L Draper

NATIONAL INSTITUTE OF OCEANOGRAPHY

WORMLEY, GODALMING, SURREY

Waves at Owers Light Vessel, Central English Channel

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L. DRAPER and H. C. SHELLARD*

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N.I.O. Internal Report No. A. 46

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Waves have been recorded by a Shipborne Wave Recorder (Tucker, 1956) placed on the Owers Light Vessel which is stationed in about 14 fathoms of water 7 miles south-east of Selsey Bill. The records from one year of operation, from October 1968 - September 1969 have been analyzed, mainly following the method of analysis developed by Tucker (1961) from theoretical studies by Cartwright and Longuet-Higgins (1956). The methods of presentation of Figures 1-12 are those recommended 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 records (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, for the whole year.

Figure 11 is a persistence diagram for the whole year.

Figure 12 is a presentation which enables an estimate to be made of the most probable value of the height of the highest wave likely to occur in various long term durations.

Figures 13 and 14 are presentations relating to the wind and wave conditions existing at all times during the year of wave measurement.

Discussion of Results from the Wave Measurements

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 54 percent of the time. The highest measured wave (H_1) of 25 feet with a zero-crossing period of 7.1 seconds, occurred on 23rd December. 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 3 feet and a zero-crossing period of between 4 and 5 seconds, which occurred for 151 thousandths, or 15.1 percent, of the time. The rapid attenuation of the shorter waves with depth means that the pressure units, which are necessarily situated at about 4.8 feet below means 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 figure 57 in the lower left-hand corner denotes the occurrence of calm records, i.e., 5.7 percent of the time.

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 the 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.)

An important feature of this analysis is the number of waves with high values of steepness, which would appear to result in the occurrence of individual waves steeper than that theoretically possible. The reason for this is almost certainly the presence of strong tidal currents, which can reach 2.8 knots at spring tides, according to the Admiralty chart. As the vessel is anchored, when the current is flowing strongly in the same direction as the waves, the vessel behaves as though it were travelling through the water at a speed equal to that of the current, resulting in an encounter period shorter than the true wave period. The effect of this on the subsequent analysis is that the apparent period, and therefore the apparent wave-length, is shorter, giving increased steepness. The converse situation also applies when the tidal flow is reversed, resulting in a longer encounter period. The overall result of this effect is that there is a spread of apparent wave period introduced by the method of recording, but this is more important in its effect at shorter periods and nearly negligible at longer periods. With a current of 2.8 knots travelling in the same direction as the waves, a real period of about 4 seconds will appear as one of about 3.2 seconds, 5 seconds appears as about 4.2 seconds, 6 seconds appears as about 5.2 seconds, 7 seconds appears as about 6.2 seconds, 8 seconds appears as about 7.2 seconds. This diagram (Fig. 10) bears a strong resemblance of the scatter diagram in the Varne data Report (A.34), where the maximum current is 2.6 knots. 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 40 occasions, or spells in excess of 24 hours on 15 occasions.

From Figure 12 it seems that the height of the highest wave in a year is likely to be about 30 feet and the highest in a 50-year interval is likely to be about 37 feet high. This extrapolation is uncertain in view of the curvature at the upper end of the graph, and the small number of measurements on which it is based.

Wind Conditions

During the time when waves were being measured, the wind speeds at Calshot, the nearest and most appropriate recording station, were somewhat lower than average for a typical year. There was no time when the hourly mean speed reached gale force (34 knots). The figures from Calshot for the years 1960-70 were as follows:

	Mean Speed Knots	No. of hours of gale
1960	10.5	7
1	10.2	0
2	11.5	18
3	12.0	8
4	11.1	0
5	11.0	10
6	10.2	4
7	10.4	19
8	10.4	1
9	9.8	0
1970	9.6	7
11-year average	10.6	6.7
year of wave data	9.8	0

From this it may be reasonable to deduce that the recorded wave heights and periods were somewhat lower than average. If one accepts the Darbyshire coastal waters relationship where wave height is proportional to the wind speed to the power of 1.5, then the heights given in this report should be increased by about 12% to achieve "average" conditions. Wave period is proportional to the square root of wind speed and should be increased by 4%.

The wave data in this report is exactly as measured. None has been modified to take account of the average wind conditions prevailing during the year.

Comparison of Wave Data with Wind Speeds at Calshot

The twelve month's consecutive wave data at Owers Light Vessel (50°43'N, 00°47'W), are correlated with corresponding wind speed measurements made at Calshot (50°49'N, 01°18'W).

The wave data used were 2917 tabulated values of the significant wave heights, H_s, in feet; these were transferred to punched tape. Hourly mean wind speeds and directions tabulated from the Calshot anemograph records (effective height 10 metres) for the period October 1968 to September 1969, inclusive, were also punched on tape. By means of a computer program specially written for the Meteorological Office KDF9 computer at Bracknell the following print-outs were obtained:

(1) A combined frequency distribution of wave heights in the ranges 0.0-0.9, 1.0-1.9, etc., feet and of wind speeds averaged over the previous hour, for each whole knot. Also included were mean wave heights and root mean square values of wave height above and below the mean for each wind speed class.

(2) A table similar to (1) but using wind speeds averaged over the previous three hours instead of over the previous hour.

Since the scatter of the data in these print-outs was rather large and there were 30 wind speed classes compared to only 16 wave height classes the wind speed frequencies were grouped into two-knot classes before preparing Figures 13 and 14 which present the results diagrammatically.

Fig. 13 is a contingency diagram of the same type as that published by Hogben in 1969, showing the relationship between wave heights measured by wave recorders aboard weather ships on Station India (59°N, 19°W) and wind speeds measured by the ships' anemometers at a height of 19½ metres. Naturally the ranges of wave heights and wind speeds in Fig. 13 are considerably smaller than those shown in Hogben's diagram but the shape of the mean wave height curve is similar, as also is the scatter of the observations, although this might have been expected to be greater because Owers Light Vessel and Calshot are over 20 miles apart. For comparison, the mean wave heights for corresponding 5 knot speed ranges at Owers and at OWS India were approximately as follows:

Speed	0-5	6-10	11-15	16-20	21-25	26-30	kt
Owers LV	2	3	4	6	9	9*	ft
OWS India	7	7	8	10	12	15	ft

*based on only 10 observations

It can be seen that for calm wind conditions there is a residual wave height. This is due to swell reaching the site from both local and distant sea areas.

Fig. 14, based on print-out (2), was prepared in the expectation that the wave heights might be more closely related to wind speeds averaged over the previous three hours than to those averaged over the previous hour. There is some improvement but it was considered to be too small to justify a further extension of the averaging period to, say, 6 or 12 hours, especially as this would have involved detailed consideration of fetch, requiring wind directions to be taken into account.

Acknowledgements

This task has been undertaken on behalf of the National Physical Laboratory Hovercraft Sea State Committee, of which the authors are members. The N.I.O. Shipborne Wave Recorder which was used is owned by the Ship Division of the National Physical Laboratory. The authors wish to express their appreciation to the Elder Brethren of Trinity House for permission to install the equipment in the vessel, + to the many Trinity House staff concerned, especially the Masters and crew for taking the records. They also wish to acknowledge the efforts of their colleagues who installed and maintained the equipment and helped in the analysis.

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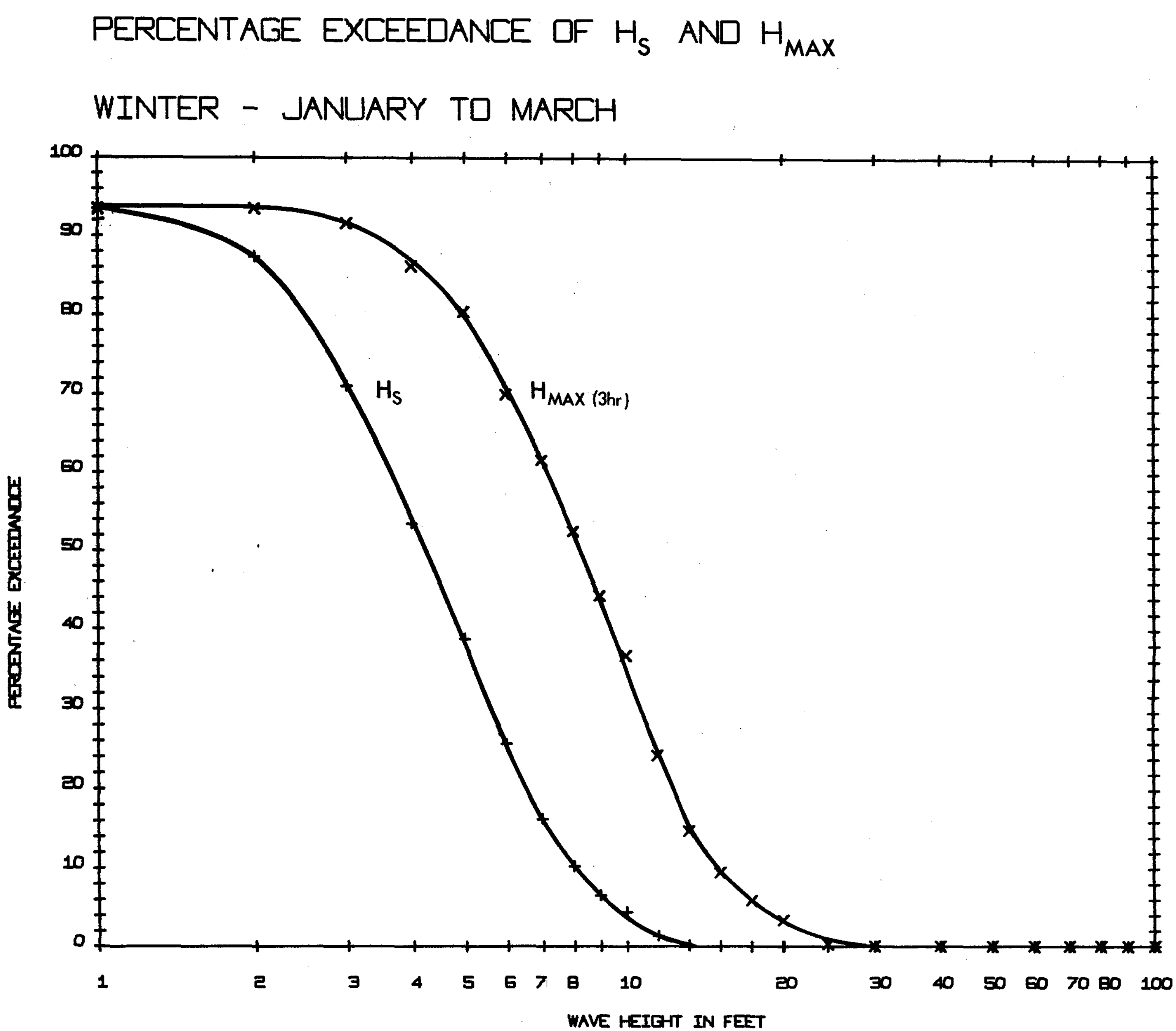


PERCENTAGE EXCEEDANCE OF H S AND H MAX
WINTER - JANUARY TO MARCH
PERCENTAGE EXCEEDANCE
100
90
80
70
60
50
40
30
20
10
0
H S
H MAX (3hr)
1
2
3
4
5
6
7
8
10
20
30
40
50
60
70
80
100
WAVE HEIGHT IN FEET

Fig.1
OW

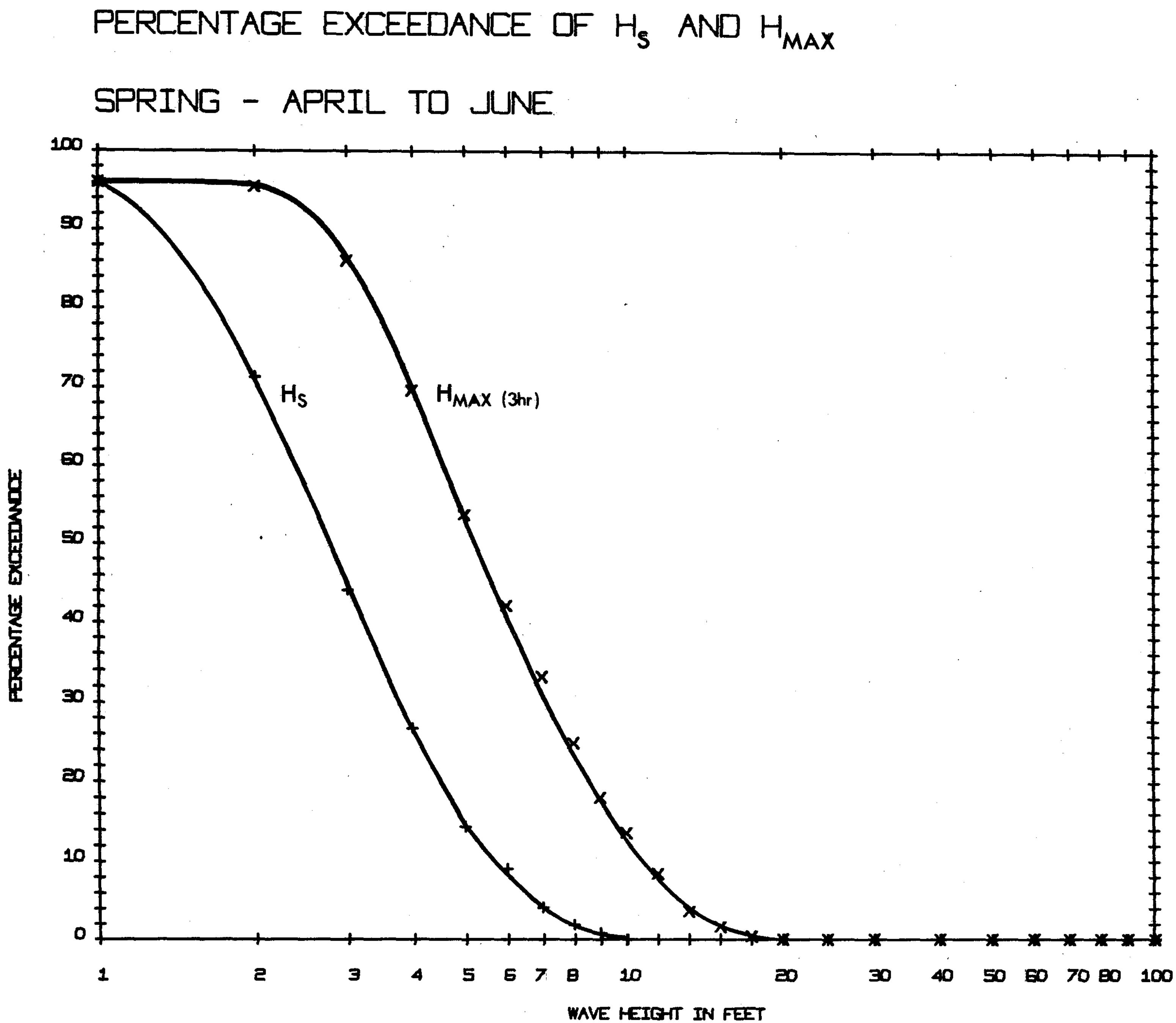

PERCENTAGE EXCEEDANCE OF H_S AND H_{MAX}
SPRING - APRIL TO JUNE
PERCENTAGE EXCEEDANCE
WAVE HEIGHT IN FEET
H_S
H_{MAX} (3hr)
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
10
20
30
40
50
60
70
80
100

Fig.2
OW

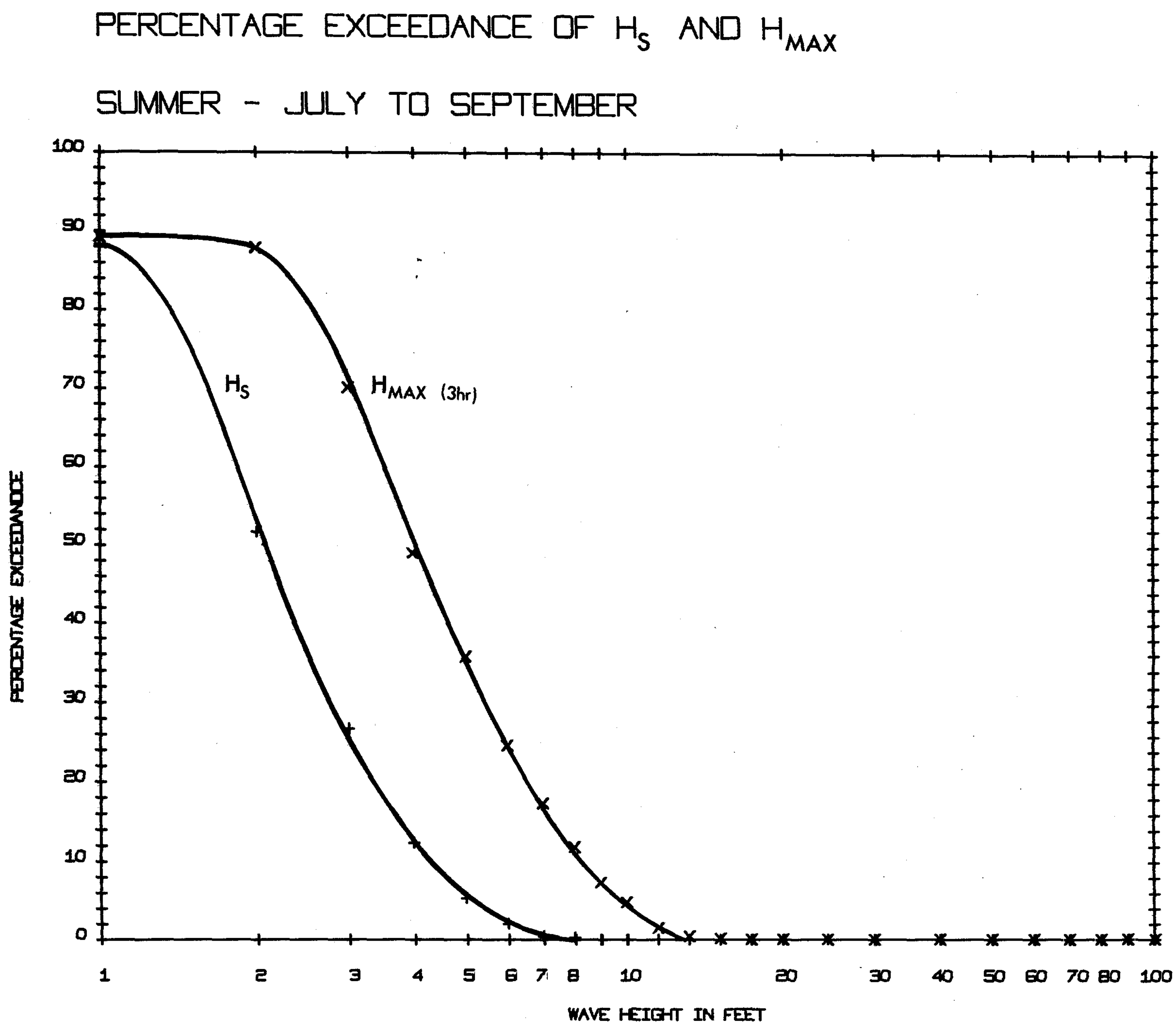

PERCENTAGE EXCEEDANCE OF HS AND HMAX
SUMMER - JULY TO SEPTEMBER
PERCENTAGE EXCEEDANCE
100
90
80
70
60
50
40
30
20
10
0
HS
HMAX (3hr)
1
2
3
4
5
6
7
8
10
20
30
40
50
60
70
80
100
WAVE HEIGHT IN FEET

Fig.3
OW

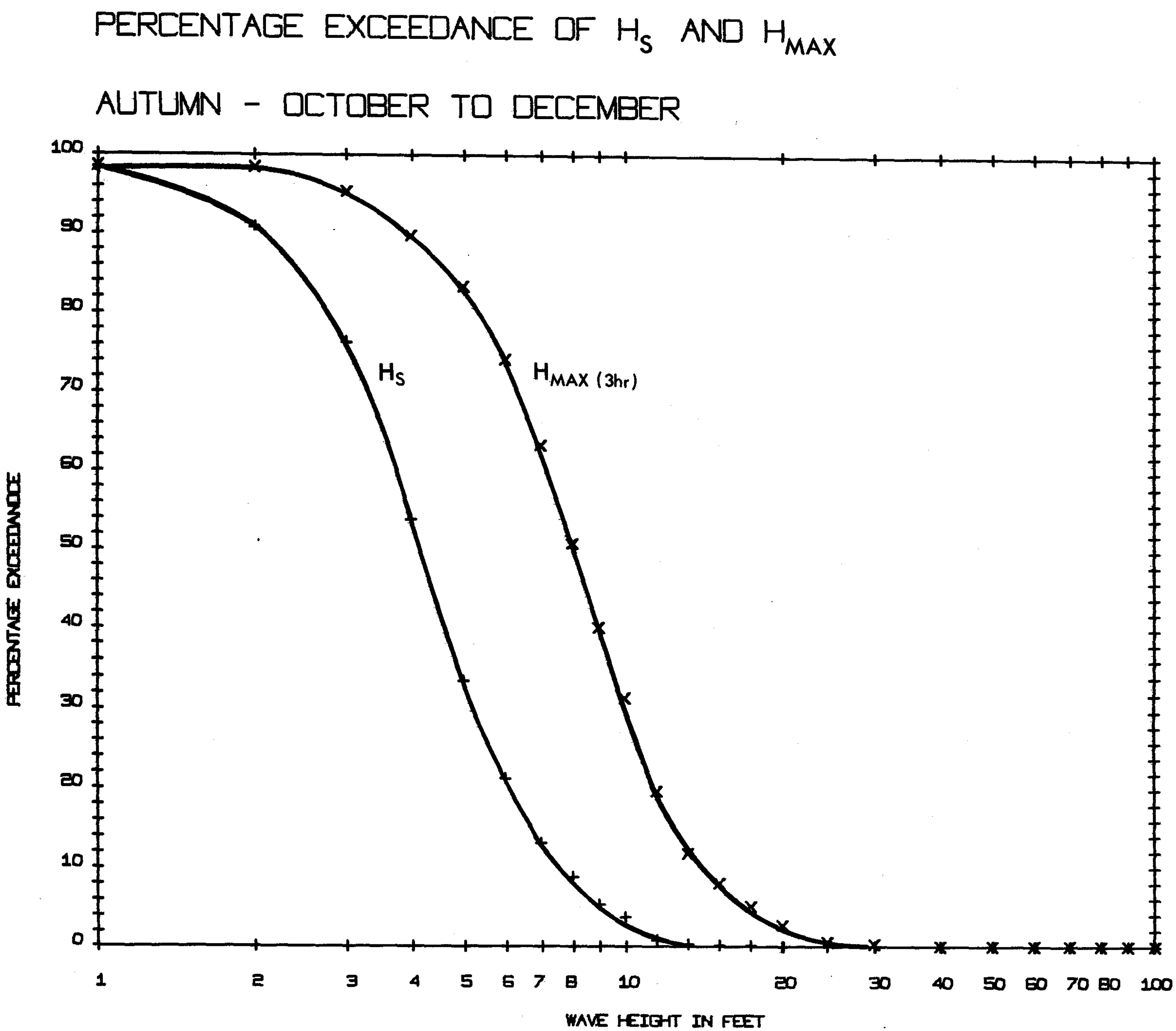
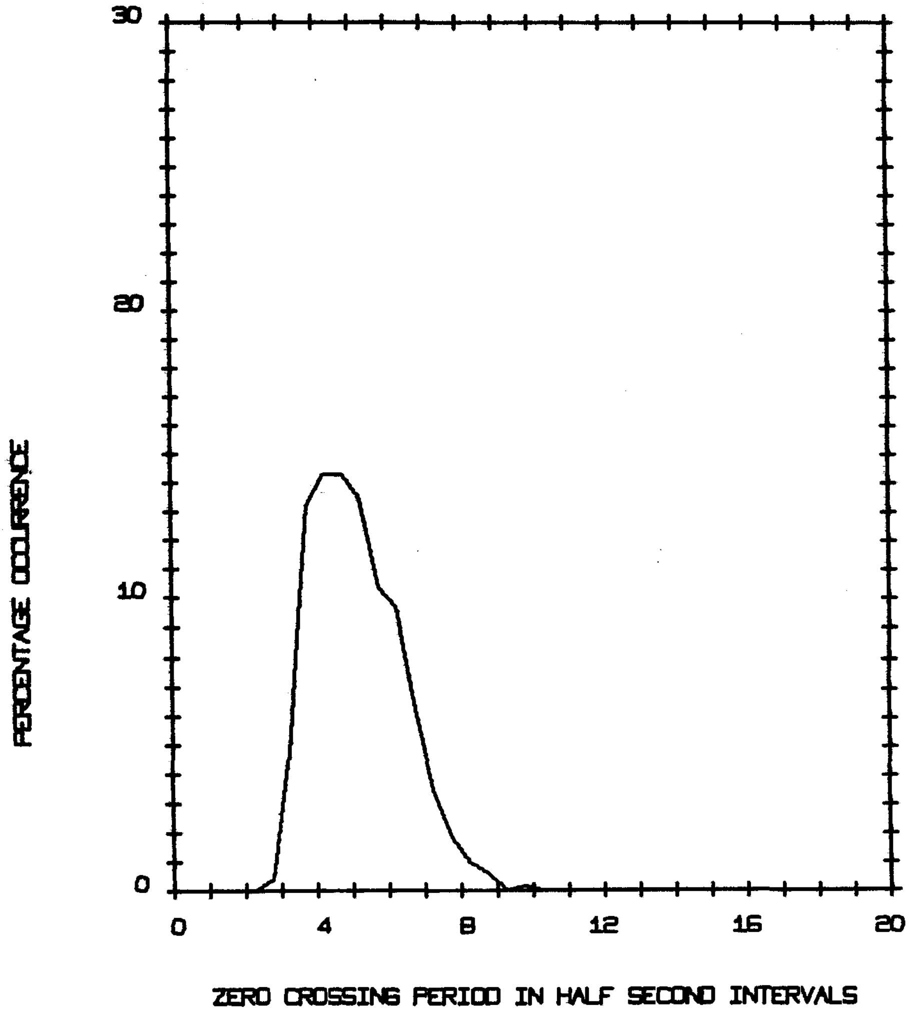

PERCENTAGE EXCEEDANCE OF H_S AND H_{MAX}
AUTUMN - OCTOBER TO DECEMBER
100
90
80
70
60
50
40
30
20
10
0
PERCENTAGE EXCEEDANCE
H_S
$H_{MAX\ (3hr)}$
1
2
3
4
5
6
7
8
10
20
30
40
50
60
70
80
100
WAVE HEIGHT IN FEET

Fig.4
OW

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

WITHIN HALF-SECOND INTERVALS

WINTER - JANUARY TO MARCH



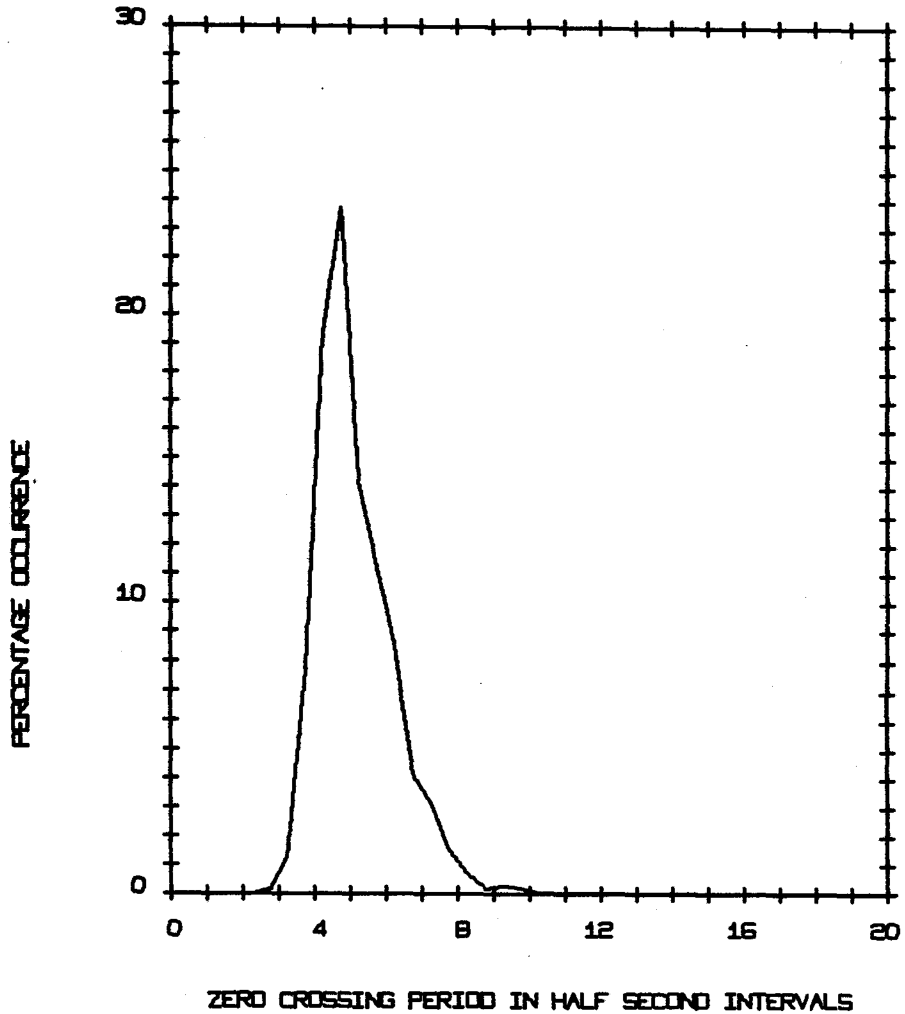
CALM = 6·52 PER CENT

Fig.5
OW

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

WITHIN HALF-SECOND INTERVALS

SPRING - APRIL TO JUNE



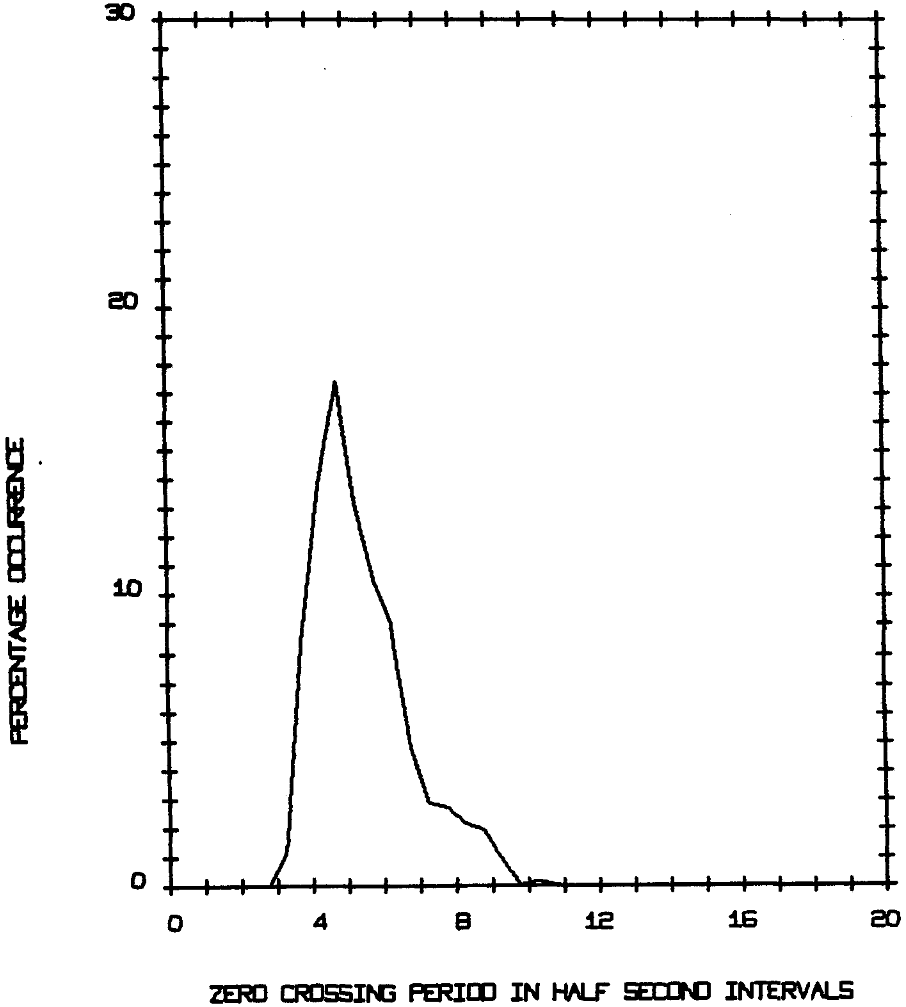
CALM = 3.98 PER CENT

Fig. 6
OW

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

WITHIN HALF-SECOND INTERVALS

SUMMER - JULY TO SEPTEMBER



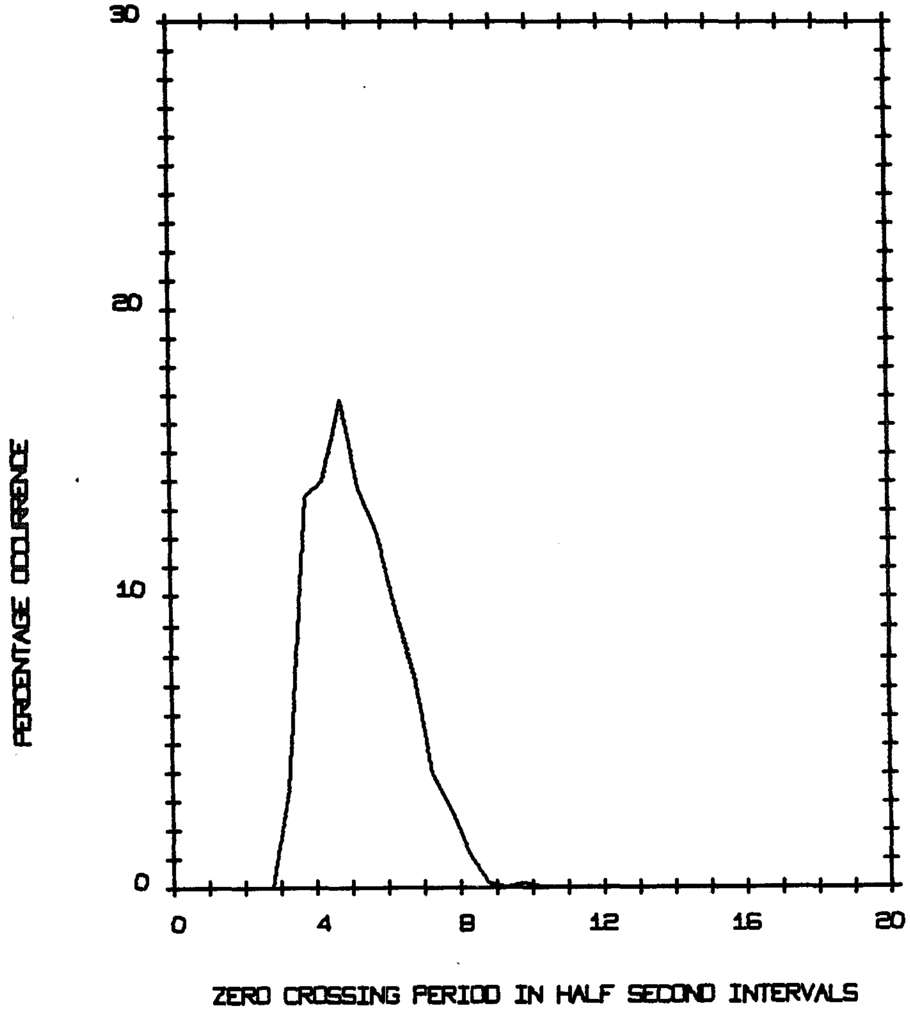
CALM = 10·73 PER CENT

Fig.7
OW

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

WITHIN HALF-SECOND INTERVALS

AUTUMN - OCTOBER TO DECEMBER

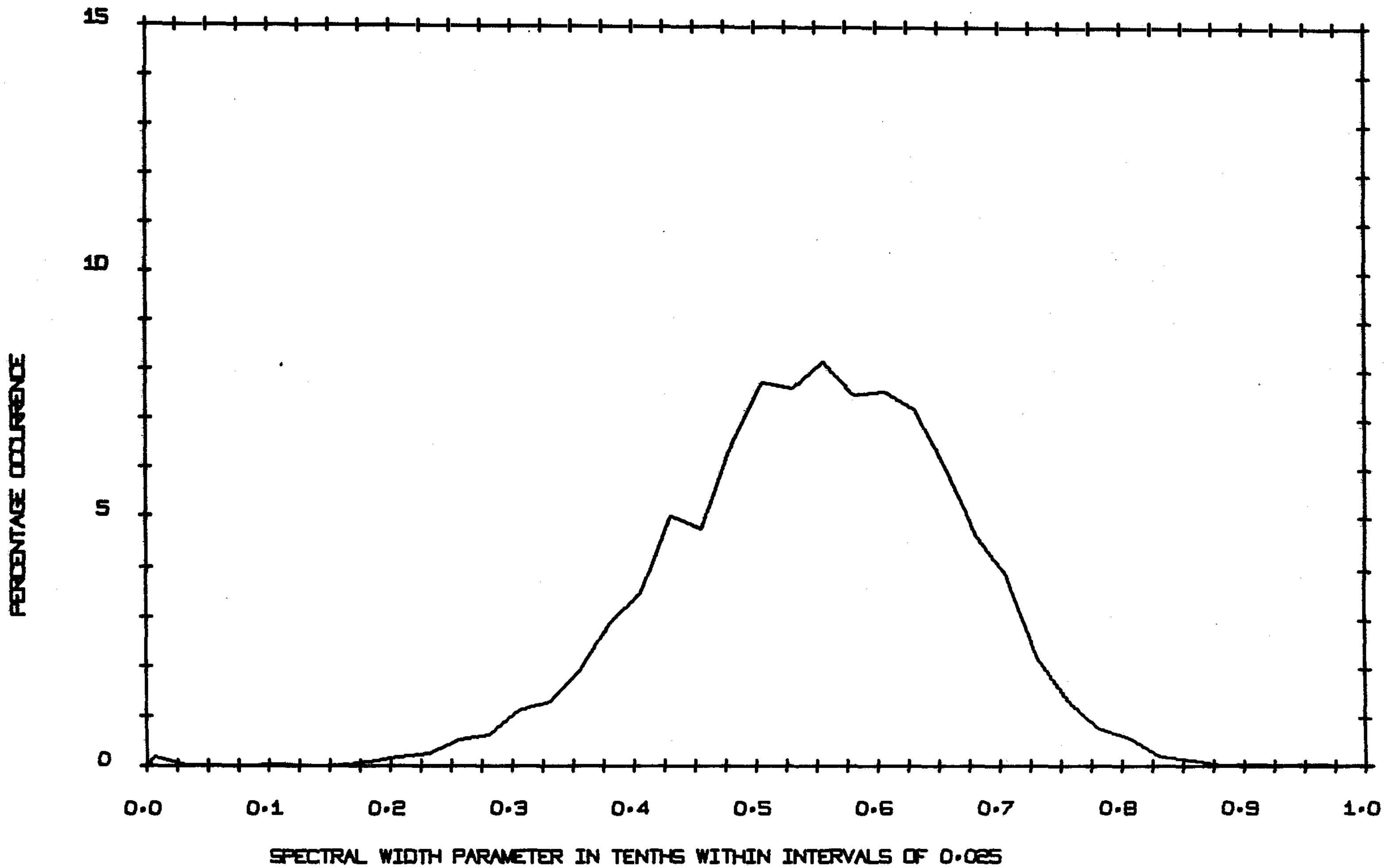


CALM = 1·49 PER CENT

Fig.8
OW

GRAPH OF SPECTRAL WIDTH PARAMETER

FOR A WHOLE YEAR



CALM = 5·68 PER CENT

Fig.9
OW

SCATTER DIAGRAM FOR THE WHOLE YEAR

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

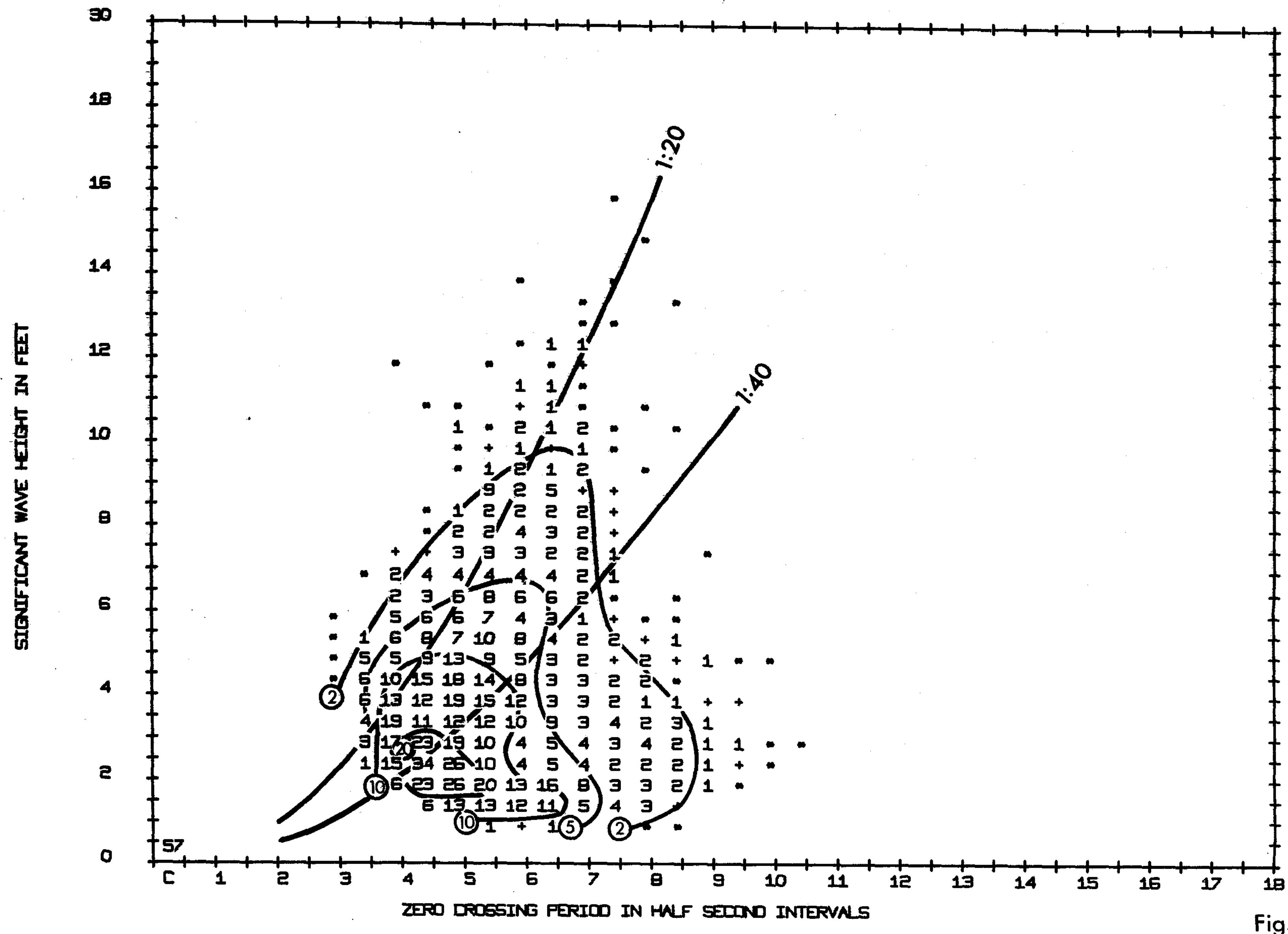


Fig.10
OW

PERSISTENCE DIAGRAM FOR THE WHOLE YEAR

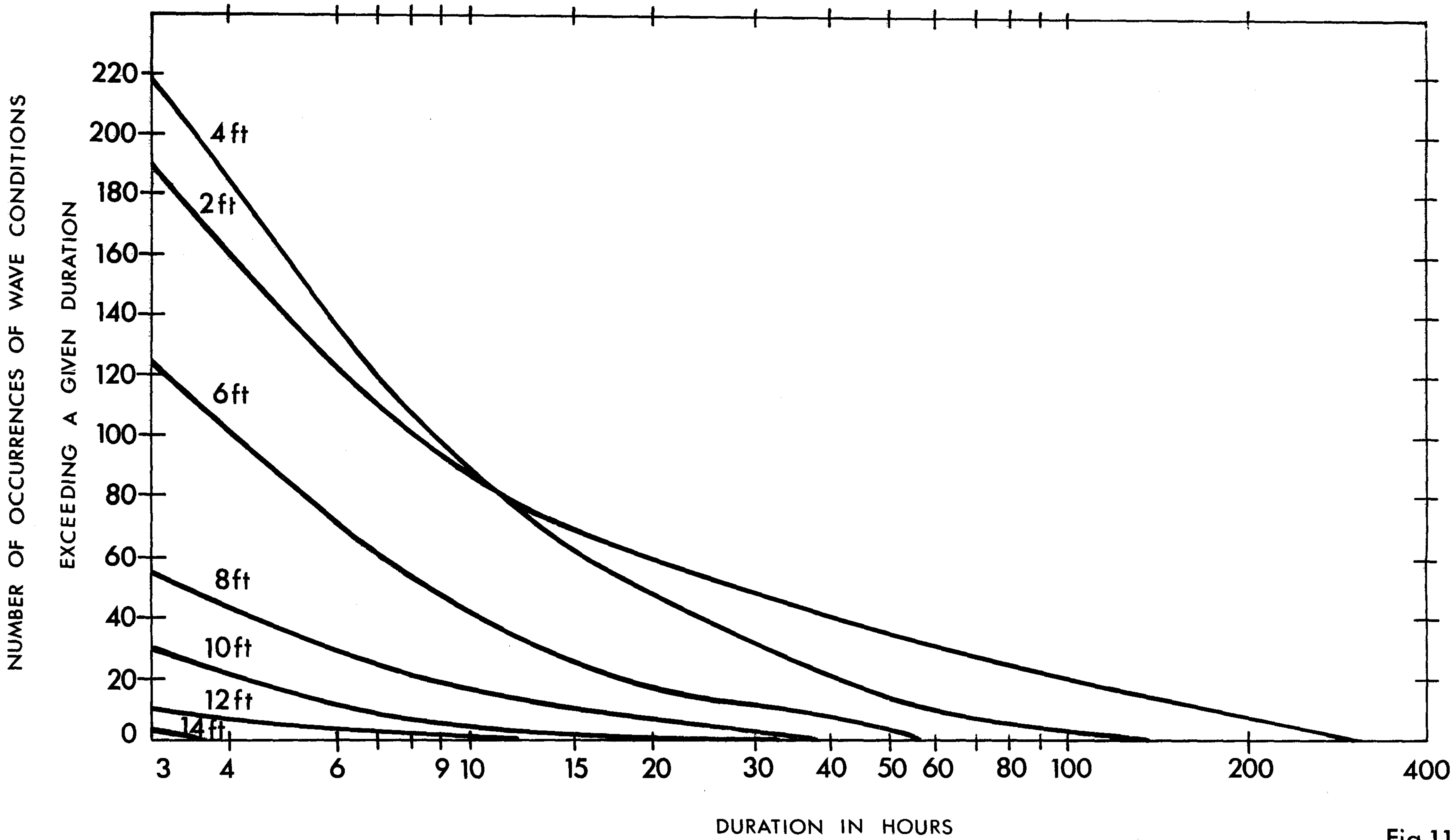


Fig.11
OW

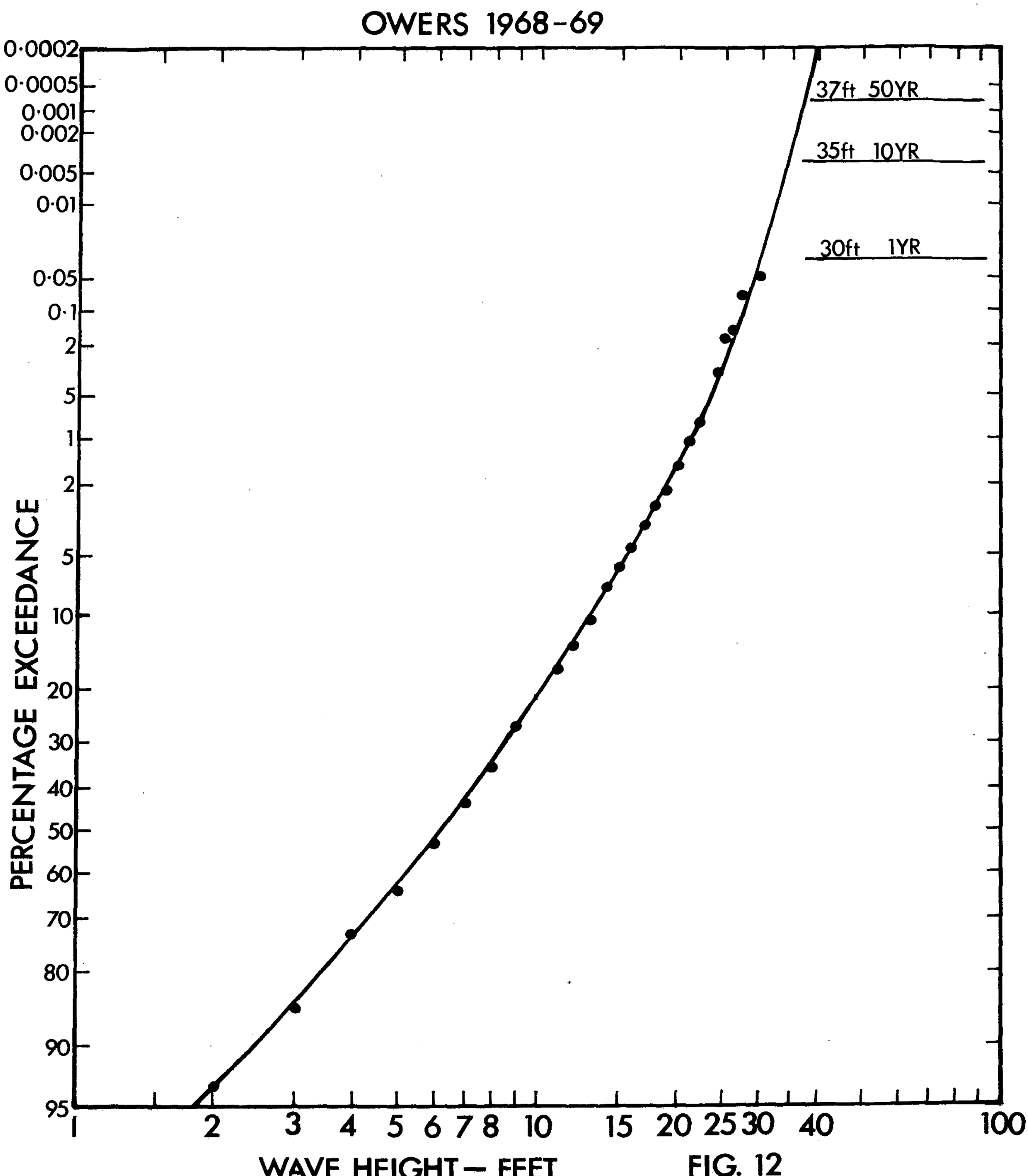

OWERS 1968-69
37ft 50YR
35ft 10YR
30ft 1YR
PERCENTAGE EXCEEDANCE
0·0002
0·0005
0·001
0·002
0·005
0·01
0·05
0·1
2
5
1
2
5
10
20
30
40
50
60
70
80
90
95
1
2
3
4
5
6
7
8
10
15
20
25
30
40
100
WAVE HEIGHT — FEET

FIG. 12
OW

FREQUENCY DISTRIBUTION (parts per thousand) OF WAVE HEIGHTS AT OWERS LIGHT VESSEL AND MEAN WIND SPEEDS OVER PAST HOUR AT CALSHOT

TOTAL OBS. = 2917 PERIOD - OCT. 1968 to SEPT. 1969 inc,

MEAN WAVE HT. ——— R.M.S. ABOVE/BELOW MEAN - - - - - - -

1 observation = * 2 observations = +

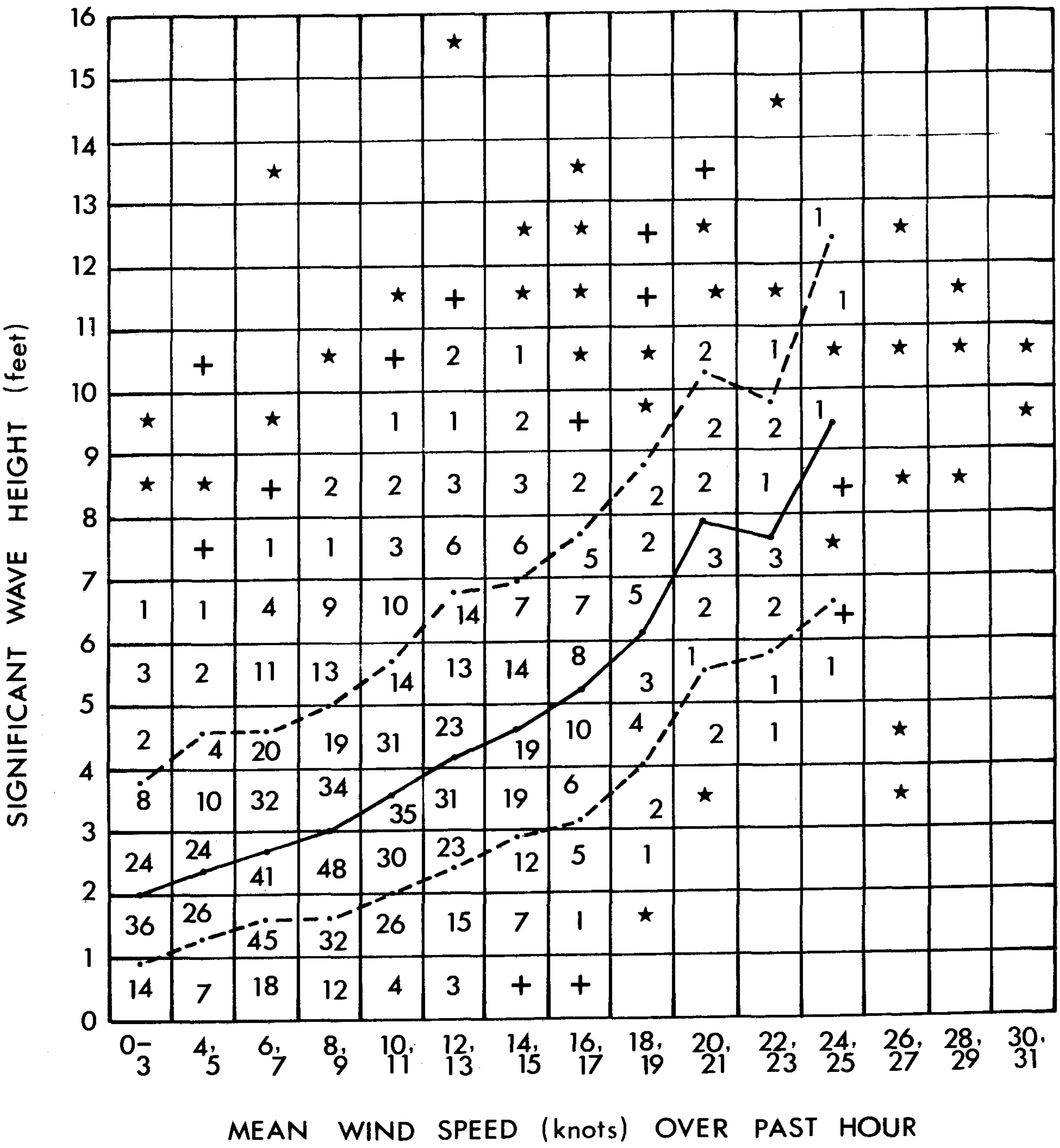


FIG. 13
OW

FREQUENCY DISTRIBUTION (parts per thousand) OF WAVE HEIGHTS AT OWERS LIGHT VESSEL AND MEAN WIND SPEEDS OVER PAST THREE HOURS AT CALSHOT

TOTAL OBS. = 2917 PERIOD - OCT. 1968 to SEPT. 1969 inc.

MEAN WAVE HT. ——— R.M.S. ABOVE / BELOW MEAN - - - - -

1 observation = ★ 2 observations = +

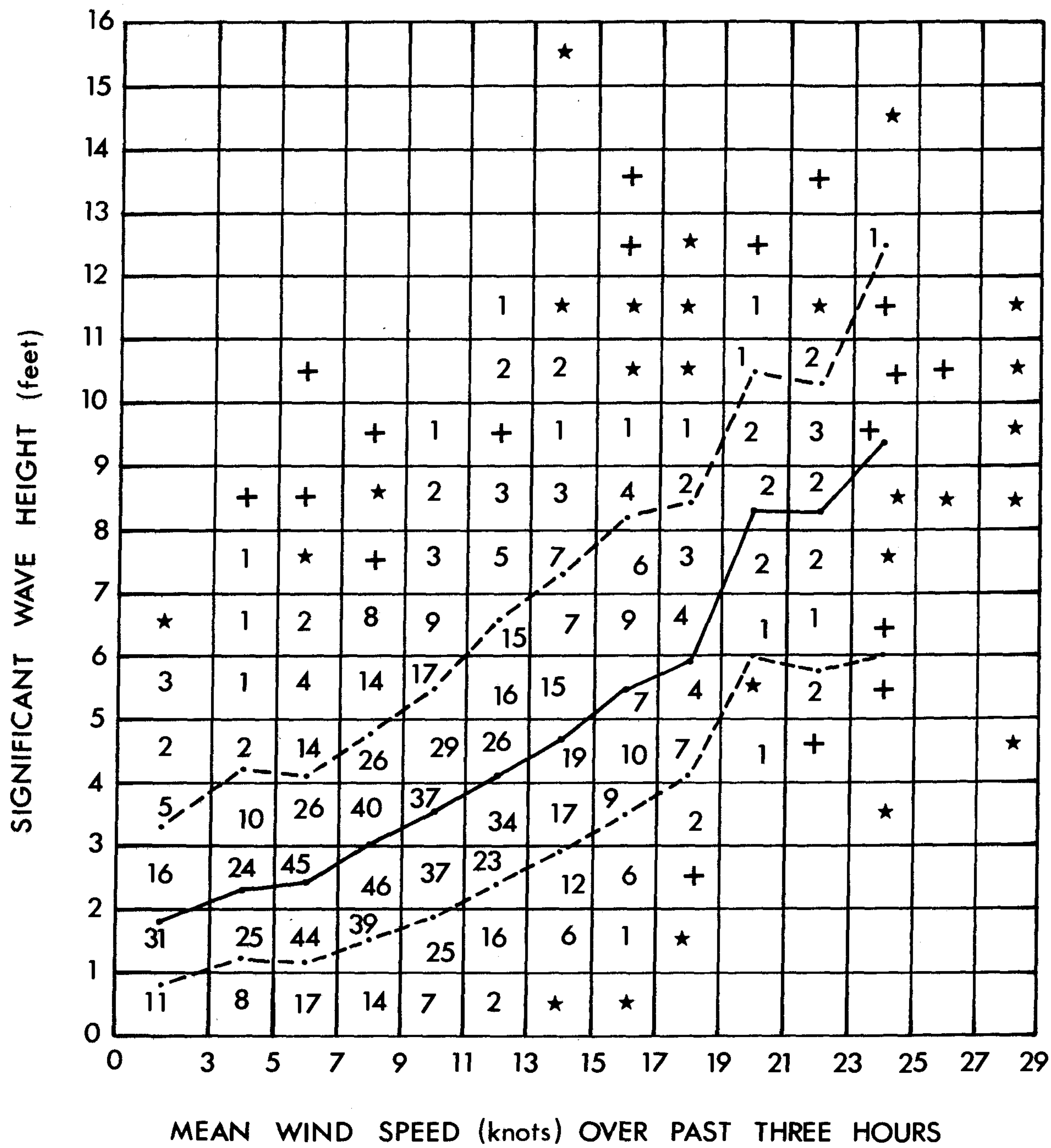


FIG. 14
OW