

Part 2 FIELD AND LABORATORY INSTRUMENTS AND EQUIPMENT



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Chapter 12

WAVE-MEASURING BY MEANS OF THE INTEGRATOR

P.J. Wemelsfelder Rijkswaterstaat, The Hague, Netherlands.

1. Introduction.

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Civil engineers concerned with problems of coastal engineering or with harbours, shipping, carrying out of works, are at present more interested in waves than ten or more years ago.

It is possible to gather data about waves by means of wave recorders of which several types have been developed. Some of them work quite satisfactorily.

Tet there are some disadvantages. As such may be mentioned:

- . a relatively expensive apparatus.

- . service and survey ask for highly qualified people. . analyzes of the records take much time and man-power. . the amount of paper makes in laborious to study records. . the records pile up and it is difficult to handle them.

The engineer does not want the diagrams itself, not even does he want to know the true history of the movements of the water-surface from second to second. What he wants is well defined information. He aims at obtaining some representative figures, characterising the wave motions as concisely as possible in order to apply those figures in the field of engineering.

So it would be an advantage if we could succeed in measuring immediately such characteristic figures without making use of full wave records, thus saving the expensive wave recording stations and the elaborate work to make extracts from the records. A solution for this problem is being developed in the Netherlands. A short description of the principles of the instrument, called Integrator, and some details of the construction are given here.

Principle of the integration method.

When we consider the vertical water movement we can determine:

The total vertical movement either upward or downward, during a given period e.g. 20 minutes. By adding all movements, the great as well as the small ups and downs are taken into 1. account. Of course it is sufficient to add only the upward or only the downward movements, because these values are equal to each other.

2. As the second characteristic quantity we may regard the number of times the vertical movement of the waterlevel reverses. Here it is also sufficient to count only one sense of reversal.

A wave movement is then characterized by the integration I of the downward movements, shown in fig. 1 by a heavy line and of the number N of all high as well as low "crests" accentuated in fig 1 by a dot.

N = 34 I = 15,6 m/min From this results: $T = \frac{60}{N} = 1,8$ sec $Hg = \frac{1}{4} = 0,47 \text{ m} + 1/3 = 1,57 \quad 0,47 = 0,74 \text{ m}$ H max = 3,0. 0,47 = 1,40 m (did not occur in the 2 minutes reproduced).

The symbol I is that of Integration, the symbol N that of number. The most manageable figures are obtained by taking the minute as unit of time.

In practice it has appeared that the measurings are very well reproduceable and not affected by a personal factor.

But it is necessary to observe a measuring interval of sufficient length. As is well known, wave motion is a very variable motion. According to Puts [1] the standard deviation of the wave heights is 0,5 Hg and consequently the max. deviation is about 1,0 hg. For an average of 100 waves the max. deviation will then be:

$$\sqrt{100}$$
 Hg = 0,1 Hg,

i.e. an average of 100 waves may still be 10 % wrong. Gonsequently it seems not to be admissable to take a group of less than 100 waves. Roughly speaking this requires a surveying period of at least

$$\frac{100}{60}$$
 T = 2 T min

For short wind waves of 2 to $2\frac{1}{2}$ second this becomes at least 5 minutes and during a storm with waves of 8 - 10 sec a time interval of 20 minutes has to be observed. This is in accordance with the results of analyses of wave records in England and the United States.

3. Significance of I and N.

It is evident that a great value of I indicates a strong watermovement and large amplitudes. A large value of N indicates a short vived wave. Now the question has to be answered whether this I and N are sufficiently characteristic to typify a wave movement. From:

= Hg and
$$\frac{60}{N}$$
 = T

we find some "mean wave height" Hg and some "mean wave period" T. From a number of wave diagrams of strongly diverging values of I and N, it could be deduced that between this mean wave height Hg and the significant wave height H 1/3 the relation H 1/3 = 1,6 Hg (\pm 5%) exists.







Fig. 2. Relation between Hg, H 1/3 and H_{max}.

This means that the integration method immediately gives the value of H 1/3 and consequently this method of measuring may be considered as a sufficient source of information as far as the Significant Wave Height is required. Moreover it appears from a lot of diagrams that a fixed

Moreover it appears from a lot of diagrams that a fixed relation exists between Hg and the maximum wave height Hm over a period of 10 to 20 minutes.

This relation is, roughly speaking:

The addition - 20 % means that within a more restricted time interval a really high wave sometimes does not occur. The wave amplitude to be taken in that case as a maximum sometimes deviates even as much as 20 % downward from the top value Hm (fig. 2).

From theoretical investigations of Putz [1][2][3], it has appeared that, for normal wave patterns, fixed relations exist between the quantities introduced above. In [1] Putz mentions as a result of 25 series each consisting of more than 100 waves:

$$H 1/3 = 1.6 Hg$$

and Snodgrass mentions in [4]:

$$Hm = 1.87 H 1/3.$$

With H 1/3 = 1,6 Hg this gives Hm = 3 Hg. This is just the same as I have found.

From 1661 observations at Cuttyhank in Bermuda with waves up to more than 7 m Seiwell [5] deduces a ratio of 1,57. So the same ratio appears to be true for very greatly deviating wave magnitudes. Putz arrives at the conclusion that there must be one mathematical model to which each normal and homogenous wave movement responds.

Based on these investigations, together with those of Pierson, Neumann and James [6] and others, it may in my opinion be expected that the integration method, at least with more or less normal waves, procures the right parameters from which every other required value can be deduced.

On the other hand this means that the parameters I and N are generally adequate to describe wave movements for the use of engineers.

4. <u>Deviating wave movements</u>.

Of course, in a number of cases the wave motion is somewhat more complicated. I think e.g. of the following circumstances:

waves in the surf sone; waves rolling up against a beach; waves thrown back by a vertical wall; interfering wave systems; short waves superimposed upon swell; waves superimposed on seiches in harbours.

Accordingly the relations betwee I and N and the other magnitudes characterising a wave movement will be liable to modifications.

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There are not yet any data available from which eventual modifications in the standard relations might be deduced. Besides it is quite uncertain how large and of what importance they will appear to be for the different theoretical and practical problems as we are engaged with. However, we may assume that such questions can be solved.

5. The IN-diagram.

If we can detect I and N from the waves by any suitable detector by means of simple impulses we can integrate these impulses and record them. This can be realised in the form of a diagram as shown in fig. 3

The recorder gives the integrated value of I and N hour after hour as hourly sums and therefore represents directly their values per minute on calibrated paper. This produces about 5 cm diagram per day so that a single roll of 25 m is sufficient for more than a year. I suppose that it will be possible to keep a recorder in action during a long time without any survey.

The recording in I and N per hour gives ample occasion to follow the changes in the wave movement in detail, which is e.g. of importance for the study of the relation with a rapidly changing wind. It is of so use to take a shorter period than one hour and it is not desirable because the period of observation becomes too short then and this tends to make the influence of the normal fluctuations too great.

There are some impuls recorders available on the market. But they are too complicated and the costs are high. A more simplified construction will be sufficient.

With such an apparatus the following advantages are to be attained:

1° <u>Continuous recording</u> by which a complete survey of the wave movement at the measuring station is obtained, without interruptions. This gives a complete base for statistical research, variations per season, correlation with wind directions and wind forces, with systematic measurings or observations of sand transport, impediment to navigation, etc.

2° Restricted extent of the diagrams.

The problem of the large quantities of paper created by the registration of wave diagrams in the wellknown form, is solved here. A year's diagram of an IN-recorder requires no more paper than a wave diagram of 24 hours. This means a marked simplification in refinding definite parts of records.

3° Saving of office work.

Measuring out complete wave diagrams is a timedevouring work. The integrator does this work automatically and puts the results on the chart. The values of N and I can immediately be measured from the diagram for the definition of frequencies and correlations. Hereby N and I are obtained in a form which shows the history of the wave movement and greatly facilitates the refinding of important episodes.

So the apparatus procures great advantages for incidental as well as for systematical research of wave movements.

Of course it will be recommendable to take complete wave diagrams at the same spot, from time to time as well, in order to be able to determine the wave forms also in detail. It will be possible to learn whether the wave movement is in accordance with the "standard model" and if not so, what further explanation follows from this for the interpretation of I and N, and their relation to Hg, H 1/3, etc.

I call such a station a "Reference station". Measurings in detail in the surroundings can be related herewith and may be less complete.

6. <u>Construction</u>.

The integrator is intended and constructed as a floatoperated instrument. The float can drive:

- 1° a mechanically operated instrument mounted on a pier or pileconstruction. It is a great disadvantage of this solution that in time of bad weather the diagrams are not immediately at our disposal;
- 2° a device, procuring suitable impulses which are transmitted by cable to an impuls recorder on shore.
- 3⁰ a short wave radio transmitter. The signals to be transmitted are of a very simple character.
 - These three projects are partly realised already, partly in development now.

First of all a remark about the float tube: it has appeared that a float tube which is open only at the bottom does not follow the wave movement exactly, whether by lagging behind or by overshooting. A favourable experience was obtained with float tubes having a longitudinal split of about 2 to 3 cm wide. A float of 1 dm² is satisfactory. The float line is slung over a perspex-wheel (sp.w. 1, 3, small moment of inertia!) and is kept tight by a spring. The axle of the float wheel (Circumference 50 cm) runs free in one direction but in the other direction it takes along (without any loss) a counter which for each 2 rotations (z 1 m float movement) moves forward one figure. Consequently the increase of I is equal to the number of metres by which the water level has risen (or fallen) at this point. The tidal movement, max. 3 cm/minute, can be quite neglected.

max. 3 cm/minute, can be quite neglected. The number N is counted by recording each reversal of the sense of rotation of the float axle. This counter does not react on movements less than 3 cm so that bobbing up and down of the float does not influence the number N. It is possible to increase the backlash of the counter N, but as the analysis of wave diagrams indicates, 5 cm should not be exceeded.

I admit that here are to be solved some problems. It is not possible to bring them in discussion now.



7. Self-counting integrator: IN-indicator.

A simplified execution is a non-writing integrator or the IN-counter device. The counters I and N must have at least 6 figures to

make readings for greater time-intervals possible.

Fig. 4 shows such a counter device in operation. In the smallest form the counters can be built in a small case of 18 x 18 x 18 cm. A number of them can be used as auxiliary devices, e.g. in a harbour complex, in order to be able to determine the simultaneous values of I and N at different points of such a complex. The indicators must then be read at program moments by personnel.

8. Hand-operated integrator.

> A special finish is the hand-operated integrator shown in figs 5 and 6.

In this form the apparatus is easily to be carried and can be operated by hand. When the current is not too strong, the float remains nearly vertically beneath the apparatus owing to the pulling force of the spring. In this way wave heights can be measured in all sorts of places where the observer can come by foot, with no preparation whatever.

The measuring period has to be 5 minutes at least. With a couple of these travelling integrators it is possible te measure a complete harbour complex along quays, jetties, mooring huoys etc. during a storm and it is also easy to determine at what values of I and N ships of a given tonnage will begin to get into trouble by wave action or swell. In the same way it can be determined when under certain circumstances hydraulic operations as transport of fascine mattresses, fascine works, dredging, suctionwork etc. must be stopped owing to the wave action.

Of course these observations must be effected at the place of the operation and just at the moment stopping of operations is considered. The measurings can often take place from a jetty, but are to be done from a dredging machine or other implement in other cases. The problems connected to this, such as reflection, pitching or rolling of the ship etc. have not yet been solved. A project for measuring I and N on board ship, but quite independent of the movements of the ship, has been taken in hand meanwhile. It is intended to use a hesepipe and to integrate the movements of a pneumatic plunger. This is in construction now.

9. Example of an observation in practice with the integrator.

Figs 7 and 8 show as an example a sketch of an observation in a harbour complex. It is a single incidental measuring (28th Dec. 1953) from a series performed with the hand-operated integrator in Scheveningen harbour.

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Fig. 5 . The hand operated integrator



Fig. 6. The observer operating the hand-integrator.







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The significant wave amplitude at I = 9 m/min. was 100 cm in the neck of the harbour. The regular course of the measured values of I shows that it is possible to determine well fixed values in this way. This kind of measurings has proved to be excellently reproduceable and the figures are not effected by a personal factor.

Such a measuring can be repeated during a number of storms so that a picture can be obtained of the course of the wave reduction e.g. for testing of laboratory experiments, comparisons with other harbours, hindrance to vessels etc. Relating to a reference station opens still more possibilities.

10. Determination of I and N from wave-diagram.

Comparison of I and N values of an integrator station with corresponding values of a station of which complete wave diagrams are available, is possible in the following way. On wave diagrams having a short time scale, a section can be set of 20 minutes and on a slip of paper the successive wave heights can be added. This can also be done with a curvimeter which is pushed on the paper for the rising parts of line so that only all upward going movements are added. The curvimeter then gives the value of I. Meanwhile the compiler doing this, counts the number 20 N in the 20 minutes.

11. Conclusion.

The main features of the integration device are the following:

- 1° simplified instrument;
- 2° saving of surveying;
- 3° measuring at much more locations possible;
- 4^o the method is adapted for routine observations as well as for incidental observations;
- 5° no highly qualified manpower required;
- 6° records very reduced;
- 7° records to be consulted easily;
- 8° figures I and N are immediately appropriate in the field of engineering.

References.

[1]	R.R. Putz - "Statistical Distributions for ocean waves"
[2]	1952. id - "Wave height variability; prediction of
[3]	distribution function" 1950. id - "Wave height variability; prediction of distribution function" 1951
[4] [5]	F.E. Snodgrass - "Ocean wave Measurements" 1952. H.R. Seiwell - "Results of research on surface waves on
[6]	the western north atlantic" 1948. Pierson, Neumann and James - "Practical methods for
	observing ocean waves by means of wave spectra and statistics. 1953.

RESUME

MESURES DE LA HOULE AU MOYEN DE L'INTEGRATEUR P. J. Memelsfelder

Jusqu'ici, les mesures sur la houle ont été uniquement effectuées au moyen d'instruments qui fournissent des graphiques permettant de reconstituer l'histoire chronologique du phénomène. Ces enregistrements donnent des indications en partie superflues, leur dépouillement est laborieux, surtout lorsqu'il s'agit d'en extraire les données vraiment utiles.

Nous proposons une méthode nouvelle pour obtenir plus directement les informations caractéristiques nécessaires, à savoir :

- 1) Le mouvement vertical total I de la surface libre en mètres par minute au moyen d'un intégrateur ou d'un enregistreur.
- 2) La fréquence N des vagues par minute, c'est-à-dire le nombre d'inversions par minute du sens du mouvement d'un flotteur.

Les mesures I et N ont un caractère représentatif, puisqu'ils conduisent à la détermination de H_{ave} , H_{1} , H_{max} , d'après les résultats théoriques de Putz, Seiwell, Pierson.

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L'intégrateur se compose d'un appareil actionné par un flotteur qui donne des impulsions à des compteurs, ou à des enregistreurs, soit mécaniquement, soit electriquement, ou par commande radio. Un enregistrement continu peut être réalisé de manière à donner les valeurs de I et de N d'heure en heuro et cela pendant une période aussi longue qu'on le veut. Le diagramme a une longueur de 5 cm. par jour seulement. Dans un dispositif plus simple, les indications des compteurs peuvent être relevées, à vue, une fois par jour, par exemple. On a réalisé un appareil mobile actionné à la main ; avec ce dispositif, deux opérateurs peuvent relever le complexe entier d'un port pendant une tempête, le long des quais et dans le voisinage des bouées d'amarrage. Ce dernier modèle a été spécialement conçu en vue de l'étude des obstacles à la navigation, de l'exécution des travaux, du transport des matelas de fascines, de dragages, de la relation entre le déplacement du sable et l'action de la houle.

Quelques-uns de ces instruments, déjà réalisés, sont en service aux Pays-Bas ; d'autres dispositifs sont à l'étude.

Bien que quelques-uns de ces problèmes n'aient pas encore reçu de solution satisfaisante (estimation du jeu admissible du compteur N de l'influence des irrégularités de la houle sur N et, par conséquent, de leur répercussion sur les valeurs numériques de I et de N, construction d'un intégrateur pneumatique pour les navires), les résultats paraissent pleins de promesses et nous encouragent à perfectionner encore notre matériel.