OCEAN WAVES

. . AND MARINE OIL OPERATIONS

By Dale F. Leipper

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A MAJOR portion of The Oil and Gas Journal for February 23, 1950, was given over to a symposium on design of offshore drilling structures. The symposium dealt largely with the damage done to platforms by the hurricane of October 3, 1949, in which Ohio Oil Co. suffered losses exceeding $200,000. It consisted of papers by experts in the fields of design, engineering, meteorology, and insurance. Since two independent research organizations are now engaged in blueprinting a program for an investigation of damaging forces in hurricanes, it seems appropriate to discuss further some of the important considerations involved.

In the course of the Journal's symposium it was brought out that there are two ways in which offshore structures may be altered so as to withstand the damaging effect of hurricane waves. One way is to strengthen the structure or to reduce its wave resistance, and the other is to raise the platform above the zone of wave action.

In their articles, the symposium authors are in general agreement upon five important points:

1. That forces doing the major damage are vertical forces associated with ocean waves.

2. That elevation of platform decks above the zone of wave action is the best means for preventing further damage in hurricanes.

3. That many additional data concerning ocean waves and oceanographic conditions are needed.

4. That the Sverdrup-Munk wave theory is probably not applicable to the special situation of hurricanes on the Continental Shelf of the Gulf of Mexico (although one author, Krick, used this theory without discussing its limitations in computing wave heights at the platforms, thus indicating that he does not agree on this point).

5. That the standard weather forecast made for the general public does not contain all the information an offshore operator desires or needs, especially as regards the state of the sea.

On the basis of these points, the primary question which must be answered for the offshore industry is: **For each given drill site, what is the maximum elevation of wave crest above the bottom which is probable?**

Dale F. Leipper is department head of Texas A. & M.'s newly organized department of oceanography. He has had wide experience as a physical oceanographer and marine meteorologist. The new department at Texas A. & M. is the only one of its kind on the Gulf Coast, and it has available a complete shore laboratory.

The answer to this question will come only from the sciences of climatology, meteorology, oceanography, and probability. There is no way in which it might be obtained from engineering methods alone, unless measurements could be taken at every site over a period of years long enough to establish the probabilities of occcurrence of various hurricane wave heights. This is obviously impractical.

Secondary problems deal with the forces exerted by waves on platform structure below the main deck. According to M. B. Willey, one is led to believe that "the designs now in use are satisfactory. Structures so constructed will remain intact in even a severe hurricane provided the decks and other flat surfaces of considerable area are out of the reach of the wave mass." Further knowledge of the distribution of forces in waves can aid greatly, however, in increasing the efficiency of structure design. From a suitable series of observations collected at times and places known from oceanographic considerations to be typical or critical, the necessary empirical knowledge can be obtained.

The complicated nature of ocean waves is such that, even in regions where recording devices are operating, it usually appears that the most valuable information on waves can be obtained by the application of an appropriate oceanographic theory which makes use of detailed meteorological and geological data. Such a theory is needed to permit the computation of wave characteristics for the short fetches, the shallow waters, and the hurricane wind speeds peculiar to the Gulf Coast. Only on the basis of a sound theoretical framework may a series of observations be carried out which will permit the eventual perfection of an applicable theory. Only by incorporation in such a theory will observational material find its maximum value and provide means for prognosticating wave characteristics at different times and places under varying conditions.

It should be emphasized that the only satisfactory solution of the hurricane wave problem will come from

Grand Isle, La., laboratory of Texas A. & M. College Research Foundation.

the integration of the particular skills of the oceanographer, the meteorologist, and the marine engineer.

Relation Between Engineering and Oceanography

Studies of the properties of sea water and of materials contained in it are the responsibility of the oceanographer. Some of the particular properties to which attention must be given are electrical conductivity, diffusive characteristics and the manner of transmission of sound, light, and heat. Results obtained by study of such properties are useful to the engineer. For example, in an investigation of corrosive properties of sea water in heat exchangers one company found in more efficient to operate a $10,000 heat exchanger than a $3,000 one.

If we consider forces, the major ones operating in the oceans are those related to the tides, wind waves, currents, hydrostatic pressures, heat energies and stresses of the wind on the sea surface.

Proper interpretation and application of knowledge concerning these forces requires a combination of theoretical work and engineering. Such a combination will prevent needless effort being spent in the development of theories which have no application and in the application of theories which have assumptions not met in nature.

Engineers and oceanographers have worked separately on their common problems. Closest cooperation was probably obtained in University of California but even there the two departments concerned were separated by 600 miles. The engineering department at Berkeley has successfully engaged in projects related to sea-water distillation, ripple waves in tanks, formation of gravity waves, stability of ship models, wave energy, wave recorders and amphibious craft and their operation. Some studies have been conducted jointly with the Scripps Institution and others have employed meteorologists and oceanographers working in the department of engineering.

On the Gulf Coast, engineers have faced many difficult marine problems but have as yet sought relatively little help from physical or meteorological oceanographers. One reason is that there has been only one such specialist in this region. The academic positions open in the department of oceanography at Texas A. & M. now make it possible to overcome this difficulty.

Our Gulf Coast has a unique set of problems. In addition to those arising here in engineering owing to the action of ocean waves, currents, tides, and winds, there are others brought about by the growth of organisms and by chemical reactions. These problems involve beach erosion and sedimentology, fouling, effects of weather, corrosion, fresh-water supply, navigation, extraction of raw materials from the sea, sanitation, recreation, defense, and offshore construction and operation. The Gulf Coast needs a well coordinated local oceanographic program similar to the ones conducted on the Atlantic and Pacific coastlines.

Nature of Oceanographic Research

There are a number of characteristics which practically all oceanographic investigations including wave studies have in common. One of these is the tendency to become more and more involved in a wider and wider range of marine subject matter as the investigation advances. Another is that there are a surprisingly large number of similar parts making up oceanographic projects which, on the surface, would appear to be entirely unrelated. As a result of these characteristics there are two alternate approaches to oceanographic research. The first is to attack the problem immediately at hand and then to find it becomes gradually more and more involved in other phases of oceanography. The second approach is to plan a comprehensive investigation which consists of a united attack upon the basic aspects of the science which are pertinent.

One of the most vital parts of an oceanographic research program is the development of a group of men who are expert in local problems. Benefits obtained from the influence of these men, who are living and working in the region where the research is being conducted and where the results are applied, may far exceed benefits derived from their formal, published technical reports.

Ocean-Wave Research

As an example of an investigation which illustrates many of the characteristics of oceanographic research projects as described above, we may consider an ocean-wave investigation. At the Scripps Institution of Oceanography, the writer was studying waves under H. U. Sverdrup in the summer of 1943, when wave research was begun there.

From that time on, such work has been continually conducted a La Jolla. The Scripps Institution's wave theory have been used by one of its authors, W. N. Munk, in the absence of any more applicable theories to compute wave heights in Gulf Coast hurricanes. However, the limitations of this theory in the hurricane situation have always been carefully discussed. Krick has implied that the theory is applicable in its present form. Evidence opposed to this application is as follows:

First, the fact that maximum waves observed October 3, 1949, greatly exceeded those computed from this theory by Munk. Second, wave heights were computed by Krick subsequent to the hurricane, which was not an intense one, using the same theory and he got wave heights 61 per cent greater than those of Munk. Third, two references may be quoted—the first written by a student of Sverdrup and approved by him.

"Since the evaluation of the constants in the Scripps Institution wave theory is based on observations which do not include the special features of the tropical storm, the conclusions reached in this paper will have to be modified as more detailed observations of the sea and swell associated with these storms are made." (Waves and Swell from a Tropical Storm, Chief of Naval Operations, Aerology Section, Washington, D. C.)

Also, William L. Donn in the August 1949 issue of the American Geophysical Union Transactions states ". . . (1) the forecast theory of Sverdrup and Munk appears inapplicable to storms in which the velocity of the winds is high and the fetch is short."

It shall be kept in mind that the Sverdrup-Munk theory has found application in a wide variety of other situations and that it is chiefly on the Gulf Coast hurricane situation that major difficulties arise. Additional work must be done, giving particular attention to the short fetches, high wind velocities, and shallow waters which are found there. It is quite likely that many aspects of this previous theory may be modified and made applicable when suitable empirical data have been obtained.

The Scripps wave work began with work by one scientist, Sverdrup, but grew until it has at various times received the sponsorship of the Army Air Forces, the Hydrographic Office, the Bureau of Ships, the Office of Naval Research, the U. S. Marine Corps, the Geophysics Institute of University of California, the Beach Erosion Board, the U. S. Army Engineers, and different industries. In addition to sponsorship, these agencies furnished cooperation of various kinds such as the use of airplanes, ships, and instruments; the assignment of men to participate in research; the sponsorship of students by providing funds for research assistantships, and technical advice. There was cooperation with other organizations such as the department of engineering at Berkeley which conducted model studies, developed methods of observation, designed instruments, and made engineering applications of wave data. Meteorological information was furnished by the U. S. Weather Bureau and the department of meteorology at University of California at Los Angeles. Geologists conducted studies of changes in topography, sedimentation, and erosion which provided information on wave action. Such widespread cooperation could not have been furnished to other than a educational institution.

The wave work has been conducted over a period of 7 years with major contributions by Sverdrup and Munk. During most of this time the personnel participating also included a draftsman, a secretary, a computer, and various graduate students in physical oceanography. This gives an idea of the scope of a successful project on ocean waves. With the results of this work available, the development for the Gulf Coast region will be somewhat simplified, although still extensive. However, because of the number of agencies interested, no one group of industries need carry the full burden of sponsorship if the program is properly planned.

The Beach Erosion Board has already assisted in local wave studies, having furnished a wave-recording instrument. Dr. Martin Mason, who is chief of the engi-

neering and research section, has received requests from other companies for similar recording instruments. However, such equipment cannot be issued until there is assurance that a satisfactory coordinating agency in wave work has been selected. Other organizations such as the Office of Naval Research would no doubt contribute to the sponsorship of basic work on hurricanes under conditions which exist here. Also, the staff of the A. & M. department of oceanography is planning work on waves in conjunction with its academic program.

The basic problem is to determine how the wind acts on the sea surface to set up and modify waves and currents. The Eckman theory, which is now used to calculate currents, is known to be inadequate. The oil platforms offshore provide a unique opportunity to obtain for the first time the information which is needed to revise this theory. Texas A. & M. has a staff position for another physical oceanographer - marine meteorologist and expects to select for the position the best qualified available man for work on oceanographic waves and currents, combining the theoretical and the practical approaches, who may contribute to the solution of pertinent problems.

There are a number of oceanographic and engineering problems which are related to waves and are of particular importance along this coast. One of these concerns the applicability of the model laws. When the wind exceeds 7 m. per second the ocean surface changes in character, becoming hydrodynamically rough. This phenomenon is a basic one in the study of waves and currents and probably cannot be reproduced or allowed for in model studies. Another problem is the determination of the distribution of the forces in ocean waves. One present theory states that the force is maximum at the crest because particle velocities are maximum here. It should be remembered that this part of the wave has the least mass and therefore in spite of its velocity may not have great striking power.

There are few data indicating the height of storm tides offshore although this information is vital to construction engineers. A simple device could be made to obtain such data. This might consist of a large piece of pipe such as is used with tide gages having a sealed bottom except for one small subsurface hole large enough to permit water level in the pipe to change over a period of several hours, but small enough that passing wind waves would have no effect on the water level. A valve could be put into the hole to allow water to pass slowly into the hole but not out. Thus, after the hurricane, the stand of water in the pipe would indicate the maximum height of the storm tide.

Regardless of whether or not wave heights may be properly forecast or calculated, there is one oceanographic tool which is becoming an accepted part of marine engineering work. This is the refraction diagram which shows localities where a given set of deep-water ocean waves will build up or converge and other localities where the same waves will be reduced or diverge. These diagrams make use of wave characteristics, bottom topography, and water depth. Those constructed in the past have been referred to mean sea level. However, information on convergence and divergence is most vital at the time when a hurricane strikes. At such a time the general sea level near shore is considerably higher than mean sea level and refraction diagrams should take this into account. Apparently they do not do this now.

Before refraction diagrams can be drawn, the periods and directions of waves which occur in deep water must be known. Upon this information and upon detailed bottom topographic charts, wave - refraction diagrams are based. At the present time each company which wants a refraction diagram must pay for the complete recomputation of these statistics although the information is exactly the same for all locations in a given region. If the industries concerned were to sponsor jointly, once and for all, a careful compilation of hurricane statistics, then refraction diagrams for proposed new drilling sites could be constructed with relatively little effort and cost.

From what has been said, it can be concluded that the needed information about hurricane waves on the Continental Shelf of the Gulf Coast can be obtained only by a thorough theoretical and empirical study integrated with an over-all oceanographic research and forecasting program. If the study is properly organized many interesting agencies will contribute to its progress.

The oceanographic problems of the Gulf Coast are well defined and the only satisfactory means for attacking them is agreed upon by all who are trained in this field of work. Texas A. & M. College has taken large steps in initiating these major undertakings. The college administration feels that they may in this way contribute to the general welfare of the region and to the economic and cultural development related to one of our greatest natural resources, the Gulf of Mexico.

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