V393
.R46

[redacted]

MIT LIBRARIES
3 9080 02754 3385

[redacted]

NAVY DEPARTMENT
DAVID TAYLOR MODEL BASIN

HYDROMECHANICS

○

AERODYNAMICS

○

STRUCTURAL
MECHANICS

○

APPLIED
MATHEMATICS

THE DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN

by

W. E. Cummins

MASS. INST. OF TECHNOLOGY
AUG 1 9 1976
BARKER ENGINEERING LIBRARY

HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

July 1959 Report 1362

OCT 5 1959

PRNC-TMB-648 (11-56)

THE DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN

by

W. E. Cummins

For Presentation to the 12th American Towing Tank
Conference at the University of California
Berkeley, California
September 1959

July 1959 Report 1362

TABLE OF CONTENTS

ABSTRACT

The method which the David Taylor Model Basin plans to use for measurement of directional spectra in the Seakeeping Basin is presented. This method makes use of a linear array of wave-height probes supported on a rotatable beam. For each orientation of the array, the spectrum along a line perpendicular to that orientation can be determined. A nonuniform arrangement of the wave probes along the beam is given which optimizes the directional selectivity of the array.

This procedure was selected from a comprehensive survey of various methods by N. F. Barber, of New Zealand.

INTRODUCTION

The Maneuvering-Seakeeping Basin which is under construction at the David Taylor Model Basin will become operational near the end of 1959. This basin is a rectangular tank, 250 feet by 350 feet, and it has banks of wavemakers of the pneumatic type along two adjacent sides, and beaches along the remaining sides.[1] The individual wavemakers in each bank are 25 feet long. It is planned to operate the elements in each bank in unison in order to generate long-crested waves. It will be possible to vary both frequency and amplitude of the waves generated, according to an assigned program, thus creating long-crested random waves. However, it is possible in principle to operate each wave-maker in a bank independently, according to different programs, thus generating short-crested random waves. These wave systems would be expected to provide

---

[1] References are listed on page 18

a much more realistic model of the conditions actually occurring in nature than would the long-crested wave trains, either regular or irregular. Provisions are being made to independently drive the wavemakers in the short bank in this manner, and it is hoped that this feature of the facility will become operational in 1960.

Model tests in such short-crested wave systems will be useful only if the waves can be characterized in some meaningful manner. The only pattern for characterization which comes close to satisfying our requirements is that developed by Dr. Pierson, based on the spectrum analysis of stationary random processes.[2] This necessitates a measurement program of no small magnitude. It may be noted that to date very few directional sea spectra have been obtained, and these were quite expensive, both in labor and in money.[3]

The technique used for these full-scale measurements required the determination of the instantaneous wave pattern over a large area by means of stereo pairs of photographs. This procedure would be completely unsuitable for use in the Seakeeping Basin because of both cost (many model seas will need to be characterized) and technical faults. The stereo-pair technique is based on the assumption that the directional spectrum is stationary with respect to both time and space. Therefore, a spectrum determined from the entire wave pattern in the space photographed, at a given instant, completely characterizes the system for all time and all points in the space. This assumption, although quite reasonable for waves in the open ocean for periods of time which are not too long, will be far from valid in the model basin. We may assume that the system is stationary in time for a given wavemaker program, but there is reason to believe that the directional spectrum will show significant variation over the basin. At points near the center of a unit wavemaker the waves are nearly unidirectional, the wave pattern being essentially determined by a simple wavemaker, but at points remote from the bank the range of directions will be great because disturbances are received from many wavemakers. Therefore, for calibration purposes at least, the wave system must be characterized at many different points in the basin, and must be based upon measurements taken only in the immediate neighborhood of those points. Thus, in contrast to the stereo pair technique, the measurement must be based on observations over a long period of time over small regions, rather than over the entire basin at a given instant.

Barber, of New Zealand, has had some success in the development of techniques for determining the directional spectra of natural wave systems. His services were engaged to develop suitable techniques for similar measurements in this new facility. He found a variety of solutions, and these will be published shortly in a comprehensive report.[4] This present paper describes the procedure which has been selected for use at the Taylor Model Basin. This method is believed to be the one which best suits the needs of the Model Basin for this particular facility. It may be noted that the technique is closely related to a method developed by Marks for the analysis of stereo pairs.[5]

REQUIREMENTS FOR THE SYSTEM

It would be desirable in principle to completely characterize the model sea which a ship model encounters, by measuring the actual waves around the model during a run. This would permit a precise, nonstatistical correlation of the model response with the waves causing the response. However, such a procedure would have two inherent faults. First, the measurement would be extremely difficult and the data reduction quite laborious, at least by any methods presently available. Second, the measured wave of encounter would be incorrect, because it would include the distortions arising from the presence of the model.

We have adopted the alternative procedure of carrying out a calibration of the wave system for each wavemaker program. This will be done once, in rather extensive detail, and the results will provide a basis for all future ship model tests with that program. This necessitates a statistical analysis of model motion data and as a consequence there will be reason for concern about sample length and its effect upon confidence limits. At times, many runs under similar conditions will be required in order to obtain adequate statistical reliability. Nevertheless, this is the only course open, if one is to carry out tests in short-crested random seas.

What is needed, then, is a system of measurement which is reliable, simple, and not too time-consuming. Because the directional spectra of the wave systems are not expected to be identical at all points in the basin, the system should permit the determination of the spectra over a fairly small region, based only upon measurements in that region. These considerations provided the basis for selection of the particular measurement system chosen.

DESCRIPTION OF MEASUREMENT SYSTEM

The measurement system consists simply of a rotatable linear array of six wave-height probes. The probes, which are of the capacitance type, are distributed along a 30-foot beam. Figure 1 is a diagrammatic sketch of the entire device. The spacing along the beam has been chosen to optimize the directional selectivity of the array.

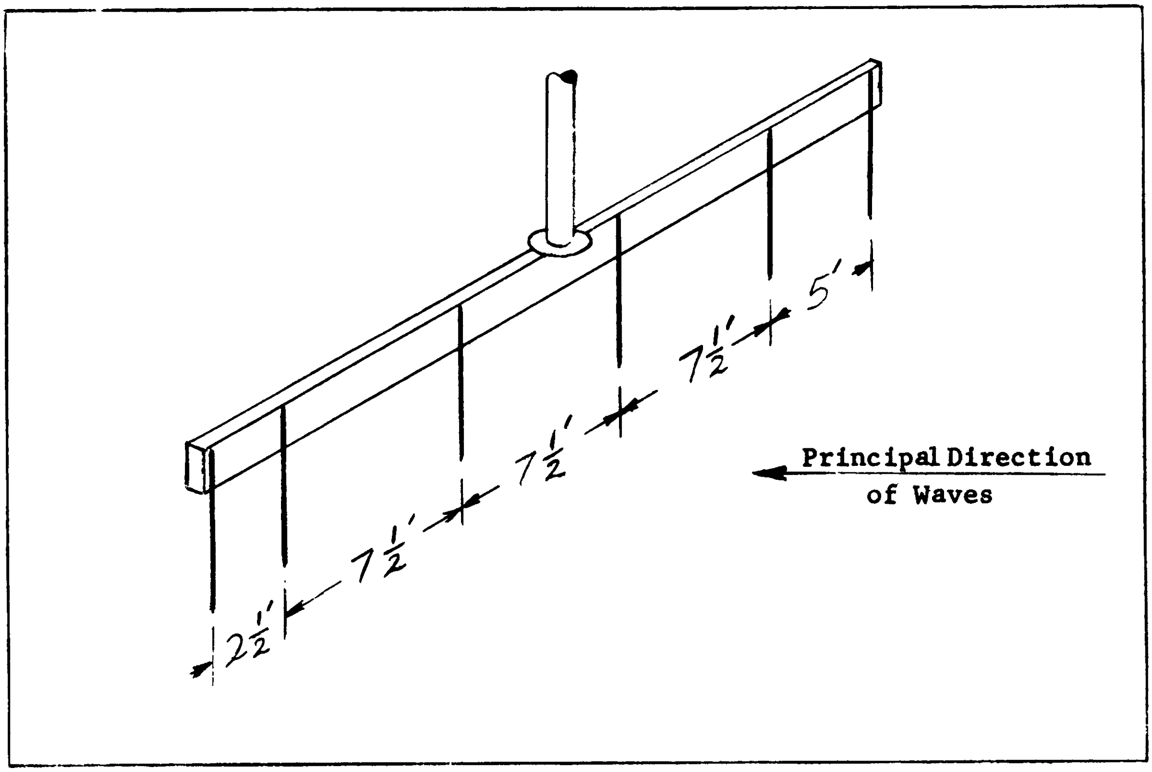

Figure 1 - Rotatable array of wave-height probes

THEORY OF MEASUREMENT SYSTEM

It is considered in the spectral theory of random waves that the sea surface can be represented as the sum of an infinite number of elementary sinusoidal waves of the form

$$a \cos 2\pi (\ell x + my + ft + \alpha) \qquad [1]$$

The power of each of these waves is $\frac{1}{2} a^2$. Since water waves obey the relation

$$(\ell^2 + m^2)^{\frac{1}{2}} = k = \frac{\pi}{g} f^2 \qquad [2]$$

the frequency as well as direction of travel is determined when ℓ and m are assigned. The wave length is 1/k. The waves can be represented by a spectrum, or density function, $E(\ell, m)$. We take advantage of the additivity of the power in the definition of this function: the net power of all the elementary waves for which

$$\ell_1 \leq \ell \leq \ell_1 + \delta\ell$$

$$m_1 \leq m \leq m_1 + \delta m$$

is $E(\ell_1, m_1)\,\delta\ell\,\delta m$. The spectrum may be represented by contours in the (ℓ, m) plane. (See Figure 2.)

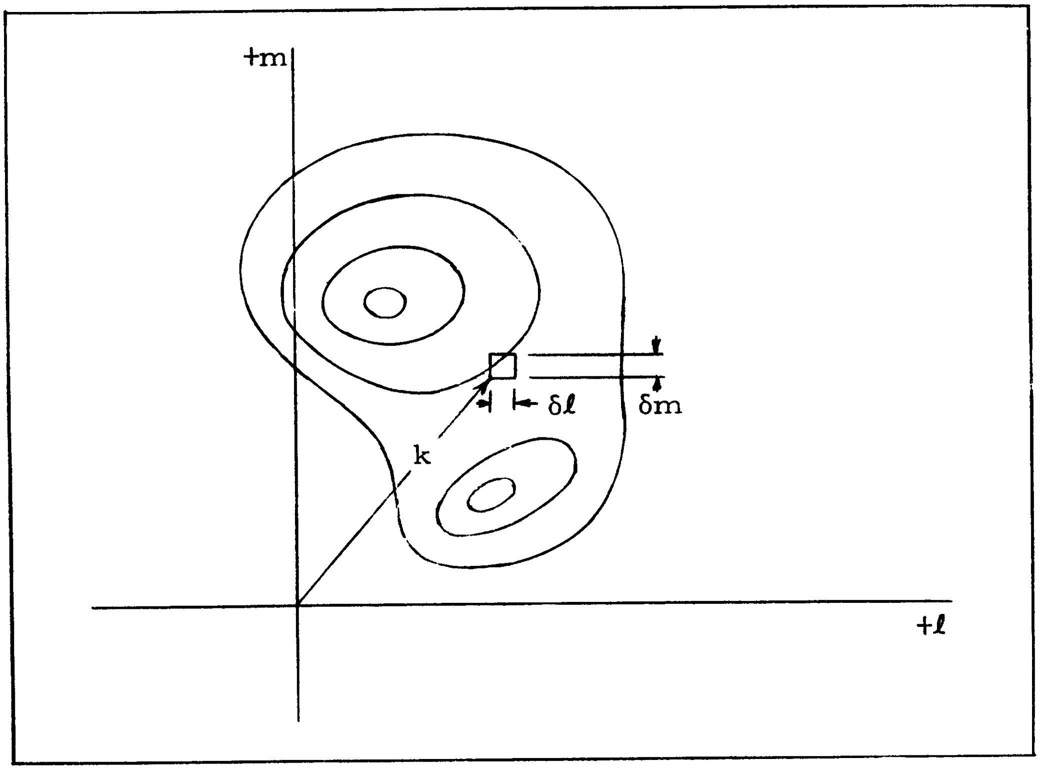

Figure 2 - Contours of a directional spectrum $E(\ell, m)$, in (ℓ, m) plane

Let u(x, y, t) be the wave height at (x, y) at time t. The function

$$\rho(X, Y) = \overline{u(x, y, t)\, u(x + X, y + Y, t)} \qquad [3]$$

is of considerable importance. The following relation holds:

$$\rho(X, Y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(\ell, m) \cos 2\pi(\ell X + mY)\, d\ell\, dm \qquad [4]$$

In other words, $\rho(X, Y)$ is the Fourier transform of the power spectrum. If we restrict attention to the values of $\rho(X, Y)$ along a given line, say, the x-axis, we have

$$\rho(X, 0) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(\ell, m) \cos 2\pi\ell X\, d\ell\, dm$$

$$= \int_{-\infty}^{\infty}\left(\int_{-\infty}^{\infty} E(\ell, m)\, dm\right) \cos 2\pi\ell X\, d\ell = \int_{-\infty}^{\infty} E(\ell) \cos 2\pi\ell X\, d\ell \qquad [5]$$

where

$$E(\ell) = \int_{-\infty}^{\infty} E(\ell, m)\, dm \qquad [6]$$

If $\rho(X, 0)$ is found from measurements along the x-axis, $E(\ell)$ can be found from the inverse Fourier transformation of Equation [5]. Unfortunately, the spectrum $E(\ell, m)$ cannot be determined from $E(\ell)$, since the integral Equation, [6], has an unlimited number of solutions. This difficulty can be overcome if the wave-height signal is filtered so that only a narrow band of frequencies is permitted to pass. That is, only the portion of the spectrum within an annulus of radius k in the (ℓ, m) plane will contribute to the measured signal. (See Figure 3.) Let this spectrum be $\delta E(\ell, m)$. We have

$$\delta E(\ell, m) = E(\ell, m), \text{ for } k_o \leq k \leq k_o + \delta k$$

$$\delta E(\ell, m) = 0 \text{ elsewhere.}$$

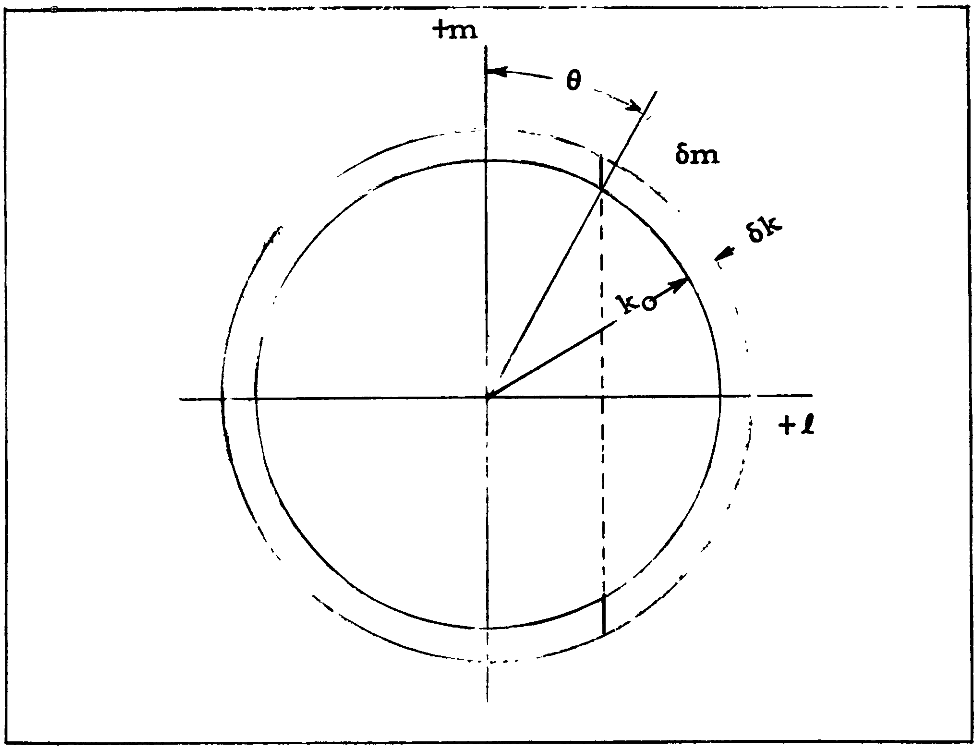

Figure 3 - Annulus in which spectrum of filtered signal lies

Let

$$\delta E(\ell_o) = \int_{-\infty}^{\infty} \delta E(\ell_o, m)\, dm$$

$$= [\delta E(\ell_o, m_o) + \delta E(\ell_o, -m_o)]\, \delta m$$

If the waves are known to come from only the upper half of the (ℓ , m) plane, we have

$$\delta E(\ell_o) = \delta E(\ell_o, m_o)\, \delta m$$

$$= E(\ell_o, m_o)\, \delta m \qquad [7]$$

Then since

$$\delta m \cos\theta \approx \delta k$$

and

$$\sin\theta = \ell_o / k_o$$

we have

$$E(\ell_o, m_o) = \delta E(\ell_o) \cos\ \theta / \delta k$$
$$= \delta E(\ell_o) \sqrt{k_o^2 - \ell_o^2} / k_o\ \delta k \qquad [8]$$

Thus, if $\delta E(\ell_o)$ can be found for each band of frequencies in the wave signal, the spectrum $E(\ell, m)$ can be determined for successive annular bands in the (ℓ, m) plane. The practical difficulty is that $\delta E(\ell_o)$ can be found only by an inverse Fourier transformation on the function $\rho(X, 0)$. This requires a knowledge of $\rho(X, 0)$ between $-\infty$ and ∞, in principle, and in practice, at least a detailed knowledge of its behavior out to where it becomes small. This would require many wave detectors, distributed over an extensive portion of the x-axis. This is operationally difficult and it violates the requirement that measurements be restricted to a relatively small region. A procedure which avoids these difficulties is developed below.

Suppose we have a pair of detectors on the x-axis at x_r and x_s. Let

$$|x_r - x_s| = \Delta_{r,s} \qquad [9]$$

Then

$$\overline{u_r u_s} = \rho(\Delta_{r,s}, 0) = \int E(\ell) \cos 2\pi\ell\Delta_{r,s}\, d\ell$$

Now, let there be detectors at x_1, x_2 ... x_N. Consider the sum of these N signals:

$$U(t) = \sum_{1}^{r=N} u_r(t)$$

The power of this signal is

$$\overline{U^2} = \sum_{1}^{r=N}\sum_{1}^{s=N}\overline{u_r u_s}$$

$$= \sum_{1}^{r=N}\sum_{1}^{r=N}\int_{-\infty}^{\infty} E(\ell)\cos 2\pi\ell\Delta_{r,s}\, d\ell$$

$$= \int_{-\infty}^{\infty} E(\ell)\left[\sum_{1}^{r=N}\sum_{1}^{s=N}\cos 2\pi\ell\Delta_{r,s}\right] d\ell$$

$$= \int_{-\infty}^{\infty} E(\ell)\, g(\ell)\, d\ell \qquad [10]$$

where

$$g(\ell) = \sum_{1}^{r=N}\sum_{1}^{s=N}\cos 2\pi\ell\Delta_{r,s} \qquad [11]$$

If the probes can be so arranged that $g(\ell)$ is negligible, except in the neighborhood of $\ell = 0$, and $g(\ell)$ is greater than zero in the limited region in which it is not negligible, the relation in Equation [10] can be approximated by

$$\overline{U^2} = E(0)\int_{-\infty}^{\infty} g(\ell)\, d\ell \qquad [12]$$

In particular, if we take the area of the portion of the spectrum of U between f and f + δf, we have

$$\delta\overline{U^2} = \delta E(0)\int_{-\infty}^{\infty} g(\ell)\, d\ell \qquad [13]$$

or

$$\delta E(0) = \delta\overline{U^2} \Big/ \int_{-\infty}^{\infty} g(\ell)\, d\ell \qquad [14]$$

Using Equation [8], we have

$$E(0, m) = \delta\overline{U^2} \Big/ \delta m \int_{-\infty}^{\infty} g(\ell)\, d\ell \qquad [15]$$

where

$$\delta m = 2\pi f \, \delta f \,/\, g$$

Thus, E(0, m) can be determined from the spectrum of U(t).

We have considered the array to lie along the x-axis, but since the choice of orientation of the axes is purely arbitrary, the preceding analysis applies equally well to any angular position of the array. Thus, we can find $E(\ell, m)$ along any radial line by simply placing the array normal to that line.

The accuracy of the method will depend upon how sharply tuned the array is, as reflected in the behavior of the function $g(\ell)$. The tuning will, in general, be sharper for the high-frequency waves than for low-frequency waves. Suppose the interval $(-\Delta\ell, +\Delta\ell)$ is the region in which $g(\ell)$ differs significantly from zero. Then, the only portions of the filtered annulus which will contribute to the integral in Equation [10] lie in the angular interval $\left(-\sin^{-1}\frac{\Delta\ell}{k_o}, +\sin^{-1}\frac{\Delta\ell}{k_o}\right)$ (See Figure 4.) Therefore, the directional selectivity of the array is

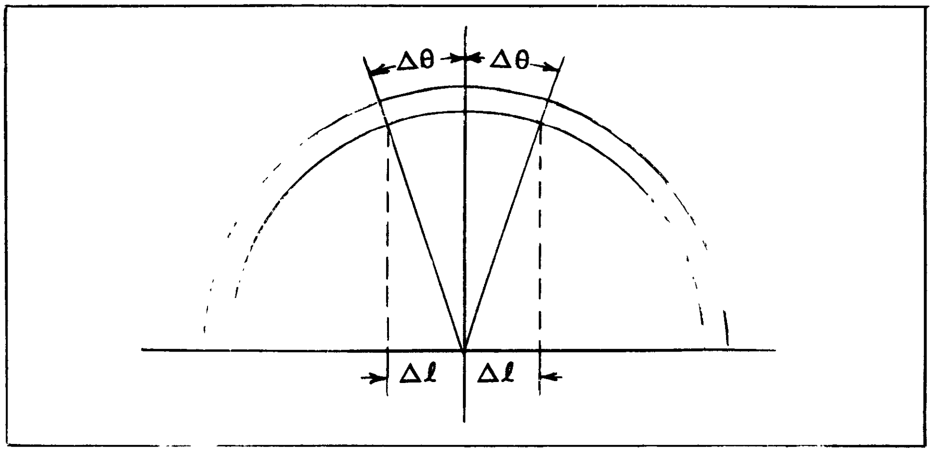

Figure 4 - Directional selectivity of array

inversely proportional to k_o, or to f^2.

One inherent disadvantage of this system is that the linear array cannot distinguish between front and rear. In the derivation of Equation [7] it was assumed that the waves came from only the upper-half plane. The region in which the spectrum is significantly large many extend beyond one quadrant in the (ℓ , m) plane. In such a case, if the entire spectrum is to be mapped, there will be positions of the array in which it will receive waves from both front and rear. (See Figure 5.) Thus, for such a spectrum, errors will be introduced which may be of significance. It is not expected that such spectra will be used in the Seakeeping Basin, and in fact, it may not be possible to generate them by means of a single bank of wavemakers.

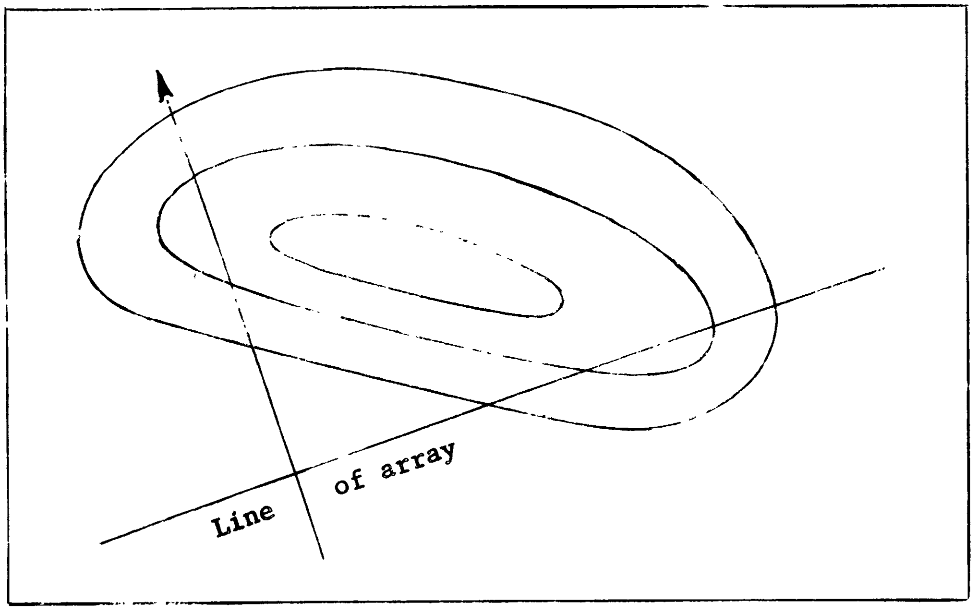

Figure 5 - Position of array for which waves would be received from front and rear

OPTIMUM SPACING OF WAVE DETECTORS

The most obvious wave-probe arrangement is to place the probes at equal intervals along the beam. The function $g(\ell)$ for this arrangement, using six probes, is

$$g(\ell) = 6 + 2 \sum_{n=1}^{5} n \cos (2\pi n \ell s/5) \qquad [17]$$

where s is the total length of the array. This function is plotted in Figure 6. It should be noted that $g(\ell)$ is periodic, with peaks at $\ell = \pm 5/s$, etc. If the spectrum contains significant energy in regions of the (ℓ, m) plane which approach or cross the lines $\ell = \pm 5/s$, the approximation in Equation [12] may be seriously in error. If s is 30 feet, the value $\ell = \pm 5/s$ corresponds to waves as long as 6 feet, and hence there is a possibility of trouble for certain orientations of the array.

Barber found a technique which not only eliminates this problem but also improves the directional selectivity of the array. Rather than place the probes at equal intervals, he chose the arrangement:

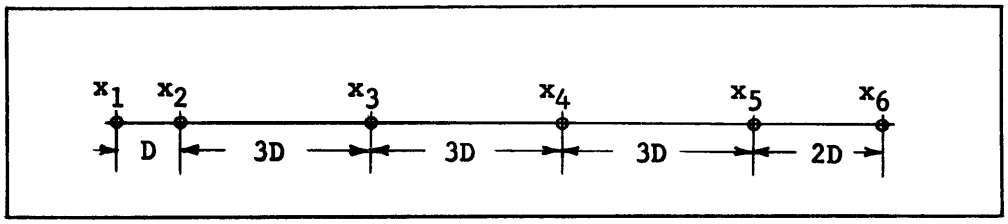

Figure 6 - Optimum spacing of wave detectors

where $D = s/12$

The spectra of the following functions are then obtained

$$U_1 = \sum_{1}^{6} u_i$$

$$U_2 = u_4 + u_5 + u_6 \qquad [18]$$

$$U_3 = u_3$$

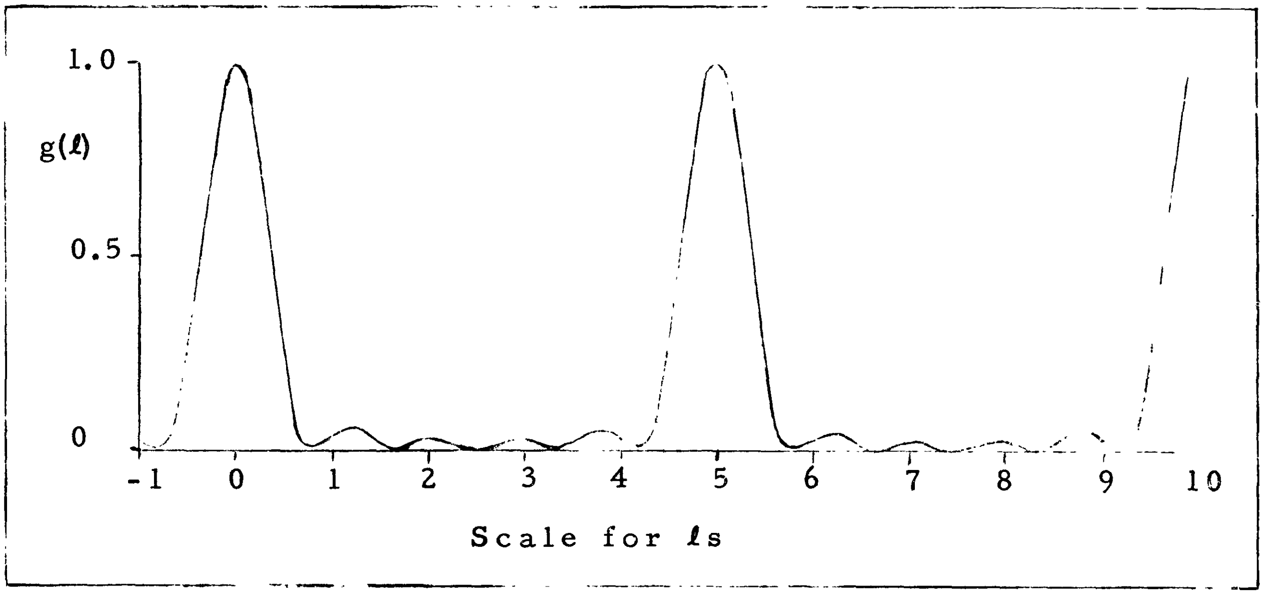

Figure 6a - The function g(ℓ) for six equally spaced probes

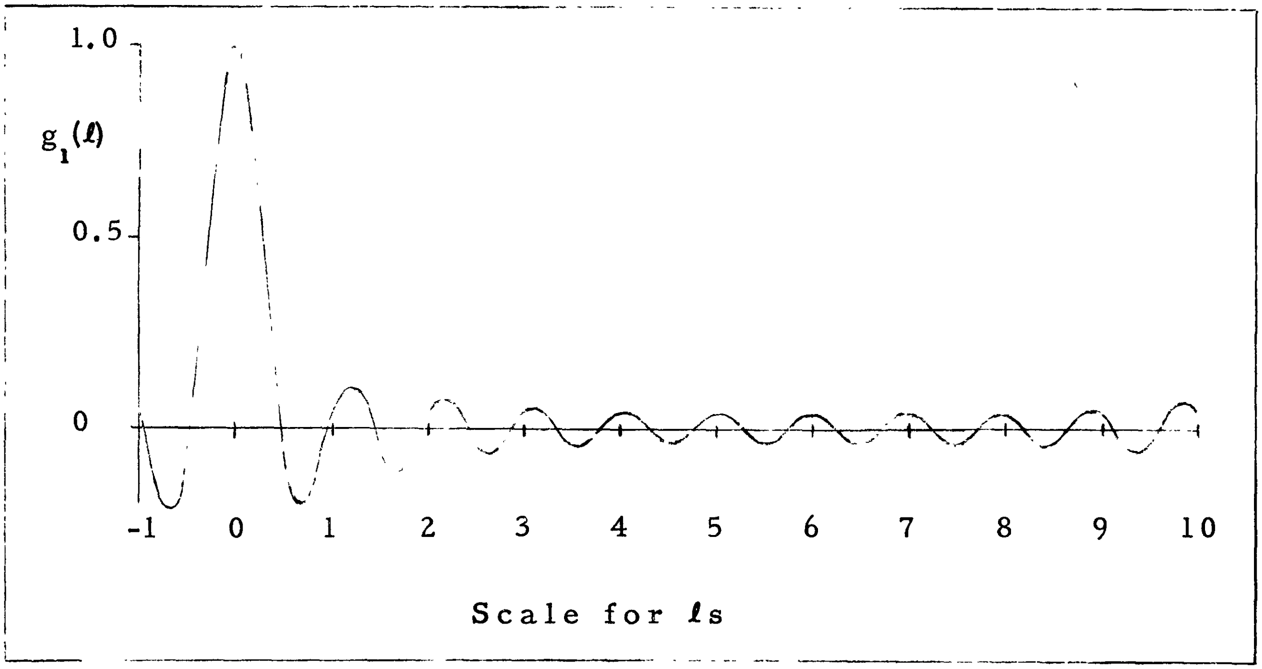

Figure 6b - The function g_1(ℓ) for optimum spacing of six probes

Let these spectra be E_1, E_2, E_3. We combine them in the following way:

$$\xi = E_1 - E_2 + 2E_3 \qquad [19]$$

Then, if we take the power between f and f $+\delta f$, it is easily shown that there exists a relation

$$\delta\xi = \int_{-\infty}^{\infty} E(\ell)\, g_1(\ell)\, d\ell \qquad [20]$$

where

$$g_1(\ell) = 1 + 2 \sum_{n=1}^{12} \cos 2\pi \ell n D \qquad [21]$$

This function is plotted on Figure 6. This function is also periodic, but the next peaks are at ± s/12, corresponding to waves not greater than 2½ feet in length. Such waves are not expected to be of significant amplitude in the Seakeeping Basin.

The selectivity is also improved, as can be seen by the narrower peak of $g_1(\ell)$. The portion of the annulus which contributes to the integral in Equation [20] is

$$2\Delta\theta \approx 2 \sin^{-1} 0.45 / k_o s \qquad [22]$$

This is plotted on Figure 7.

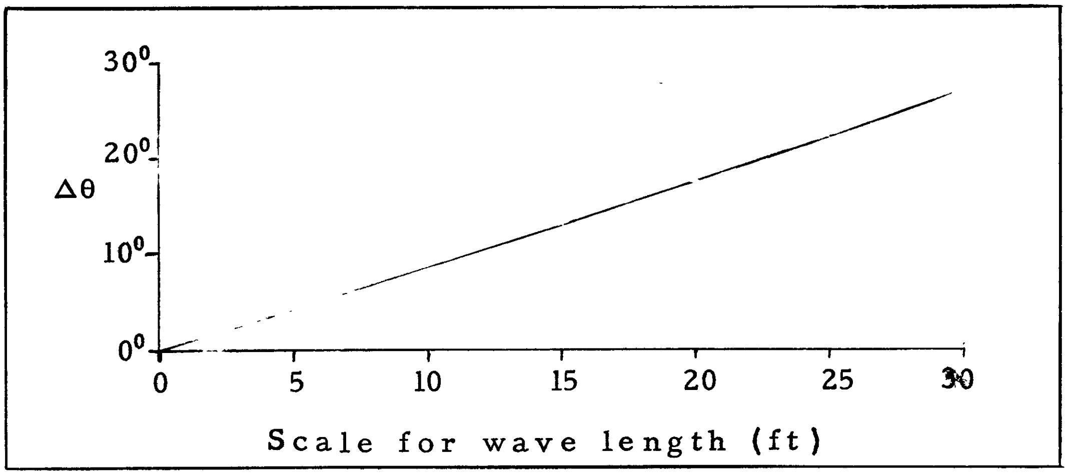

Figure 7 - Angular selectivity for optimum array, 30 feet long

The computation of E(0, m) is analogous to that in Equation [15]

$$E(0,m) = \delta\xi \Big/ \delta m \int_{-\infty}^{\infty} g(\ell)\, d\ell \qquad [23]$$

DISCUSSION

The advantages of the scheme which has been described are:

(1) It is simple in principle.

(2) The equipment required for the measurements is of conventional type and requires no extensive development.

(3) The determination of the directional spectrum depends upon measurements within a circle of a 15-foot radius of a selected position. This should be adequate at all positions except in the immediate neighborhood of the bank of wavemakers. This region is of only limited interest, since it will not be used for model tests.

(4) The equipment required for analysis is also available. (See the paper by Mr. Marks being given at this Conference.[6])

The disadvantages are:

(1) The array cannot distinguish between waves coming from the front and the rear. Therefore, since the array must be rotated to map the spectrum, serious errors may occur if the spectrum spreads beyond one quadrant in the (ℓ , m) plane.

(2) The angular discrimination is a function of frequency, and tends to be poor for longer waves. However, it is not anticipated that such waves will contain significant amounts of energy.

ACKNOWLEDGMENT

Although the author accepts complete responsibility for the presentation of the method given here, he wishes to make it clear that the ideas leading to this system are those of Mr. N. F. Barber. The scheme as presented by Mr. Barber has merely been modified to be compatible with the analysis capabilities of the Taylor Model Basin.

REFERENCES

1. Brownell, W. F., "A Rotating Arm and Maneuvering Basin," David Taylor Model Basin Report 1053 (July 1956) given at the American Towing Tank Conference, Sept 1956, included in Transactions of the 11th General Meeting of American Towing Tank Conference, David Taylor Model Basin Report 1099, Vol III (Sept 1957).

2. St. Denis, M., and Pierson, W. J., Jr., "On the Motion of Ships in Confused Seas," Trans. Society of Naval Architects and Marine Engineers, Vol. 61 (1953).

3. Chase, J., et al., "The Directional Spectrum of a Wind Generated Sea, as Determined from Data Obtained by the Stereo Wave Observation Project," New York University, College of Engineering, Research Division.

4. Barber, N. F., "A Review of Methods of Finding the Directional Spectrum of Water Waves in a Model Tank," David Taylor Model Basin Report 1363, (in review).

5. Marks, W., "The Use of a Filter to Sort Out Directions in a Short-Crested Gaussian Sea Surface," Trans. American Geophysical Union, Vol. 35, n 5 (Oct 1954).

6. Marks, W., and Strausser, P., "Reduction of Seakeeping Data at the David Taylor Model Basin," David Taylor Model Basin Report 1361 (July 1959).

INITIAL DISTRIBUTION

Copies	
3	CHBUSHIPS, Technical Information Section, (Code 335)
100	American Towing Tank Conference

David Taylor Model Basin. Report 1362.
DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN, by W.E. Cummins. For presentation to the 12th American Towing Tank Conference at the University of California, Berkeley, Calif., Sep 1959. July 1959. 19p. illus., charts, tables, diagrs.
UNCLASSIFIED

The method which the David Taylor Model Basin plans to use for measurement of directional spectra in the Seakeeping Basin is presented. This method makes use of a linear array of wave-height probes supported on a rotatable beam. For each orientation of the array, the spectrum along a line perpendicular to that orientation can be determined. A nonuniform arrangement of the wave probes along the beam is given which optimizes the directional selectivity of the array.

This procedure was selected from a comprehensive survey of various methods by N.F. Barber, of New Zealand.

1. Water waves – Measurement – Test methods
2. Maneuvering-seakeeping basins – U.S. – David Taylor Model Basin
3. David Taylor Model Basin – Test facilities
I. American Towing Tank Conference, 12th, Berkeley, Calif. 1959
II. Cummins, W.E.

David Taylor Model Basin. Report 1362.
DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN, by W.E. Cummins. For presentation to the 12th American Towing Tank Conference at the University of California, Berkeley, Calif., Sep 1959. July 1959. 19p. illus., charts, tables, diagrs.
UNCLASSIFIED

The method which the David Taylor Model Basin plans to use for measurement of directional spectra in the Seakeeping Basin is presented. This method makes use of a linear array of wave-height probes supported on a rotatable beam. For each orientation of the array, the spectrum along a line perpendicular to that orientation can be determined. A nonuniform arrangement of the wave probes along the beam is given which optimizes the directional selectivity of the array.

This procedure was selected from a comprehensive survey of various methods by N.F. Barber, of New Zealand.

1. Water waves – Measurement – Test methods
2. Maneuvering-seakeeping basins – U.S. – David Taylor Model Basin
3. David Taylor Model Basin – Test facilities
I. American Towing Tank Conference, 12th, Berkeley, Calif. 1959
II. Cummins, W.E.

David Taylor Model Basin. Report 1362.
DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN, by W.E. Cummins. For presentation to the 12th American Towing Tank Conference at the University of California, Berkeley, Calif., Sep 1959. July 1959. 19p. illus., charts, tables, diagrs.
UNCLASSIFIED

The method which the David Taylor Model Basin plans to use for measurement of directional spectra in the Seakeeping Basin is presented. This method makes use of a linear array of wave-height probes supported on a rotatable beam. For each orientation of the array, the spectrum along a line perpendicular to that orientation can be determined. A nonuniform arrangement of the wave probes along the beam is given which optimizes the directional selectivity of the array.

This procedure was selected from a comprehensive survey of various methods by N.F. Barber, of New Zealand.

1. Water waves – Measurement – Test methods
2. Maneuvering-seakeeping basins – U.S. – David Taylor Model Basin
3. David Taylor Model Basin – Test facilities
I. American Towing Tank Conference, 12th, Berkeley, Calif. 1959
II. Cummins, W.E.

David Taylor Model Basin. Report 1362.
DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN, by W.E. Cummins. For presentation to the 12th American Towing Tank Conference at the University of California, Berkeley, Calif., Sep 1959. July 1959. 19p. illus., charts, tables, diagrs.
UNCLASSIFIED

The method which the David Taylor Model Basin plans to use for measurement of directional spectra in the Seakeeping Basin is presented. This method makes use of a linear array of wave-height probes supported on a rotatable beam. For each orientation of the array, the spectrum along a line perpendicular to that orientation can be determined. A nonuniform arrangement of the wave probes along the beam is given which optimizes the directional selectivity of the array.

This procedure was selected from a comprehensive survey of various methods by N.F. Barber, of New Zealand.

1. Water waves – Measurement – Test methods
2. Maneuvering-seakeeping basins – U.S. – David Taylor Model Basin
3. David Taylor Model Basin – Test facilities
I. American Towing Tank Conference, 12th, Berkeley, Calif. 1959
II. Cummins, W.E.

David Taylor Model Basin. Report 1362.
DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN, by W.E. Cummins. For presentation to the 12th American Towing Tank Conference at the University of California, Berkeley, Calif., Sep 1959. July 1959. 19p. illus., charts, tables, diagrs.
UNCLASSIFIED

The method which the David Taylor Model Basin plans to use for measurement of directional spectra in the Seakeeping Basin is presented. This method makes use of a linear array of wave-height probes supported on a rotatable beam. For each orientation of the array, the spectrum along a line perpendicular to that orientation can be determined. A nonuniform arrangement of the wave probes along the beam is given which optimizes the directional selectivity of the array.

This procedure was selected from a comprehensive survey of various methods by N.F. Barber, of New Zealand.

1. Water waves – Measurement – Test methods
2. Maneuvering-seakeeping basins – U.S. – David Taylor Model Basin
3. David Taylor Model Basin – Test facilities
I. American Towing Tank Conference, 12th, Berkeley, Calif. 1959
II. Cummins, W.E.

David Taylor Model Basin. Report 1362.
DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN, by W.E. Cummins. For presentation to the 12th American Towing Tank Conference at the University of California, Berkeley, Calif., Sep 1959. July 1959. 19p. illus., charts, tables, diagrs.
UNCLASSIFIED

The method which the David Taylor Model Basin plans to use for measurement of directional spectra in the Seakeeping Basin is presented. This method makes use of a linear array of wave-height probes supported on a rotatable beam. For each orientation of the array, the spectrum along a line perpendicular to that orientation can be determined. A nonuniform arrangement of the wave probes along the beam is given which optimizes the directional selectivity of the array.

This procedure was selected from a comprehensive survey of various methods by N.F. Barber, of New Zealand.

1. Water waves – Measurement – Test methods
2. Maneuvering-seakeeping basins – U.S. – David Taylor Model Basin
3. David Taylor Model Basin – Test facilities
I. American Towing Tank Conference, 12th, Berkeley, Calif. 1959
II. Cummins, W.E.

David Taylor Model Basin. Report 1362.
DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN, by W.E. Cummins. For presentation to the 12th American Towing Tank Conference at the University of California, Berkeley, Calif., Sep 1959. July 1959. 19p. illus., charts, tables, diagrs.
UNCLASSIFIED

The method which the David Taylor Model Basin plans to use for measurement of directional spectra in the Seakeeping Basin is presented. This method makes use of a linear array of wave-height probes supported on a rotatable beam. For each orientation of the array, the spectrum along a line perpendicular to that orientation can be determined. A nonuniform arrangement of the wave probes along the beam is given which optimizes the directional selectivity of the array.

This procedure was selected from a comprehensive survey of various methods by N.F. Barber, of New Zealand.

1. Water waves – Measurement – Test methods
2. Maneuvering-seakeeping basins – U.S. – David Taylor Model Basin
3. David Taylor Model Basin – Test facilities
I. American Towing Tank Conference, 12th, Berkeley, Calif. 1959
II. Cummins, W.E.

David Taylor Model Basin. Report 1362.
DETERMINATION OF DIRECTIONAL WAVE SPECTRA IN THE TMB MANEUVERING-SEAKEEPING BASIN, by W.E. Cummins. For presentation to the 12th American Towing Tank Conference at the University of California, Berkeley, Calif., Sep 1959. July 1959. 19p. illus., charts, tables, diagrs.
UNCLASSIFIED

The method which the David Taylor Model Basin plans to use for measurement of directional spectra in the Seakeeping Basin is presented. This method makes use of a linear array of wave-height probes supported on a rotatable beam. For each orientation of the array, the spectrum along a line perpendicular to that orientation can be determined. A nonuniform arrangement of the wave probes along the beam is given which optimizes the directional selectivity of the array.

This procedure was selected from a comprehensive survey of various methods by N.F. Barber, of New Zealand.

1. Water waves – Measurement – Test methods
2. Maneuvering-seakeeping basins – U.S. – David Taylor Model Basin
3. David Taylor Model Basin – Test facilities
I. American Towing Tank Conference, 12th, Berkeley, Calif. 1959
II. Cummins, W.E.

MIT LIBRARIES DUPL
3 9080 02754 3385