CHAPTER 3

WAVE MEASUREMENTS BY A PRESSURE TYPE WAVE GAUGE

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ABSTRACT

The paper deals with comparative measurements of irregular model waves by a pressure type wave gauge and a continuous wire wave gauge. For the depth and wave conditions used in the study it is concluded that the height of individual waves obtained by a pressure type gauge and using the first order wave theory may be in considerable error, while wave height distributions and wave spectra are fairly good estimated.

INTRODUCTION

Pressure type wave gauges have been extensively used in many locations throughout the world. Along the Norwegian coast wave measurements with such gauges have been carried out at four exposed locations since 1959 by the Norwegian State Harbour Authorities. The data from these gauges are collected by and analysed at the Technical University of Norway.

The Norwegian gauges are placed close to the bottom at depths 17-20 m.

When using pressure type wave gauges, the wave height is usually obtained by using the first order wave theory, sometimes modified by an emperical factor which often is a function of the wave frequency.

According to the first order wave theory the relation between the wave height and the recorded differential pressure is the following

$$\Delta p = \gamma \cdot \frac{H}{2} \frac{\cosh k\,(d-z)}{\cosh kd}$$

where:

γ= specific weight of water. H = wave height
k= $2\pi/L$. L = wave length. d = water depth
z= vertical distance from the still water level to the pressure gauge

A record of pressure variations due to waves is more or less similar to what has been sketched in Fig. 1. The apparent wave period may be obtained by some method like the zero-up-crossing method which has been used in this paper as shown in Fig. 1.

First order wave theory leads to errors in the wave height estimates, (1), (2) and (3). Higher order wave theories have not usually been used because of the excessive computing work involved to obtain wave heights from the pressure records. It should also be pointed out that really no reliable wave theory exists for short crested irregular waves. For practical reasons it has therefore been usual to modify the wave heights obtained by first order wave theory by some empirical factor.

The work reported in this paper were carried out to investigate in a wave flume the accuracy of pressure wave gauges with particular reference to the conditions of the gauges along the Norwegian coast. All the data in this paper are presented as model data. However, if a linear scale of 1:20 is applied the water depth used in the wave flume corresponds to 20 m, the significant wave periods to 9 seconds and the significant wave heights to 3 to 5 metres.

WAVE MEASUREMENTS

The measurements of wave heights by a pressure wave gauge and a continuous resistance wire gauge were made in a wave channel, 78 metres long, 3,8 m wide and with a water depth of 1 m.

The wave channel is equipped with a wave generator which can generate unidirectional regular or irregular waves. The unidirectional spectra of the irregular waves can be of any reasonable shape and the significant waves up to 25 cm high.

The pressure wave gauge was a pressure transducer from a Swedish company: SWEMA. The transducer was mounted outside the channel and connected by a plastic tube to a pressure tap in the channel wall. As shown in Fig. 2 the continuous wire gauge was located in the same cross-section as the pressure gauge.

Recordings of pressures from regular waves were analysed using both first and fifth order wave theory. Fig. 3 shows comparisons of pressures measured by the pressure gauge and pressures calculated from wave heights obtained by the wire gauge using the first order wave theory. Fig. 4 shows a similar comparison between measured pressures and pressures obtained by the fifth order wave theory. There is a fair agreement between measured pressures and pressures calculated according to the fifth order wave theory, indicating that the testing arrangement was working satisfactorily.

It should be pointed out that the pressure transducer and the set up in the model is an ideal pressure gauge with a full pressure response for all frequencies. Prototype gauges may, due to hydraulic, mechanical and electronical conditions respond to the pressures differently than the transducer used in the present investigation.

Fig. 5 shows a sample of simultaneous recordings of irregular waves from the continuous wire gauge and the pressure gauge. This sample shows a characteristic feature of the pressure wave gauge, namely that it does not record as many waves as the wire gauge.

The zero upcrossing method was first applied to the recording from the wire gauge, and the waves were numbered consecutively. Then the same procedure was applied to the pressure gauge record. Waves that could more or less be traced to be the same on the two records were given the same numbers while waves on the pressure gauge that could not be traced on the continuous wire gauge were given a combined number corresponding to the waves on the wire gauge recording during the same time interval.

Fig. 6 shows a comparison of waves measured by the wire gauge and waves obtained from the pressure gauge using first and fifth order wave theory respectively. Only waves which are comparable according to Fig. 5 have been used in Fig. 6. The agreement is not very good, and it is probably not to be expected to be better. The usual concept of irregular waves is that the irregular surface configuration is generated by regular waves travelling at their own individual speed. It is then understandable that a poor result is obtained when applying a theory that is valid to only the individual waves to a phenomenon that is an interference of many waves.

Some calculations have been made to compare wave power-spectra and wave height distributions from the wire gauge and the pressure gauge.

The calculations of the wave power spectra and the wave height distributions were based on records of 100-200 consecutive waves, varying somewhat from sample to sample. The power spectras were calculated through the autocorrelation function and the raw spectra smoothed according to the Hanning method. The time lag used in the calculations was 1/4 seconds, and eighty points were calculated of the autocorrelations function.

The power spectra of the waves measured by the pressure gauge were obtained by calculating the power spectra of the pressures and applying a transfer function according to the first order wave theory.

The wave heights used in obtaining the wave height distribution are those obtained by applying the zero upcrossing method. The wave heights from the pressure gauge were obtained by using the apparent wave period when calculating the pressure response factor.

Fig. 7 and 8 show spectra and wave height distributions from the two gauges. The agreement is rather good. Several similar analysis have been made. The agreement was not always as good as shown in Figs. 7 and 8, but the agreement between significant wave heights obtained from the pressure and continuous wire gauge was in general within 10% of the wave height.

In view of the poor accuracy on the individual waves obtained by the pressure gauge, it is quite surprising that the accuracy is so good when dealing with the waves in a statistical manner.

CONCLUSION

The present investigations have shown that wave heights of individual waves obtained from pressure records of irregular unidirectional waves may have considerable errors, irrespective of whether first or fifth order wave theory is used.

However, using first order wave theory when analysing pressure gauge records of unidirectional irregular waves may give reasonably accurate wave spectra and wave height distributions. In particular a fair estimate of the significant wave height is obtained.

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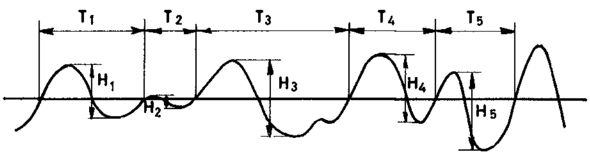

FIG. 1 ZERO UPCROSSING

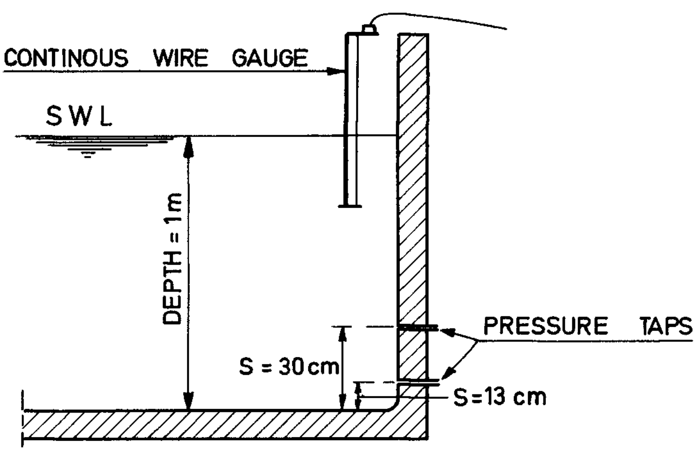

FIG. 2. SETUP LOCATION OF PRESSURE TAPS
AND CONTINUOUS WIRE GAUGE

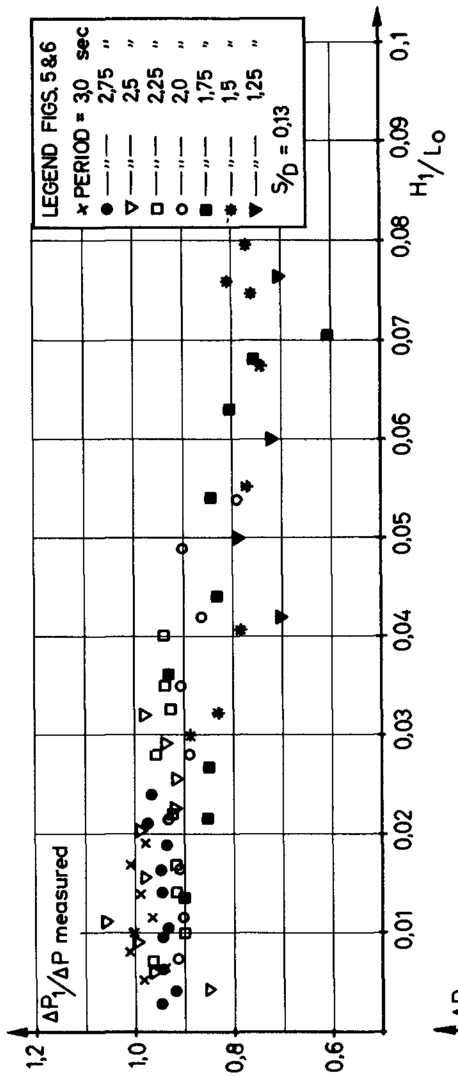

FIG. 3

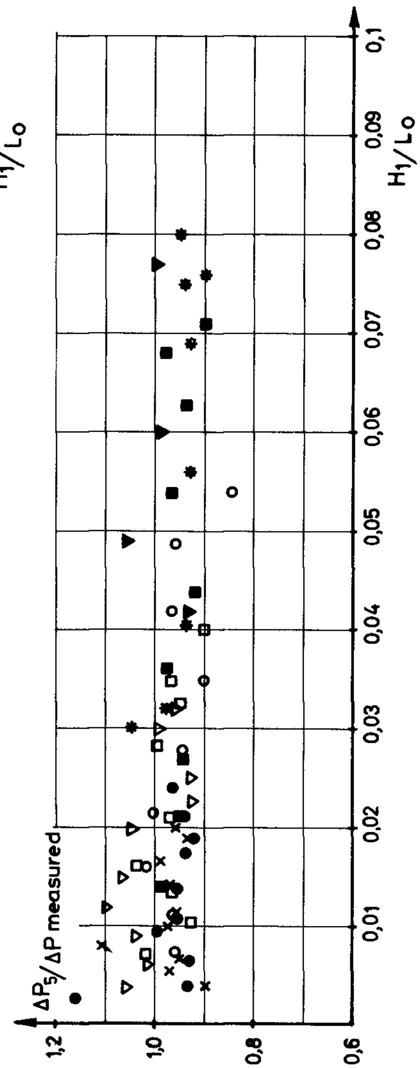

FIG. 4

Δp_1 = PRESSURE VARIATION ACCORDING TO 1st ORDER WAVE THEORY

Δp_5 = " " " " 5th " " "

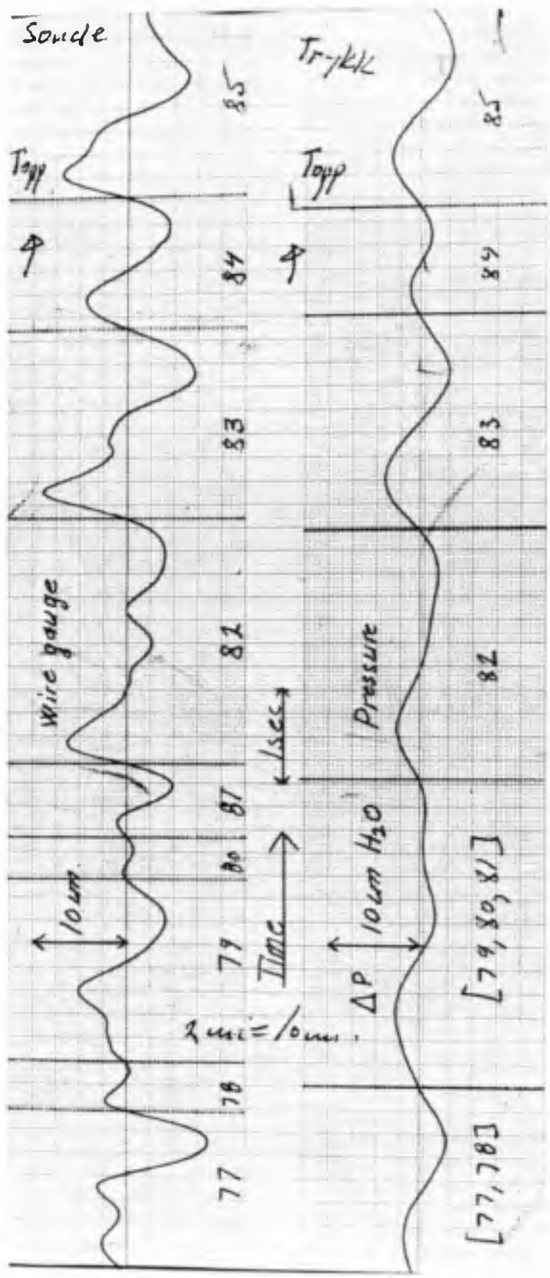

FIG. 5 SIMULTANEOUS RECORDINGS FROM THE CONTINOUS WIRE GAUGE AND THE PRESSURE GAUGE

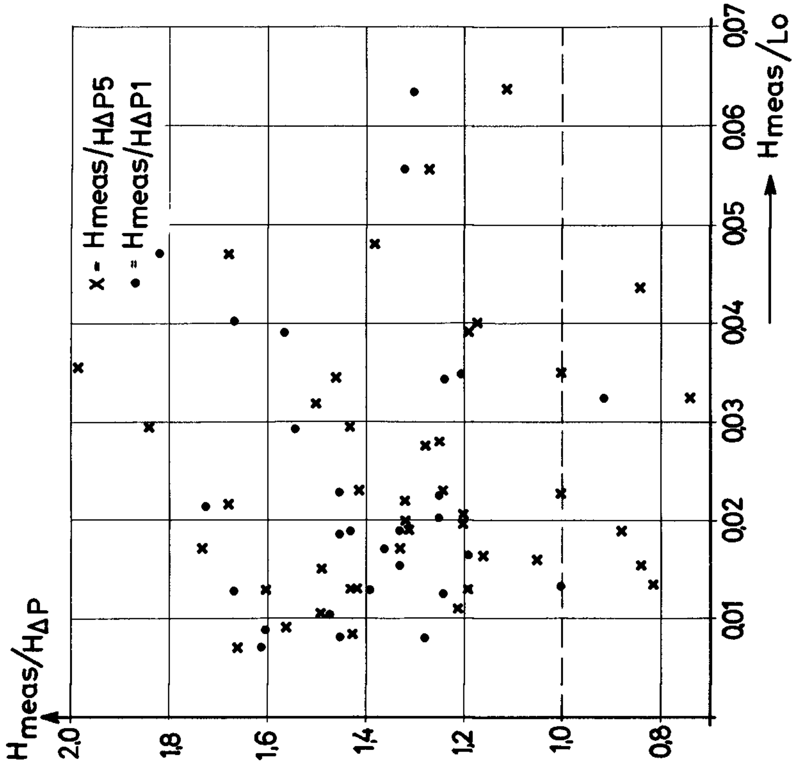

FIG. 6 COMPARISON OF WAVEHEIGHTS OBTAINED BY A CONTINOUS WIRE GAUGE, (H means), AND A PRESSURE GAUGE, ($H_{\Delta p}$)

$H_{\Delta p1}$ = ACCORDING TO 1^{st} ORDER WAVE THEORY

$H_{\Delta p5}$ = " " 5^{th} " " "

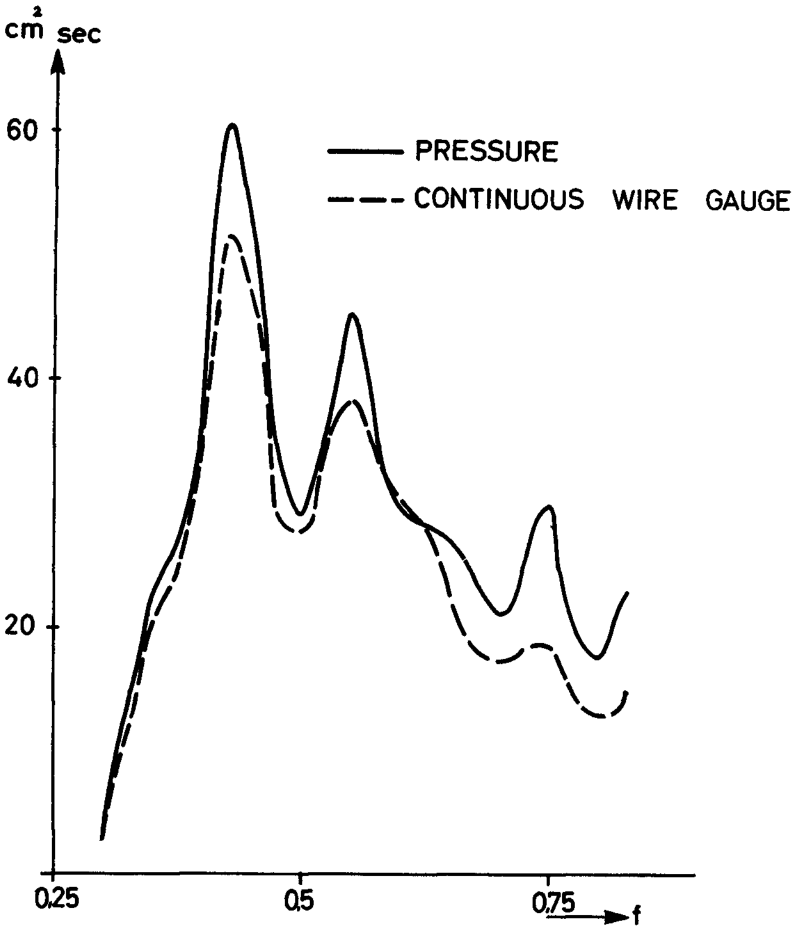

FIG. 7 WAVE SPECTRA

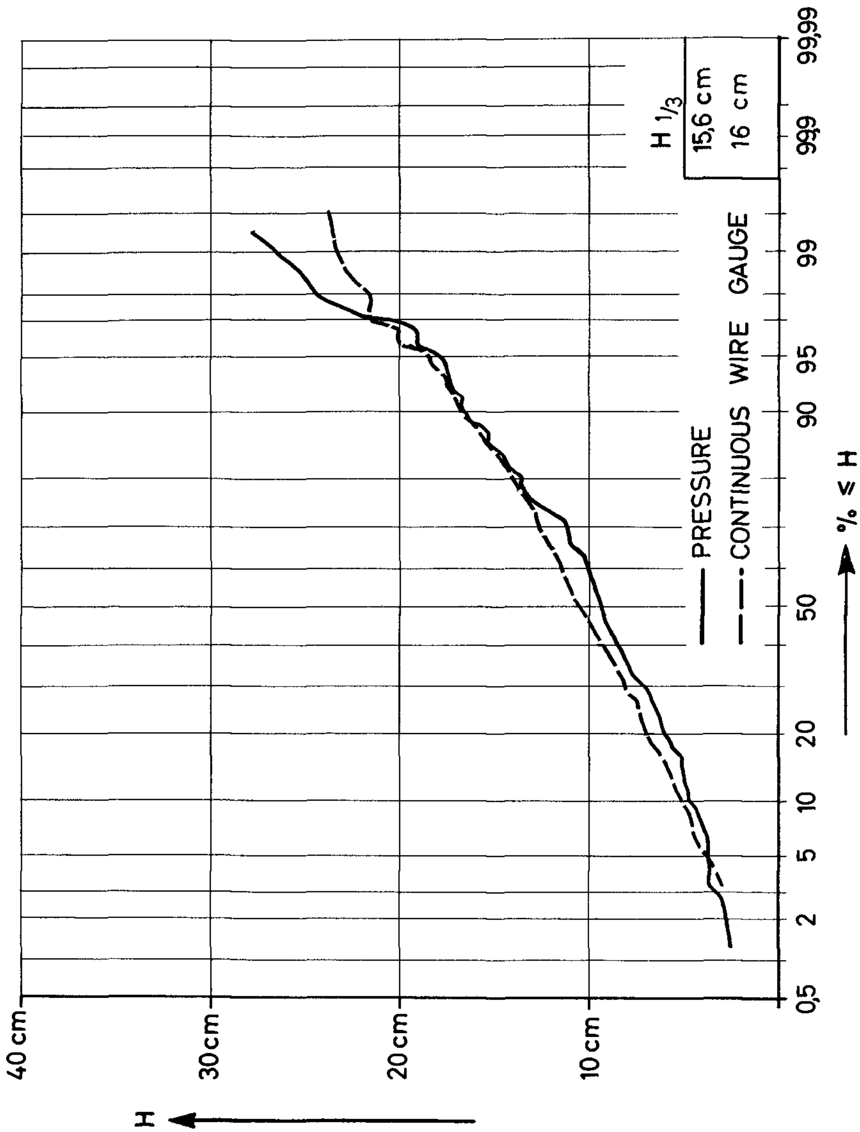

FIG. 8 WAVE HEIGHT DISTRIBUTION