Reprinted from the Journal of the Institute of Navigation, Vol. 24, No. 3, July 1971

Severe Wave Conditions at Sea

Laurence Draper

1. INTRODUCTION. Perhaps the most surprising thing about sea waves is that they come in a vast range of shapes and sizes. The casual observer on a ship in waters not exposed to an ocean, for example the southern North Sea, may rightly think that the waves he can see have all been generated

by the same wind blowing over some particular stretch of water for a fixed length of time. It then seems almost logical to deduce that all the waves ought to be of the same height, length and shape. Unfortunately this is not the case, the energy of sea waves is locked in wave components spread over a wide range of wave periods, each of which travels at a speed dictated by its period. Considering the very simple case of a sea with only two wave components, when a crest of one component overtakes the other, a higher wave will ensue. As a result of this process, high waves come in groups; during the time in which the components gradually get into phase the wave height builds up giving a train of waves of increasing height, which then decreases as the faster component travels away, until when they are out of phase the sea is temporarily fairly calm. This is the reason why it is commonly said that every seventh wave is the highest, although whether it is every fourth or every fourteenth depends on the relative speeds of the components.

2. THE HEIGHT OF WAVES. In the sea there are not two components but an infinite number, and their continual interplay makes it difficult to ascribe meaningful numbers to wave height. However, there is one parameter, named significant wave height, and defined as the average height of the highest one-third of all the waves, which is a useful one to have. It is a meaningful parameter to the theoreticians, and it has the additional virtue that on average it is very close to the value which an experienced seaman would give if asked to estimate the wave height. It has been shown by both theory and measurement that if the sea is watched for the duration of about 60 waves, typically about 10 minutes, the height of the highest wave which appears is about 1·60 times the significant height and if the sea is watched for 3 hours the height of the highest individual wave will be about twice that of the significant height. The same theory, due largely to Cartwright and Longuet-Higgins, tells us that whilst one wave in 23 is twice the height of the average wave, one in 1175 exceeds it by three times and only one wave in over 300,000 exceeds four times the average height (300,000 waves is equivalent to about once a month at sea). It is perhaps important to stress that this refers to the average height, which is about 0·63 times the significant height.

These improbable events are, of course, very rarely experienced, and almost never recorded by an instrument. However, there is in existence one record (Fig. 1), taken by the Commissioners of Irish Lights with a Shipborne Wave Recorder on *Daunt* light-vessel off Cork, showing a wave 4·1 times the average height. According to theory, this is likely to occur only once in about 700,000 waves, or one record in about 10,000. The actual height of this wave was about 42 feet, at a time when the significant height was 16·5 feet.

An important characteristic of individual waves is their lack of longevity; once again, it is simply because the really big wave is the result of a chance superposition of many components overtaking each other at one point in space and time. Before long, perhaps two or three wave

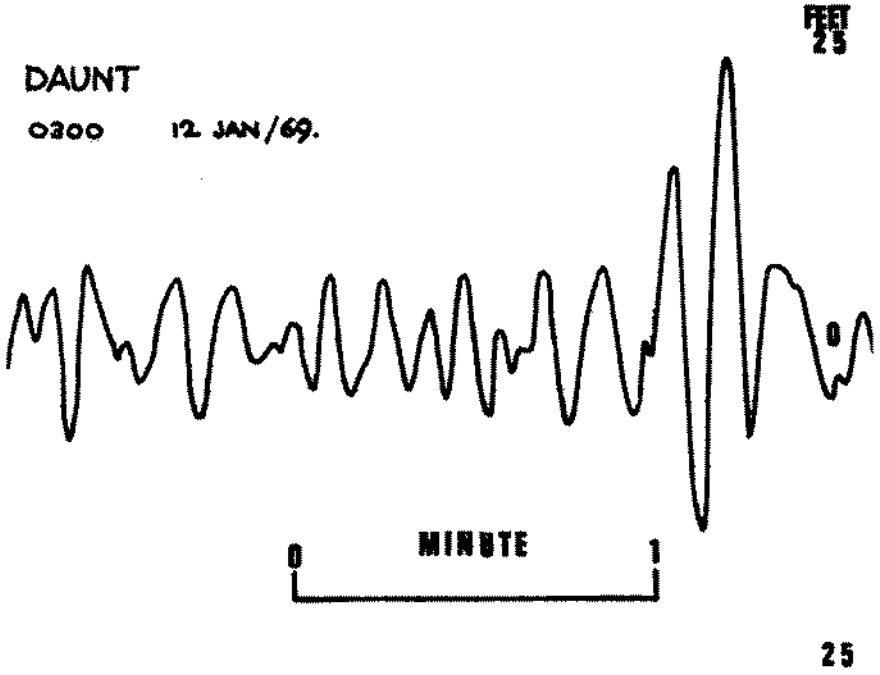

FIG. 1. Wave recorder trace taken on light-vessel *Daunt* off Cork

periods and over a distance of less than a mile, the height of any large individual wave has decreased and it is no longer distinguishable from any other wave.

It might be of interest to mention some of the large storm waves which have been reported. In 1826 Captain Dumont D'Urville, a French scientist and naval officer in command of an expedition, reported meeting waves 80 to 100 feet high, but he and three colleagues who supported him were openly ridiculed. There is an interesting report by Captain (later Admiral) Robert Fitz-Roy in the *Narrative of the Surveying Voyages of H.M.S. Adventure and Beagle, 1826–36*, London, 1839, Appendix to vol. II, p. 297.

> 'In H.M.S. *Thetis*, durin in unusually heavy gale of wind in the Atlantic, not far from the Bay of Biscay, while between two waves, her storm try-sails were totally becalmed, the crest of each wave being above the level of the centre of her main-yard, when she was upright between the two seas. Her main-yard was sixty feet from the water-line. I was standing near her taffrail, holding by a rope. I never saw such seas before, and have never seen any equal to them since, either off Cape Horn or the Cape of Good Hope.'

This is an objective and unemotional report by an experienced sailor, and if there were several waves higher than 60 feet then the highest of all would have been appreciably higher than this. The 112 foot wave experienced by the U.S.S. *Ramapo* in the North Pacific in 1933 still seems

to be the highest reliably observed wave. In the last few years perhaps the highest claimed is the 90–100 foot wave which hit a drilling rig off Vancouver Island about 3 years ago. There is a Russian stereophotograph of the Antarctic sea surface in which the vertical distance between the highest and lowest points appears to be 82 feet, although if these two points are not on the line of travel of the wave energy it may not necessarily be justified to refer to this as a wave height.

An interesting point is that there is just as much likelihood of an unusual trough occurring as there is of an unusual crest, but of course these are not as likely to be seen unless an unfortunate vessel happens to fall into one. Nevertheless, such things have been experienced, for example, the report by the Master of the *Edinburgh Castle*, Commodore W. S. Byles, R.D., that in 1964 his vessel 'charged, as it were, into a hole in the ocean at an angle of 30° or more'. This report prompted Commander I. R. Johnston, R.N. (retd.), to recount his startling experience in the cruiser *Birmingham* during the Second World War when his vessel fell into a similar hole. The interesting thing is that, to the author's knowledge, such holes have only been reported off South Africa; there seems to be no obvious explanation for such a geographical preference, as these phenomena ought to occur at any place if waves are present.

3. High waves in British waters. Out in north-eastern parts of the open North Atlantic, the highest wave likely to be experienced each year at any location will be about 70 or 80 feet in height, and even a few miles off Land's End there will probably be a wave of over 50 feet in height almost every year. In the north-eastern Irish Sea, the eastern end of the English Channel and the southern North Sea, the highest wave each year at any open-water point is likely to be in excess of 30 feet.

As one goes northwards in the North Sea, extreme wave conditions become more severe. Structures such as those which are being operated by the hydro-carbon companies are designed to survive, for example, the 50-year wave. At places where waves have been recorded, such as Smith's Knoll, this can be estimated in two ways. One is to extrapolate the measured wave data, and this yielded an estimate of 56 feet as the height of the highest wave occurring in 50 years. The second method is to use the estimates of extreme wind speeds made by H. C. Shellard of the Meteorological Office and to apply these to a wave forecasting technique, and if one does this with the National Institute of Oceanography's technique, one ends with a figure of 53 feet as the height of the highest wave likely to be exceeded once in 50 years. The apparent agreement is better than one can expect if one considers the errors at play in both methods. In the extreme north of the North Sea conditions are approaching those of the North Atlantic. In its first winter, 1969/70, a Shipborne Wave Recorder on the Norwegian rescue and weather ship *Famita*, 160 miles east of Peterhead, recorded a wave 61 feet high, and the estimated height of the highest wave in the storm was 76 feet. More recently, in the storm of 18–21 October 1970, during which time the wind was mainly from

between west and north, the highest waves seemed to have been reported from the more easterly areas of the sea, and there were several visual observations of waves of over 70 feet in height, although the highest wave actually recorded by *Famita* in the storm was only 51 feet high.

Over the last quarter century the understanding of sea waves has improved tremendously, theory has helped us understand the processes and factors at play, and measurements have enabled us to determine with a fair degree of accuracy the sizes of the waves. It is of interest that far from ridiculing the old sailors' stories about enormous waves, modern research has confirmed that such monsters can occur, and that wave heights can exceed by an appreciable amount the maximum values which have been accepted in responsible circles.

4. ACKNOWLEDGMENT. I am indebted to Miss Margaret Deacon for bringing to my attention the report of Captain Fitz-Roy.

REFERENCE

Byles, W. S. (1965). The one from nowhere, *British and Commonwealth Review*, Feb. (This article is quoted in *The Marine Observer*, **35**, 210, October 1965, together with the comments from Commander I. R. Johnston, R.N. (retd.).)