L Draper

NATIONAL INSTITUTE OF OCEANOGRAPHY
WORMLEY, GODALMING, SURREY

Waves at Varne Light Vessel Dover Strait

by

L. DRAPER and R. GRAVES

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SCATTER DIAGRAM VARNE LIGHT VESSEL DATA.

DATA INPUT ARRAY

15.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	1.0	4.0	3.0	1.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	1.0	1.0	2.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	2.0	6.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	3.0	6.0	5.0	2.0	3.0	1.0	0.0	0.0	0.0	0.0
	0.0	0.0	1.0	2.0	9.0	12.0	8.0	2.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	3.0	9.0	14.0	9.0	5.0	2.0	0.0	0.0	0.0	0.0	0.0
	0.0	1.0	6.0	20.0	21.0	12.0	7.0	2.0	0.0	0.0	0.0	0.0	0.0
	0.0	1.0	12.0	33.0	32.0	17.0	4.0	2.0	0.0	0.0	0.0	0.0	0.0
	1.0	8.0	18.0	35.0	33.0	20.0	7.0	1.0	1.0	2.0	0.0	0.0	0.0
	0.0	7.0	40.0	65.0	44.0	24.0	9.0	2.0	2.0	1.0	0.0	0.0	1.0
	0.0	2.0	18.0	53.0	58.0	52.0	34.0	16.0	7.0	6.0	2.0	1.0	1.0
0.	0.0	0.0	0.0	1.0	9.0	12.0	18.0	8.0	3.0	4.0	1.0	1.0	0.0
	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5

VARNE LIGHT VESSEL DATA (NIO INTERNAL REPORT A34 (1968))

PREDICTED WAVE OCCURRENCES IN 1 YEAR

ACT.NO.OF WAVES FOR EACH HT.INTERVAL

1 TO 5 FEET	1726133.391	1669554.025	908675.072	516693.681	302910.902
6 TO 10 FEET	182734.791	112273.055	70198.543	44605.053	28713.992
11 TO 15 FEET	18657.076	12193.683	7993.283	5243.231	3434.934
16 TO 20 FEET	2243.888	1459.889	945.146	608.557	389.579
21 TO 25 FEET	247.923	156.830	98.600	61.600	38.229
26 TO 30 FEET	23.558	14.406	8.737	5.251	3.125
31 TO 35 FEET	1.841	1.072	0.617	0.351	0.197
36 TO 40 FEET	0.109	0.059	0.032	0.017	0.008

NO.OF WAVES EXCEEDING GIVEN HEIGHTS

1 TO 5 FEET	3890190.972	2220636.941	1311961.870	795268.191	492357.288
6 TO 10 FEET	309622.496	197349.439	127150.896	82545.843	53831.851
11 TO 15 FEET	35174.774	22981.090	14987.807	9744.575	6309.641
16 TO 20 FEET	4065.752	2605.862	1660.716	1052.158	662.579
21 TO 25 FEET	414.655	257.825	159.224	97.624	59.394
26 TO 30 FEET	35.836	21.429	12.692	7.440	4.315
31 TO 35 FEET	2.473	1.401	0.784	0.432	0.235
36 TO 40 FEET	0.126	0.067	0.035	0.018	0.009

1st table. 1 refers to 0 → 1.0

2 " " 1+Δ → 2.0

3 " " 2+Δ → 3.0 etc

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Figures:

Waves have been recorded by a Shipborne Wave Recorder (Tucker, 1956) placed on the Varne Light Vessel which is stationed in 15 fathoms of water south west of the Varne Bank in the Dover Strait. The records from the first year of operation, from February 1965, have been analyzed, 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 recently 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 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_s and T_c (Tucker, 1961):

$$\epsilon^2 = 1 - (T_c / T_s)^2$$

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 28 per cent of the time. Wave heights are generally higher in the winter months, but it is worthy of note that the highest measured wave of 25 feet in height and with a zero-crossing period of 6•43 seconds occurred on 18 September, and a wave 19 feet in height was measured on 29 July. 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 2 and 3 feet and a zero-crossing period of between 4•5 and 5 seconds, which occurred for 65 thousandths, or 6•5 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•9 feet below mean water level, do not record waves which have a period of less than about 3•5 seconds; this is the cause of the cut-off below that period.

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.) 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 2·6 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 wavelength, 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 2·6 knots travelling in the same direction as the waves, a real period of about 4 seconds will appear as one of about 3·3 seconds, 5 seconds appears as about 4·3 seconds, 6 seconds appears as about 5·1 seconds, 7 seconds appears as about 6·2 seconds, 8 seconds appears as about 7·2 seconds. 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 35 occasions, or spells in excess of 24 hours on 14 occasions.

A 'Lifetime' wave can often be predicted by use of the presentation used in Figure 12, but in this case the pronounced curvature makes reliable extrapolation rather unreliable.

Acknowledgements

The authors wish to thank the Corporation of Trinity House for permission to install the equipment on their vessel and the masters and crew for operating it. The efforts of their colleague Mr. J.W. Cherriman, which resulted in the reliable operation of the instrument, are very much appreciated.

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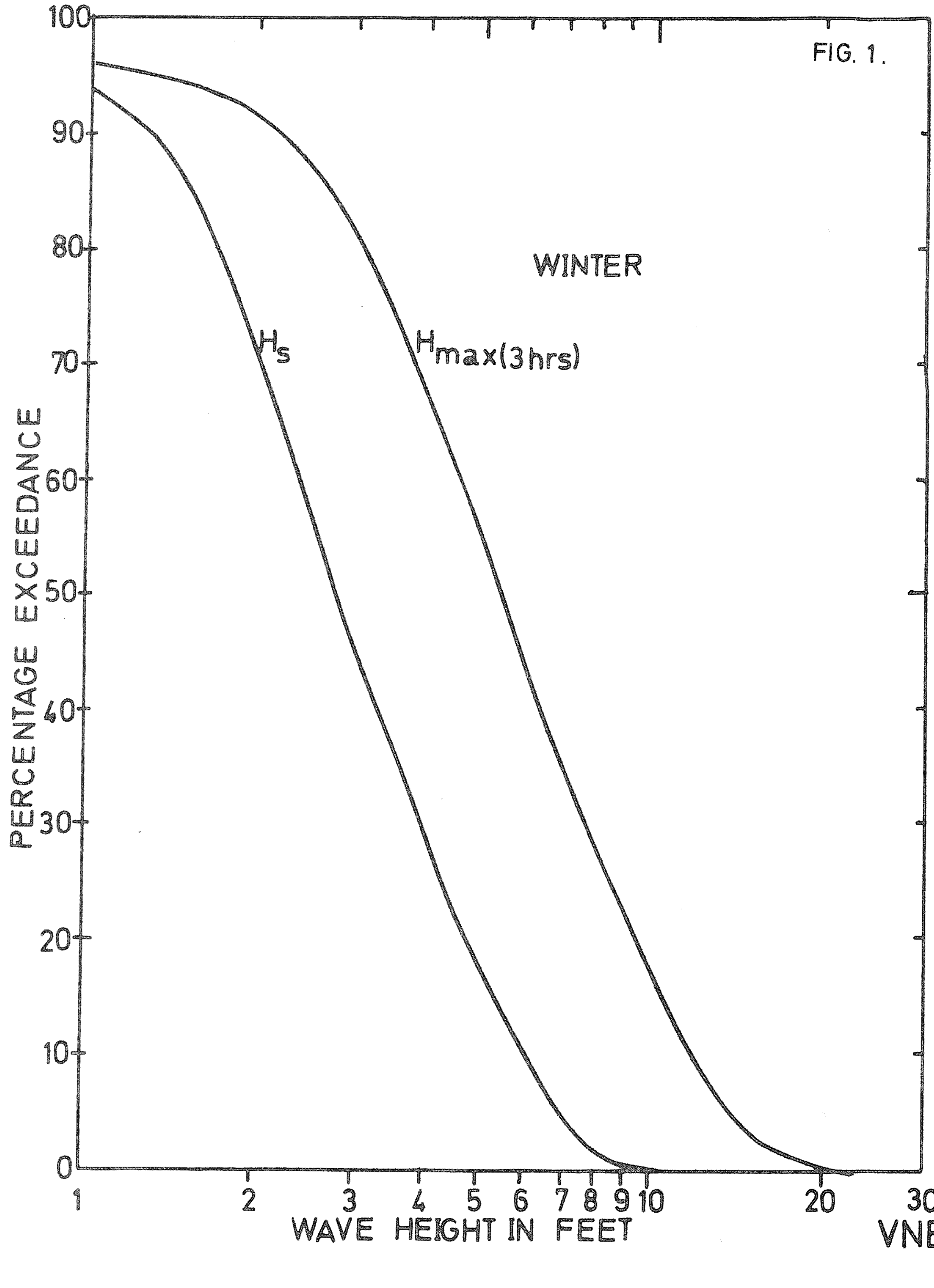
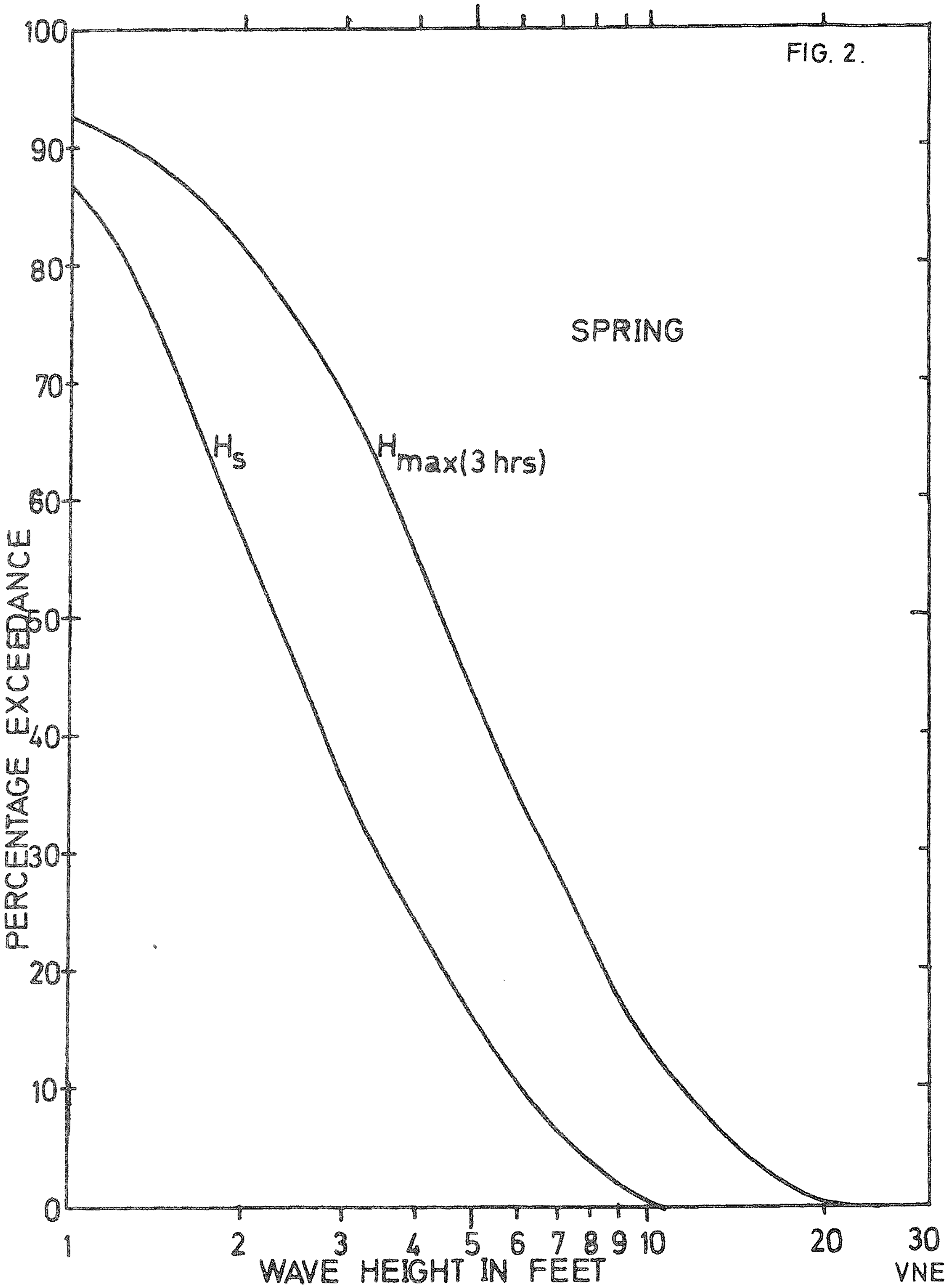
FIG. 1.


WINTER
H_s
$H_{max(3hrs)}$
PERCENTAGE EXCEEDANCE
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
20
30
WAVE HEIGHT IN FEET

VNE

FIG. 2.


SPRING
H_s
$H_{max(3 hrs)}$
PERCENTAGE EXCEEDANCE
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
20
30
WAVE HEIGHT IN FEET
VNE

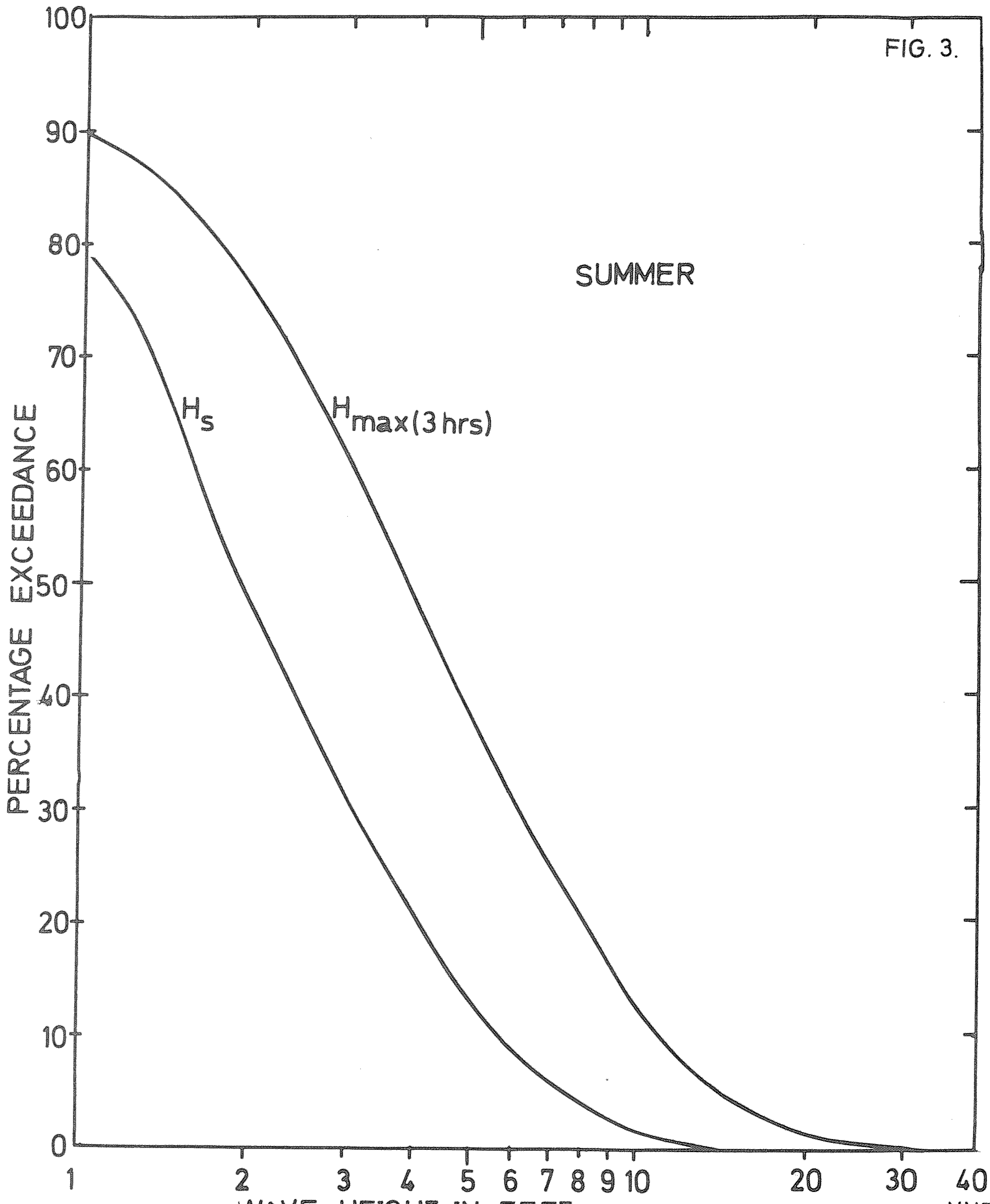


FIG. 3.
SUMMER
H_s
$H_{max (3 hrs)}$
PERCENTAGE EXCEEDANCE
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
20
30
40
WAVE HEIGHT IN FEET

VNE

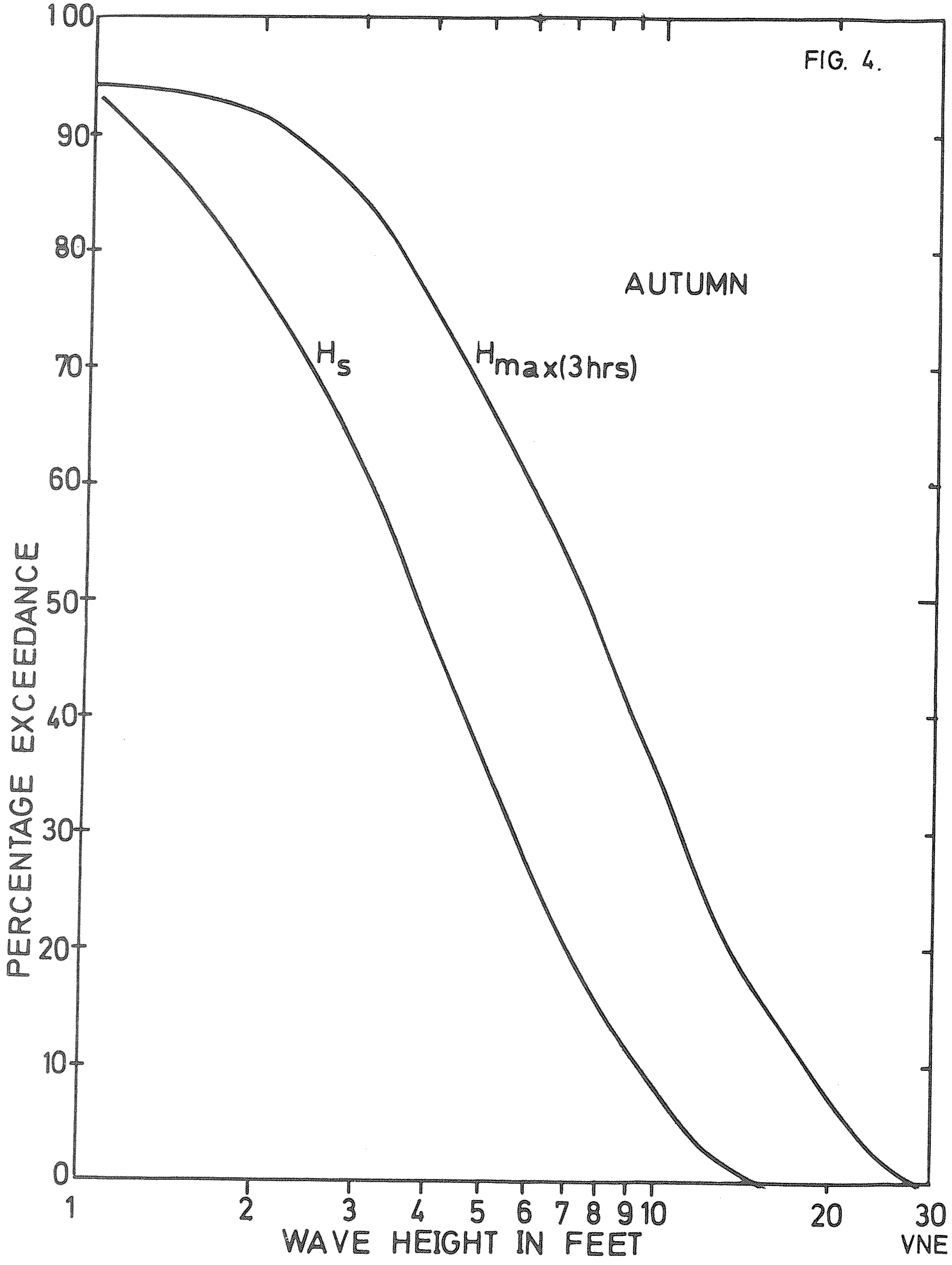


FIG. 4.
AUTUMN
H_s
$H_{max(3hrs)}$
PERCENTAGE EXCEEDANCE
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
20
30
WAVE HEIGHT IN FEET
VNE

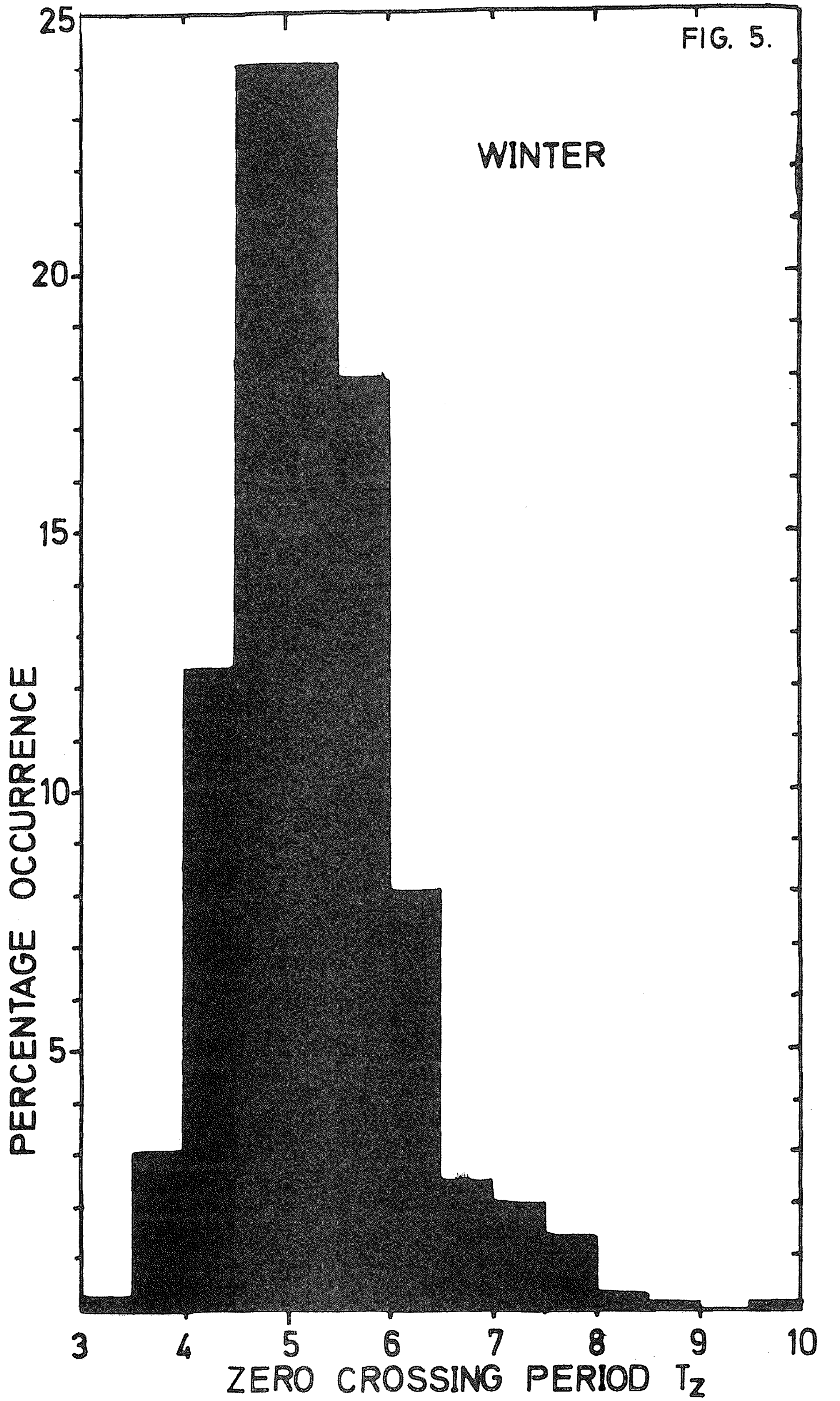


FIG. 5.
WINTER
PERCENTAGE OCCURRENCE
25
20
15
10
5
3
4
5
6
7
8
9
10
ZERO CROSSING PERIOD T_Z
IN SECONDS
VNE

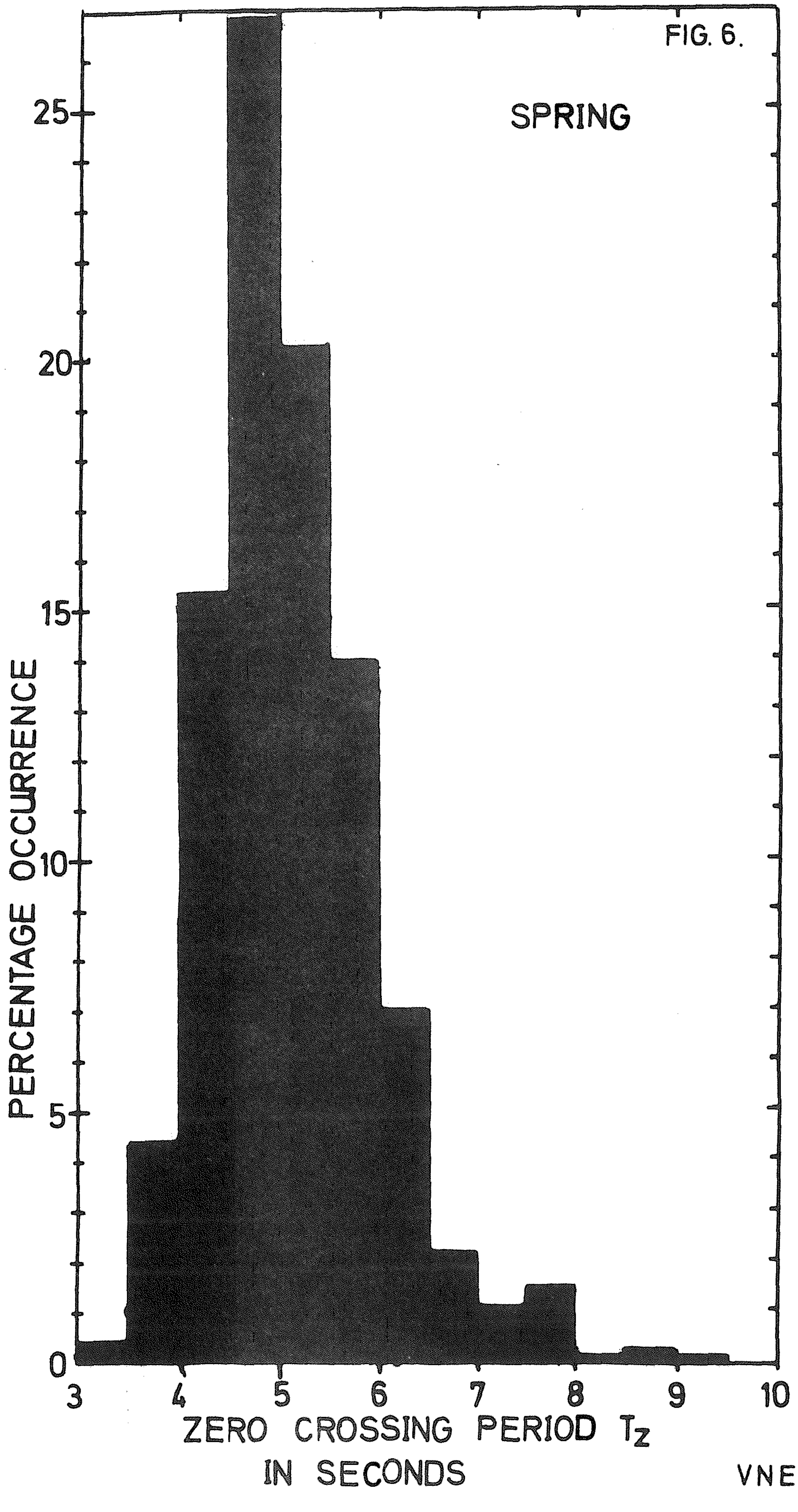


FIG. 6.
SPRING
PERCENTAGE OCCURRENCE
0
5
10
15
20
25
3
4
5
6
7
8
9
10
ZERO CROSSING PERIOD T_z
IN SECONDS
VNE

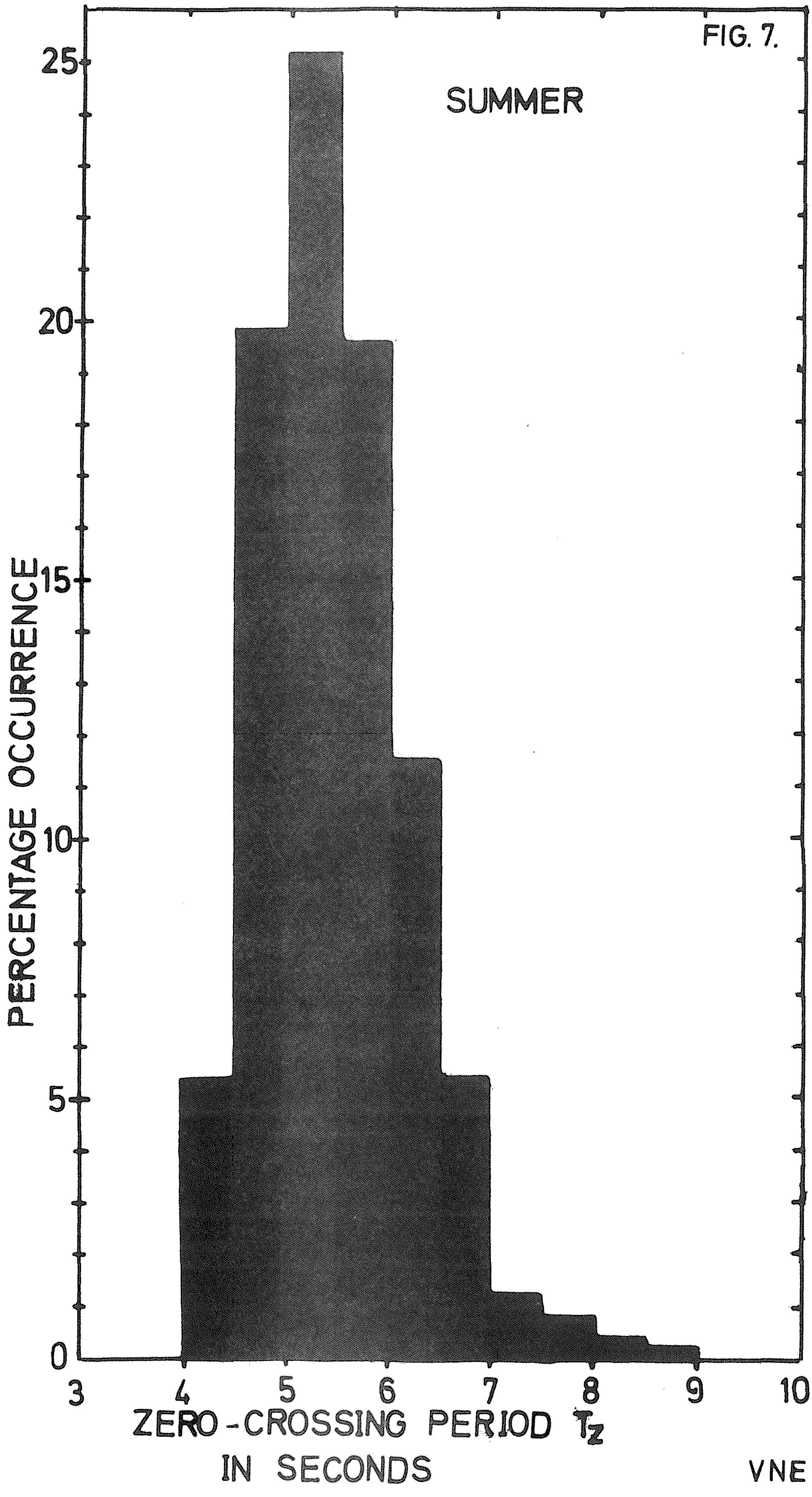


FIG. 7.
SUMMER
PERCENTAGE OCCURRENCE
0
5
10
15
20
25
3
4
5
6
7
8
9
10
ZERO-CROSSING PERIOD T_z
IN SECONDS
VNE

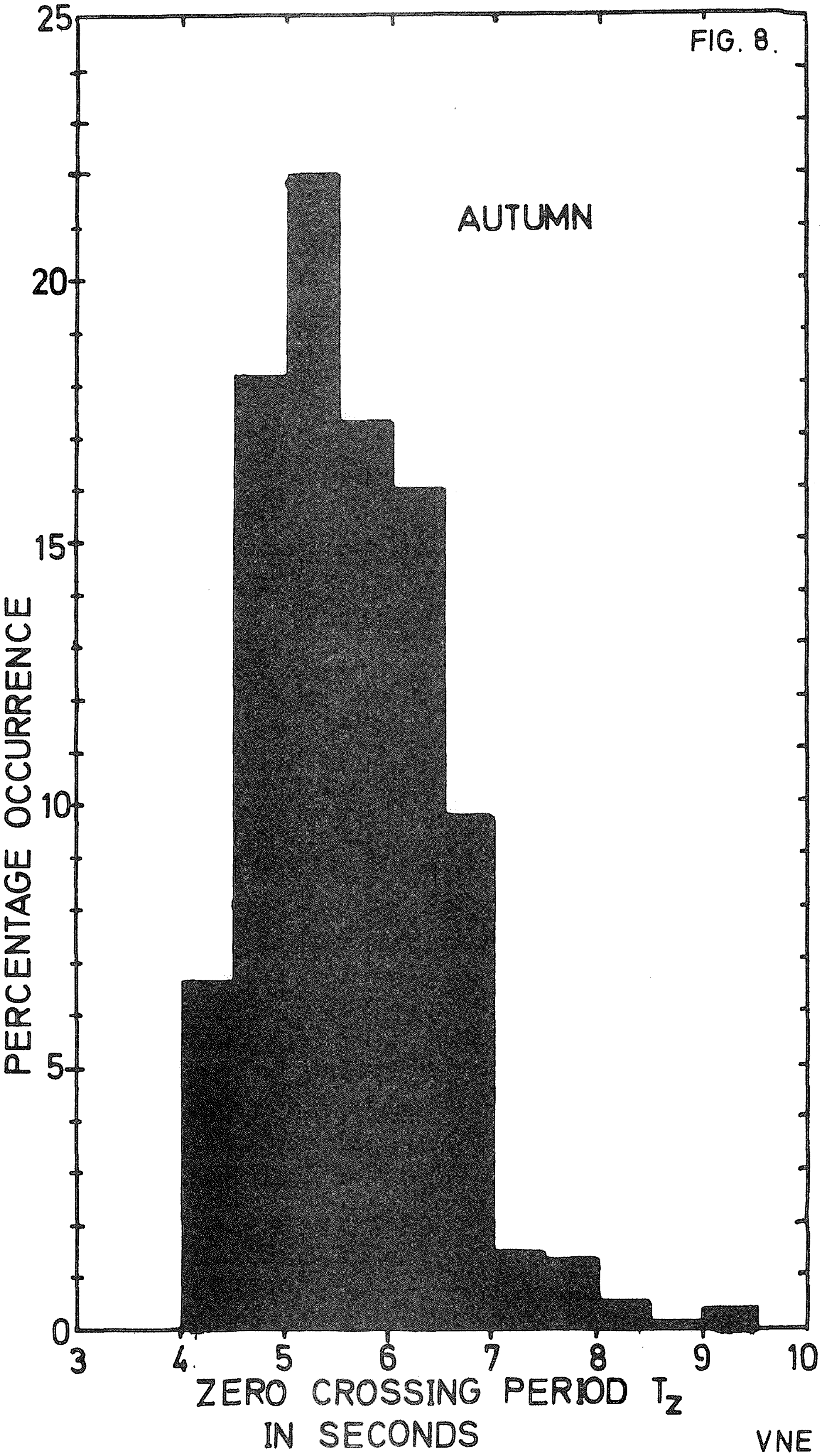


FIG. 8.
AUTUMN
PERCENTAGE OCCURRENCE
25
20
15
10
5
0
3
4
5
6
7
8
9
10
ZERO CROSSING PERIOD T_Z
IN SECONDS
VNE

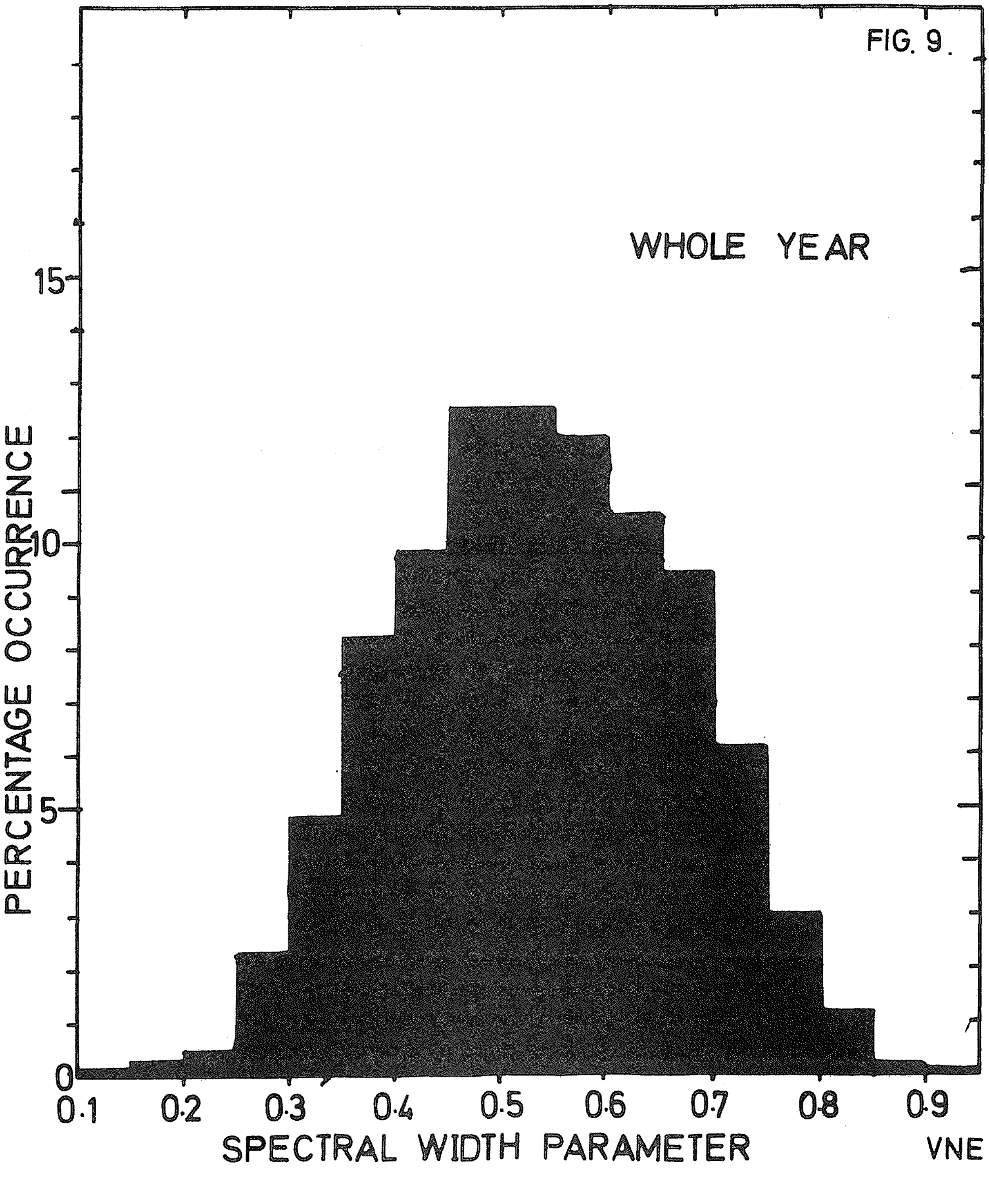


FIG. 9.
WHOLE YEAR
PERCENTAGE OCCURRENCE
15
10
5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
SPECTRAL WIDTH PARAMETER
VNE

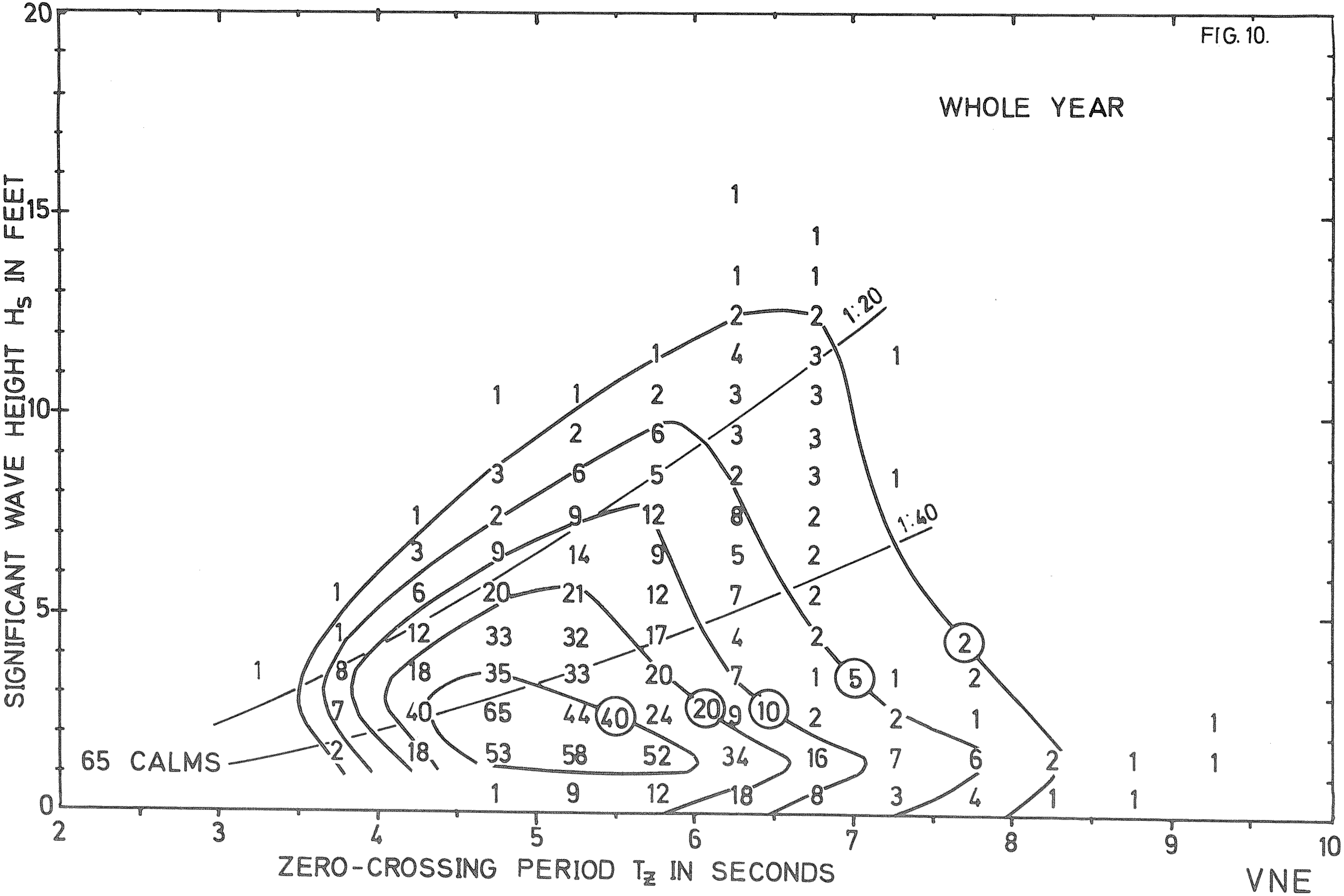
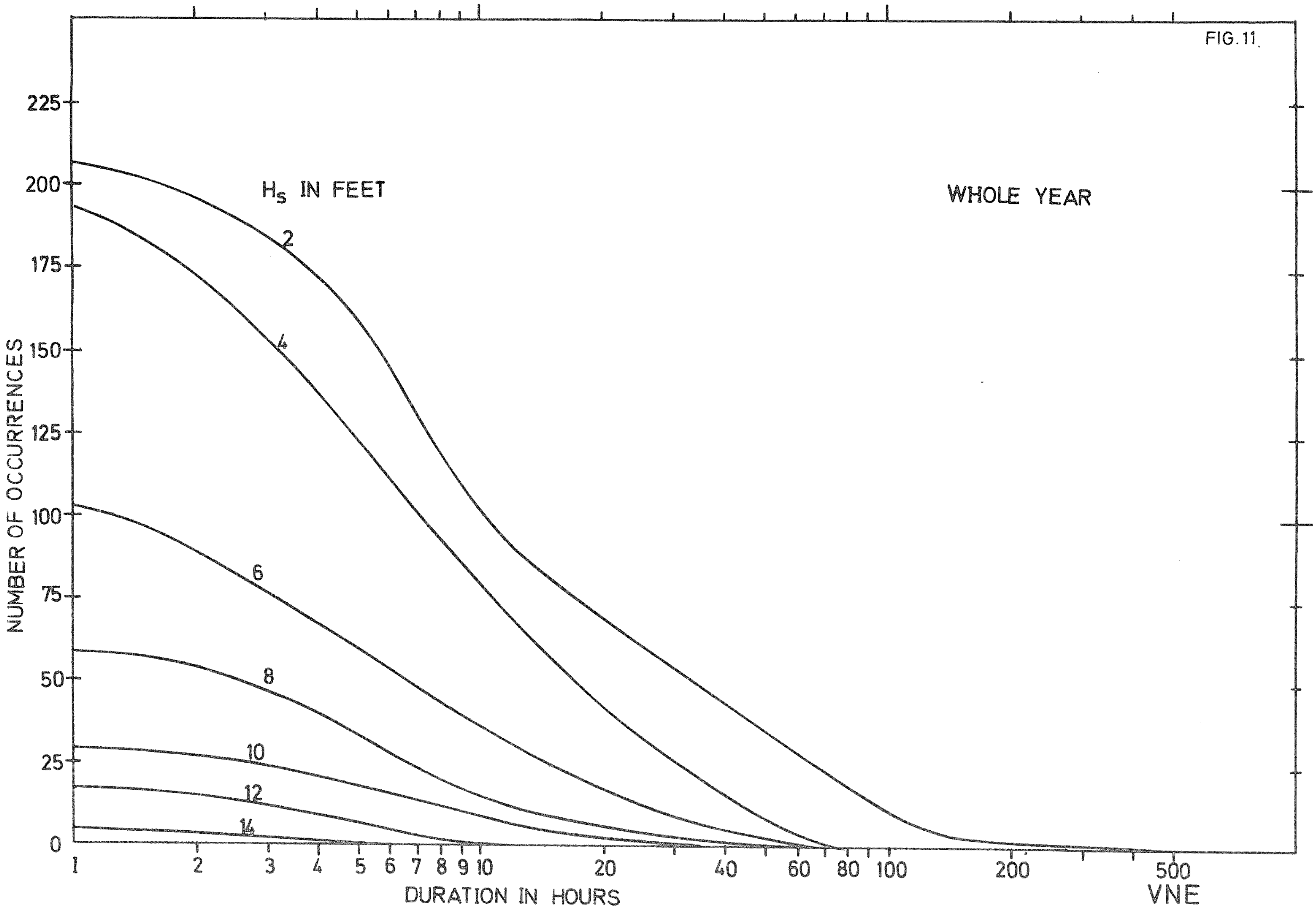


FIG. 10.
WHOLE YEAR
SIGNIFICANT WAVE HEIGHT H_S IN FEET
ZERO-CROSSING PERIOD T_Z IN SECONDS
65 CALMS
1:20
1:40
VNE

FIG. 11.



NUMBER OF OCCURRENCES
225
200
175
150
125
100
75
50
25
0
H_s IN FEET
WHOLE YEAR
2
4
6
8
10
12
14
1
2
3
4
5
6
7
8
9
10
20
40
60
80
100
200
500
DURATION IN HOURS

VNE

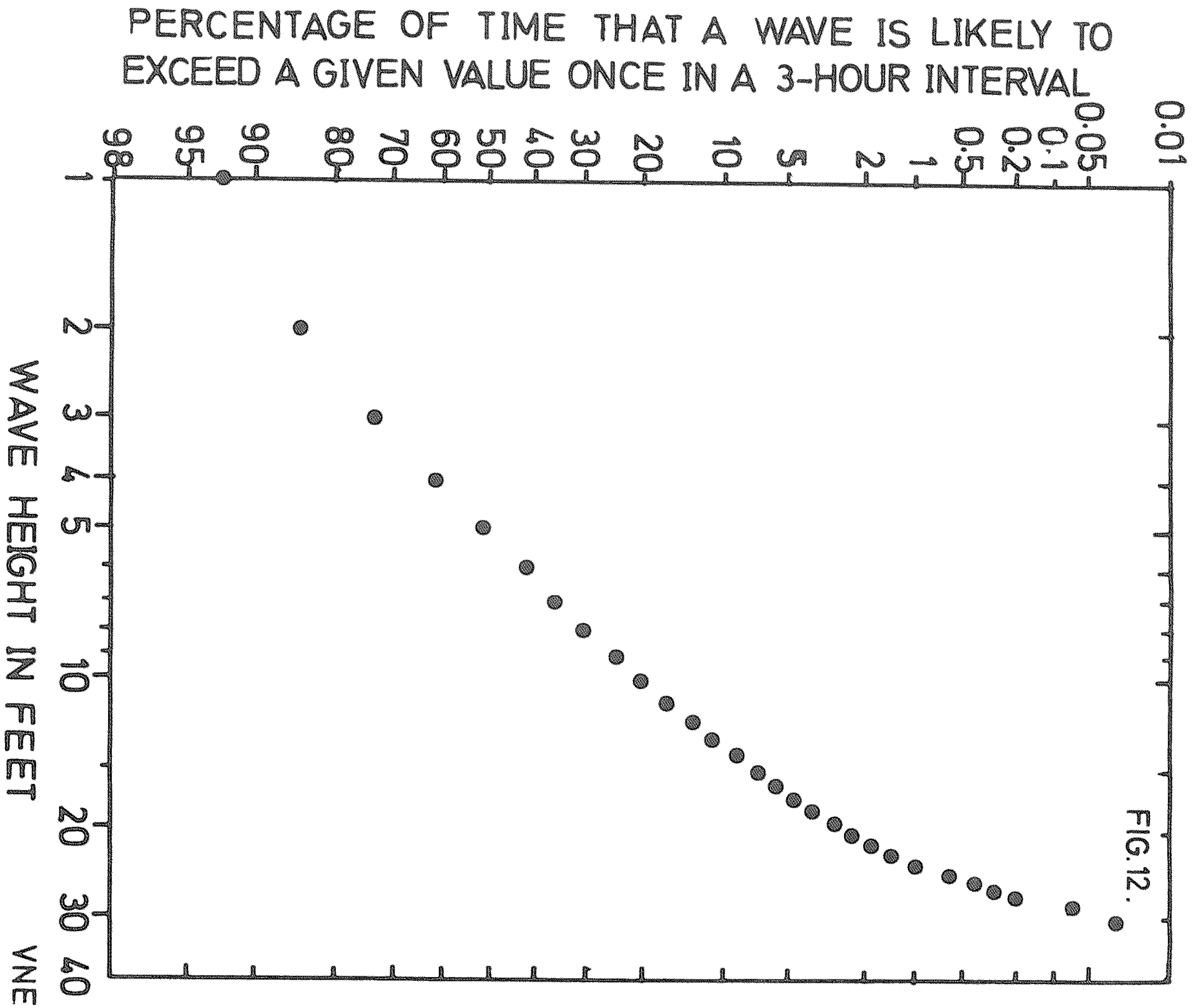

PERCENTAGE OF TIME THAT A WAVE IS LIKELY TO
EXCEED A GIVEN VALUE ONCE IN A 3-HOUR INTERVAL
98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
1 2 3 4 5 10 20 30 40
WAVE HEIGHT IN FEET

FIG. 12.

VNE