L Draper

NATIONAL INSTITUTE OF OCEANOGRAPHY

WORMLEY, GODALMING, SURREY

Waves at North Carr Light Vessel, Fife Ness

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N.I.O. Internal Report No. A. 50

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CONTENTS

Waves have been recorded by a Shipborne Wave Recorder (Tucker, 1956) placed on the North Carr Light Vessel which is stationed in 23 fathoms of water in the North Sea, 2 miles north east of Fife Ness, immediately to the north of the Forth Estuary. The records from the first year of operation, from mid-June 1969, have been analysed, mainly following the method of analysis developed by Tucker (1961) from theoretical studies by Cartwright and Longuet-Higgins (1956). The method of presentation is that recommended by N. I. O. for data for engineering purposes (Draper, 1966).

Records were taken at three-hourly intervals, and the analysis 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.

(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 $H_1 = f(H_s)$ where f is a factor related to the number of zero-crossings in the record (Tucker, 1963). A similar relationship is used for the calculation of H_s from H_2.

(f) H_{max} (3 hours)

= The most probable value of the height of the highest wave which occurred in the recording interval (Draper, 1963).

(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, 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.

Figure 11 is a persistence diagram for the whole year.

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

Discussion of Results

From Figures 1 - 4 may be determined the proportion of time for which H_s or $H_{max\ (3\ hours)}$ exceeded any given height. For example, in the Winter the significant height exceeded 4 feet for 50 per cent of the time. Wave heights are generally higher in the winter months; the highest measured waves of 25.4 feet in height occurred twice, once with a zero-crossing period of 7.58 seconds and once with a period of 9.17 seconds. There is little seasonal variation in either the wave period or spectral width parameter. The scatter diagram of Figure 10 relates the significant wave height to zero-crossing period, with the numbers of occurrences expressed in parts per thousand; for example, the most common wave conditions were those with a significant height of between 1.5 and 2 feet and a zero-crossing period of between 3.5 and 4.5 seconds, which occurred for 52 thousandths, or 5.2 per cent, of the time. The rapid attenuation of the shorter waves with depth means that the pressure units, which are necessarily situated at about 4.0 feet below mean water level, do not record waves which have a period of less than about 3 seconds; this is a cause of the cut-off below that period. The number 112 in the lower left-hand corner indicates the occurrence of calms (11.2%). A calm is deemed to occur when the sum of maximum crest and maximum trough on the record does not exceed 1 foot. The actual wave height will be higher than this, because in such circumstances the wave period is usually short and the correction factor will be fairly high, but this limit is about the lowest practicable one for purposes of analysis.

A parameter which is sometimes of interest is the wave steepness, expressed as wave height : wave length; it may also be expressed as a decimal number. It should be noted that the steepness of a wave is not the same as the maximum slope of the water surface during the passage of a wave. Lines of constant steepness of 1 : 20 and 1 : 40 are drawn on Figure 10. (In this case, steepness relates to significant wave height : wave length calculated from the zero-crossing period.) From the persistence diagram, Figure 11, may be deduced the number and duration of the occasions in 1 year on which waves persisted at or above a given height. For example, if the limit for a particular operation of a vessel is a significant height of 6 feet, it would have been unable to operate for spells in excess of 10 hours on 32 occasions, or spells in excess of 24 hours on 18 occasions.

A 'Lifetime' wave can be predicted by use of the presentation used in Figure 12. The data at the upper end of the distribution is not as well behaved as would be preferred; this is probably caused by the (necessarily) small amount of information on which it is based. Nevertheless it seems reasonable that the 50-year wave height might lie between 50 and 60 feet.

Wind Conditions

During the time when waves were being measured, the mean wind speed at Bell Rock, the most appropriate recording station 9 miles to the north east, was 15.9 knots; this is very close to the 11-year (1960-70) average of 16.0 knots, but the number of hours of gale, at 134, was well below the 11-year average of 242. The figures are as follows:-

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	11 years
Hourly mean speed - knots	14.3	16.3	17.3	15.9	15.7	17.5	16.9	17.7	13.3	14.7	16.2	16.0
Hours of Gale	153	257	418	184	257	334	260	390	148	108	151	242

Differences Between Presented & 'Average' Data

The data presented in this report is exactly as measured; no attempt has been made to modify it to account for the differences between actual wind and the 11-year average conditions. Although the mean wind speed was close to average the fact that the number of hours of gale force winds was appreciably below normal suggests that the occurrence of the higher waves during the year of recording was probably somewhat lower than usual. All the other data should be reasonably representative of normal conditions - the differences in mean wind speed from the 11-year average are equivalent to a difference of under 1 per cent in wave height and even less than this in period.

Acknowledgements

This information was obtained as a joint project between the Northern Lighthouse Board and the National Institute of Oceanography. The author would like to express his appreciation of the willing co-operation of the staff of the Board, especially to the Master and Crew for the careful way in which they took the records, also to those of the author's colleagues who installed and maintained the equipment and to those who analysed the records.

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PERCENTAGE EXCEEDANCE OF HS AND HMAX

WINTER - JANUARY TO MARCH

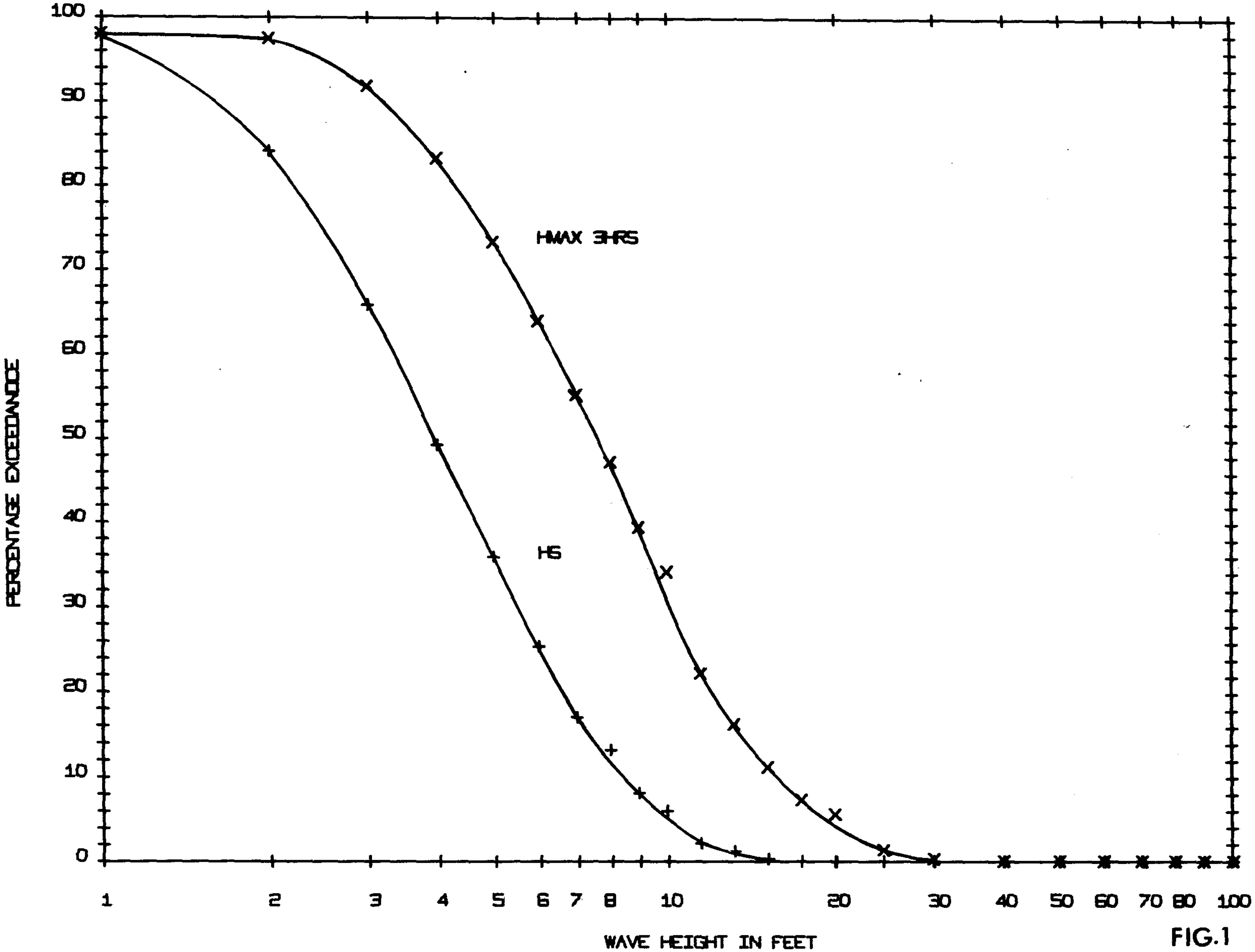


FIG.1
NC

PERCENTAGE EXCEEDANCE OF HS AND HMAX

SPRING - APRIL TO JUNE

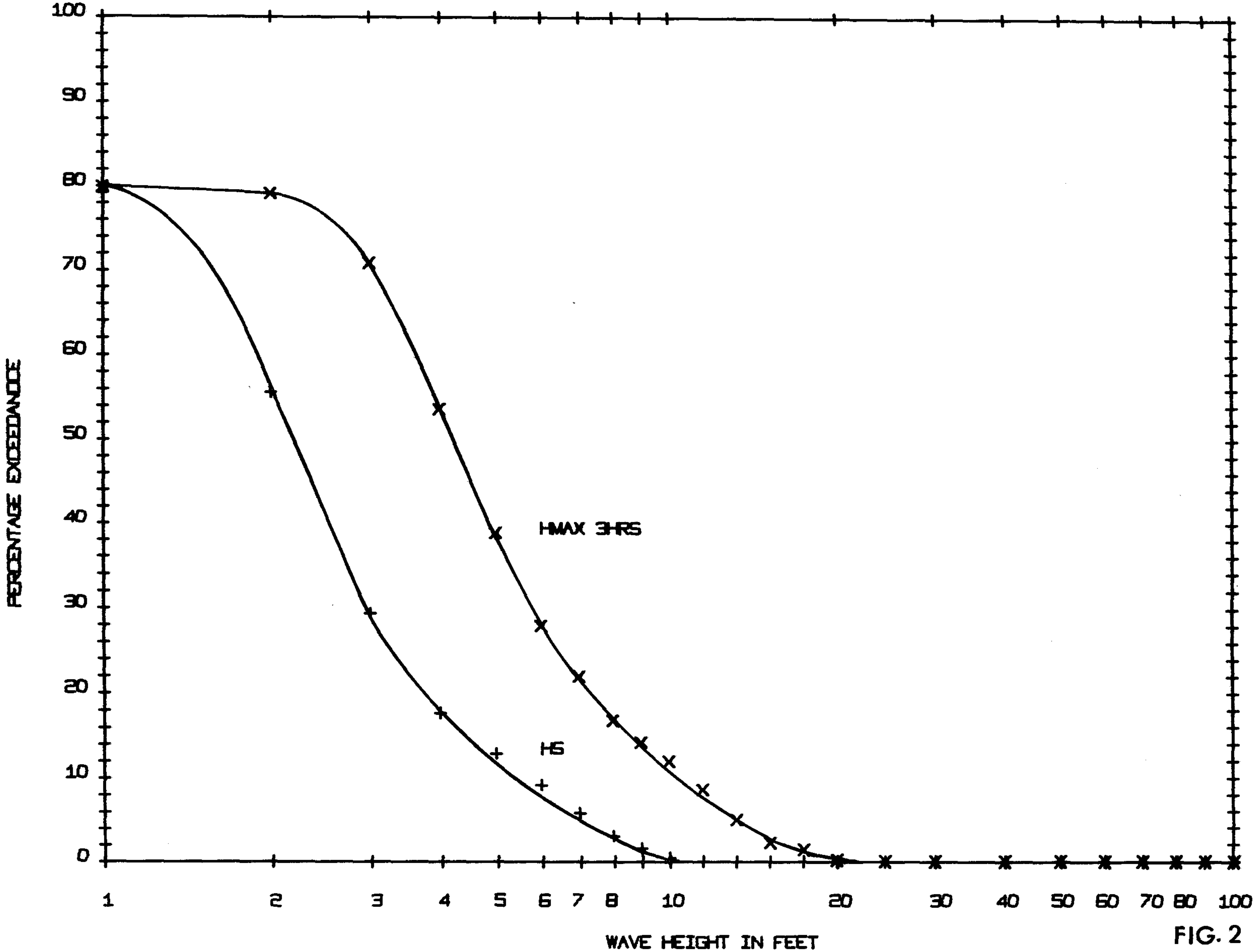


FIG. 2
NC

PERCENTAGE EXCEEDANCE OF HS AND HMAX

SUMMER - JULY TO SEPTEMBER

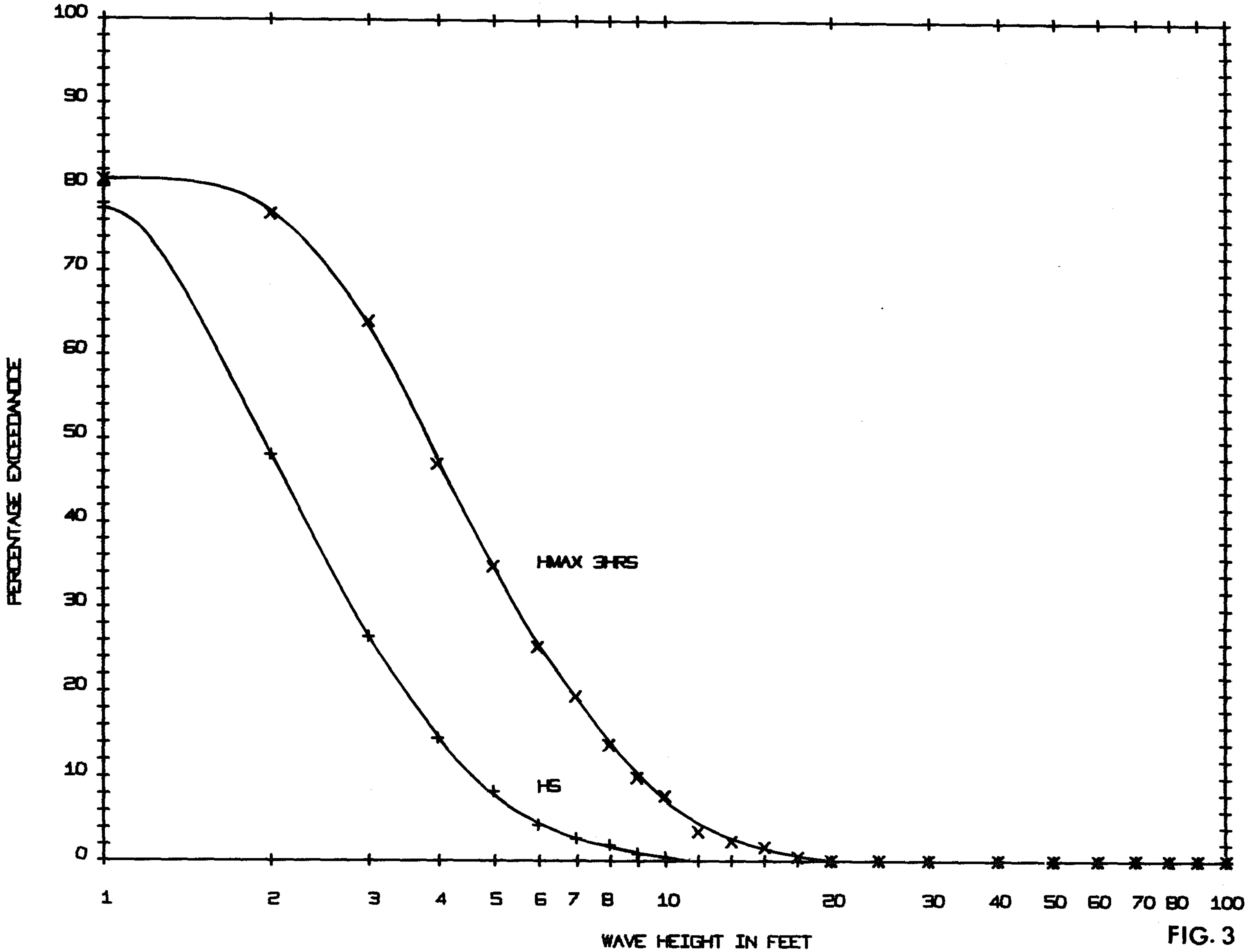


FIG. 3
NC

PERCENTAGE EXCEEDANCE OF HS AND HMAX

AUTUMN - OCTOBER TO DECEMBER

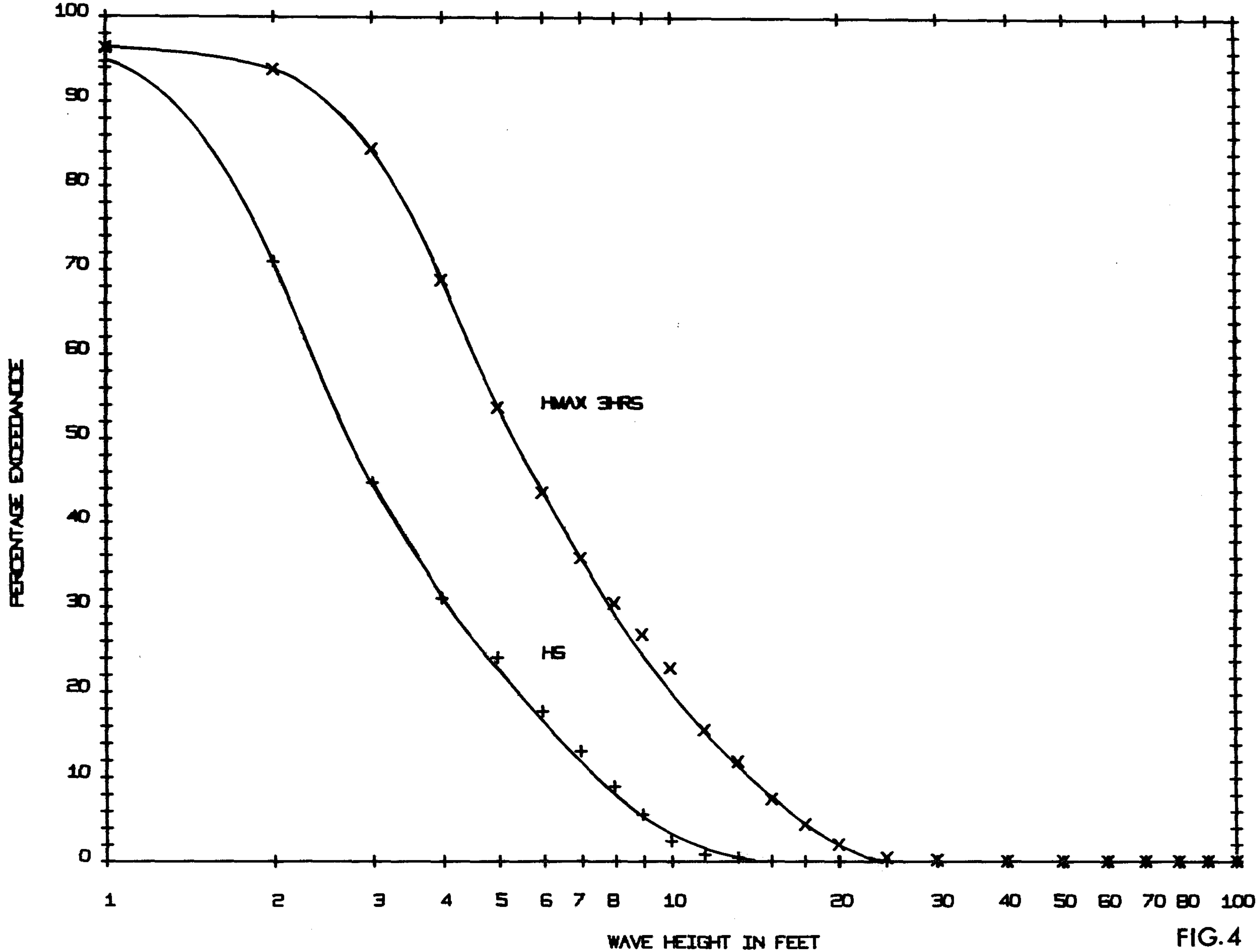
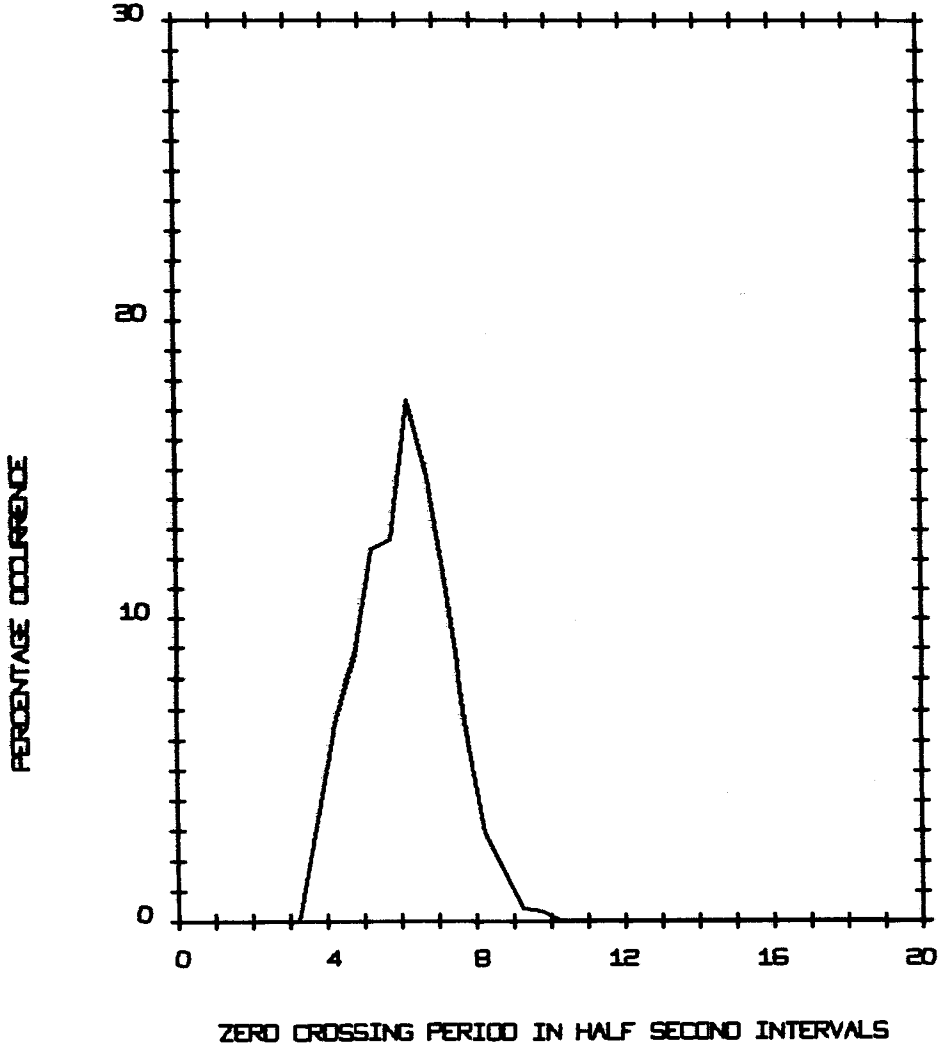


FIG. 4
NC

GRAPH OF PERCENTAGE OCCURRENCE OF TZ

WITHIN HALF-SECOND INTERVALS

WINTER - JANUARY TO MARCH



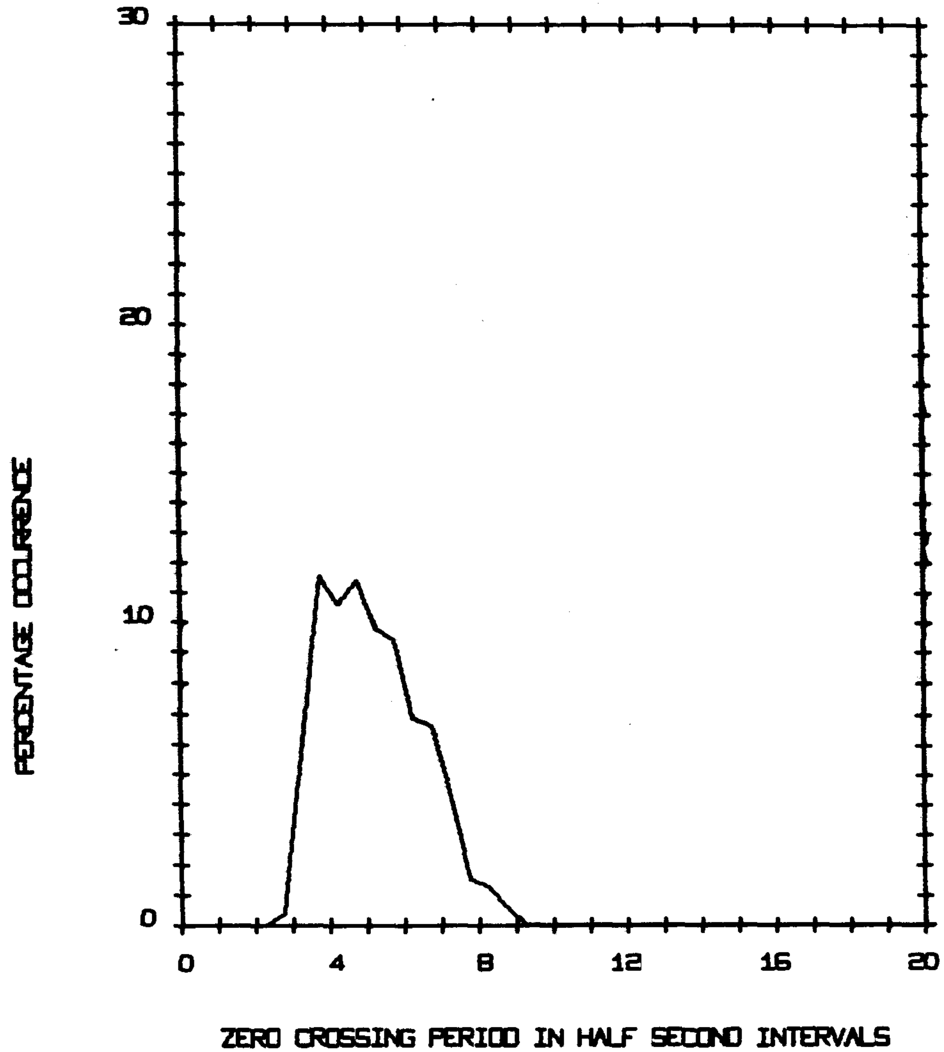
CALM = 1·94 PER CENT

FIG. 5
NC

GRAPH OF PERCENTAGE OCCURRENCE OF TZ

WITHIN HALF-SECOND INTERVALS

SPRING - APRIL TO JUNE



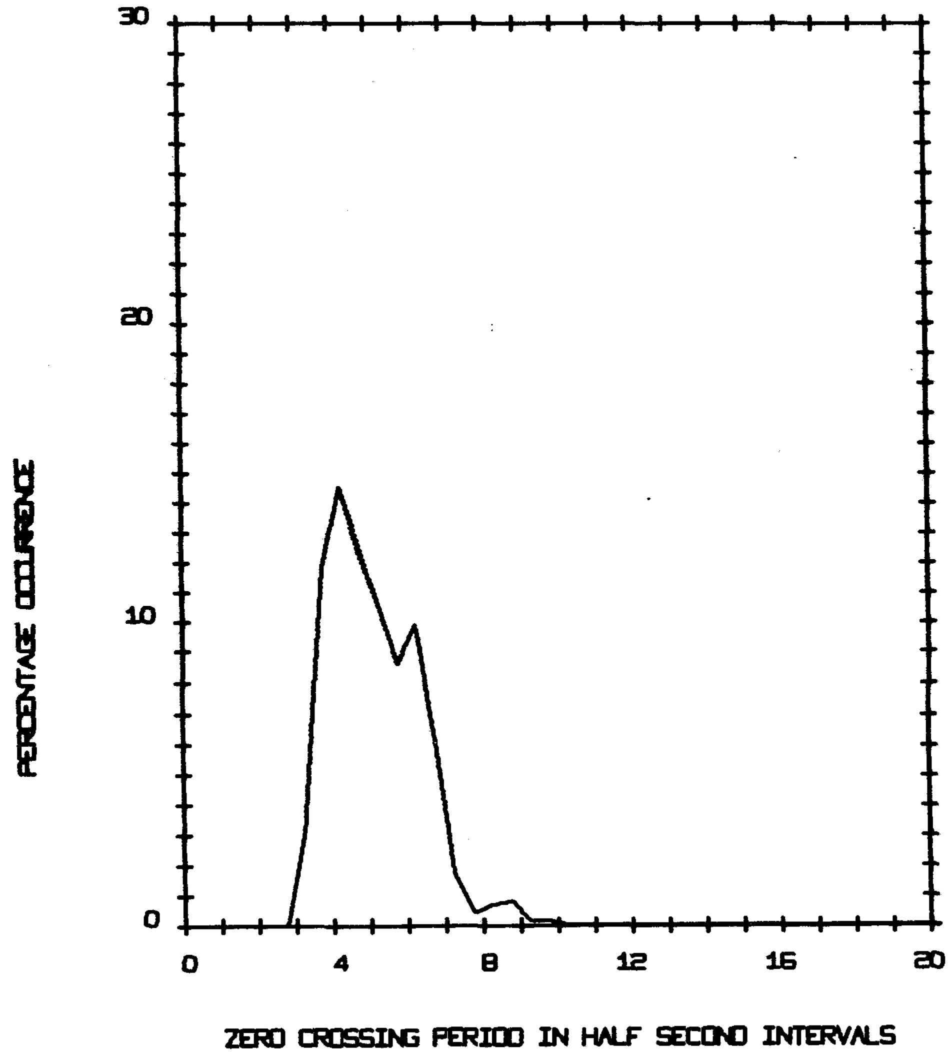
CALM = 20·19 PER CENT

FIG. 6
NC

GRAPH OF PERCENTAGE OCCURRENCE OF TZ

WITHIN HALF-SECOND INTERVALS

SUMMER - JULY TO SEPTEMBER



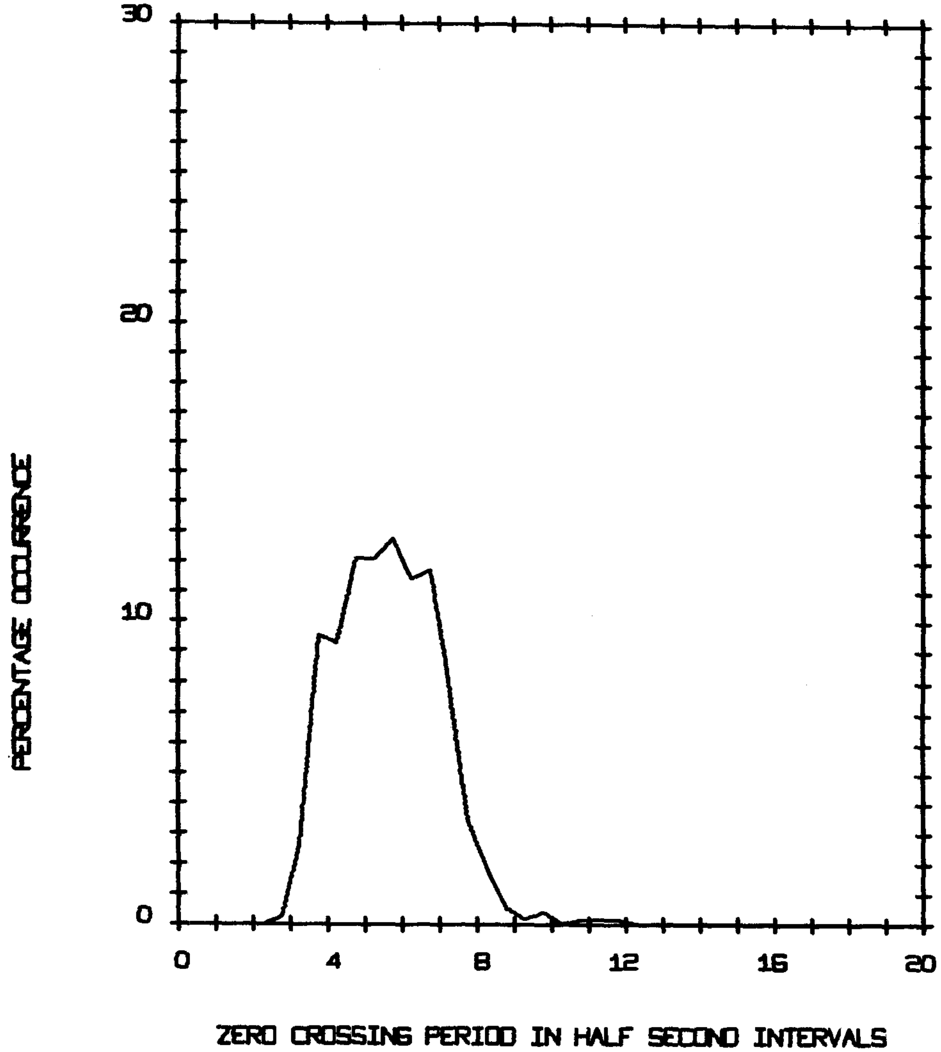
CALM = 19·15 PER CENT

FIG. 7
NC

GRAPH OF PERCENTAGE OCCURRENCE OF TZ

WITHIN HALF-SECOND INTERVALS

AUTUMN - OCTOBER TO DECEMBER



CALM = 3·53 PER CENT

FIG.8
NC

GRAPH OF SPECTRAL WIDTH PARAMETER

FOR A WHOLE YEAR

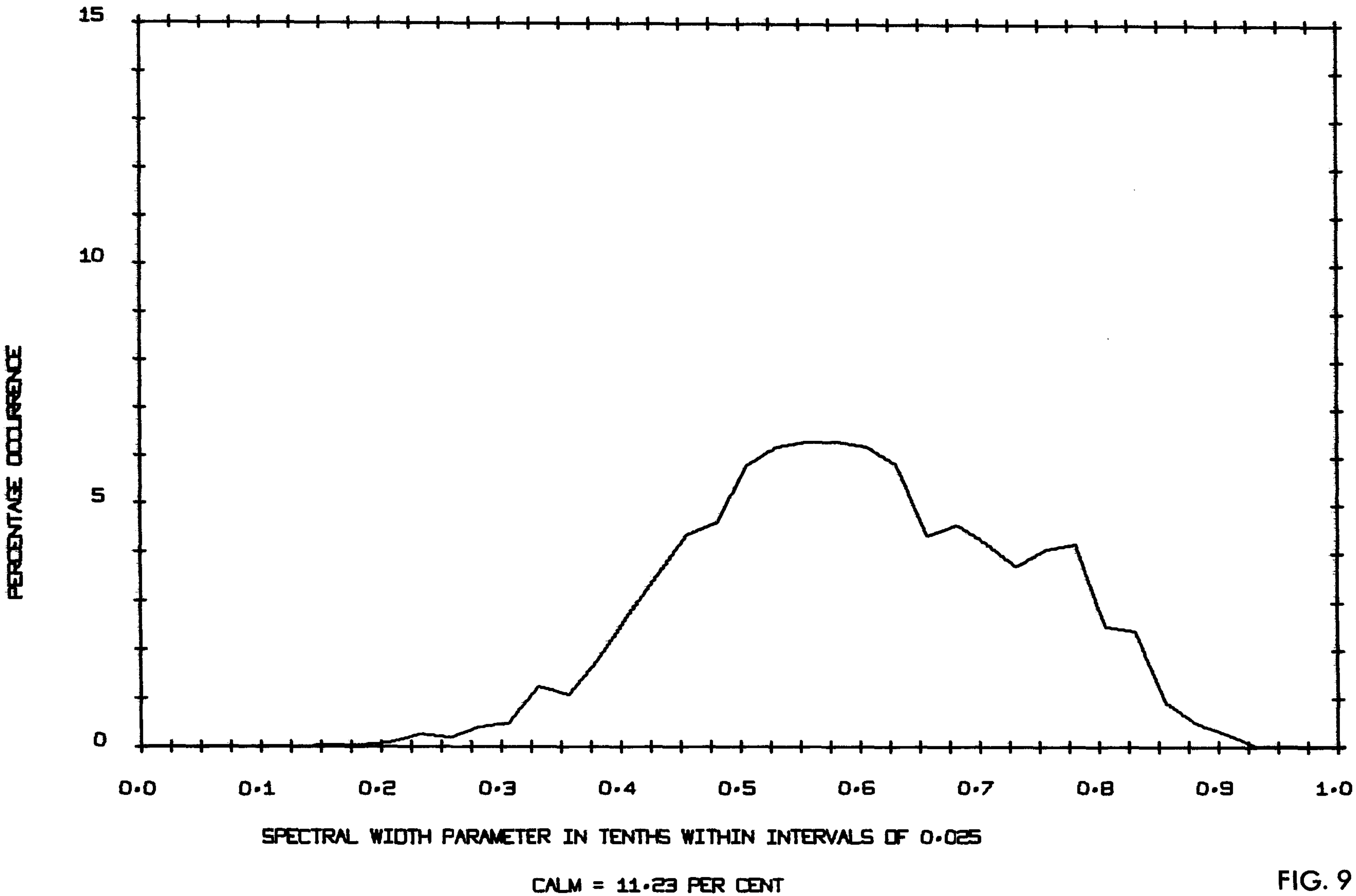


FIG. 9
NC

SCATTER DIAGRAM FOR THE WHOLE YEAR

IN PARTS PER THOUSAND   * = 1 OCCURRENCE, + = 2 OCCURRENCES

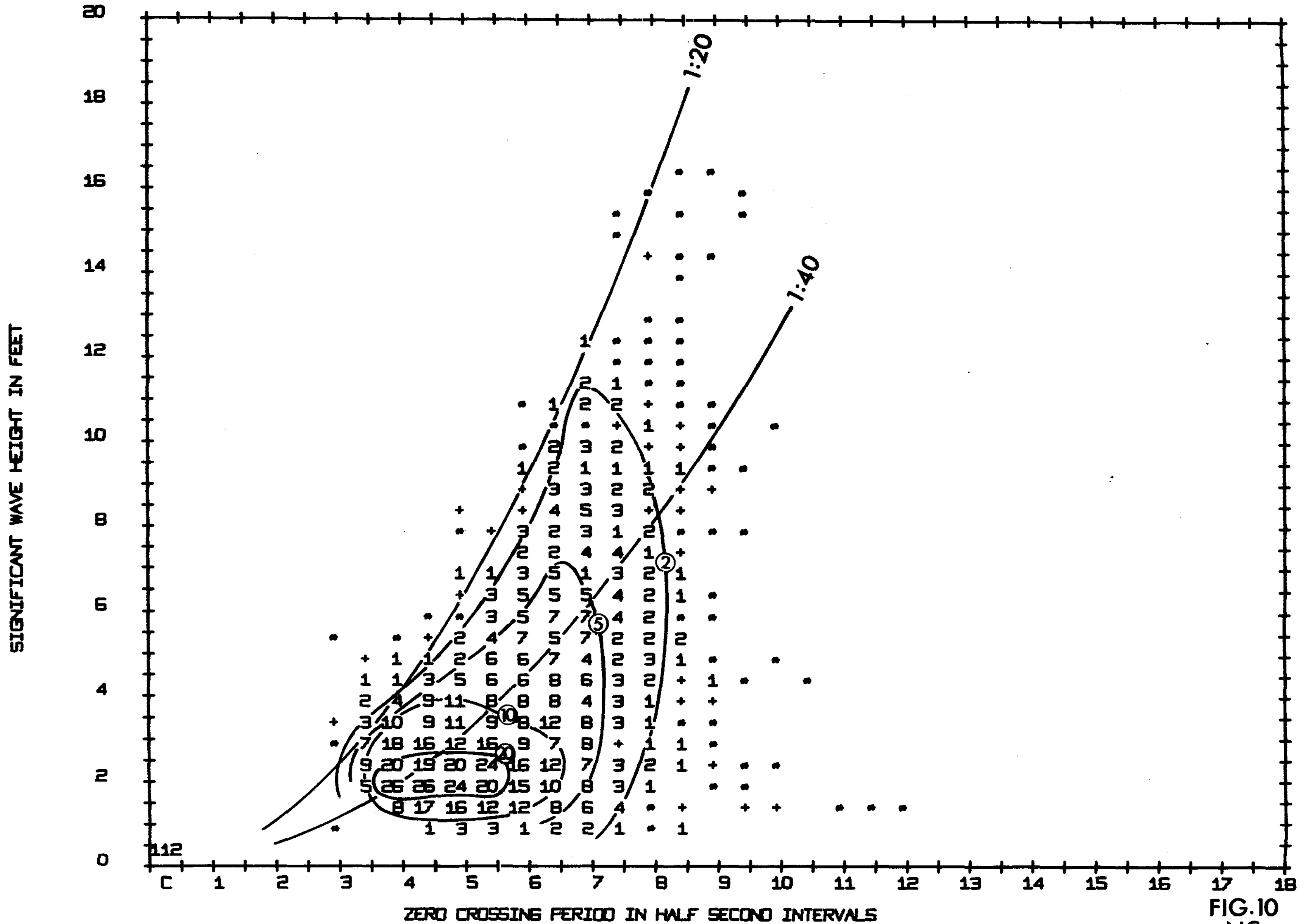


FIG.10
NC

PERSISTENCE DIAGRAM FOR THE WHOLE YEAR

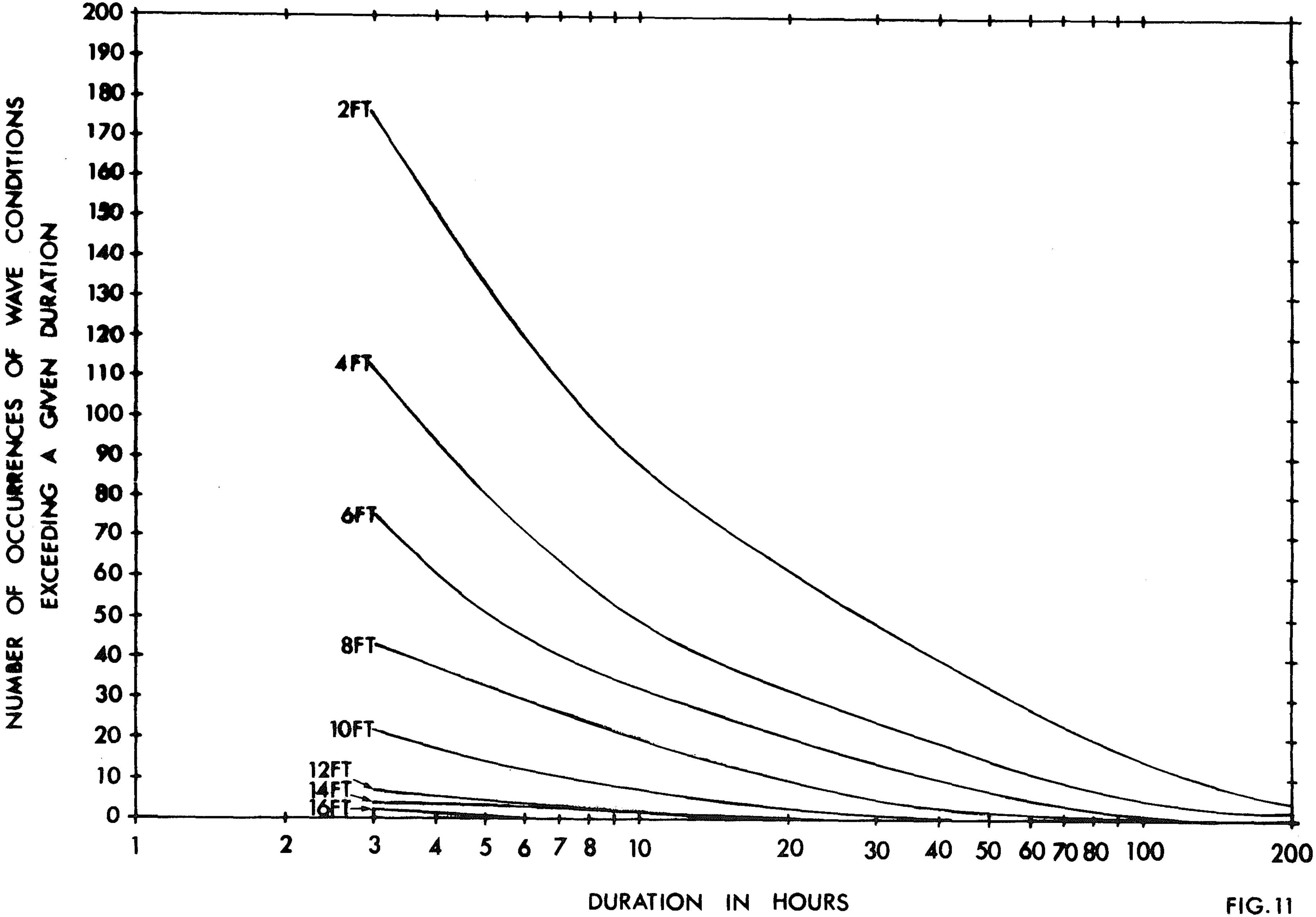


FIG. 11
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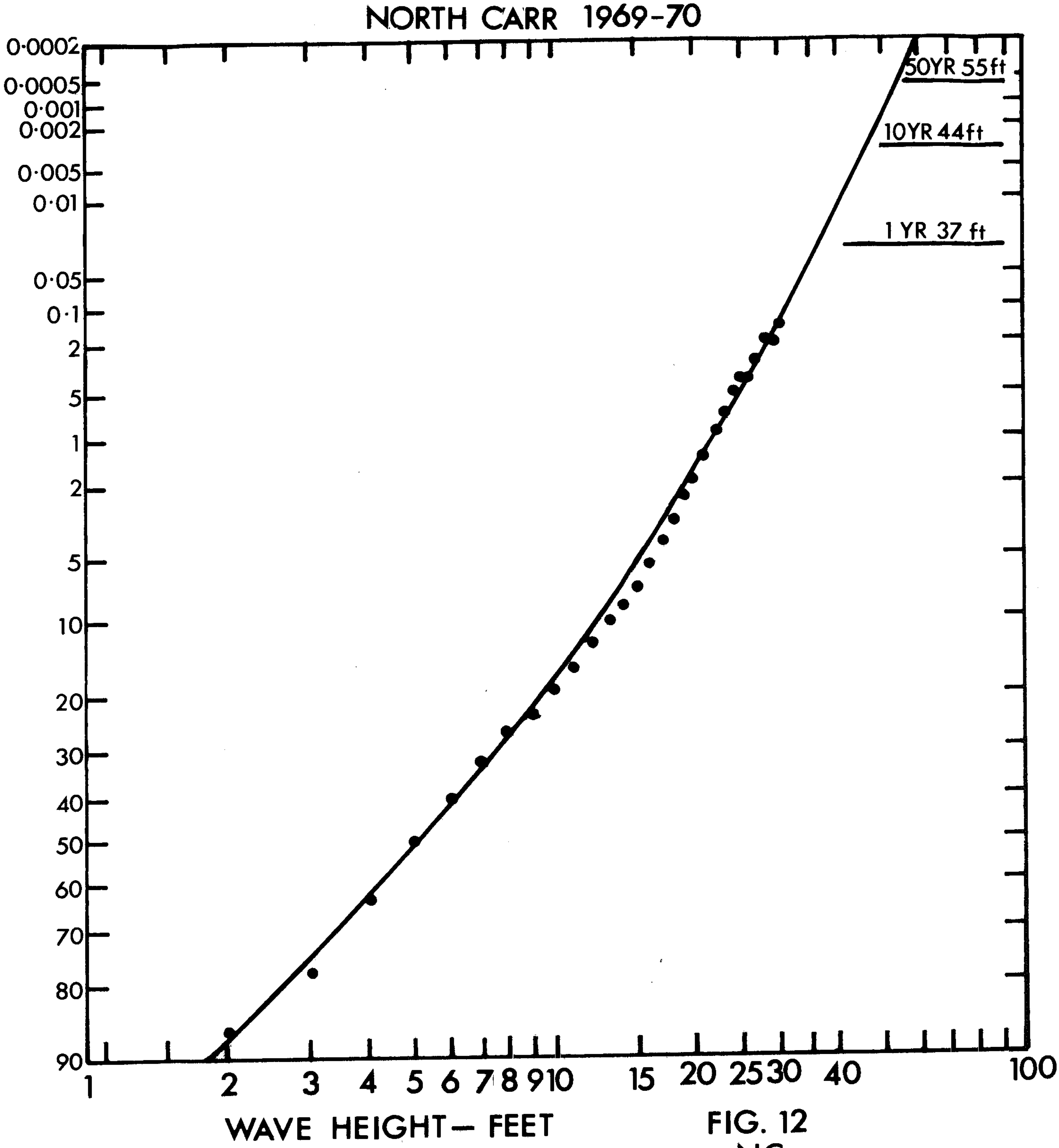
NORTH CARR 1969-70
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80
90
50YR 55ft
10YR 44ft
1 YR 37 ft
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3
4
5
6
7
8
9
10
15
20
25
30
40
100
WAVE HEIGHT— FEET
FIG. 12
NC