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An analysis of the Wave Observations in the Bay of Bengal

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1. Introduction

Quantitative observations of period and heights of waves in the Indian Seas were introduced from January 1949. Since then heights and periods of waves as observed in the Bay of Bengal and the Arabian Sea are reported by the ships in metres and seconds respectively. A preliminary analysis of these observations relating to the Bay of Bengal for the year 1952 and those for July 1953 has been made in order to have an idea of heights and periods of waves prevailing in the Bay during different months and their relation with the prevailing winds.

The Bay of Bengal is visited year after year by a number of storms and depressions. As the frequency of occurrence of storms and depressions in the Bay in different months of the year 1952 and in July 1953 is not very different from the average frequency, the results of the present analysis is expected to represent the average conditions of the Bay of Bengal.

2. Distribution of observations

Of the total number of wave observations from ships in the Bay of Bengal during the year 1952, 2075 observations which were readily available and which contained the necessary information were considered for the analysis along with 283 similar observations during July 1953. Their distributions in the various five degree squares (actual number of observations as well as the percentage distribution) are shown in Figs. 1 and 2 respectively.

The heights of waves are given in ranges of $\frac{1}{2}$ metre, the ranges being $<\frac{1}{4}$m, $\frac{1}{4}-\frac{3}{4}$m, $\frac{3}{4}-1\frac{1}{4}$m, $1\frac{1}{4}-1\frac{3}{4}$m etc, the periods in ranges of 5 sec or less, 5—7 sec, 7—9 sec, 9—11 sec and so on and wind speed in ranges of 0—2 kts, 3—7 kts, 8—12 kts, 13—17 kts etc.

3. Results of analysis and discussion on the results

Wave height and wave period as functions of distance from coast line at intervals from 5 to 40 hrs after a wind of 40 kts started to blow over an undisturbed water surface, are shown graphically in Fig. 1·8 of U.S. Navy H.O. publication No. 604 entitled "Techniques for forecasting wind waves and swell". Table 1·2 of this publication gives highest significant waves produced by different wind speeds and corresponding fetches and durations. It is stated that the waves of the character shown in that table may be present in the trade wind regions and may be approached in the westerlies of the Southern Oceans. Values of significant wave height (H_s) and significant wave period (P_s) for different wind speeds have been computed from the above table for the present analysis.

Wave heights and wind speeds—Frequency of occurrence of waves of different heights with each range of wind speed in each month and their percentage distribution (as percentage of the total number of observations under each wind speed range) are worked out. The average heights of waves associated with each wind speed range in different months are shown in Table 1. It is observed that barring the cases which are associated with very low wind speeds and a few others in which the number of observations are too meagre to be representative, wave heights increase with increasing wind speeds. Anomalous values of large wave heights in association with very low

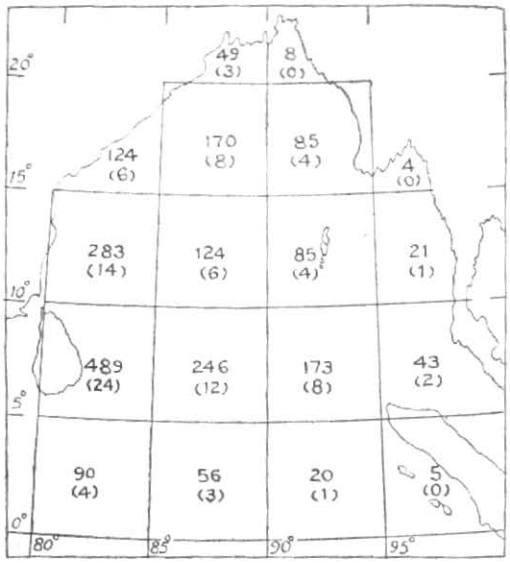

Fig. 1. Distribution of wave observations in the Bay of Bengal—1952

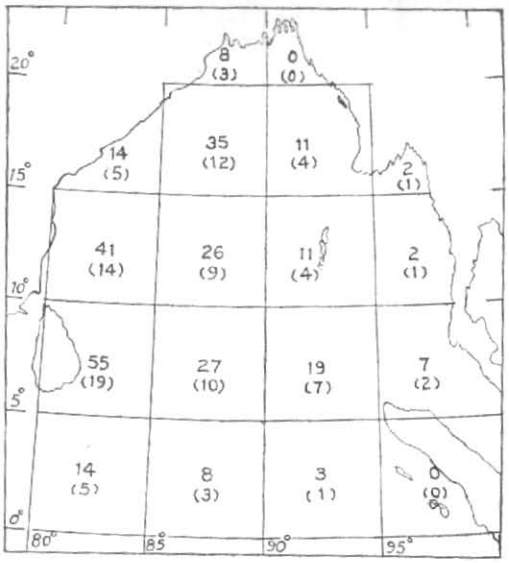

Fig. 2. Distribution of wave observations in the Bay of Bengal—July 1953

(Top figures are the actual number of observations and figures within brackets are the percentages of the total number)

TABLE 1

Average height of waves (in metres) associated with each wind speed range in different months (1952)

	Wind speed (knots)						
	0—2	3—7	8—12	13—17	18—22	23—27	28—32
Jan	0·13	0·81	1·22	1·44	1·50	1·67	..
Feb	0·34	0·73	1·01	1·21	2·00	..	..
Mar	0·67	0·64	1·00	1·18	2·00	..	..
Apr	0·41	0·63	0·88	1·43	3·00	..	..
May	0·83	0·92	1·29	1·47	1·90	2·34	3·33
Jun	—	0·89	1·21	1·83	2·28	3·25	0·83
Jul	1·43	1·00	1·07	1·56	2·18	3·80	2·50
Jul (1953)	*(1·00)*	*(0·76)*	*(1·06)*	*(1·40)*	*(1·78)*	*(2·06)*	*(3·21)*
Aug	2·00	1·75	1·42	1·41	2·10	1·59	—
Sep	0·63	1·05	1·59	1·46	1·57	0·50	—
Oct	0·71	0·93	1·21	1·82	1·59	2·13	—
Nov	0·62	0·83	0·95	1·35	1·07	2·00	3·33
Dec	0·60	0·70	0·95	1·26	1·30	—	—

wind speed of less than 3 kts is due to the fact that such a low wind speed has little effect in building up fresh waves or in maintaining the waves already generated. The waves observed with low wind speeds of 2 kts or less must have been generated under a previous life history of wind and its fetch. One interesting feature which is significant is that the average height and the frequency of occurrence of a particular height range under a particular wind speed varies from month to month. The average height under any particular wind speed range is generally greater in monsoon and pre-monsoon months than that in other months. In order to show the nature of the above variation in different seasons, average wave heights under different wind speed ranges for the different seasons, *viz.*, January-March, April-May, June-September and October-December have been represented graphically in Fig. 3. In this figure the variation of highest significant wave heights with wind speed has also been shown. Larger values of wave heights in monsoon and pre-monsoon seasons is explained by the fact that the fetch or duration of a steady wind for any area in the Bay of Bengal is more in these seasons than in any other season. During winter months winds over a large area of the Bay are often unsteady and variable and as such the average heights under different wind speed ranges in these months are small.

Figs. 4(a) and 4(b) give the percentage frequencies of occurrence of waves of different heights for each range of wind speed for January 1952 and August 1952 respectively. The highest significant waves produced by the different wind speeds are also marked on the figures as H_s. It is clear from these figures that in January as well as in August the most frequent height of waves associated with each kind of speed range increases progressively as the wind speed increases. This may, therefore, be taken as a normal feature for the whole year. It will be seen from Figs. 4(a) and 4(b)

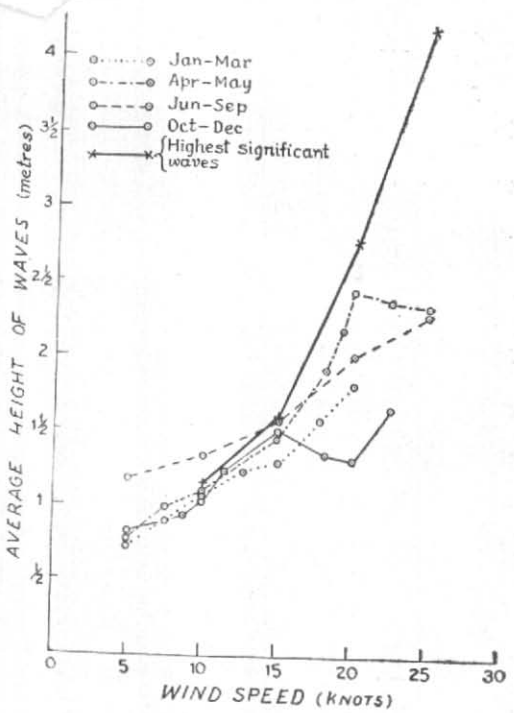

Fig. 3. Variation of wave height with wind speed in different seasons

that with wind speeds, 8—12 kts, most of the waves observed have heights greater than the highest significant waves that can be generated by that wind speed. With increasing wind speeds the percentage of observations of waves higher than the highest significant waves decreases gradually. The effect of large fetch and large duration of observed wind speed appears to be the cause for the observed wave heights becoming greater than the highest significant waves in the wind speed range of 8—12 kts or so. When the observed wind speed is high, the effect of fetch and duration of wind becomes less prominent.

Wave periods and wind speeds—Frequency of occurrence of waves of different periods with each range of wind speed in each month and their percentage distribution (as percentage of the total number of observations under each wind speed range) are worked out. The average periods of waves associated with each wind speed range in different months are shown in Table 2.

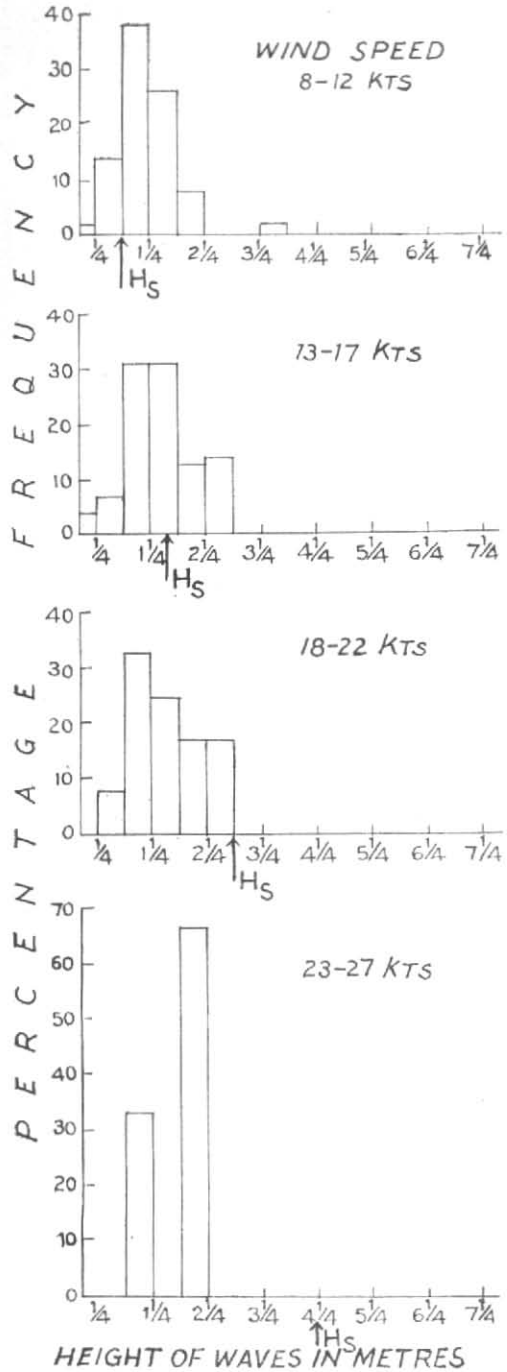

Fig. 4(a)—January 1952

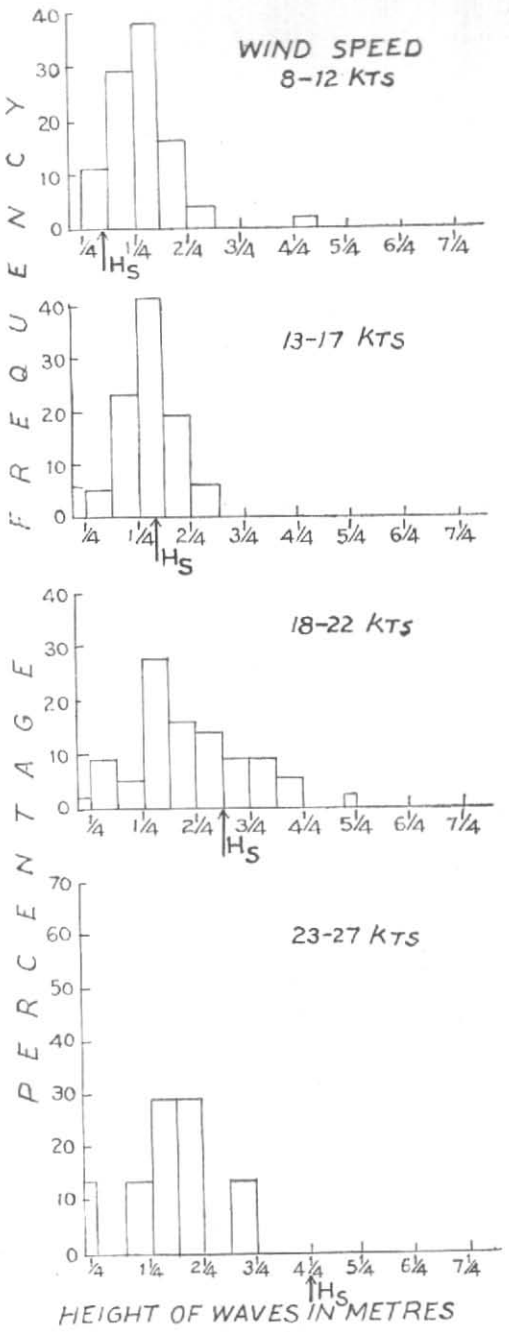

Fig. 4(b)—August 1952

Frequencies of wave heights in different wind speed ranges

(H_s — Height of the highest significant wave)

While in some cases the periods of waves show a tendency to increase with increasing wind speed, in others no such tendency is observed. The periods of waves depend not only on the strength of the generating winds but also on other factors like gustiness, natural periods of waves which were already existing and their fetch. The curves shown in Fig. 1·8 in U.S. Navy H.O. Publication No. 604 are relevant in this connection. It will be seen from the curves that a wind speed of 40 kts with a fetch of 200 nautical miles and a duration of 20 hrs gives a period of about 9 sec and the same wind increases the period to only 11 sec with a fetch of about 500 nautical miles and a duration of 40 hrs. It is thus clear that in order to increase the wave period appreciably, a large increase in wind force, fetch and duration is necessary, if other factors stated above remain constant. Variation of average wave periods in different seasons under different wind speed ranges as against the periods associated with the highest significant waves is shown in Fig. 5. It will be seen from this figure that the nature of variation of wave period with increasing wind speed is not very regular

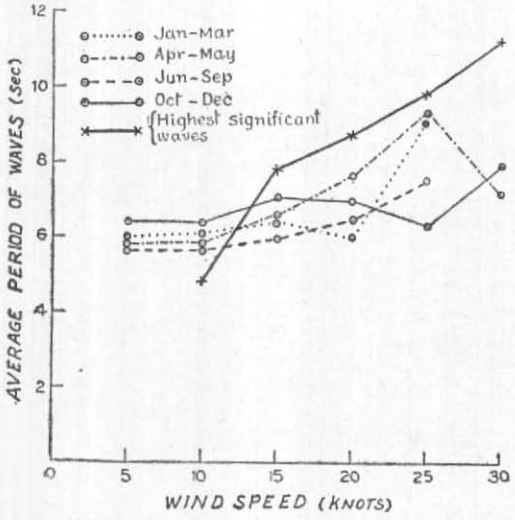

Fig. 5. Variation of wave period with wind speed in different seasons

TABLE 2

Average period of waves (in sec) associated with each wind speed in different months

	Wind speed (knots)						
	0—2	3—7	8—12	13—17	18—22	23—27	28—32
Jan	5·0	5·5	6·0	6·5	6·7	9·2	—
Feb	6·0	6·1	6·2	6·7	5·3	—	—
Mar	6·0	6·4	6·2	6·0	6·0	—	—
Apr	5·7	5·2	5·4	6·0	—	—	6·0
May	6·1	6·7	6·3	7·1	7·7	9·3	8·4
Jun	—	7·3	6·8	6·6	6·8	8·0	—
Jul	6·8	5·8	6·0	6·3	6·9	7·0	—
Jul (1953)	*(6·1)*	*(5·4)*	*(6·5)*	*(6·4)*	*(7·1)*	*(7·1)*	*(8·3)*
Aug	6·0	6·4	6·2	6·9	7·3	7·7	—
Sep	8·0	3·2	3·6	4·2	5·0	—	—
Oct	5·4	6·0	6·6	7·5	6·8	7·0	6·0
Nov	5·6	6·5	6·3	6·5	7·8	6·0	12·0
Dec	6·1	6·8	6·3	7·4	6·3	6·0	6·0

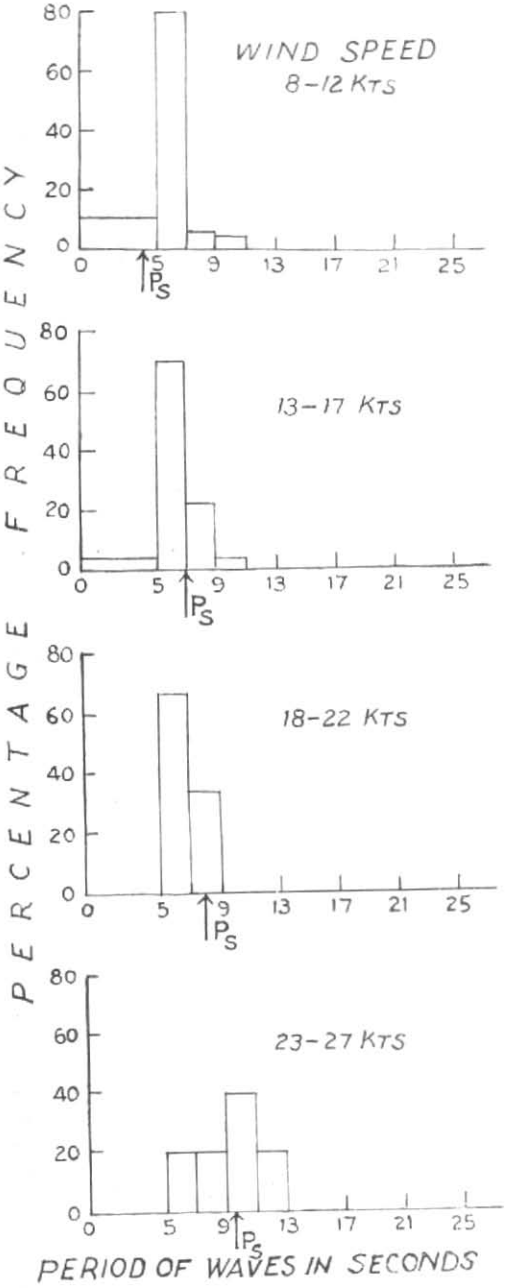

Fig.6(a) —January 1952

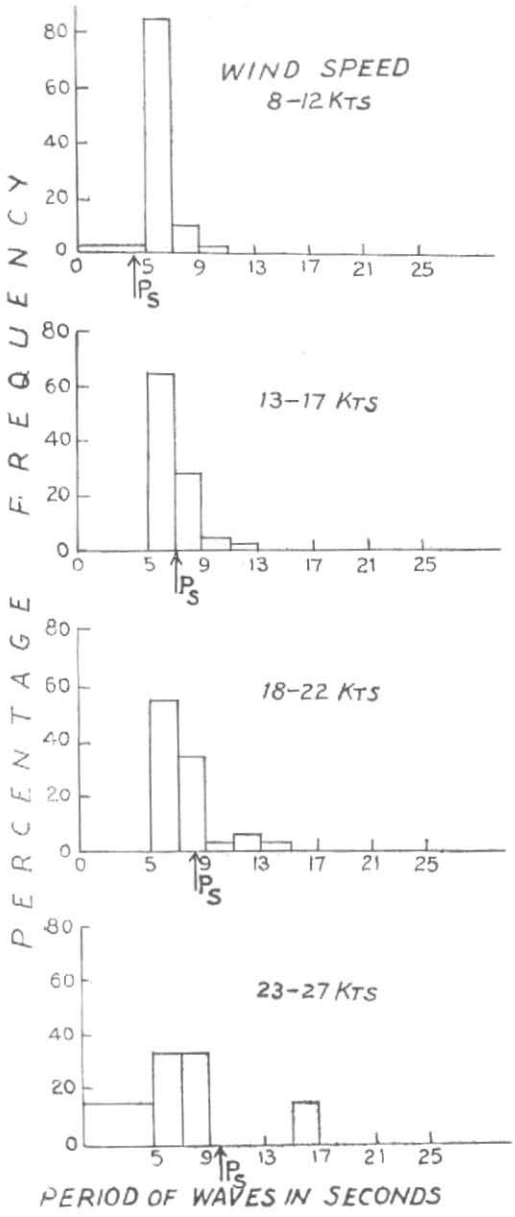

Fig. 6(b)—August 1952

Frequencies of wave periods in different wind speed ranges
(P_s — Period of highest significant wave)

in any season. Irregularity becomes more marked in high wind speed which is perhaps due to increased gustiness associated with higher wind speeds.

Figs. 6(a) and 6(b) give the percentage frequency of occurrence of waves of different periods for each range of wind speed for January 1952 and August 1952 respectively. Periods associated with highest significant waves produced by the different wind speeds are also marked on the figure as P_s. As in the case of wave heights, the percentage of cases exceeding the periods corresponding to the highest significant waves decreases as the wind speed increases.

Association between heights and periods of waves—If we consider that after a calm condition a steady wind has been blowing for a certain period over an extensive fetch, we would expect that a particular wave height will grow which will be associated with a particular period, *i.e.*, for a particular wind speed range the value of P_s corresponding to a particular value of H_s should be more or less defined. The relation between P_s and H_s should, however, differ under another wind speed range. In order to study this relation, the frequencies of association of different heights with different periods for each speed range have been worked out for August 1952 and shown graphically in Fig. 7. Theoretical relationship between wave heights and wave periods in different wind speed ranges on the basis of U.S. Navy H.O. Publication No. 604 is shown by smooth curves in Fig. 7. It will be observed that for the speed range 8—12 kts, most of the maximum frequencies lie beyond the theoretical curves which is clear from the fact, as discussed earlier, that the influence of fetch and duration of steady wind is more prominent in building up the waves than the magnitude of the observed wind of low speed (8—12 kts in this case). In the ranges of wind speed 13—17 kts and 18—22 kts the maximum frequencies lie close to the theoretical curve, but in the case of wind speed of 18—22 kts the maximum frequencies are

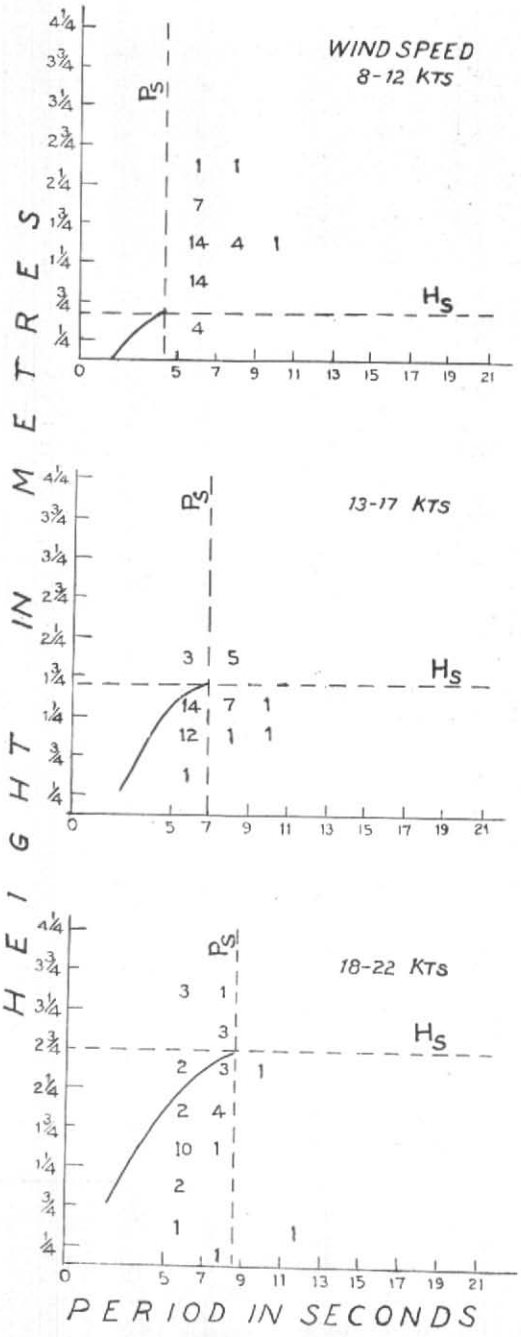

Fig. 7. Frequencies of wave heights associated with different periods

more shifted towards lower wave heights. For wind speed of 18—22 kts, heights deviate more from the theoretical curve than the periods. The effect of increasing wind speeds is not as prominent in building up long periods as in giving rise to high waves. This explains the special features noticed in the diagram referred to above. As the number of observations relating to wind speed range of 23—27 kts are meagre, no conclusion can be drawn from those observations.

The observations which have been made in the foregoing paragraphs on the basis of analysis of data from January and August 1952 are generally true for other months as well because no special features characteristic of any particular season have been assumed or determined to find the relation between wind speed, wave height and wave period. The factors which determine this relationship are more or less prevalent in all the months of the year.

Comparative study of observations for July 1952 and July 1953—With a view to finding out whether the present analysis of wave observations of 1952 for the Bay of Bengal can be taken to represent the conditions in other years also, a comparative study of the observations for July 1952 and July 1953 has been made. The average heights and periods associated with each wind speed range in July 1953 are included in Tables 1 and 2 respectively. Frequency distributions of wave heights and wave periods under different wind speed ranges as well as the average values of wave heights and wave periods for the two years agree fairly well.

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