 curves plotted by the recorder, A-open thermistor without case, B - encased thermistor with transformer oil.

The curves show that the response time of the thermistor is increased adversely when it is encased in stainless steel case. However the increased response time has

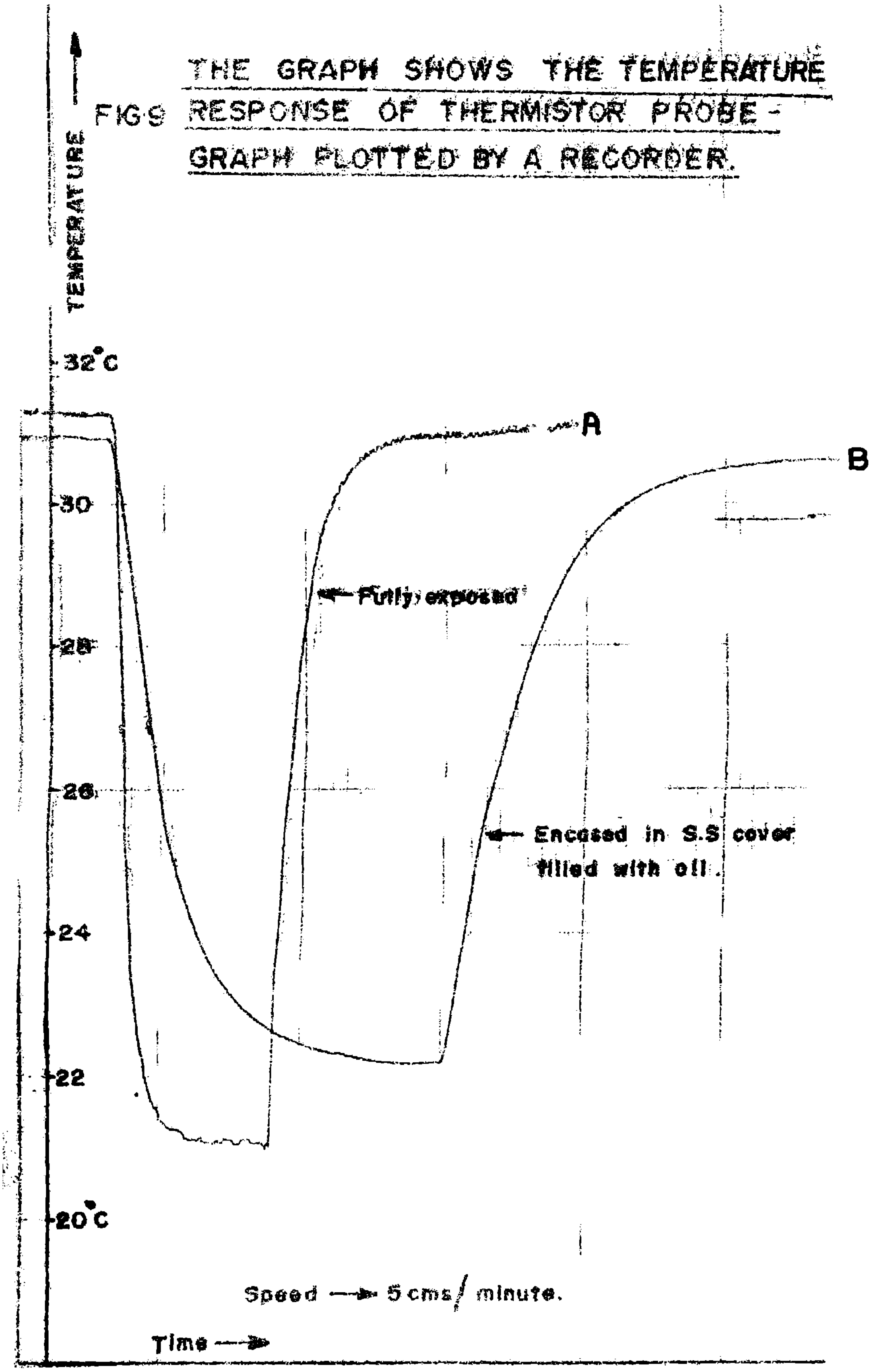


FIG.9 THE GRAPH SHOWS THE TEMPERATURE RESPONSE OF THERMISTOR PROBE - GRAPH PLOTTED BY A RECORDER.

not affected the equipment adversely, since 2 minutes time can be allowed for temperature measurements without any problem.

2.3.3 FEATURES OF THE THERMISTOR PROBE

1. Dimensions		60 mm length, 9 mm dia.
2. Case		Stainless steel tube with 60 mm length, 7 mm I.D. 9 mm O.D.
3. Filling liquid		Transformer oil
4. Resistance variation	..	200 ohm to 320 ohms corresponding to 20°C to 34°C without the shunt resistance 390 ohms
5. Response time		less than 15 sec. for temperature variations from 21°C to 34°C without encasing. About 60 sec. for temperature variation between 22°C to 31°C with stainless steel encasing and transformer oil filling.
6. Capacity to withstand pressure	..	tested up to 30 kg/cm^2 with no adverse results.

2.4 SALINITY CELL

The resistance of any conductor varies directly as its length (l cm) and inversely as its area (a sq. cm); that is

$$R = \rho l/a \text{ ohm}$$

where ρ is a constant, the specific conductance or resistivity of the conducting material. The specific conductance designated by K, of a given material is defined as $1/\rho$ ohms $^{-1}$ cm $^{-1}$, hence may be written as

$$R = l/ka$$

This relation shows that for obtaining higher values of R, the salinity cell should be long with very low cross sectional area. Considering the practical limitations and the equivalent resistance requirements of the complete electronic system, the length of the cell is taken to be 21 cms, with a cross sectional diameter of 8 mm as shown in Fig.10. Two platinum electrodes of .5 x 1 sq.cm. area were used for passing electricity to the solution. This has resulted in an equivalent resistance of about 150 ohms corresponding to 35 salinity at 30°C. This matches well with the other sensors in the system. The extra lengths of 7 cms. each provided on either sides of the cell reduces the conductance through the outer path to the minimum.

2.4.1 SHUNTING OF SALINITY CELL

As per the system design adopted, the electrical

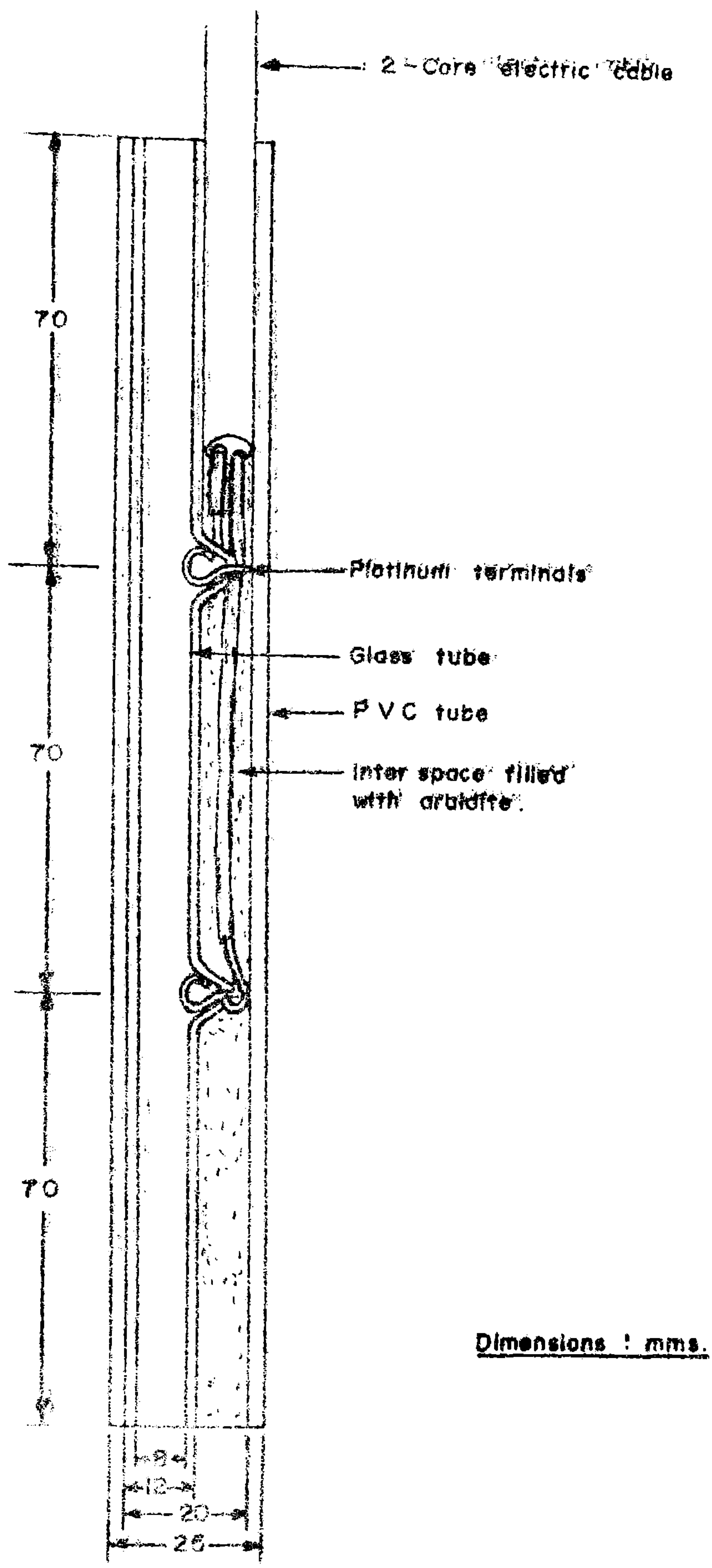


FIG. 10 CROSS SECTION OF SALINITY CELL

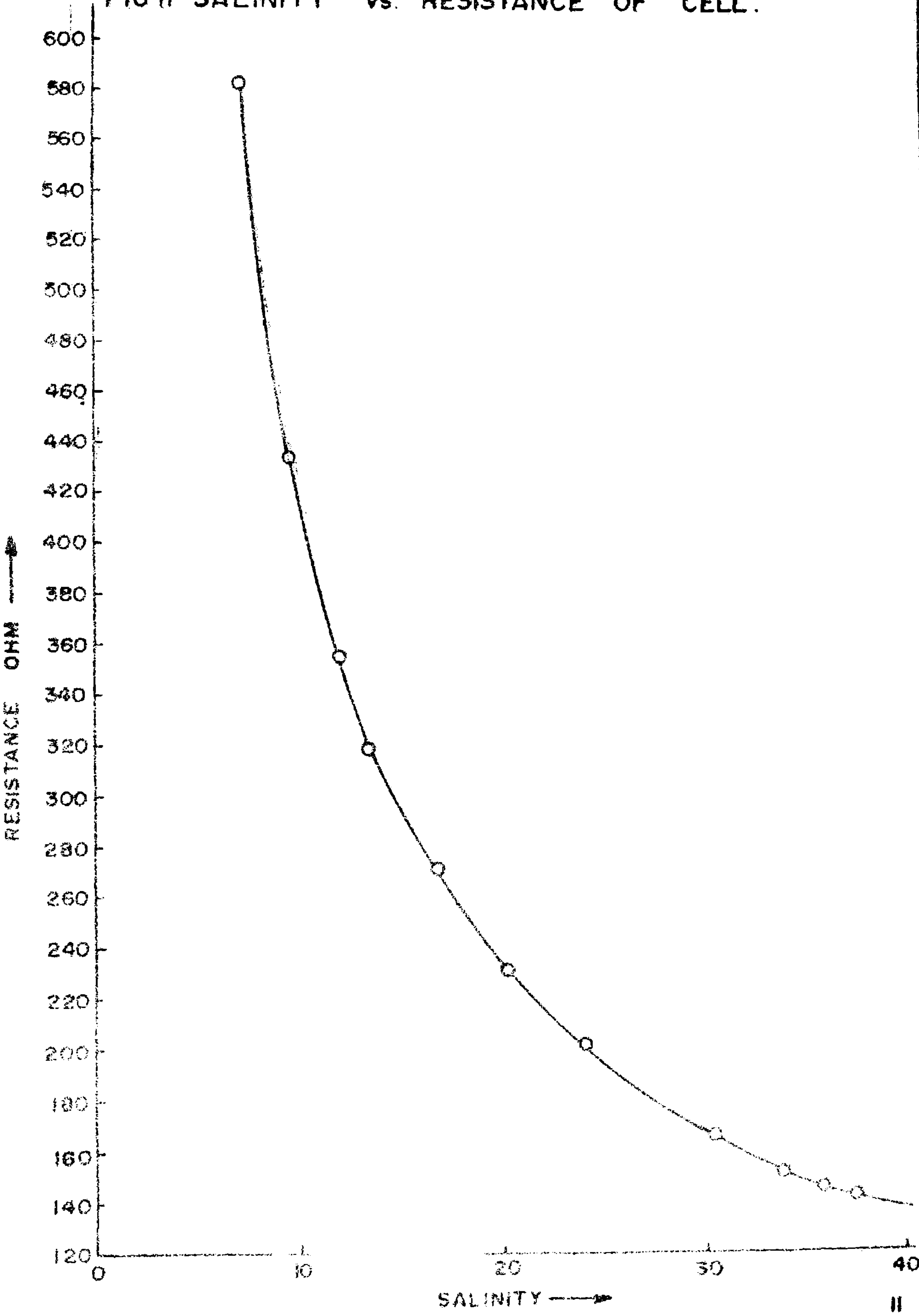
resistance of the cell is the basic criterian which has to be limited with in certain range as per its requirements. Similar to thermistor probe, salinity probe also undergoes variations in electrical resistance universely proportional to salinity at constant temperature as given in the graph in Fig.11. It varies from infinity to approx. 150 ohm corresponding to 0 to 35 salinity at 30°C. This wide variation cannot be accommodated in the system which has been planned. Hence the cell is shunted with an appropriate resistance so that its effective resistance comes with in the required range. The shunting has further helped to reduce the non-linearity of the cell characteristics, as given in Fig.12, though it could not make it fully linear unlike the thermistor sensor.

2.4.2 BOUNDARY EFFECTS

The cell conducts through the shortest distance between the electrodes as well as through a wider path outside the cell. The presence of conducting materials affect this external path. Similarly the insufficient area around the probe also affects the conductivity of this path. Experiments were conducted to find out these limits.

It has been noticed that the characteristics of the cell has not been effected when stray conducting materials such as a metal plate or rod remain more than 50 mm away from the sensor.

FIG·II SALINITY Vs. RESISTANCE OF CELL.



2.4.3 POLARISATION EFFECT ON THE CELL

The cell terminals undergo polarisation, as they are subjected to electrolysis. During electrolysis Hydrogen and Oxygen are released and their bubbles are formed on the electrode restricting the easy passage of electrons. This gradually increases the resistance of the electrical path. This can be reduced by removing the bubbles mechanically. But the most satisfactory method of overcoming polarisation is to employ a rapidly alternating current of low intensity. The direction of the current is reversed a thousand times per sec. and the polarisation produced by each pulse of the current in one direction is neutralised by the next in the opposite direction.

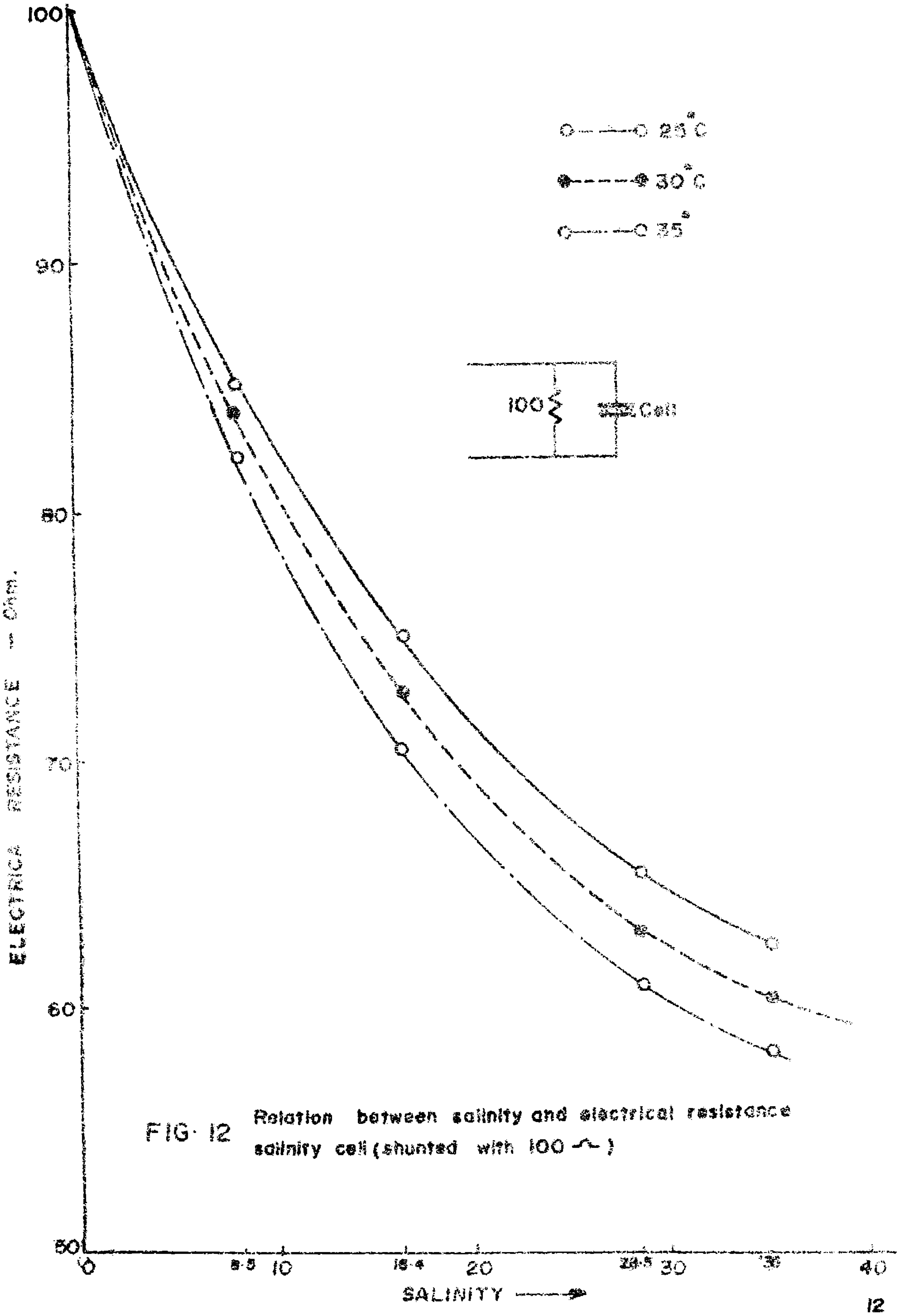
2.4.4 EFFECT OF TEMPERATURE ON SALINITY CELL

The conductivity of sea water increases with temperature. Salinity is a constant for given sea water even at different temperatures. But conductivity is different at different temperatures.

The equivalent conductance at infinite dilutions increases with increasing temperature as described by Samuel Gladstone (1940) and a formula of the type

$$A_{t^\circ} = A_{25^\circ} \; (1 + x) \; (t - 25)$$

is applicable where A_{t° and A_{25° are the values at t° and 25° respectively, as x is a constant for each electrolyte. For salts x is about 0.019 to 0.021, so that the



FIG· 12 Relation between salinity and electrical resistance salinity cell (shunted with 100 Ω) equivalent conductance at infinite dilution at ordinary temperature increases by about 1.92 to 2.2 per degree.

The results described apply particularly to infinite dilution. But similar conclusion holds for strong electrolytes at appreciable concentrations.

When conductivity increases with temperatures, electrical resistance decreases. The exact nature of variations in electrical resistance is needed for making corrections for the temperature effect on salinity readings. The graphs in Fig.12 shows how the effective electrical resistance of the salinity cell varies with temperature at different values of salinity. The graphs show that the temperature effect on the cell is near to zero at zero salinity. The effect is higher at higher values of salinity and the resistance of the cell decreases with increase in temperature at a given salinity value.

The salinity sensor can withstand any reasonable hydrostatic pressure as its inter space is filled with araldite and made solid with no air gap.

2.4.5 FEATURES OF SALINITY CELL

The relevant features of the cell are as follows:

1. Electrical resistance as the salinity varies from 0 to 35 PPT at 30°C	..	infinity to 150 ohm without shunting (varies up to ±5% for different pieces)

2. Electrical resistance as the salinity varies from 0 to 35 PPT at 30°C by shunting with 100 ohms	..	1) 100 to 60 ohms
3. Distance between terminals		70 mm
4. Length of cell		210 mm
5. Diameter of glass tube		8 mm
6. Thickness of glass tube	..	1 mm
7. Inside diameter of outer PVC tube	..	20 mm
8. Outside diameter of PVC tube	..	25 mm
9. Filling material		araldite
10. Minimum water level needed above and below the cell		5 mm
11. Maximum distance where conducting materials do not affect the cell	..	10 cms.

2.5 DEPTH SENSOR

The depth sensor developed for the system consists of a stainless steel bellows whose expansion is a function of hydrostatic pressure acted upon it from inside. The expansion of the bellows is converted to inductance of an electrical coil. The inductance ~~various~~ of the coil is taken as the measure of the depth to which the sensor is exposed.

2.5.1. DESIGN OF BELLOWS

The pressure rating of the bellows depends on their physical dimensions and the characteristics of the materials with which the bellows are made. Bellows are made out of stainless steel and in special cases out of Nickel, Berilium copper etc. The pressure can be applied either from outside or inside as needed. The squirm pressure of an internally pressurised bellows is given by

Ps = $2\pi K/L$ where K is the overall spring rate and L is the maximum working length. A more conservative formula allowing for some eccentricity tolerance is

$$Ps = 5.02\left[\frac{K}{L} \times \frac{ID}{OD}\right]$$

where ID and OD are the inside and outside diameters of the bellows. The design details of one of the bellows made by M/S Servometer Corporation as per the specific needs of the case are given in Fig.38

The life of a bellows is expected between 5000 and 10,000 cycles of operation. These bellows manufactured by Servometer Corporation is very precise and unique, based on the new electrodeposition technique for obtaining uniform wall thickness. As shown in Fig.13, the bellows is encased in a stainless steel tubes with further protective covering with flexible neoprine hose for easy transmission of pressure. The ferrite rod mounted on the tip of the bellows

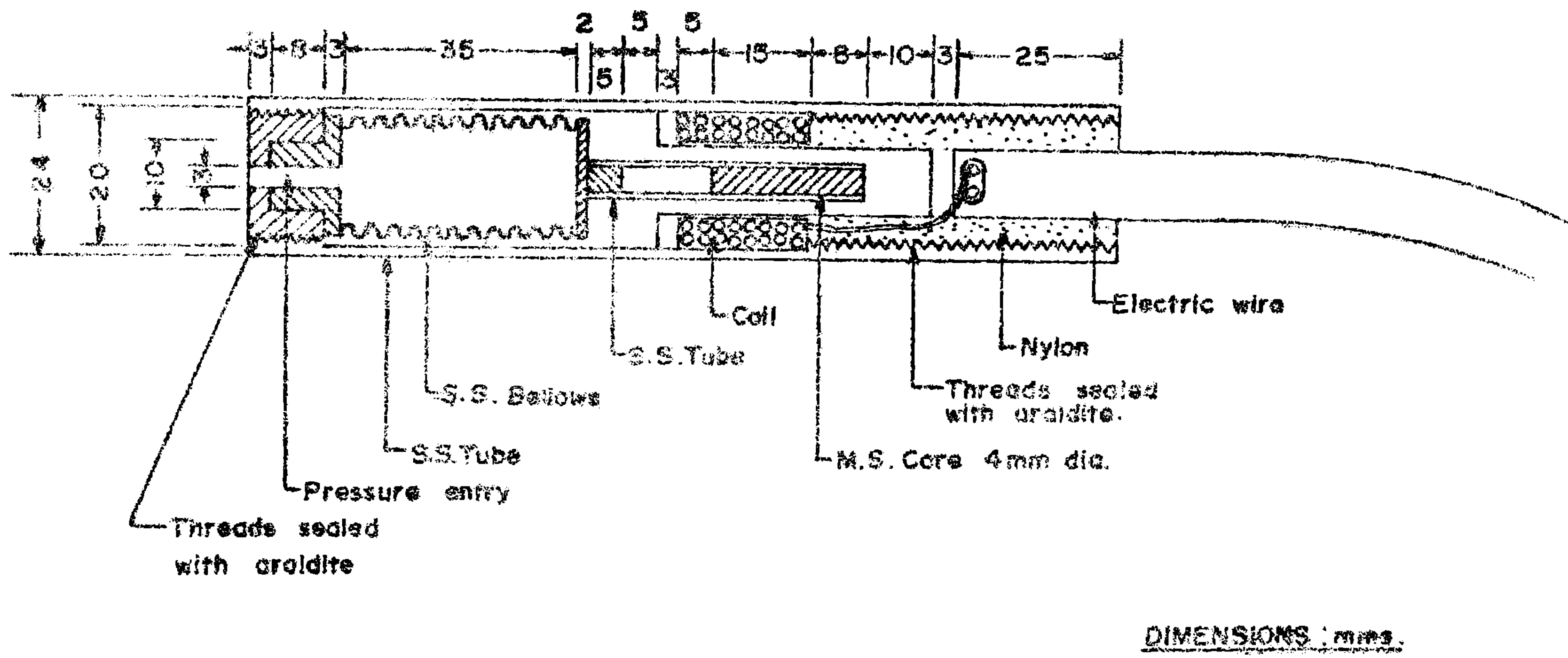


FIG. 13 CROSS SECTION OF DEPTH TRANSDUCER

moves alongwith the contraction of the bellows. This rod acts as the plunger core of an electrical coil thereby altering its electrical inductance.

2.5.2 ELECTRICAL COIL OF TRANSDUCER

The electrical coil produces inductance variations proportional to the position of the plunger core inside the coil.

The length and diameter of the coil is already fixed based on the property of the bellows and the space available. Since the bellows moves about 4 mm corresponding to about 100 m depth, the length of coil is decided to be more than 3 times more in order to avoid the non-linear end portions as shown in Fig.14. which is explained in detail below.

2.5.2.1 DESIGN OF THE COIL

The basic features of the coil needed are:

1. Dimensions should match with the bellows movements i.e. 4-5 mm for 100 m depth.
2. The impedance should match with the common signal conditioner, i.e. about 50 ohms variation below 470 ohm at 1000 Hz.
3. The nature of inductance variation should be similar to that of salinity and temperature, i.e. inversely proportional to the depth.
4. Inside diameter of coil: 8 mm (for accomating a core of 4 mm dia)

The inductance of the coil with air core is given by

$$L = \frac{4 \pi N^2 A}{L} \times 10^{-9} \text{ Henries}$$

where N = no. of twins, A = area of cross section of coil and L = length coil

If the solenoid contains a rod of iron of constant permiability μ and of the same cross sectional area as that of solenoid

$$L = \frac{4 \pi N^2 A \mu}{L} \times 10^{-9} \text{ Henries}$$

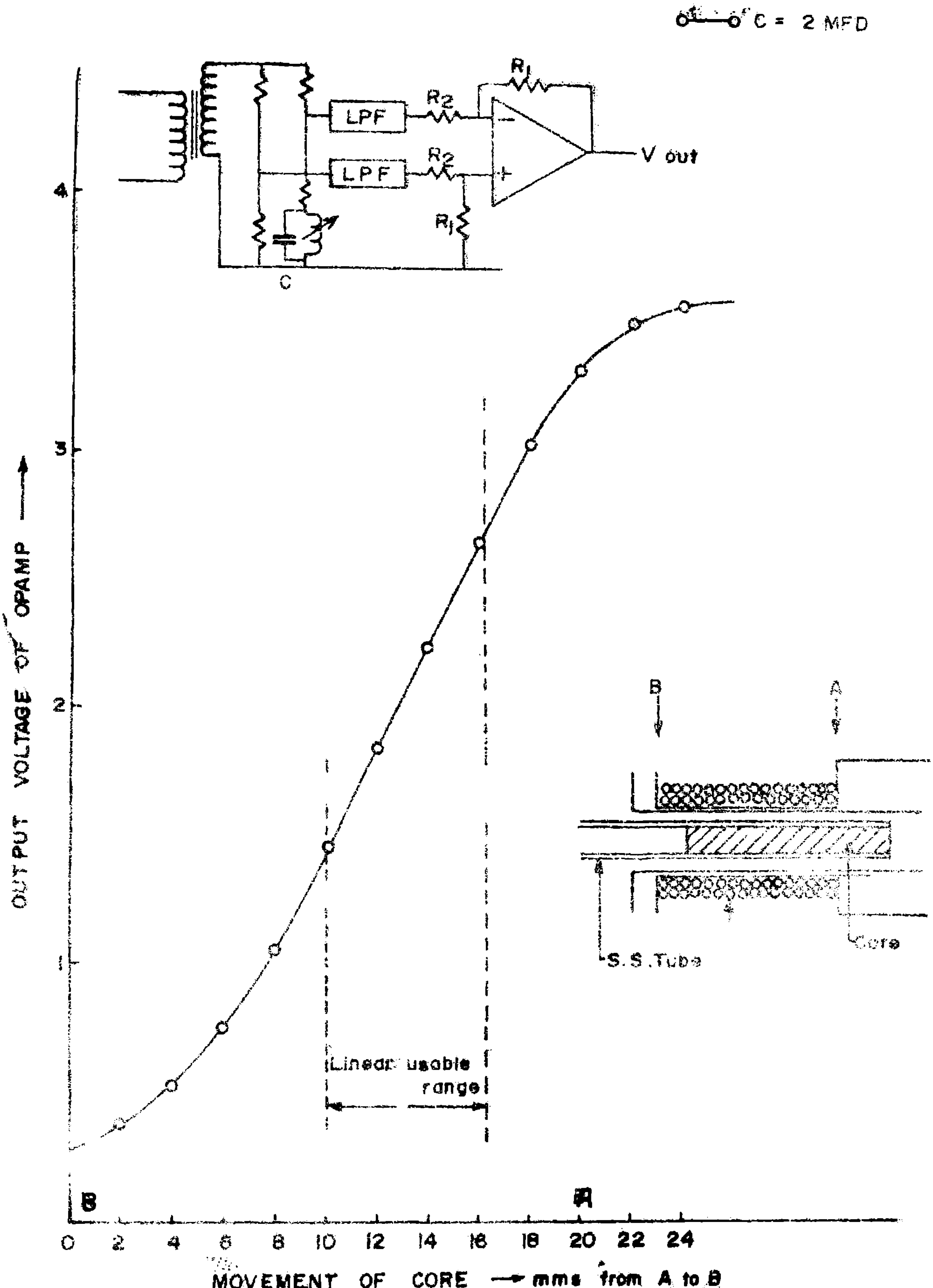
Under the decided values of the dimensions of the coil, namely,

I.D.	..	8 mm
O.D.		between 9 and 15 mm
Length	..	25 mm
Gauge of wire	..	42 SWG
Diameter of core	..	4 mm

The number of turns of coil was estimated to be 2500

2.5.2.2 RESPONSE OF COIL ON CORE MOVEMENTS

The formula above gives the inductance and thus the impedance of the coil in the presence of the core movements on an ideal condition. But the coil parameters deviate from the ideal condition at the ends of the coil. The exact nature of the impedance at the ends is seen in the graph in Fig.14 after conditioning the signal.



IG·14.RESPONSE OF CORE POSITION AND OUTPUT VOLTAGE OF OPAMP

The graph shows that towards the ends of the coil, the response is non-linear. Only about 1/3 of the total length of the coil is linear. This property was studied with coils of different lengths. It was confirmed that for longer coils, this non-linearity is negligible in comparison with its length. In general, about 3 to 6 mm length of the coil on either sides become non-linear due to the end effects. The magnetic flux lines here are curved and the linear relationship is not followed. It was found from the actual measurements that the coil should be at least 20 mm in order to avoid the end effects properly.

2.5.2.3 FABRICATION OF THE COIL

The actual fabrication of the coil is very important as it has to work at very hazardous environment. The coil should have the following properties.

1. Capacity to withstand high hydrostatic pressure.
2. No effect on saline water in the long run.
3. Should withstand shock and vibration.
4. No electrical leakage in the presence of the highly conductive sea water.

In order to achieve the above properties, the coil was moulded in nylon with araldite as the sealing agent. It was found that under this condition the coil could withstand hydrostatic pressure even much above the required limit. After deciding the features of the bellows, the coil and the core, the final dimensions were decided and fabricated as in Fig.13 which shows the cross section with all details and without the final neoprene cover.

2.5.2.4 THE FEATURES OF THE DEPTH SENSOR

Four types of depth sensors using three different types of bellows of types SK-8180A, SK-8180B, SK-8180C and 9519 were constructed, with the features given below:

1. Range	..	30 m, 100 m and 200 m
2. Length		160 mm
3. Diameter		25 mm
4. Types of bellows	..	316 quality stainless steel bellows manufactured by M/s. Servometer Corporation, U.S.A., Types SK-8180A, SK-8180B, SK-8180C and 9519
5. Length of coil	..	25 mm
6. I.D. of coil		8 mm
7. Thickness of core	..	4 mm
8. No. of turns of coil	..	2500 turns of 42 SWG copper enamelled wire
9. Inductance variation of the sensor:		
a) 30 m depth	..	38.5 mH to 29.7 mH
b) 100 m depth	..	37.7 mH to 29.3 mH
c) 200 m depth		37.9 mH to 29.2 mH
10. Coil excitation	..	1000 Hz sinusoidal waves at 5V P.P.

11.	Pressure protection	Coil was moulded in nylon with araldite sealing

2.5.2.5 AMBIENT TEMPERATURE EFFECTS ON THE COIL

The ohmic resistance of coil varies proportional to its temperature. Even though the coil is concealed inside the steel case, it will slowly pick up the ambient temperature and change its electrical resistance which will directly reflect on the readings proportionally. If this error is not eliminated, the depth readings will have to be corrected according to the temperature changes of the water similar to that done for salinity measurement. But this error is comparatively low and is proportional to the temperature. Therefore this can be fully eliminated. The resistance variation of the coil was studied with the help of a hot oven and the graph was plotted. These proportional changes in resistance was opposed with that of a thermistor which has got resistance characteristics inversely proportional to the temperature. The thermistor was shunted with an appropriate resistance so that its effective resistance variation is exactly equal to that of the coil, but in opposite direction. The Fig.15 gives both the curves which are sufficiently linear. As the hot oven could not be maintained at critical temperatures the values could not be taken precisely.

The thermistor with its shunt resistance was connected in series to the coil and the experiment was repeated.

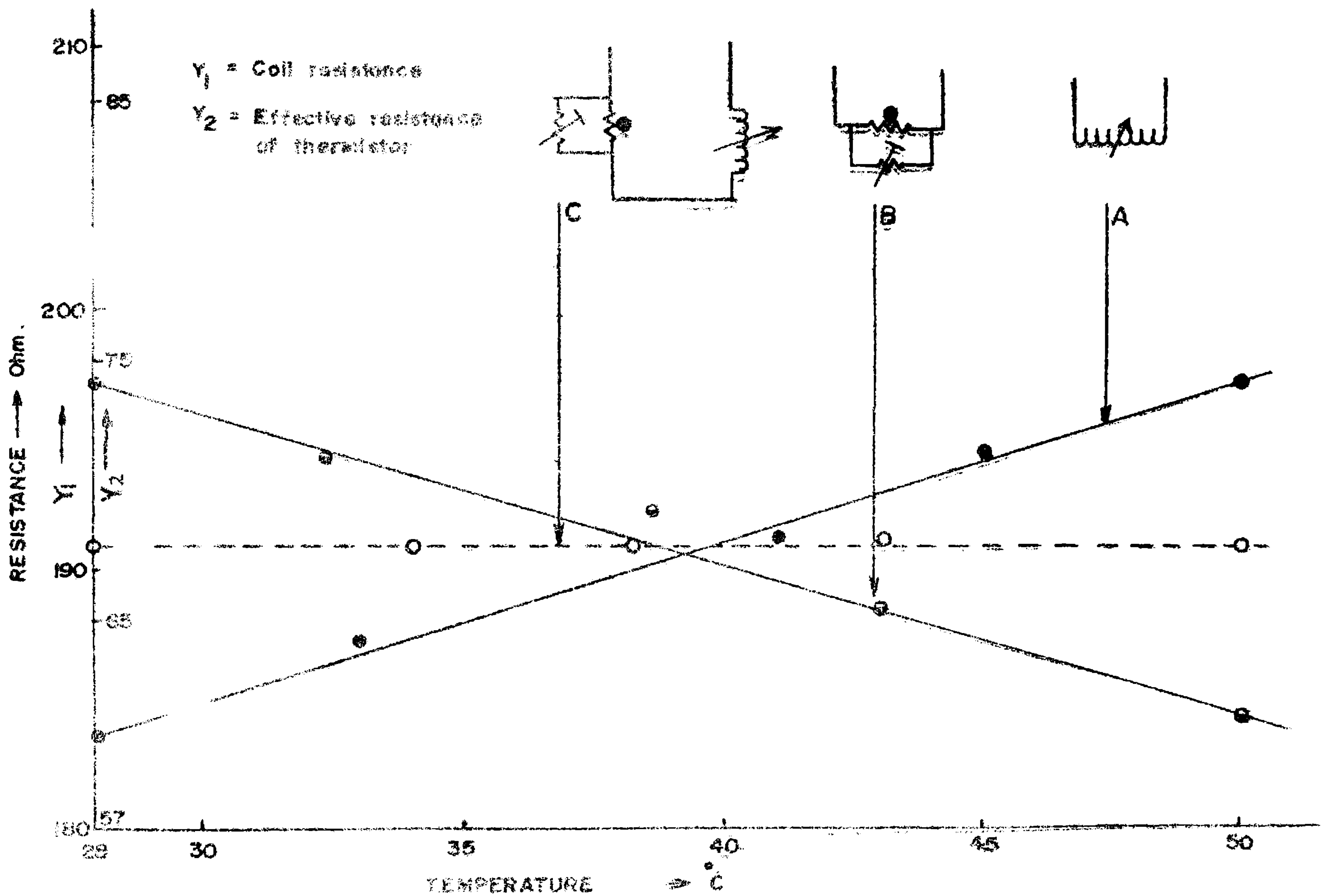


FIG 15 THE EFFECT OF TEMPERATURE ON (A) COIL, (B) SHUNTED THERMISTER AND (C) THE COMBINATION OF A AND IN SERIES. Y-AXIS OF C IS GIVEN AS Y_1+Y_2

The ambient temperature effect, as shown in the third curve, is found fully eliminated.

2.6 UNIFORM SIGNAL OUTPUTS FROM SENSORS

In order to make the complete system simpler, highly portable with easy and reliable operation, the signals from sensors must have uniform signal output. This has been achieved fully in the case of sensors of salinity, temperature and depth. Though the signals from current and current direction are different in nature they are quite strong so that they could be displayed without much problems.

2.6.1 UNIFORM FEATURES OF SENSORS

The following are relevant features of the sensors which have made them accommodative to the composite instrument system.

2.6.1.1 SENSOR OUTPUTS

Signal output	Range of resistance/impedance
Temperature	220 ohm to 180 ohm, diff. 40 ohm
Depth	200 ohm to 150 ohm, diff. 50 ohm
Current	450 to 462 ohm, diff. 12 ohm for rotor-electric induction. 12 ohm pulses of 0 to 17.7 Hz corresponding to 0 to 400 cms/sec. speed. 'ON-OFF' pulses of 6V for magnetic induction
Current direction	0 to 2000 ohms
Salinity	100 ohm to 60 ohm

2.6.1.2 OPERATIONAL SUPPLY VOLTAGE

Salinity	..	Excitation by A.C. bridge at 5V
Temperature	..	Excitation by A.C. bridge at 5V
Depth	..	Excitation by A.C. bridge at 5V
Current	..	Excitation by A.C. bridge at 5V
Current direction	..	Excitation by D.C. bridge at 6V

2.6.1.3 SIGNAL TRANSMISSION

Salinity	..	2-core unshielded cable
Temperature	..	2-core unshielded cable
Depth	..	2-core unshielded cable
Current	..	2-core unshielded cable
Current direction	..	3-core unshielded cable (one core used for clamping the stylus)

2.7 MULTIPLEXER

The function of the multiplexer in the system is to give connections to the different sensors in time, one by one, so that the sensors come in the circuit one by one and their respective informations are displayed in the display meters, one by one.

The essential features needed for the multiplexers here are:

1. Contact resistance should be extremely low - below .1 ohm
2. Both a.c. and d.c current should be allowed to pass though the multiplexer switching contacts.

3. Should be very compact, as this has to be accommodated inside the underwater probe. Should not take more than 100 c.c.space.

4. Should operate on 9V with very low current consumption.

5. Should be very rugged as it has to withstand all the shock and vibration of the remotely operated under water probe.

6. Facility for remote operation.

There are quite some multiplexers available in the market using integrated circuits belonging to both analogous as well as digital types as described in the Data Acquisition Hand Book (1978) of National Semiconductor Corporation.

All of these multiplexers shown above have high contact resistances above 150 ohms, as these are used for multiplexing after signal conditioning, engaging different signal conditioners for each sensor. Since the aim of this work is to make the remotely operated under water probe very compact, rugged and small with minimum electronics and power consumption, not even one signal conditioner can be kept inside the under water unit. Therefore multiplexer has to be engaged prior to signal conditioning where contact resistances of the order of fractions of ohms are significant. The whole success of this method of remote operated data acquisition depends very much on the extremely low contact resistance of the multiplexer. There is no suitable multiplexer available in the market with the above features. Hence this task was taken up and four different types were developed as given below:

2.7.1 MUX-100

I.C. timer multiplexer MUX-100 is a multiplexer control system for accomplishing the required switching function as shown in Fig.16. Before connecting the power from the onboard supply, the terminal remains closed. This terminal is used to connect the 'current sensor' which requires an independant and long time. When the power is switched on, the normally closed relay used for connecting current sensor remains opened disconnecting the sensor. The timer 555 integrated circuit oscillates at 8 seconds 'on' and 2 sec. 'off'. The output of this timer is connected to a CMOS counter integrated circuit 4017 which under the given circuit fonfiguration changes its output levels from low to high, one by one, corresponding to each pulse from the 555 timer. The process is repeated indefinitely until the power is 'off'. 4017 counter has got 10 outputs and the system needs only 4 outputs for engaging 5 sensors and one engerising coil which has to work in parallel to the direction sensor. One sensor (current) is got connected when the power is disconnected to the under water unit. Hence only 4 outputs are needed. The first four outputs are amplified

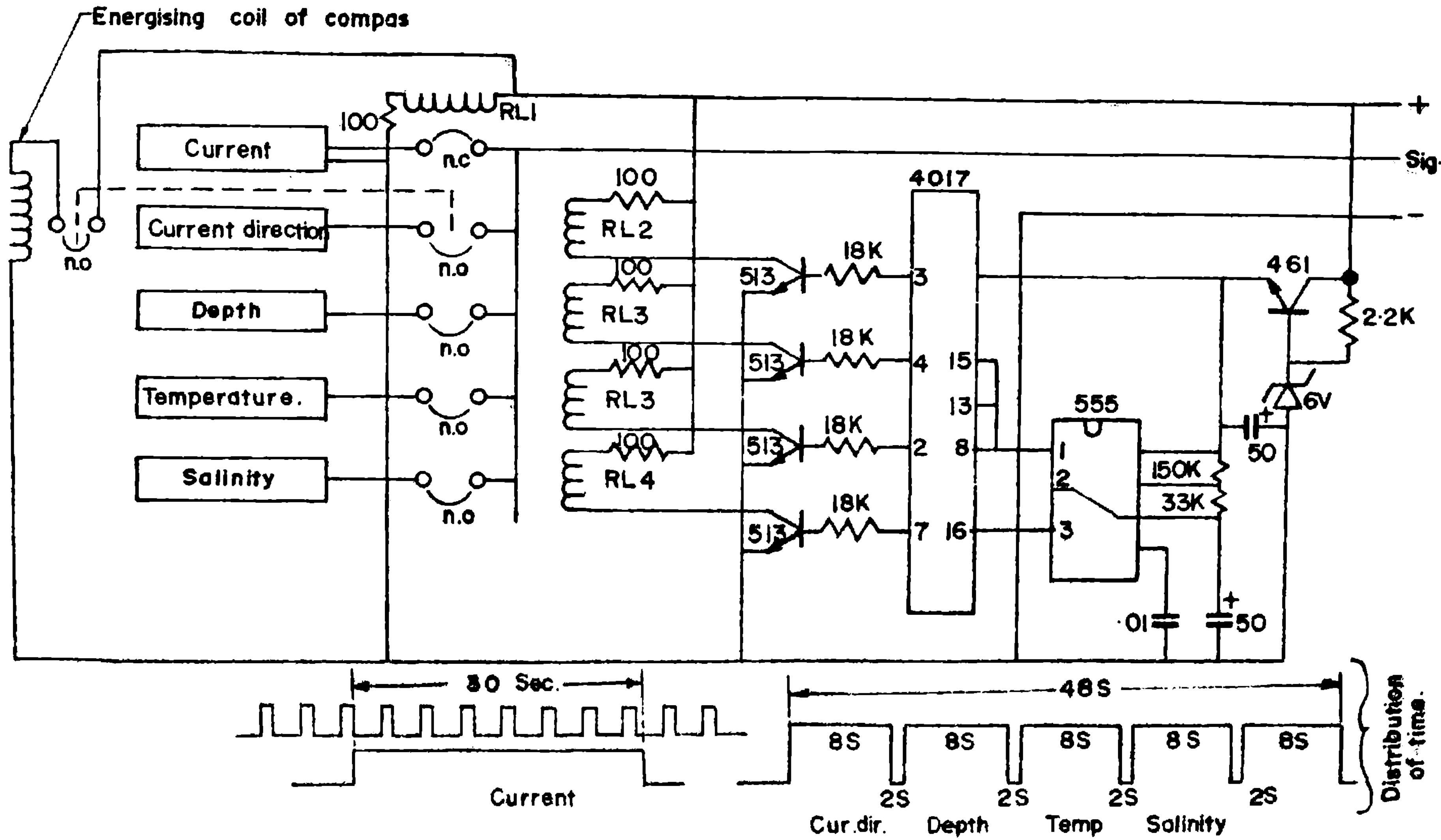


FIG 16 REMOTE OPERATED MULTIPLEXER — MUX-100

using transistors CIL 513 and connected to 4 Nos. reed relays. The number of relays are switched on one by one according to the generation of positive pulses in the timer 555. The current direction sensor needs 2 contacts independantly, one for connecting to the potentiometer resistance and the other for actuating the coil of the compass. Hence the first output is used to operate 2 reed relays through 2 independant amplifiers as given in the circuit. Now the timer takes 8+2+82+8+2+8 = 38 secs. for scanning the four sensors one by one. If the power is not switched off after 38 secs., the 5th, 6th etc. outputs also will be activated. This will lead to confusion. Another time controlled relay in the onboard display unit switches off the complete system after 48 secs. The last 10 secs. is used to display a 'reference' signal. (Please see the operation of the equipment for more details).

The multiplexer MUX-100 has met all the requirements needed for the system. As it has got gold plated reed relay contacts, the contact resistances are extremely low-below 50 milli ohms. Being reed switches, they do not create problems of vibration. MUX-100 scans the sensors in a given sequence. The change from one sensor to another is indicated by an alarm signal produced during the 2 secs. 'off' time which reminds the operator that it is time to switch over the sensor to the next one. The multiplexer system is found to work quite reliably without a single failure. But 10 secs. interval is needed between two operations.

2.7.2 MUX-110

As shown in Fig.17, MUX-110 also uses one counter I.C. 4017 for switching on reed relays one by one. Here instead of the relays are switched on automatically using the pulses generated from a built-in astable multivibrator, The required command pulses are generated and sent manually at required times from the on-board unit. Therefore the multiplexer operation is always at our control. As shown in Fig.17 when the power is switched on, 4017 is 'on' with its 1st output in high state. The +ve power line to the under water unit is switched 'off' for a short duration of .2 to 2 secs. This switches off part of the electronics including the amplifier and the relays. But the 4017 counter and its associated parts do not go off since sufficient energy is stored in the 500 MFD condenser which keeps the counter alive even when the power is off. The diode does not allow this charge to be distributed to other parts during the 'off' time. This 'off' signal results in a -ve signal at the base of PNP transistor 222. Therefore the PNP transistor conducts during this -ve input producing a +ve signal to the input of 4017 counter. The counter after obtaining a pulse in its input,changes its output to the next position. This process is repeated for every 'switch off' action in

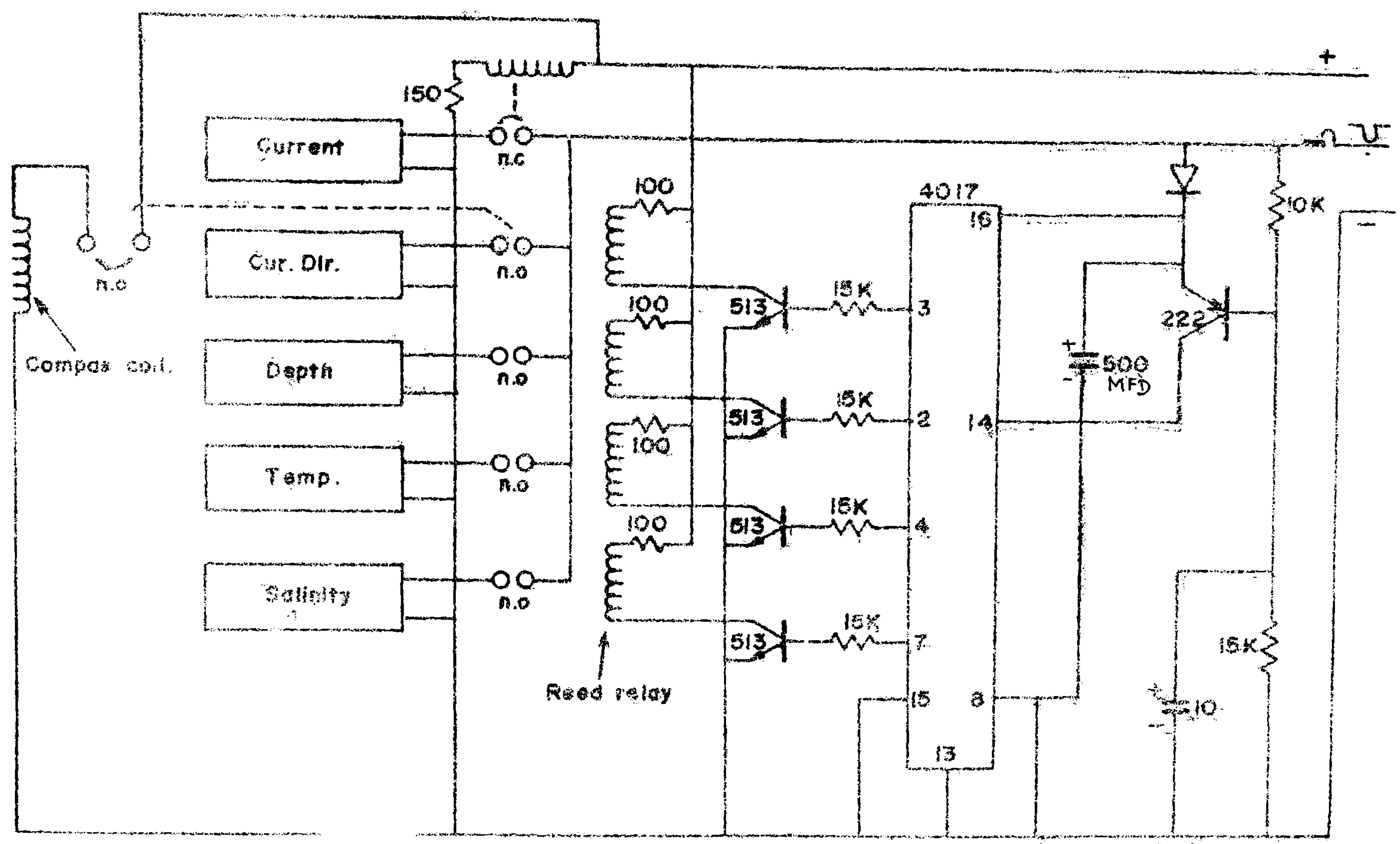


FIG 17 REMOTE ERATED MULTIPLEXER MUX 110

the 'onboard' unit of the instrument.

This method is also found to be quite reliable. It has got the advantage over the MUX-100 that the sensor can be selected as and when needed by pressing a switch. The disadvantage is that there is an uncertainty about the starting sensor. Because the charge stored in the circuit does not allow the first output to be set on every time unless enough long duration is given to discharge it completely. That means, more than 2 minutes has to be allowed between 2 operations.

2.7.3 MUX-120

MUX-120 is a mechanical type multiplexer engaging a reduction gear motor and read switches activated by the magnet mounted on a rotating arm connected to motor. As shown in Fig.18 the shaft of the motor working on 6V is connected to a worm wheel, the rotation of which is further stepped down in decade. The handle takes step-wise positions in its rotatory motion. During one complete rotation, it takes 10 positions. One magnet is mounted on the arm and 10 sensitive reed switches were fixed close to the 10 positions such that each reed switch turns from its normally opened condition to closed condition. In this condition 10 sensors can be connected. But as there are only 5 sensors, and only 4 additional contacts are needed, 4 pairs of opposite sensors are connected in parallel. 2 Nos.

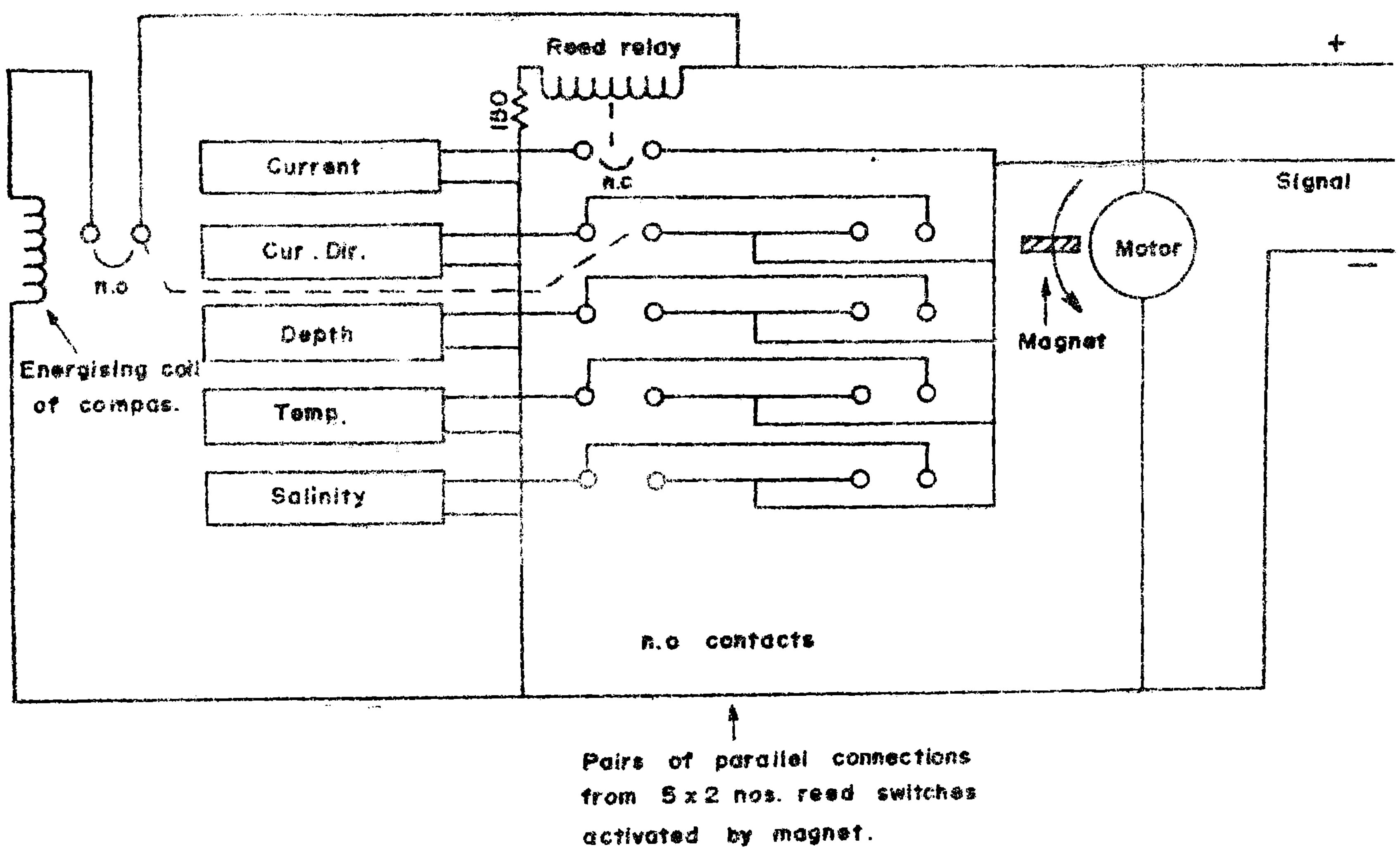


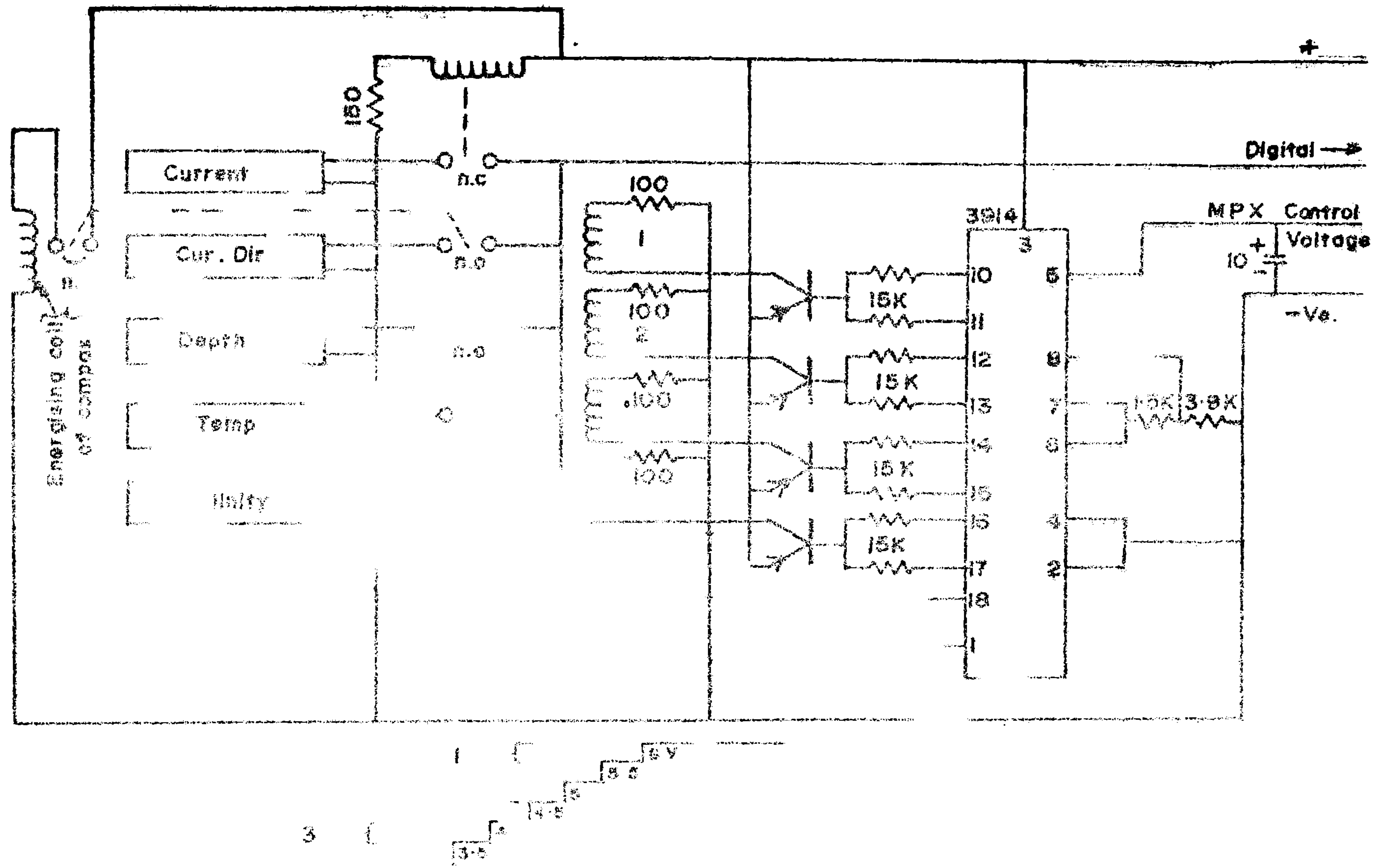
FIG 18 REMOTE OPERATED MULTIPLEXER - MUX - 120

magnets were used and both the switches in the pairs were activated. This has further ensured the operation of switches. In the second place (i.e. current direction) the two switches are used separately for connecting potentiometer sensor and its energising coil.

This multiplexer also is found to be quite dependable. It takes current only for a very short duration of 2 seconds when the motor works for changing position from one sensor to another. The rest of the time it does not take any current unlike other types explained earlier.

2.7.4 MUX-130

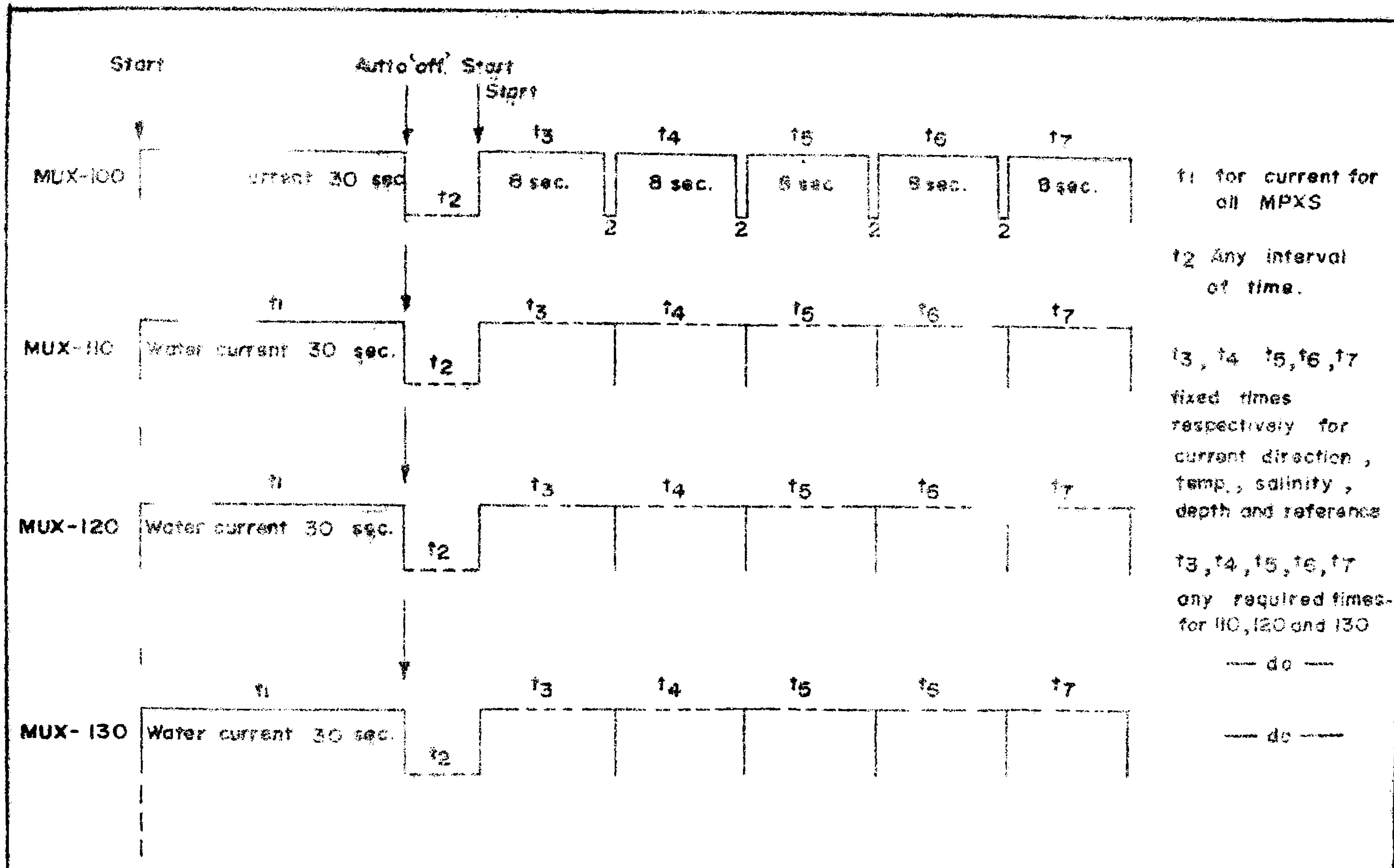
This multiplexer engages a new generation integrated circuit LM3914 from National semiconductor, U.S.A. The I.C. has 10 outputs. When voltage is applied to its input, either one of the ten outputs goes 'low' while all others remain 'high'. Any required output terminal can be brought to 'low' by feeding the appropriate voltage to its input. The outputs are connected to reed relays after amplification. Here also, since only 4 outputs are needed, as shown in Fig.19, two consecutive outputs are joined. The required input voltages are set in the 'onboard' meter and connected to the 'under water unit' through the long cable by means another pole of the same selector switch. One advantage of MUX-130 is that any sensor can be selected at any time, while in others, they can appear only in the particular


+
Digital
MPX Control Voltage
10
-Ve.
3914
150
100
1
100
100
.100
15K
15K
15K
15K
3.9K
n.c
n.o
n.o
Current
Cur. Dir
Depth
Temp
Energising coil of compas

sequence. The disadvantage is that 4-core cable is needed to operate the under water probe as against 3-core needed in all other cases. Because, one extra line is needed for applying the required input voltage to the LM3914, as shown in Fig.19.

The Fig.20 shows the time sharing of the multiplexers MUX-100, 110, 120 and 130. Here in all cases t_1 the time taken for current measurement is independant of multiplexer operations. t_2 is any interval time after current measurement, which is common in all cases. t_3, t_4, t_5 & t_6 are the times for current direction, depth, temperature and salinity. These follow in sequence in MUX-100, 110 and 120. But in 130, the sensors can be selected in any order. In MUX-100, the times given are constant and in all other cases, they can be altered as needed.

The chart below gives the comparative features of the four multiplexers.



FIG·20 TIME SHA NG CHART OF MULTIPLEXERS

2.7.5 COMPARATIVE FEATURES OF THE FOUR MULTIPLEXERS

	MUX-100	MUX-110	MUX-120	MUX-130
1. Space needed	100x50x20 mm	100x50x20 mm	60 diax50 mm	100x50x20 mm
2. No. of core needed for the cable	3	3	3	4
3. Current consumption	60 mA constant	60. mA constant	100 mA for 2 sec. and [illegible] for the rest	60 mA constant
4. Operation	Automatic in sequence	Manual in sequence	Manual in sequence	Manual as per choice
5. Reliability	Good	Good	Good, but should be more care-ful	Good
6. Interval between two operations	Minimum 10 seconds	Minimum 2 minutes	No restri-ctions	No restrio-tions

2.8 SINGLE 3-CORE or 4-CORE CABLE FOR TRANSMISSION OF 5 PARAMETERS FROM THE UNDER WATER PROBE

It is one of the specific aims of the project to reduce the number of cable used for operating different instruments under water for the benefit of convenience in handling as well as simultaneous data collection. Though a multicore cable with enough cores independantly for every sensor can solve the problem, the use of such a cable is quite undesirable for operation in rough sea conditions as its comparatively thin cores and their insulations are likely to be damaged easily during the operations. More over, the handling of such cable will be quite tiresome. The aim of reducing the number of core to 3 or 4 is to make the operation easy. Further, such cable with 3-core or 4-core are plenty available in the market and their selection and procurement will not be of any problem.

The number of core is reduced to 3 for operating the complete system and 4 in the case of MUX-130. It can be reduced to 2 also by incorporating the signal conditioner, A/D converter and transmitting the signals super imposing on the supply line. This will make the under water probe to be heavy, bulky, complicated along with much power consumption. This will spoil the very aim of developing a reliable acquisition system of easy and convenient operation. The very basic philosophy of such remote operated data acquisition systems is that the remotely operated sensor probe should be most rugged, simple with minimum electronics and controls so that it is subjected to minimum complaints. Thus the present number of the core i.e. 3 in the case of MUX-100, 110 and 120 and 4 in the case of 130, is the result of a compromise between the essential requirements and operational problems.

The cores of the cable are engaged as follows:

1. +ve supply line
2. -ve supply line
3. signal carrying line and
4. multiplexer control line (in the case of MUX-130)

The third core carries the signal from the sensors one by one. There are no stringent specifications for this 3-core and 4-core cable.

2.8.1 THE FEATURES OF THE CABLE

The requirements of this cable are very liberal, as given below:

1. Voltage	..	Above 9V
2. Current	..	200 mA max.
3. Insulation		Suitable for 20V
4. Sheathing	..	Normally PVC, preferably neoprene for better durability
5. Breaking strength	..	Normally 100 kgs., preferably above 200 kgs so that the necessity of additional wire

		rope or plastic rope for supporting the weight and hydrodynamic drag of the under water unit can be avoided.
6. Pliability	..	very high
7. Diameter		About 10 mm
8. Shielding		Not needed
9. Armouring		Not needed. This will reduce the pliability of the cable.
10. Material of core		tinned copper
11. Core size	..	Approx. 40/.2/3 or 40/.2/4
12. Electrical resistance	..	Less than 10 ohms for 100 m length

Even though it needs only maximum 9V at maximum 200 mA, this cable can handle 440V at 15 Amps. Tne end connections and joins have been made strong so that the equipment can be operated in the most hazardous environments safely and covers the standards stipulated for hazardous environments.

2.9 SIGNAL TRANSMISSION

The signal is transmitted from the under water probe to its display console on-board the vessel through the cable. Only the -ve supply line and one of the cores (other than the +ve supply line) comes in the circuit loop of the sensors. Since the signals are not conditioned before transmission, the properties of the cable affect the signal during the transmission up to certain level.

2.9.1 THE RELEVANT PROPERTIES OF THE SIGNAL

2.9.1.1 THE FREQUENCY OF THE A.C. SIGNAL

The a.c. waves passed through a cable undergoes attenuation in relation to frequency. For higher frequencies, attenuation also is high. The frequency of a.c. signal in the system under report is limited to 1000 Hz where the attenuation is found to be low.

2.9.1.2 SHAPE OF THE A.C. SIGNAL

The shape of the a.c. signal undergoes distortion while passed through cable. This distortion depends upon the capacitance and inductance associated with the circuit loop. The distortion is least or minimum for sinusoidal waves. Hence sinusoidal waves were used as signal carriers in the system.

2.9.1.3 VOLTAGE OF THE A.C. SIGNAL

High voltage signal will undergo attenuation due to insulation breakdown. Since the voltage of any of the signals does not exceed 9V, there is no such problem.

2.9.1.4 IMPEDANCE OF SIGNAL

This is a very important factor which affects (other than the +ve supply line) comes in the circuit loop of the sensors. Since the signals are not conditioned before transmission, the properties of the cable affect the signal during the transmission up to certain level.

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2.9.1.4 IMPEDANCE OF SIGNAL

This is a very important factor which affects seriously all types of sensors and instrumentation especially those of remote operated types. If the impedance of the signal is high, noice in the surroundings will penitrate into the system and the system will fail to provide reliable data. The system will need very complicated and expensive noice eliminating methods. As the impedance is lower, the system is more and more immune to noise problems. The speciality of the system under report is that all the sensors are at very low impedance so that they are highly immune to noice and no special efforts are needed to protect them from noice. Not even the minimum standard precaution of using shielded cable is needed in the system for noice elimination.

2.9.2 THE PROPERTIES OF CABLE IN RELATION TO SIGNAL TRANSMISSION

2.9.2.1 OHMIC RESISTANCE OF THE CABLE

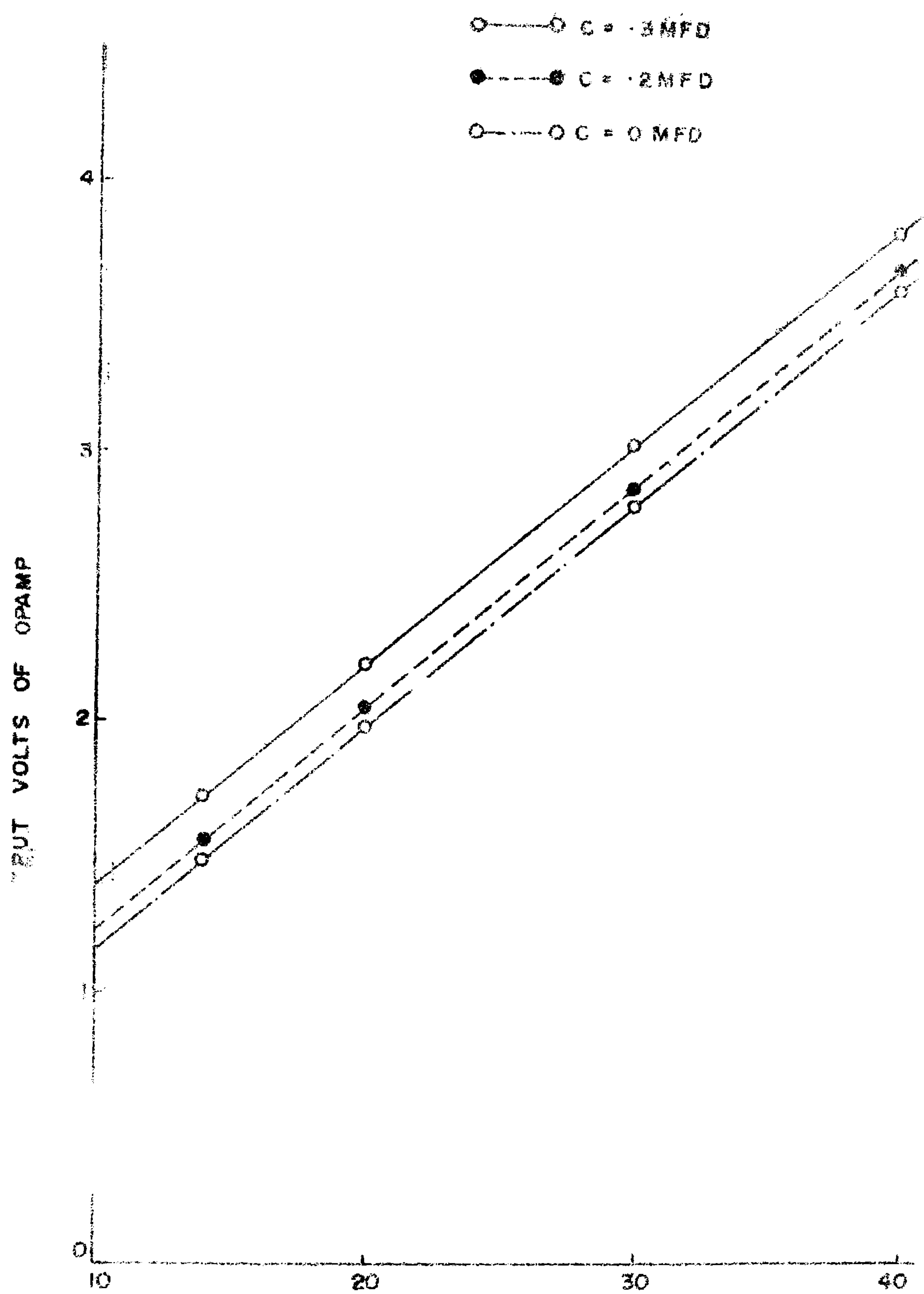
The ohmic resistance of the cable adds to the series resistance of the sensor in the Wheatston bridge network. This resistance is quite low for 500 metres of cable and it can be accommodated in the bridge. Any alteration in small values of cable can be adjusted in the series 'zero set' provision given in the electronic circuit. The sensors are calibrated with the complete length of cable and their ohmic resistances are also included here.

2.9.2.2 CAPACITANCE OF THE CABLE

Cable has got a capacitance formed by the long conducting cores and the insulation as the dielectric material. The cable having uniform structure throughout its length, the capacitance is proportional to its length. The capacitance of cable affects the performance of sensors differently.

The capacitance shifts the signal level of sensors with pure ohmic resistances, i.e. thermistor, current direction and salinity. Since the calibration is done with the long cable, this is got rid of and any effects due to the alterations in the length of cable can be eliminated by precisely adjusting the presets given in series to the sensors. The effect of capacitance on the other sensor of current direction is insignificant as its signal level variation is much higher, i.e. from 0 to 2000 ohms. It's effect on the current sensors do not cause any problems as the rotations of the rotars are detected digitally. The effect of capacitance on thermister is given in the Fig.21. The shifts caused can be fully eliminated by calibrating the instrument with its cable.

The effect of capacitance on sensors with reactive resistance is much complex. The capacitance virtually forms a tank circuit with the coil in the sensor. The capacitance may cause even resonance to the sensor coil.

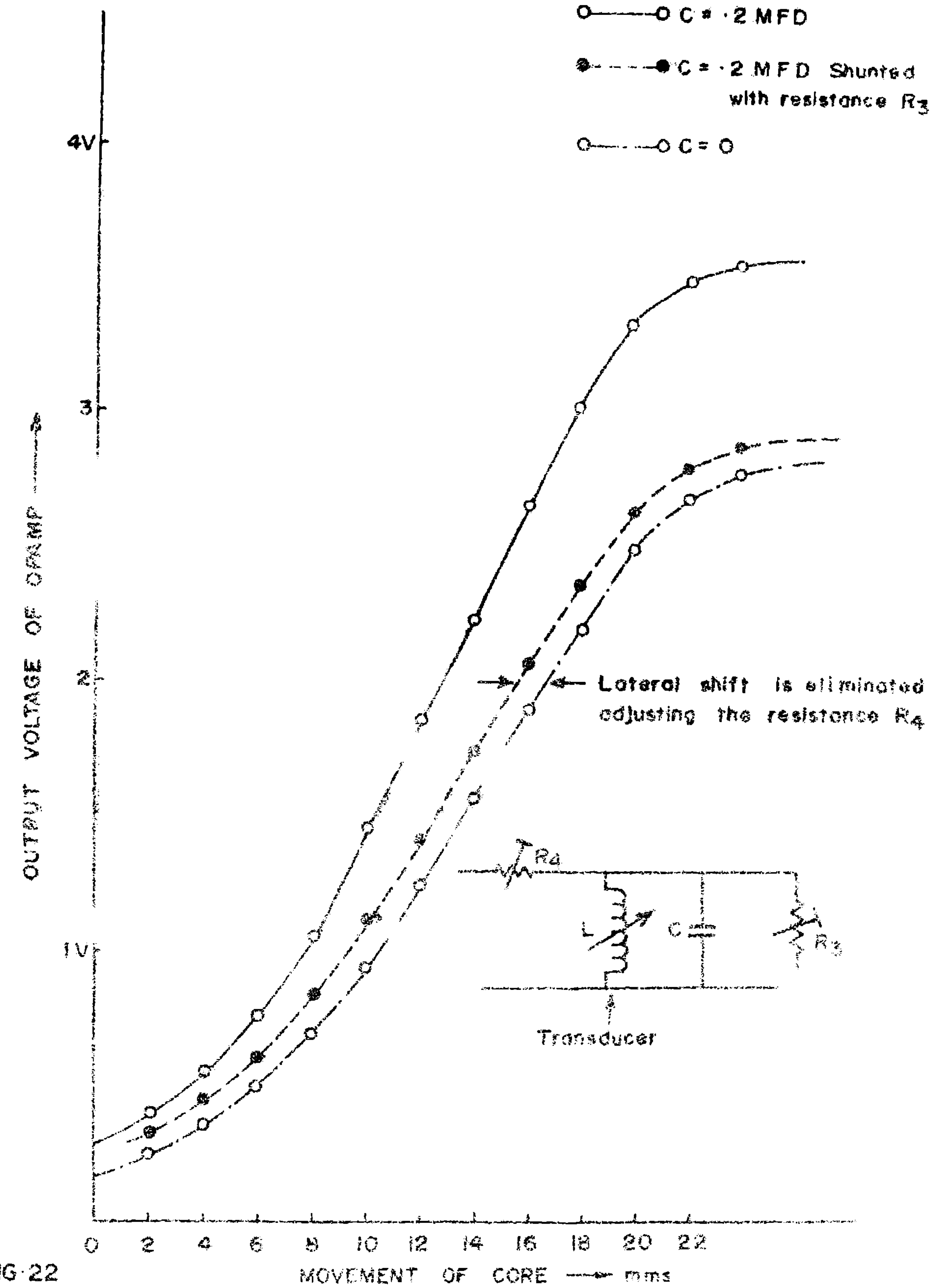


TEMPERATURE °C ⟶

FIG 21 EFFECT OF CAPACITANCE ON THERMISTER IN THE CIRCUIT

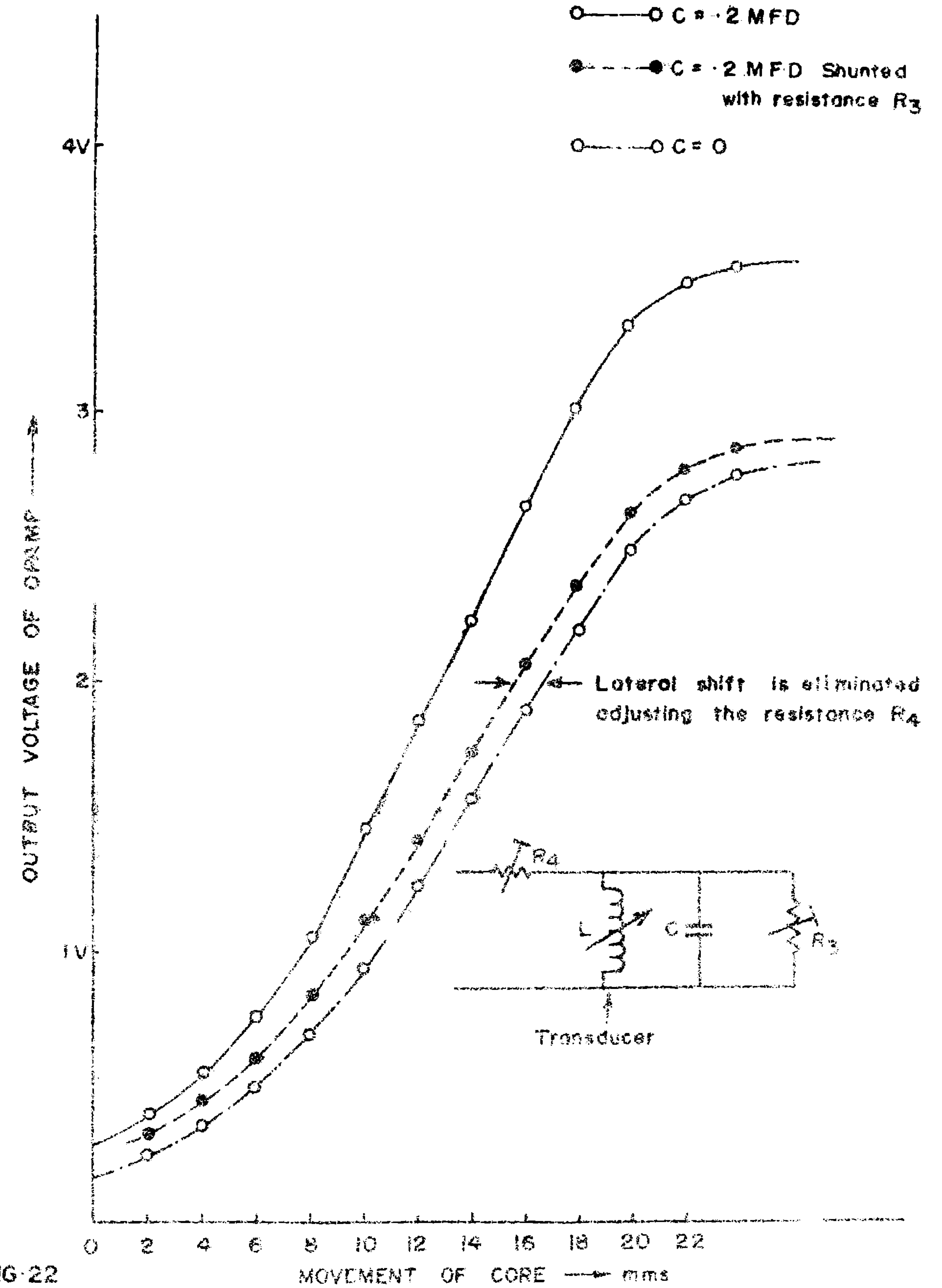
One important conclusion derived from the above analysis is that the coils of sensors should be designed such that they never come near to resonant levels. Because the signal output goes non-linear around the resonance levels. Resonance being a function of the frequency of excitation as given in the expression $f = \frac{1}{2\pi\sqrt{LC}}$, the frequency of excitation f of the sensor, the inductance L of the sensors and the capacitance C of the cable should be selected to avoid this unwanted region.

The transducers are designed to have reactive sensor elements having impedance in the range 20 to 40 mH, which when excited with 1000 Hz. sinusoidal waves give impedance variations from approx. 120 ohm to 240 ohms. This goes well matched with other sensors with ohmic resistance of the system (except current and current direction which are separately treated) as per the design requirements. Under this condition the sensor coil with the capacitance of 500 m cable are far away from resonance level. The capacitance needed for resonance should be above ·4 MFD (equivalent to aprox. 1000 meters of cable) for making resonance. It is clear from the mathematical analysis as well as the practical measurements from the laboratory experiments that the signal level of sensor is raised in the presence of capacitance as seen in Fig.22.



FIG·22

THE GRAPH SHOW HOW THE SHUNT RESISTANCE AND SERIES RESISTANCE ELIMINATE THE EFFCT OF CAPACITANCE AND LATERAL SHIFT



FIG·22

THE GRAPH SHOW HOW THE SHUNT RESISTANCE AND SERIES RESISTANCE ELIMINATE THE EFFCT OF CAPACITANCE AND LATERAL SHIFT

2.9.2.3 INSULATION RESISTANCE OF CABLE

The insulation resistance of the cable is associated with leakage problems. High insulation resistance is needed for signals with high impedances. Since the impedance of the signals here are very low, this question does not arise. Moreover, as the signal impedance is extremely low even slight damages of the cable due to water leakage at high pressures will not create detectable errors.

2.9.2.4 DIELECTRIC CONSTANT OF INSULATING MATERIAL

The values of this property of insulating material directly affects the capacitance of the cable whose affects have been already analysed above. The dielectric constant affects the capacitance as given:

$C = \frac{KA}{4\pi d}$ where K is the dielectric constant, A is area of capacitor (proportional to the length of cable) and d is the distance between the plates (ie. core)

SIGNAL PROCESSING

3. SIGNAL PROCESSING

The signals from the five sensors are to be processed before display in their final devices.

The signals are conditioned in three ways. The current signals are processed purely digitally for display in electromagnetic counter. The current direction is conditioned to d.c. voltage excited with d.c. voltage in a bridge. The other sensors of salinity, temperature and depth were excited with a.c. sinisoidal waves for producing d.c. voltage at the final stages.

3.1 SIGNAL PROCESSING FOR CURRENT SENSORS

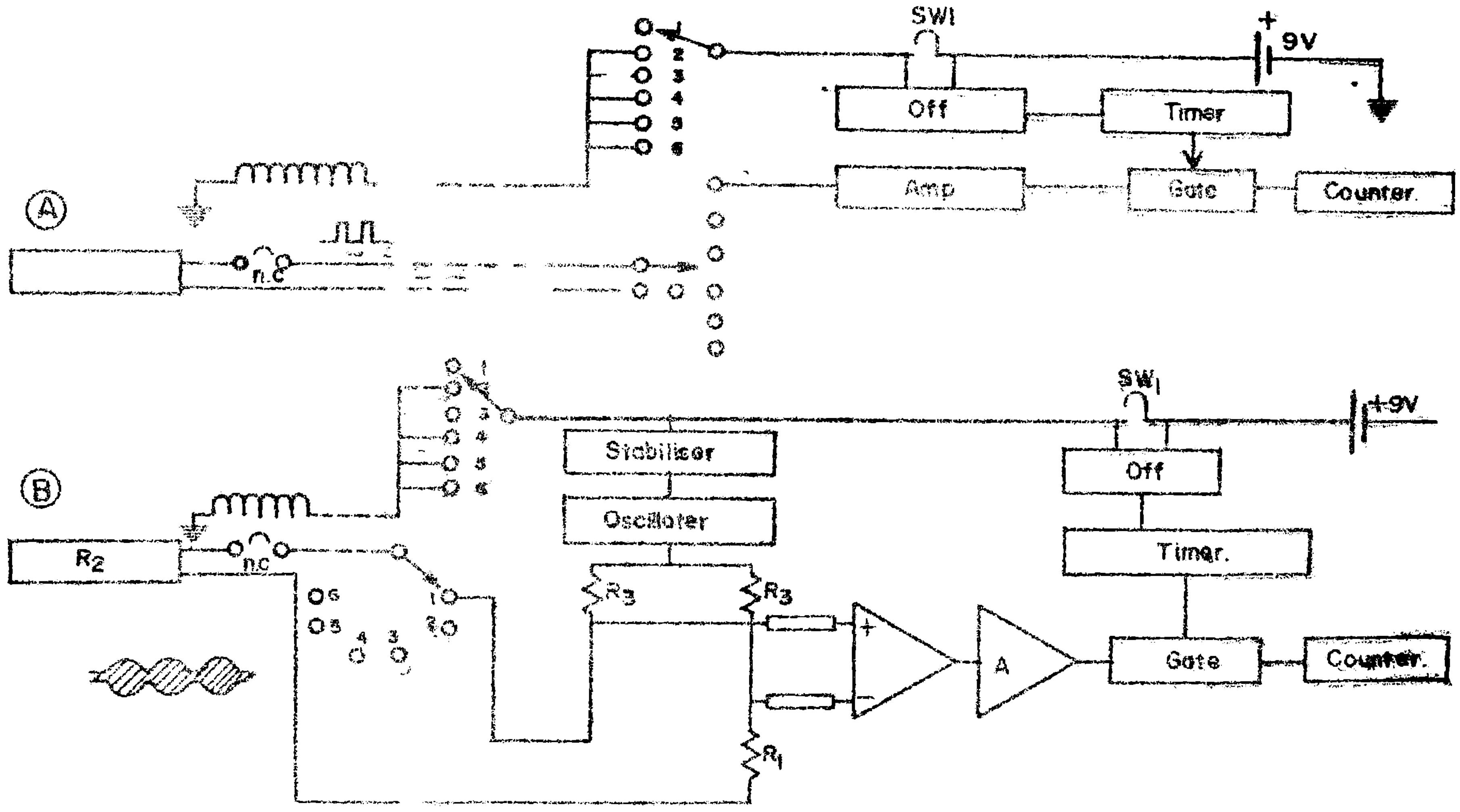
Rotors are used for sensing water current. The advantages of rotors over impellers are already described in the review. Two types of rotors have been developed for this purpose, with basically same features but differing in dimensions as mentioned earlier in 2.1.

The rotors were used to produce electric signals proportional to water current using two methods independantly namely, magnetic induction and electric induction. The Fig.23 shows the block diagram of the operation of the two methods.

3.1.1 MAGNETIC INDUCTION

Here the rotor makes 'make and break' operation by means of a magnet mounted on it and a reed switch consealed on the stator. Since the rotor has to carry a magnet as shown in Fig.4, only the large rotor can be used in this case. As shown in Fig.23 and 24, the 'make and break' operation is utilised for short circuiting the voltage at the base of the transistor Q_1 in Fig.24. The transistor conducts when the reed switch is open. The transistor is open when the reed switch is closed. The voltage at the collector of the transistor oscillates accordingly producing pulses. These pulses are further amplified using the 'darlington pair' transistors and fed to e.m. counter for registering the number of pulses. The pulses are counted for a definite time interval so that the number counted coincides with the current speed in cm/sec. This has got the advantage that it gives current averaged over the duration of counting. The time interval is found out during actual trials conducted in towing tanks with known speeds. This time is a constant and it depends on the features of the rotor. In the case of the large rotor this time is found to be 30 seconds, while for the small rotor it is 24.5 secs.

The required time is produced from an i.c. timer 555. The i.c. 555 operates in monostable under the configuration given in the Fig.24. This is a highly stable device for generating time delays or oscillations. In the time delay mode of operation, the time is precisely set



(A) with magnetic induction (B) with electric induction

FIG 23 BLOCK DIAGRA RENT METER PART OF THE SYSTEM.

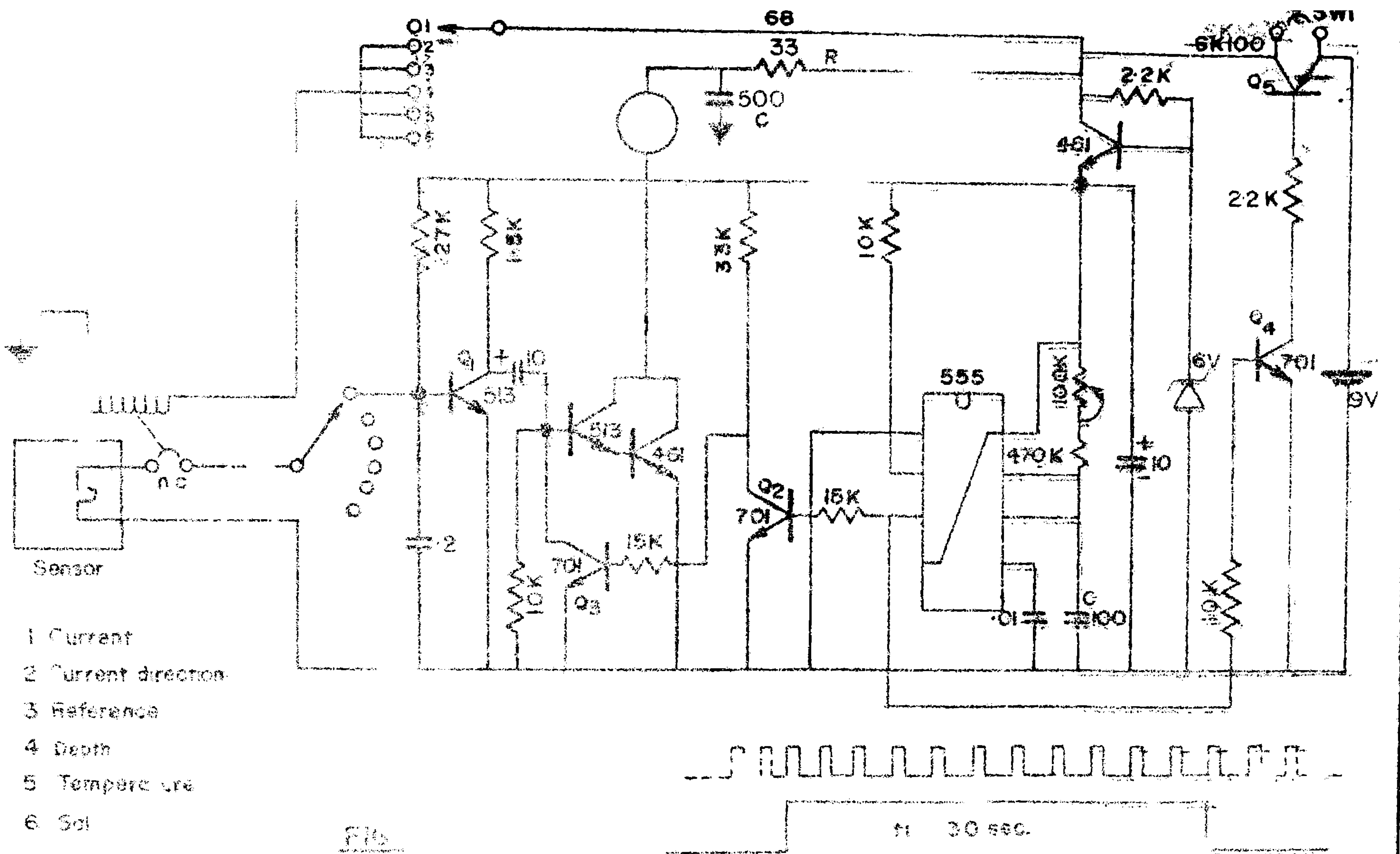


Fig.

CIRCUIT DIAGRAM OF CL ... TER (Mogr ... Inductio PART OF ... E SYSTEM by one external resistor and capacitor. The output circuit can source or sink up to 200 mA. Integrated circuit is a very reliable one and takes low current for operation. It has got a wide supply voltage ranging from 4V to 30V. As the power is switched on, the 555 timer operated in monostable producing a +ve pulse at its output No.3 point. The duration of this positive pulse depends on the values of R and C in Fig.24 as given by the relation.

$T = 1{\cdot}1\ R\ C$ secs.

The pulse goes to low after the time 'T'. This pulse is inverted using transistor Q_2 and fed to the base of Q_3 which otherwise keeps conducting, having obtained +ve voltage from the collector of Q_2. During the conducting stage Q_3 short circuits the pulses arriving at the base of darlington pair to -ve supply line. The +ve pulse generated as the 555 timer makes the transistor non-conducting thus allowing the current pulses to go through the darlington pair and finally to the e.m. counter. The R.C. value of the timer is critically adjusted to obtain the time decided based on the calibration of the equipment.

The same pulse from the timer switches on the transistor Q_4 which in turn switches on Q_5. When this pulse goes down, the counting is stopped and the complete power supply also goes 'off' automatically. When a further reading is needed, the press switch SW1 is given a short press for generating a +ve pulse from 555 timer alongwith switching on the complete electronics. Further, the pulse holds the supply on shorting the SW1 by the conducting transister Q_5.

Even though the display is done in e.m. counter which takes about 300 mA for its operation, the average current taken by the circuit is only as low as 30 to 50 mA. The 500 MFD capacitor keeps the charge just sufficient for making one count with short duration of milli seconds. The condenser is further charged through the resistor R_2. This arrangement spends energy very cautiously further adding safety and durability to the system preventing the flow of higher current which otherwise does.

3.1.2 ELECTRIC INDUCTION

The electric induction sensor consists of an electric coil and a ferrous piece for causing inductance variation on the former. As shown in the Fig.2 and 25, the coil is excited by sinusoidal a.c. signal of 1000 Hz produced from the oscillator. The coil forms one arm of the wheatstone bridge. The bridge gets balanced when

$R_1 = R_2$ where $R_1 = 470$ and R_2 is the effective impedance in the opposite arm, R_2 is a reactive resistance, given by

$$R_2 = \sqrt{R^2 + L^2 \omega^2}$$

Where R is the total ohmic resistance in the arm of the bridge.

A small change in inductance ΔL of the coil imbalances the bridge producing a voltage proportionally

The complete electronics for current sensor with electric induction consists of a voltage stabiliser, oscillator, wheatston bridge net work, 2 Nos. low-pass filters, a differential operational amplifier, booster pulse amplifier, darlington pair current amplifier, e.m. counter, I.C. 555 timer, electronic gate and automatic power off.

The voltage stabilisation at 6V is obtained by means of the stabilized supply with transistor 461 and zener diode. or with I.C. 7806.

The oscillator is designed for sinusoidal oscillations at 1000 Hz.

The bridge net work used in the system has 2 Nos. 1K ohm resistors and one 470 ohm resistor. The sensor forms part of the 4th arm. When the bridge is balanced, the output is zero and noice may penittate into the system at this stage. Instead of balancing the bridge, the two outputs which carry strong 1000 Hz, sinusoidal signals at low impedance, are separately passed to the next stage. The 1000 Hz oscillations in the arm with the sensor gets modulated with the pulses from the sensor.

The two outputs are separately detected and passed through low-pass filters to produce smoothed d.c. voltage. At balanced stage of the bridge both the lines have got approx. 2V d.c. level. While one line is quite steady, the other is superimposed with the pulses corresponding to the rotation of rotor.

The two d.c. lines with steady d.c. and oscillating d.c. are fed to the inverting and non-inverting inputs of an opamp with LM358. This is an opamp working on single supply ranging from 3V to 30V and having very high amplification up to 120 d.B. Since the opamp is operated in differential mode the output will be an amplified version of the difference between the inputs. The difference between the inputs is the pulses representing the rotation of rotor. Therefore the output of the opamp gives pulses amplified according to the amplification factor given to the opamp.

If e_1 and e_2 are the input voltages fed to the inputs of the opamp and R_2 is the effective values of the input resistors as per the drawing in Fig.25, the amplification factor is R_1/R_2 and the signal is amplified to a level of $R_1/R_2\ (e_1-e_2)$. In the particular case here, R_1 is infinite and R_2 is near to zero. Hence the signal (e_1-e_2) is amplified to the maximum possible i.e. 120 d.B. resulting in saturated square pulses at the output of the opamp. The

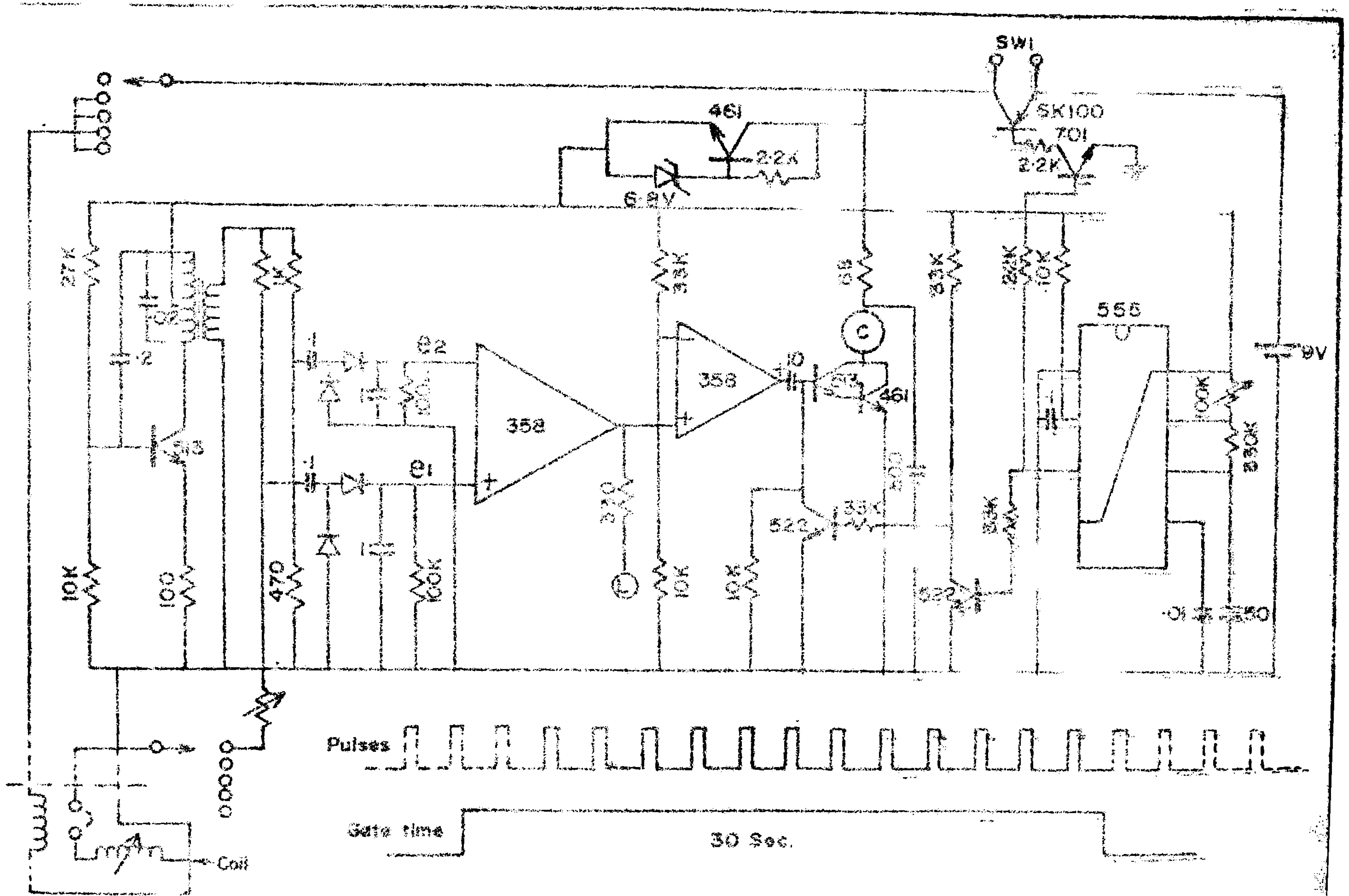


FIG 25 CIRCUIT DIAGRAM OF CURRENT METER (ELECTRIC INDUCTION) PART OF THE SYSTEM

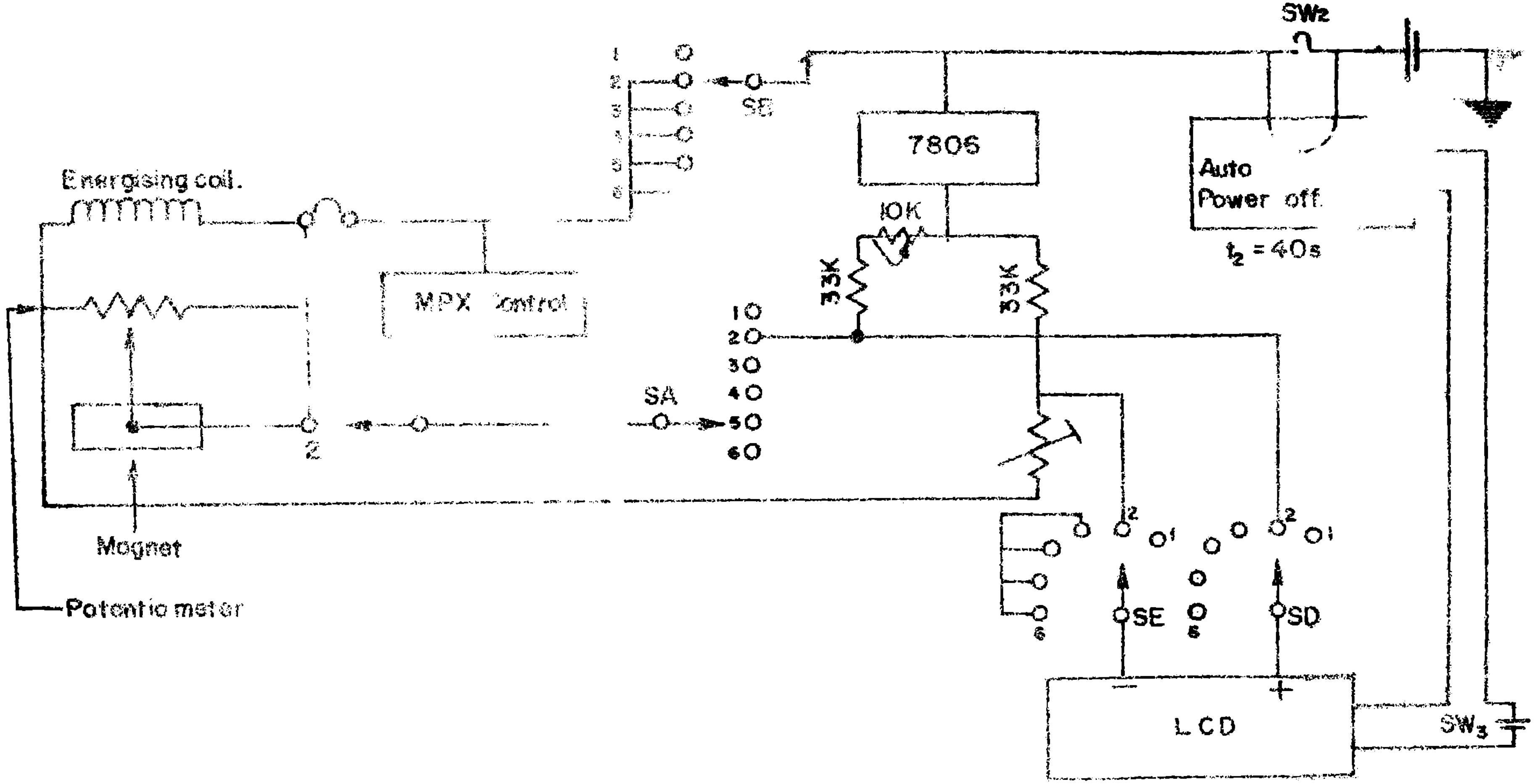
pulses are buffer amplified by the remaining part of the dual opamp 358. The pulses from the output of the second opamp is passed to the electronic gate prior to the darlington pair power amplifier.

The operation of the electronic gate and the generation of the time pulse from timer 555 and the automatic off switch are exactly as described in 3.1.1.

The darlington pair amplifier consists of two transistors 513 and 461 having amplification factors β1 and β2. The darlington pair provides an amplification factor of β1 x β2.

The electro magnetic counter used in the system has got 6 digits. It can be reset to zero by pressing the reset button. The e.m. counter has got an impulse rate of 50 impulses per second. This means that it can be used for registering water current up to 50 x 24.5 cms/sec, because 24.5 is the gate time i.e. it has got a higher limit up to 1125 cms/sec. which is a much higher range than what is needed.

The +ve pulse from the timer is used to hold on the power and switch it off automatically when the counting is over exactly as in the case of the circuit described above for magnetic induction.



IRCUIT OF RENT DIRECTION ART HE COMPLETE
STEM

3.2 SIGNAL PROCESSING FOR CURRENT DIRECTION

The electronics for processing d.c. signal from the electro magnetic direction compass consists of a wheatstone bridge powered with stabilised supply from I.C. 7806. The output D.C. signal level from the bridge is derived as shown in Fig.26 and 27.

This voltage output of 0-360 mV is directly fed to a LCD panel meter to display the current direction 0 to 360° in terms of 0 to 360 mV. in the LCD panel meter of range 1.999V.

3.3 L.C.D. (LIQUID CRYSTAL DISPLAY) PANEL METER FOR DISPLAY OF SIGNALS

A single LCD meter is used to display (1) current direction after converting 0 to 360° to 0 to 360 mV. (2) Salinity from 0 to 40 PPT after conversion to 0 to 400 m.V. (3) Temperature from 15°C to 40°C after conversion of 150 m.V. to 400 m.V. and (4) Depth from 0 to 100 metres after convertion 0 to 100 m.V. It is also used for displaying one reference point at 000 m.V.

LCD is a recent development in the digital display of information. The earlier type display namely, LED takes power of the order of 150 mA at 5V for displaying information in 3½ digits. Many portable meters cannot afford to spend so much current just for display alone. But liquid crystal displays (LCD) takes only extremely low current as low as 1 mA.

The LCD of Intersil used in the system consists of an I.C. 7106 with 40 pins and single plate 3½ digit LCD with 40 pins. The I.C. 7106 receives analogous input signal and converts them to digital form. Fig.28 gives pin connections and brief details of the I.C.

3.4 SIGNAL PROCESSING FOR SALINITY, TEMPERATURE AND DEPTH

A single circuit is used for conditioning the signals for salinity, temperature and depth except for the minor alteration given for salinity by providing positive feed back for the purpose of linearisation of the response curve, as shown in Fig.27.

3.4.1 OSCILLATOR

It has got an oscillator producing sinusoidal waves at 1000 Hz. as shown in Fig.34 and 35. The frequency of the oscillator is decided by the L.C. values of the tank circuit, as given by

$$f = \frac{1}{2\pi\sqrt{LC}}$$

The oscillations are further buffer amplified using transistor 461 with emitter follower configuration in order to make the output sufficiently stable. The secondary of the transformer T_2 produces waves at 5V P.P.

3.4.2 WHEATSTONE A.C. BRIDGE

The 5 V.P.P. oscillations are used to energise the wheatstone bridge network in the same manner as explained

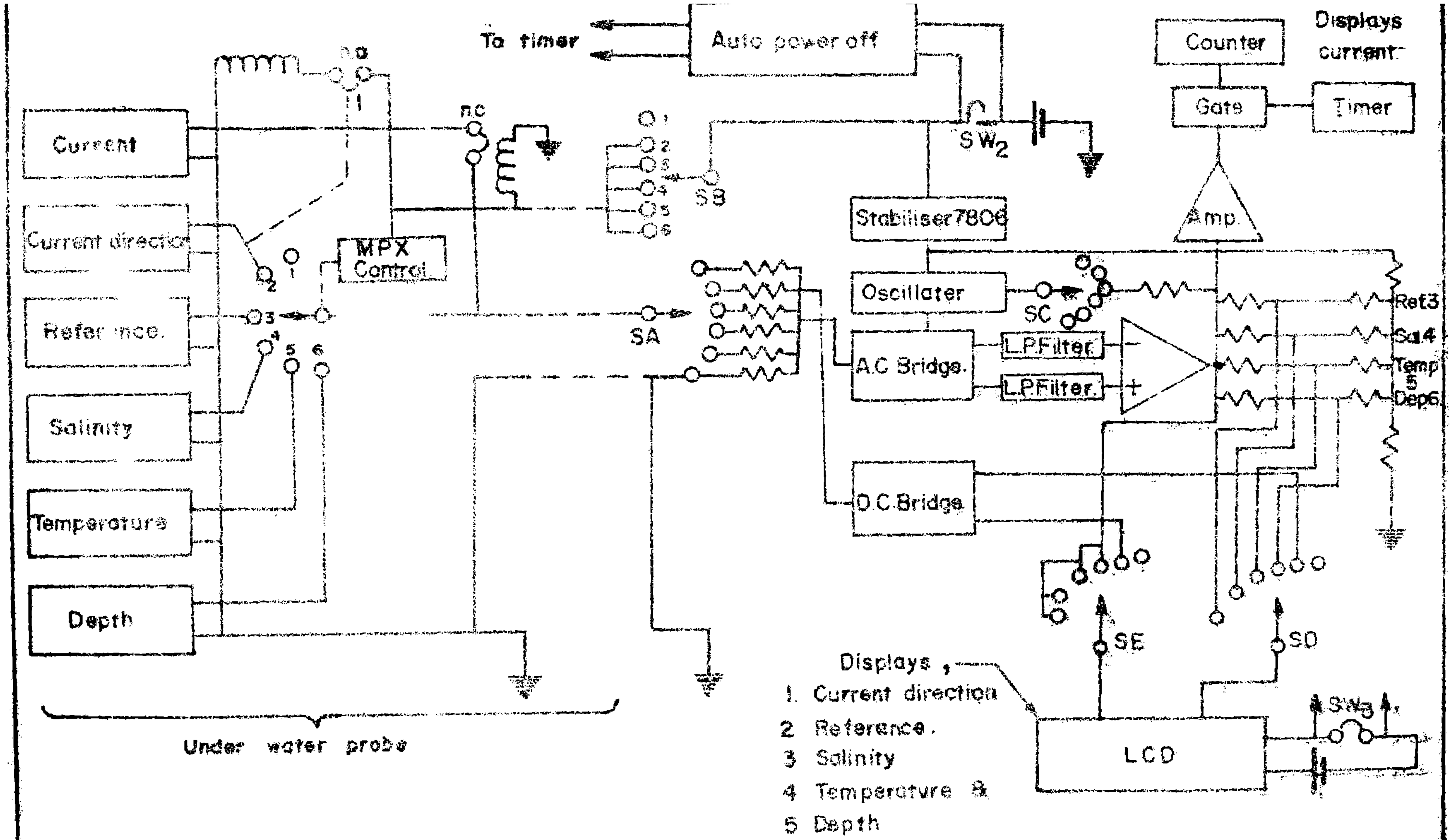


FIG. 27 BLOCK DIAGRAM COMPLETE SYSTEM WITH ELECTRIC INDUCTION SENSOR FOR CURRENT

INTERSIL

ICL7106, 7107
3½ Digit Single Chip A/D Converter

FEATURES

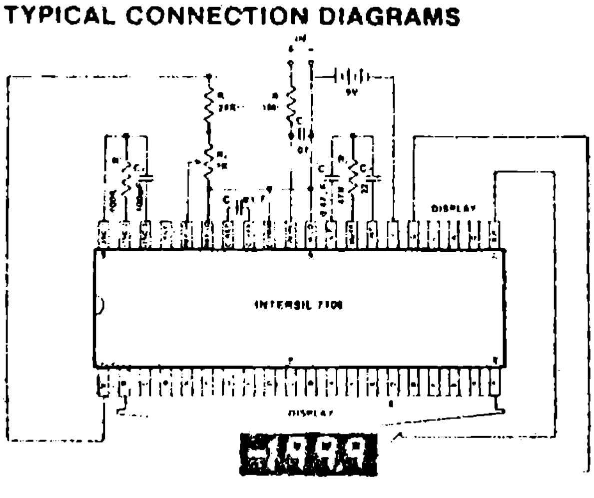
- Guaranteed zero reading for 0 volts input on all scales.
- True polarity at zero for precise null detection.
- 1 pA input current typical.
- True differential input and reference.
- Direct display drive — no external components required. — LCD ICL7106 — LED ICL7107
- Low noise - less than 15μV pk-pk (95% of time).
- On-chip clock and reference.

GENERAL DESCRIPTION

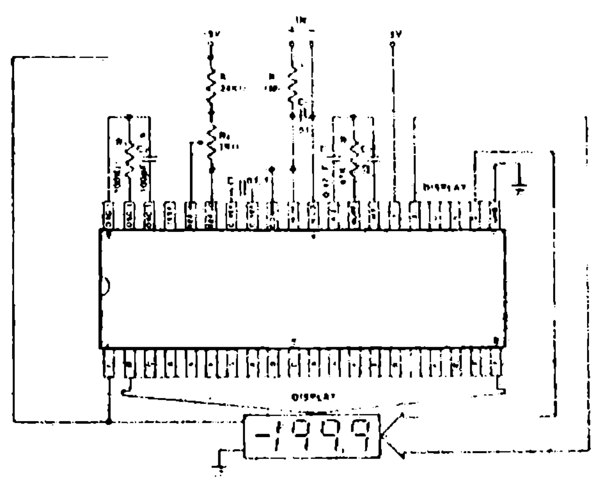
The Intersil ICL7106 and 7107 are high performance low power 3-1/2 digit A/D converters. All the necessary active devices are contained on a single CMOS I.C., including seven segment decoders, display drivers, reference and a clock. The 7106 is designed to interface with a liquid crystal display (LCD) and includes a backplane drive; the 7107 will directly [illegible] an instrument size light emitting diode (LED) display.

The 7106 and 7107 bring together an unprecedented combination of high accuracy, versatility and true economy. High accuracy like auto-zero to less than 10μV, zero drift of less than 1μV/°C, input bias current of 1 pA, and roll-over error of less than one count. The versatility of true differential input and reference is useful in all systems, but gives the designer an uncommon advantage when measuring load cells, strain gauges and other bridge-type transducers. And finally the true economy of single power supply operation (7106), enabling a high performance panel meter to be built with the addition of only 7 passive components and a display.

TYPICAL CONNECTION DIAGRAMS



ICL7106 with Liquid Crystal Display

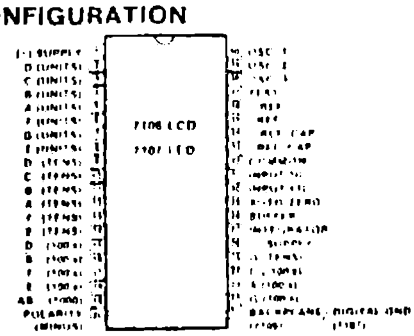


ICL7107 with LED Display

ORDERING INFORMATION

Part	Package	Temp. Range	Order Part #
7106	40 pin ceramic DIP	0°C to +70°C	ICL7106CDL
7106	40 pin plastic DIP	0°C to +70°C	ICL7106CPL
7107	40 pin ceramic DIP	0°C to +70°C	ICL7107CDL
7107	40 pin plastic DIP	0°C to +70°C	ICL7107CPL
7106 Kit	Evaluation kits contain IC, display, circuit		ICL7106EV/Kit
7107 Kit	board, passive components and hardware		ICL7107EV/Kit

PIN CONFIGURATION



ICL7106, 7107 3½ Digit Single Chip A/D Converter — Data Acquisition

INTERSIL, INC., 10710 N. TANTAU AVE., CUPERTINO, CA 95014 (408) 996-5000 TWX 910-338-0228

Printed in U.S.A.

FIG. 28

in current meter with electric induction. The sensors of salinity, temperature and depth form the parts of the fourth arm, one by one, as selected by the selector switch at the time of operation. The resistance changes or impedance changes in the sensors of salinity, temperature and depth cause proportional voltage changes across the sensors. These a.c. voltage across the sensors appear as modulated signals with 1000 Hz oscillations as carrier. These voltages are at very low impedance and their signals are much strong. Therefore they are free from noise problems.

3.4.3 LOW PASS FILTERS

The modulated signals are detected and passed through low pass filters independantly as shown in the Fig.27, 29 and 31. One of these d.c. lines is steady while the other varies its level according to the signal level. Both of them are above 2 V.D.C.

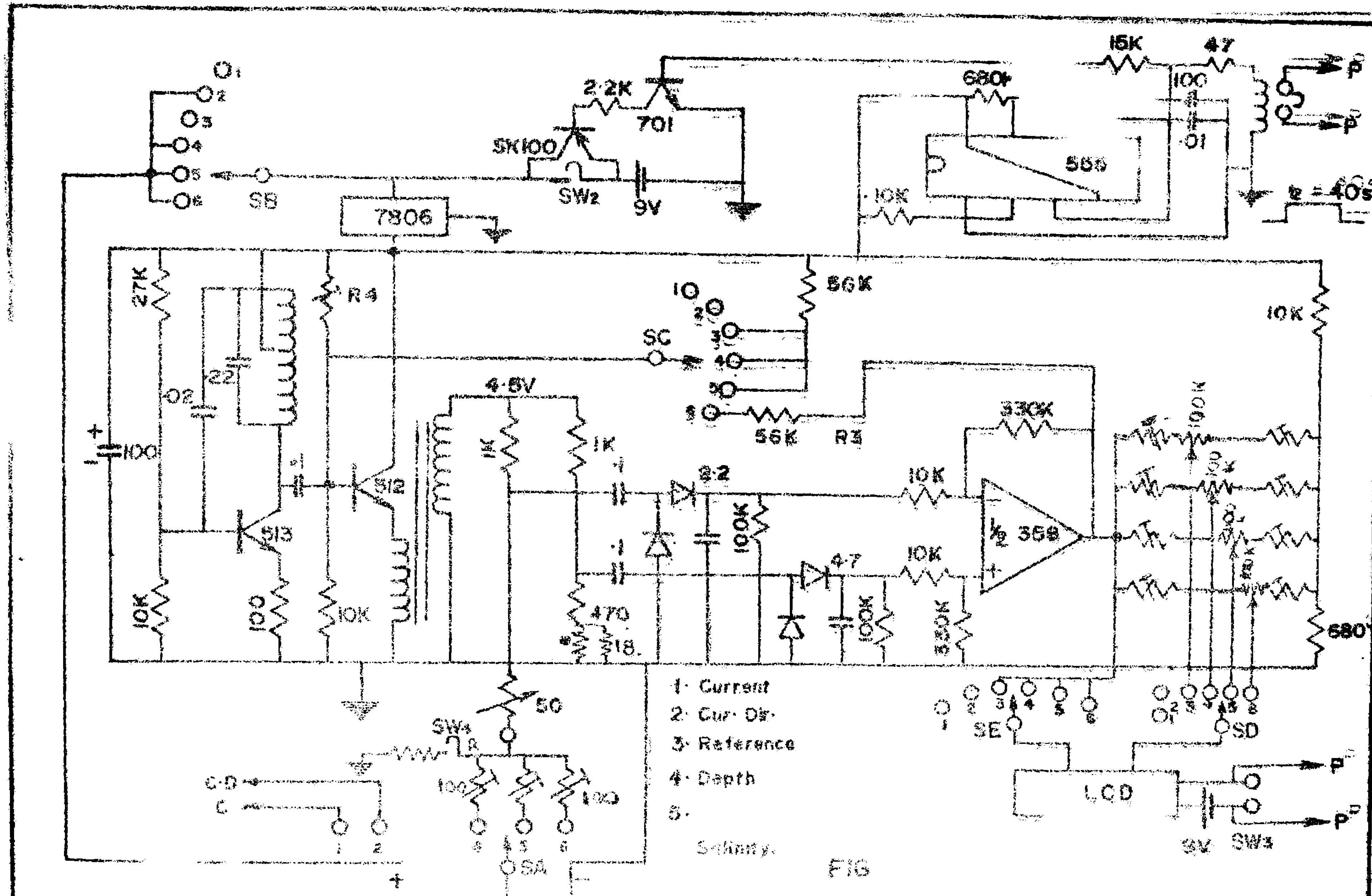
3.4.4 DIFFERENTIAL OPAMP

The d.c. lines with steady level and changing level respectively are fed to the non-inverting and inverting inputs of an opamp. The output of the opamp gives the difference in the d.c. signals amplified to the given amplification factor, R_1/R_2 (V_2-V_1) where R_1 is the feed back resistance, R_2 is the input resistance, V_1 is the steady voltage given to the inverting input of the opamp and V_2 at the non-inverting input of the opamp.

The signal (V_2-V_1) is amplified to the maximum such that it covers the full range available leaving enough margins at both lower and upper levels so that the signal does not get saturated. The Fig.30 shows the response curve of the opamp with input signal (resistance variation) and output voltage. The signal saturates at 4.2V when the supply is 6V. The curve shows that the relation between input signal and output voltage is quite linear making an abrupt saturation at 4.2V. This sharp saturation enables to utilise the entire range for measurement purpose. Still, 0.4V is left at both upper and lower portions of the curve to ensure that the signal is far away from its saturation levels. Since all the sensors of salinity, temperature and depth have been designed with high outputs and fairly uniform levels, the same response curve could be used for all of them. Certain alterations are made in the feed back arrangement as explained below for presenting salinity in linear fashion

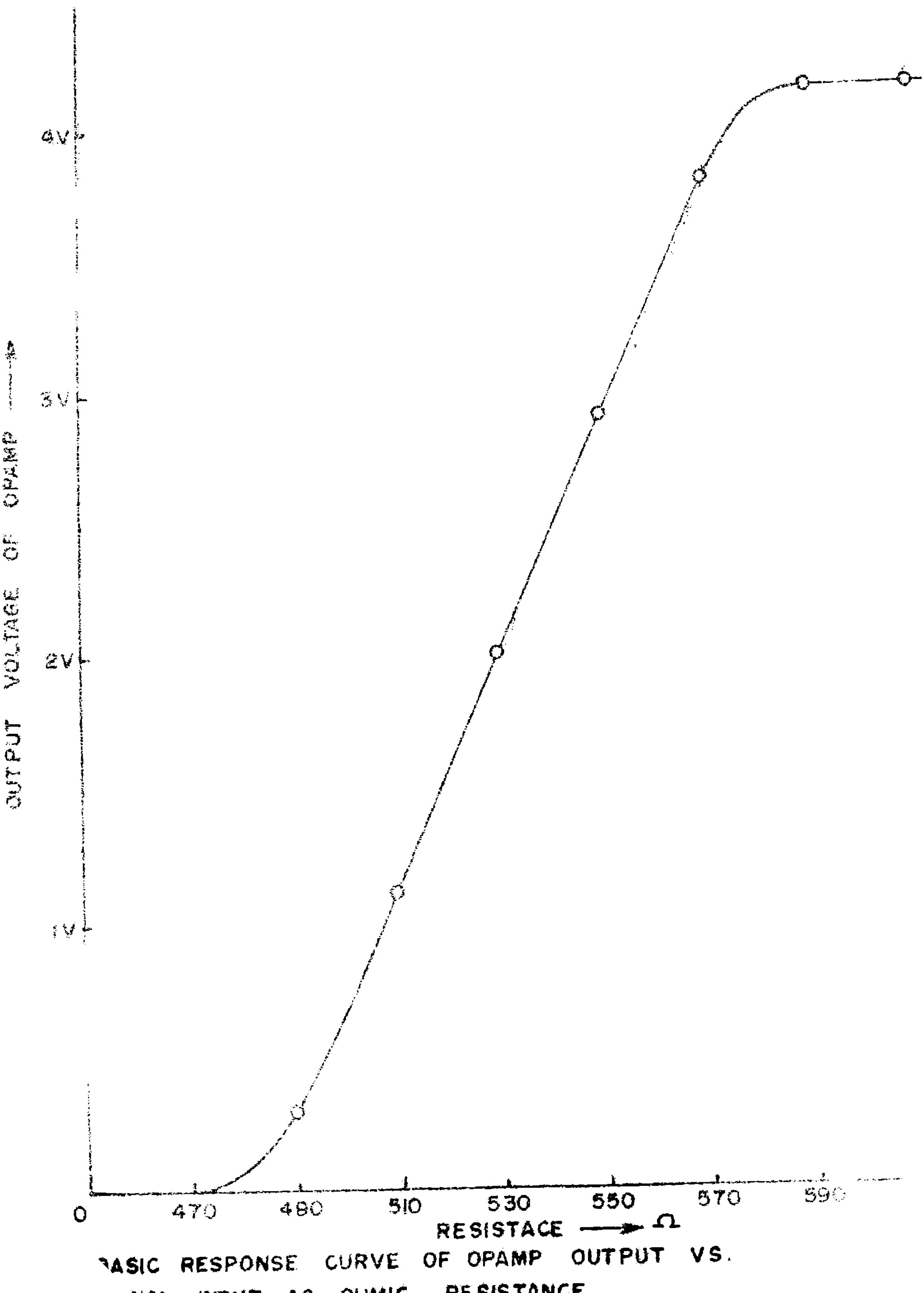
3.4.5 LINEARISATION OF SALINITY SIGNALS

As shown in Fig.11 the salinity sensor makes changes in resistance inversely and non-linearly proportional to salinity, making lower sensitivities at higher salinities. This nature is most unwanted, as higher sensitivities are needed at higher salinities, i.e. at sea water values. Because, the sea water salinity comes in this region with



FIG

CIRCUIT DIAGRAM OF SALINITY, TEMP DEPTH & RE FREP PORTIONS OF THE SYSTEM.



BASIC RESPONSE CURVE OF OPAMP OUTPUT VS.
NAL INPUT AS OHMIC RESISTANCE

only very small variations from 34 to 35 or 36 PPT. This undesirable nature has been reduced considerably by shunting the cell as shown in Fig.12. Further linearisation is done in the amplifier as described below, based on a positive feed back process.

Salinity is never reported to be displayed linearly in salinometers. Microprocessors are used very recently to compute the salinity directly from the conductivity values. Linear signal outputs are obtained from conductivity cells are reviewed in the introduction. But conductivity of sea water is not the final informatioon needed by oceanographers. It is salinity what is needed. Salinity is further computed from conductivity using the relation alongwith temperature corrections.

The response curve correlating salinity and resistance as seen in Fig.12 is non-linear and the output of the amplifier also will follow exactly the same as it is linear. The method followed here for producing linear output for salinity uses a non-linear amplifier such that both the non-linearities are opposed resulting in a linear output. Non-linear amplifiers are usually made utilising the non-linear response of semiconductor diodes, base-collector conduction of transistor etc. It is also done by means of a series of analogue switches critically set to follow the particular curve required. The first and second methods can be done here also. But signal has to be further conditioned to suit to their respective required levels, which makes the system much complicated. The third method also requires more sophisticated electronics which is undesirable considering the portable nature and stringent needs of this field operated instrument.

Therefore attempt was made to develop a simple and reliable method for linearising the non-linear signal of salinity cell. This was achieved by means of a simple passive component namely a resistance. Resistance R_3 as shown in Fig.29 gives the necessary bleeder current to the buffer amplifier. When this bleeder current is drawn for the output of the opamp, the response of the amplifier alters and it becomes non-linear. This non-linearity is in inverse order to that of the characteristic non-linearity of the salinity cell. Then the resultant becomes linear. Different responses can be obtained with different values of R_3. The required value of R_3 is determined during calibration. This value is found to be 56 K. for the given settings. Highest possible linearity could be achieved by precisely setting another constant fleeder resistance using R_4 whose value is found to be around 2M$\pm$500 K. ohm.

The function of the feed back resister R_3 is explained as below. The oscillator buffer amplifies oscillations from the output of transformer T_1 drawing bleeder current from its positive supply line. This being a constant current, the output oscillations also will have constant nature. While the oscillator and amplifier are engaged for measurement of salinity, bleeder current is obtained from the output of opamp. Since the bleeder current is drawn from a varying voltage, the oscillations also vary accordingly. The amplifier output is maximum at higher salinities and minimum at lower salinity. Therefore, the amplifier output at higher values further pushes it upwards after obtaining enhanced oscillator outputs. The required value of the feed back resistance R_3 is found out during calibration using known salinity values of sea water samples. The method is reliable and simple. The entire need of linearisation of salinity is achieved by means of simple feed back process using a single passive component.

3.5 FEATURES OF THE ELECTRONIC CIRCUIT

The electronic circuit used for processing salinity, temperature and depth, basically uses common circuits consisting of an oscillator, bridge net work, detectors, low pass filters, operational amplifier, balancing circuit, timer circuit and automatic power 'off' circuit.

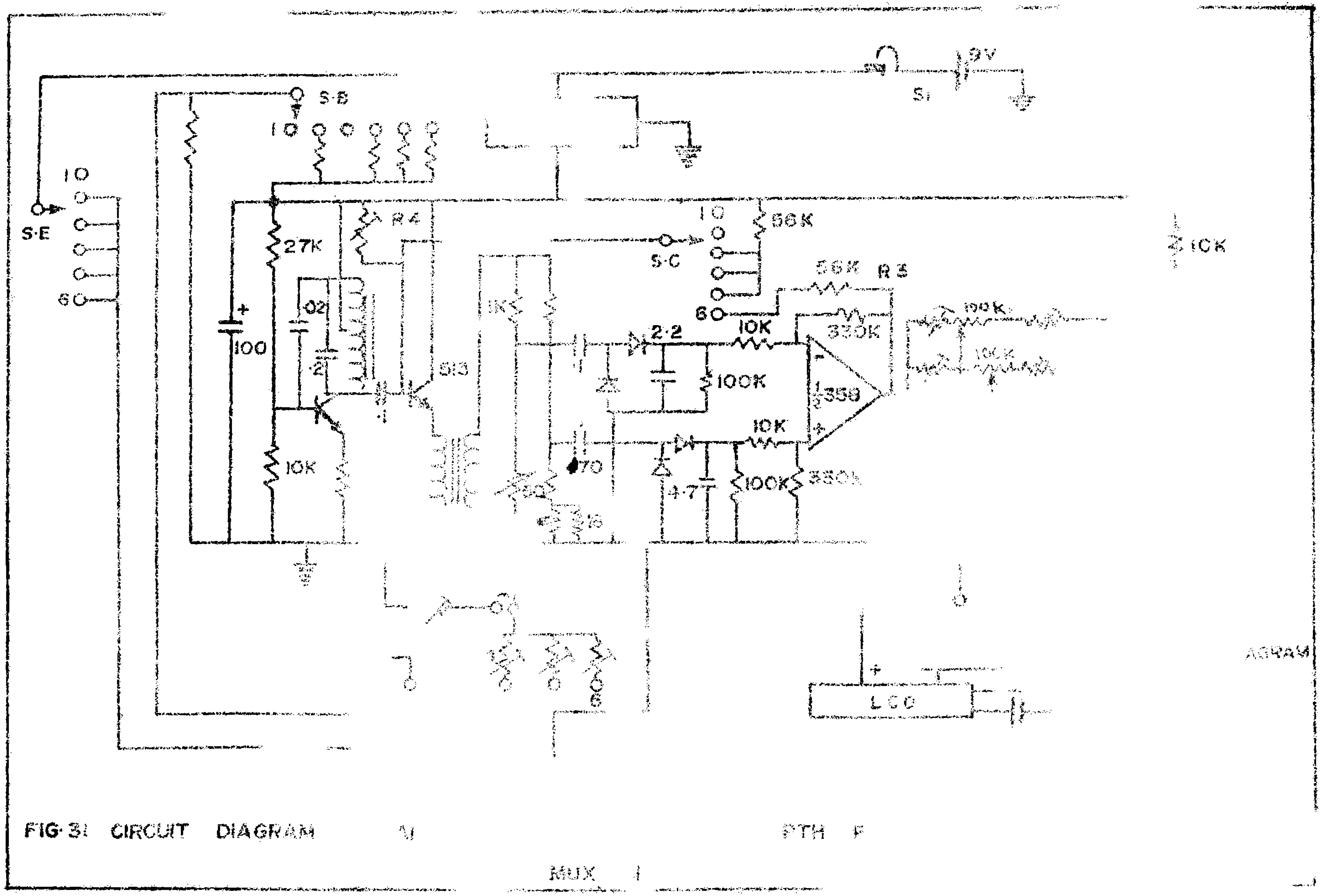
3.5.1 NOVAL SIGNAL CONDITIONER

The signal conditioner consists of an oscillator, bridge circuit, detectors, low pass filters and opamps. The novelty here is that unlike in the conventional methods, the two outputs of the bridge are separately detected and passed through low pass filters in order to produce d.c. signals. Those d.c. signals, one of which carrying the information from the sensor, are fed to the inverting and non-inverting inputs of an operational amplifier to produce the signal alone amplified as shown in Fig.29 and 31. The specific noval feature here is the independant detection and smoothing prior to feeding to the opamp for obtaining specific advantages mentioned below:

As described in 2.7 above 4 types of multiplexers were developed for facilitating remote operation. While multiplexers MUX-100, 110 and 120 can be operated with 3-core cable, MUX-130 needs 4-core cable and it has got its specific advantages as explained in 2.7.4. Fig.29 shows the multipin connection and controls for use alongwith 3-core cable while Fig.31 shows the same for the use with 4-core cable (i.e. with MUX-130)

3.5.2 SPECIFIC ADVANTAGES OF THE SIGNAL CONDITIONER

The design feature followed results in the following advantages. The small changes in the supply voltage and frequency of the oscillator do not make proportional changes in the signal output, because changes affect both the d.c. input lines which go to the inverting and non-inverting inputs of the opamp. As the opamp is operating in differential mode, these errors which appear common



FIG·3: CIRCUIT DIAGRAM

in two inputs are cancelled because of the high CMRR (common Mode Rejection Ratio) of the system. The response to ambient temperature is also eliminated to a high degree here.

3.5.2.1 FREQUENCY STABILITY

The performance of the signal conditioner depends on the stability of the oscillator frequency. The frequency has been made independent of the load variations when the basic amplifier is buffer amplified in emitter follower configuration followed by a transformer coupling. The emitter follower configuration allows low output impedance with high input impedance which is the basic requirement for achieving stability. On measurements, the oscillator is found to have no frequency variations.

During salinity measurements, the oscillator output is made to undergo variations proportional to salinity by providing feed back as given in the Fig.29. This can cause unstability to the frequency as well. In this case the frequency varied only from 985 Hz to 991 Hz when salinity varied from 0 to 38 despite a large variation in output voltage of the oscillator from IV P.P. to 4.5V P.P.

3.5.2.2 STABILITY AGAINST AMBIENT TEMPERATURE VARIATIONS

The CMRR of the circuit operating in differential mode allows cancellation of ambient temperature effect to a considerable level. But large changes of ambient temperature caused drift in the electronics. This problem is solved using a built-in temperature compensator in the electronics using a thermistor. The thermistor with its negative temperature coefficient of resistance opposes the temperature drift of the amplifier in the given arrangement as shown in Fig.29 and 31. The exact amount of compensation needed from the thermistor is critically set by altering the sensitivity of the thermistor. The sensitivity is altered precisely by shunting it with a resistor whose value is found out during temperature environmental test. It is found that only a very small correction is needed from thermistor to compensate the wide ambient temperature variations which is evident from the high shunting given to the thermistor to reduce its sensitivity. The thermistor sensitivity is reduced by shunting to the required level.

CALIBRATION

4. CALIBRATION

The instrument has been calibrated taking every factor independently. The facilities needed for calibrating all parameters except current, can be produced in the laboratory.

4.1 CALIBRATION OF CURRENT

The following are the factors to be found out during calibration of water current.

1. Threshold current value.
2. Plotting a curve between the actual speed of water current and the r.p.s. of the rotor.
3. If the curve is found to be sufficiently linear, find out the constant time during which the water speed in cms/sec coincides with the number of rotations of the rotor.

1. Threshold value of current.

The factors that decide the threshold value are inertia of the rotor and friction. Low inertia gives low threshold value. The rotor has been designed for extremely low intertia by making it small in size, least in weight and extremely low friction on the supports. Extremely low friction is achieved using pin and socket assembly at the rotating points.

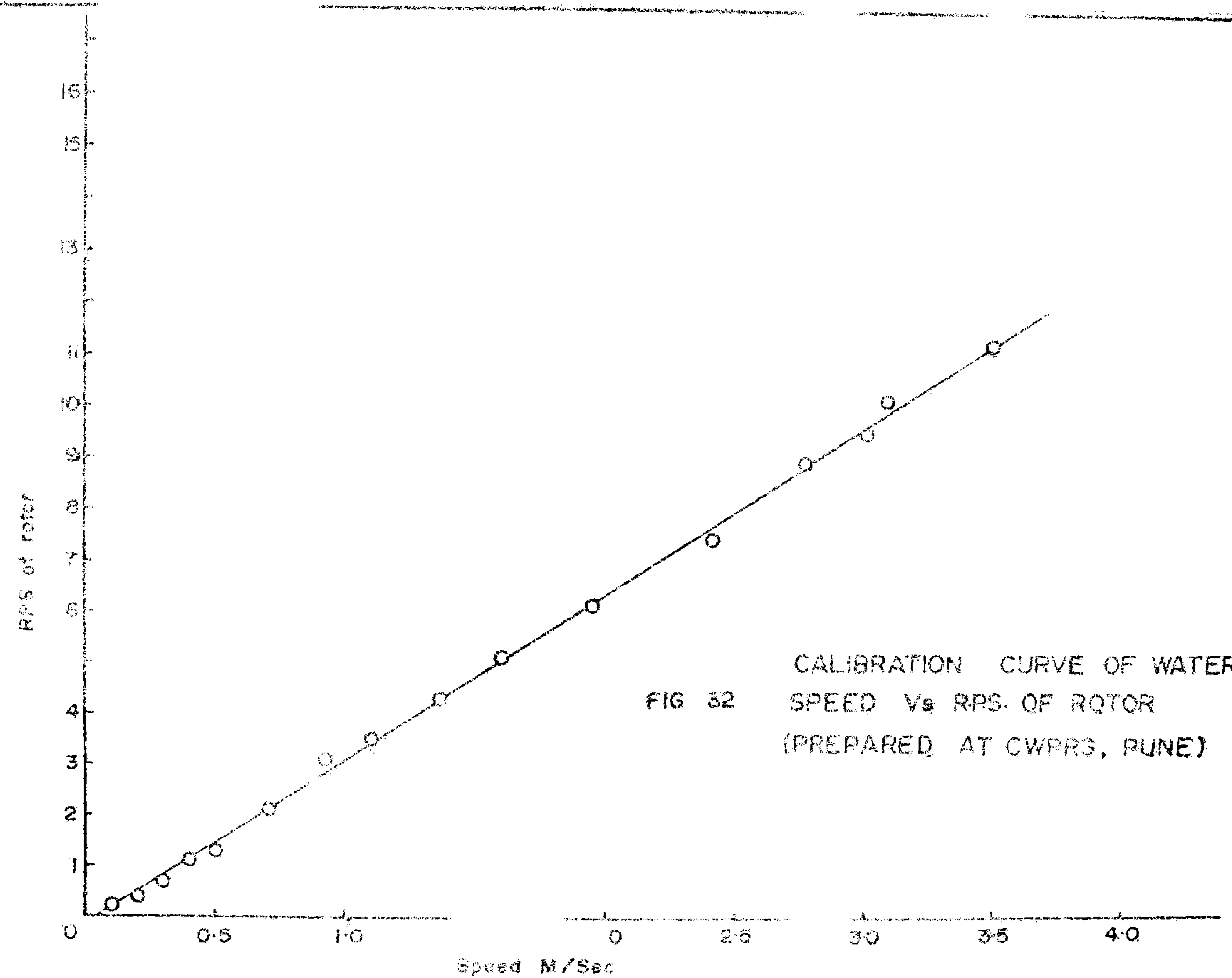


FIG 32 CALIBRATION CURVE OF WATER SPEED Vs RPS. OF ROTOR (PREPARED AT CWPRS, PUNE)

The threshold value was found to be 3 cms/sec. The calibration chart was prepared by subjecting the under water probe to water flow using a towing tank and a trolley over it. The instrument was calibrated in the towing tank of Central Water & Power Research Station, Pune

The tank has got 228 m length, 2.13 m depth and 3.66 width with a maximum towing speed of 4.5 m/sec. The trolley which moves over the tank has got precise machineries for smooth movements and its measurements.

The probe was suspended from the trolley at a water depth of 1 metre. The trolley was given different speeds between 2 cms/sec and 350 cms/sec. The rotor rotations were noted for 10 seconds in each case. The graph drawn between r.p.s. of rotor and speed of trolley (relative speed of senser in water) is given Fig.32. The exact time needed for the counts in e.m. counter to coincide with the speed of trolley in cms/sec is found out to be 30 seconds, for large rotor. That means, if the current meter is operated for 30 seconds, the number of rotations of rotor will coincide with the speed in cms/sec.

4.2 CALIBRATION OF CURRENT DIRECTION

A precision magnetic compass was used to make a thick line on the floor refering to the north-south direction. The under water probe was kept over the line so that its vertical fin is parallel to the line. Now the tail portion

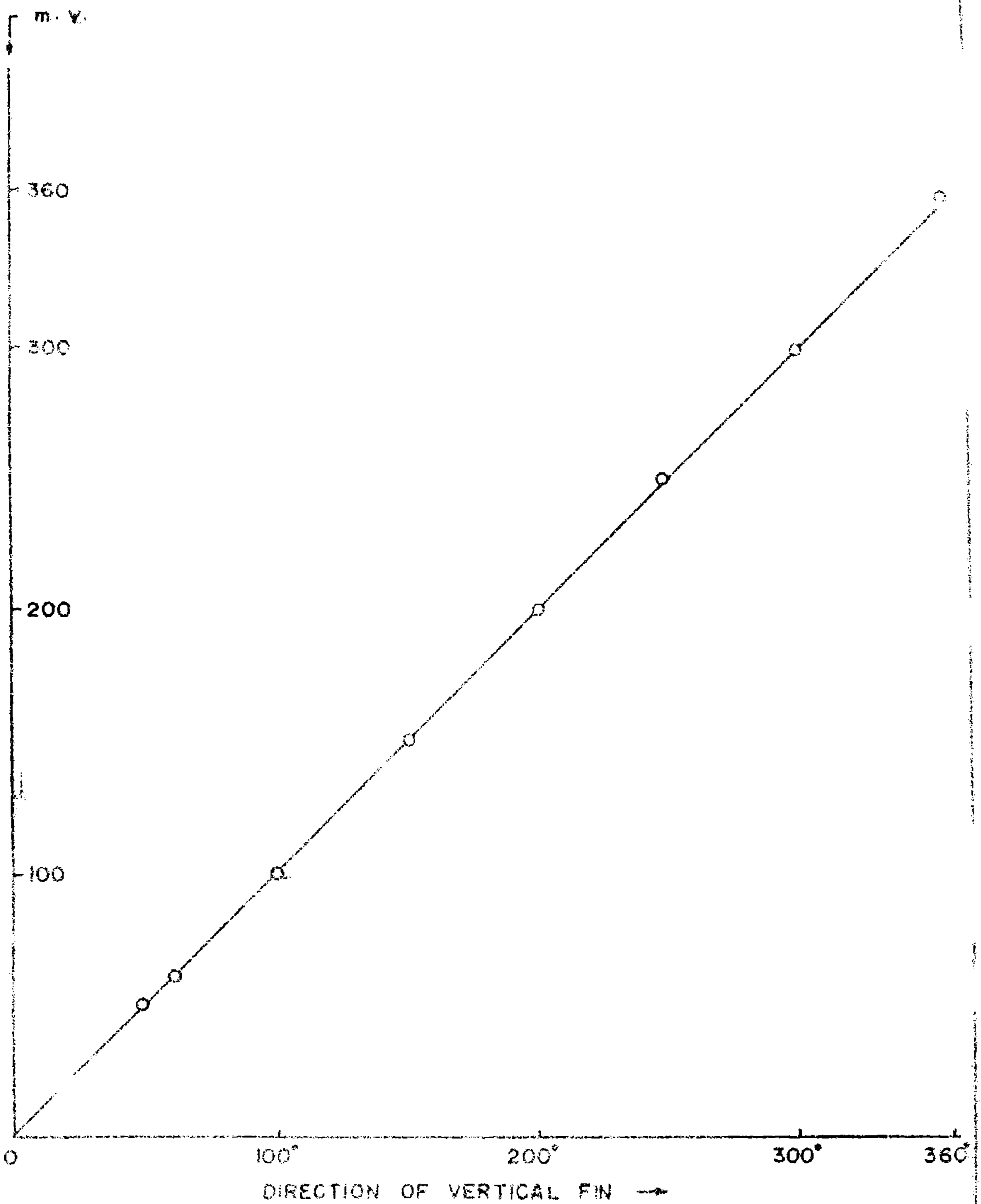
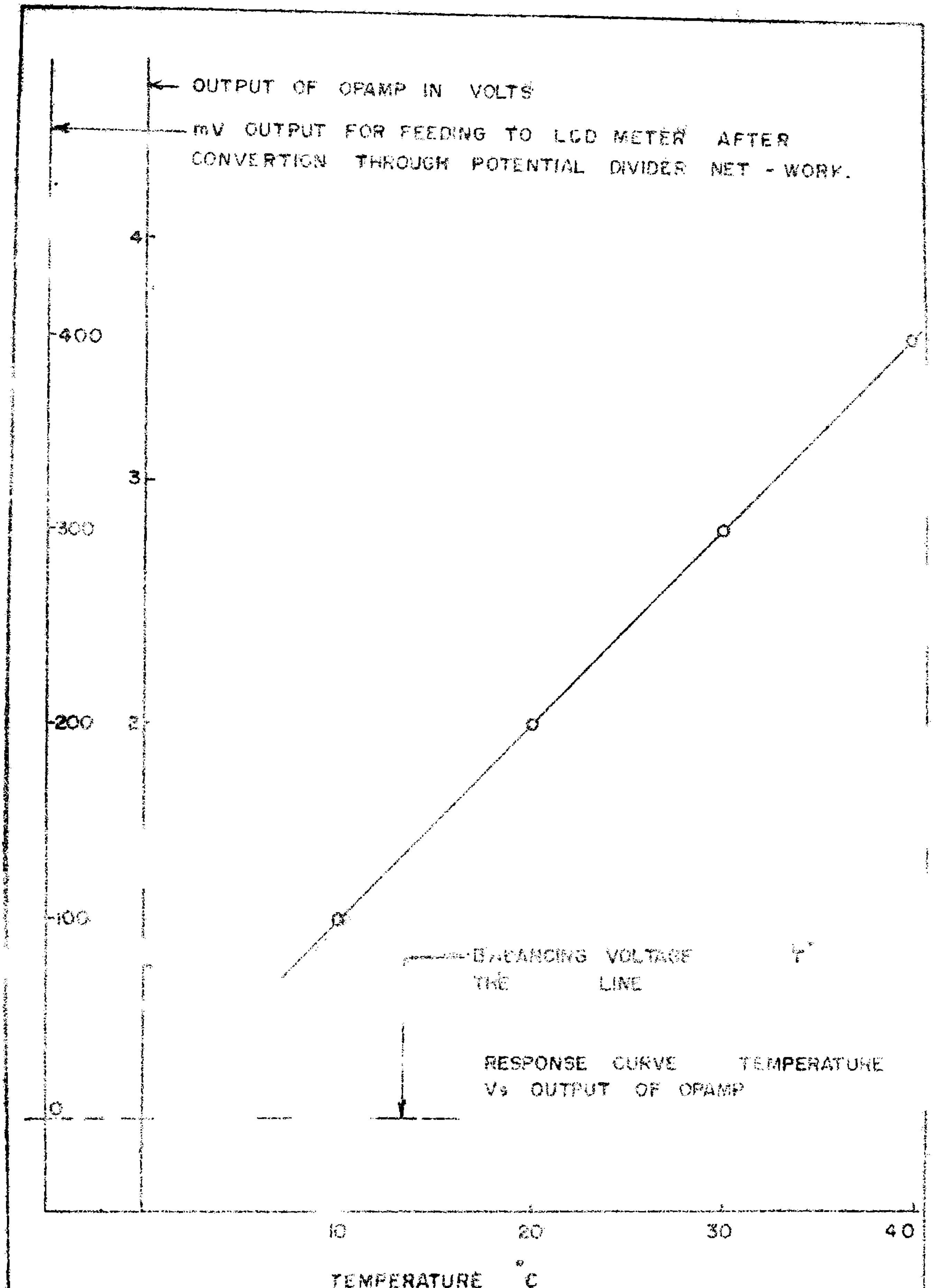


FIG 33 ·· IBRATION OF CURRENT DIRECTION

is directed Northwords. The direction sensor at this condition should correspond to maximum electrical resistance i.e. 2000 ohm. The outer cover of the unit was removed and the remaining portions kept in the original condition. The direction sensor was mounted such that when energised,it gave out a signal corresponding to the maximum, i.e. 2000 ohm. The sensor was fixed in this condition. Now this should correspond to 360° in the LCD meter. The 22 turn 10 k. preset (Fig.26) and the resistance R were adjusted so that the LCD readings indicated 360° when directed to North and 000° when turned slightly to the clockwise direction to correspond to 0 ohm of the sensor. Now the extreme ends are decided. The points in between should indicate proportionally if the electronic circuit used is working normally. This has been confirmed as shown in Fig.33. Extreme care was taken during the whole course to see that no magnetic materials are present in the vicinity of the sensor.

4.3 CALIBRATION OF TEMPERATURE

Temperature baths were prepared from 10°C to 40°C. The temperature sensor was immersed in the bath for sufficiently long time and the meter readings noted. The 100 ohm and 100 k. ohm 22 turn presets connected to the thermistor sensor and at the output of opamp respectively were adjusted such that the LCD meter was fed with 100 mV to



FIG·34 TEMPERATURE CALIBRATION

400 mV corresponding to 10°C to 40°C. The third digit represented the first decimal point. Fig.34 shows the calibration of temperature.

4.4 CALIBRATION OF SALINITY

Sea water samples were prepared covering the entire range with values 8.50, 16.4, 27.2, 28.5 and 35. These samples were maintained at temperatures of 20°C, 25°C, 30°C and 35°C using hot water baths. The 100 ohm and 100 k. ohm preset pots. in series to the salinity cell and the output of opamp (Fig.29) were adjusted so that the readings in the LCD came to 000 and 35.0 when the salinity cell was immersed to the corresponding solutions of 000 and 35.0 both at 30°C. '000' salinity solutions means either distilled water or air. The feed back resistance R_4 of the circuit was adjusted such that the meter indicated linear response with the sample values at 30°C, as shown in Fig.35. The meter readings for the solutions for all other values were noted and the graph prepared. The reliability of the sea samples were compared with the Copenhagen sample. The dotted lines in Fig.35 are the actual lines passing through the points. The continuous lines are the straight lines passing through maximum points. The mathematical relation represents the continuous lines. This causes an error of maximum of $\pm$.2 salinity at certain points. This error can be eliminated if the salinity values are directly taken from the graph.

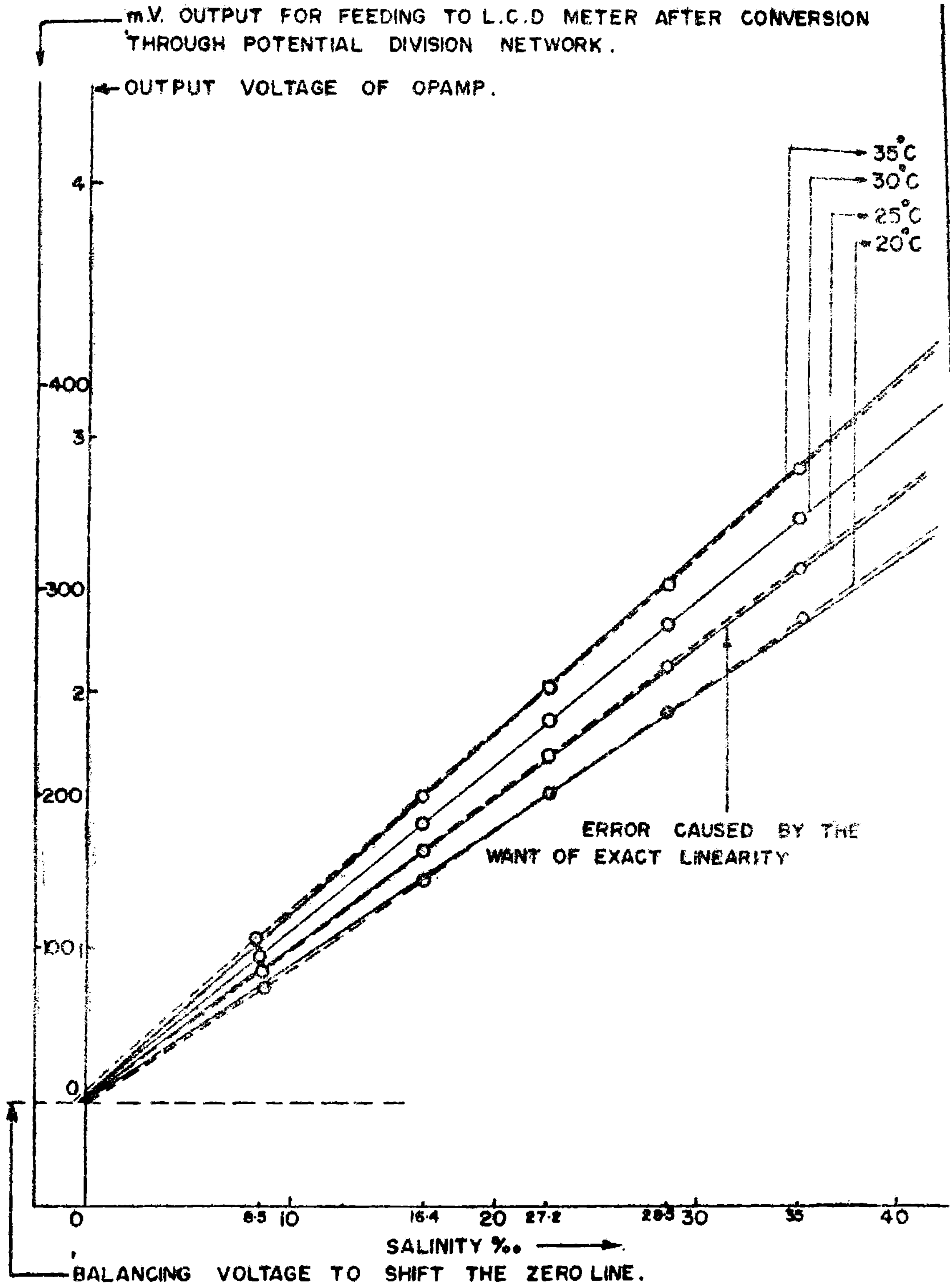
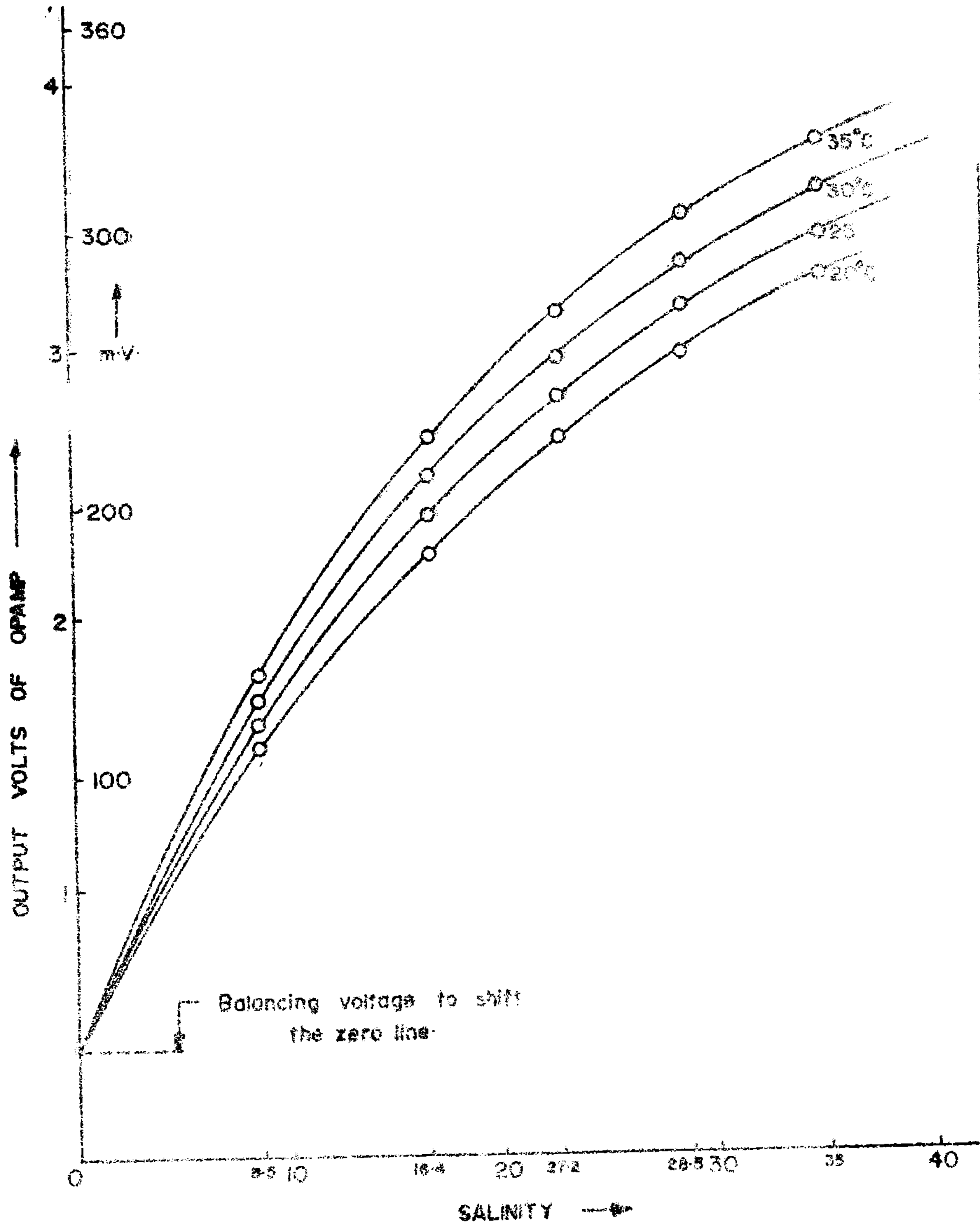


FIG. 35 RESPONSE CURVE OF SALINITY Vs OUTPUT VOLT OF OPAMP FOR DIFFERENT TEMPERATURES AFTER LINEARISATION



FIG· 36 RESPONSE CURVE OF SALINITY Vs OUTPUT VOLTAGE OF OPAMP FOR DIFFERENT TEMPERATURES (with out linearisation)

Now the meter directly gives the salinity when the temperature of the sample is 30°C, while all other data gave straight lines making symmatrical lines on either sides of the 30°C line. This symmatrical nature of the curves haveresulted in the formation of a linear relation between the meter readings and the actual salinity, given by

$S = R \tan (45 \pm K.D)$

where S = salinity in PPT

R = meter reading

D = difference in temperature of the water sample from 30°C.

K = a constant

Positive (+) is used when temperatne is below 30°C and negative (-) when it is above 30°C. It is found that the value of K varies between 0.55 to .65. But this can be made to be fixed if the cells are made alike during commercial manufacture of the equipment. This relation can be used up to an accuracy of ± .2 salinity. Better accuracy of ±.05 can be achieved directly from the graph in Fig.36. Where the curves are not linearised. The accuracy in the linearised graph (Fig.35) reduced, because the process of linearisation is not obtained to the required extend.

4.5 CALIBRATION OF DEPTH

A pressure chamber was used for the primary setting and calibration. The pressure developed in the chamber was

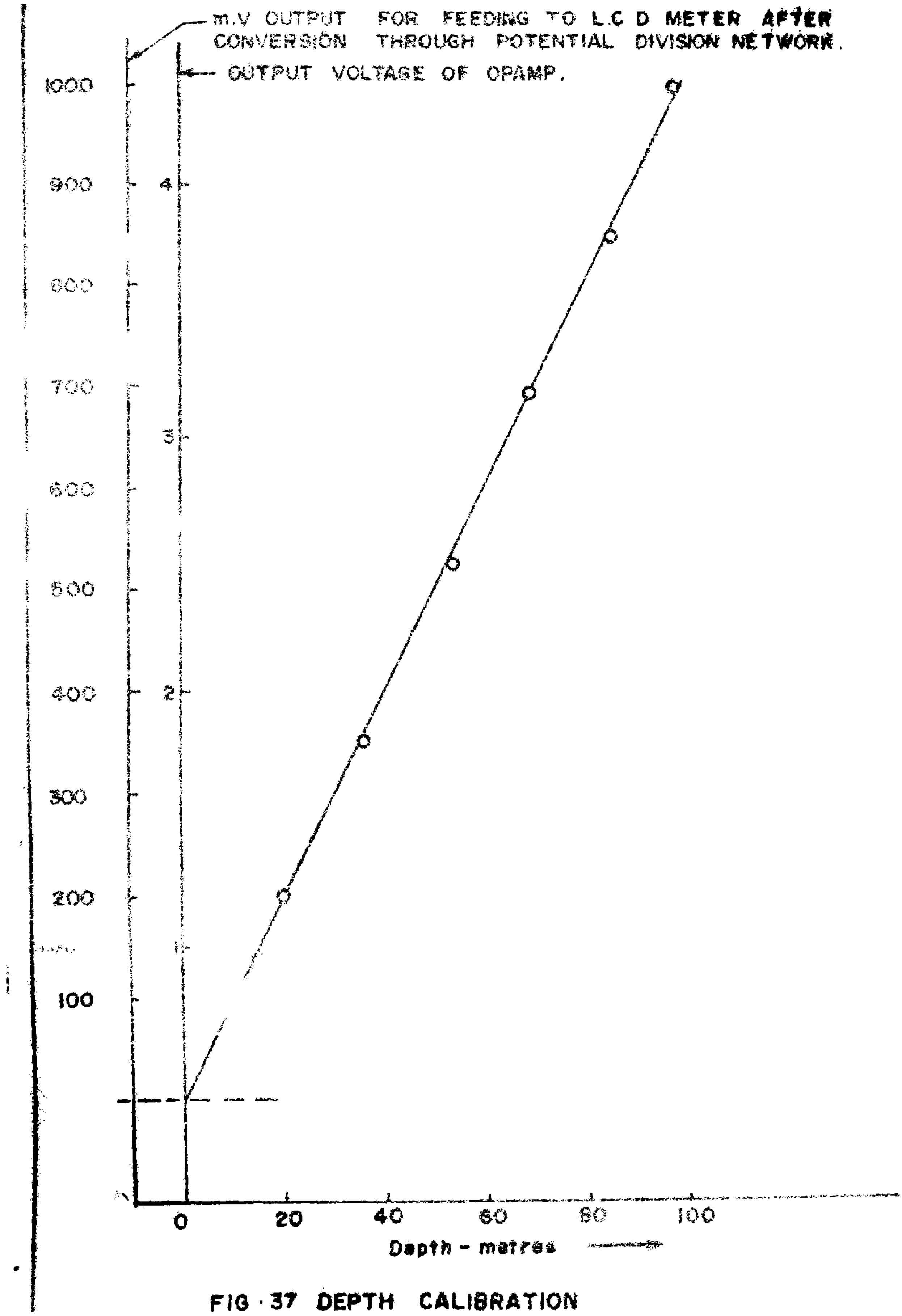


FIG · 37 DEPTH CALIBRATION

applied to the inlet tube of the sensor. The required pressure was estimated as below:

Pressure $P = h\rho g$

where p = pressure in kg/cm^2

h = height of water say 100 m

ρ = density of water, say 1

g = acceleration due to gravity, 980 cm/sec^2.

Here pressure needed for 100 m water column is 9.8 kg/cm^2.

The 100 ohm and 100 K. ohm 22 turn presets in series to the depth sensor (Fig.29) and at the output of opamp respectively were adjusted such that the LCD readings are 000 and 98.0 when the pressure applied are 0 and 10 kg/cm^2. The sensor was later subjected to precise setting in deep water tank. The probe was immersed to different depths up to 100 m and the LCD readings precisely set. The meter readings were found to be quite linear as given in the graph in Fig.37.

In all the cases above, except in current & current direction, the 'zero set' of the instrument was adjusted '000' invariably before taking measurements.

SERVOMETER

Q 78-895

PROPOSED ELECTROFORMED NICKEL BELLOWS DESIGN

SK - 8180 C

Customer Central Inst. of Fisheries Tech.
Electronics & Instrumentation Div.
Address Willingdon Island Matsyapuri
Cochin 682029 India

Application Engineer
Bob Burner

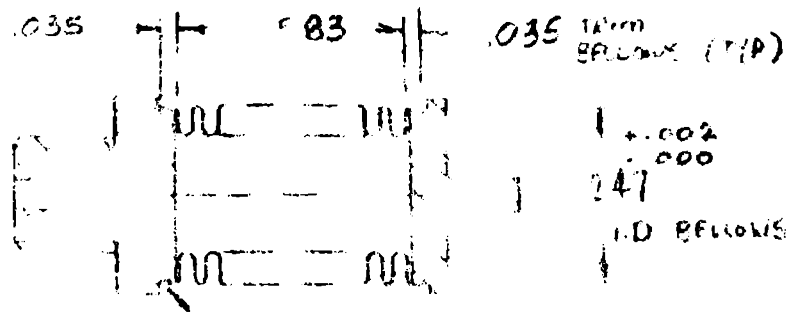
Date 8/23/78

Engineer T. K. Sivadas

P/N

Telephone ( )   Ext.

Inquiry Letter 8/1/78



TOLERANCES

Bellows O.D. (in.)	.250
Bellows I.D. (in.)	.150
Convolution Pitch (in.)	.022
Wall Thickness (ref.)	.0012
Effective Area (in.)^2 (93)	.029
No. Grooves	50
Convolutions Active:	
Before Assembly	50
After Assembly	49
Max. Allowable Axial Stroke:	
Compression (in.)*	.398
Extension (in.)*	.199
Max. Pressure Ratings (psi):	
Work @50% Stroke	184
Proof-@Free Length	322
Burst-@Free Length	460
Buckling-@ (Int.)	3.8
Spring Rate (lbs. in.)	
@ .120	
Before	1.43
After	1.46
Spring Tolerance	± 30%

Max. Bend Angle 119°

Max. Offset Rating (in.) 1.05

Min. ...

Regular Nickel ... Welding ✓E

Sulfur-Free Nickel ... Welding

Or Corrosion Resistance

Id Plate ✓

Pass ...

Other Finish

Leak Test ✓ No

Notes:

1. Max. Operating ... Usage 3.0"? ...
2. *-Values Are Maximum ... Combinations Of ... Please Con... Bellows Normal ... Copper ... To Wall.

Note

A Gold ... comparison ...
To ...

Servometer Corp.
Cedar Grove, New Jersey

Fig 38 DETAILS OF BELLOWS

RESULTS AND DISCUSSION

5. RESULTS AND DISCUSSION

The work has resulted in the development of a technology complete with all aspects and accessories needed for the easy, accurate and simultaneous acquisition of the five important marine environmental parameters which are directly and indirectly related to the living marine resources of the sea. Special efforts have been made to cover all aspects of problem so as to make it complete in every respect. The details of the problems, methods employed and results obtained thereof are described above in the appropriate chapters. The photograph of the composite equipment developed is given in Fig.39. The Fig.40 shows drawing of the same with the details of the parts indicated.

This chapter gives brief account of the end results and a discussion on them.

The various results achieved successfully as descrete parts for supplementing to the composite system are given below:

1. Development of two types of sensors for current measurement.
2. Development of direction sensor for current.
3. Development of sensor for temperature.
4. Development of sensor for salinity.
5. Development of sensor for depth of operation.

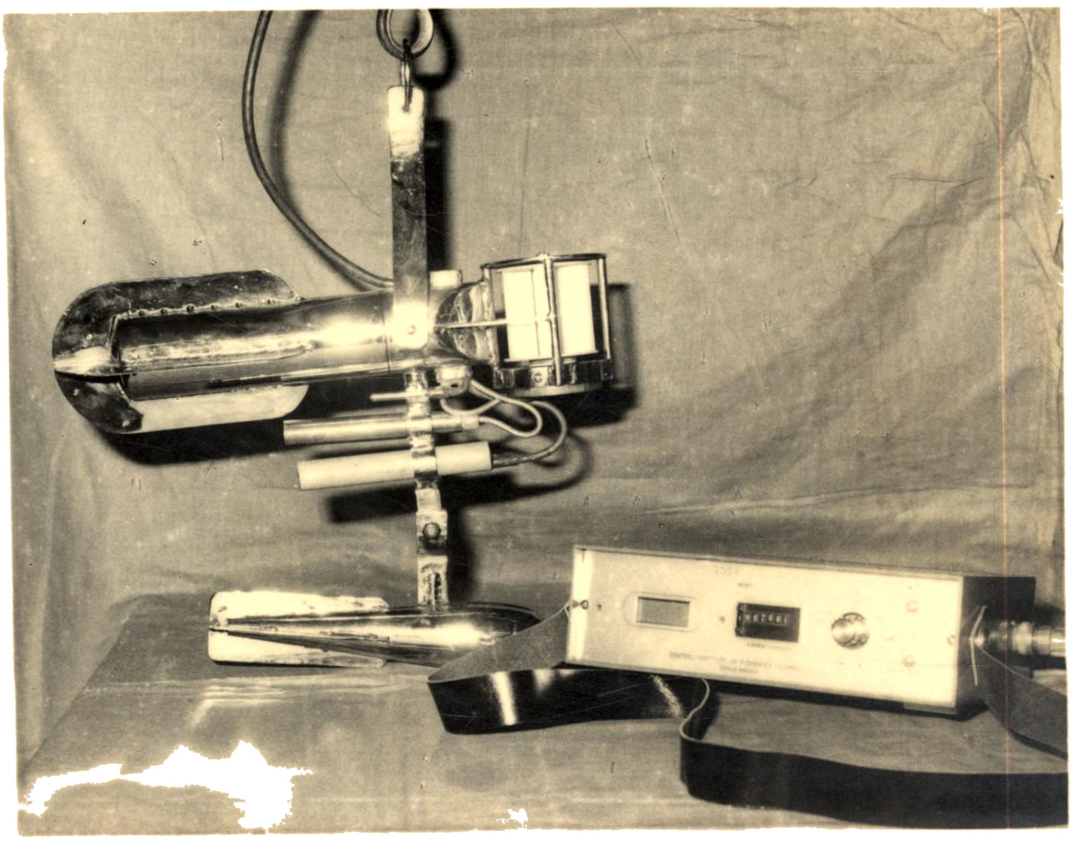


Fig. 39 PHOTOGRAPH OF THE COMPOSIT INSTRUMENT DESCRIBED IN THIS THESIS AND LATER NAMED 'OCEAN TELE-LAB'

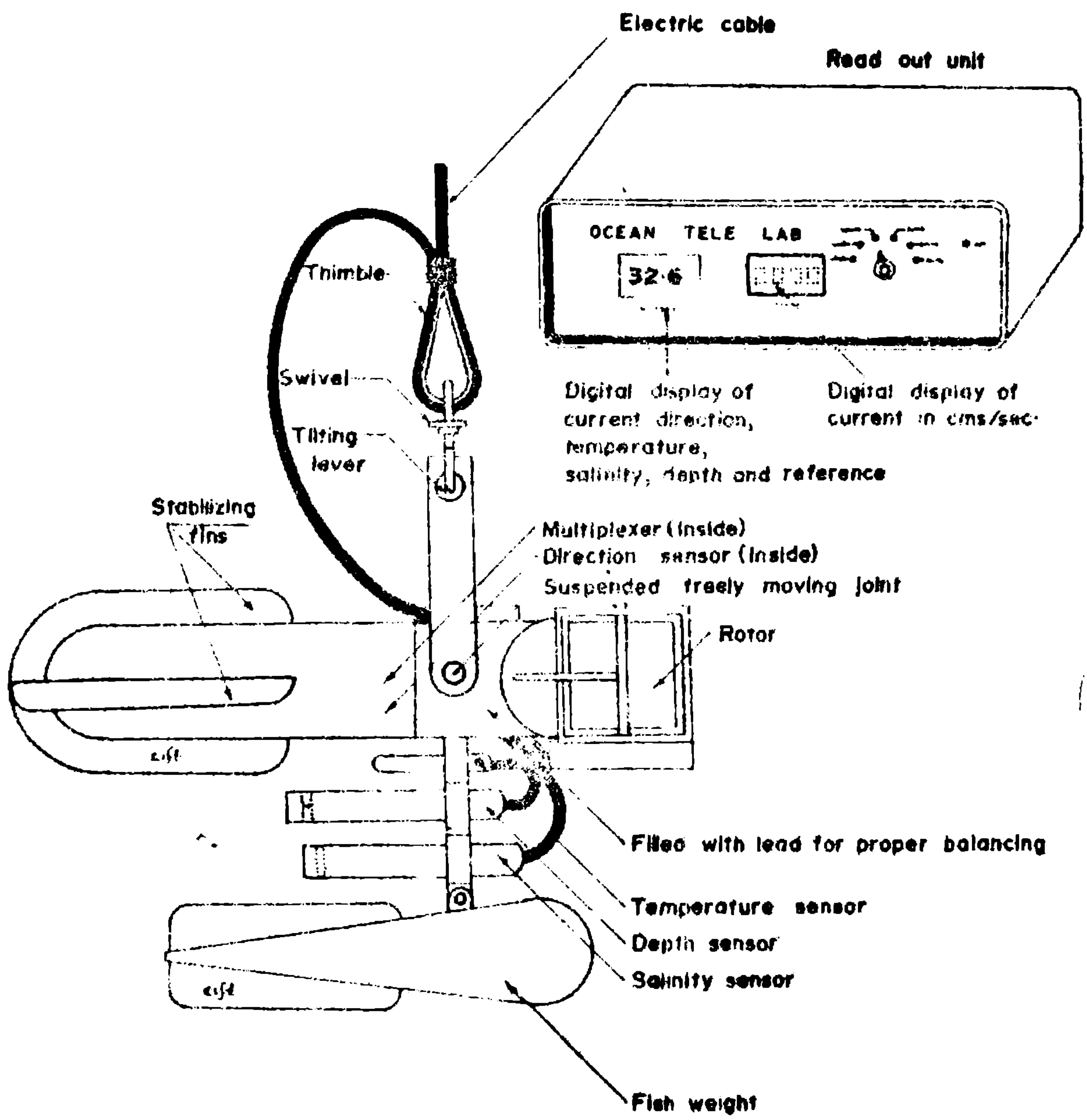


Fig. 40 SHOWS THE VARIOUS PARTS OF THE COMPOSIT EQUIPMENT

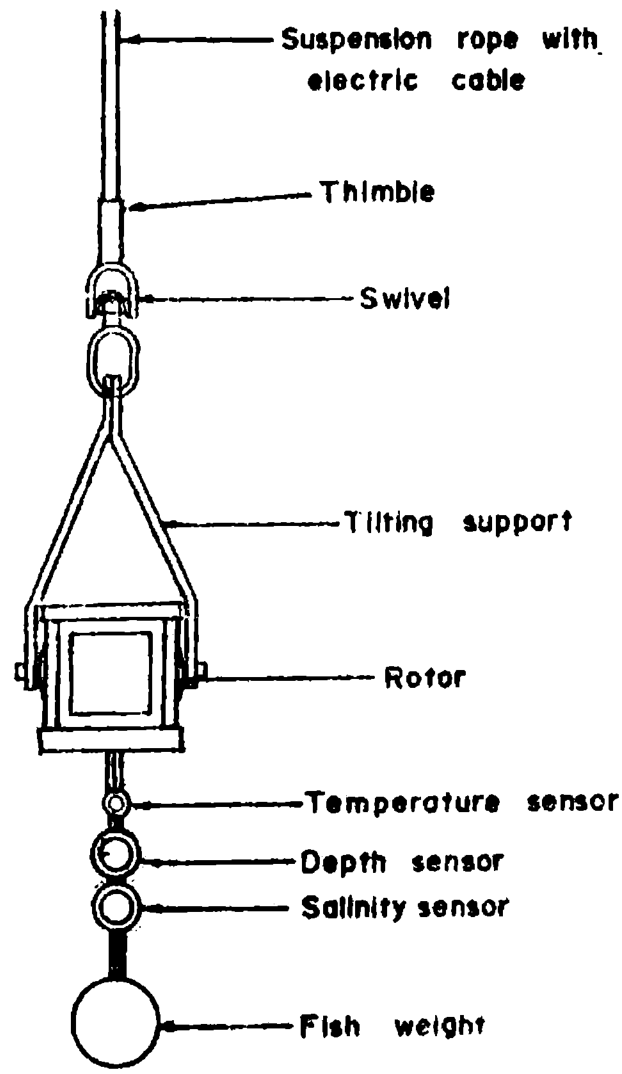


Fig. 41 FRONT VIEW OF THE UNDER WATER PROBE

6. 4 types of remotely operated multiplexers suitable for the system.
7. Low impedance sensors matching to the system free from noise problems.
8. A common signal conditioner for salinity, temperature and depth.
9. Compact under water probe with streamlined design.
10. Single and compact read out unit with low power consumption.
11. Single 3-core and 4-core cable for transmission of 5 parameters.

The reliability of the various sensors, signal conditioners and other controls including display methods used, have been established further through the fabrication and constant use of several descrete units of the composite system, and also incorporating them in some recently developed large automatic data acquisition systems are given below:

1. Laboratory salinometer (Fig.42) for salinity measurements in the laboratory.

   The 2-electrode type salinity cell (2.4) alongwith the signal conditioner (3.4) with linearised salinity values were used in this instrument. It gives an accuracy of $\pm$ .05 in the range 0 to 38 when measurements are taken from the graph.

2. Salinity-Temperature-~~Depth~~ meter (Fig.43) for measurement of salinity and temperature ~~and depth~~ from the field. Same type of salinity cell (2.4) and temperature cell (2.3) were used here along with signal conditioner with out positive feed back. The instrument gives accuracies of ±.05 salinity, ±° 05°C temperatmre in the range 0 to 38 and 15 to 35°C respectively. Both salinity and temperature are given two ranges each in order to attain the above accuracies.
3. Salinity-Temperature-Depth meter (Fig.44) for continuous measurement of salinity, temperature and depth in the fieled up to 200 m depth. The same type of sensors of salinity, temperature and depth are used with a single signal conditioner as described above with out positive feed back. More than ~~half~~ a dozen units of this instruments have been fabricated with a common digital display in LCD with ranges and accuracies of 0 to 38, ±•1 salinity, 15 to 35°C, ±• 1°C temperature and 0 to 100 m, ±° 1 m depth.
4. Direct reading digital current meter (Fig.45) for instantaneous measurement of water current and direction using inductive type current sensor (2.1.2) and the signal conditioner with digital display of current in e.m. counter in cms/sec

- G 3432 -

averaged over 24.5 sec. as mentioned in 3.1.2. The ranges and accuracies are 0 to 400, ±2cms/sec and 0 to 360°, ± 5°

5. Coastal Oceanographic Data Acquisition System - CODAS (Fig.46). This large automatic remote operated data acquisition provides data on coastal marine environment in 16 channel. It employs the same type sensors for salinity, temperature, water level (depth) and current along with several others for other environmental parameters. A common signal conditioner of the type mentioned in 3.4 is used for making primary signal conditioning. The ranges and accuracies are the same as (4) above except for salinity. Salinity has got a short range of 28 to 38 with an accuracy of ±.05. The system is installed in Alleppey and operated successfully.

6. Environmental Data Acquisition System - EDAS (Fig.47)

   This large data acquisition in 16 channels developed for automatic acquisition of environmental data employs the same type sensors for current, salinity and depth (water level in rivers) and same signal conditioners for current (3.1.2) and others (3.4).

7. Universal Marine Telemeter (Fig.48) This remote operated under water data acquisition system

developed for the measurement of salinity, temperature and depth (trawl depth) employs the same type of sensors mentioned above and same type of common signal conditioners. This equipment measures several other hydrodynamic parameters of the fishing gear system alongwith that of the environment where the trawl system is operated.

The various points considered and handled during the development of the system relevant to the context are the following.

5.1 SELECTION OF IC^{S} AND COMPONENTS

The IC^{S} and active components used in the equipment are popular and inexpensive types and noted for their ruggedness and reliability namely, timer 555, opamp LM358, Voltage stabilizer 7806, transistors CIL 513, CIL 461 and SK100. The opamp works on single supply of 4 to 30V. The components used in the system do not have stringent requirements. The passive components are quite popular types with 5% tolerance. No special efforts are needed in the components or printed circuit board for suppression of noice or shielding against noice.

5.2 SELECTION OF CONNECTORS

Special care has been given in the selection of switches and connectors. Most switches and connectors undergo corrosion in the marine environment which leads to loose contact and associated problems. Best quality gold plated switches and contacts with military specifications were used in the equipment. The box was made out of bakelite, instead of metal. Plugs and sockets which causes loose contact were eliminated as far as possible.

5.3 COMPOSITE DESIGN FEATURES

Much simplicity and compactness could be achieved with a composite design approach. Sensors for temperature, salinity and depth were designed to produce signals of uniform nature so that a single signal conditioner could be used in common. Same liquid crystal display was used to display current direction, temperature, salinity and depth.

5.4 RUGGED AND SEAWORTHY SENSORS

The major success of oceanographic instruments depend upon the seaworthiness of the sensors. The sensors should produce signals at high level at low impedance so that they are immune to noice. This has been achieved sufficiently in the case of all sensors. Therefore the complete system could be made quite seaworthy.

5.5 LOW POWER REQUIREMENTS

The instrument needs only one 9V dry cell for operation. Another miniature 9V cell is used for operating the LCD. The equipment takes 50 to 100 mA current from the large supply and 1 mA from the small cell. Both the batteries last for 5 to 8 months normally, depending upon the frequency of operation.

5.6 ENVIRONMENTAL TESTS

The equipment was first subjected to environmental tests within the limitations in the laboratory and field.

5.6.1 AMBIENT TEMPERATURE EFFECTS

The effect of ambient temperature in the circuit of salinity, temperature and depth was studied in detail. The circuit was shifted to a hot oven of 50°C maintained at 30°C. The output voltage is continuously recorded in a strip chart paper. Fig.49 gives the chart prepared by recorder without any manual errors and interference. The voltage level shifted from 3.175 to 3.125 in about 2 minutes. The test was repeated shifting the circuit to lower temperature of 30°C which is followed by upward shift of signal as shown in the graph. The maximum voltage change is 0.050V which comes to about 1.25% variation on the total signal level of 4V.

The above shift of 0.050V is eliminated when automatic temperature compensation is given by means of thermistor used in series to the sensor as shown in Fig.29. The test was repeated in this condition and the result is plotted by the recorder as given in Fig.50. Here the shift of circuit from 30°C to 50°C and vice versa does not alter the signal level.

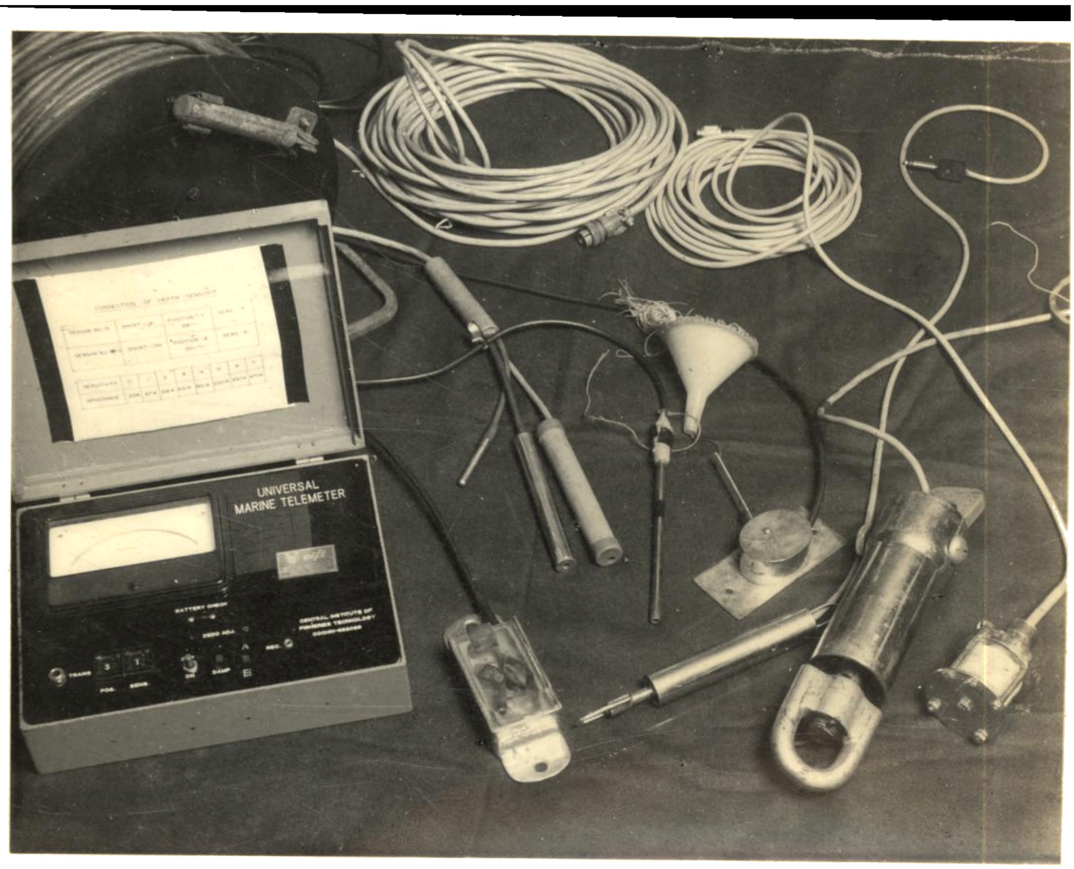


Fig 48 PHOTOGRAPH OF THE UNIVERSAL MARINE TELEMETER WITH SOME OF ITS UNDER WATER TRANSDUCERS

Fig 47 PHOTOGRAPH OF THE DATA PROCESSING/ DISPLAY UNIT OF ENVIRONMENTAL DATA ACQUISITION SYSTEM

Fig.46 PHOTOGRAPH OF THE RECEIVER SHORE UNIT OF THE COASTAL OCEANOGRAPHIC DATA ACQUISITION SYSTEM (CODAS

[redacted]

Fig 45 PHOTOGRAPH OF DIRECT READING DIGITAL CURRENT METER

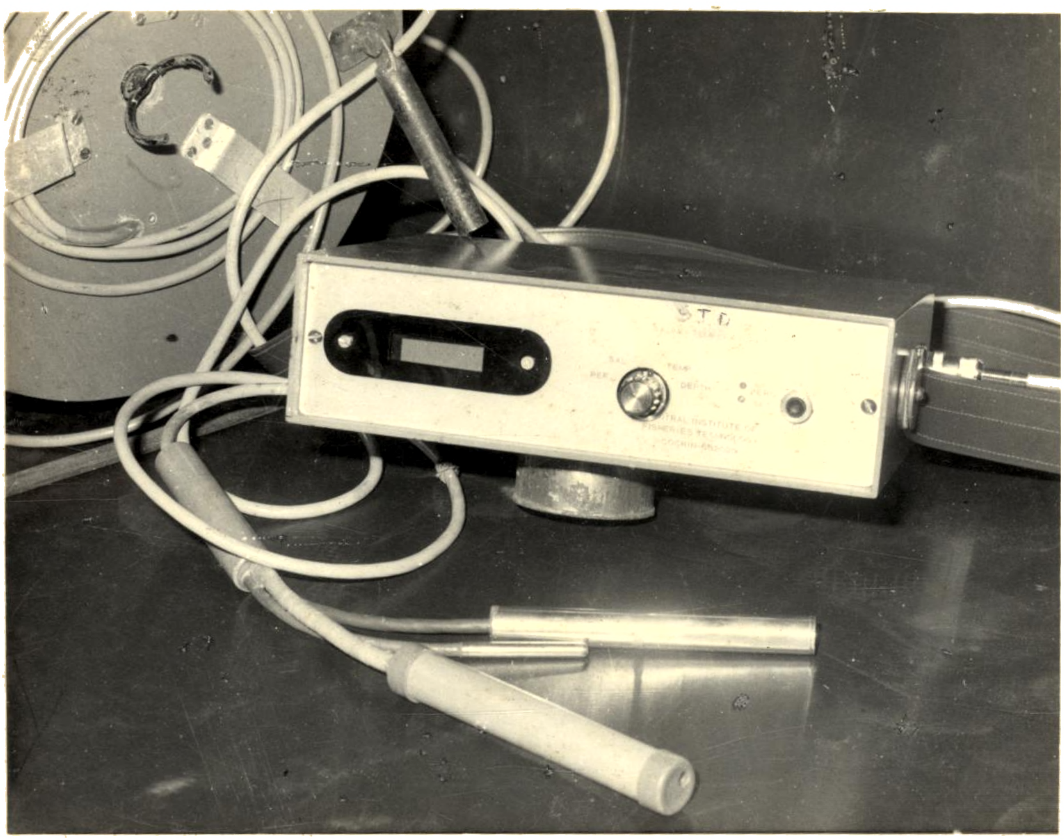


Fig 44 PHOTOGRAPH OF SALINITY TEMPERATURE -DEPTH METER.

Fig 43 PHOTOGRAPH OF SALINITY TEMPERATURE METER.

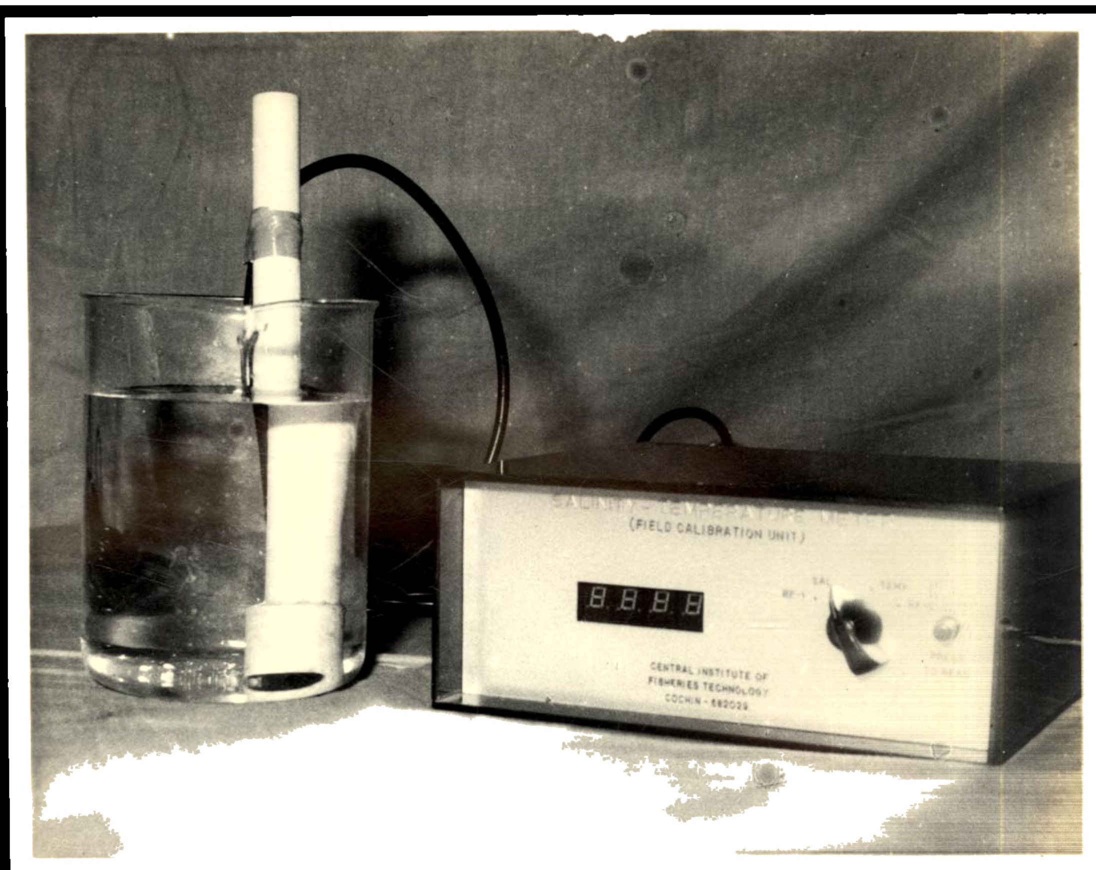


Fig 42 PHOTOGRAPH OF LABORATORY SALINOMETER

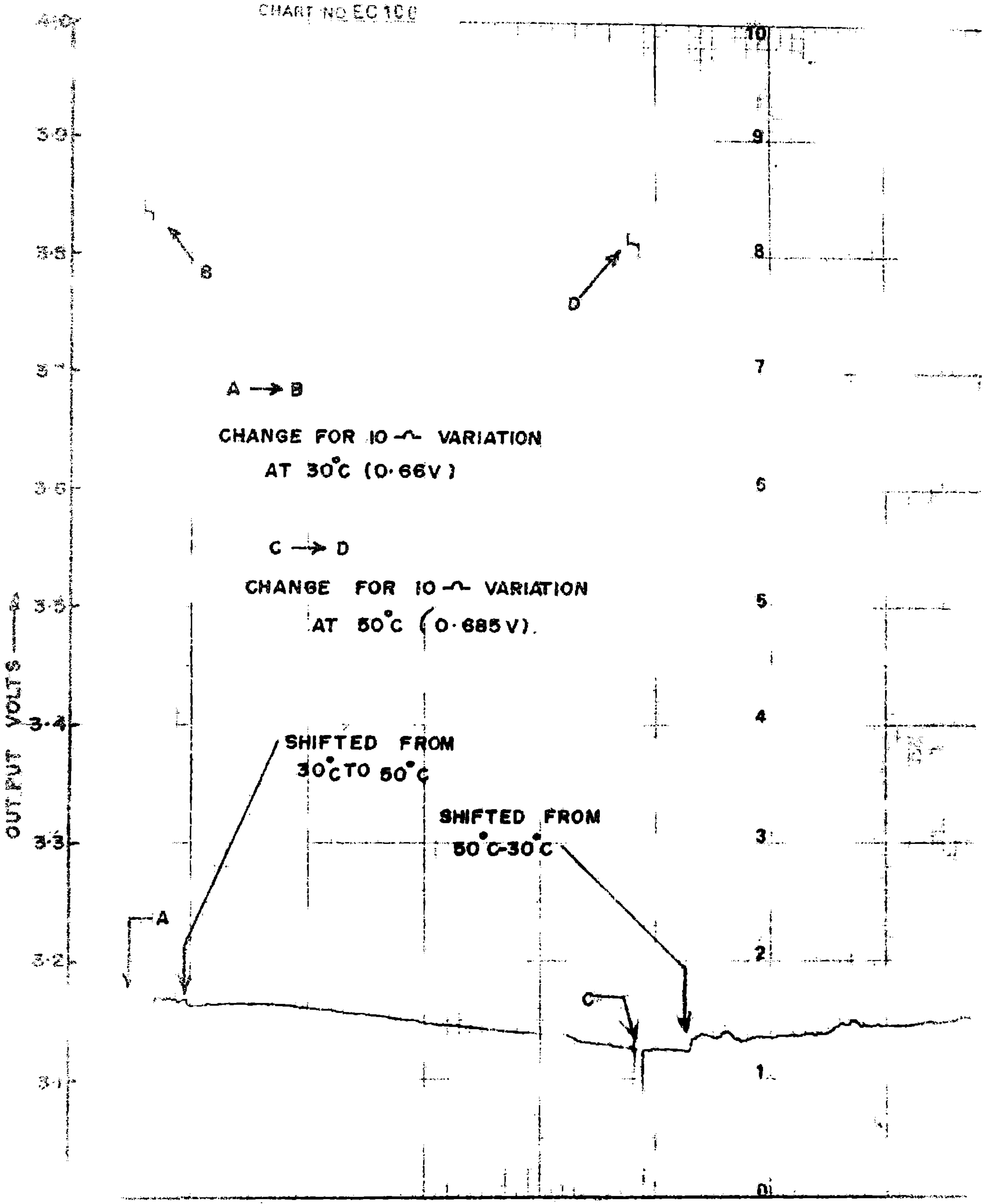
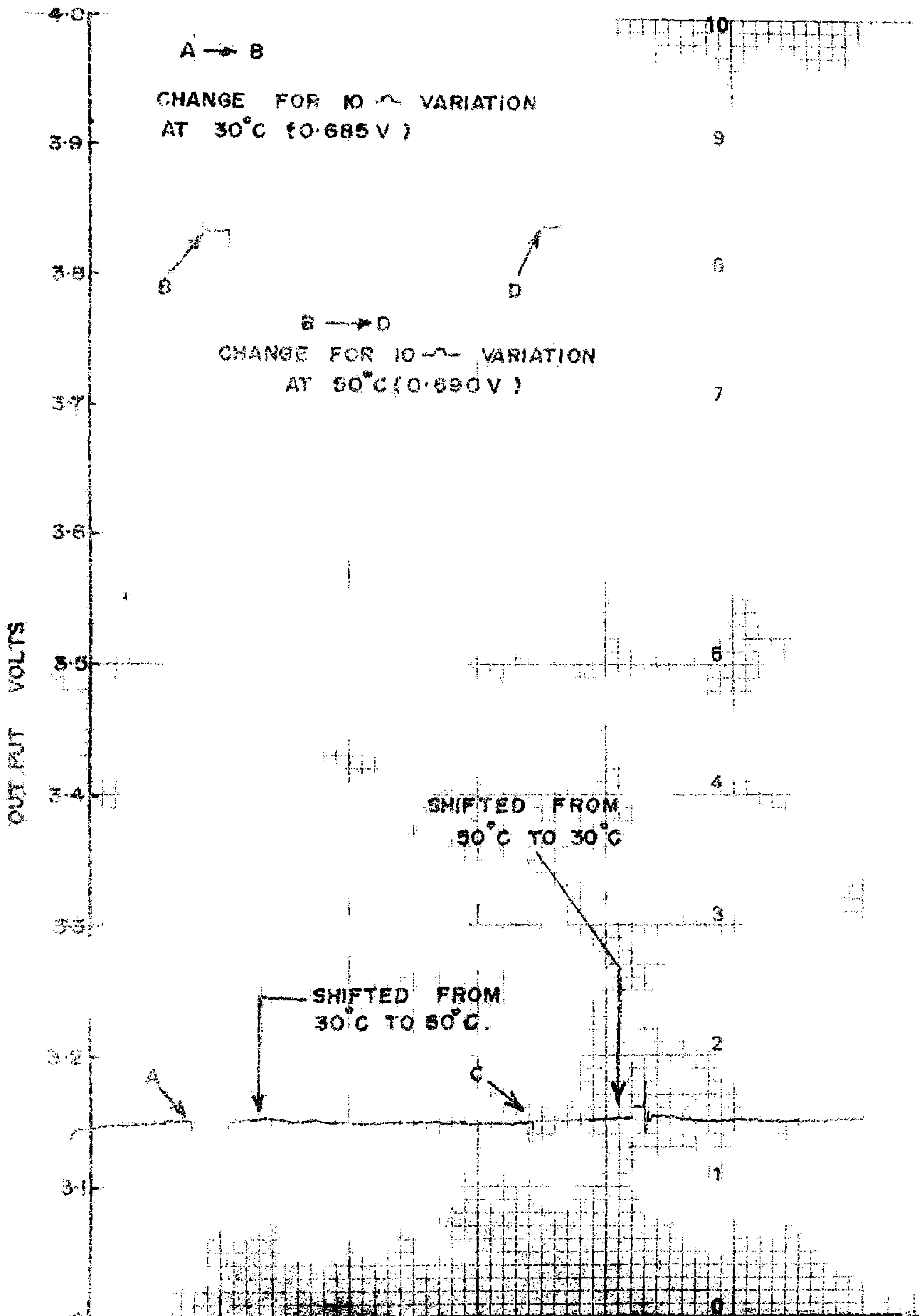


Fig. 49 TIME —— 5 cms / MINUTE



A → B
CHANGE FOR 10 ∿ VARIATION
AT 30°C (0·685 V)
B
D
B → D
CHANGE FOR 10 ∿ VARIATION
AT 50°C (0·690 V)
SHIFTED FROM
50°C TO 30°C
SHIFTED FROM
30°C TO 50°C.
A
C
OUTPUT VOLTS
4·0
3·9
3·8
3·7
3·6
3·5
3·4
3·3
3·2
3·1
3·0
10
9
8
7
4
3
2
1
0

Fig. 50

The effect of ambient temperature on the sensitivity of the circuit was also studied. The signal level was altered by changing the value of an ohmic resistance through 10 ohm at both 30°C and 50°C. In the first case the signal varied from 3.175 to 3.835 (i.e. from A to B in Fig.49) making a shift of 0.66V. In the latter case the signal level shifted from 3.125 to 3.81 (i.e. from C to D) making a shift of 0.685V.

The experiment was repeated in the case of the circuit with thermistor for temperature compensation. Here the 10 ohms signal change shifted the voltage from 3.150 to 3.835 at 30°C (i.e. from A to B in Fig.50) making a difference of 0.685V. The same shift of 10 ohms variation at 50°C changed the voltage from 3.152 to 3.835 (i.e. from C to D) making the same voltage variation of 0.685. This shows the shift in signal level is fully compensated with the method using thermistor.

5.6.2 HUMIDITY TESTS

The equipment showed no significant drift or any malfunctioning during its field tests on board small fishing vessels exposed to heavy humidity and salt water spray. This indicates that the equipment can withstand such high humidity environments as in marine conditions. The body and panels of the equipment are made out of backelite and acrylic which have no adverse action in the marine conditions. The LCD meter is well sealed against the entry of humid air. The gold plated multiway switch making sliding type contacts did not create any problems. The LCD plate is found to develop dark patches after 18 to 24 months. This is understood to be an in herent problem of the LCD plates commonly found everywhere.

5.6.3 SHOCK AND VIBRATION

The equipment was taken several times onboard fishing vessesl and kept over its vibrating decks. It could withstand the shock and vibration of the environments. There are no delicate parts which are damaged due to shock and vibration.

5.6.4 STREAM LINED DESIGN FOR THE UNDER WATER PROBE

Stream lined design is essential for reducing bulkness, and reducing the required fish weight. The additional sensors of salinity, temperature and depth are mounted below the cylinderical body parallel to its length so that they offer minimum resistance to motion as shown in Fig.41.

5.7 ERRORS AND LIMITATIONS

The errors and limitations of the equipment are as follows.

5.7.1 TEMPERATURE RESPONSE

As the temperature probe has to withstand high hydrostatic pressure, it has been encased in strong stainless steel casing filled with transformer oil. This has affected the response time of the sensor adversely from about 30 second to 70 seconds as shown in the Fig.9. This means that the sensor should be allowed to remain in the place for about 70 seconds prior to taking the measurements.

5.7.2 BOUNDARY EFFECT OF SALINITY CELL

The salinity cells, in general, whether conductive types or inductive types, have boundary effects. The conduction takes place not only inside but also outside the cell. This is more significant in the case of inductive sensors, where the boundary effect extends up to 20 to 40 cms. around the sensor. In the present case, the boundary effect is found up to 5 cms. and 2 cms. along the sides and along the edges respectively. This means that there should be at least 5 cms. and 2 cms. sea water at the sides and edges of the cell and also that there should not have metallic objects along the sides nearer than 5 cms short circuiting the paths. These boundary effects do not pause any problems during field measurements. But while taking measurements from collected water samples, care should be taken to see that the sensor is positioned away from its water boundaries for at least 5 cms. The design of the sensor has been carefully done to avoid any possibility of conductive metal parts to come nearer than 5 cms.

5.7.3 SELF OSCILLATION DUE TO POSITIVE FEED BACK

The non-linear response of salinity is made linear by making the amplifier response to be non-linear through positive feed back. The positive feed back can cause self oscillation if it exceeds certain level. Though the feed back level is sufficiently below the stage of self oscillation, it has affected the fastness of the signal adversely. It takes about 2 seconds for the signal to come to steady value. This means that the salinity readings should be taken only after 2 seconds lapse after switching over to it. This time being too short, has not caused any problem for actual measurements. The curves A and B in Fig.51 shows the two responses of the amplifier without positive feed back (where the measurement are taken using the graphs in Fig.36) and with positive feed back (where the measurements are taken the using the graphs in Fig.35) respectively.

5.7.4 RANGES AND ACCURACIES

The ranges can be altered with in certain limits as shown below and the accuracy will vary accordingly.

Current:

Range	0 to 400 cms/sec
Resolution	1 cm/sec
Accuracy	± 2 cm/sec

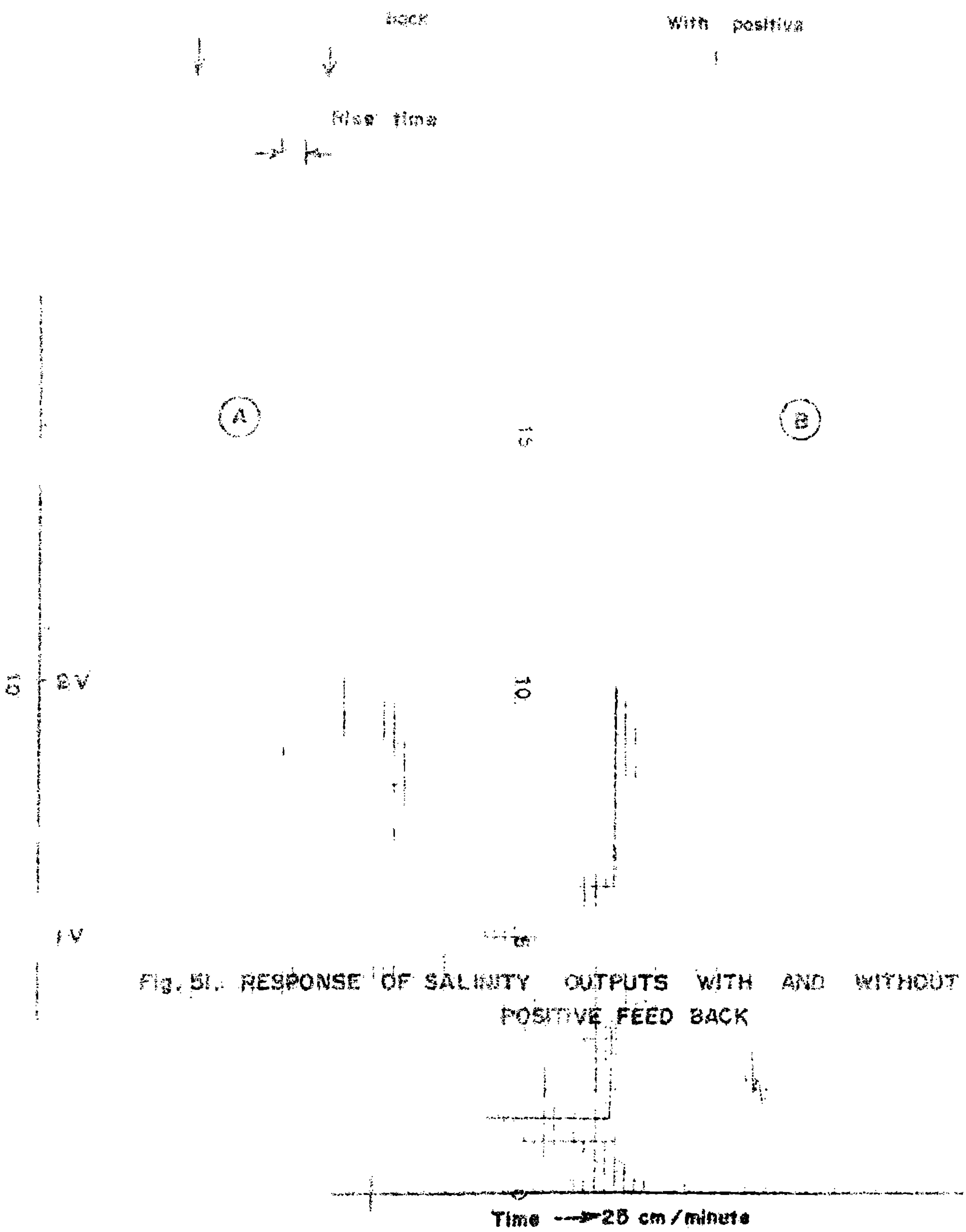


Fig. 51. RESPONSE OF SALINITY OUTPUTS WITH AND WITHOUT POSITIVE FEED BACK

Currenct direction:

Range	0 to 360°
Resolution	1°
Accuracy	±5°

Salinity:

Range	0 to 38
Resolution	·1 (for full range) ·05 (for short ranges)
Accuracy	±·05 in the short sub-range of 32 to 37 for oceanic measurements; ±·1 for the full range, with out linearisation; ±·2 for full range with lineri-sation and following the linear formula; ±·1 full range with linearisation and following the calibration graph.

Temperature:

Range	10 to 35°C
Resolution	·05°C
Accuracy	±·1°C for full range, ±·05°C for subdivided ranges

Depth:

Range	0 to 30 m, 100 m, 200 m
Resolution	°1 m
Accuracy	±°1m for 30 m ±005 m for 100 m ±1 m for 200 m

The ranges of temperature can be altered without loosing accuracy. 15°C to 35°C can be altered to 0 to 20°C. But further wider ranges of say, 0 to 35°C will affect the linearity of the signal and a graph will have to be followed for precise measurements. Same design of depth sensor can be used for further deeper waters also changing the bellows.

5.8 NOVELTIES OF THE EQUIPMENT

There are novelties incorporated at various stages of the equipment for specific purposes.

5.8.1 THE 'ROTOR' WITH ELECTRIC INDUCTION

An entirely new technique has been employed here for sensing the rotation of the rotor. The new technique is that the rotation of a rotor is sensed in terms of changes in inductance of an electric coil once in every rotation. The specific advantage of this novel technique is that the rotation could be sensed without causing any mechanical or magnetic loads, so the rotor could be designed small and compact.

5.8.2 THE SALINITY CELL WITH 2 ELECTRODES

The salinity cell has got only two electrodes instead of 3 or more used in conventional types. The sensor was so designed in order to accommodate it into the composite nature of the system with uniform signal outputs from sensors.

5.8.3 THE DEPTH SENSOR WITH 2 TERMINAL INDUCTANCE VARIATION

The depth sensor which produces electric signals proportional to the depth has got only two leads instead of 4 or 5 needed for the conventional LVDT types. The sensor was designed with 2 terminals to accommodate into the system.

5.8.4 THE COMPOSITE SIGNAL CONDITIONER

The signal conditioner used in the equipment accepts both inductive as well as resistive signals for convertion into anolagous voltage. The two outputs of the wheatstone bridge are independantly detected, filtered and fed to the inputs of an opamp to produce the signal alone at the output.

5.8.5 LINEARISATION OF SALINITY SIGNAL

The salinity is presented linearly unlike the conventional methods where it is presented in non-linear style with less sensitivity at higher salinity values. The salinity curves are presented here in straight lines passing through the zero points given by

$S = R \tan (45 \pm KD)$ where provision is given for temperature correction also.

5.9 SPECIFIC ADVANTAGES OF THE EQUIPMENT

The novelties introduced have resulted in several advantages for the manufacturer as well as for the user.

5.9.1 ADVANTAGES TO THE MANUFACTURER

1. The rotor is freely mounted on two pins. It does not require any mechanical or magnetic coupling to inside the chamber for the purpose of producing signals, unlike many conventional types. Hence the design and construction of the associated parts are much easier.

2. A thin and small (.5 mm thick, 1.5 cm dia) ferrous piece mounted on the rotor and used for producing pulses does not add any significant weight or other problems to the rotor. Hence the rotor could be made much small.

3. The coil used to pick up the signals is sufficiently small (20 mm dia, 4 mm thick) for moulding inside the body of the equipment. As it is moulded it is free from the high hydrostatic pressure. Several associated manufacturing problems are eliminated.

4. A single signal conditioner is used for salinity, temperature and depth, thereby reducing the cost as well as the complications.

5. A single 3-core cable is used to convey the signals from the five sensors, one by one. This has eliminated the need of an expensive multicore cable which is not indigenously available. In the second model of the instrument

a 4-core cable is used and the information could be displayed in any order for any length of time.

6. All the I.C^{s} used need only single supply.

5.9.2 ADVANTAGES TO THE USER

1. It is much easy and convenient for operation as the under water probe is much small and compact.

2. The measurements on current, current direction, salinity, temperature and depth are obtaianed one by one, by inserting a single probe as against several probes needed otherwise.

3. It works on a single 9V dry cell with very low current consumption (50-100 mA). Another miniature cell is used for operating LCD. Both the batteries work normally for 6 to 8 months. Both the cells are easily available.

4. The salinity is displayed linearly unlike the conventional types. This makes the calibration and occasional checking easy.

5. Temperature correction for salinity values is done based on a simple mathematical relation. This eliminates the probable manual observational errors while reading the temperature correction graphs.

6. Current is displayed digitally averaged over 30 seconds. This average value is more desirable to the user.

7. All the information are displayed in their engg. units except salinity for which correction has to be applied

for any deviation in temperature from 30°C.

5.9.3 TESTING AND SIMULATION FACILITIES

It is very important that field operated instruments should have facilities to test and confirm its proper operation at any time. Because much expensive and elaborate efforts which are several times costlier than the equipment are usually done for operating the equipment by way of chartering survey ship and engaging scientists. The reliability of the instrument can be checked by simulating the signals as given below and their proper operation can be confirmed.

5.9.3.1 CURRENT

A signal generator is used to feed signals into the system corresponding to the r.p.s. of the rotor. The required frequency corresponding to the r.p.s. (Fig.32) which in turn gives a particular known current velocity is fed and the proper operation and calibration is confirmed. Portable and handy signal generators covering the entire range has been made for the purpose.

5.9.3.2 CURRENT DIRECTION

Current direction can be tested at any place with the help of a magnetic compass.

5.9.3.3 DEPTH

The equivalent ohmic resistance corresponding to zero, maximum and middle point of the range of depth are noted first. The depth sensor is replaced by these resistors and the readings are tested.

5.9.3.4 TEMPERATURE

Temperature can be checked dipping the probe in water baths of different temperatures. If this is not available, the same procedure of simulating with equipment resitors is followed here also.

5.9.3.5 SALINITY

Salinity can be checked by dipping the probe into saline water of known temperature. Alternatively, equivalent resistors are connected to the terminals and the readings tested.

For replacing the sensors easily, a separate connector has been prepared with cables so that the existing connector with its sensors need not be disturbed.

6. OPERATION OF THE EQUIPMENT

Two models of the equipment have been fabricated namely, model-A using multiplexer MUX-130 and model-B using multiplexer MUX-100. There are slight differences in their mode of operation.

6.1 EQUIPMENT MODEL-A (USING MUX-130)

1. Release the under water probe to the depth unwinding the cable from the winch.
2. Connect the cable to the meter through the plug.
3. Turn the multiway switch to the required information, say current and make a short pressing (of duration between .05 to 3 secs) in the small press switch marked 'current' after resetting the e.m. counter to 'zero'.
4. Now the rotation of rotor is registered in the e.m. counter for 30 secs. time and stops the operation. Now the complete equipment is switched 'off' automatically.
5. Turn the switch to another required information, say, current direction. Press the other press switch and note the readings for the LCD meter. Repeat the same for all the remaining parameters of depth, temperature and salinity in whatever sequence and duration needed. The exact values of

salinity are to be found either using the mathematical relation or from the graph in Fig.36. In actual use, this graph is prepared in large sheet for easy and accurate readings.

6.2 EQUIPMENT MODEL-B (USING MUX-100)

The procedure for operation is the same as in model-A except for the small alterations as given below.

1. Unlike in the other model, current direction,depth temperature and salinity can be operated only in their particular sequence for fixed durations of 10 secs. each. They automatically change from depth to temperature and salinity. These change-over is indicated by sudden changes in meter readings as well as an alarm. Then the multiway switch should be turned from depth to temperature and then to salinity in order.

6.8. ADJUSTMENTS AND PRECAUTIONS

1. The 'Reference Position' should show 000 reading. If not, adjust the small screw adjuscent to it such that the reading comes to 000.

2. Never switch on the instrument for the next series of measurements before 20 seconds interval in the case of model-B, becuase the multiplexer inside the probe is still alive for 5-6 seconds and so it will be confused if the operation is made during this period. But this restriction does not exist for the current measurement which lasts for 30 secs. Because multiplexer does not operate during this time. The above restriction is not applicable to the model-A using MUX-130.

3. The presence of magnetic materials affect the current direction measurements. Hence care should be taken to this effect especially when measurements are done from steel vessels.

4. While taking measurements on salinity, see that there is no conducting material closer than 5 cms. and also that there is at least 5 cms. water all around it. This will not be a problem during field operations. But care should be taken to follow the conditions during measurements from collected water samples.

5. It is desirable to wash the probe in fresh water after operation.

6. While packing the instrument in to box, make sure that its switches are free

7. Replace the bottom screw socket of the rotor after 1 to 2 years depending on the use. for the brass socket might have undergone wear and tear.

8. Replace the batteries after 6-8 months operation.

6.4 FIELD PERFORMANCE

The transducers, signal conditioners, multiplexers etc. developed for an integrated system design and described in this thesis have been used in several instruments. Some of them are descrete instruments, while others complex ones capable of monitoring several parameters utilising the facilities and specific advantages of the components for composite system performance. The descriptions given in this thesis is that of such a complex one with portable type of operation from small fishing vessels, as shown in the photograph and drawings in Figs. 39, 40 and 41. The Coastal Oceanographic Data Acquisition System (CODAS - Fig.46) and Environmental Data Acquisition System (EDAS - Fig.47) are much larger automatic data acquisition systems using the type of transducers, signal conditioners and similar type multiplexers for automatic acquisition of data from the field. The Universal Marine Telemeter(Fig.48) using same type transducers for salinity, temperature, depth, water flow inside net and several others for sensing the hydradynamic performance of the fishing gear, is designed as a fully under water system for manual acquisition of data from the fishing gear and its visinity. Laboratory Salinometer (Fig.42) is meant for salinity measurements in the laboratory from collected water samples. Salinity Temperature Meter (Fig.43), Salinity-Temperature-Depth meter (Fig.44) and Direct Reading Digital Current water (Fig.45) are other independant portable instruments for instantaneous field measurements of the parameters. Several units of these portable instruments have been fabricated and are being constantly used by many Departments in the country, namely, Central Institute of Fisheries Technology and its Regional Centres, National Institute of Oceanography, Fisheries College of Tamil Nadu Agricultural University, Fisheries College of University of Agricultural Sciences, Bangalore, Marine Biological Centre of Indian Institute of Science, Bangalore, Centre for Earth Science Studies, Trivandrum and its Regional Centres, Water resources Division, Pune, Investigation Circle of Kerala State Electricity Board, Radiation Technology Division of Bhabha Atomic Research Centre, Mangalore Port, P.G.Centre of Shri Venkateswara University, Oil and Natural Gas Commission etc. Further, many other Departments have used these instruments for short duration for their investigations.

The defects noticed during operations and actions taken are listed below:

1. Drift noticed in the meter readings initially for 10 to 20 seconds. This was rectified by replacing the transformer of laminated cores of the oscillator with ferrite core, replacing the PCB made of laminated sheet with that of glass-eposy and replacing the stabilized supply using transistor-zenerdiode combination with I.C. 7806.
2. The pressure inlet holes of the depth sensor is chocked with clay and silt in due course. This was solved by providing an external cover to the sensor

with flexible neoprene hose. Initially the hose is filled with fresh water so that pressure is passed through.

3. The needle of microammeter used for indicating the information oscillates along with the rolling of boats, making the measurements difficult. This is a serious problem while taking measurements using small boats which roll heavily especially when they are anchored for taking measurements. The problem was solved replacing the analogous meters of old designs with digital LCD meters.

4. Aluminium/steel cases of the instruments get heavily corroded in the marine environment, since they are exposed to salt water spray often times. Such metallic cases were replaced with that of laminated sheets and fibre glass.

5. The display plates of LCD meters develop black patches with in 18 to 36 months of operation of the meters. Later, the black patches cover the entire space and the measurements cannot be taken at all.

   This is a common problem of poor quality LCD plates now available in the country. Some of the LCD meters of even reputed manufacturers abroad also show the same defects. The solution to this problem is to replace the LCD plates with new ones when the black patches are seriously developed. The LCD plates cost approximately Rs.120/- each and it is expected that more reliable types will soon appear in the market. But these defects do not affect the readings in any way.

6. The current meter registers current even when no current is visually observed.

   This problem arises where current is measured from anchored boats and ships. Even if there is no current, the waves and the movement of the boat causes a relative movement of the under water probe and it is registered as current which some times comes up to 4 to 5 cms/sec. This is a general problem while taking measurements in rough sea. Such errors are prominent when the actual current is zero or nearer to zero. Usually measurements nearer to this levels have no practical utility. Such errors became less in the same condition when the probe is lowered to depths from the surface waters.

7. Fast measurements of temperature is not possible as the probe is lowered to depths.

   Yes, it is a limitation of the instrument, because the sensor with its strong stainless steel cover takes about 90 seconds (maximum) to sense the temperature fully. Therefore measurements can be taken only after keeping the probe in the position for at least 90 seconds.

8. The fish weight attached is insufficient for the equipment.

   Actually there are different fish weights available for use in the instruments at different current ranges. A large fish weight solves the problem. But it is unnecessary to handle heavy fish weights which are difficult to handle. It is one advantage of this design that the fish weights can be altered without affecting the readings, because the under water probe alignes to water flow and remains horizontal.

9. The under water cables have broken some times.

   The above problem has been found when measurements are taken from the trawl net connecting the cable from the net to the boat. As the vessel moves, high hydrodynamic drag force exerts on the cable and makes it break some times. This can be avoided by careful and occasional adjustment of the length of cable according to the changing tension when the under water system moves out of its normal track because of the under water currents. The permanent solution is to use electromechanical cable, which are not available in the country.

As mentioned in 5.9.3 testing and simulation facilities, the proper operation of the equipment can be tested with simulation facilities. The performance of the equipment have been compared with other imported types wherever possible. In the case of salinity, the reliability can be further confirmed by collecting water samples from the same place and its chemical analysis in the laboratory.

Some of the observations using the composite equipment

Date	Time Hrs.	Location cochin	Current cms/sec	Current Direction	Salinity	Temperature °C	Depth m	Remarks
27-1-1983	10.07	Oil tank berth	14	326	30.1	30.6	.006	Since the current
"	10.08		11	315	30.7	30.9	1	velocity is
"	10.09		6	350	31.3	30.4	2	low, the
"	10.10		1	347	31.7	30.5	3	direction
"	10.11		4	147	32.0	30.6	4	fin is not fully
"	10.12		0	147	32.1	30.6	5	aligned and
"	10.14		2	316	32.1	30.6	4	hence there
"	10.15		2	272	32.0	30.7	3	is consider-able diffe-
"	10.16		8	302	31.7	30.6	2	rence in the
"	10.18		14	325	30.4	30.7	1	values of
"	10.19		17	324	30.2	30.9	.008	direction

Date	Time Hrs.	Location cochin	Current Cms/sec	Current Direction	Salinity	Temperature °C	Depth m	Remarks
17-5-1983	10.15	Shipping channel about 500 m from the mouth	16	282	33.9	32.2	4	When the current is very low, the direction is very unsteady because, the direction is not properly aligned.
	Repeat		15	273	34.1	32.2	4.1	
	11.30	Shipping channel about 7 K.M. from shore – right side	15	185	35.4	31.0	5	
	"	"	16	176	35.5	30.0	10	
	11.35	"	12	178	35.5	31.4	5	
	"	"	11	168	35.6	30.0	10	
	Repeat	"	9	176	35.6	30.0	10	
	14.15	"	16	165	35.7	29.3	10	
	Repeat	"	11	162	35.2	29.3	10	
	14.25	"	23	175	35.7	29.8	12.5	
	14.30	"	12	160	35.5	32.2	5	
	Repeat	"	15	172	35.5	32.1	5	

Date	Time Hrs.	Location cochin	Current cms/sec	Current Direction	Salinity	Temperature °C	Depth m	Remarks
14-3-1983	18.05	Oil tank berth			33.7	31.9	3	Current
	19.05				33.1	31.9	"	measurements not taken,
	20.05				32.0	32.0	"	as it cannot
	21.05				31.4	31.9	"	be very
	22.05				31.8	32.0	"	correct, in
	23.05				32.9	32.0	"	the presence
	24.05				34.2	31.7	"	of a ship
15-3-1983	01.05				34.2	31.7	"	anchored around
	02.05				35.2	31.6	"	
	03.05				35.2	31.5	"	
	04.05				35.2	31.5	"	
	05.05				35.2	31.6	"	
	06.05				35.6	31.3	"	
	07.05				34.6	31.4	"	
	08.05				33.6	31.1		

SUMMARY AND CONCLUSIONS

7. SUMMARY AND CONCLUSIONS

India has got a long coastal line compared to many other countries and we look forward to better solutions to many of our immediate and future problems connected with food, transportation, energy etc. We have already initiated large programmes and started investing heavily in these activities. Our ambitions programmes for the exploitation of the living resources have further increased with the recent declaration of the 'Exclusive Economic Zone' whereby we are solely responsible for expoitation of the resources up to 200 miles. In the energy field, we have wide programmes and many potential oil grounds have been located both in Arabian Sea and Bay of Bengal. The bathymetry of Bay of Bengal and around Lakshadweep islands has shown potential source of ocean thermal energy and we have already initiated a programme for tapping energy based on the temperature difference between upper and lower layers of the ocean. Port and harbour development is another highly promising activity associated with our long coast connecting most of the important cities.

All these activities are to be promptly supported with adequate knowledge of the marine environment which are fast changing. Our progress in marine instrumentation is comparatively very poor. It is very important that we should have self sufficiency in instrumentation to support our ambitions marine programmes. Marine instrumentation has unique problems associated with hazardous and hostile environments to which the sensors are exposed.

The recent spectacular developments in electronics are mostly concentrated in computer technology and data processing. But this is only one aspect of the total instrumentation chain. The initial aspects such as sensing of information from the highly complex marine field remains far separated from the above developments.

This thesis reports on the details of the works done to develop a complete system for acquisition of the important marine environmental parameters namely, current, current direction, salinity, temperature and depth. It encompasses transducers, signal conditioners display arrangements and remote controlled multiplexer which constitue the system. The various associated instrumentation and environmental requisites and problems have been discussed and solved to considerable extend. The design and development features of this composite system includes an integrated approach in order to make the final equipment to be simple, inexpensive and easy for operation from small and large boats. This could be achieved with the successful development of all required components with features matching between them, such as sensors, signals conditioners remote operated multiplexers, common display methods, quick performance check and calibration methods. The major success rests on the development of sensors with excellent performance characteristics suitable for marine environment. Out of the 5 sensors, that of current salinity and depth are quite noval types with specific advantages. The environmental effects have been eliminated to the required extend. The common signal conditioner for salinity, temperature and depth has noval design features for achieving simplicity, reliability and accomodating the three sensors of different functional requirements.

Field operated instruments have additional problems because of the environmental effects on the remote operated sensors and the signal conditioners. The very features of the sensors with very low impedance and high signal levels have made them immune to heavy R.F. and other environmental noice. The instrumentation problem associated with extension of cable has been solved rendering the system flexible for alteration of cable length for different requirements.

Occasional testing and calibration is a very desirable requirement of field operated instruments through such facilities are not usually provided in them. The facilities provided in this equipment for simulation of signals enables quick checking and its calibration before an expensive marine survey operation is condcted.

The reliability of the various sensors, signal conditioners and multiplexers developed for the equipment and other associated methods for field checking, compensation for environmental effects etc. have been further established with the successful development of several descrete instruments and large automatic data acquisition systems. Many such instruments based on the same technology are under operation in different conditions including the most hostile and hazardous environment on the floating dynamically stabilized oil rig SEDCO 445 operated in Bay of Bengal for oil and Natural Gas Commission.

The technology developed is expected to go a far way in our marine exploratory programmes providing useful data for various activities connected with the exploration and exploitations of the living and non-living resources of the ocean, and other engineering constructions. The operation of the equipment can be extended to other more challenging areas such as wireless transmission of data from moored buoys, under water recording in deep ocean capsules etc. with suitable devices for transmission and under water recording respectively. The data reduction part can be further modified incorporating microprocessors so that the actual salinity can be directly obtained instead refering to a much complex data relating to meter readings, temperatures and salinity.

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SYMBOLS AND ABBREVIATIONS USED

A		ampere
a.c./A.C.		alternate current
C		capacitance
c.c.		cubic centi metre
d		distance
dB.		decibel
d.c./D.C.		direct current
e.m.		electro magnetic
F	..	Farad
f.		frequency
gm		gram
H	..	Henry
Hz	..	Hertz
I.C.		integrated circuit
I.D.	..	inside diameter
L		inductance
m	..	metre
mA		milli ampere
MFD		micro Farad
mV		milli Volt
MUX		multiplexer
O.D		outside diameter
R		resistance
sec.		second
SWG		Standard Wire Gauge
V	..	Volt
VPP		Volts peak to peak
X_C	..	capacitative impedance
XL	..	inductive impedance
ρ	..	density
ω	..	$2\pi f$
μF	..	micro Farad