WAVES IN CARDIGAN BAY, IRISH SEA

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L. DRAPER and T. G. WILLS

IOS Report No. 32

January 1977

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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CONTENTS

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L. Draper[(a)] and T.G. Wills[(b)]

Waves have been recorded by a Waverider buoy placed in a water depth of about 30 metres at 52°12'N 4°50'W, approximately 17 kilometres north west of the town of Cardigan. It was in operation from 5 January to 31 December 1973. The radio receiver was placed on a headland giving a radio transmission distance of about 18 kilometres. All of the records have been analyzed to give what is in effect a complete year's wave data. The records were on charts; the analysis mainly followed the method developed by Tucker (1961) from theoretical studies by Cartwright and Longuet-Higgins (1956). The method of presentation is that recommended for data for engineering purposes by Draper (1966).

Records were taken for fifteen minutes at three-hourly intervals, and the analysis of the first twelve minutes of each record yields the following parameters:

(a) H_1 = The sum of the distances of the highest crest and the lowest trough from the mean water level.

(b) H_2 = The sum of the distances of the second highest crest and the second lowest trough from the mean water level.

(c) T_z = The mean zero-crossing period, obtained by dividing the duration of the record (in seconds) by the number of occasions the trace passes in an upward direction through the mean water level.

(d) T_c = The mean crest period.

From these measured parameters the following parameters have been calculated, after allowing for instrumental response:

(e) H_s = The significant wave height (mean height of the highest one-third of the waves): this is calculated separately from both H_1 and H_2, and an average taken. The relationship between the parameters is: $H_s = f.H_1$ where f is a factor related to the number of zero-crossings in the records (Tucker, 1963). A similar relationship is used for the calculation of H_s from H_2.

(a) Institute of Oceanographic Sciences, Wormley.
(b) Instrumentation and Trials Dept., Royal Aircraft Establishment.

(f) $H_{max(3\ hours)}$ = The most probable value of the height of the highest wave which occurred in the recording interval (Draper, 1963). (The recording interval is the time elapsed between the start of successive records).

(g) ϵ = The spectral width parameter, which is calculated from T_z and T_c (Tucker, 1961): $\epsilon^2 = 1 - (T_c/T_z)^2$.

The results of these measurements are expressed graphically and divided into seasons thus:

Winter:	January	February	March
Spring:	April	May	June
Summer:	July	August	September
Autumn:	October	November	December

For each season a graph (Figures 1-4) shows the cumulative distribution of significant wave height H_s and of the most probable value of the height of the highest wave in the recording interval, $H_{max(3\ hours)}$.

The distribution of zero-crossing period is given for each season (Figures 5-8).

The distribution of the spectral width parameter is given for the whole year (Figure 9).

Figure 10 is a scatter diagram relating significant wave height to zero-crossing period, for the whole year.

Figure 11 is a storm persistence diagram for the whole year.

Figure 12 is a plot of $H_{max(3\ hours)}$ on probability paper, for the whole year.

Figure 13 is a plot of $H_{max(3\ hours)}$ on Weibull probability paper, for the whole year.

Summary and Discussion of Results

Before using these data please refer to the penultimate paragraph entitled Wind Conditions.

Highest Waves

The highest value of H_1 (after correction for instrumental response) was 6.8 metres; it occurred on 12 February with a zero-crossing period of the whole record of 6.79 seconds. Waves of almost this height occurred at other times (autumn and winter) in the year.

Percentage occurrence of wave heights

Figures 1-4 indicate for what proportion of time H_s or $H_{max(3\ hours)}$ exceeded a particular height. The autumn and winter months had, as expected, more waves exceeding any given height than did the spring and summer months. For example, in the winter the significant height exceeded 1 metre for 48% of the time, whereas in the summer this value was exceeded for 24% of the time.

Zero-crossing periods

Figures 5-8 show only a little seasonal variation in the zero-crossing period. In the winter the most common period was about 6 seconds whereas in the summer it was about 5 seconds. However, occasionally the arrival of a very low swell in locally calm conditions gave zero-crossing periods in the upper tens of seconds.

Spectral width parameter

Figure 9 shows the spectral width parameter to lie mainly between 0.5 and 1, due principally to the Irish Sea being relatively small and almost enclosed, resulting in a rarity of swell from other areas.

Scatter diagram

The scatter diagram (Figure 10) shows, in parts per thousand, the numbers of occurrences of particular combinations of zero-crossing period and significant wave height. It indicates that in 1973 the waves most often encountered at this location had a period of between 4 and 5 seconds and a significant height of between 0.4 and 1.2 metres. Within these values wave conditions occurred for 181 thousandths, or 18.1%, of the time. It can be seen from the diagram that there are no waves recorded having periods appreciably less than 3 seconds. This is due to the size and characteristics of the buoy.

A parameter which is sometimes of interest is wave steepness, expressed as wave height:wave length. It should be noted that the steepness of a wave is not the same as the maximum slope of the water during the passage of a wave. Lines of constant steepness of 1:20 and 1:40 are drawn on Figure 10. (Wave length L was computed using the linear theory with period T in deep water, that is $L = gT^2/2\pi$). The great majority of the waves represented on this diagram are less steep than 1:18.

The steepness of the wave conditions at the time of occurrence of the highest wave measured in the year, defined as significant wave height versus length calculated from the zero-crossing period, is 1:16.7 and the steepness of that individual wave, again related to zero-crossing period, is 1:10.6 (steepness is sometimes expressed as a decimal number, for example 1:20 and 0.05 describe the same steepness).

In many reports on wave conditions a small percentage of the time is reported as being calm. This is because there is a lower limit to the size of undulation on the chart which is amenable to analysis. In this case the chart scale was an expanded one, compared with other installations, also the short-period cut-off occurs at a slightly shorter period than with the shipborne recorder, the main instrument of our wave data collection programme so far. Usually, waves of less than 0.3 metre crest to trough are taken as calm; in this case it was possible to read the chart to 0.1 metre.

Persistence of storms

The diagram is prepared by listing the durations in the entire year for which the wave conditions stay at or above a given threshold value; for each wave height level the cumulative total of occurrences of a given duration or longer are calculated, so that from this diagram may be deduced both the number and the durations of occasions in 1 year on which waves persisted at or above a certain height. For example if a vessel is unable to leave a particular harbour in conditions of significant wave height 2 metres or above, then it would have been prevented from operating for spells of 10 hours or more on 30 occasions during the year; 11 of these would have been spells of at least 24 hours, and so on.

Lifetime wave prediction (Draper, 1963)

Values of $H_{max(3\ hours)}$ have been plotted on both log-normal probability and Weibull probability paper. The former yields a 50-year lifetime wave height of 13 to 15 metres with the most likely value at about 14 metres. The Weibull presentation indicates 13 metres. Allowing for the winds being lighter than average in 1973 the 50-year prediction from the log-normal distribution becomes 16 metres and from the Weibull distribution it becomes 15 metres.

Wind conditions

An analysis of wind conditions at Valley, in Anglesey, Milford Haven and the Aberporth Meteorological Office shows that in 1973 the mean wind speed at Valley was 89% of an 11 year average, at Milford Haven it was 93% of a 9-year average and at Aberporth, Cardigan, it was 93% of a 15-year average. If the mean speed over the generating area is therefore taken to be 92% of a long-term average it may be reasonable to assume that the wave heights measured were between 85 and 88% of typical conditions, depending on whether wave heights generated here are related to the wind speed to the power 2 or 1.5, appropriate to deep and shallow water respectively (Darbyshire, 1961). In view of the relatively shallow water in the Bay it may be reasonable to take a wave-height value of 87% of normal. Accordingly, to obtain average conditions, all wave heights in this report should be increased by about 15%, and periods by about 4%.

Acknowledgements

The authors wish to acknowledge the assistance provided by the Meteorological Office in the task of collating over 2500 Datawell records and in the provision of meteorological records used in the production of this report. They also gratefully acknowledge the considerable assistance of many colleagues at all stages of the project.

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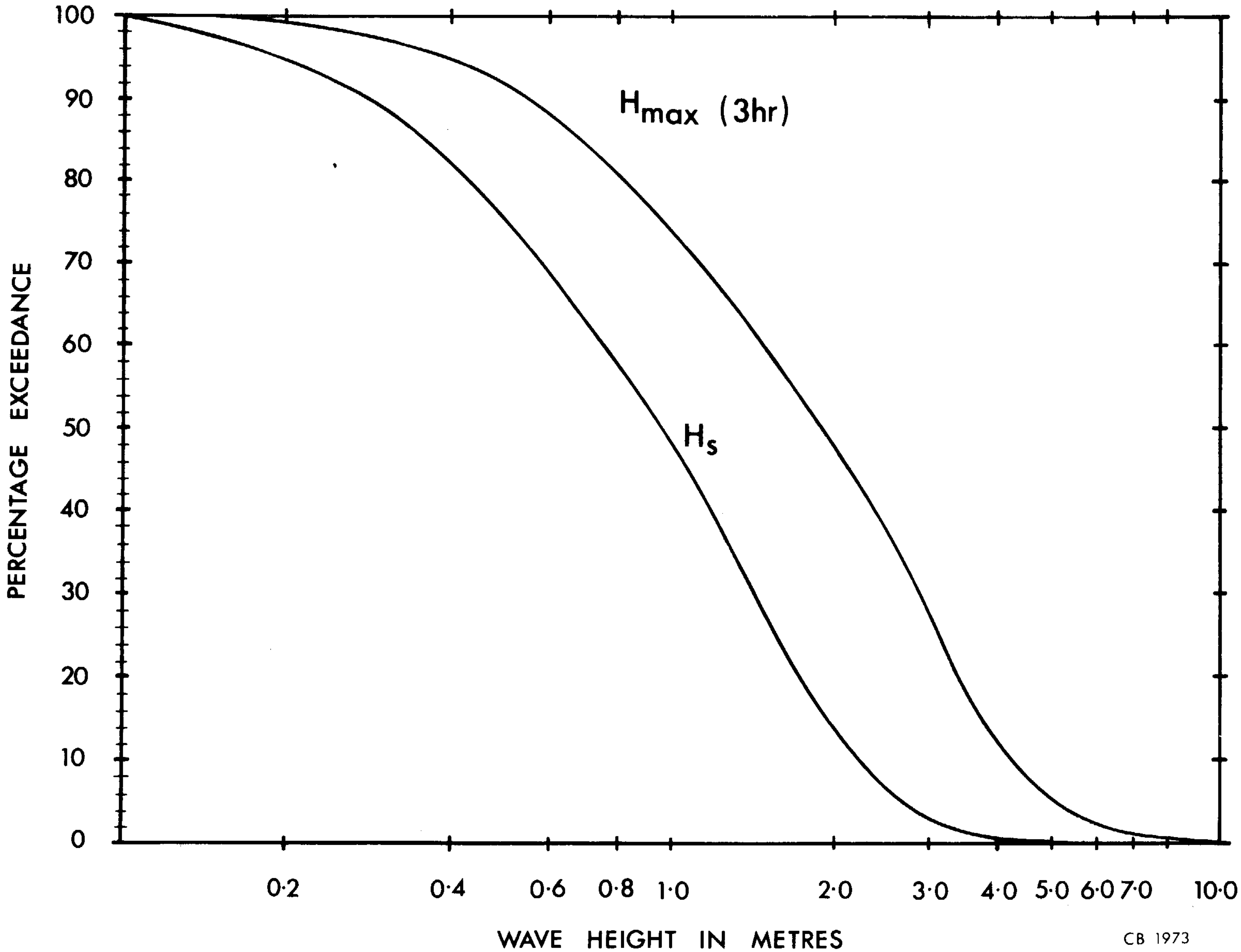
PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

WINTER – JANUARY TO MARCH



CB 1973

FIG.1

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

SPRING — APRIL TO JUNE

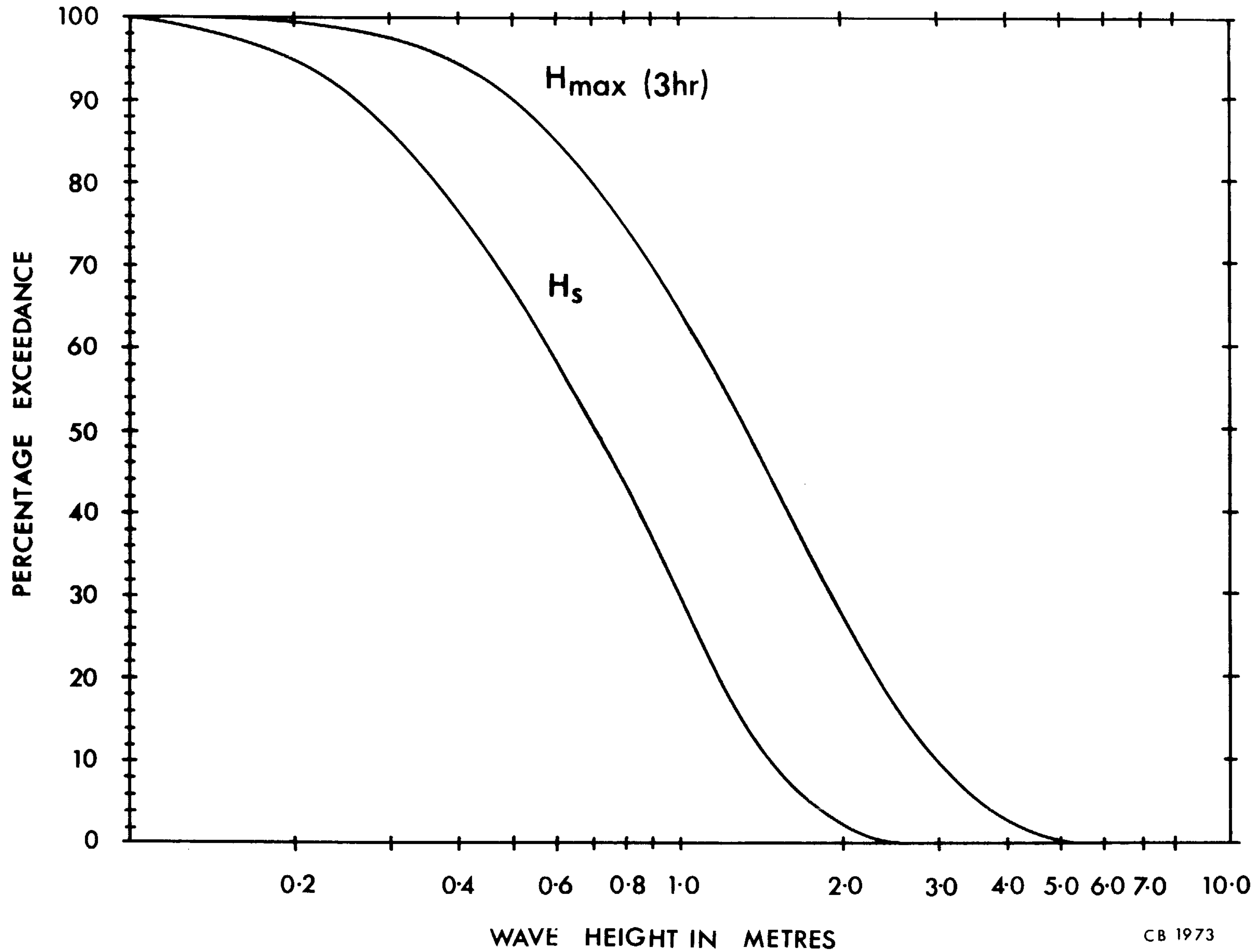


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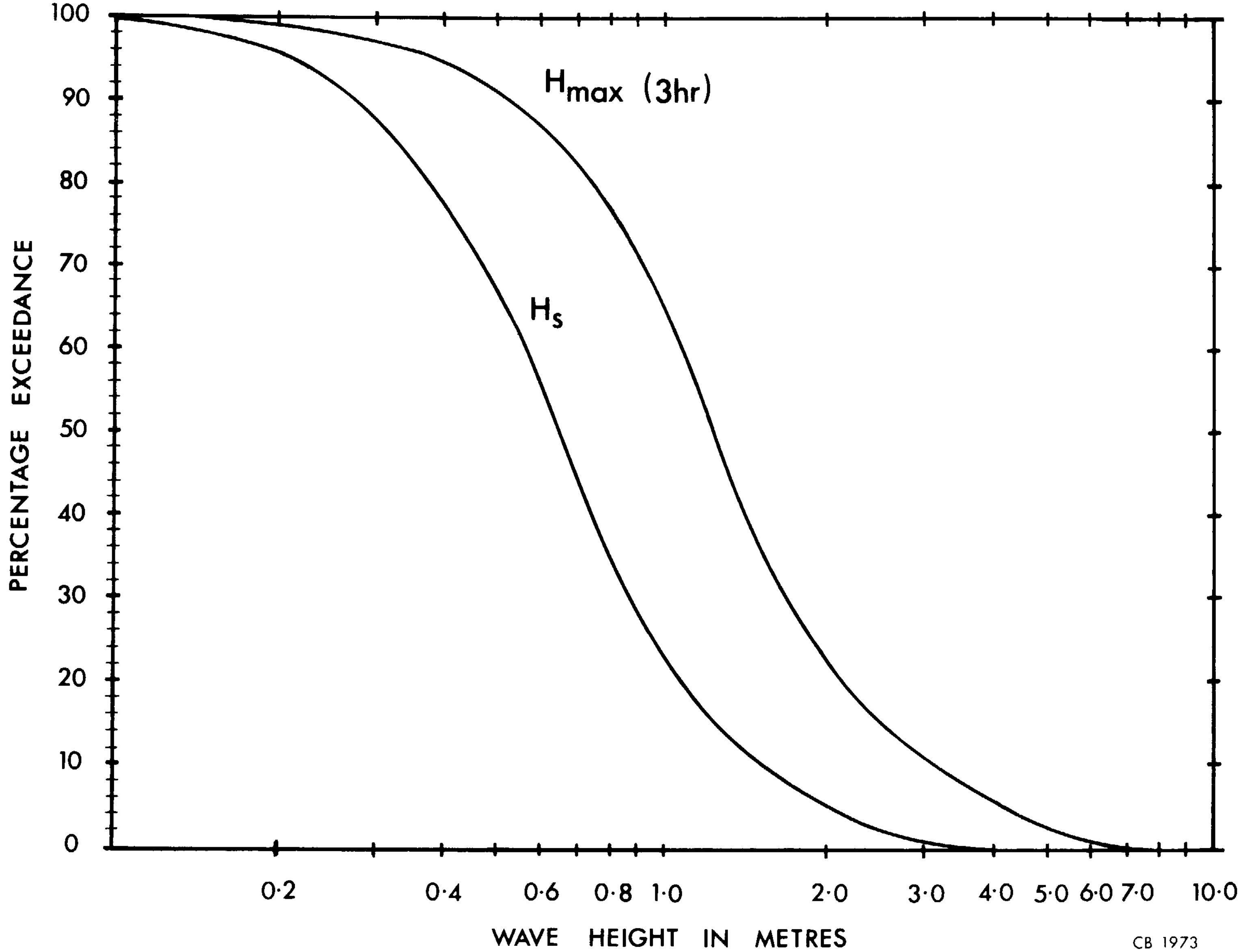
FIG. 2

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

SUMMER – JULY TO SEPTEMBER

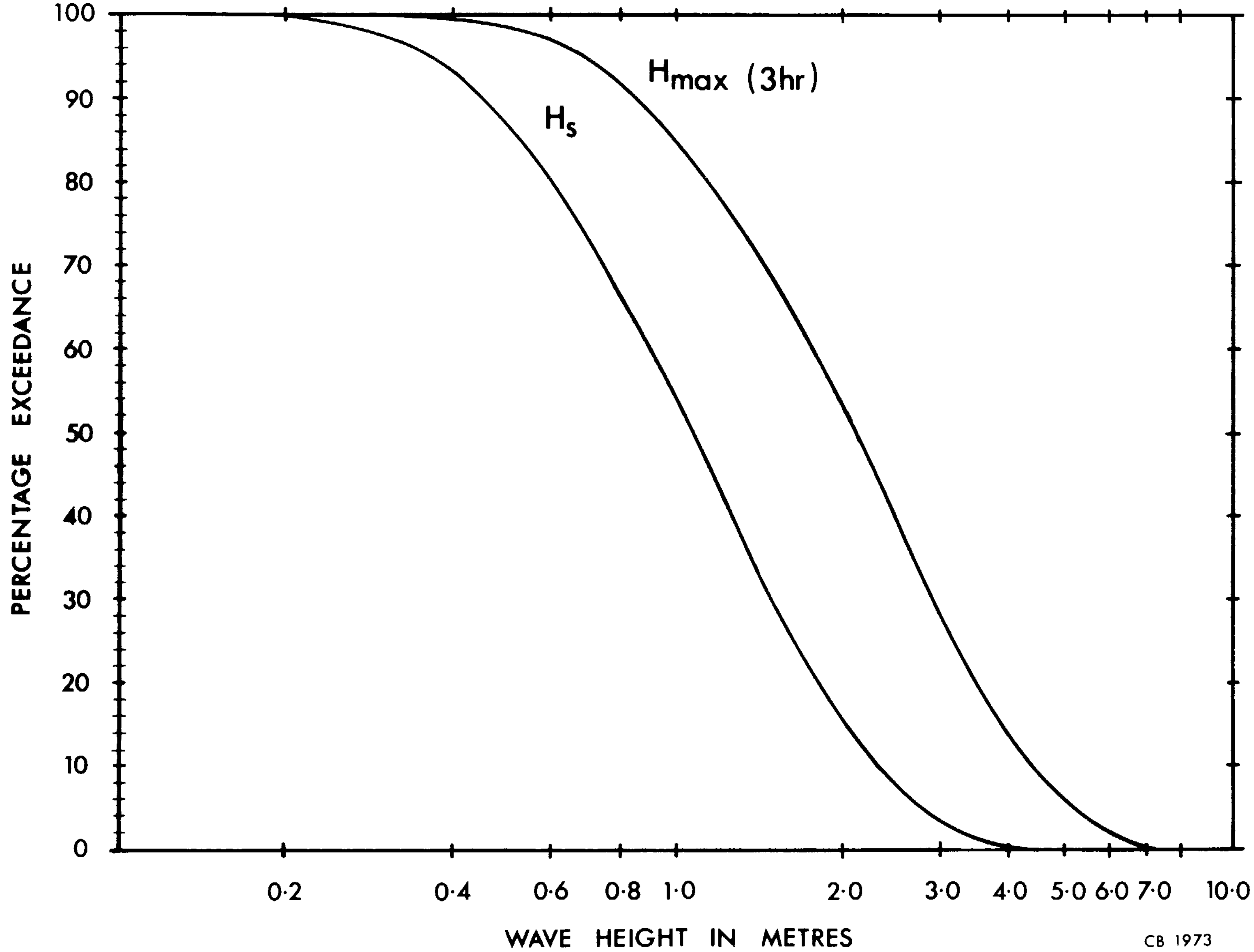


CB 1973

FIG. 3

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

AUTUMN – OCTOBER TO DECEMBER

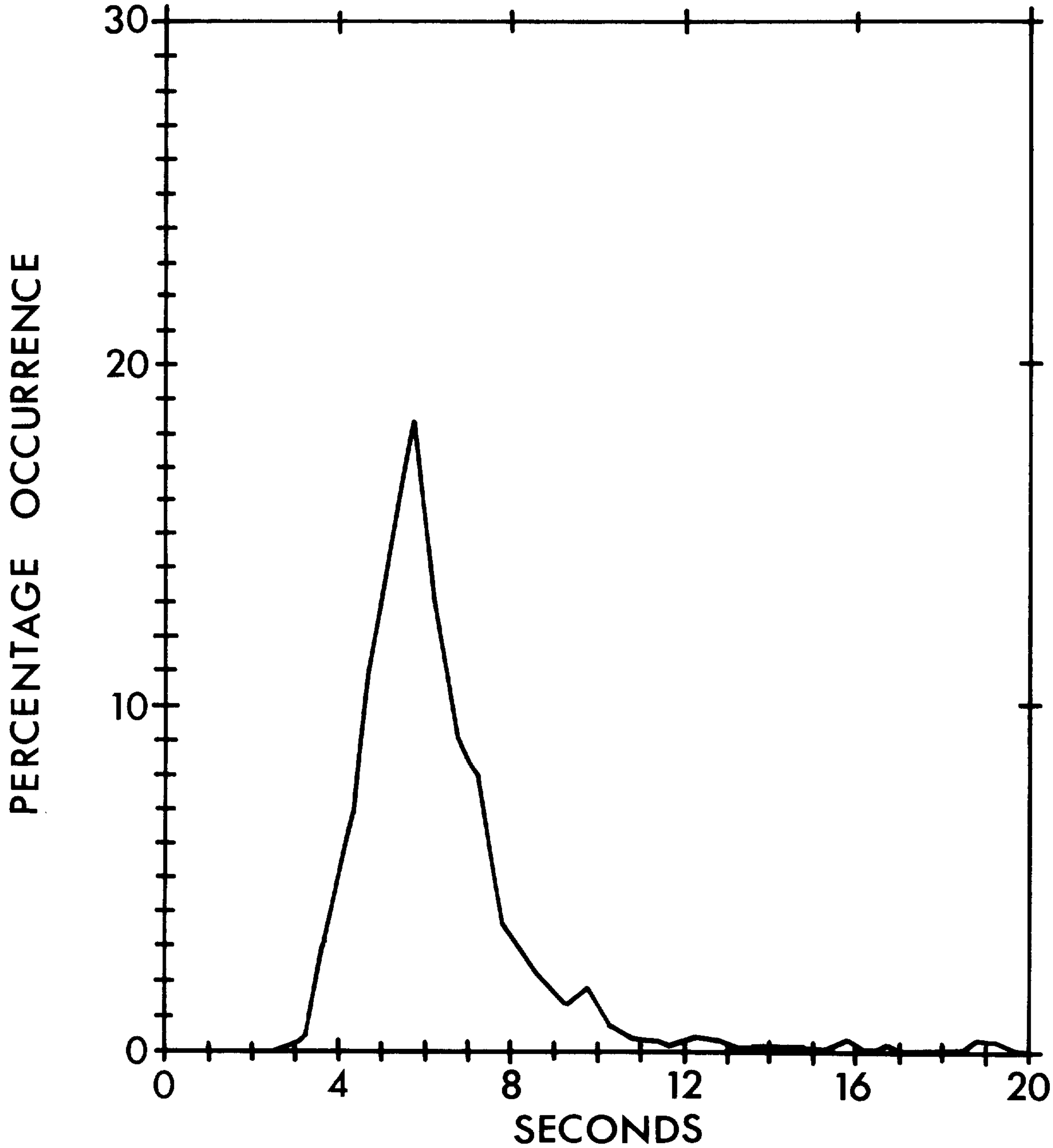


CB 1973

FIG. 4

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

WINTER — JANUARY TO MARCH



ZERO CROSSING PERIOD

(PLOTTED IN HALF SECOND INTERVALS)

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FIG. 5

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

SPRING — APRIL TO JUNE

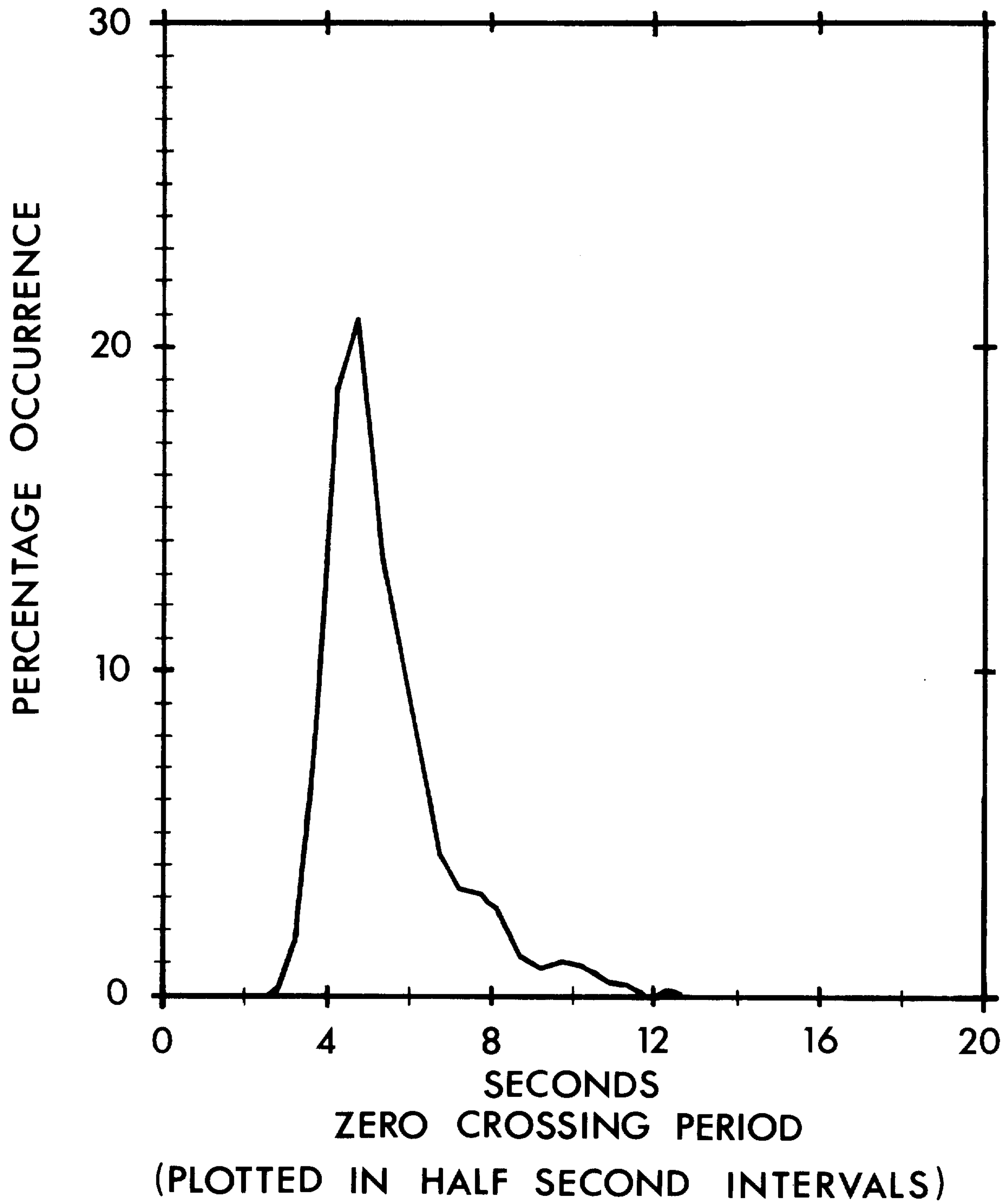

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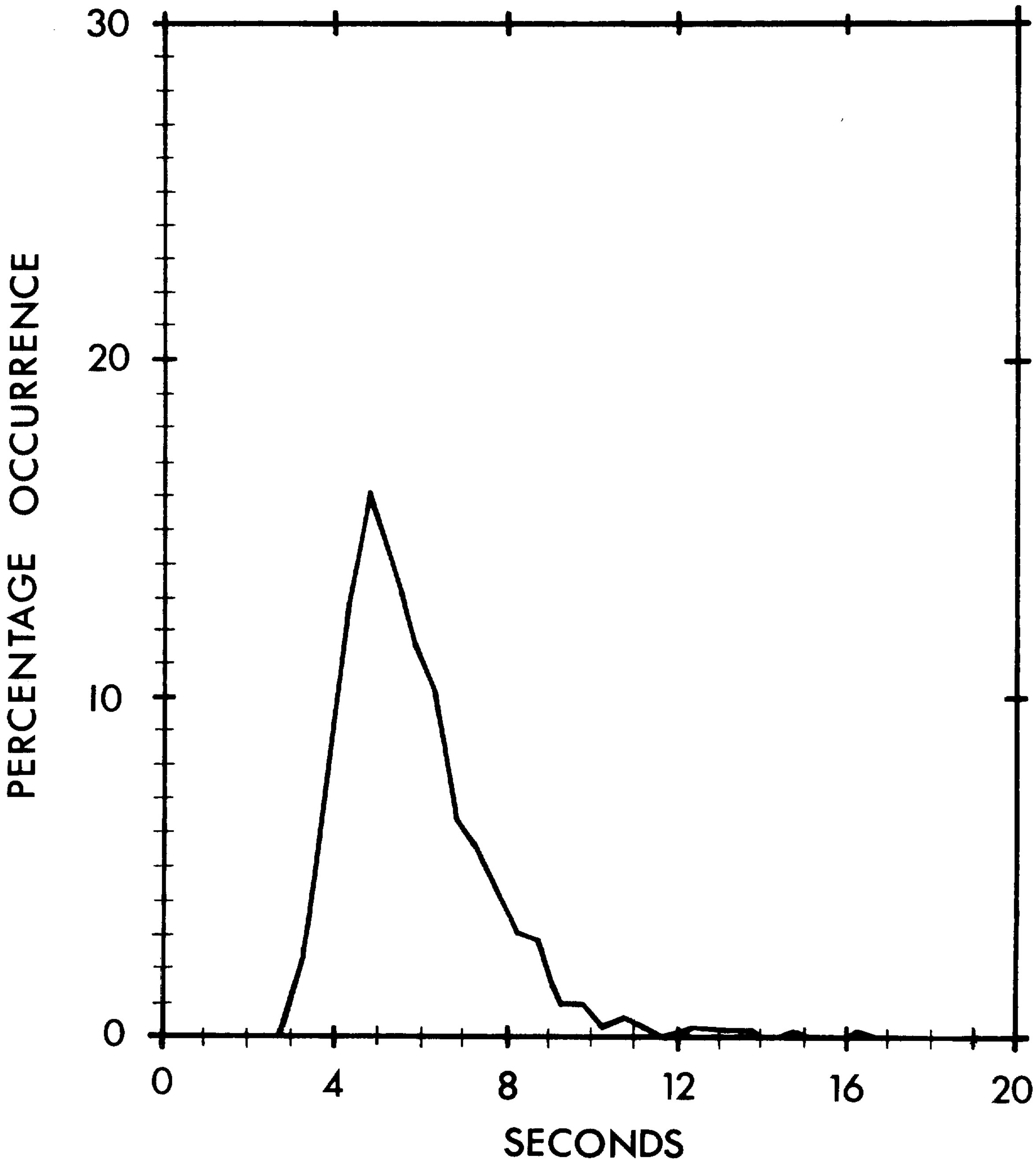
FIG. 6

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

SUMMER — JULY TO SEPTEMBER



ZERO CROSSING PERIOD

(PLOTTED IN HALF SECOND INTERVALS)

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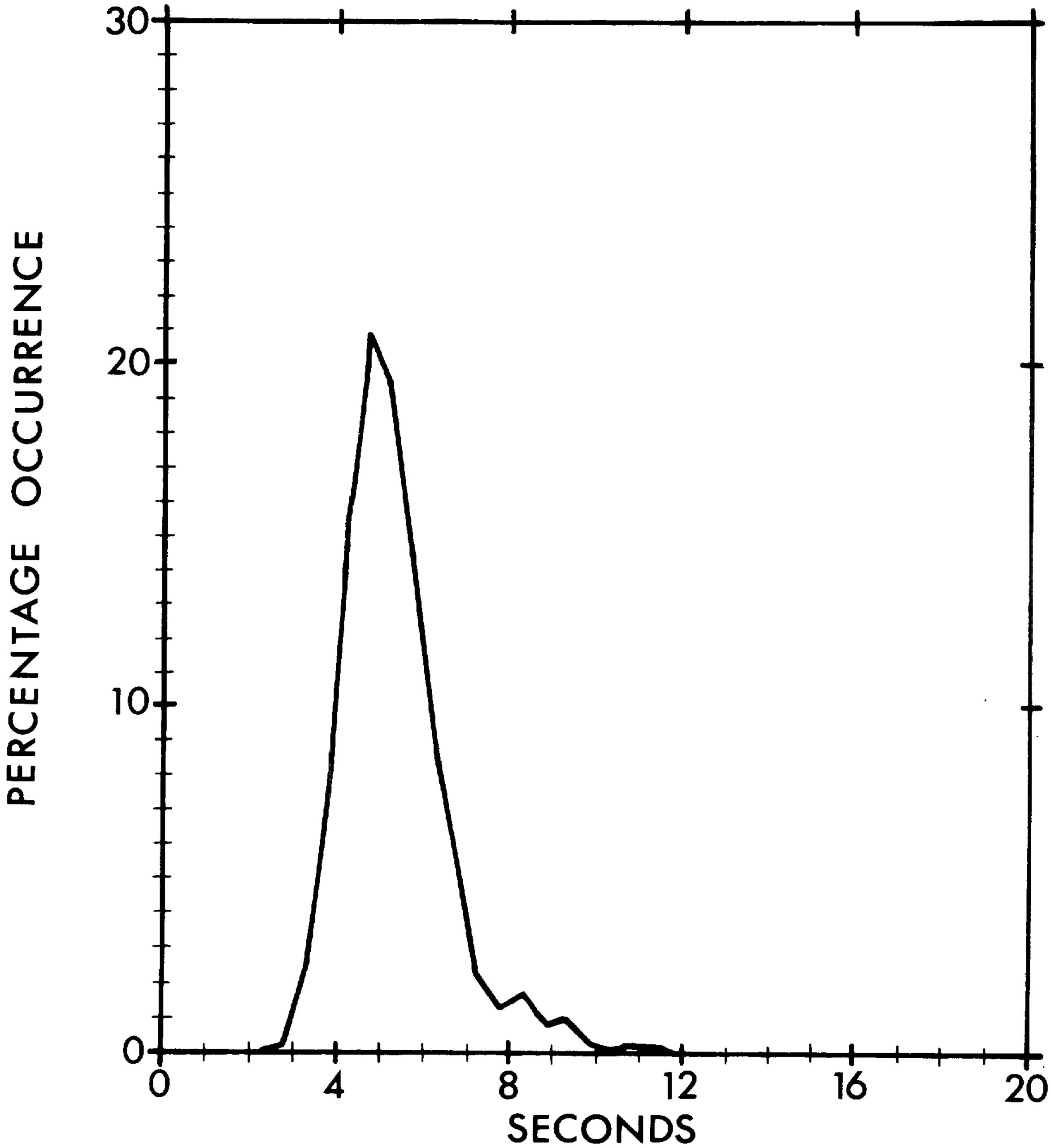
FIG. 7

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

AUTUMN — OCTOBER TO DECEMBER



ZERO CROSSING PERIOD

(PLOTTED IN HALF SECOND INTERVALS)

CB 1973

FIG. 8

GRAPH OF SPECTRAL WIDTH PARAMETER FOR A WHOLE YEAR.

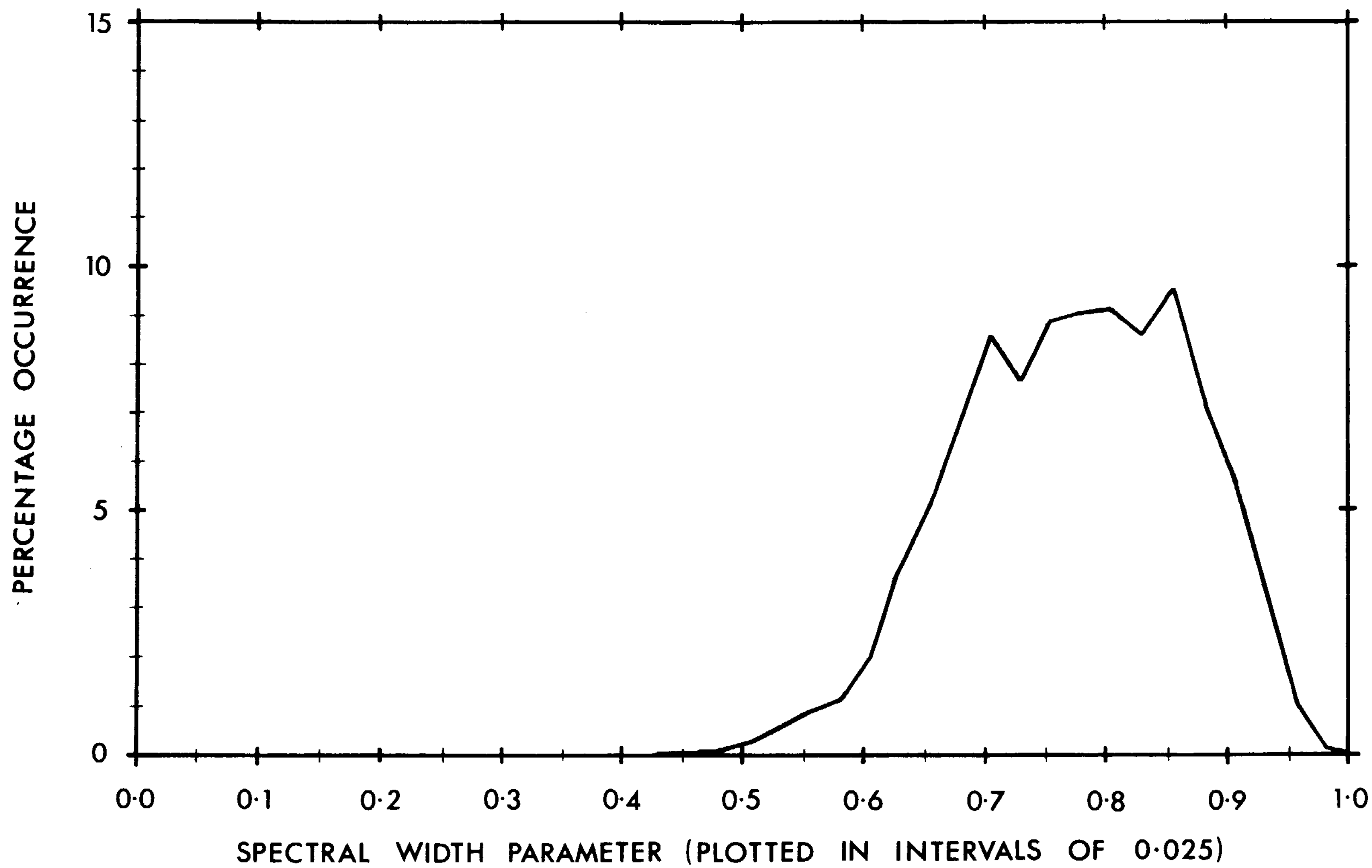


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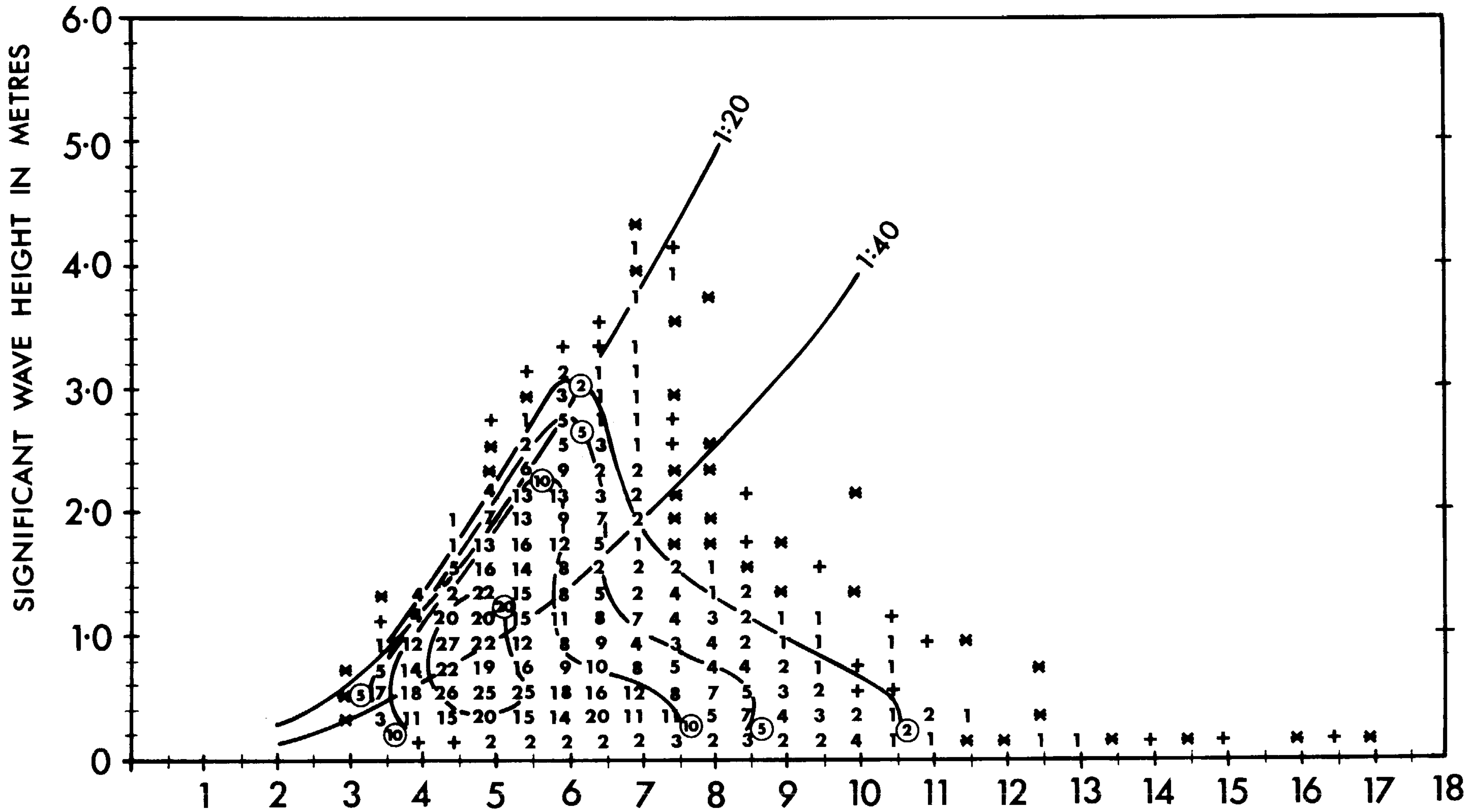
FIG. 9

SCATTER DIAGRAM FOR THE WHOLE YEAR

IN PARTS PER THOUSAND ✖ = 1 OCCURRENCE (0·3 part)
+ = 2 OCCURRENCES (0·7 part)



SECONDS
ZERO CROSSING PERIOD
(IN HALF SECOND INTERVALS)

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FIG. 10

PERSISTENCE DIAGRAM FOR THE WHOLE YEAR

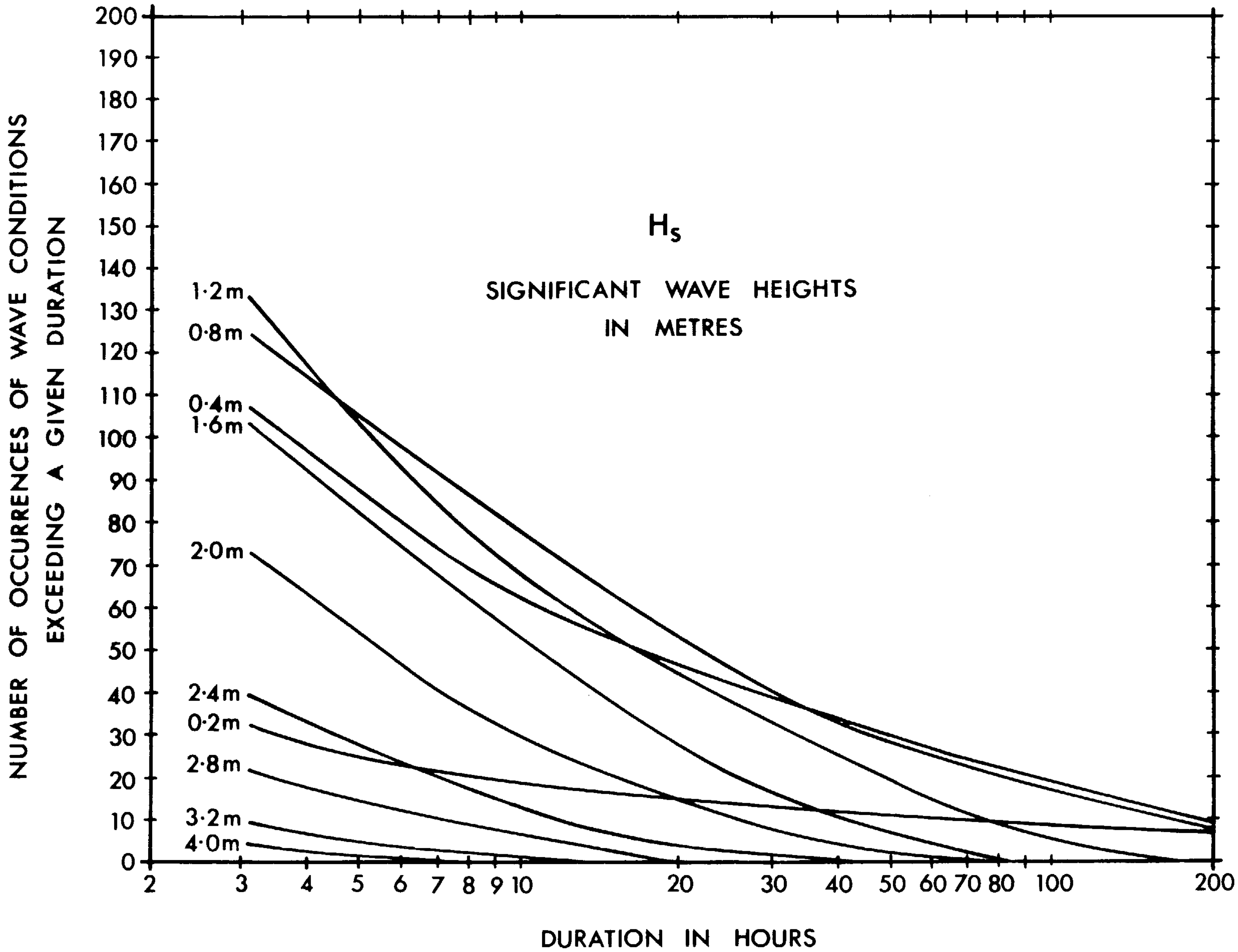

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FIG. 11

LIFETIME WAVE PREDICTION LOG — NORMAL PROBABILITY

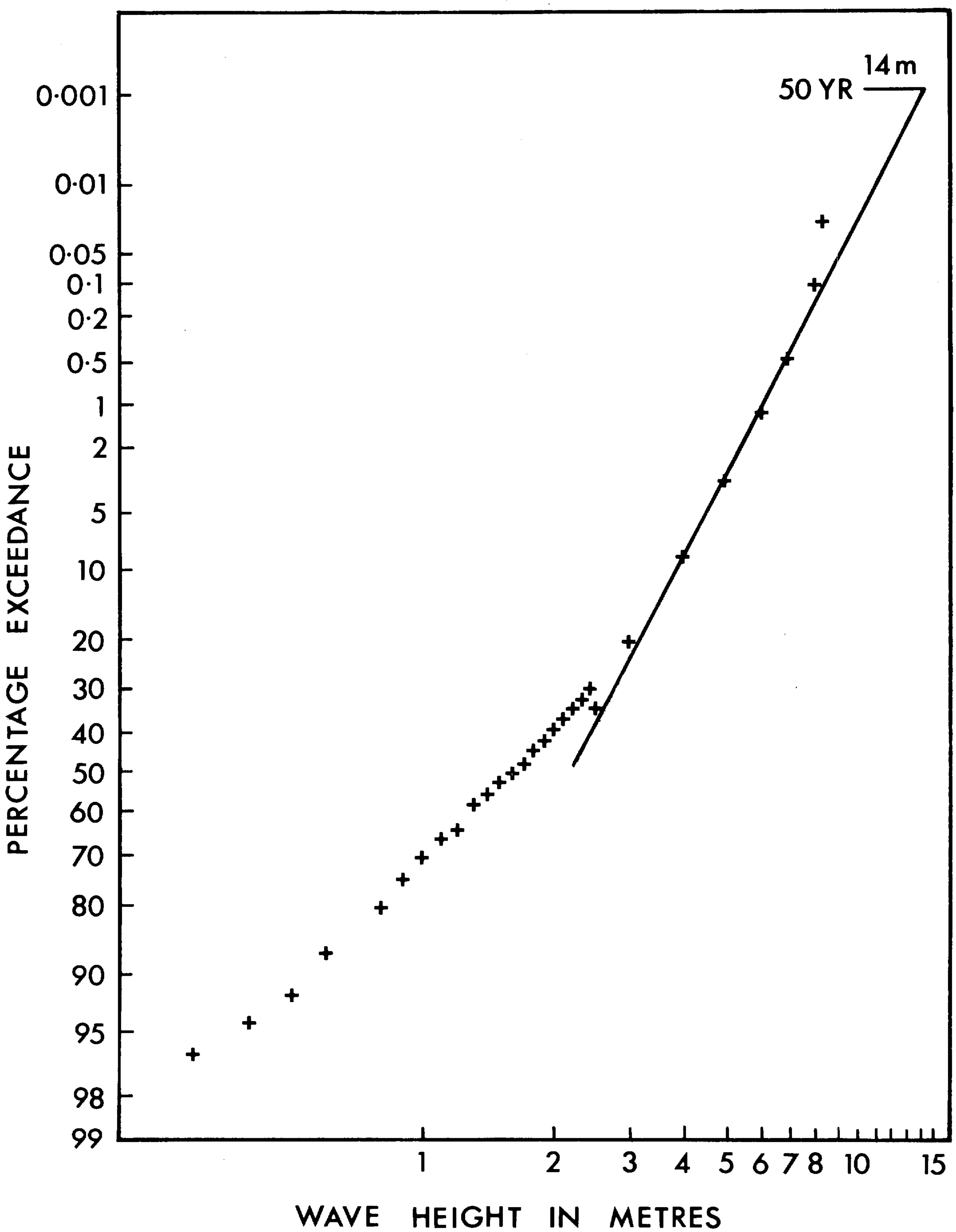

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FIG. 12

LIFETIME WAVE PREDICTION — WEIBULL

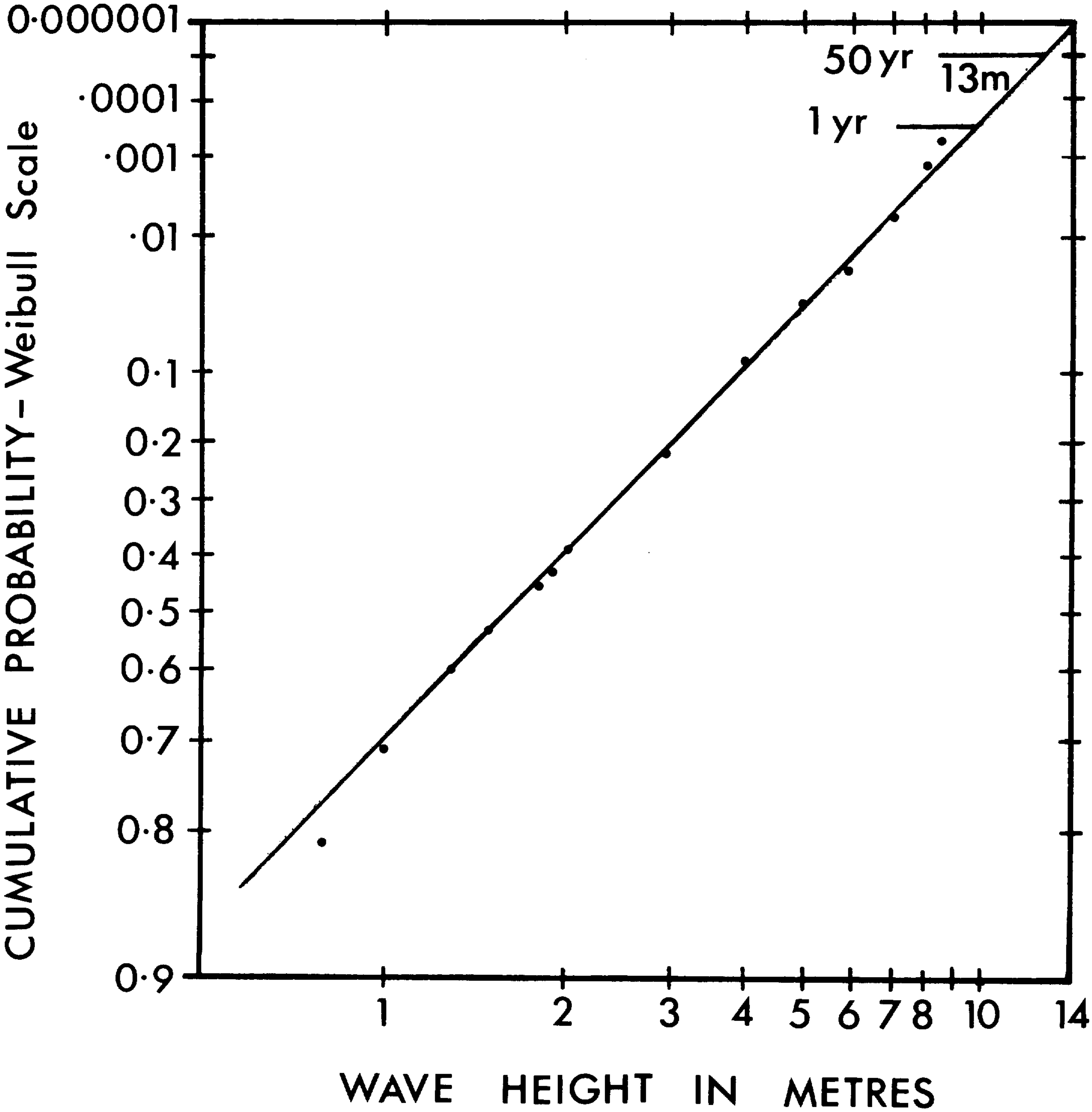

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FIG. 13