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WAVES MEASURED AT GALLOPER LIGHT VESSEL SOUTHERN NORTH SEA

BY
L DRAPER

DATA FOR MARCH 1971 TO FEBRUARY 1972
AT POSITION 51°43.9'N 01°57.8'E

REPORT NO 57
1977

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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WAVES MEASURED AT GALLOPER LIGHT VESSEL SOUTHERN NORTH SEA

by L. Draper

1. INTRODUCTION

Waves have been recorded by a Shipborne Wave Recorder (Tucker, 1956) placed on the Galloper Light Vessel which is stationed in 16 fathoms of water (at low tide) nearly 30 miles ESE of Harwich. The records were made from January 1971 to March 1974 and those from March 1971 to February 1972 inclusive have been analysed, mainly following the method of analysis developed by Tucker (1961) from theoretical studies by Cartwright and Longuet-Higgins (1956). There was no significant change in the calibration during this time. The method of presentation is that recommended for data for engineering purposes (Draper, 1966). The methods of analysis and presentation, and the definitions used in this Report, have been reviewed by Tann (1976). At the time of recording, the instrument was calibrated in feet, and these units have been retained throughout the analysis (1 metre = 3.28 feet).

2. RECORDING ROUTINE, AND ANALYSIS

Records were taken for 15 minutes at three-hourly intervals, and the analysis of the first 12 minutes of each record (to allow for small faults in records) yields the following parameters:

2.1 Parameters and definitions

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

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

(c) T_z = The mean zero-up-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.

The expected values of H_1 and H_2 are a function of the significant wave height and of the number of zero-up-crossing waves in the analysed record. These values of H_1 and H_2 have been corrected for the depth below the surface of the pressure sensors by the formula, using T_z as the period parameter, given by M. Darbyshire (1961) (her equation 1 with $K = 2.5$). The depths of the pressure sensors were assumed constant at 4.5 feet.

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

(e) H_s = The significant wave height, defined as 4σ where σ is the root mean square surface elevation: this is calculated separately from both H_1 and H_2, and an average taken. Note that this derivation does not necessarily yield exactly the same value as would be achieved using the classical definition of the highest one third wave height

(f) $H_{max(3\ hours)}$ = The most probable value of the height of the highest wave which occurred in the recording interval of 3 hours (Draper, 1963). (The recording interval is the time elapsed between the starts of successive records.) The values of $H_{max(3\ hours)}$ calculated are deemed to refer to a 3-hour duration centred on the nominal recording time.

(g) ε = The spectral width parameter, which is calculated from T_z and T_c (Tucker, 1961):

$$\varepsilon^2 = 1 - (T_c/T_z)^2$$

(h) Calm = Any record where the sum of the highest crest plus the lowest trough on the record (H_1) is less than 1 foot is classified as Calm

2.2 Treatment of missing data

Where data are missing, small gaps of up to four consecutive records have been filled by linear interpolation, the one larger gap of 2 days has been filled by duplicating the preceding day and the following day. (See also the discussion under 5.6 Persistence.)

3. PRESENTATION OF DATA

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 an exceedance diagram (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, $H_{max(3 \text{ hours})}$.

The distribution of zero-up-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-up-crossing period.

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

Figures 12 and 13 enable 'lifetime' wave predictions to be made using log-normal and Weibull distributions.

4. WIND CONDITIONS DURING THE YEAR OF RECORDING, AND COMPARED WITH THE LONG-TERM AVERAGE

The Meteorological Office has analysed wind conditions at Manston, near the eastern tip of Kent. This station was chosen by the Meteorological Office as the most suitable station to assess the normality of wind (and therefore wave) conditions during the year of wave recording. The winds used were those which blew from between 300^0 clockwise to 180^0, the principal directions for the generation of waves at Galloper. The average wind speed from March 1971 to February 1972 inclusive was 10.9 knots compared with the 16-year mean 1961-1976 of 10.7 knots, the total number of hours of gale in the year was nil compared with the long-term average of 0.96 (these are only for easterly winds). The easterly gales, when they occur at all, are expected within the six winter months October to March inclusive. Accordingly, it may be deduced that these wave data are fairly close to the long-term average. The seasons are also representative, the summer was somewhat less windy than average, the others a little more windy. The lack of the long-term average of one hour's gale is not likely to have been significant. An interesting comment by the Meteorological Office is that westerly gales in the area exceed easterlies by more than ten to one. The figures provided by the Meteorological Office are as follows:

	Monthly mean 1-hourly spot winds	
	1961-1976	MAR 71-FEB 72
JAN	12.6 knots	13.0 knots
FEB	11.6	11.2
MAR	12.1	12.7
APR	11.1	11.4
MAY	10.5	9.1
JUNE	10.0	12.2
JULY	9.1	8.9
AUG	9.2	8.8
SEP	9.0	8.0
OCT	10.0	11.1
NOV	11.9	12.9
DEC	11.9	11.4
YEAR	10.7	10.9

5. INTERPRETATION AND DISCUSSION

5.1 Highest waves

The highest value of H_1 (after correction for instrumental response) of 27.5 feet occurred on 28 January; it is associated with a zero-up-crossing period of the whole record of 6.7 seconds. There were other waves of almost this height during the same storm, and also in December.

5.2 Percentage exceedance of wave heights

Figures 1-4 indicate for what proportion of the time H_s or $H_{max(3\ hours)}$ exceeded a particular height. The higher waves are much more common in the winter than in the summer months; for example, a significant height of 6 feet was exceeded for 32 percent of the time in the winter whereas in the summer it was exceeded for only 5 percent of the time.

5.3 Zero-up-crossing period

Figures 5-8 show little seasonal variation in the zero-crossing periods which lie entirely in the range 2.5 seconds to 8 seconds. This contrasts, for example, with conditions in the NE Atlantic where the values range from 6 to 14 seconds. Over half of the zero-crossing periods lie between 3.5 and 5 seconds.

5.4 Spectral width parameter

Figure 9 shows the spectral width parameter to lie mainly between 0.4 and 0.7, with the most common values between about 0.5 and 0.6. (A high value indicates a tendency towards fully developed sea and a low one indicates swell.)

5.5 Scatter diagram

The scatter diagram (Figure 10) shows, in parts per thousand, the number of occurrences of particular combinations of zero-crossing period and significant wave height. It indicates that for the year as a whole the waves most often encountered had a zero-crossing period of between 3.5 and 4.5 seconds with significant heights of between 2 and 4 feet. The cut-off below 2.5 seconds period is caused by the attenuation of wave motion with depth; the pressure units, which are necessarily situated at about 4.5 feet below mean water level, do not record waves having periods less than about 2.5 seconds.

Lines of steepness of 1:20 and 1:40 are shown on this diagram; steepness here is defined as the ratio of significant wave height: wave length. Wave length is calculated from the zero-crossing period using the formula for waves in deep water $L = \frac{gT_z^2}{2\pi}$. In shallow water, and especially for longer-period waves, the actual wave lengths will be less than the values calculated by this formula. The appearance on this diagram of some short-period waves having high steepness is probably due to the strong currents producing a reduced apparent period on the record. Tidal currents in the area can reach a speed of 1.7 knots at springs (source: Admiralty Chart 2182a).

5.6 Persistence diagram (storms)

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 threshold value of wave height. If, for example, the limit for a particular operation of a vessel is a significant wave height of 6 feet, it would have been unable to operate for spells in excess of 10 hours on 50 occasions, or spells in excess of 24 hours on 22 occasions

The effect of the discontinuity caused by the 2-day gap has been reduced by reversing the order of the data used for in-filling. For example, the first day is filled by: for the first missing record, repeating the last actual record; for the second missing record, repeating the second from last actual record; and so on. The inverse of this is applied to fill the second missing day, drawing records from the first day following the stoppage. In this way there is only one abrupt discontinuity - where the two "folded-in" sets meet.

5.7 'Lifetime' wave prediction

Values of $H_{max(3\ hours)}$ have been plotted on log-normal (Draper, 1963) and Weibull probability paper. On both presentations the resulting value of the most likely height of the highest wave with an average return period of 50 years is 38 feet. Neither method results in a good straight line for all data but the upper ends in each case seem to lie on a straight or very slightly curved line. If the winds had contained the average duration of gales, this tendency to curvature at the upper end might have been reduced or even eliminated. Because of this it seems prudent to accept the figures derived from the straight line extrapolations, which in any case exceed the curve extrapolations by only about 2 feet. No explanation can be given for the non-linear appearance; it may be due to the complicated topographic and current structure of the area.

6. CONCLUSIONS

From the meteorological data, the year of wave measurement 1971-72 can be assumed to have been reasonably representative of a typical year. The presentations of wave data in this Report can therefore be used without modification for planning purposes to indicate likely conditions in a typical year at Galloper Light Vessel.

7. ACKNOWLEDGEMENTS

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PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

WINTER—JANUARY TO MARCH

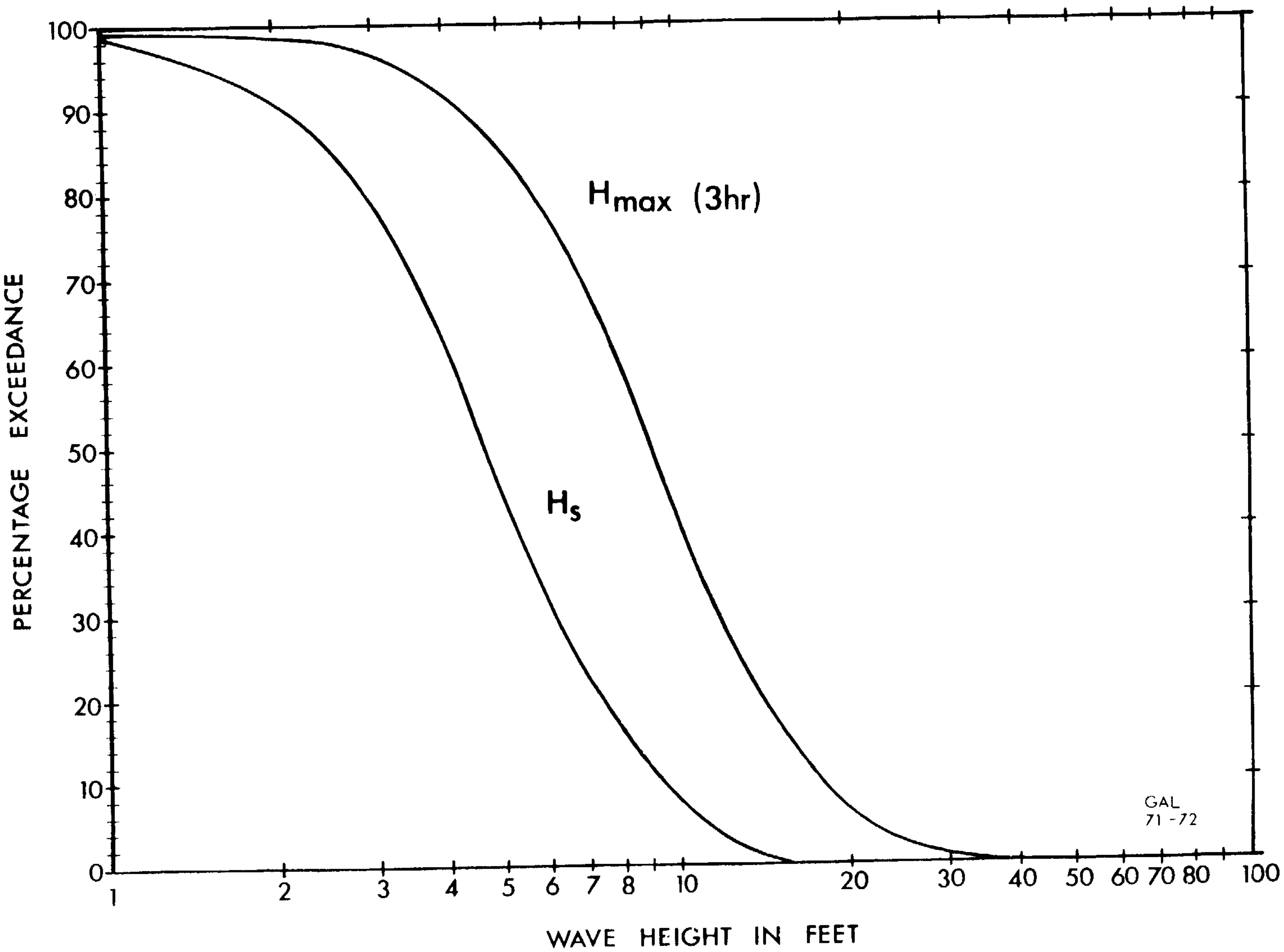


FIG. 1

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

SPRING — APRIL TO JUNE

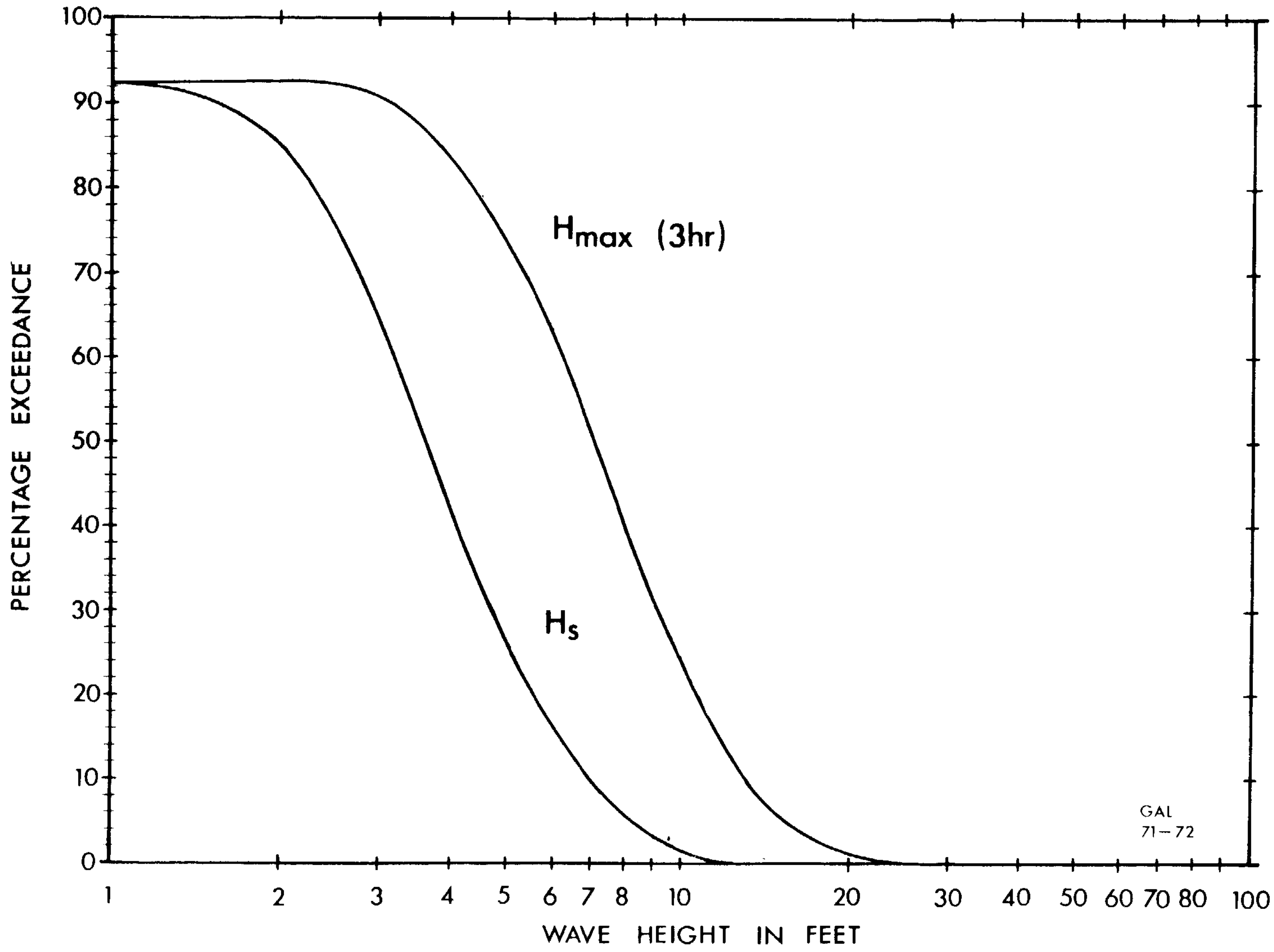


FIG. 2

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

SUMMER — JULY TO SEPTEMBER

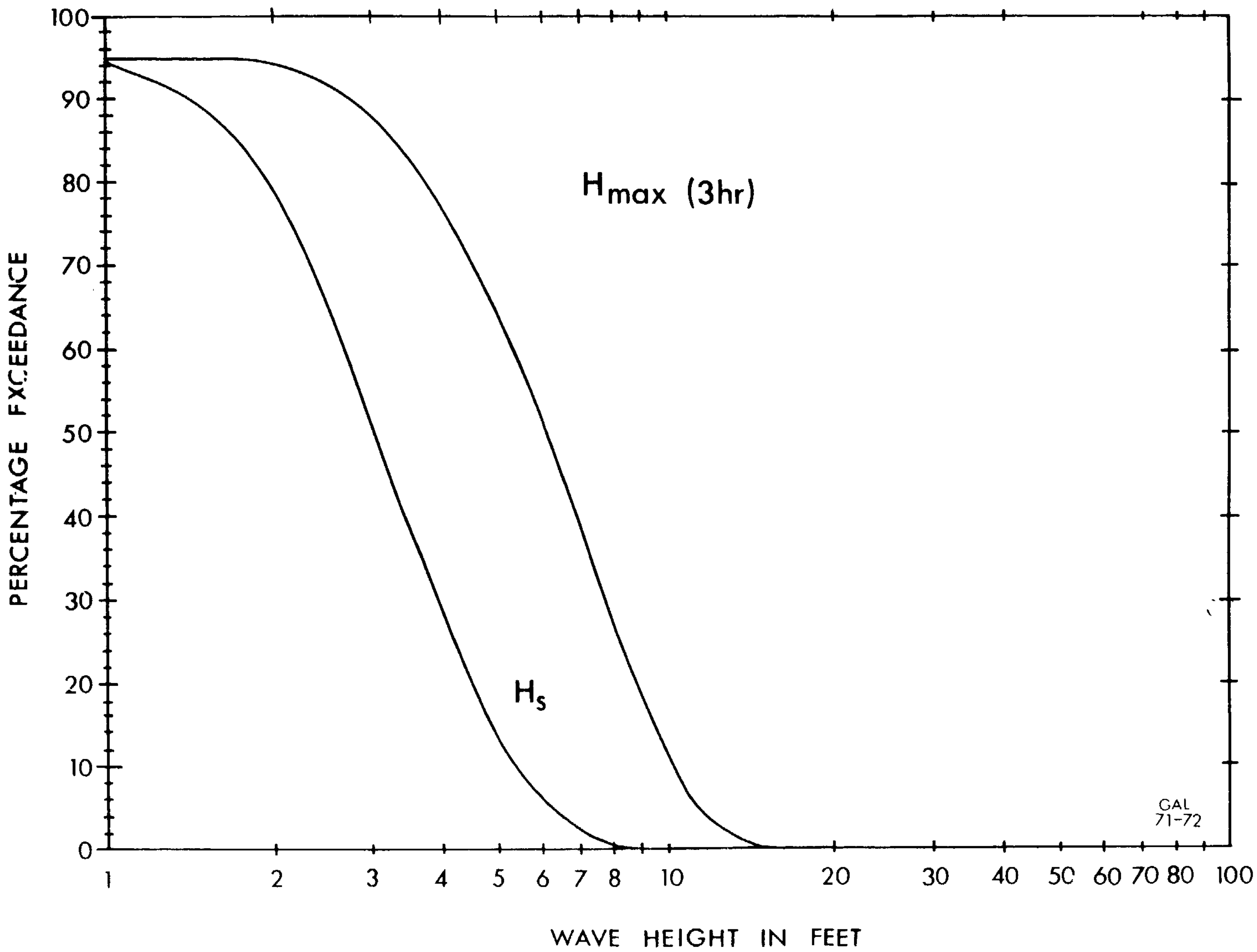


FIG.3

PERCENTAGE EXEEDANCE OF H_s AND H_{max}

AUTUMN — OCTOBER TO DECEMBER

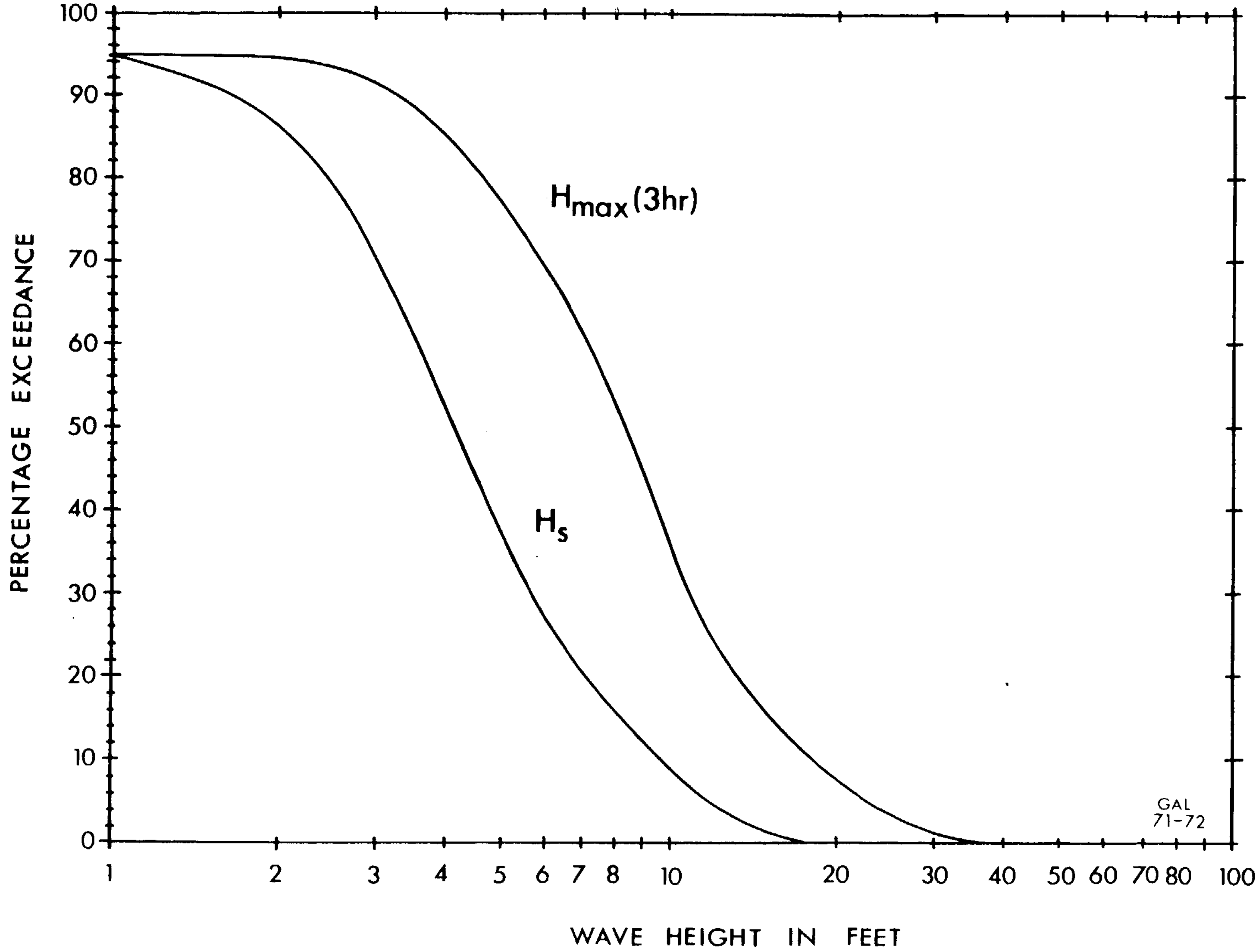
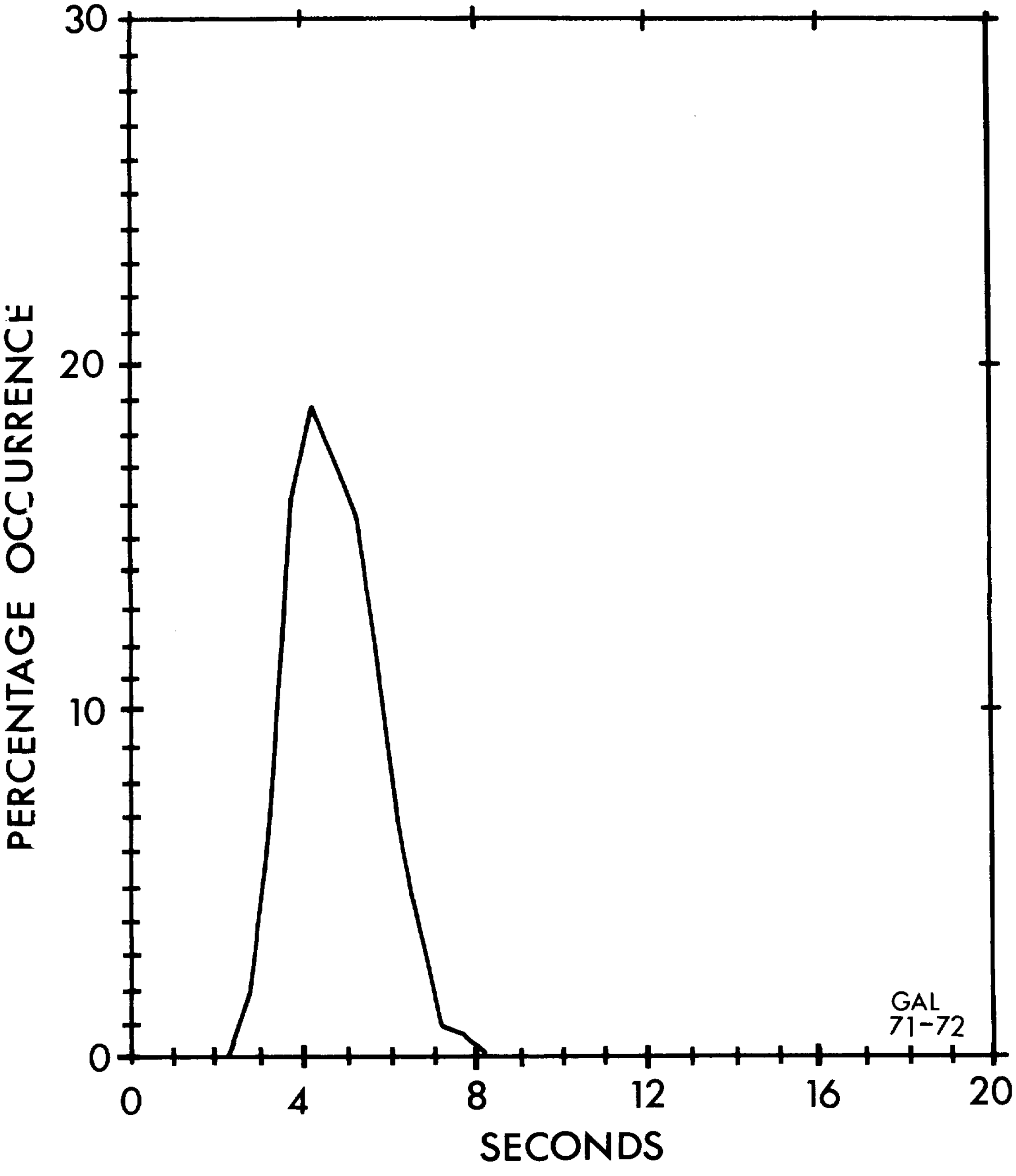


FIG. 4

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

WINTER - JANUARY TO MARCH



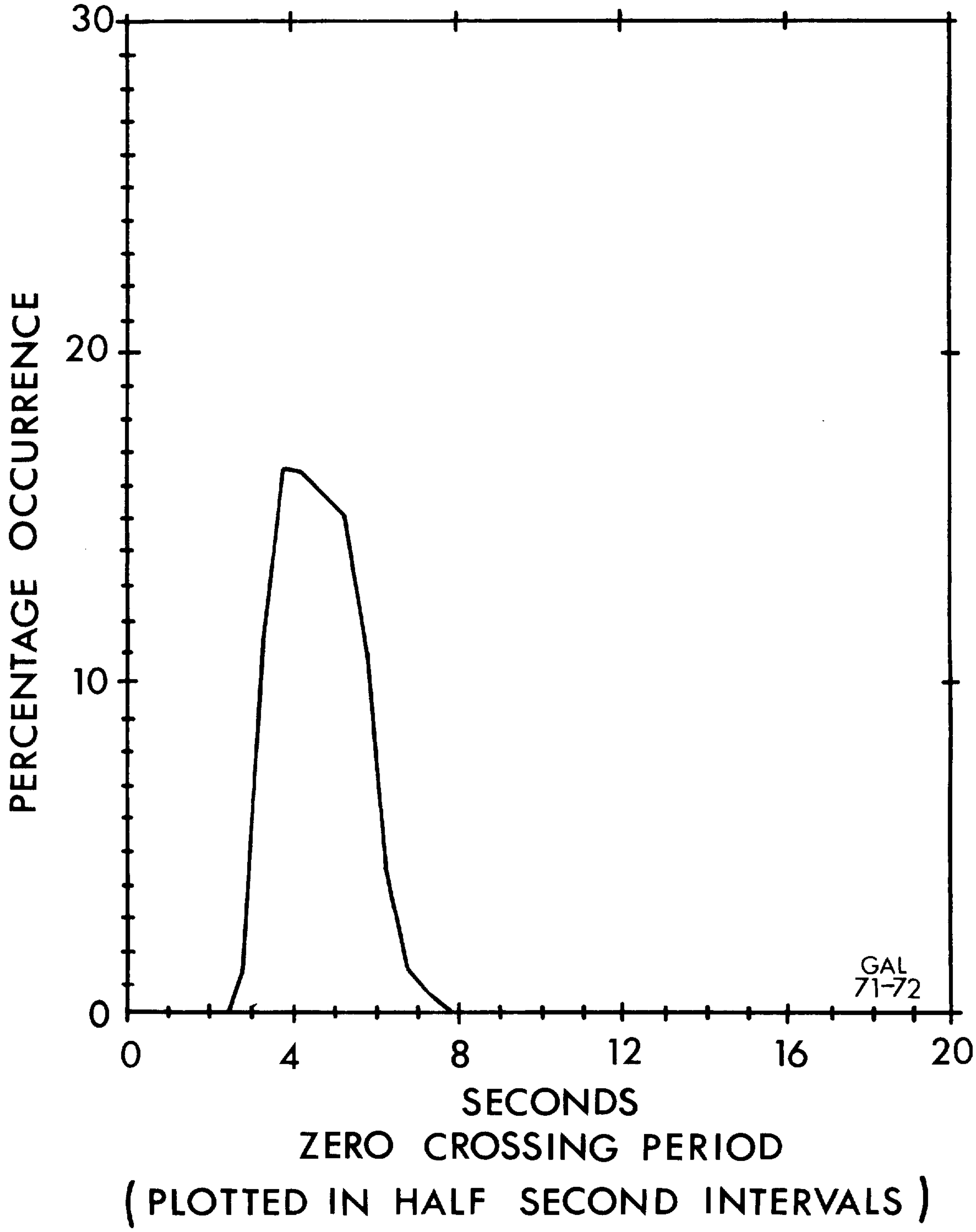
ZERO CROSSING PERIOD
(PLOTTED IN HALF SECOND INTERVALS)

CALM = 1·23 PER CENT

FIG. 5

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

SPRING – APRIL TO JUNE

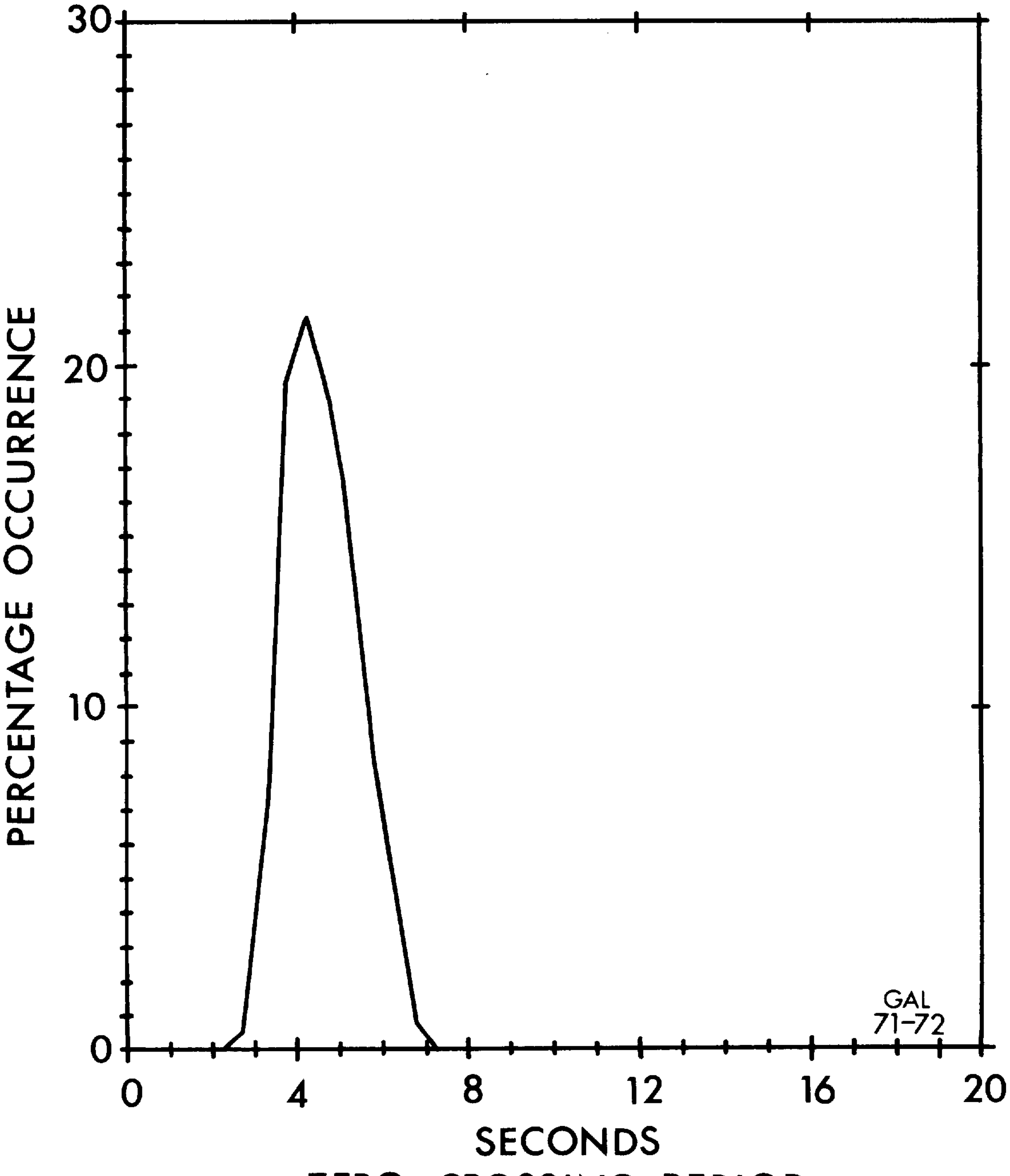


CALM = 7·41 PER CENT

FIG. 6

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

SUMMER – JULY TO SEPTEMBER



ZERO CROSSING PERIOD

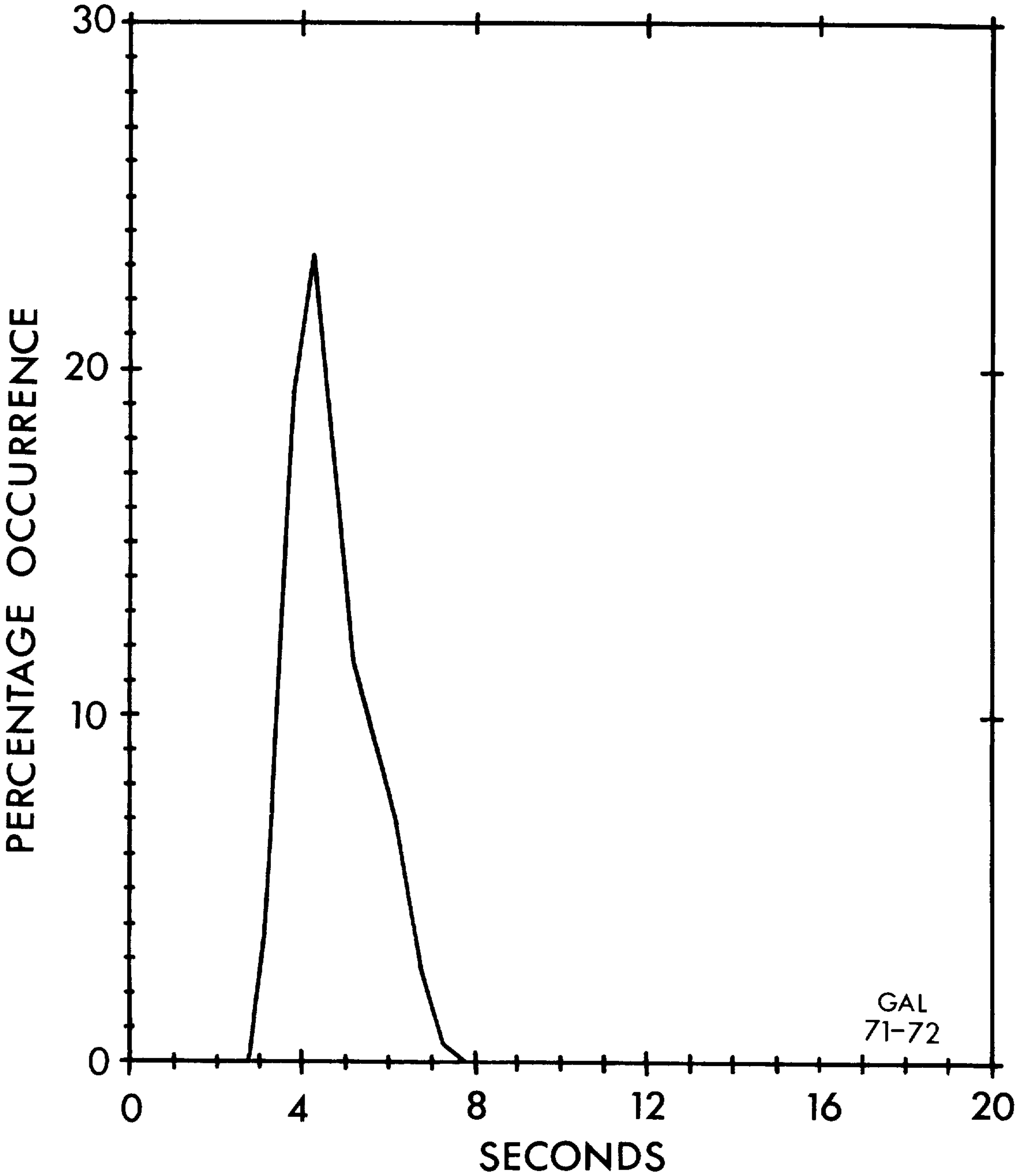
(PLOTTED IN HALF SECOND INTERVALS)

CALM = 5·43 PER CENT

FIG. 7

GRAPH OF PERCENTAGE OCCURRENCE OF T_Z

AUTUMN–OCTOBER TO DECEMBER



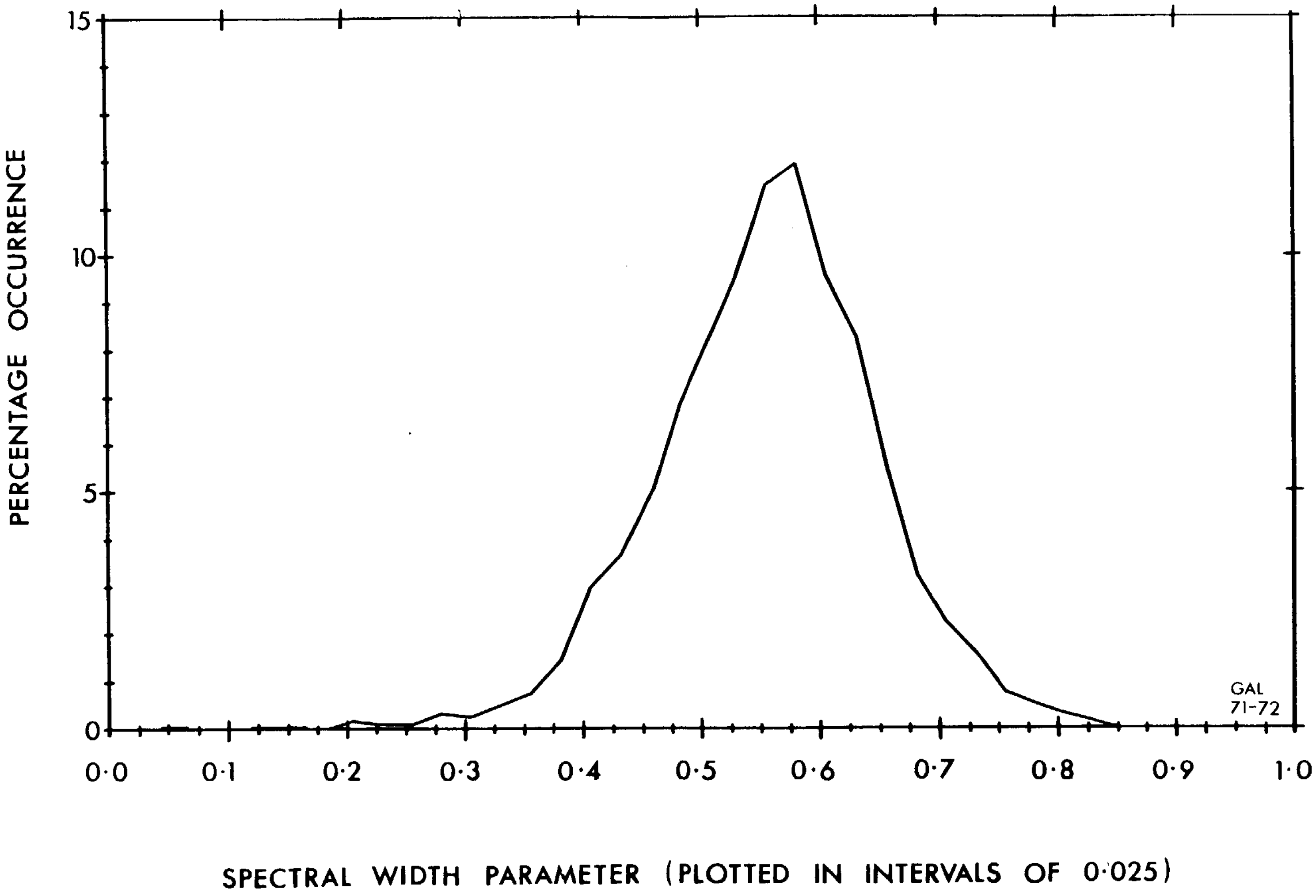
ZERO CROSSING PERIOD

(PLOTTED IN HALF SECOND INTERVALS)

CALM = 5·29 PER CENT

FIG. 8

GRAPH OF SPECTRAL WIDTH PARAMETER
FOR A WHOLE YEAR



CALM = 4·84 PER CENT

FIG. 9

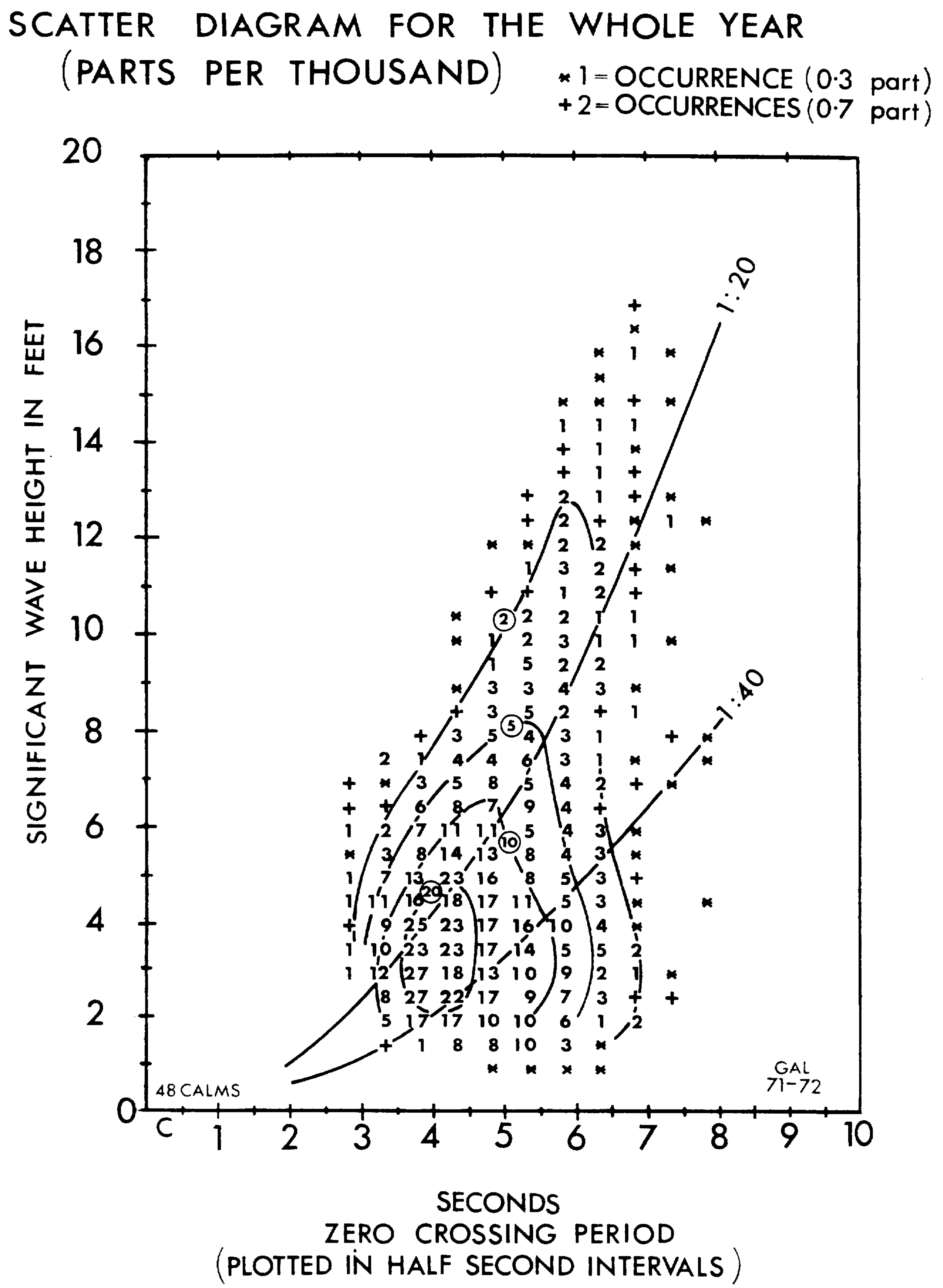

SCATTER DIAGRAM FOR THE WHOLE YEAR
(PARTS PER THOUSAND)
* 1 = OCCURRENCE (0·3 part)
+ 2 = OCCURRENCES (0·7 part)
SIGNIFICANT WAVE HEIGHT IN FEET
SECONDS
ZERO CROSSING PERIOD
(PLOTTED IN HALF SECOND INTERVALS)
48 CALMS
GAL
71-72
1:20
1:40

FIG. 10

PERSISTENCE DIAGRAM FOR THE WHOLE YEAR

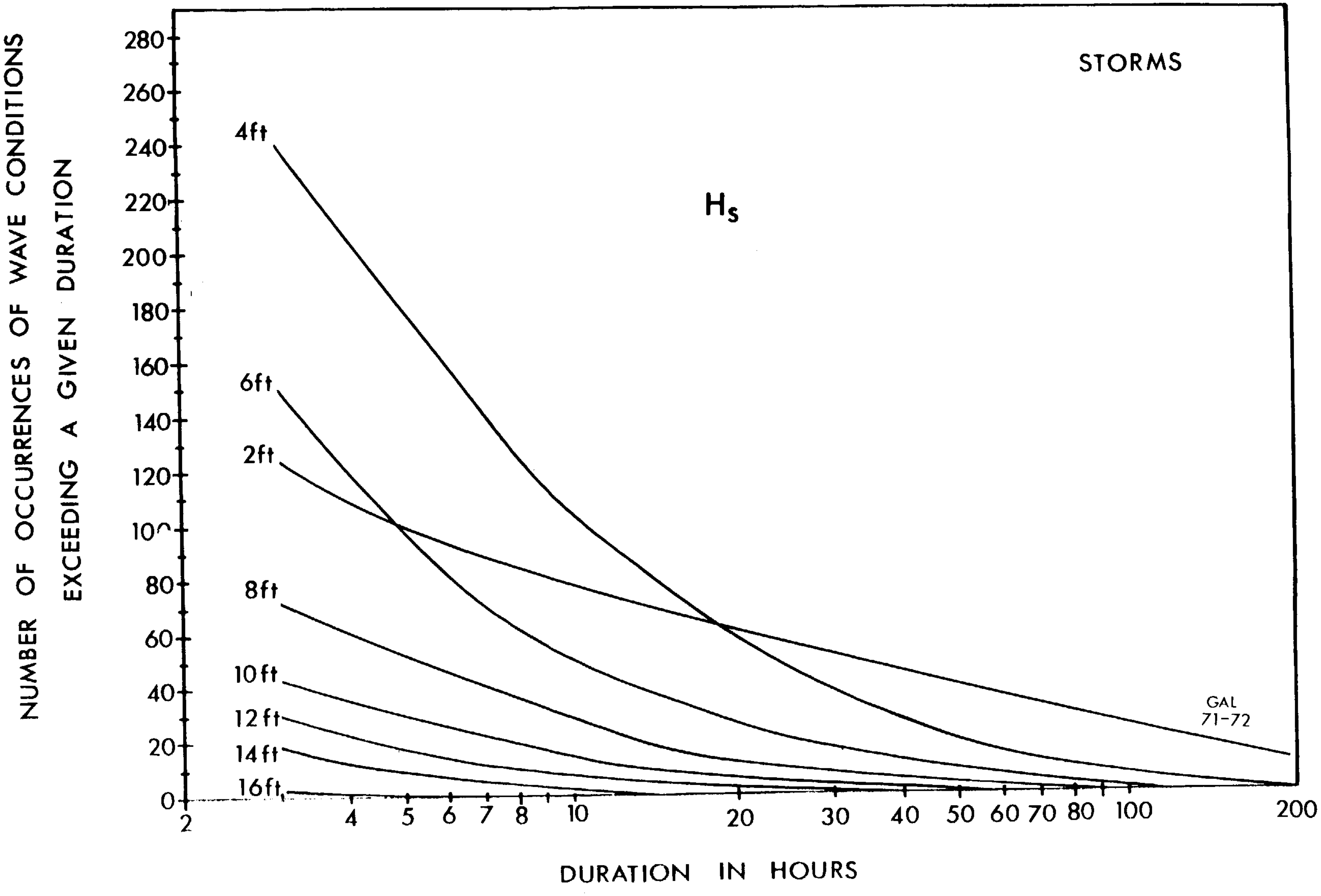


FIG. 11

LIFETIME WAVE PREDICTION — LOG-NORMAL

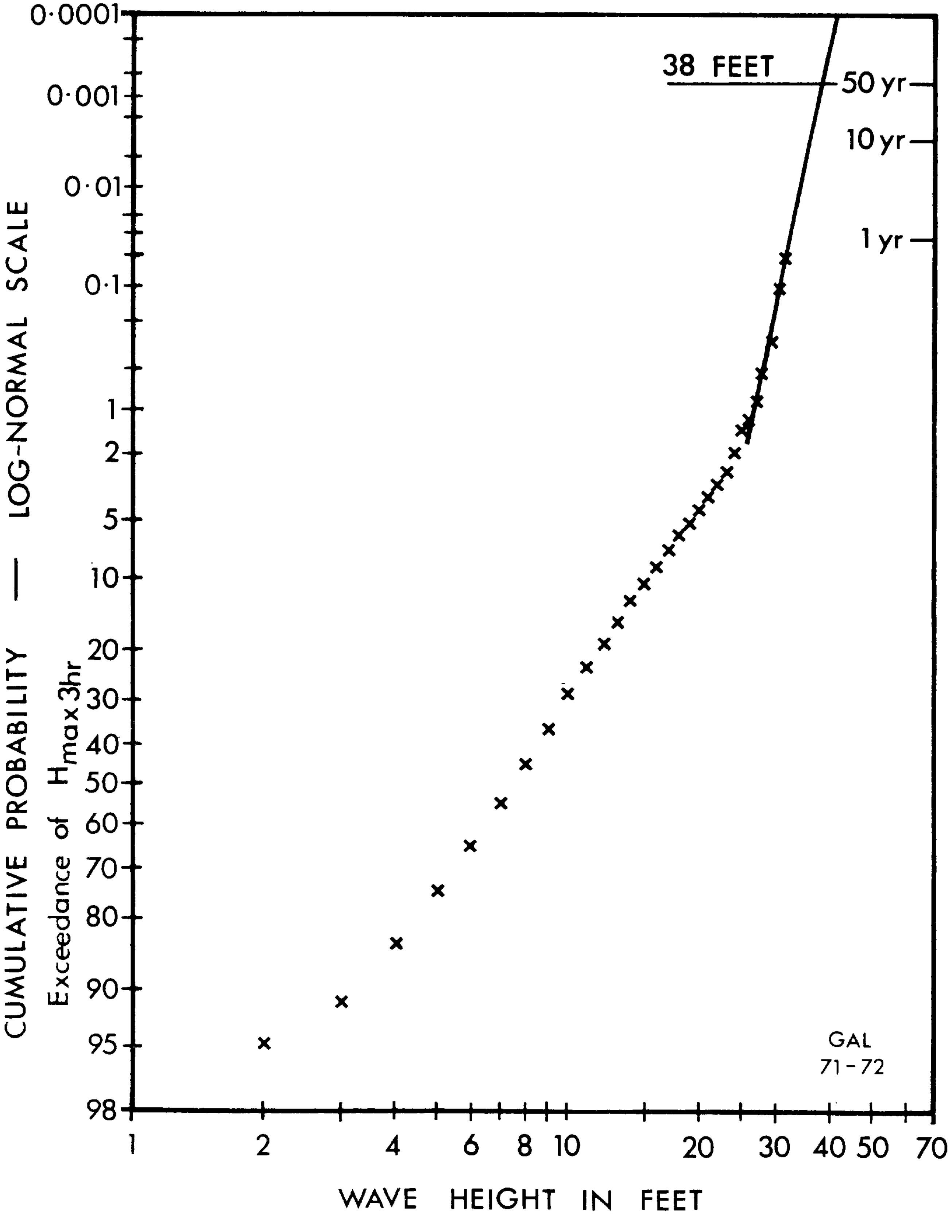


FIG. 12

LIFETIME WAVE PREDICTION – WEIBULL

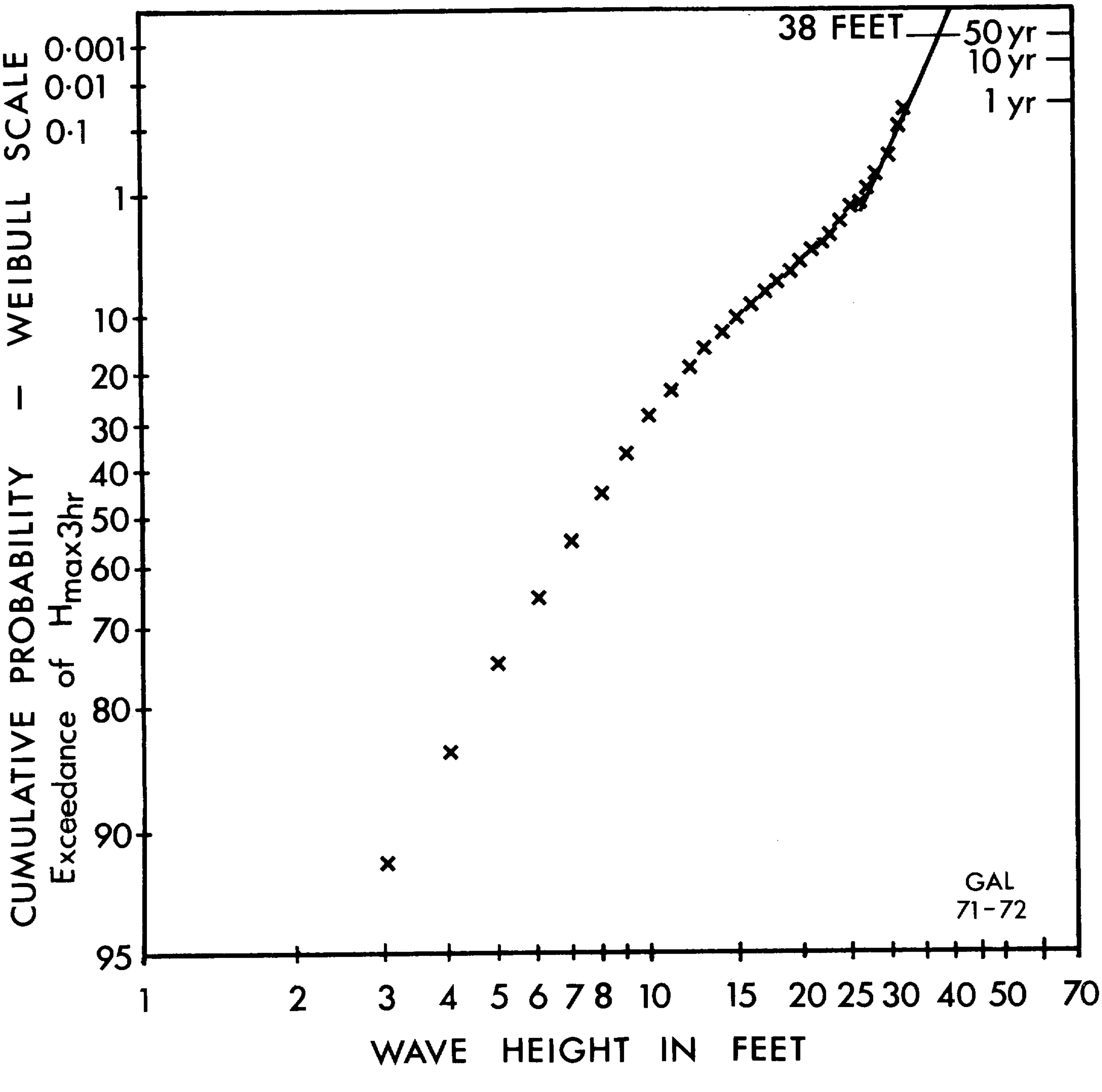


FIG. 13