WAVES AT DOWSING LIGHT VESSEL, NORTH SEA

BY

L. DRAPER

I.O.S. REPORT NO. 31

DECEMBER 1976

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF
OCEANOGRAPHIC
SCIENCES

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CONTENTS

Waves have been recorded by a Shipborne Wave Recorder (Tucker, 1956) placed on the Dowsing Light Vessel, which is stationed approximately twenty five miles due east of Spurn Head at the mouth of the Humber. The depth of water under the vessel is about 14 fathoms with deepening water in a narrow trench to the North, but with shallower water (of 5 to 8 fathoms) to the East and South. The records for a year of operation from May 1970 have been analyzed, mainly following the method developed by Tucker (1961) from theoretical studies by Cartwright and Longuet-Higgins (1956). The form of presentation is that recommended for data for engineering purposes (Draper, 1966).

Records were taken for 15 minutes at three-hourly intervals, and the analysis of the first 12 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 values 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 function of the number of zero-crossings in the record (Tucker, 1963). A similar equation is used for the calculation of H_s from H_2.

(f) $H_{max(3 \text{ hours})}$ = 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, 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 distributions 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 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_s on probability paper, for the whole year.

Figure 14 is a plot of $H_{max(3\ hours)}$ on Weibull probability paper, for the whole year.

DISCUSSION OF RESULTS

Wind conditions

The mean wind speed for the year in which the wave measurements were made has been compared with the fourteen-year mean speed. The nearest station where suitable wind data were available is Manby in Lincolnshire; unfortunately it is not at the coast but for comparison purposes is acceptable. The mean speed for 1957-1970 was 9.5 kt whilst the mean speed for the 12 months of wave recording was 8.8 kt. Moreover, no winds reached gale force at Manby in the year of interest whilst on average there were 2.8 days on which gale force winds occurred. It therefore seems reasonable to conclude that the wave data represents less-than-average severity. Assuming that the Manby data is representative, then the mean wind speed in the vicinity of the Dowsing Light Vessel was 7% lower during 1970-71 than average, so the wave heights in this report would have been about 10% lower than average, and the wave periods would have been 3% or 4% lower than average. These wind-wave relationships are based on the work of Darbyshire (1961).

The Wave Data

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 winter the significant height exceeded 5 feet for 32 percent of the time. The highest recorded individual wave, 27 feet crest to trough, occurred on two occasions, 20 October and 30 December, with zero-crossing periods of the whole records of 6.82 and 7.83 seconds respectively. (It is of interest that subsequently, on 17 November, 1975, a wave of height 32 feet was measured. The zero-crossing period of the record was 10.8 seconds. The wave recorder was removed in September 1971 and replaced in October 1975).

Figure 5, the distribution of zero-crossing periods in winter, shows several occasions with wave periods of $10\frac{1}{2}$-11 seconds; during the Spring, Summer and Autumn (Figures 6-8) the maximum period was about 9 seconds. Otherwise Figures 5-8 indicate little seasonal variation in the zero-crossing period distribution, with a modal value of 4-5 seconds for all seasons.

The scatter diagram of figure 10 relates the significant wave height to zero-crossing period, with the number of occurrences expressed in parts per thousand. There are nearly three thousand records taken in a full year, so that an asterisk*, which represents one occurrence, is equivalent to one part in three thousand, and a plus sign +, which represents two occurrences, is equivalent to two parts in three thousand. As an example, the most common wave conditions were those with a significant height of between 2.5 and 3 feet with a zero-crossing period of between 4 and 4.5 seconds, which occurred for 25 thousandths, or 2.5 percent, of the time. The rapid attenuation of the shorter waves with depth means that the instrument's pressure units, which are about 4.8 feet below the mean water level, do not record waves which have a period of less than approximately 3 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 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. (Wave length L was computed using the linear wave theory with period T in deep water, that is $L = gT^2/2\pi$.) The figure indicates numerous waves steeper than 1:20, in contrast to the situation in an area exposed to the open Atlantic - see for example Figure 10 in 'Waves off Land's End' (Draper and Fricker, 1965).

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 of 55 separate occasions, or spells in excess of 24 hours on 22 separate occasions.

Figures 12 and 13 are plots on probability paper of values of $H_{max(3\ hours)}$ and H_s respectively. The data on both plots appear to fall into two approximately linear portions, with a division at a significant wave height of about 12 feet, and $H_{max(3\ hours)}$ of 23 feet. Perhaps the apparent change in wave height distribution is related to bathymetry of the area. A linear extrapolation of the upper portion of the $H_{max(3\ hours)}$ and H_s data yields 50 year return wave heights of 45 feet and 23 feet respectively. Figure 14 shows the cumulative probability distribution of the $H_{max(3\ hours)}$ data plotted on Weibull probability paper. A linear extrapolation of the data with $H_{max(3\ hours)}$ greater than 24 feet gives a 50 year average return wave height of 44 feet, in good agreement with the result derived assuming a log-normal distribution.

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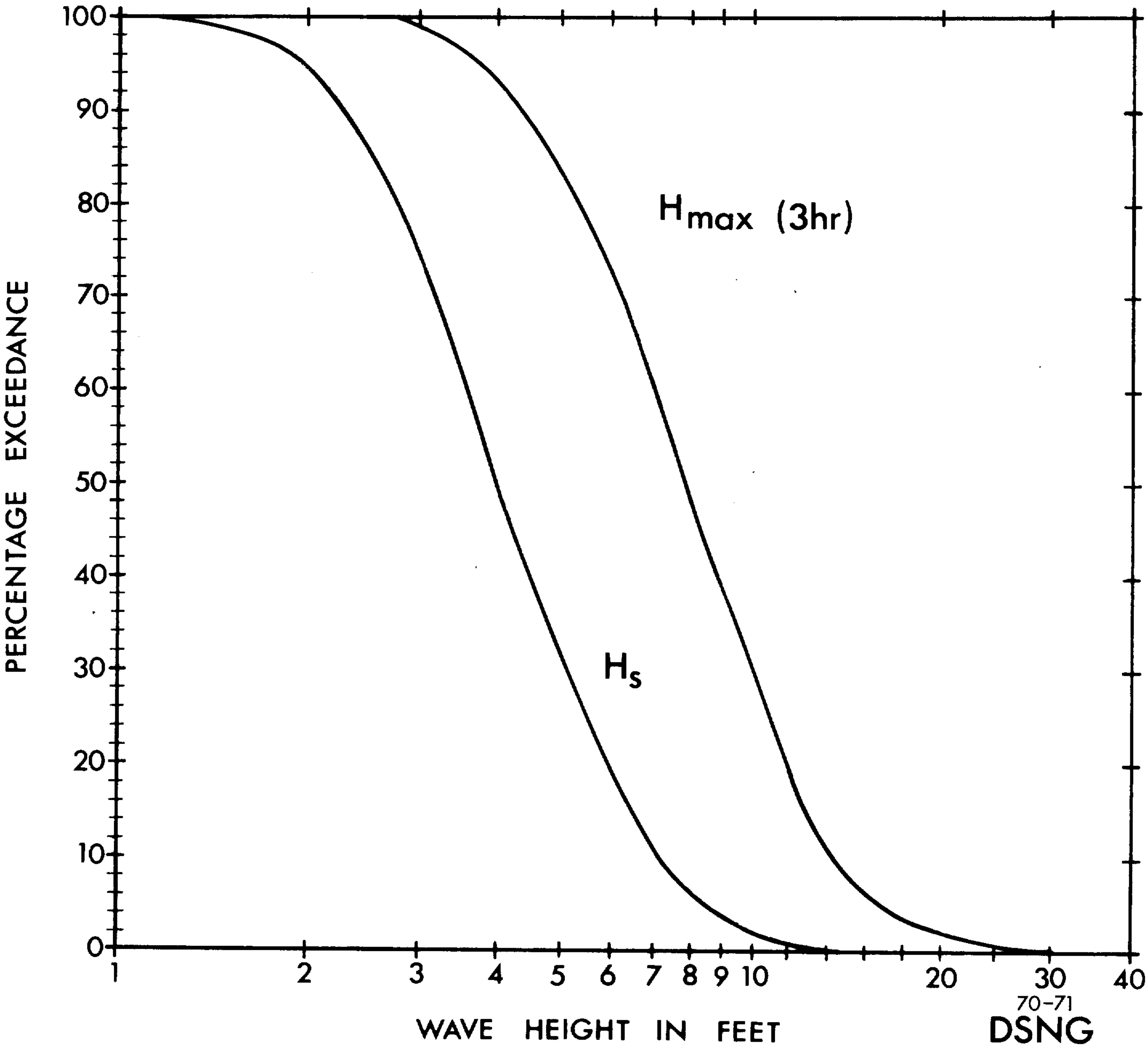
PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

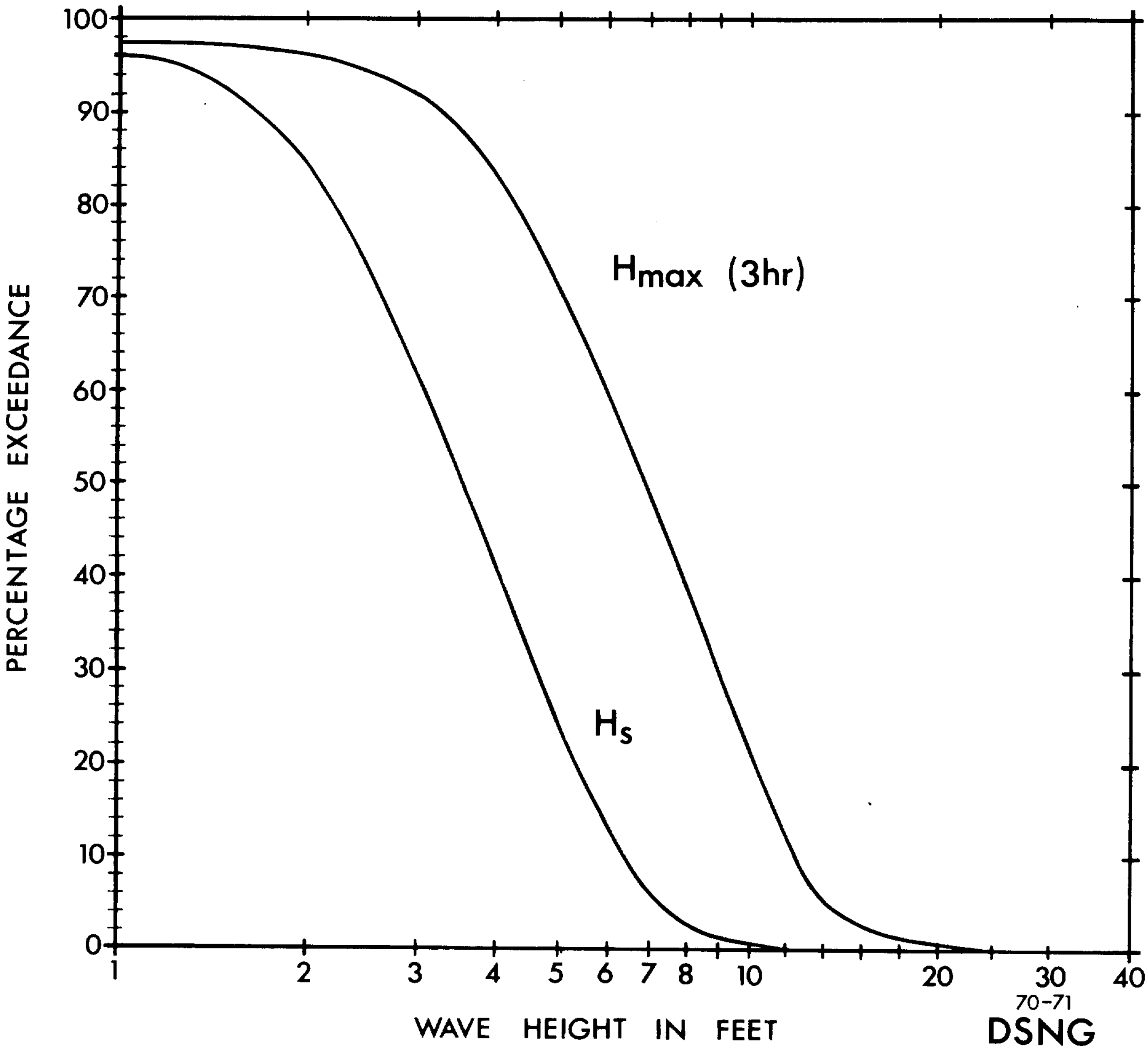
WINTER — JANUARY TO MARCH



70-71
DSNG
FIG.1

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

SPRING – APRIL TO JUNE



70-71
DSNG
FIG.2

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

SUMMER — JULY TO SEPTEMBER

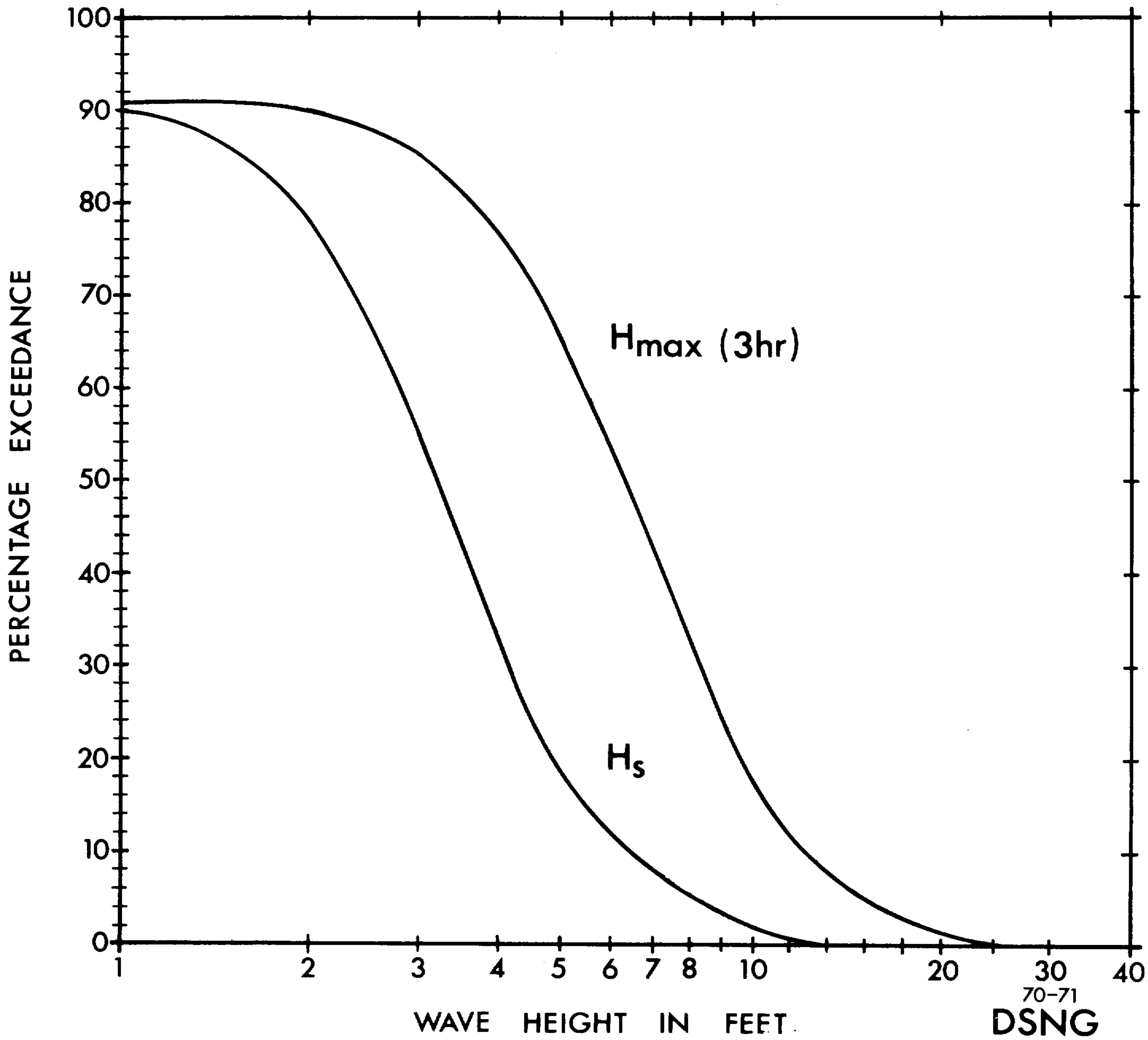


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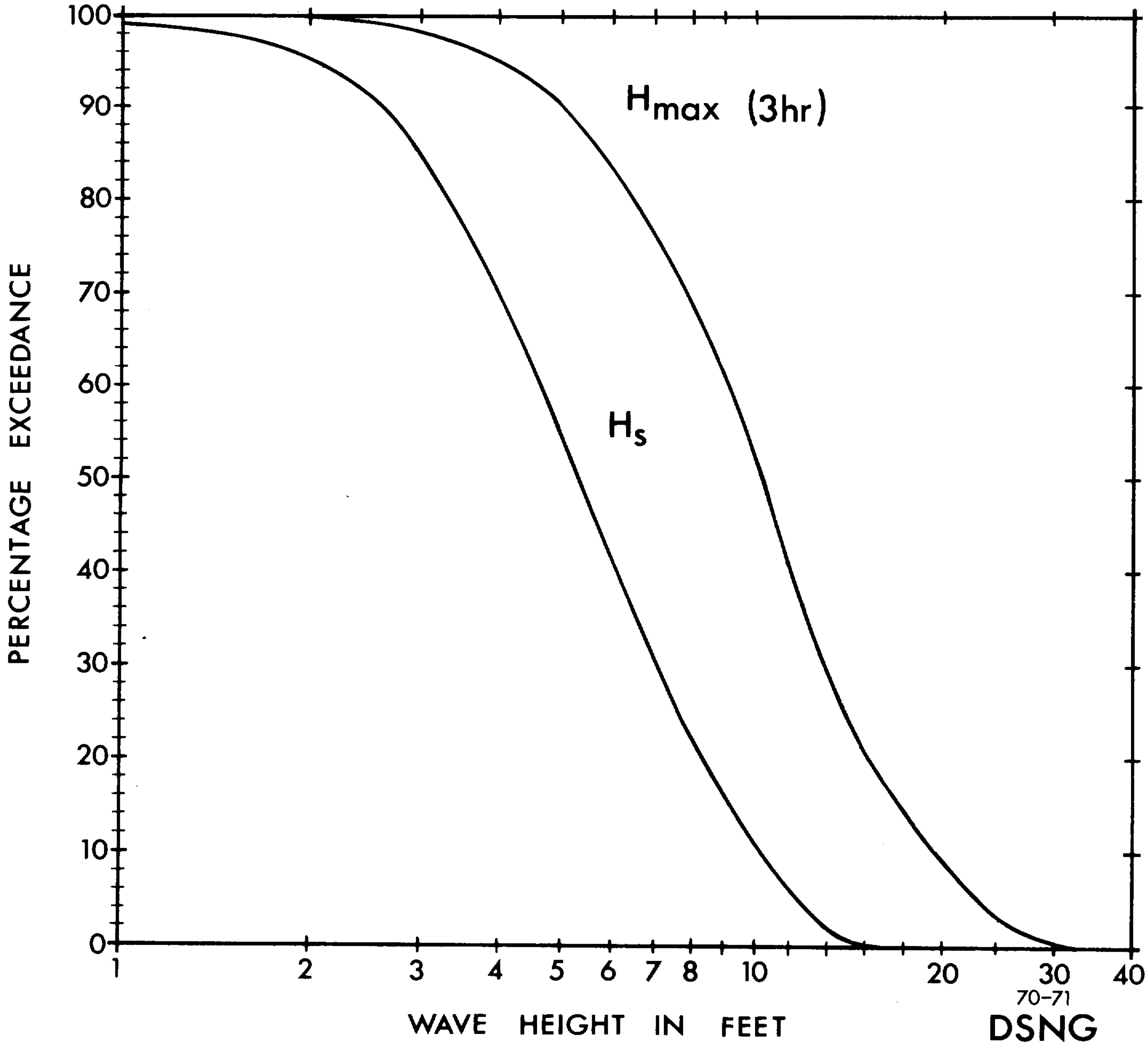
FIG. 3

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

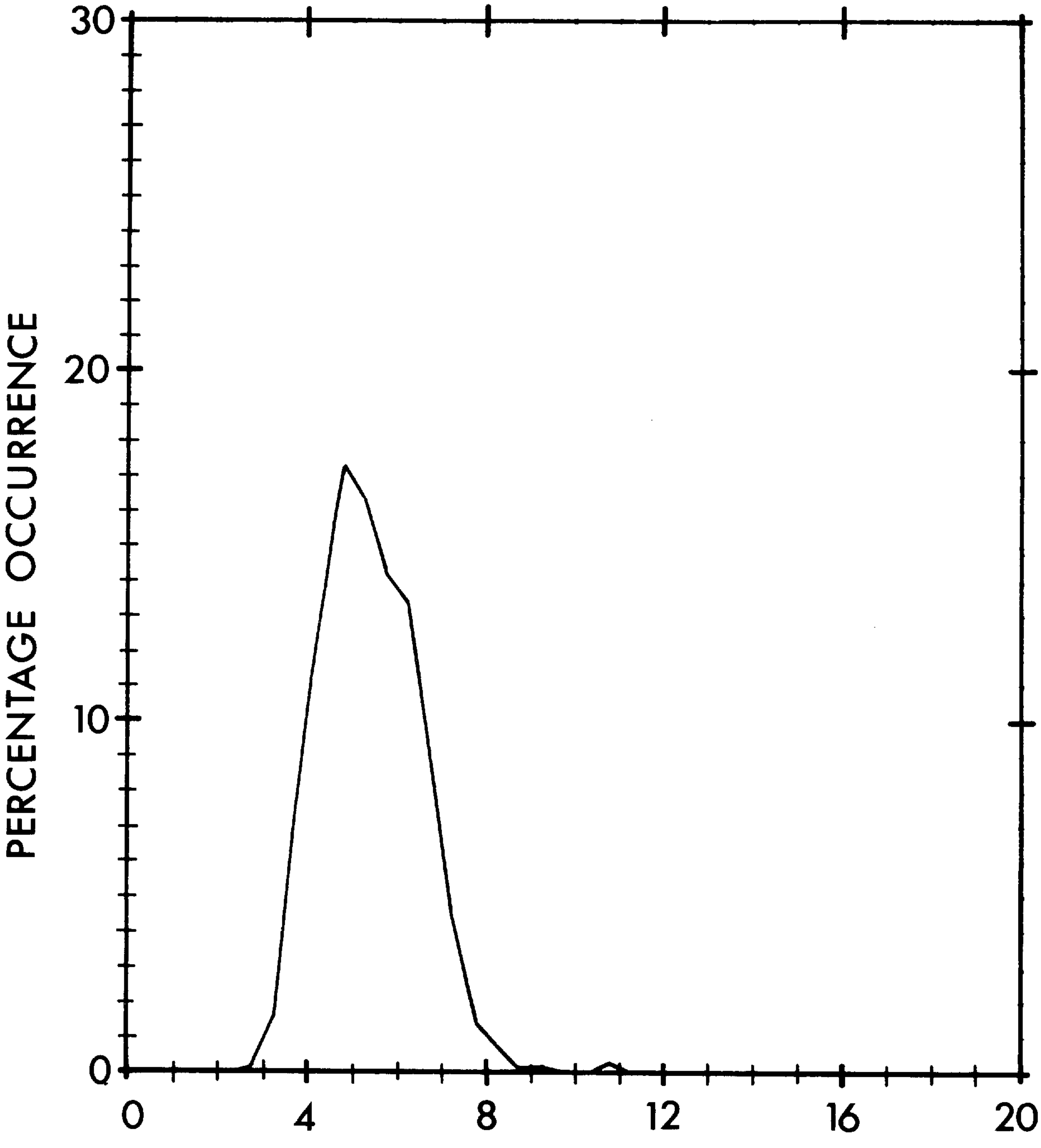
AUTUMN — OCTOBER TO DECEMBER



70-71
DSNG
FIG. 4

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

WINTER – JANUARY TO MARCH



ZERO CROSSING PERIOD

(PLOTTED IN HALF SECOND INTERVALS)

CALM = 0·00 PER CENT

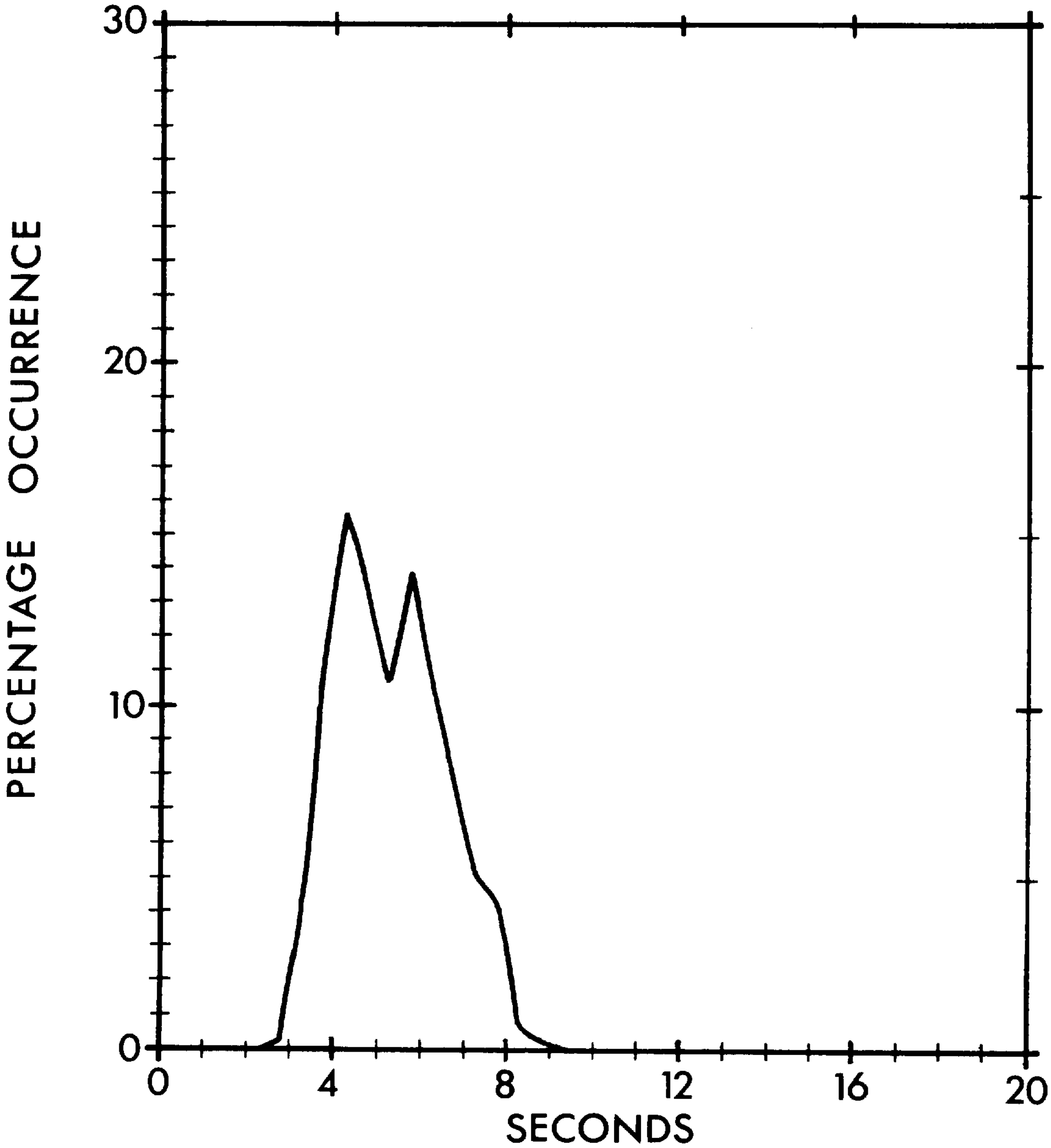
70-71

DSNG

FIG. 5

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

SPRING – APRIL TO JUNE

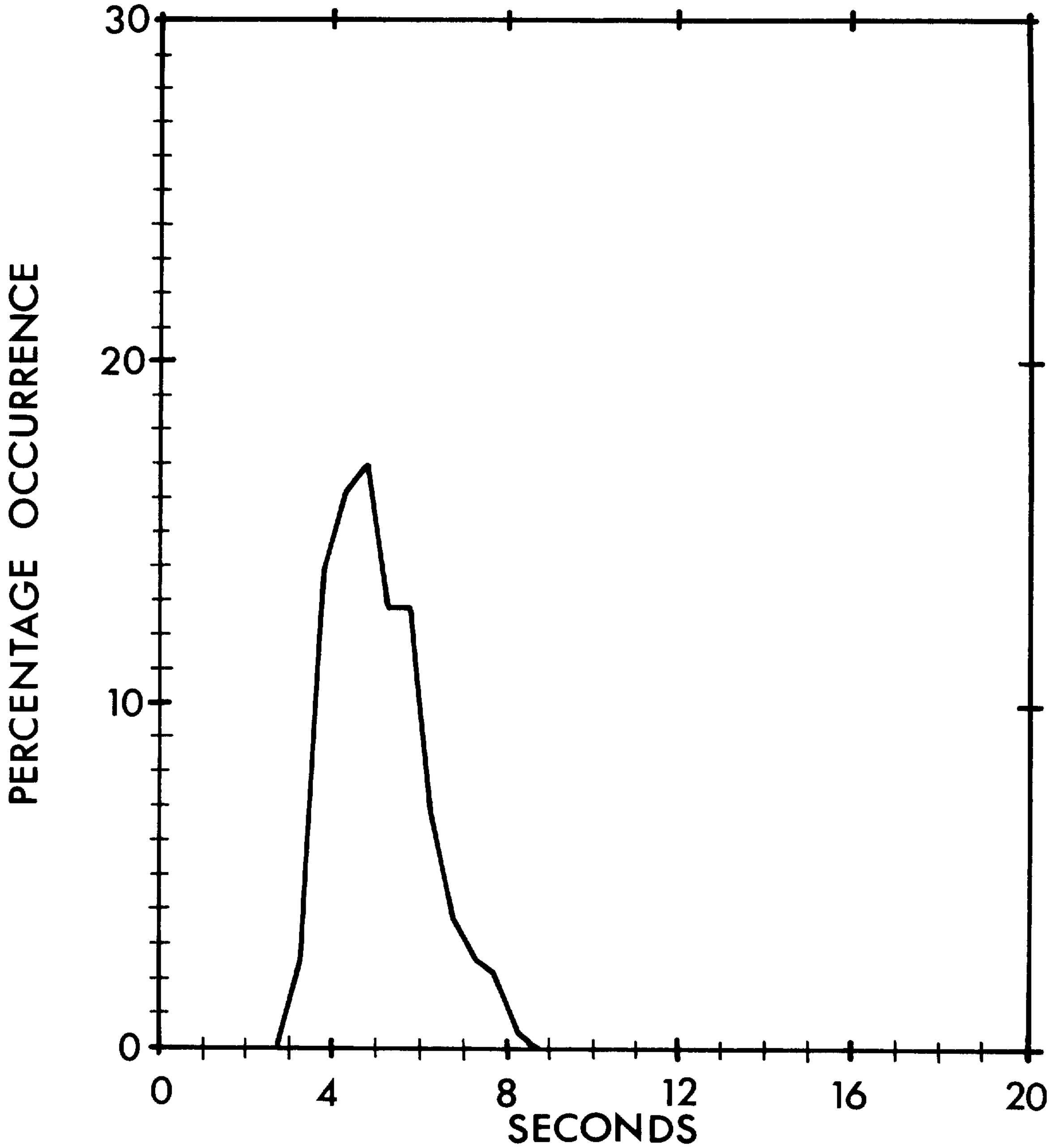


ZERO CROSSING PERIOD
(PLOTTED IN HALF SECOND INTERVALS)

CALM = 2·60 PER CENT

70-71
DSNG
FIG. 6

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z
SUMMER — JULY TO SEPTEMBER

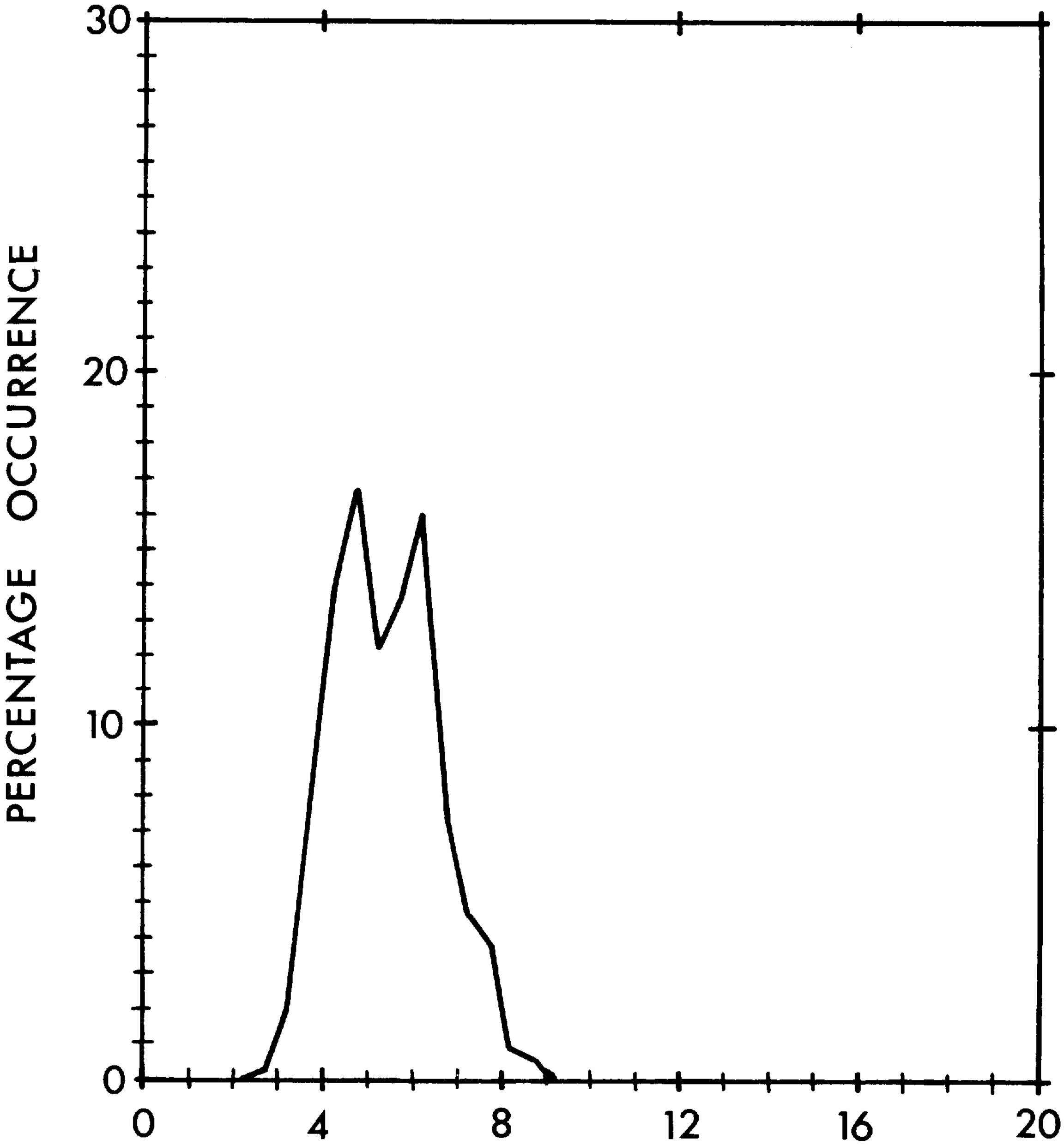


ZERO CROSSING PERIOD
(PLOTTED IN HALF SECOND INTERVALS)

CALM = 0·54 PER CENT

70-71
DSNG
FIG. 7

GRAPH OF PERCENTAGE OCCURRENCE OF T_z
AUTUMN — OCTOBER TO DECEMBER 1970-71



SECONDS

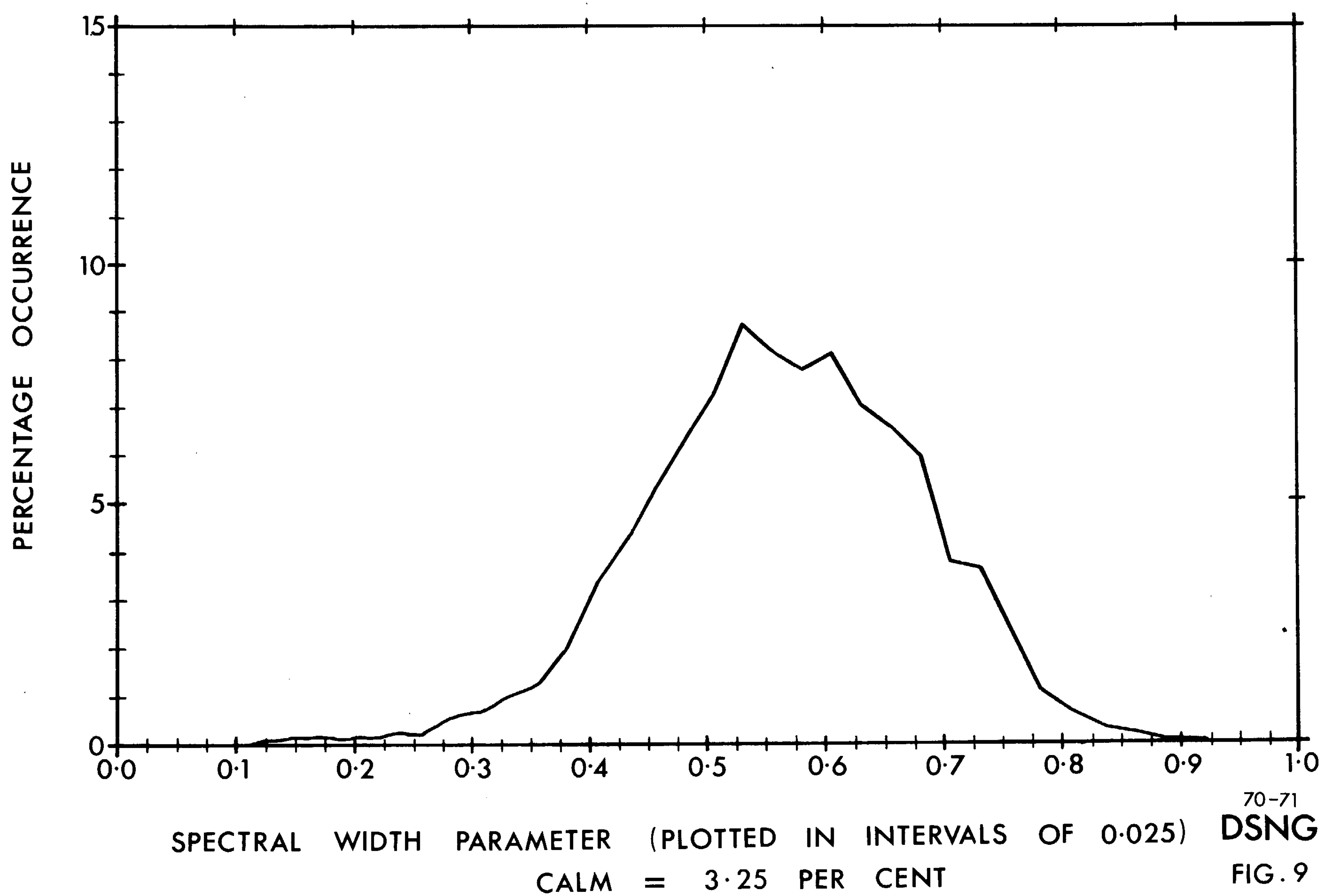
ZERO CROSSING PERIOD

(PLOTTED IN HALF SECOND INTERVALS)

CALM = 0·54 PER CENT

70-71
DSNG
FIG. 8

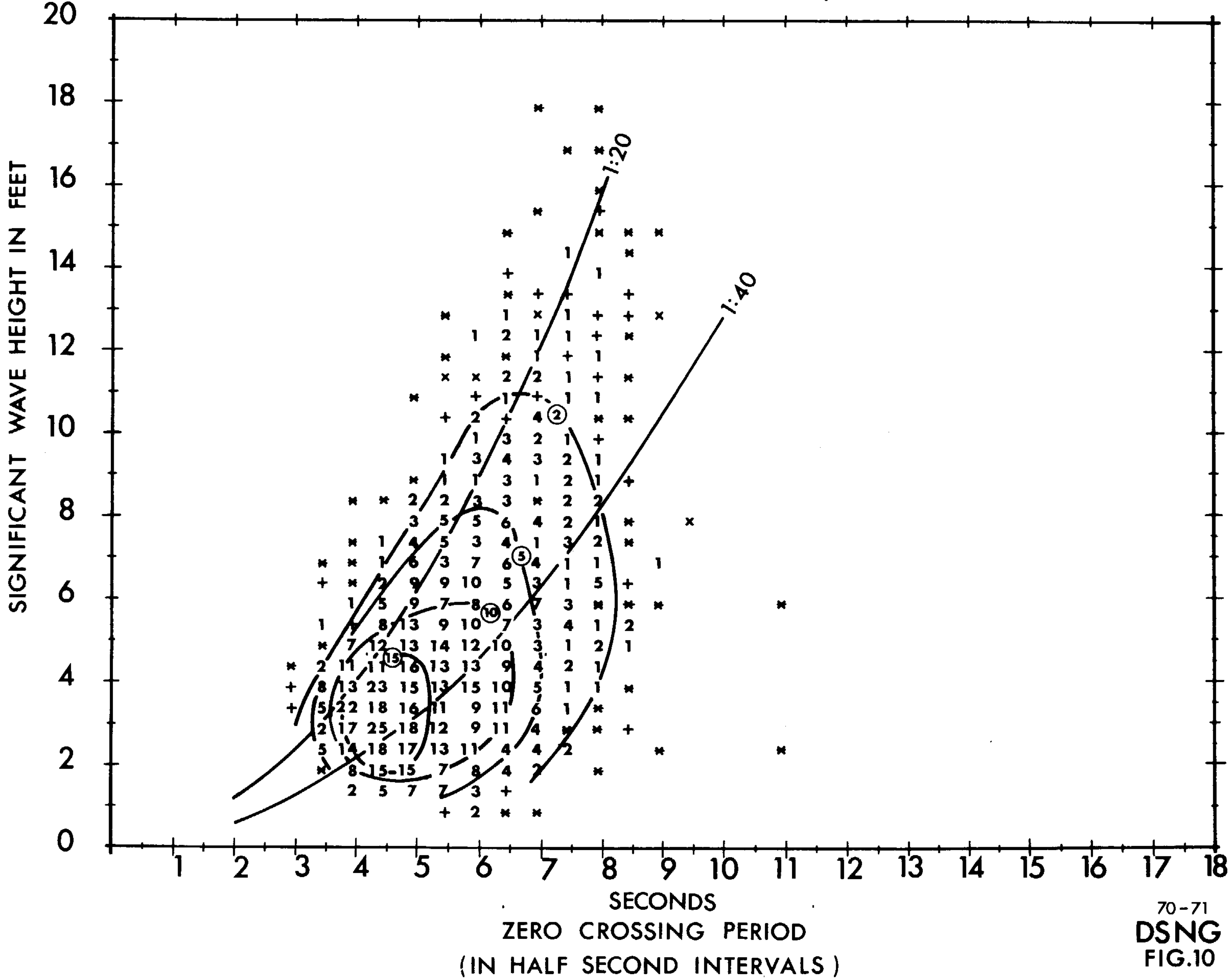
GRAPH OF SPECTRAL WIDTH PARAMETER FOR THE WHOLE YEAR.



70-71 DSNG

FIG. 9

SCATTER DIAGRAM FOR THE WHOLE YEAR
IN PARTS PER THOUSAND × = 1 OCCURRENCE (0·3 part)
+ = 2 OCCURRENCES (0·7 part)



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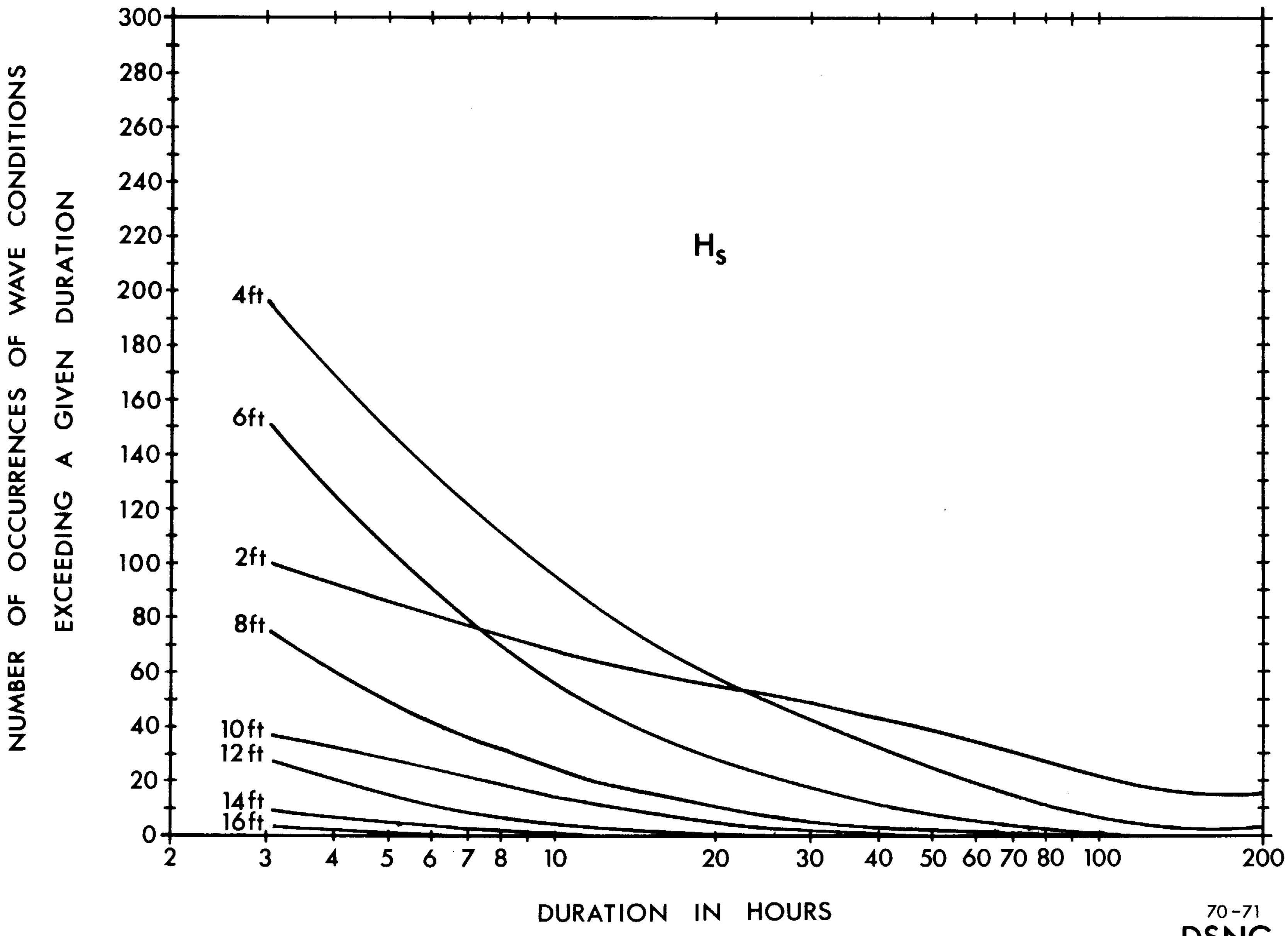
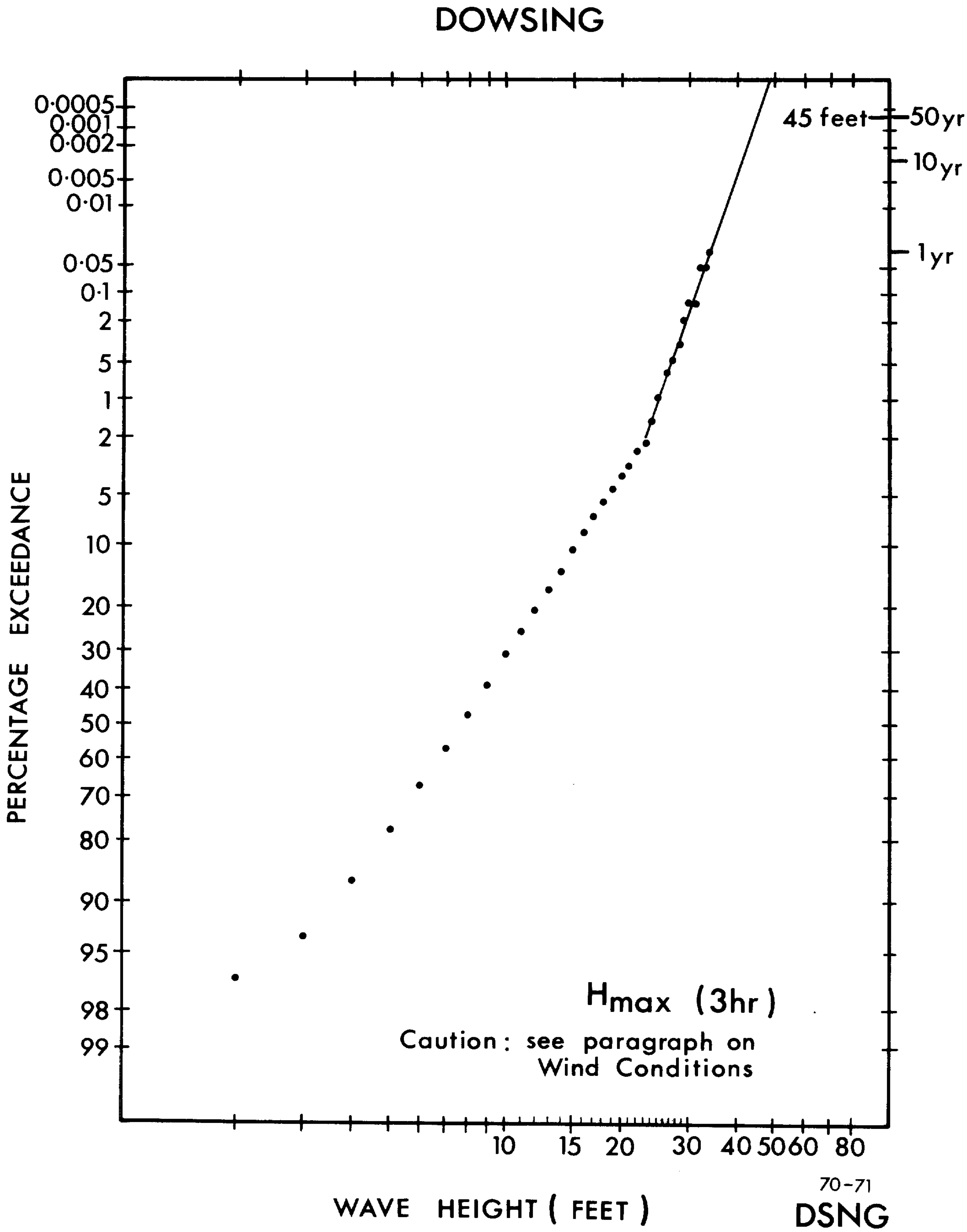
DSNG
FIG.10

PERSISTENCE DIAGRAM FOR THE WHOLE YEAR



70-71
DSNG
FIG. 11



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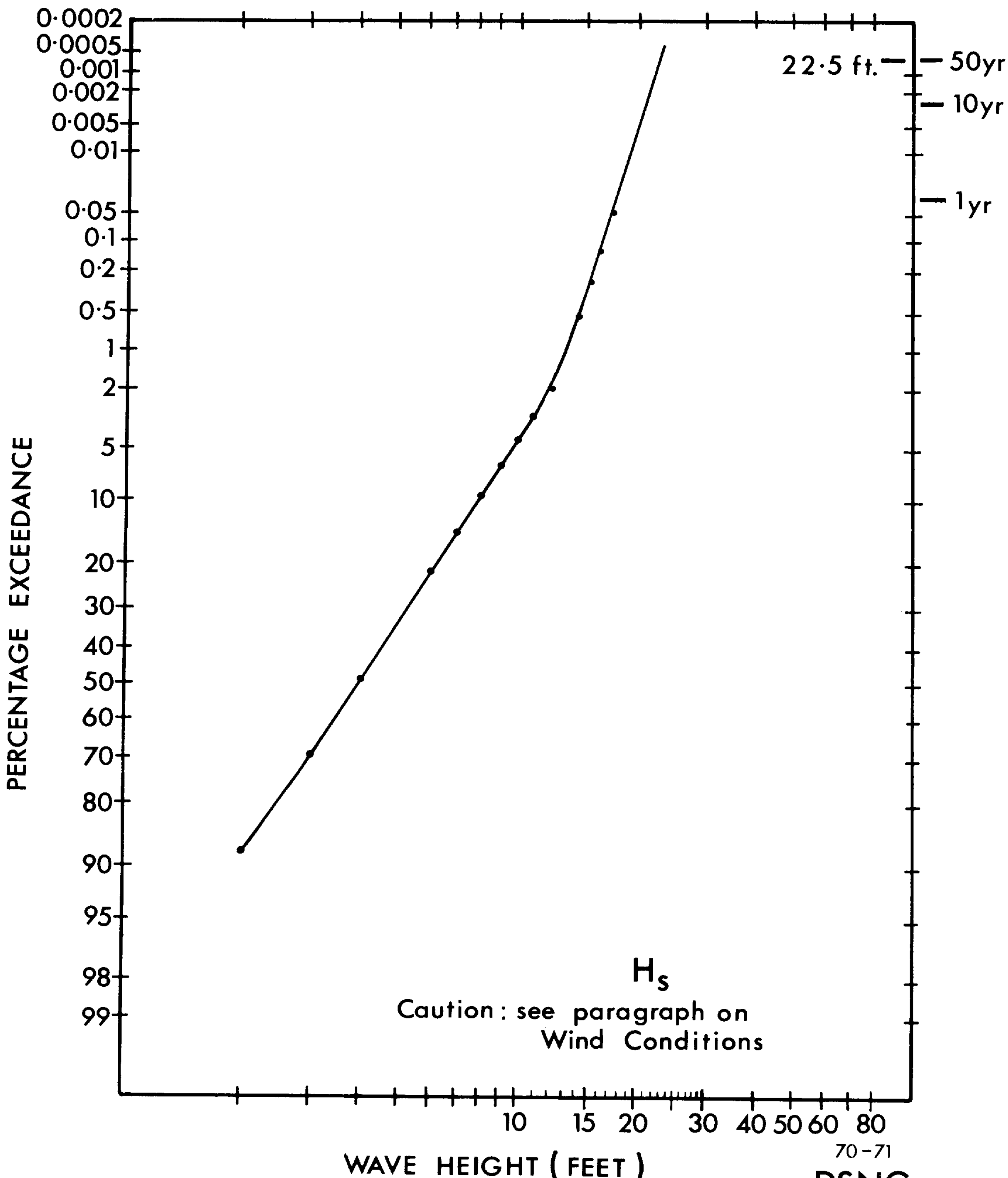
DSNG
FIG. 12

DOWSING



70-71
DSNG
FIG. 13

DOWSING — WEIBULL

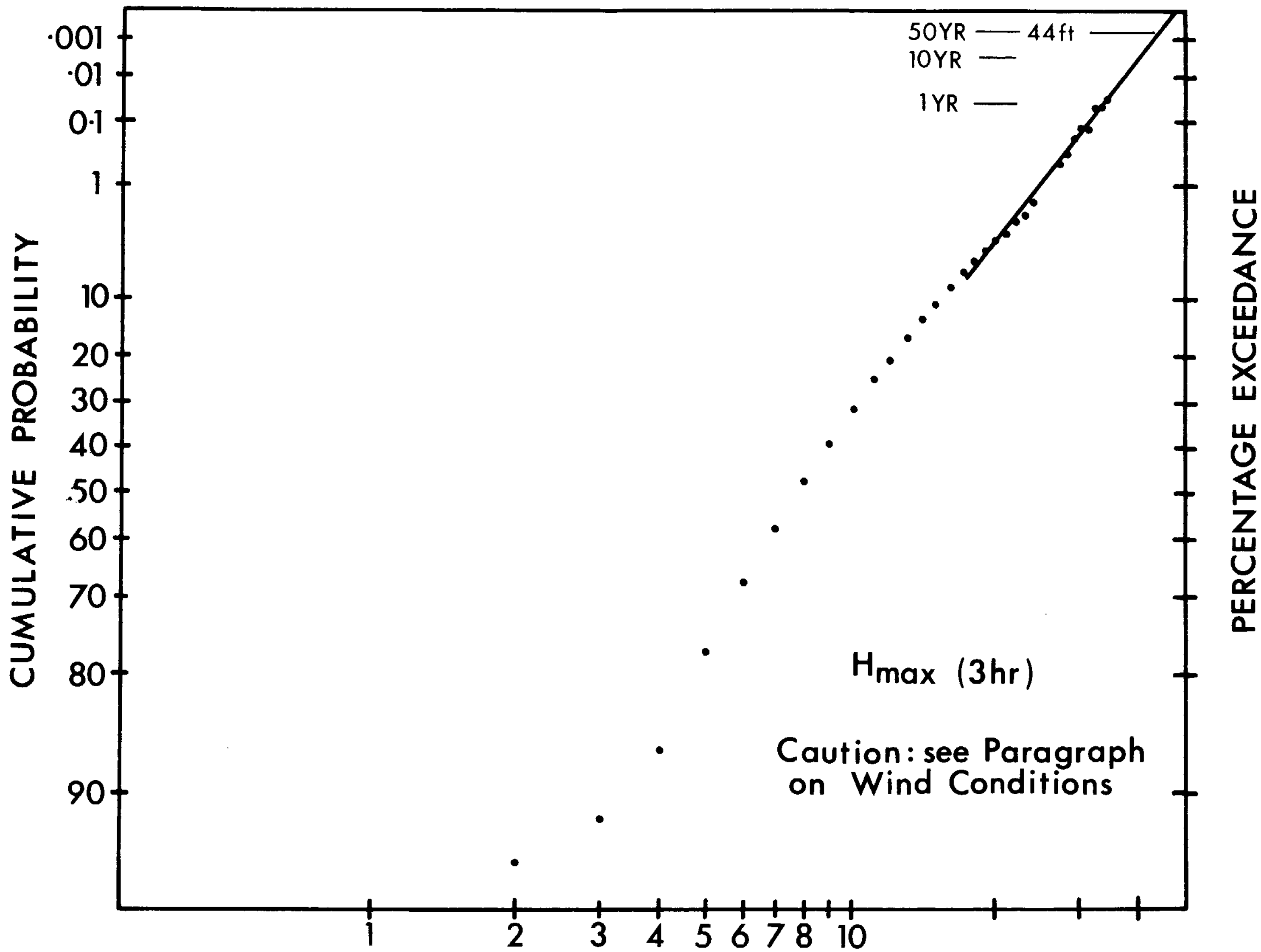


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FIG. 14