# A new instrument for simple observations of current speed and direction in the field

By

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## Summary

The paper describes an electronically controlled Savonius-type current meter with small dimensions and low weight. The start and readout of the instrument is initiated by holding a magnet outside its transparent pressure housing, through which the results are read.

Several applications are demonstrated and discussed.

Measurements of current speed and direction is of vital importance in all kinds of scientific and applied work that deal with water. To cover the need for current measurements a number of different currents meters have been developed. Most of the modern current meters that have been made during the last 10 years are designed for users that possess large ships, with winch or lifting equipment and want long series of recorded measurements. For the user who needs a simple instrument to check the current speed and direction, and for the user who does not possess expensive signal processing equipment little has been done.

Till now two instruments have been generally available for the latter user. The most known instrument of that kind is the Ekman current meter.

The Ekman current meter consists of a propeller and a compass disc. After the instrument has been placed in its measuring position, the propeller is released by the impact of a messenger. The revolutions made by the propeller are counted by a mechanical counter which also dispenses small metal spheres into compartments on the compass disc. At the impact of another messenger the propeller is relocked and the instrument may be pulled up for inspection and reading.

The major shortcoming of the Ekman current meter is frequent failing of the release and locking mechanism - in particular in cold weather. It is also impractical to use several Ekman's under each other on the same string. Rotor friction and the load of driving the revolution counter mechanism also reduce the instrument sensitivity.

The alternative choise for our non-prosperous user is the pendulum current meter. This instrument consists of a simple compass made by hanging a bar magnet from a thin thread in a transparent chamber filled with gelatine jelly. The transparent chamber is mounted on a V-shaped vane. Before use the gelatine is heated until it liquidises. When the current acts on the vane, it tilts an angle $\alpha$ with the vertical plane. When the gelatine stiffens, the compass suspension thread is locked in this angle. The bar magnet is simultaneously locked in the horisontal angle $\beta$. Now the instrument may be pulled up. By measuring $\alpha$ and $\beta$ current speed and direction can be calculated.

The pendulum current meter is cheap and lightweight, but it is cumbersome to operate in the field due to the need for heating between each measurement. Also the sensitivity and accuracy is difficult to define as the moment of freezing is unpredictable.

In summary there is a need for an instrument that combines the good properties of both Ekman and the pendulum without including their less beneficial ones.

The instrument should be lightweight, reliable, and easy to use, have a precision comparable to expensive current meters and the possibility to be checked for malfunction in the field.

For about a year a group in Bergen has been working with such an instrument.

Fig. 1 shows the mechanical design. The lower part of the instrument is a combined rotor bearing and protection cage. The upper part of the rotor contains two magnets which produce an alternating magnetic field as the rotor moves. The sensor assembly is screwed to a transparent plastic tube of outer diameter 6 cm which can take a pressure of up to 1000 m of water. The transparent tube contains a magnetic field sensor, electronic timing and counting circuits, a circuit for locking the compass, the compass itself and four penlight batteries. Total weight in air is appr. 1500 g. When the electronic circuit is active, impulses from the the magnetic field sensor are fed to a solid state counter which accumulates the number of rotor revolutions. When a current measurement has been completed, a DC - current is passed through a coil that surrounds the compass. the magnetic field from the coil then forces the compass needle to lock in its position just prior to the activation.

The use of the instrument is initiated by starting an internal clock. The clock gives impulses for each Ti seconds - Ti being typically 210 seconds. A measurement cyclus will last for Ti seconds during which the number of rotor revolutions are counted and integrated. Prior to the integration the user can program the instrument to stay insensitive to rotor signals for a delay period Td which is a multiplum of Ti.

Td = n. Ti

n is an integer (n $\geq$ o $<$ 9).

The delay period is needed to give the user time to place the instruments in the water at wanted depths.

Starting of the instrument is done by holding a small magnet, from f. ex. a magnet stirrer outside a magnet sensitive switch on the electronic card inside the tube. As soon as Td has elapsed, the rotor counts are integrated for the succeeding Ti seconds. At the termination of Ti the compass needle locks.

After this time the instrument can be brought up to the surface for reading. Reading of direction is done by inspecting the compass through the transparent instrument top. Reading of current is done by holding a small magnet outside a marked "READ"-position on the instrument. This operation activates a 3 digit pocket calculator type display which is directly connected to the counter.

For the rotor presently used (made by Aanderaa Instruments) the current speed V is calculated from the expression

$$V = \frac{21 \cdot n}{Ti} + V_t$$

$V_t$ is the treshold current value which appr. equals $1,5\,cm/s$, $n$ is the number of counts indicated on the display. For the convenience of reading Ti is often chosen equal to 210 seconds.

After reading, the compass needle is released by moving the magnet outside a third marked position called RESET COMPASS. The communications between user and instrument via light and magnetism makes it possible to operate the instrument without opening it thus reducing most of the leak hazard. The electronic circuits that are used draw virtually no power during standby conditions. Since no battery switch is needed, the batteries will last for at least several months.

A simple block diagram for the instrument electronics is shown in Fig. 2.

Suspension and mooring.

The design shown in Fig. 1 makes several modes of mooring possible. Fig. 3 shows some typical uses.

Fig. 3a shows several identical instruments hanging under each other in order to obtain a vertical current profile. For this application all instruments are started simultaneously and then placed in position.

Fig. 3b shows how the instruments are snapped on to a standard hydrographic wire without the need for cutting.

Fig. 3c shows the mounting of the instrument to a standard Nansen bottle in order to measure both current and water properties.

Fig. 3d shows how the current can be measured from a ship without adding the ships own drifting speed.

## Practical results with the instruments.

Prototypes of the instrument have been tested by several Norwegian users. In particular the Institute of Marine Research has put effort into the testing.

A typical field test was carried out in the Masfjord in Western Norway, June 1977. This is a typical Norwegian fjord. The water movement is ruled by tides, wind and freshwater run-off.

During the test the hydrographic conditions were characterised by a brackish water layer in the uppermost 2 - 3m with a strong density gradient. This gradient was strongest at the head and decreased towards the mouth. The anchor station was situated near the mouth (Fig.4) . Even here there is an increase in the density from surface to 2 m depth of about 7 $\sigma_t$ - units. Between 2m depth and 10 m depth there is a moderate density gradient, and below 10 m the water is relatively homogeneous.

Table 1 and figure 5 shows a typical event during the test. Temperature and salinity was measured by a YSI salinoterm. To measure the current velocity we used an Aanderaa current meter RCM4, in addition to our new current meters. Unfortunately not more than five new current meter were available at that time, so we used RCM4 for the measurements in 7 and 15 m depth.

From table 1 it can be seen that the current vectors coincide with the north-south direction to the nearest $10^o$ with exception of the current vector in 2 m depth. Here the direction of the current vector is $290^o$. In figure 5 the north component of this current vector is used. The explanation for why this current meter did not indicate a direction along the north-south line like the others, could be that it was near the depth where the current was reversing. The direction indicated is the mean direction over a vertical column equal to the height of the current meter, which is 43 cm. The speed is indicated by the Savonius rotor which represent the lowermost 7 cm of this column. Therefore it is possible that the speed indicated by the rotor is in fact directed straight southward.

The current velocity profile in figure 5 is characteristic for a 34 hours period from 21 June, 23 hours to 23 June, 09 hours. During this time the the wind headed north with a speed, $U_a$, varying from 4m/s to 6/ms with an average of about 4, 5m/s. This shows how the estuarine circulation can be reversed even over a longer period of time due to wind effects. Assuming that current velocity increases linearly from 2m depth to the surface, the surface current will be 37cm/s. This indicates a wind factor, $\frac{U_w}{U_a}$ 100%, of about 8%, and shows the effect of stratification on wind current, $U_w$. The measurements are in good agreement with earlier measured and calculated wind factors. (PICKARD and RODGERS, 1959), (GADE, 1970), and (RYE, BRUUN and HOUMB, 1974).

DISCUSSION.

The field tests have shown that the new current meter is well fit for making instantaneous current velocity profiles in fjords and coastal waters. During the tests we operated 5 current meters, but we could easily have operated up to 10 meters. Due to small dimensions and low weight it is easy to pay out the current meters by hand on a string, even from a rowboat.

When the current meters are operated from an anchored ship, it seems most convenient to use them in "gallows" attached to the hydrowire as seen in Fig. 3b. To eliminate distortion of the earth magnetic field from the ship hull, the hydrowire ought to be kept at least 2 meters from the ship-side, at least for the current meters that are used in the upper 5 meters. During the test we experienced some problems with sufficiently

strong clamping of the compass needle. When the instrument struck against the ship side - as the instruments were taken in - the compass needle would sometimes jump from its original clamped position to another arbitary one - depending on the impact energy.

This problem will be eliminated in a future design in which the compass will be read electronically. The compass angle will then be stored in a similar solid state memory as presently done with the current speed information. This will both eliminate the compass reading hazard and reduce power consumption.

In a future design it is also planned to increase the current meter memory capacity to make room for e.g. 1000 individual measurements of current speed and direction. This will enable an easy sampling of the current variations over e.g. one tidal period. Readout of data in the new instrument may be done via the display as now or by transferring the information to a printer via a convenient plug.

The current meter must be used with care in regions with strong gradients as the vane that detects the direction is appr. 20cm higher up than the current speed sensor.

Measurements in the wave zone must also be performed with care. With an integration time of 3,5 minutes and sampling of the direction at the 'end of the integration period, a considerable bias between direction and speed may occur. HALPERN and PILLSBURY (1976) measured the difference in kinetic energy between Aanderaa RCM4 and an AMF current meter which records speed and direction continuously. At high current fluctuations the RMC4 indicated up to 10 times higher kinetic energy than the AMF-instrument.

The use of surface buoys can also bias the current velocity. LOENG (1976) showed that the current velocity indicated by an Aanderaa current meter 4m below a surface buoy could be 6 times higher than the current velocity from a fixed point.

References.

GADE, II.G. 1970. Hydrographic Investigations in the Oslofjord
        Report 24 Geophysical Institute, University of Bergen,
        1970.

HALPERN, D. and PILLSBURY, R.D. 1976. Near-Surface Moored
        Current Meter Measurements. MTS Journal, 10(7): 32 - 38.

LOENG, H. 1976. A Comparison of Current Meters and Mooring
        Methods in the Kattegat. Report 43, Geophysical Institute,
        University of Bergen, May, 1976. 17pp.

PICKARD, G.L. and RODGERS, G.K. 1959. Current Measurements
        in Knight Inlet, British Columbia. Journal of the Fisheries
        Research Board of Canada, 16(5): 635 - 678.

RYE, II., BRUUN, P. and HOUMB, O.G. 1974. Wind Currents in the
        Langfjord, Norway. Report from the River and Harbour
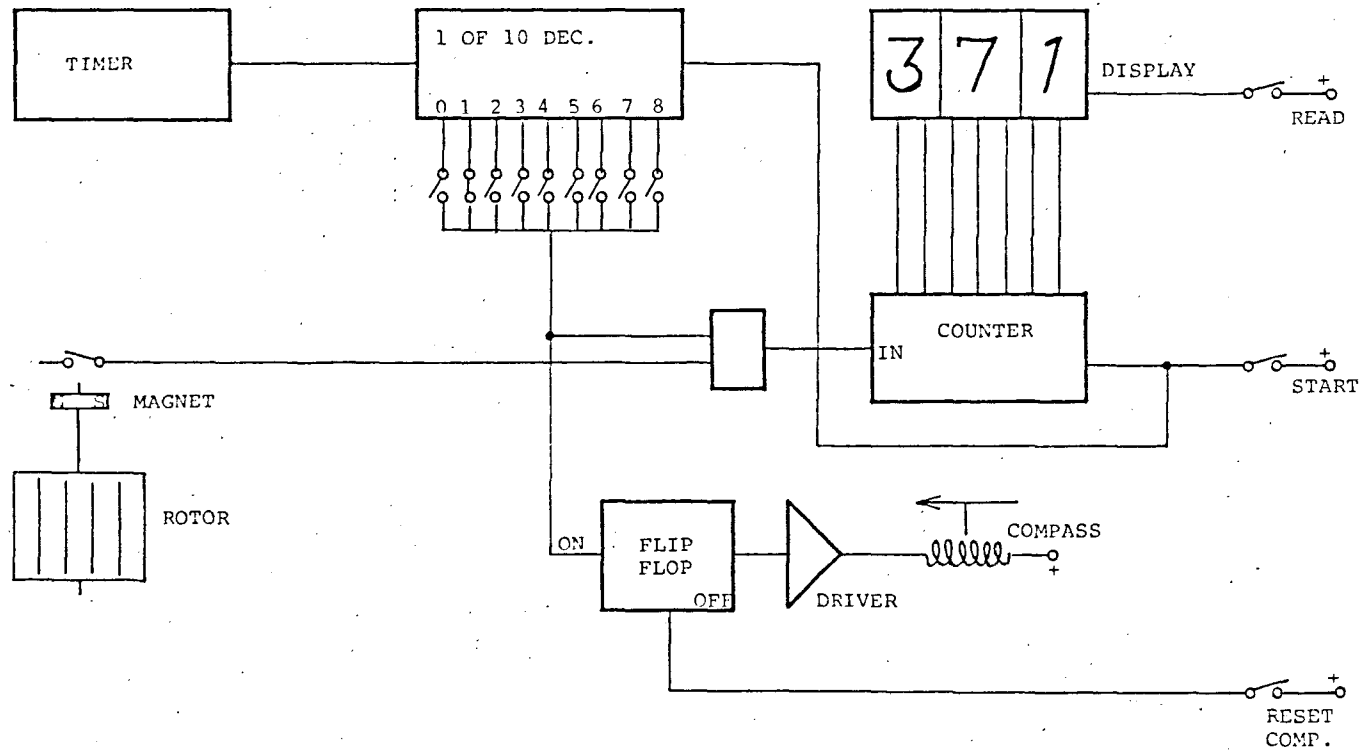        Laboratory, University of Trondheim, May 1974. 36pp.

ROTOR

COMPASS        VANE

O-RING

SUSPENSION

READ        RESET

CONTROL-LAMP

START

43 CM

K        22 CM

O-RING        BATTERIES

ROTOR

16.5 CM

Fig. 1

TIMER

1 OF 10 DEC.

0 1 2 3 4 5 6 7 8

3 7 1   DISPLAY

READ

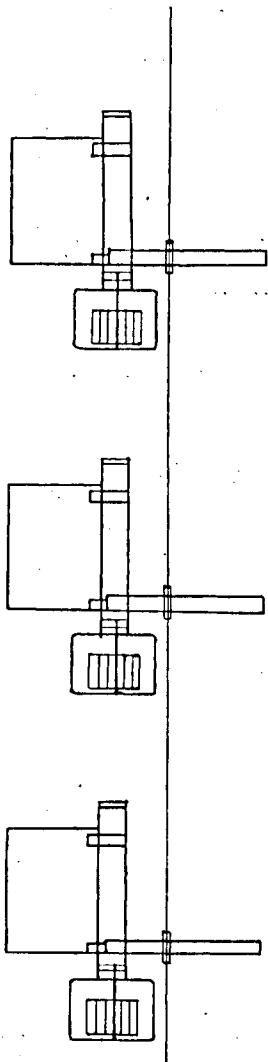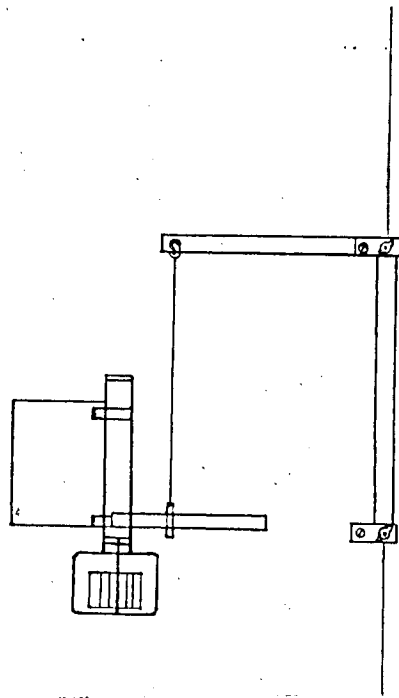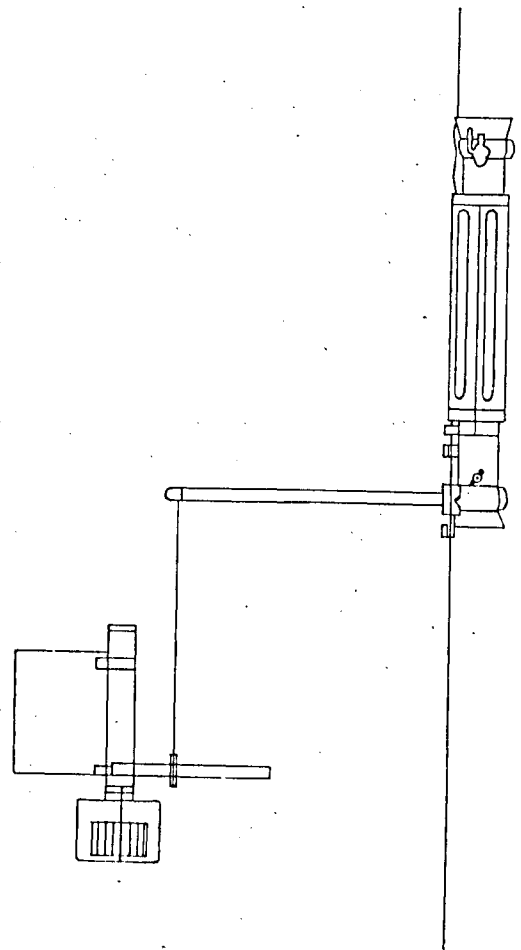MAGNET

ROTOR

IN   COUNTER
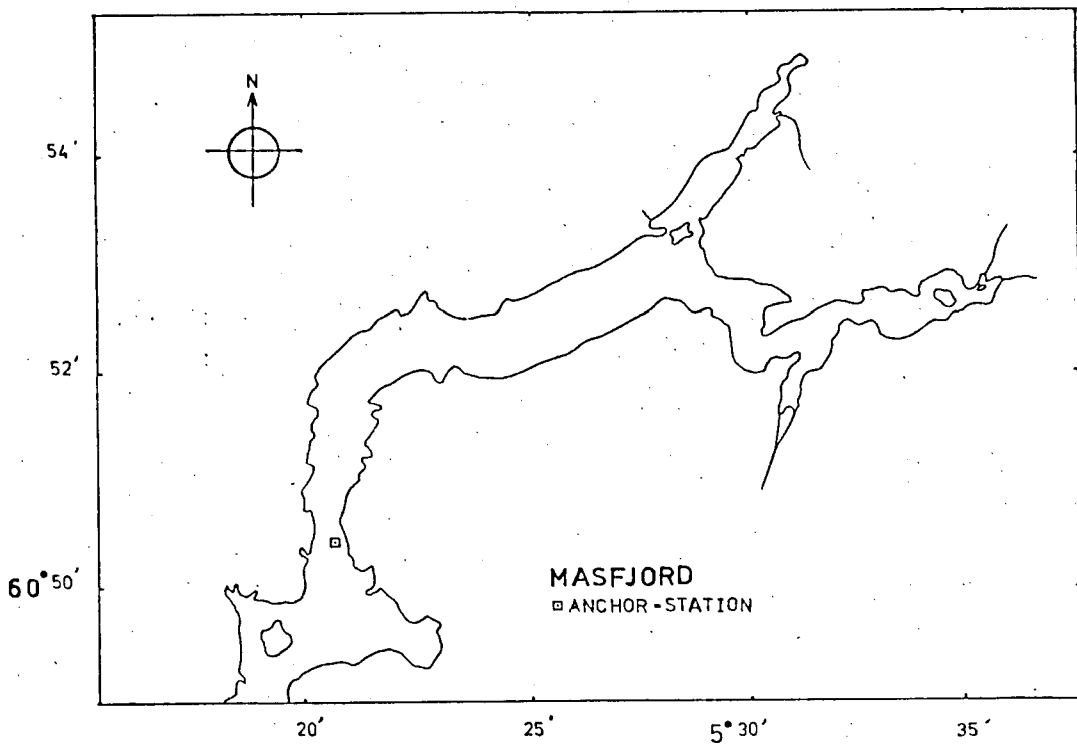
START

ON

FLIP FLOP

OFF

DRIVER

COMPASS

RESET COMP.

Fig. 2.

a)

b)

c)

Fig. 3.

Fig. 3d.

Fig. 4.
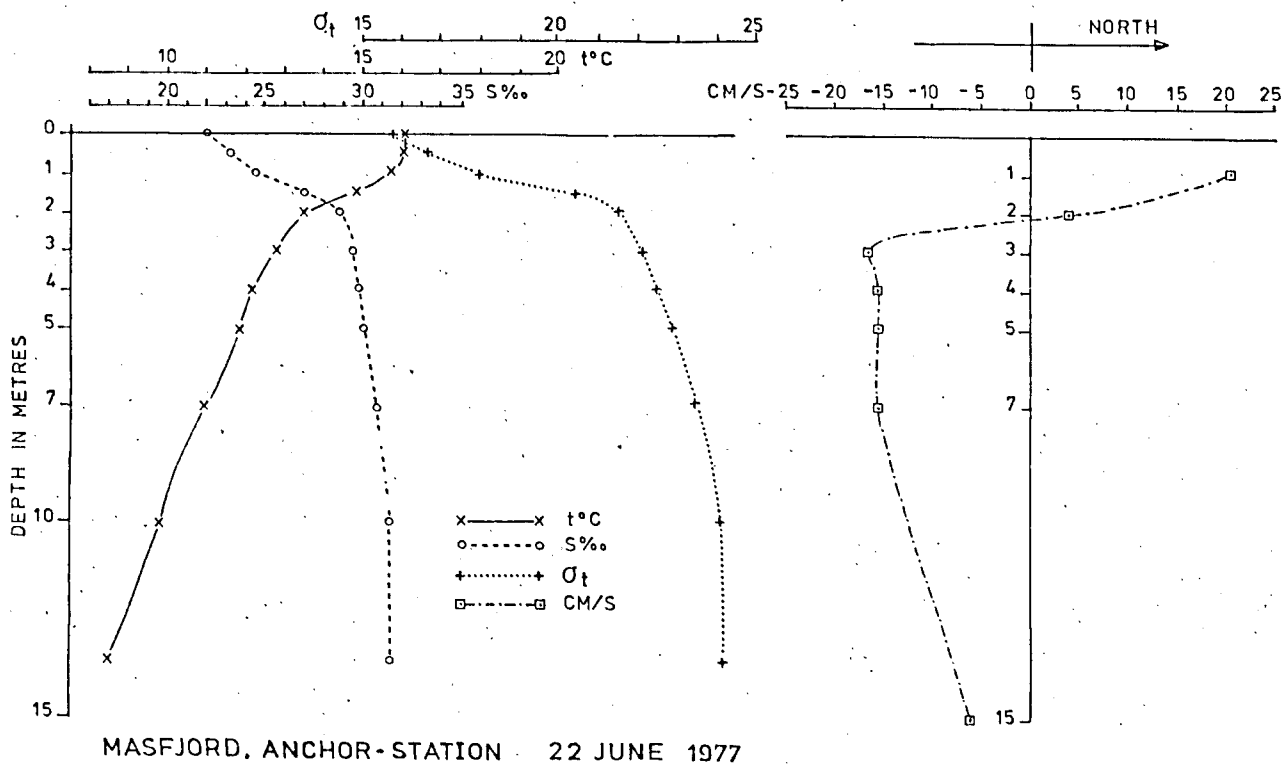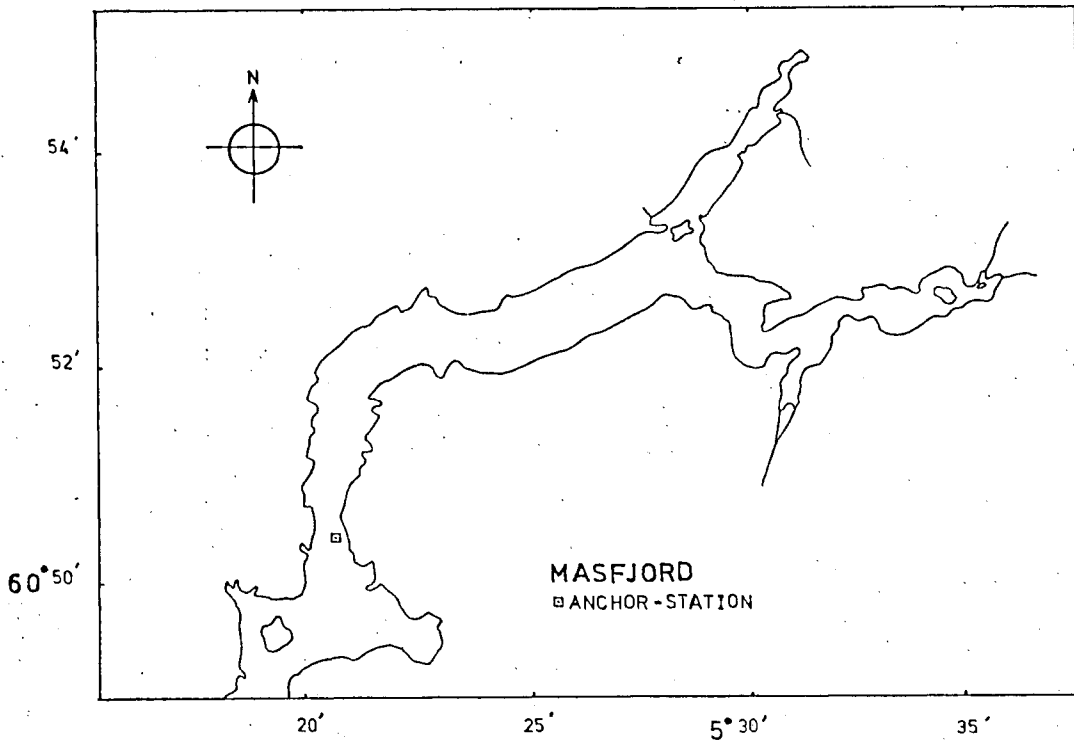


MASFJORD. ANCHOR-STATION    22 JUNE 1977
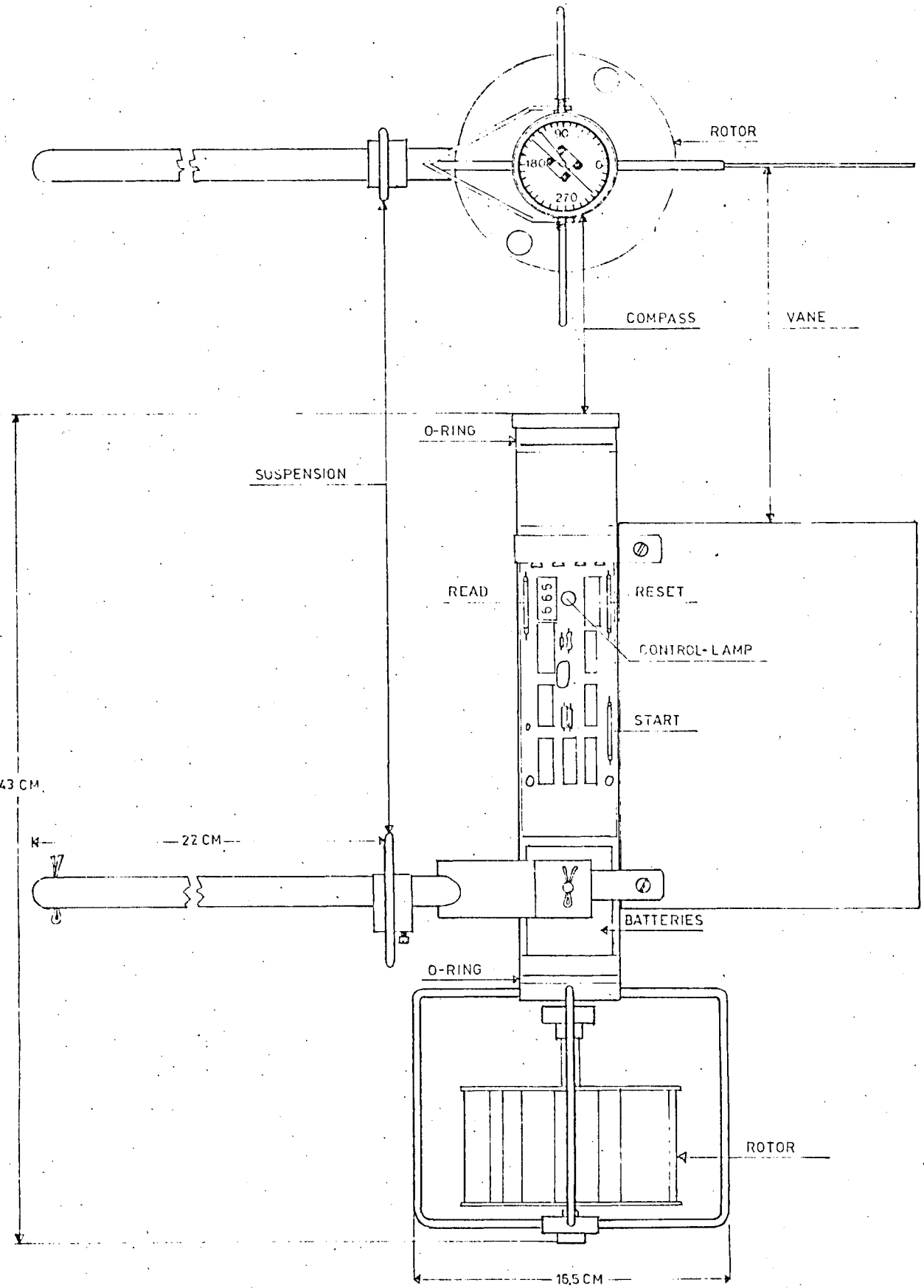
Fig. 5.

Fig. 4.
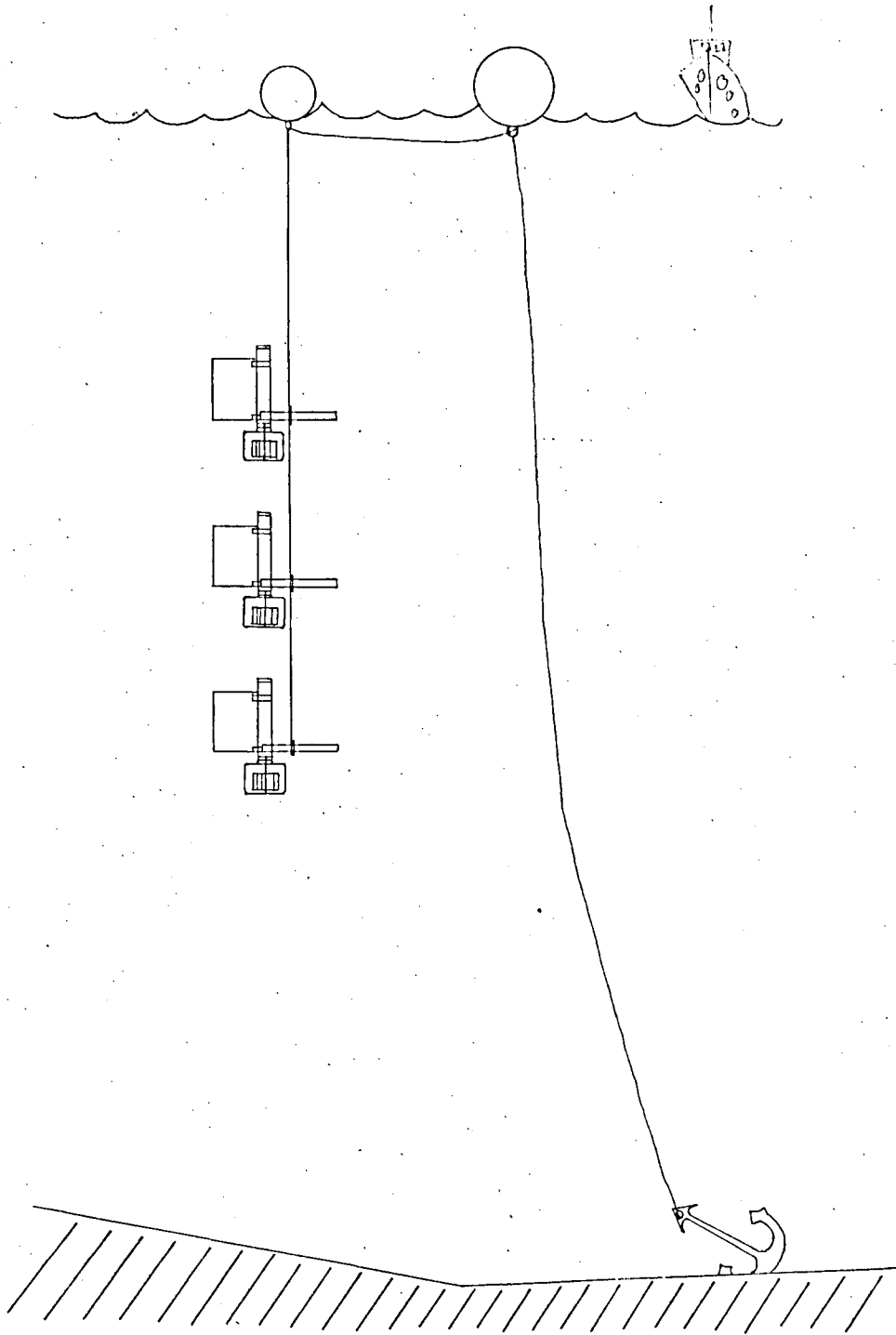


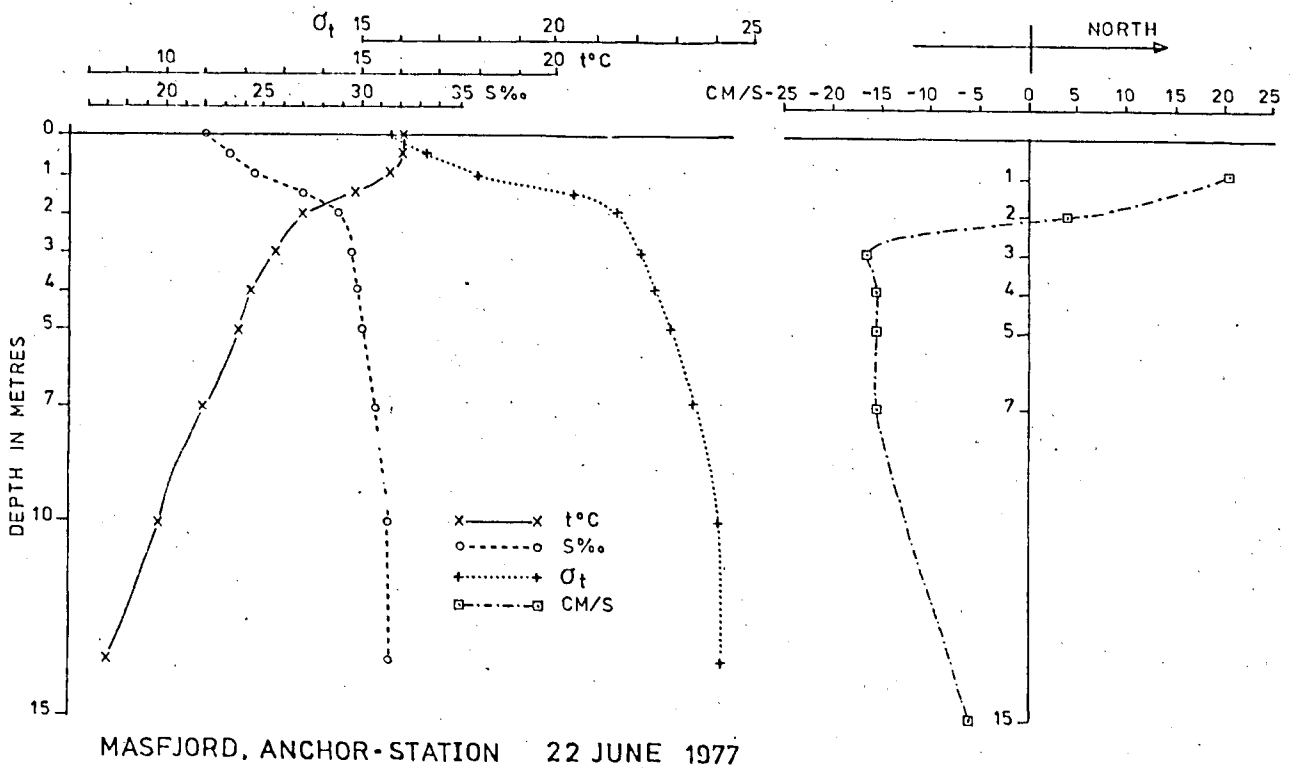MASFJORD. ANCHOR-STATION    22 JUNE 1977

Fig. 5.

Table 1.

Anchor Station, Masfjord, Norway
22 June 1977, 2130 hours.

| DEPTH m | TEMPERATURE °C | SALINITY | $\sigma_t$ | CURRENT SPEED cm/s | CURRENT DIRECTION |
|---|---|---|---|---|---|
| 0 | 16,0 | 22.0 | 15.8 | | |
| 0.5 | 16.0 | 23.2 | 16.7 | | |
| 1.0 | 15.7 | 24.5 | 17,8 | 20.7 | 350 |
| 1.5 | 14.8 | 27.0 | 19.9 | | |
| 2.0 | 13.5 | 28.8 | 21.5 | 6.7 | 290 |
| 3.0 | 12.8 | 29.4 | 22.1 | 16.6 | 180 |
| 4.0 | 12.2 | 29.8 | 22.5 | 15.6 | 170 |
| 5.0 | 11.9 | 30.0 | 22.8 | 15.8 | 170 |
| 7.0 | 10.9 | 30.7 | 23.5 | 16.5 | 160 |
| 10.0 | 9.8 | 31.3 | 24.1 | | |
| 13.5 | 8.5 | 31.3 | 24.2 | | |
| 15.0 | | | | 5.7 | 185 |

Fig. 1.   Mechanical design of the new current meter.

Fig. 2.   Block diagram of the current meter electronics.

Fig. 3.   Typical ways of using the instrument
        A   Taking a vertical current profile
        B   Snapping it to the hydrowire
        C   Combining a current measurement with a hydrographic
            cast.
        D   Measuring current from a ship without adding the ship's
            own drifting speed.

Fig. 4.   Map showing a selected anchor station near the mouth of a
West Norwegian fjord.

Fig. 5.   Measurements of current, salinity and temperature at the
anchor station shown on Fig. 4 during June 1976.