NETHERLANDS GEODETIC COMMISSION.
(RIJKSCOMMISSIE VOOR GEODESIE)

GEODETIC ACTIVITY
IN
THE NETHERLANDS
1936, 1937 AND 1938.

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GEODETIC ACTIVITY IN THE NETHERLANDS
1936, 1937 and 1938.

I. PRECISE LEVELING.

The new first-order leveling in the Netherlands which has been started in 1926 will be finished in 1939. A detailed report, dealing with the methods used and the results obtained will be published in 1940.

II. GRAVITY.

Summary.

In the period of 1936—1939 the Netherlands Navy has again given many opportunities for gravity research at sea. At the beginning of 1937 Dr. Vening Meinesz was allowed to make a trip on the submarine Hr. Ms. O 16, to the North Atlantic and at the request of the Geodetic Commission this trip was extended to Washington and the route adapted to scientific research. The outward voyage went via Horta (Azores), the Mid Atlantic Rise at 34° N lat. and the Bermudas and the homeward trip more to the north, at about 40° N lat., to Punta Delgada and thence to Lisbon. Here Dr. Vening Meinesz left the ship, which continued her way to the Spanish waters.

In connection with the problem of the second order corrections, raised by B. C. Browne of the Department of Geodesy and Geophysics of Cambridge University, England, Dr. Vening Meinesz constructed in the summer of 1937 a slow pendulum apparatus for measuring the horizontal accelerations of the ship. The Commission requested the Navy to afford them an opportunity to put this apparatus, which was still in an experimental stage, to a trial. The Navy kindly provided this opportunity by allowing Dr. Vening Meinesz to go along with Hr. Ms. O 12 on her homeward trip, from the island of Curaçao to Holland, in December 1937.

The experience obtained during this voyage led to a new construction of the slow pendulum apparatus. This was finished towards the end of April 1938 and the Navy was found willing to provide again an opportunity to put it to the test. Hr. Ms. O 13 was allotted for an eight-days trip towards the end of the Channel and Dr. Vening Meinesz, this time accompanied by Dr. W. Nieuwenkamp, Dr. of Geology of the University of Utrecht, went along. The results were satisfactory and the apparatus was adopted in this shape as final.

The Netherlands Geodetic Commission then lent the pendulum apparatus, combined with the above slow pendulum appliance, to the British Gravity Expedition, organized by Col. Sir G. P. Lenox Conyngham of Cambridge under the leadership of Mr. B. C. Browne.

It was returned in November 1938 and at the same time the Commission received the crystal chronometer which had been loaned to the British expedition and which, by kind consent of its makers and proprietors, the Bell Telephone Laboratories, was again lent by Dr. Field to the Netherlands Commission for the expedition planned for 1939. The Commission feels deeply indebted for this favour and also for the information which Mr. Browne kindly gave about the way in which he had adapted the crystal chronometer to the pendulum apparatus.

According to the first plans the new expedition should have started towards the end of April and the route was planned via Cape of Good Hope to the East Indies. In consequence of the international political disturbances, however, the Navy cancelled these plans but they opened a new possibility by allowing scientific research on board of Hr. Ms. O 19 which will leave Holland for the East Indies in the summer of this year and will take her route via the Suez Canal. In the Indian Ocean the ship will touch at Mombassa and the subsequent crossing of the Indian Ocean as well as the first part of the voyage will give plenty of opportunities for important gravity research while the crossing of the Indian Ocean will allow a sounding profile over a part where no depths are known. Dr. Nieuwenkamp, Engineer of the Netherlands Geodetic Commission, will do the research.

Besides the gravity work at sea the Commission has organized a detailed gravity investigation of the Netherlands itself. The old net of the 51 pendulum observations of the years 1912—1921 is no longer sufficient for the new scientific demands, which more and more centre on the geophysical side of the gravity work; for the knowledge of the hidden geological structures a much denser net is needed. The Commission resolved to choose a station distance of 5—10 km: this means about one thousand stations for the whole country. For special studies a still denser net may be necessary but the proposed net will suffice for all general purposes and will provide a base for more local research.

In three ways the Commission was supported in the execution of this programme. In the first place Dr. J. Pannekoek van Rheden, a geologist of the Netherlands Geological Survey, has kindly put his services at the disposal of the Commission for the making of the observations. Secondly a proper instrument for this work was available thanks to the stipend of the "Langerhuizenfonds" allotted to Dr. Vening Meinesz by the "Hollandsche Maatschappij der Wetenschappen" for the acquisition of a Holweck-Lejay gravity pendulum. In the third place a great part of the country has already been gravimetrically surveyed by the Geophysical Department of the "Bataafsche Petroleum Co" which company is willing to publish the figures of this research in the near future. The distance of their stations is the same as that chosen by the Commission. The Commission can, therefore, restrict its work to the remaining part of the country.

In the period of 1936—1939 the Commission has taken in hand the computation of Fundamental Tables for Regional Isostatic Reduction of gravity results. The principle of these tables is that published by Dr. Vening Meinesz in the "Bulletin Géodésique" No. 29, that is to say that the compensation of an elementary column of topography of infinitely small horizontal cross-section is supposed to be spread horizontally over a large area and that the way of spreading follows a bending curve, i.e. that the amount of compensation is largest in the centre and that it tapers off towards the circumference of the area. The tables have been made for five different degrees of regionality, the radius of the circumference being consecutively 29.05 km, 58.10 km, 116.20 km, 174.30 km and 232.40 km. In a vertical way the compensation has been distributed in the same way as the Fundamental Tables for local compensation of Cassinis and Dore; i.e. the compensation is equally distributed from sea-level down to a certain depth H and the tables range from H = 0 to H = 60 km. The compensation in the case of Cassinis' tables has unit density. For our tables this compensation has such a density that when all the mass is compressed horizontally till the regional distribution is brought back to local distribution, it has likewise unit density. In other words, for all five degrees of regionality the amount of mass in any horizontal plane is the same as for the table of Cassinis. We can also say it in this way. When we start from a local column of mass of unit density from sea level to a depth H, as adopted by Cassinis and when we spread out this mass in a horizontal way according to the above mentioned distribution curve, we get the mass column of which our tables give the attraction.

The deducing of the formulas needed for these tables and the computation of the tables has taken three years. The tables may be used, like Cassinis' tables, for deriving special tables founded on special assumptions about the isostatic compensation. Taking e.g. a special set of tables for some local compensation assumption derived from Cassinis' tables we may in exactly the same way, by using the new tables, derive corresponding special tables for regional distribution.

The Gravity Expedition of Hr. Ms. Submarine O 16.

The following programme shows the observations made during this voyage:

1937		Ports	Observation Station
Jan.	11	Dep. Den Helder	17
Jan.	20	Arr. Horta (Azores)	1
Jan.	25	Dep. Horta	24
Feb.	5	Arr. Hamilton (Bermudas)	1
Feb.	10	Dep. Hamilton	8
Feb.	15	Arr. Washington	1
Feb.	24	Dep. Washington	28
March	7	Arr. Ponta Delgada (Azores)	1
March	8	Dep. Ponta Delgada	11
March	12	Arr. Lisbon	1
			Total 93 stations

For the route the writer refers to the map in an article in the Proceedings of the Akademie v. Wetenschappen of Amsterdam, Vol XL, 5, 1937.

The whole trip was characterized by exceptionally rough weather and from time to time the wind even reached hurricane force. Life on board was strenuous and diving becomes difficult when the sea is so strongly disturbed. The Commission feels indebted to the Captain, Lieut-Commandeur C. J. W. van Waning, for the many dives he has nevertheless accomplished; this gave the opportunity for almost entirely completing the programme for the observations. It wishes also to acknowledge the trouble taken by the other officers for the scientific work and especially the accurate determinations of the position of the ship by Lieut. Goossens.

The second order corrections which will be discussed in the next paragraph are proportional to the square of the ship's movements and so they have been exceptionally large during this voyage; most of the observations were made at a depth of 60 m below sea-level, but even at that depth the movements were considerable and once the ship even rolled 8° to both sides. As the horizontal accelerations of the ship have not been determined, the deduction of the second order correction has been uncertain and so many of the results of this trip have a greater mean error than those of previous voyages. We have to await more figures about the wave-movement before a good estimate of these mean errors can be made, but we fear that for many stations it will exceed 10 milligals.

The results of this expedition will soon be published. They have been isostatically reduced in the Reduction Bureau of the Geodetic Association in Helsinki under the direction of Prof. Heiskanen. The results have been combined with the results of the second voyage in 1937, also isostatically reduced in Helsinki, and with all previous results in the North Atlantic between 20° N and 50° N, i.e. those of the expeditions of Hr. Ms. K 13 in 1926, Hr. Ms. O 13 in 1932 and Hr. Ms. K 18 in 1934, for making the following table for the mean isostatic anomaly for different routes and basins and a second table for the change of the anomaly over the edge of the continental shelf. Both tables give the anomalies for three methods of isostatic reduction: the Hayford system with $H = 113.7$ km, the Airy-Heiskanen system with $T = 40$ km (crustal thickness for zero topography) and the regional system according to the paper of Vening Meinesz in the Bulletin Géodésique no 29 as applied in "Gravity Observations at Sea", Vol II, 1934. The indirect or Bowie reduction has not yet been applied to these values.

TABLE I.

Mean Isostatic Anomaly over the North Atlantic Ocean.

Number of Stations		*Mean Isostatic Anomaly in milligal.* Regional	Hayford	Heiskanen T = 40 km
25	Channel — Azores	+ 21	+ 33	+ 26
33	Channel — Madeira	+ 10	+ 29	+ 16
10	Azores — Madeira	+ 18	+ 34	+ 25
4	Madeira — Canaries	— 12	+ 1	— 7
4	Azores — Canaries	+ 23	+ 24	+ 14
12	Azores — Lisbon	+ 20	+ 37	+ 30
7	Canaries — Mid Atlantic Rise at 24° N	+ 18	+ 20	+ 8
4	Azores — Mid Atlantic Rise at 34° N	+ 15	+ 26	+ 22
17	In Azores Archipelago	+ 35	+ 29	+ 40
6	Mid Atlantic Rise at 34° N	+ 12	+ 15	+ 22
4	Mid Atlantic Rise at 25° N	+ 3	+ 5	+ 12
6	West of Azores	+ 34	+ 46	+ 41
20	Azores — Cape Henry	— 8	+ 14	+ 3
13	Mid Atlantic Rise at 34° N — Bermudas	— 9	+ 12	+ 4
5	Bermudas — Cape Henry	— 29	— 11	— 19
8	Mid Atlantic Rise at 25° N — Porto Rico (Brownson Trough not included)	— 14	+ 1	0

TABLE II.

Gravity Profiles from Continental shelf to Ocean.

No	Gravity Profile	Depth of water in metres	*Isostatic Anomaly in Milligal* Regional	Hayford	Heiskanen T = 40 km
1	End of English Channel	170	— 4	— 4	+ 6
		4220	+ 16	+ 45	+ 23
2	,, ,, ,, ,,	170	— 44	— 43	— 35
		4140	+ 25	+ 38	+ 27
3	,, ,, ,, ,,	170	— 20	— 7	0
		4600	+ 25	+ 47	+ 23
4	West of Lisbon	10	— 26	— 25	— 10
		5053	+ 24	+ 31	0
5	W. Africa near Canaries	1190	— 43	— 43	— 41
		3150	— 2	— 2	— 11
6	W. Africa near Cisneros	75	— 65	— 67	— 58
		3105	— 2	+ 5	+ 1
7	N. America near Cape Henry (1st profile)	30	+ 6	+ 2	+ 11
		4242	— 31	— 21	— 19
		5290	— 27	— 3	— 17
8	N. America near Cape Henry (2nd profile)	60?	— 29	— 28	— 23
		3990	+ 1	+ 22	+ 10

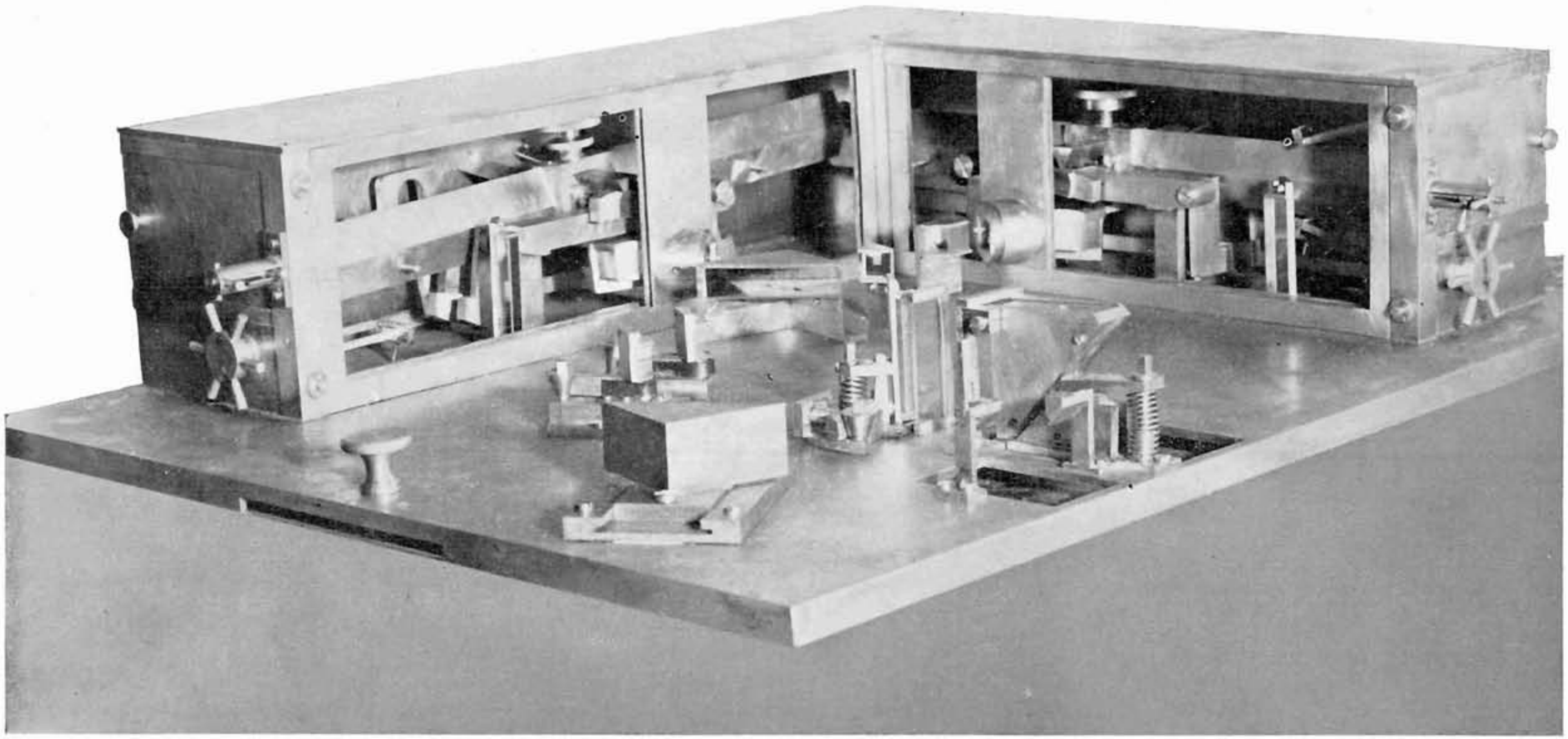

Fig 1. Slow pendulum apparatus for measuring the horizontal accelerations of the ship; to be combined with the pendulum apparatus (fig. 2).

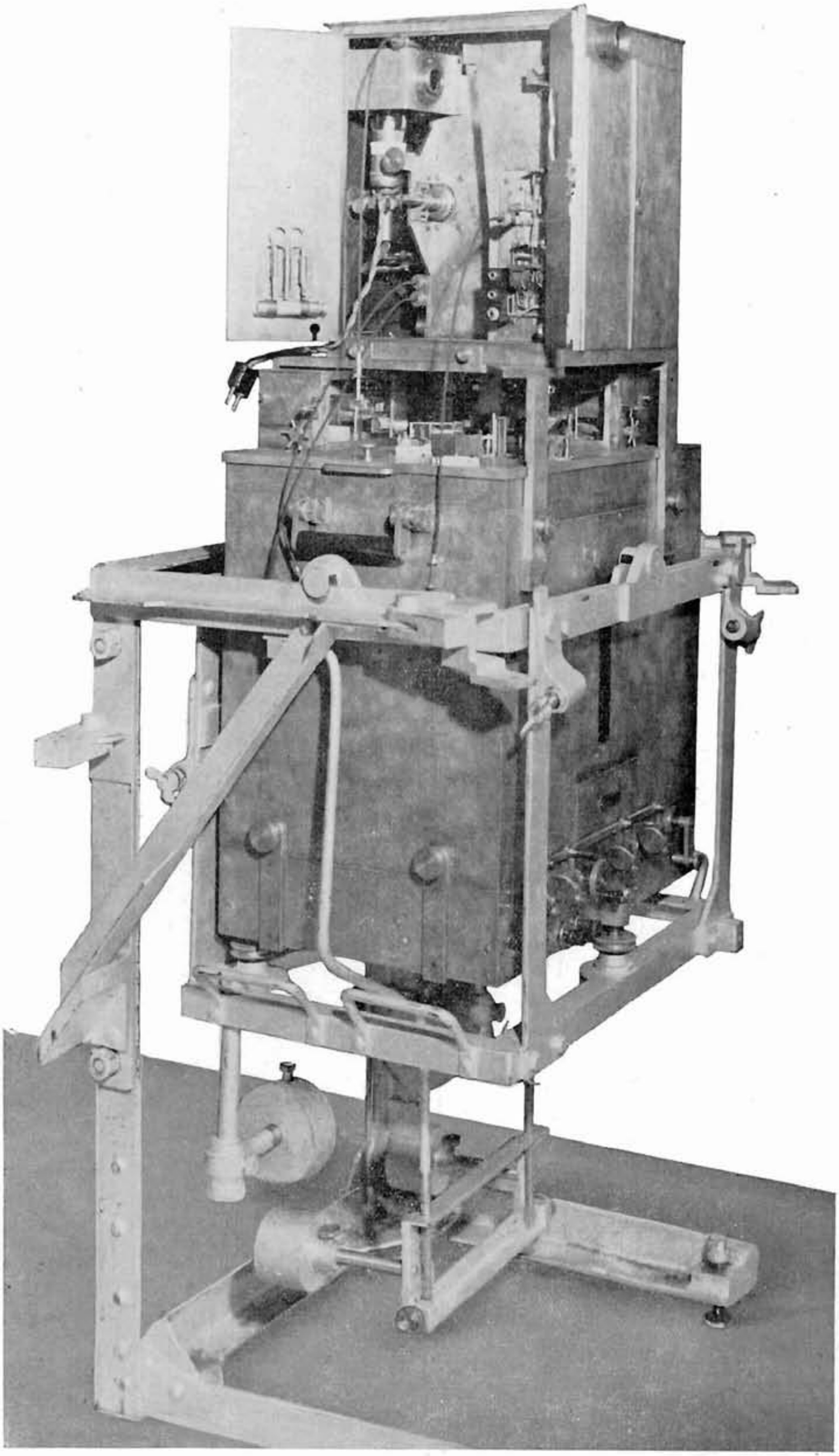

Fig. 2. Pendulum apparatus for gravity determination at sea; the slow pendulum apparatus of fig. 1 is introduced between the recording and the pendulum apparatus.

We shall not enter into a long discussion here of these tables, but the following short remarks may be made. The mean anomalies are generally positive but the figures given in table I are smaller than figures that have formerly been given for some of these basins. This is brought about by the application of the second order correction, which has always the effect of diminishing gravity. In the second place these mean values show differences for different systems of reduction and we may put the question whether another way of isostatic reduction might perhaps make them disappear entirely. A study of this question is on the way. In the third place we may call attention to the fact that the basins west of the Mid Atlantic Rise do not show any clear positive anomalies except the part directly west of the Azores; the basin between the Bermudas and America even shows fairly strong negative anomalies. The Mid Atlantic Rise, as far as a conclusion is possible from these general figures, appears not to show much difference from the adjacent basins.

The second table shows gravity figures for the continental edges. We see that for most coastal profiles the anomaly shows an increase, algebraically speaking, when going from shallow to deep water. This confirms what has been found in many cases elsewhere. One of the profiles near Cape Henry is an exception and the other profile there shows it less clearly. The change of the anomalies depends on the method of isostatic reduction and we may ask again whether perhaps another system of reduction could make it disappear. The Commission has undertaken an investigation of this point and also of related problems. The feature might e.g. also be associated with the results of the remarkable submarine seismic investigation of Ewing on the eastcoast of America, repeated by Bullard at the end of the English Channel. According to these results the continental shelf consists for a great part of loose sediments and so the topographic reduction of the gravity values over the shelf would probably have been computed with too high values for the specific gravity of these layers and the compensation reduction with a too high figure for the deficiency of mass. The result of this might give apparent anomalies resembling those that have been found and so these figures might perhaps disappear when applying better data for the reductions.

THE SECOND ORDER CORRECTIONS AND THE NEW SLOW PENDULUM APPARATUS.

A study of Mr. B. C. Browne, Cambridge, about the determination of gravity at sea, which by kind courtesy of the writer, Dr. Vening Meinesz has been able to take cognizance of before its appearance in the Geophysical Supplement of the Monthly Notices of the R.A.S. of Sept 1937, has shown that there are some second order terms of the disturbances caused by the ship's movements which have been neglected up to now, but which, even for work in submerged submarines, may attain values of several milligals and in unfavourable circumstances even as much as 20, 30 or even 40 milligals. The Commission as well as Dr. Vening Meinesz feel much indebted to Mr. Browne for this discovery and also for his kind cooperation during the further investigation of this question. As the Commission hopes soon to be able to publish in detail the theoretical foundations and the experimental results of this research and as the main lines of it have already been published by Mr. Browne in the above mentioned paper and by Dr. Vening Meinesz in two papers in the Proceedings of the Akademie van Wetenschappen of Amsterdam, XL, 8, 1937 and XLI, 6, 1938, the Commission will not enter into details here. The following short indications may suffice.

For pendulum observations the disturbance terms are

$$dg = -\frac{\overline{\ddot{x}^2}}{4g} + \frac{\overline{\ddot{y}^2}}{2g} + \frac{\overline{\ddot{z}^2}}{2g} \qquad (1)$$

$\ddot{x}$ is the vertical component of the acceleration of the apparatus and $\ddot{y}$ and $\ddot{z}$ the horizontal component; the dashes above the terms indicate mean values over the time of observation. We can derive the value of $\overline{\ddot{x}^2}$ with sufficient accuracy from the photographic records of the pendulum apparatus; the fluctuations of the chronometer marks in the pendulum curves give the necessary data. We cannot, however, directly determine the value of $\overline{\ddot{y}^2} + \overline{\ddot{z}^2}$ from these records. We can imagine two ways for its determination; to measure directly the horizontal components $\ddot{y}$ and $\ddot{z}$ of the acceleration or to rely on the theory of the wave-movement for deriving these horizontal components from the vertical one. Gerstner's theory assumes that the water particles describe circular orbits and when the ship is not too long with regard to the wave-length we may suppose the centre of gravity of the ship to do the same. The last assumption has a good chance of coming true in case of a submerged submarine at a depth that is not too small; the wave-length is great there and the ship is relatively small. Adopting these suppositions we have

$$\overline{\ddot{y}^2} + \overline{\ddot{z}^2} = \overline{\ddot{x}^2} \qquad (2)$$

and so dg can be computed when $\overline{\ddot{x}^2}$ is known.

This line of reasoning would also allow to determine the second order corrections for the old pendulum observations at sea because their records are still there. So it is important to investigate its validity. This can only be done by studying the ship's movements in different conditions of the sea and for different angles between the wave-movement and the ship's course and so for this purpose we need likewise an instrument for measuring the horizontal accelerations; this will enable us to check the above equation (2).

Mr. Browne is engaged in constructing such an apparatus, which promises good results for a wide field of problems; his accelerometer will not only measure slow wave-movements, but it will also allow the taking up of many other acceleration problems. For the special problem concerning gravity determinations at sea by means of pendulum observations the Commission has constructed the slow pendulum apparatus as shown by fig 1, which during the trial trip to the end of the Channel in May 1938, gave satisfactory results. It consists of two slow pendulums of which the full-period can be adjusted at thirty seconds or more, swinging in two vertical planes perpendicular to each other. Each measures the horizontal component of the acceleration in its swinging plane. They have the shape of horizontal rods with a vertical screw in the middle for adjusting the centre of gravity; both can be clearly seen in the picture. Screws at the ends, not visible in the picture, allow the adjustment of the centre of gravity in a horizontal sense. Both pendulums can be clamped when not in use. The whole instrument can be introduced in the pendulum apparatus for gravity work at sea; fig 2 shows it in its position between the recording and the pendulum apparatus. The two slow pendulums are recorded photographically on the same strip of paper which records the main pendulums and the same light is used for the recording. The operation of the new instrument does not give much trouble and so it does not complicate the gravity observations; the only extra manipulation is that in the beginning the slow pendulums are lowered on their knife-edges and that at the end they are raised again.

The results of the voyages of Hr. Ms. O 12 from Curaçao to Holland and of Hr. Ms. O 13 to the end of the Channel have shown that, at least approximately, equation (2) is true, but the material is far too small yet for drawing final conclusions. So many more observations will be needed before such a conclusion will be possible. Still the Commission has considered itself justified to adopt provisionally this result and to compute the second order corrections for the old gravity observations at sea on this basis. The results for the stations mentioned in Gravity Observations at Sea, 1923—1932, Vol II, have been published in the second paper by Dr. Vening Meinesz mentioned in this paragraph (Proc. Akad. Amsterdam XLI, 6, 1938). Of 486 stations 193 need correction, which in 19 cases reaches a value of 10 milligal or more; three of them exceed 20 milligal. As the expeditions of the later years of Hr. Ms. K 18, of Hr. Ms. O 16 and of Hr. Ms. O 12 have encountered more rough seas, the corrections applied to their results have in general been greater.

For future pendulum work at sea we need of course no longer rely on the above mentioned assumptions about the character of the ship's movements. The slow pendulums apparatus combined with the main pendulums enables us to determine the complete second order correction. At the same time the observations will give important material for the oceanographers about the problem of the wave-movement at different depths below the surface for different depths of the sea and in different conditions of the ocean surface.

THE EXPEDITION OF Hr. Ms. SUBMARINE O 12.

The following programme shows the observations made during this voyage:

		In	Curaçao	1 station
22	November	Departure	Curaçao	
				3 ,,
23	,,	Arrival	Curaçao	
26	,,	Departure	Curaçao	
				4 ,,
29	,,	Arrival	San Juan (Porto Rico)	
1	December	Departure	San Juan	
				12 ,,
15	,,	Arrival	Punta Delgada (Azores)	
17	,,	Departure	Punta Delgada	
				2 ,,
24	,,	Arrival	Den Helder	
			In total	22 stations

(of which 21 new stations).

This trip has been mainly intended for the testing of the slow pendulum apparatus in its provisional shape and for the measurement of wave-movements, but three gravity observations during a short preliminary trip in the neighbourhood of Curaçao and the first four gravity observations of the main voyage have been made for geophysical purposes. They were meant to give some further material about the belt of negative anomalies which as the Barracuda Gravity Expedition under Hess, Ewing and Hoskinson in its important survey of the West

Indies has shown, passes near Curaçao, to the north of that island. The following results clearly show the course of this belt in that area; they entirely confirm the Barracuda results [1]).

Latitude north	Longitude west	Depth metres	Observed gravity g_0	Normal gravity γ_0	Anomalies Free-air	Anomalies Isostatic Hayford 113.7 km
12 40	69 17	1820	978.220	978.297	— 77	— 84
13 32	69 26	4445	978.217	978.331	— 114	— 52
12 38	68 41	3000	978.157	978.295	— 138	— 107
11 34	67 50	1825	978.272	978.256	+ 16	+ 31
12 21	67 19	4718	978.087	978.285	— 198	— 113
13 08	66 56	5083	978.238?	978.315	— 77	— 16
14 11	66 30	5074	978.350?	978.358	— 8	+ 45

By kind permission of the Director of the Coast and Geodetic Survey, Col. L. O. Colbert, and of the Chief of the Section of Geodesy, Major Garner, these results have been isostatically reduced at the Bureau of the C. and G.S. under the direction of Mr. Clarence H. Swick, without expense to the Netherlands Geodetic Commission. The Commission wishes gratefully to acknowledge here this kind contribution to its work.

During the trip from San Juan to Holland the main object of the expedition was put in the foreground and long observations have been made for measuring the ship's movements for different courses with regard to the wave-direction; several times observations have been made on the same spot at different dephts below the surface. These observations took a long time and often the ship was submerged for four hours or more. Gravity observations have also been made, but of course the number of stations could not be as great in these conditions as during former expeditions. The accuracy of the gravity results has suffered from the uncertainty of the chronometer rates, which were less regular during this trip than during previous expeditions. The Commission wishes to express its thanks to the Captain, Lieut-Commander H. C. W. Moorman, for his helpful cooperation for the research; it wishes likewise to acknowledge the assistance given by the other officers.

1) MAURICE EWING, Marine Gravimetric Methods and Surveys, Proc. Amer. Phil. Soc. Vol. 79, 1, April 1938.
HARRY HAMMOND HESS, Gravity anomalies and Island arc Structure with particular reference to the West Indies, Id.