CHAPTER 114

THE MEASUREMENT OF TIDAL WATER TRANSPORT IN CHANNELS

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Summary

For the electromagnetic flow measurement in straits, channels etc use is made of the electric potential difference between two points in the bottom, near the moving water. The potential difference can be put down to natural causes the water is an electric conductor and moves in the magnetic field of the earth There are a number of quantities and variables that are of importance for the measured signal Beside this, the measurement is above all a matter of eliminating some disturbances

Information about the two measuring systems as applied in The Netherlands is given in this article

Introduction

The principle of the electromagnetic flow measurement in rivers, straits etc. has been known now for about 140 years ever since Faraday conceived the idea in 1832. But it is only in the last 30 years that it has more or less successfully been used at several places in the world [2, 3, 4, 5, 6]

In The Netherlands it has now been adapted to far smaller flows (the measurements in Washington excepted [4])

In 1964 Schumm started the investigations [7, 8]

Several difficulties had to be overcome, some of them may be of importance to those who want to apply the method themselves

At present there are two measuring systems in use

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The physical background

The method makes use of a natural phenomenon Throughout the world, water moves in the magnetic field of the earth Because water is an electric conductor, an electric potential field occurs in the water and, as a result, also in the surrounding ground, fig 1 The potential difference measured between the electrodes in P and Q or P and R is a function of all velocities in the channel, and depends also on other quantities and variables such as "the" conductivity of the water and the bottom, the shape and size of the channel, relative changes of the depth by changes of the waterlevel, the vertical component of the magnetic field B etc
The theoretical basis was laid by M.S. Longuett-Higgens in 1949 [1] and in 1964 extended by Schumm [7], but the problem is very complicated, so that our knowledge remains relatively limited
The proposition is now, that this potential difference depends only little on the velocity distribution (except in very shallow, wide straits), so that in many cases it is allowed to calibrate against mean velocity, discharge etc
The influence of the vertical component of the magnetic induction B on the calibration is obvious Fortunately in most cases it is constant enough when taken over a few years to neglect its variations. The magnetic disturbances are very small relatively and they are only an additional effect that can be compensated
The effect of the other quantities and variables is very complicated Therefore the systems are calibrated with a number of simultaneous velocity measurements, for instance once a year
The measured potential difference is highly dependent on the conductive properties of the bottom The higher it is, the lower the potential difference measured will be and the higher the influence of changes of the conductivity of the water and the waterlevel (tidal range) In The Netherlands the conductivity of the bottom is very high up to a depth of 1 km it is about one tenth of that of seawater It causes a loss of 80 percent and it is necessary to take into account the influence of the temperature on the conductivity of the water (knowledge within 3^{o} C is adequate).

In the two cases with which we are concerned it was found that the influence of the waterlevel is such that the system does not give the mean velocity but the discharge

It may be expected that the accuracy will range from 5 to 10%

The problem of the disturbances

The elimination of all kinds of disturbances is an important problem, especially in The Netherlands where the level of the signals is very low.

Four kinds are mentioned here

1. Magnetic disturbances

   Along the surface of the earth potential gradients are generated by the fluctuating magnetic field (especially the horizontal component) of the earth

   As already stated they give additional signals

   They are eliminated by compensation by means of two signals, measured far away from any flow, in two directions perpendicular to each other, between electrodes in the ground in the same way as the measurement of the flow signal fig. 2

   Thus

   $$V_{flow} = V_{PQ} - \alpha V_{AB} - \beta V_{BC},$$

   is formed,

   where α and β are suitable constants

   In our cases, where the distance between P and B is for example 15 km, the elimination is very satisfactory

2. Earth currents caused by the electric DC railway traffic

   They may cause heavy disturbances, depending on the distance to the railway system, the intensity of the traffic, the conductivity of the top layers of the bottom etc

In most cases the only thing to do is to avoid them, for instance by choosing great distances (10, 20 km) to the disturbing railway In one case the influence could be reduced by compensation with a signal measured between two points in the neighbourhood of the railway and also by choosing an adequate direction of the line between the measuring points

3 Electro-chemical disturbances in the bottom and in the electrodes

There are always fairly constant potential differences between two points in the earth They are caused by local and extended differences in the composition of the ground water and the bottom The variations in the compositions result in a drift of the zero level It can be a long-term drift, but drift with the tidal frequency is also possible for example if the electrode is placed in the neighbourhood of the boundary between the fresh and the salt water in the shore This boundary may move under the influence of the tidal changes of the water pressure, giving a slight mixing each time

The electrodes are now placed in 5 to 10 m deep pipes, as far as possible from moving or fluctuating ground water This also has the advantage of a sufficiently constant temperature

We developed special purpose Ag-AgCl-electrodes They are constant within ± 0,5 mV for a period of one year (in the laboratory) We found that many kinds of electrodes (and also ours) are extremely sensitive to electric currents, giving a long-term drift Therefore it was necessary to place a voltage follower between the electrode and the long line that connects the measuring point with the mV-meter

In one place we found a drift of the zero level as low as 0,5 mV in a week, but at other places it is greater

4. Noise

The noise that is picked up by the wires used in the telephone cables to connect the measuring points with the apparatus mainly consists of pulses and hum
Sometimes the peak value is 1000 times the signal to be measured
It is eliminated by normal filtering after the compensation of the magnetic and other disturbances has taken place, this to avoid differences between the compensating and the compensated signals

The measuring systems in The Netherlands

At present there are two measuring systems in use in the north of The Netherlands, fig. 3, for measuring the tidal flow in the Borndiep and the Marsdiep A third, in the Eyerlandse Gat, is being prepared

The Borndiep system

The Borndiep system, fig 4, has three measurements for the flow (between WD and WM, OD and WM and ZD and ZM) The measurement for the magnetic compensation is between WM and OM and WM and ZM
There is a level gauge for additional data on the "Vrijheidsplaat"
An example of the measurement between ZD and ZM, the two magnetic signals and the result is given in fig 5 The amplitude of the flow signal is 3 mV, it is the lowest signal we can measure (low electro-chemical disturbances)
Fig 6 gives an example of the flow according to "ZD - ZM" and the water level measured on the "Vrijheidsplaat"
In the middle the effect of a storm in the far distance the region between the Atlantic Ocean and the North Sea

The Marsdiep system, fig 7

The potential difference according to the flow has been measured between ZD and ND, between the electrodes in ZM, NM and OM the two magnetic signals are measured
The electric DC railway traffic causes heavy disturbances
Fortunately it is an uncomplicated case In this case compensation is possible We use the (large) signal measured between ZD and T
Due to the extensive clay layers deep in the bottom pronounced induced polarisation influence occurs It causes differences in the shape of the disturbances measured between the several points and these differences grow with the distance to the railway The ZD-T-signal must therefore be filtered so that it gets the right forms before it is used for compensation
Fig 8 is an example the disturbed flow signal, the three compensation signals and finally the result
The compensation of the railway disturbances is satisfactory, but not of the same quality as that of the magnetic disturbances If necessary, it is possible to make improvements by digital filtering or the extension of the compensation system.
The only calibration available at the moment is that of a former experimental system at the Marsdiep, fig 9
It did not work with ZD and ND but it did at two other points, one of them with more than normal electro-chemical disturbances, as will be seen on the right
We are now building a third system for measuring the flow in the Eyerlandse Gat It measures the flow signal between ZD' and N and uses the magnetic compensation signals of the Marsdiep system
A fourth system may be built next year in the straits east of Ameland

Other applications

The method is also suitable to obtain information on the flow along a coast The most simple set-up makes use of one electrode near the coast and one far inland

The signal gives a weighted average of all velocities, the weighting factor depending on the distances to the two electrodes Unfortunately we know only little about these factors theoretical research is necessary

The flow signals of rivers are usually too small to be measured by applying the present method, due to the relatively small discharges
We are now working on a modified method for fairly big rivers This method makes use of an artificial alternating magnetic field in order to separate the signal from the noise

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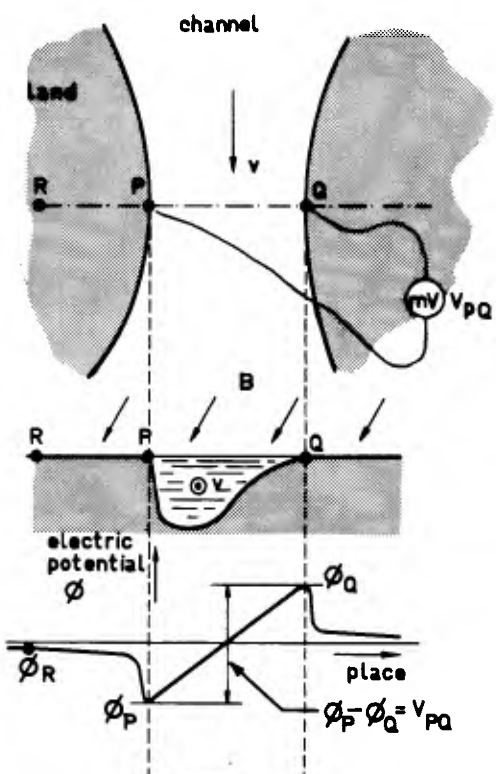

fig.1

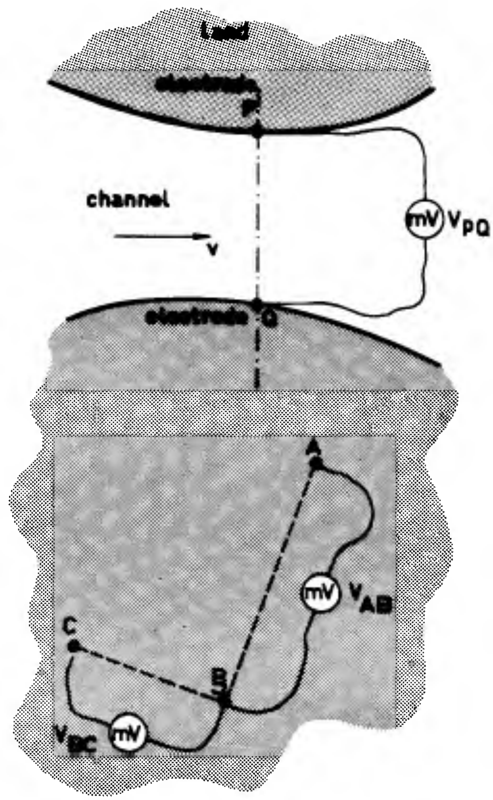

fig. 2

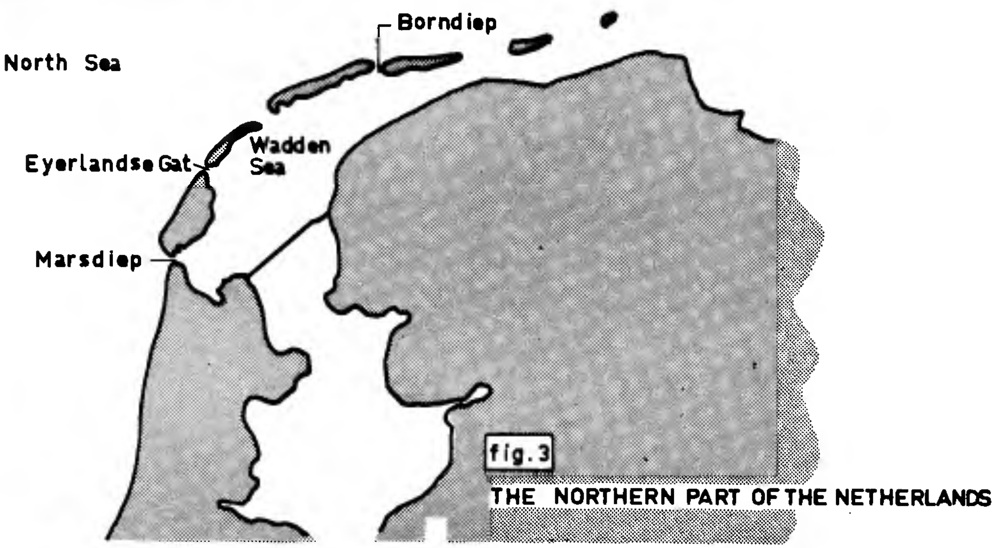

fig. 3

THE NORTHERN PART OF THE NETHERLANDS

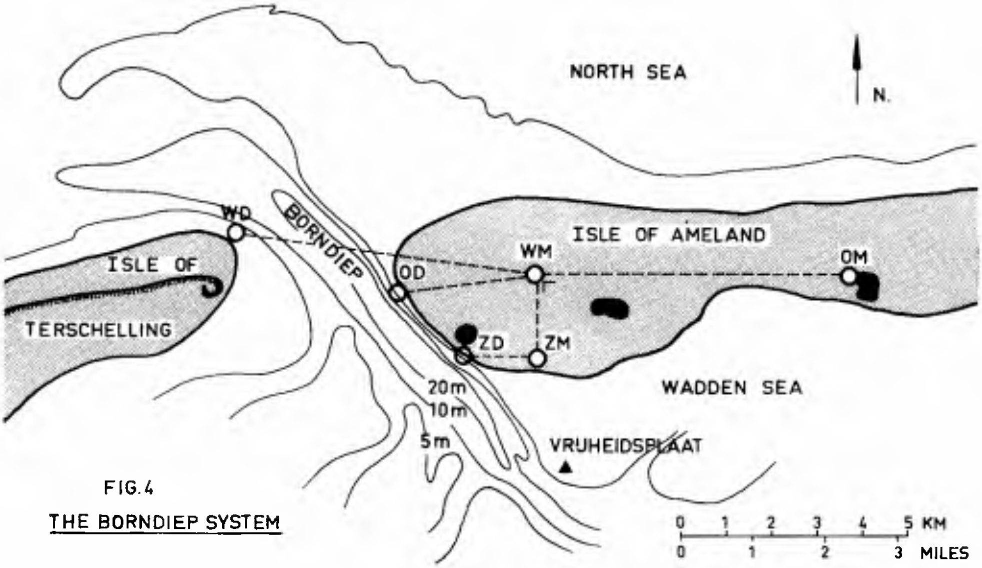

FIG. 4
THE BORNDIEP SYSTEM

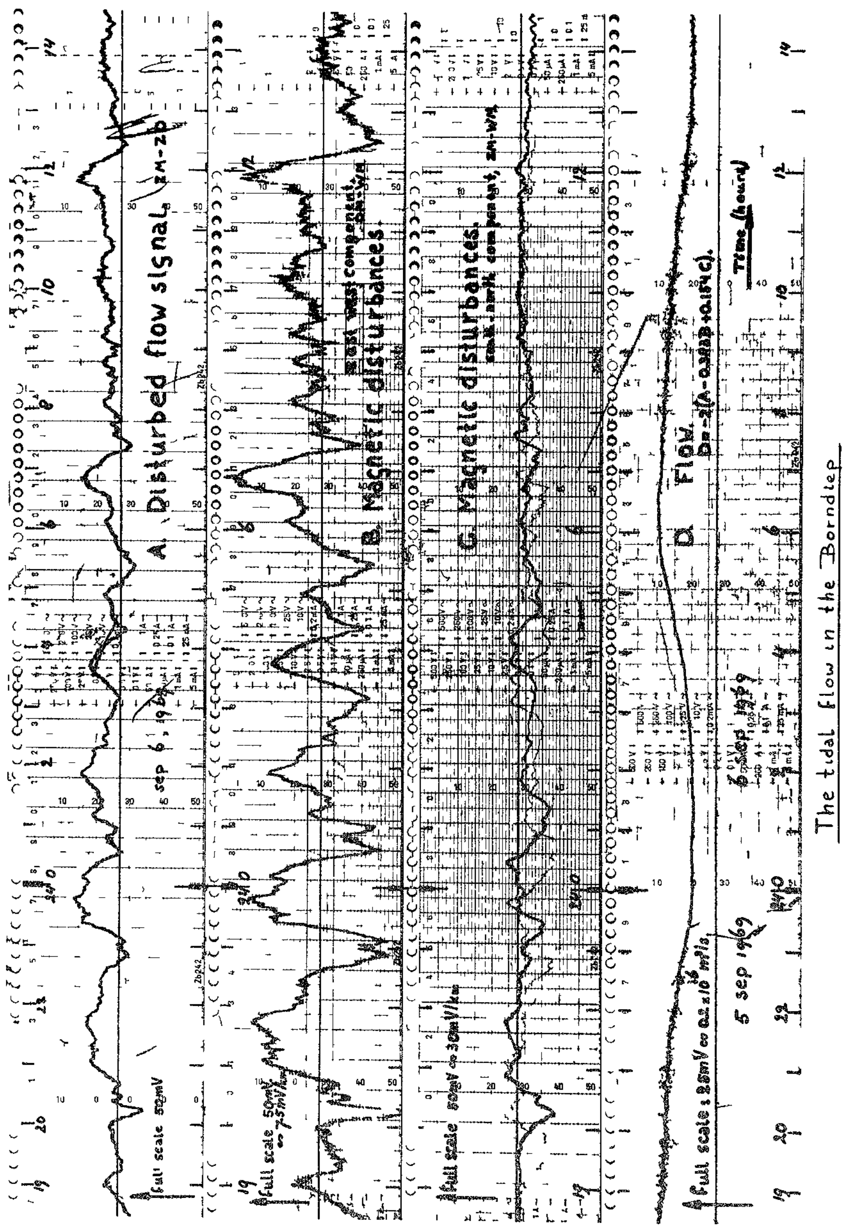
A. Disturbed flow signal, ZM-ZB
B. Magnetic disturbances
east west component, ZB-WB
C. Magnetic disturbances
mag. north component, ZM-WM
D. Flow
Time (hours)
5 sep 1969
6 sep 1969
The tidal flow in the Borndiep

FIG 5

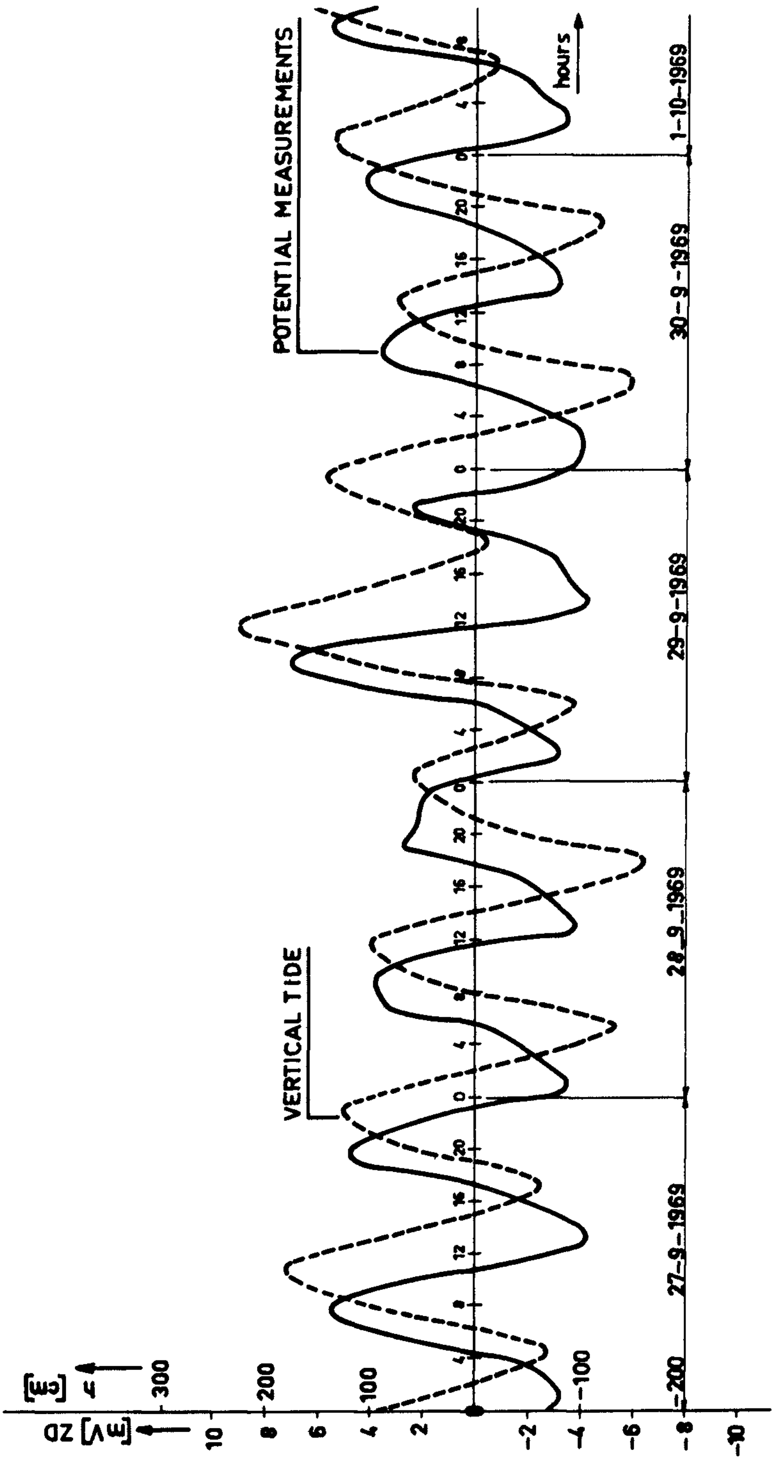

FIG 6 BORNDIEP SYSTEM

Flow and tide from 27 sep to 1 oct 1969

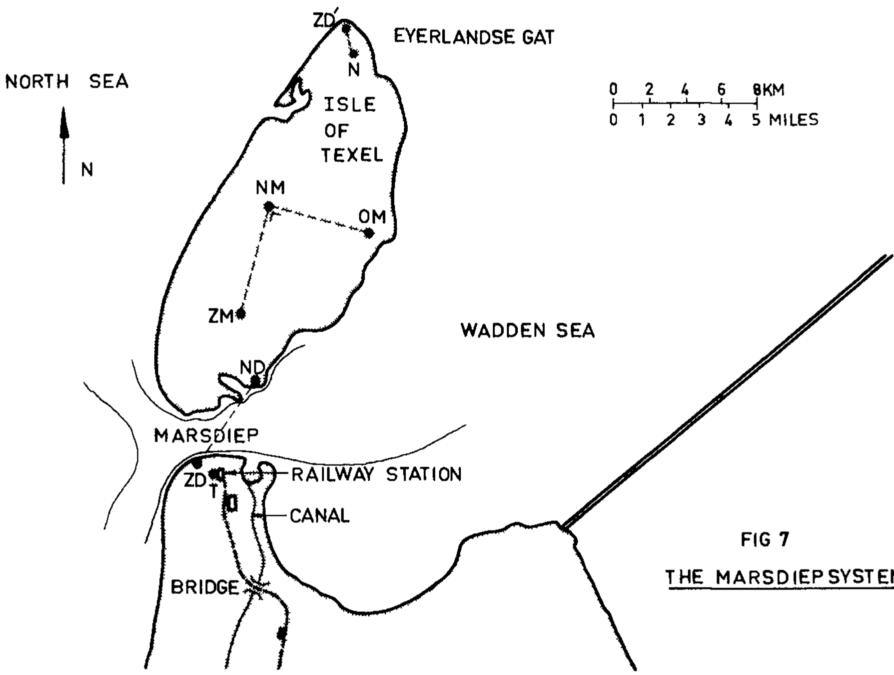

FIG 7

THE MARSDIEP SYSTEM

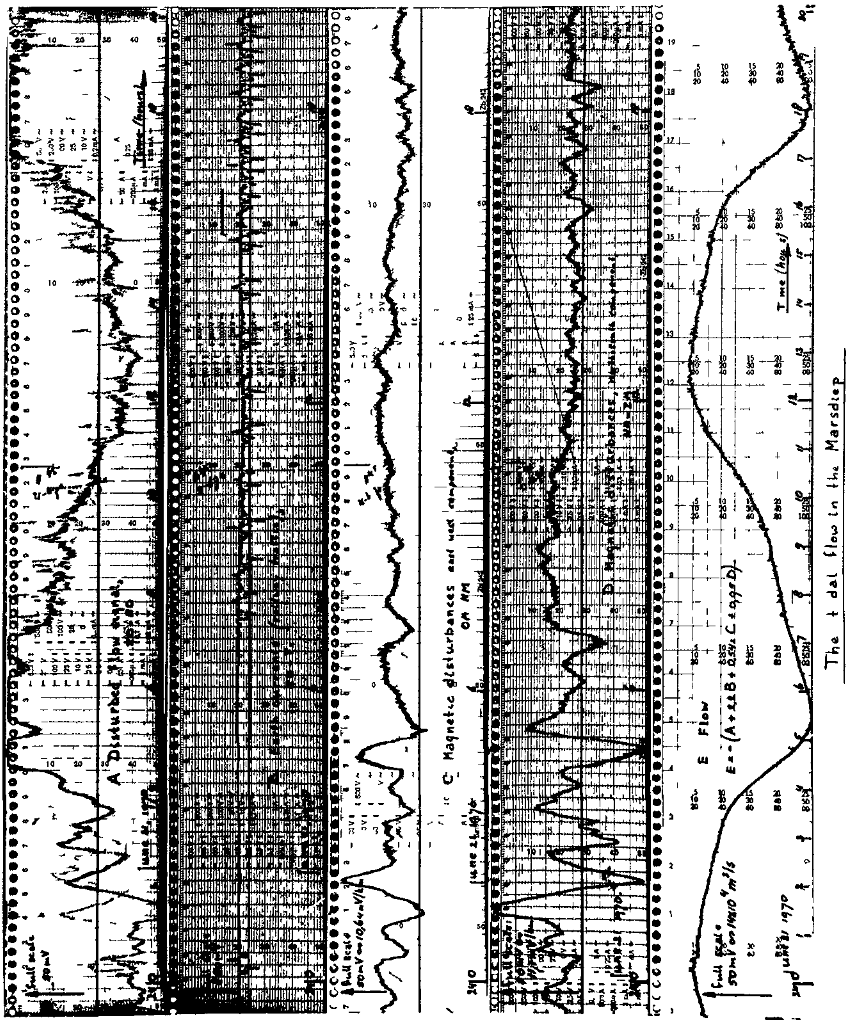
A Disturbed flow signal
C Magnetic disturbances east west component
D Magnetic disturbances, north south component
E Flow
The t dal flow in the Marsdiep

FIG 8

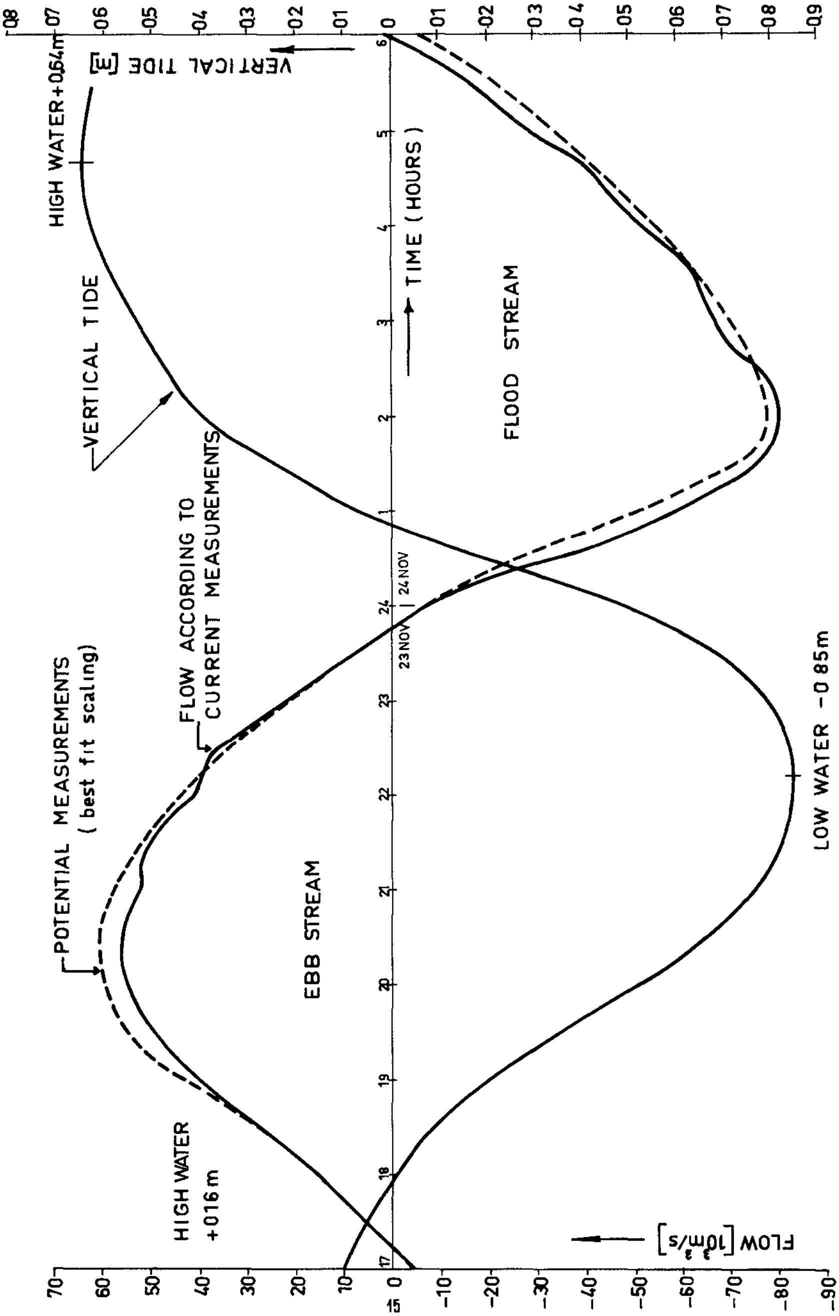

FIG 9 MARSDIEP NOV 23th-24th-1966

Calibration of a former, experimental system