HYDROGRAPHIC SURVEYING FOR OIL EXPLORATION AND EXPLOITATION

by S. HERSCHDÖRFER and G. KUIPERS (*)

NOTE ON AUTHORS

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Mr. Herschdörfer, born in 1901, started his career with the Shell Group in Roumania in 1929. In 1937 he was sent to the Far East, where he worked in Sumatra, Java, Borneo and New Guinea, initially as a senior surveyor and later as chief surveyor. In 1952 he came back to The Hague and in 1956 he was appointed Head of the Topographical Division.

Mr. G. KUIPERS was technical assistant to Mr. Herschdörfer, in charge of topographic and hydrographic materials and the development of special instruments in oil surveying. Born in 1900, he started his career with Shell in 1926 and, apart from a few years in Venezuela, worked in B.I.P.M.'s head office in The Hague until he reached retirement age in June 1960.

In our time, maps and charts have become an indispensable tool for economic and social development. Maps of all kinds are needed for projects in the spheres of land utilization, forestry, soil conservation, civil engineering design and construction, communications, etc., and, of course, also for the exploration and exploitation of mineral resources.

Hydrography has long been recognized as a means of obtaining charts for maritime communications. International navigation still depends on the exploration and exploitation of mineral resources.

However, one result of the constant increase and intensification of the world's shipping traffic is that the task which these services have taken upon themselves can never be considered as completed. Relatively few of the coasts and navigable rivers of the world have been adequately mapped. Moreover, changes in the depths of water and in coastlines and adjacent features, effected by nature or by man, render new charting and revision surveys permanently necessary.

(*) Bataafse Internationale Petroleum Maatschappij N.V., The Hague (Royal Dutch/Shell Group) : Topographical Matters, Exploration and Production Division.

Surveying in the oil industry

Surveying for the benefit of the oil industry differs fundamentally from surveying as performed by government bodies. The work of the latter is generally based on long-range programs, and their visible results, mainly maps, are mostly for public use. Surveying for the oil industry, however, is not self-contained but forms part of one great engineering project, i.e. exploration for, production, transport and finally manufacture and marketing of oil.

An oil surveyor is expected to be an all-round man. As a member of advance exploration parties in undeveloped areas, he must have the technical and organizing capacities of an explorer and must be able to traverse tropical swamps, jungle-clad mountains and sand deserts. He must have enough knowledge of civil engineering to be capable of collecting in the field all data which will be of use in designing technical installations; he must also be competent to carry out and supervise layout surveys and sometimes even to organize and supervise the execution of such projects as roadbuilding and pipeline laying. The surveyor in the oil industry has to be conversant with all aspects of his profession, both classic and modern. Land and geodetic surveying, photogrammetric and engineering surveying, are regularly applied in the search for oil, and the industry makes use of surveying methods ranging from elementary to highly advanced.

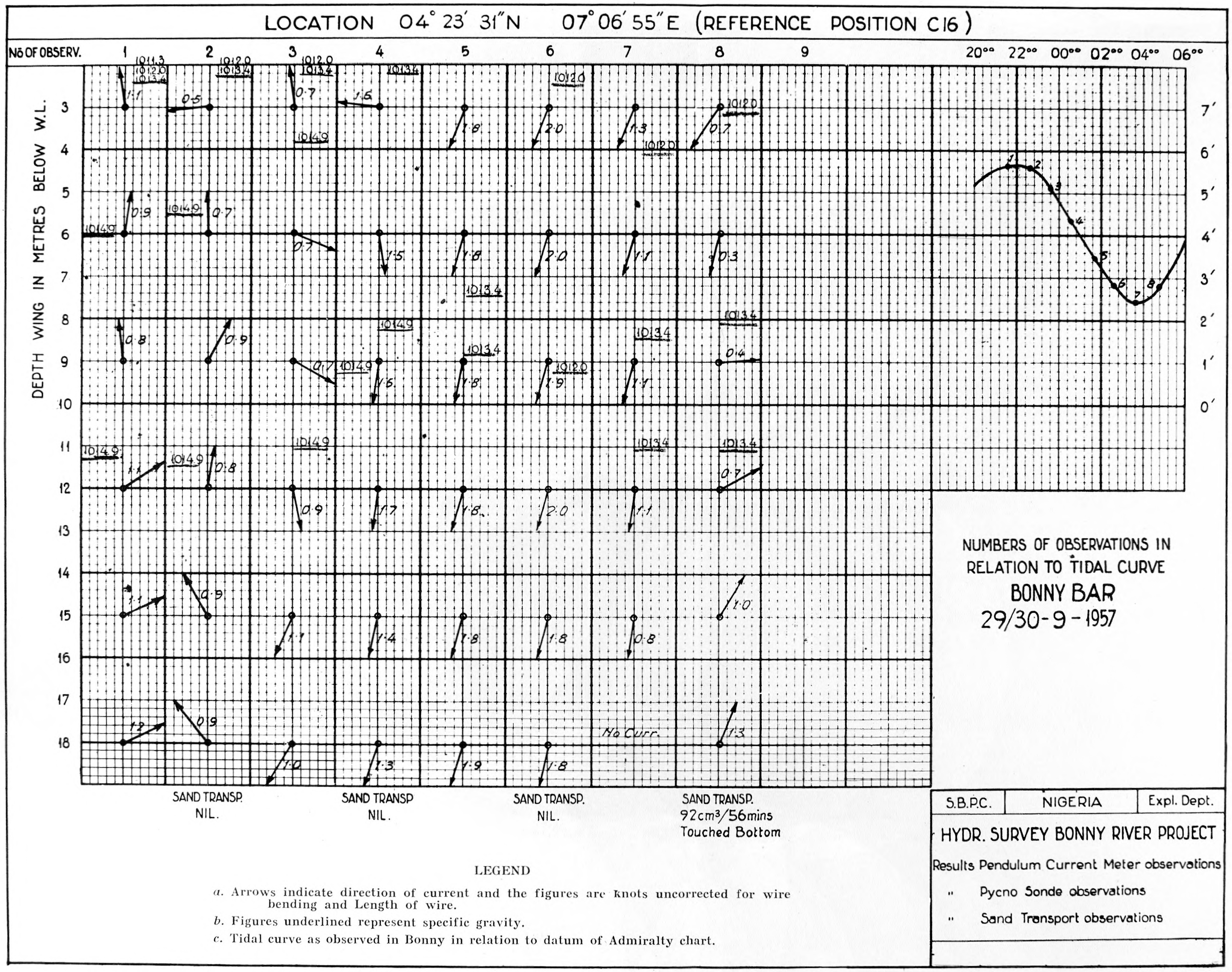
Hydrographic surveying in the oil industry

In one way or another, all surveyors working in underdeveloped countries have to do with hydrography. Submerged territory, including not only tidal marshes and flats and inland waters but also offshore areas, is often included in the survey of the adjacent land exploration areas. And the surveyor gradually comes face to face with the techniques of hydrographic surveying and the meteorological and oceanographic problems connected with it.

Without doubt, the rapid rise of offshore exploration and exploitation has created many new and important problems in hydrographic surveying, as regards not only offshore position fixing, but also hydraulic engineering. However, the incredible progress made in developing survey tools and methods since the war has also made it possible to adopt a modern and less uncomfortable approach to this branch of surveying.

The geodetic framework required for surveys on land is also required for surveys on partly or wholly submerged territory, and consequently for the maps or charts of these areas, intended to show either geological features or drilling sites, oil harbours, pipelines, floating marine installations, etc. Such a framework is usually in existence in highly developed countries, but in many regions where the oil industry is working it has to be created by the industry itself.

If we may use " position fixing " as a comprehensive term to cover not only the different kinds of surveying for geodetic framing, but also detail surveying, the hydrographic oil-surveyor will have to deal with triangulation, trilateration, intersections and resections by theodolite or sextant,



LEGEND

a. Arrows indicate direction of current and the figures are knots uncorrected for wire bending and Length of wire.

b. Figures underlined represent specific gravity.

c. Tidal curve as observed in Bonny in relation to datum of Admiralty chart.

Fig. 1.

levelling of first and lower orders, astrofixing, taut-wire traversing, Radar, Decca (map A), Raydist, Geodimeter, Tellurometer, and other electronic systems.

Hydrographic work often presents itself as a necessary supplement to a land survey. The most frequent task in this respect is sounding, which provides a picture of the depth of the sea and the slope of the sea bottom, and furnishes the necessarily accurate knowledge of the configuration of channels and fairways to harbours and navigable rivers (Map B).

Contour lines of sea or river bottoms, obtained from soundings, might be used for quantity computations in dredging or deepening channels, or for computation of the topographical corrections in offshore gravity work. Isobathic lines are also helpful when a flat sea bottom is to be chosen for siting a submersible offshore drilling barge.

The necessity of reducing sounding to a common datum makes tidal surveys a basic element in hydrography.

In many instances it will be possible to transfer an accepted datum to another place. But as oil exploration is often carried out in undeveloped and mostly uncharted regions, establishment of a new datum, or better still of several datums, for land and hydrographic surveying is inevitable, the more so as, later on, when exploitation starts, tide tables will have to be compiled for special points, e.g. for oil terminals. These tables are computed by the Liverpool Tidal Institute from long-range tidal observations.

Design engineering may require registration of the salinity and temperature of the sea water at different depths, the currents and the transport of sedimentation material in channels and at the mouths of rivers (see fig. 1).

Observation of wind and waves is also part of the task of the oil surveyor, especially in the initial period of a new venture. As meteorological conditions play a great role in offshore work, long-term weather predictions are now in the hands of men specialized in this new and rapidly developing science.

The general principles and practice of hydrographic surveying are applied by the oil surveyor in the same way as by naval hydrographers. The manuals of hydrographic surveying of the different naval hydrographic departments are very much appreciated by the topographical departments of the oil industry. However, in some cases the oil surveyor will be forced to apply hydrographic surveying methods which would not satisfy official standards, but which, under the circumstances, may fulfil the needs of oil exploration.

The following example, based on a report by the Netherlands New Guinea Petroleum Company, may serve as an illustration of such a surveying method.

Determination of altitudes by means of tide registration during a regional gravity reconnaissance survey in the Digul area of Netherlands New Guinea (see map C).

In 1956/1957 a reconnaissance gravity survey was carried out in the Digul region, the SE part of Netherlands New Guinea (map C). This survey had to be made over an extensive flat jungle and mangrove area covering some 100 000 sq. km. As it is traversed at rather regular intervals by a great number of navigable, mainly tidal rivers, it was found possible to restrict the survey to the rivers only. This also enabled the survey to be completed in the short period of time allotted.

In all, 4 775 gravity stations along 7 700 kilometres of line were surveyed within 11 months (two parties for 7 months and one party for 4 months).

Determination of the altitudes of the gravity stations at a place in line with the progress of the gravity observations was one of the main problems. Levelling, though accurate, is slow and requires a large staff. Altimeter levelling proved to be too sensitive to local climatic conditions. An altitude determination was therefore evolved which was based on tide registration.

The altitude of the stations in the tidal areas was determined by measuring the difference in elevation between the site of the station and the level of the river corrected to mean-high-water level. The determinations of altitude for the tidal areas were based on the simplifying assumption that the average of the high-water levels along the tidal rivers forms a horizontal plane (fig. 2). Admittedly this assumption introduces a certain error, which corresponds to a certain tilt of the reference plane.

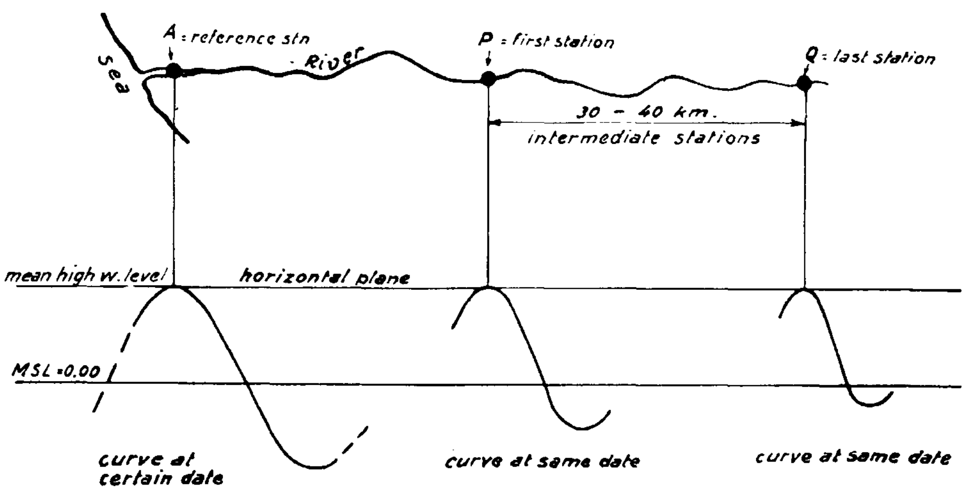


Fig. 2.

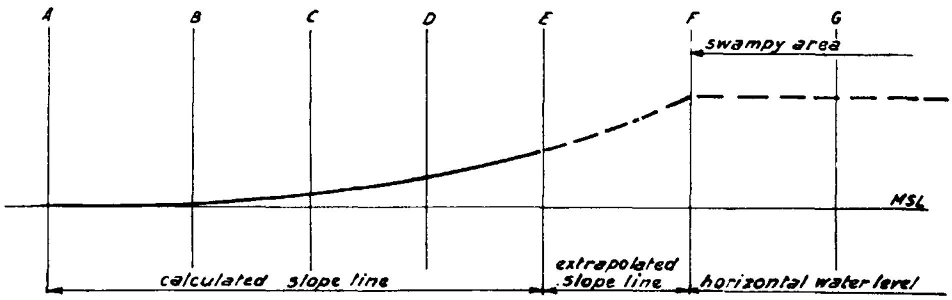


Fig. 3.

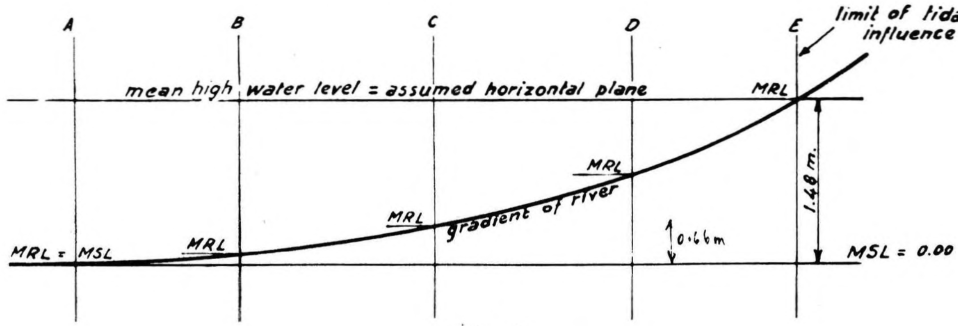


Fig. 4.

EXAMPLE OF WATER LEVEL DETERMINATION
FOR INTERMEDIATE STATIONS

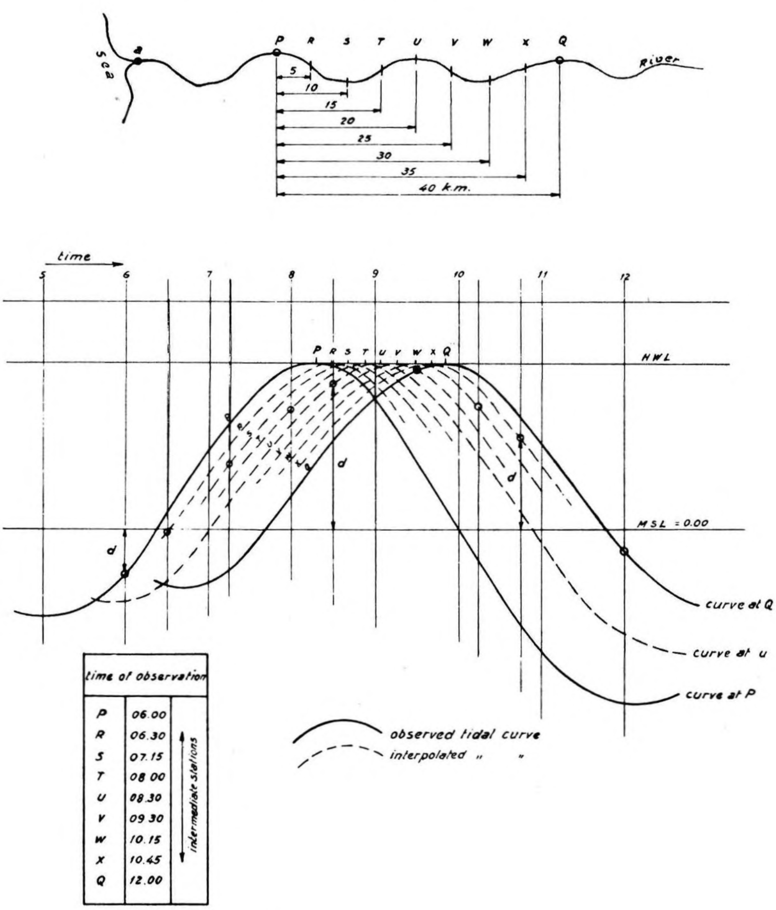


Fig. 5.

Tidal curves at P and Q, observed at the same time, have been referred to the same high-water level (HWL) and drawn with respect to one time scale.

Curves at intermediate stations have now been constructed with respect to their distances from P and Q.

Finally the heights of the water levels (d) at observation times have been read off and referred to MSL.

An approximate gradient of the river was computed from the difference between the mean river levels and the mean high water levels and this gradient could, to a certain extent, be extrapolated into the non-tidal area within the required limits of accuracy (fig. 3).

The mean river levels were computed from gauge registrations over long periods (at least one month) at stations 30 - 40 km apart. This method provided continuous curves, the maxima of which tied the curves to the assumed horizontal plane (fig. 4).

For determination of the altitude of intermediate stations, the same procedure was followed, except that the observations were restricted to a daily tidal observation including a maximum. The daily curves were plotted against a time scale with the maxima at the altitude (fig. 5). The actual altitude of the gravity station was then found from the difference between the actual water level and the gravity station by sighting along a spirit level (fig. 6).

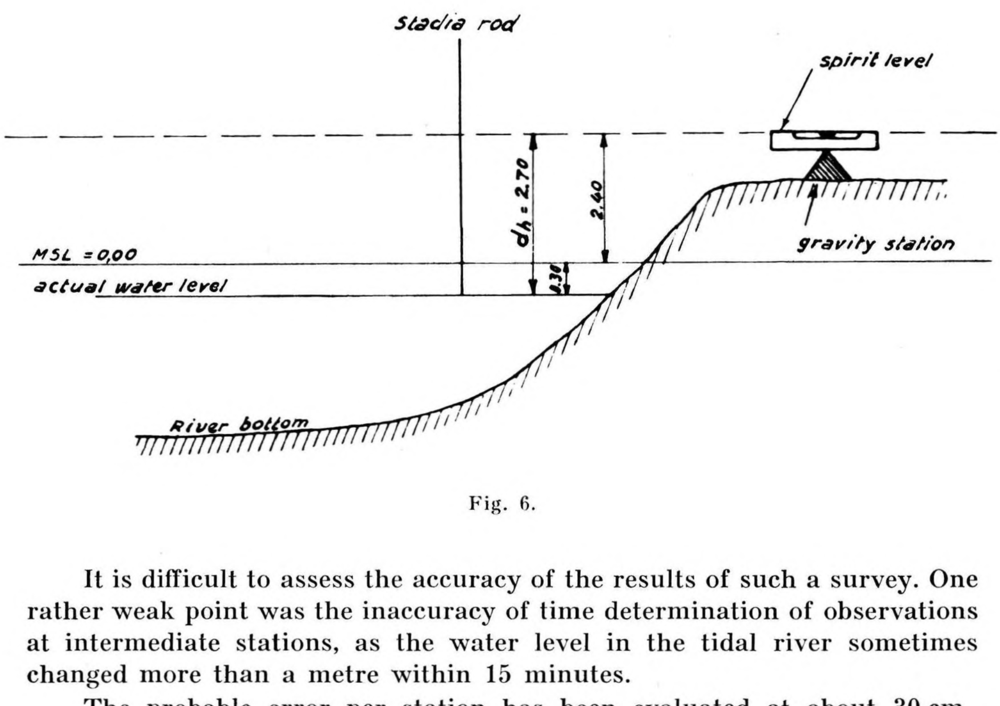


Fig. 6.

It is difficult to assess the accuracy of the results of such a survey. One rather weak point was the inaccuracy of time determination of observations at intermediate stations, as the water level in the tidal river sometimes changed more than a metre within 15 minutes.

The probable error per station has been evaluated at about 30 cm., which corresponds to a gravity value of about 0.07 milligal. In this connection the fact that the mean-high-water level is not necessarily a horizontal plane has not been taken into account.

The above-mentioned standard of accuracy therefore holds good only for neighbouring stations, while the errors unaccounted for resulted in a certain tilting over the wider areas.

The topographical work carried out later for a semi-detail gravity survey, which followed the regional reconnaissance survey, showed that the gradient computed from tidal observations was accurate to within 2 metres.

This means that tilting of the reference plane is of minor importance in slightly undulating areas, and that the assumption that the mean-high-water levels in this region form a horizontal plane is, within limits, correct.

Hydrographic instruments

A wide range of instruments is available to the oil-company surveyor for hydrographic surveying and for recording meteorological data (e.g. wind, rain, temperature, and variations in atmospheric pressure).

The principles of construction of these instruments are well known. Accordingly, no difficulties are experienced in choosing a suitable instrument for use at an installation which is subject to normal conditions.

However, in selecting such an instrument it is necessary to take into account not only the purpose for which it is required (e.g. long-term or instantaneous information) but also the local conditions prevailing at the site and the technical competence of the personnel who are to operate the instrument. Furthermore, it makes a considerable difference whether the measuring and recording elements of the apparatus can both be mounted at a location on the coast or on a jetty, which are accessible at all times, or whether it will be necessary to make use of an offshore platform where inspection of the equipment may be possible only at long intervals. In certain cases even installation on a platform may not be possible, and the measuring device, with built-in or remote recorder, has to be installed below the surface of the water, fixed by means of an anchoring system or onto a submarine structure.

Most of the marine survey instruments used by the Royal Dutch/Shell Group and named below satisfy the requirements mentioned, and could be purchased without modifications. Only in some cases did they have to be specially designed.

When a *tide gauge* is to be permanently installed at an easily accessible location, on a jetty or platform, use is made of a water-level recorder of the well-known float-operated type. Weekly records are obtained on a clock-driven drum which is provided with charts of waxed or metallic paper. In general, dry registration works much better than registration with ink, especially in humid regions.

To meet requirements for a tide gauge for semi-permanent installation, successful use has been made of a transportable pressure-operated level recorder (fig. 7), consisting of a dial-chart recorder and air-filled measuring system comprising a capillary connecting tube and diaphragm box.

An instrument suitable for unattended registration of tides for periods of several months is the Smitt Pressure-Operated Tide Recorder (fig. 8), which has been successfully used on various occasions. The entire instrument is enclosed in a heavy steel case which can be lowered to the sea bed in depths of between 5 and 40 metres; its position is marked by an anchored buoy. The pressure of the water actuates a Bourdon spring, the movement of which is recorded by an indicator pin on a roll of electrically driven registration paper. The relative height accuracy is 1 dm. An accumulator serves as the source of power.

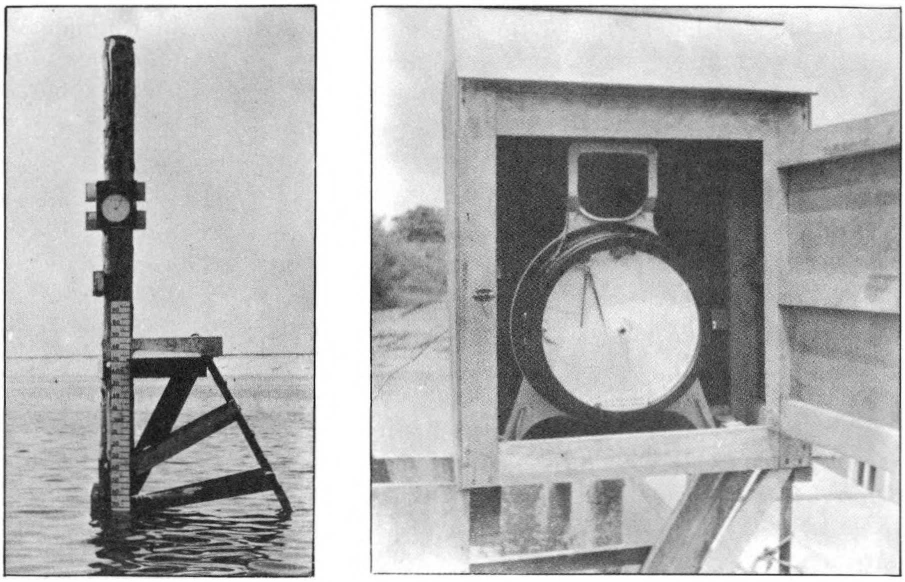


Fig. 7.

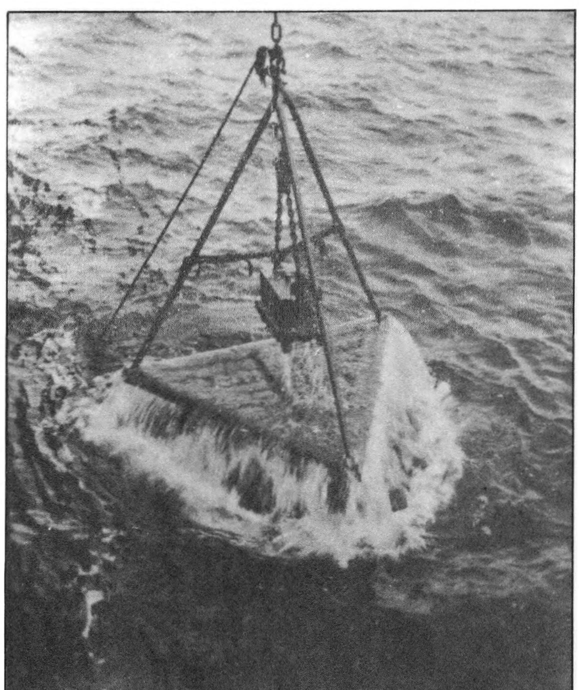


Fig. 8.

There are two main instruments which are used for measuring and recording *wave movements*. One is intended for permanent installation on a jetty or marine structure; the other is a submersible offshore instrument which can be used at any location in the sea by means of an anchored buoy system.

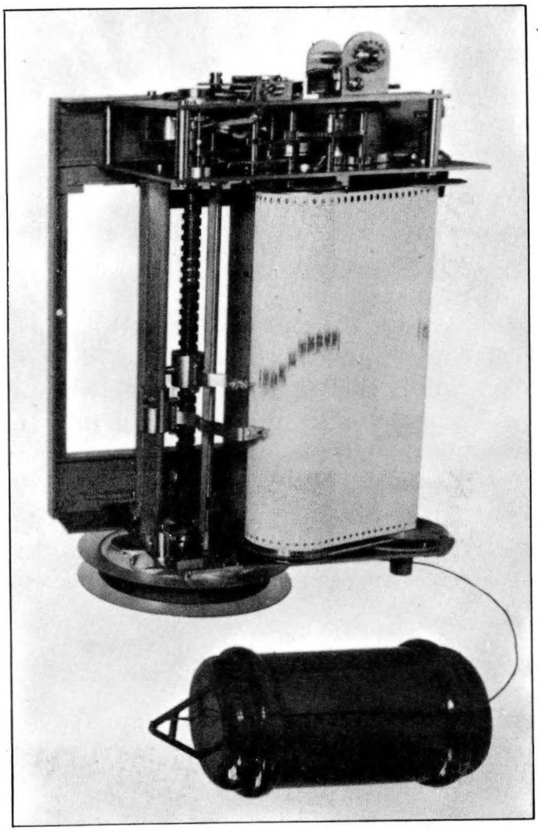


Fig. 9.

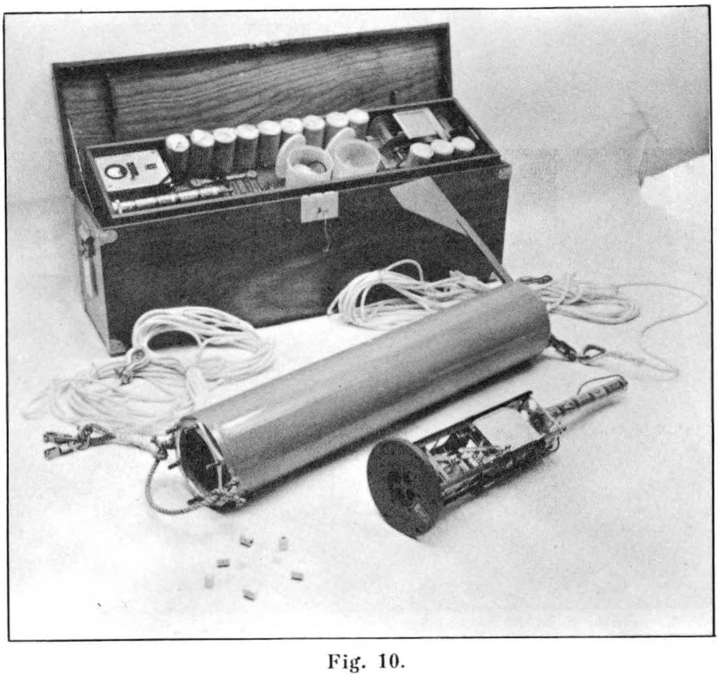


Fig. 10.

1. Float-operated Wave Recorder, designed by P. J. WEMELSFELDER (Netherlands Dept. of Public Works) (fig. 9).

The recording mechanism is operated by float movements. Unattended intermittent registration of wave amplitudes is possible for a period of months. The instrument also contains a spring-driven mechanism for additional recording of amplitudes and periods combined.

2. Offshore Pressure-operated Suspended Wave Recorder, designed by G. KUIPERS, developed and manufactured by Van Essen N. V., Delft, Holland (fig. 10).

This instrument (known for short as OSPOS) consists of a pressure-sensitive element and an electrically driven recording device enclosed in a watertight tubular container of light metal (length 110 cm, diam. 20 cm). The instrument can be anchored at the bottom of the sea and floats under water at a predetermined depth. The recorder can be set to register combined tide and wave movements continuously for about 70 hours, or intermittently throughout 30 days.

The OSPOS is in course of being redesigned in order to record photographically not only wave movements but also velocity and direction of current.

Current measurement

The simplest way of measuring provisionally the strength and direction of currents in a rather extensive marine or tidal area is still the drift method, in which use is made of floats. For more accurate measurements, however, a large number of different instruments are known, some of which are still in the experimental stage (*).

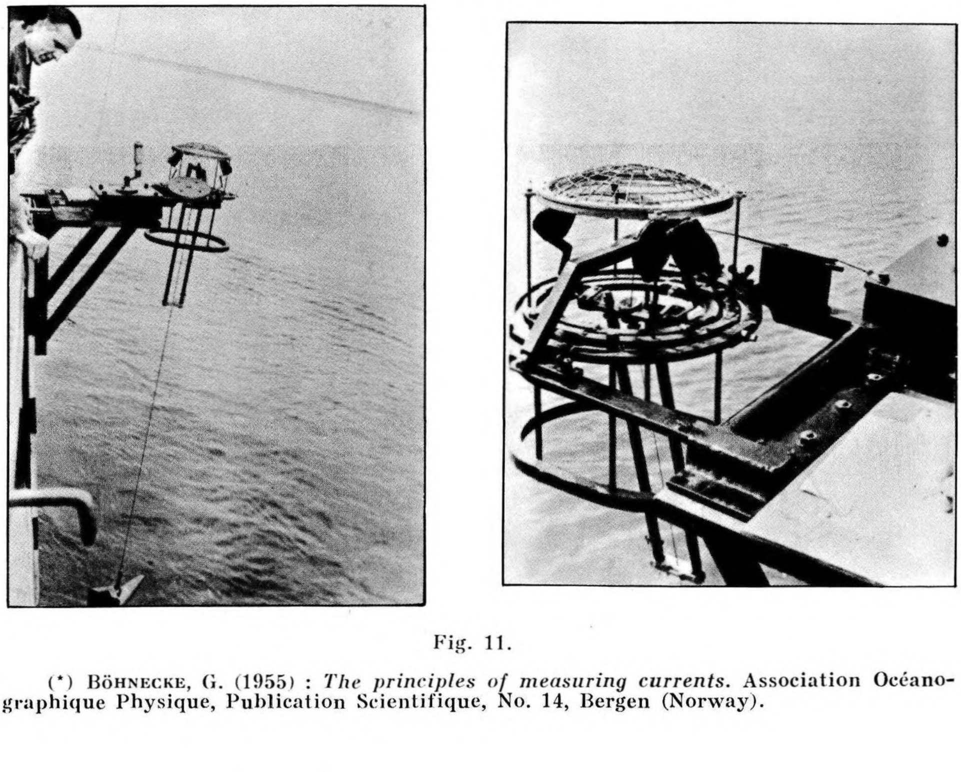


Fig. 11.

(*) BÖHNECKE, G. (1955) : *The principles of measuring currents.* Association Océanographique Physique, Publication Scientifique, No. 14, Bergen (Norway).

For direct observations from a survey ship, current meters of the propeller or paddle-wheel type are often employed. Another type of instrument used for this purpose is the pendulum current meter with wire-suspended resistance body (fig. 11).

Measurement of these instruments in open sea is only possible when weather conditions are very favorable.

Information on currents over long periods is usually obtained by means of a self-recording apparatus which is fastened to a platform or jetty installation, or to a spud pile driven in the area of the currents.

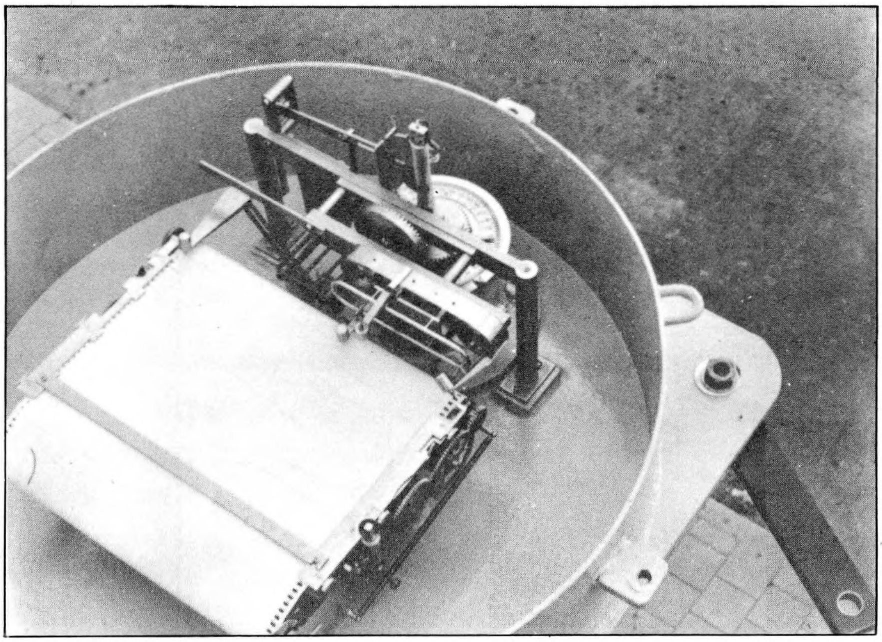


Fig. 12.

Another Royal Dutch/Shell Group instrument is the Sundermeyer-Van Essen current-velocity and direction recorder which has been specially developed for this purpose (fig. 12). It is a strongly built recorder, suitable for permanent mounting on fixed structures. A turning resistance plate and a rotating tube, fitted with a tail rudder, operate a recording pen for mechanical registration of the velocity and direction of the current. The instrument registers on waxed paper charts for periods of 30 days, and can be provided with an electromechanical remote recording system.

A common drawback of current meters when fastened to a fixed point for long periods is that drifting seaweed and growth of marine organisms on the measuring elements affect results badly after a time.

In connection with this, the measuring element of the Sundermeyer-Van Essen apparatus is now being modified in such a way as to enable the necessary periodic cleaning and removal of growths to be carried out more conveniently.

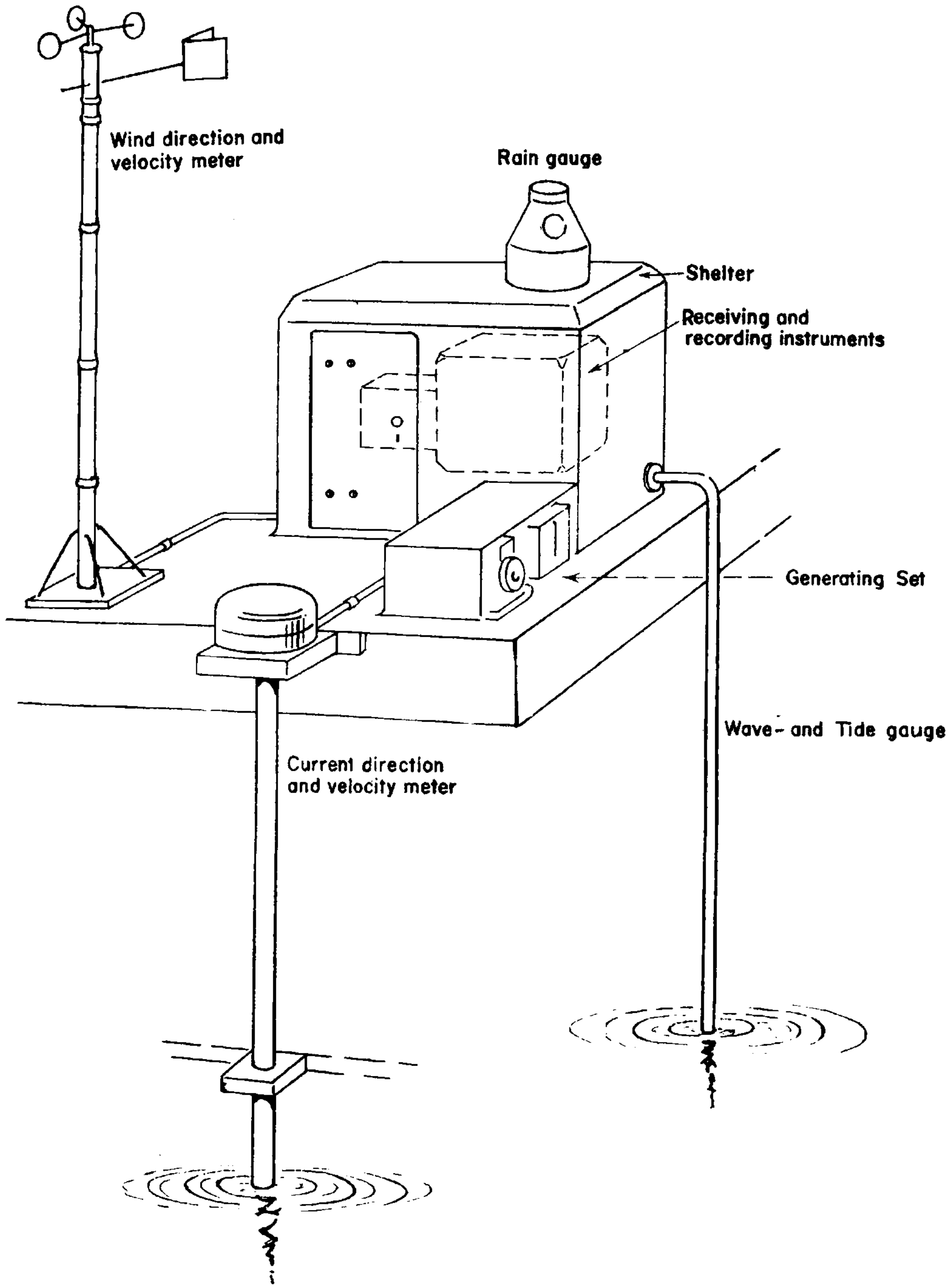


Fig. 13. — Scheme of self-contained weatherstation built on offshore platform.

Weather station (fig. 13)

For the purpose of obtaining complete, concise information on weather conditions which may affect the operational program at a remotely situated offshore installation and the precautions to be taken there, a self-contained weather station has been designed. In such a station, which can be set up, for instance, on a marine platform, the necessary measuring and recording elements are combined in one unit. The various meteorological and oceanographic phenomena are measured continuously, and the graphs are recorded photographically at the same instant, without the equipment requiring any attendance for periods of up to 30 days.

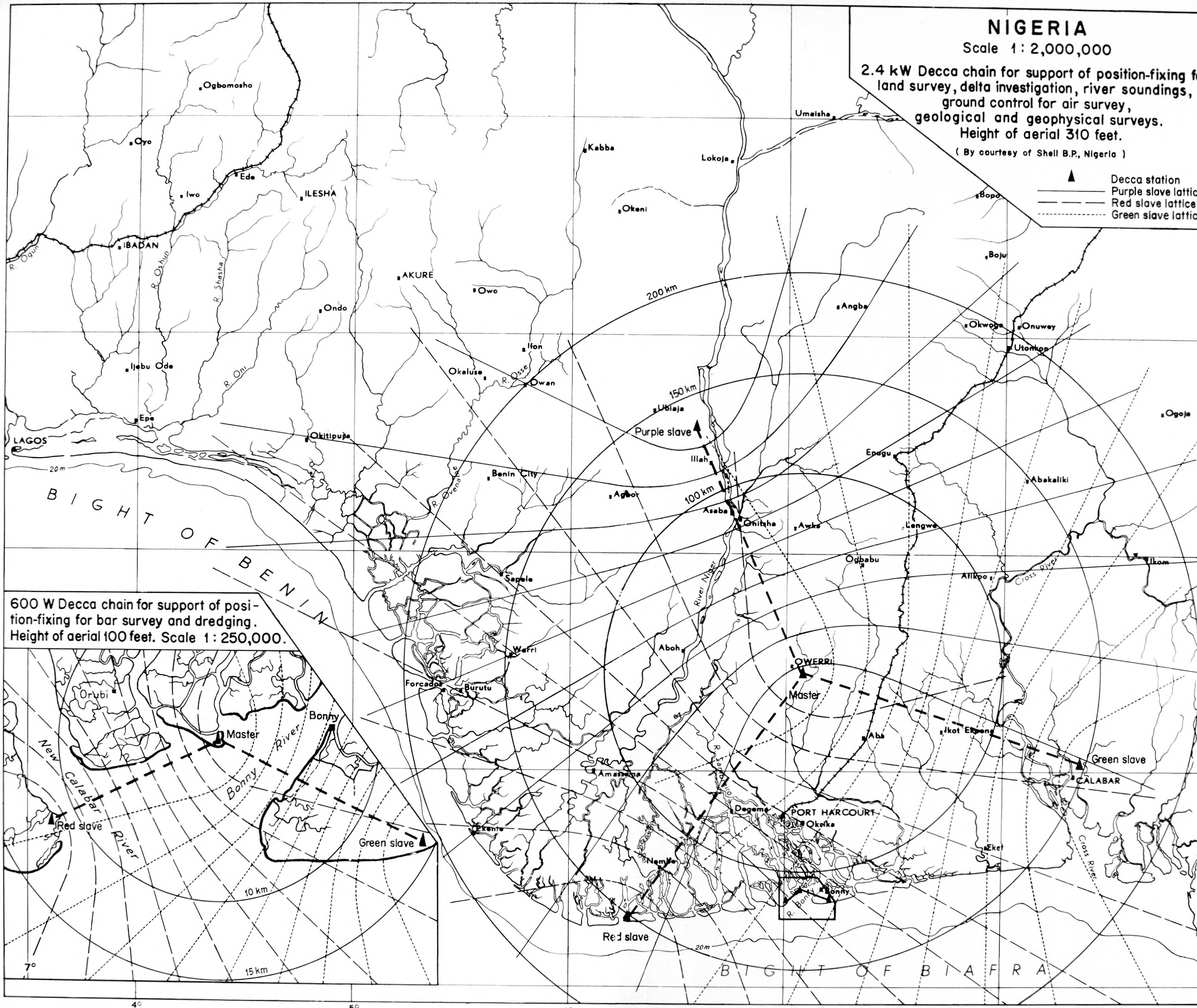
Conclusion

In the paper which he submitted to the Commonwealth Survey Officers' Conference 1959 Rear-Admiral K. St. B. Collins, C.B., D.S.O., Hydrographer of the Navy, Great Britain, refers scathingly to " the age-old story of the lack of appreciation of the necessity for adequate charting of harbours, coasts and seaways ".

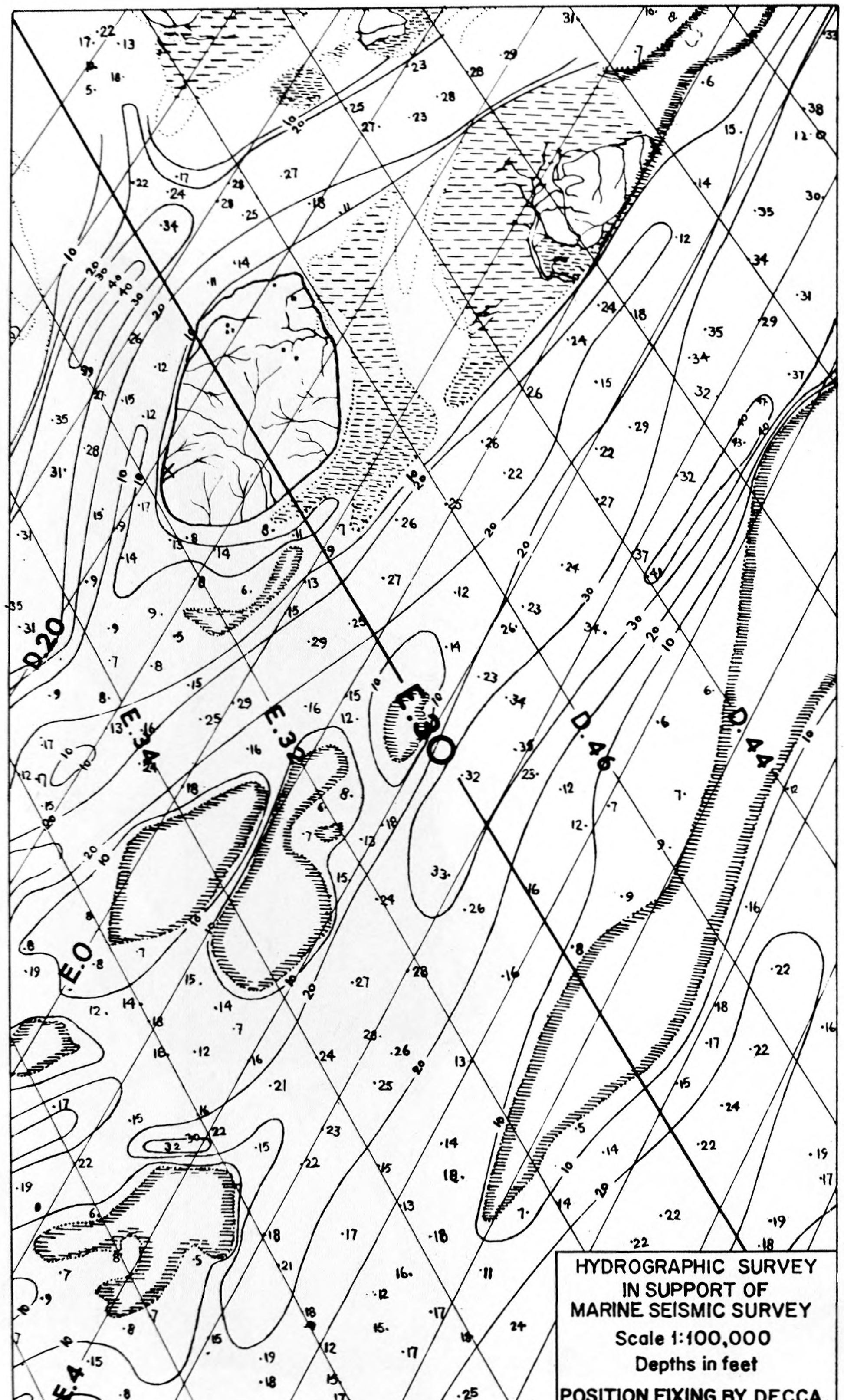
As far as the oil industry is concerned, this verdict no longer applies. In view of the rapid growth of offshore exploration and exploitation and the great expansion of their tanker fleet, the oil industry cannot afford to underestimate the value of hydrographic surveying. Imagine the consequences if a drilling platform or a jetty for super-tankers were to be built in an unsuitable place owing to inadequate current measurements and wrong soundings, or if a channel were to be dredged wrongly positioned !

The work of the official hydrographers is well known to the oil industry and is highly appreciated. But the character of the modern oil industry is such that it has to do its own hydrographic survey work for its own limited objectives. In doing so it is forced to approach surveying problems differently from the government bodies, partly because, under the specific conditions and circumstances of the industry, the time factor often plays such a predominant role. On the other hand, the oil surveyor bears a special responsibility in the design and execution of projects and installations that require great capital investments, and so must have at his disposal the most efficient methods and the most modern instruments, which yield results of the highest degree of accuracy.

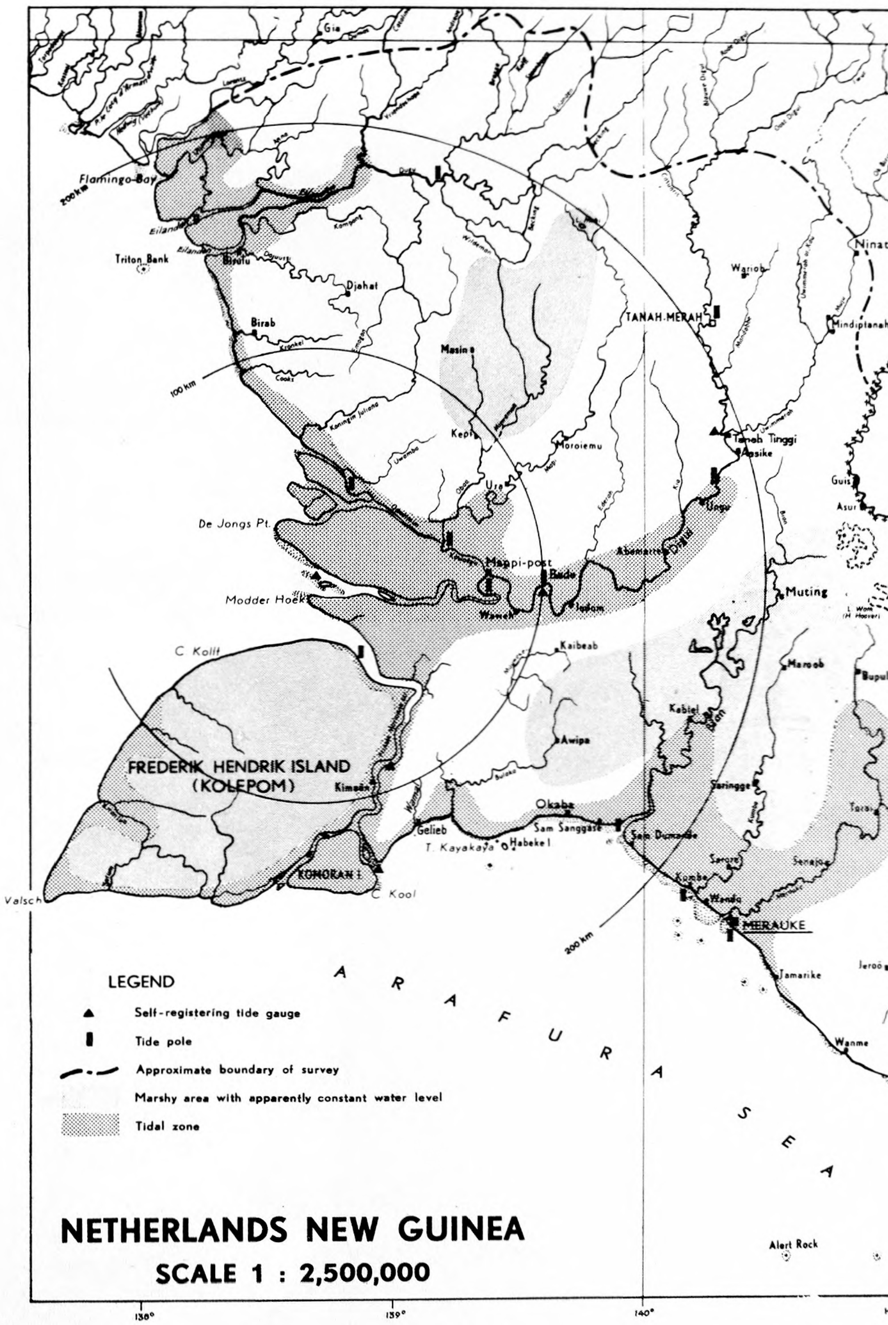
Hydrographic surveying in the oil industry is a very wide subject. Within the brief compass of this article it has been impossible to be exhaustive. Nevertheless, we hope that, by means of the limited selection of aspects which are all we have been able to handle, we have given a correct idea of what hydrographic surveying in " oil " can involve.


NIGERIA
Scale 1 : 2,000,000
2.4 kW Decca chain for support of position-fixing for land survey, delta investigation, river soundings, ground control for air survey, geological and geophysical surveys. Height of aerial 310 feet.
(By courtesy of Shell B.P., Nigeria)
Decca station
Purple slave lattice
Red slave lattice
Green slave lattice
600 W Decca chain for support of position-fixing for bar survey and dredging. Height of aerial 100 feet. Scale 1 : 250,000.
Orubi
Master
Bonny
Bonny River
New Calabar River
Red slave
Green slave
10 km
15 km
Ogbomosho
Oyo
Iwo
Ede
ILESHA
IBADAN
R. Ogun
R. Oshun
R. Shasha
AKURE
Owo
Ondo
Ijebu Ode
R. Oni
Epe
LAGOS
Okitipupa
Kabba
Okeni
Lokoja
Umaisha
Bopo
Boju
Angba
Okwoga
Onuway
Utonkon
Ifon
Okaluse
R. Osse
Owan
Ubiaja
150 km
200 km
100 km
Purple slave
Illah
Benin City
R. Ovenure
Agbor
Asaba
Onitsha
Awka
Enugu
Abakaliki
Ogoja
Lengwe
Ogbabu
Afikpo
Ikom
Cross River
Sapele
River Niger
Warri
Forcados
Burutu
Aboh
OWERRI
Master
Aba
Ikot Ekpene
Green slave
CALABAR
Amassoma
Degema
PORT HARCOURT
Okrika
Ekenta
Nembe
Eket
Bonny
Red slave
BIGHT OF BENIN
BIGHT OF BIAFRA
20m
4°
5°
6°
7°
8°
9°

Map A.


HYDROGRAPHIC SURVEY
IN SUPPORT OF
MARINE SEISMIC SURVEY
Scale 1:100,000
Depths in feet
POSITION FIXING BY DECCA.

Map B.


NETHERLANDS NEW GUINEA
SCALE 1 : 2,500,000
LEGEND
Self-registering tide gauge
Tide pole
Approximate boundary of survey
Marshy area with apparently constant water level
Tidal zone
ARAFURA SEA
TERRITORY OF PAPUA
FREDERIK HENDRIK ISLAND
(KOLEPOM)
TANAH MERAH
MERAUKE
Flamingo Bay
Triton Bank
De Jongs Pt.
Modder Hoek
C. Kolff
C. Valsch
C. Kool
Mappi-post
Muting
Okaba
Kimaan
Alert Rock
100 km
200 km

Map C.