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 discrete 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.
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 composite equipment.
Fig. 41 Front view of the underwater probe

- Suspension rope with electric cable
- Thimble
- Swivel
- Tilting support
- Rotor
- Temperature sensor
- Depth sensor
- Salinity sensor
- Fish weight
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 underwater 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 discrete 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) along with the signal conditioner (3.4) with linearised salinity values were used in this instrument. It gives an accuracy of ± .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, 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 ±0.05 salinity, ±0.05°C temperature 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 field 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
averaged over 24.5 sec. as mentioned in 3.1.2.
The ranges and accuracies are 0 to 400, ±2 cms/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 ±0.05. 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 along with 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 ICs AND COMPONENTS

The ICs 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 noise or shielding against noise.

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 cause 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 noise. 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)
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
CHANGE FOR 10-~ VARIATION
AT 30°C (0.66 V)

C → D
CHANGE FOR 10-~ VARIATION
AT 50°C (0.685 V).

SHIFTED FROM
30°C TO 50°C

SHIFTED FROM
50°C-30°C

Fig 49 TIME — 5 cms / MINUTE
A → B
CHANGE FOR 10°C VARIATION
AT 30°C (0.685 V)

B → D
CHANGE FOR 10°C VARIATION
AT 50°C (0.690 V)

SHIFTED FROM
90°C TO 30°C

SHIFTED FROM
30°C TO 50°C
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 bakelite 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 inherent problem of the LCD plates commonly found everywhere.

5.6.3 SHOCK AND VIBRATION

The equipment was taken several times onboard fishing vessels 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 UNDERWATER 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 cylindrical 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 circu-\textit{t}ing 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:

<table>
<thead>
<tr>
<th>Range</th>
<th>0 to 400 cms/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1 cm/sec</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±2 cm/sec</td>
</tr>
</tbody>
</table>
Current direction:

<table>
<thead>
<tr>
<th>Range</th>
<th>0 to 360°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1°</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±5°</td>
</tr>
</tbody>
</table>

Salinity:

<table>
<thead>
<tr>
<th>Range</th>
<th>0 to 38</th>
</tr>
</thead>
</table>
| 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, without linearisation;  
|         | ±°2 for full range with linearisation and following the linear formula;  
|         | ±°1 full range with linearisation and following the calibration graph. |

Temperature:

<table>
<thead>
<tr>
<th>Range</th>
<th>10 to 35°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>°05°C</td>
</tr>
</tbody>
</table>
| Accuracy | ±°1°C for full range,  
|         | ±°05°C for subdivided ranges |
Depth:

<table>
<thead>
<tr>
<th>Range</th>
<th>0 to 30 m, 100 m, 200 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>±1 m</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±0.1 m for 30 m</td>
</tr>
<tr>
<td></td>
<td>±0.05 m for 100 m</td>
</tr>
<tr>
<td></td>
<td>±1 m for 200 m</td>
</tr>
</tbody>
</table>

The ranges of temperature can be altered without losing 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 conversion into analogous voltage. The two outputs of the wheatstone bridge are independently 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

\[ S = R \tan (45 + KD) \]

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 obtained 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 resistors 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.