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PRELIMINARY ANALYSIS OF BENDING-MOMENT DATA FROM SHIPS AT SEA

SSC-153

By

D. J. FRITCH, F. C. BAILEY AND N. S. WISE

SHIP STRUCTURE COMMITTEE

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December 27, 1963

Dear Sir:

One of the most critical needs in ship design is to learn the actual long-term stress history of ships. The Ship Structure Committee is currently sponsoring a project at Lessells and Associates, Inc., that is measuring the vertical bending moments on ocean-going ships.

Herewith is a copy of the second progress report, SSC-153, Preliminary Analysis of Bending-Moment Data from Ships at Sea by D. J. Fritch, F. C. Bailey and N. S. Wise.

The project is being conducted under the advisory guidance of the Ship Hull Research Committee of the National Academy of Sciences-National Research Council.

Please address any comments concerning this report to the Secretary, Ship Structure Committee.

Sincerely yours,

T. J. Fabik
Rear Admiral, U. S. Coast Guard
Chairman, Ship Structure Committee

SSC-153

Second Progress Report
of
Project SR-153
"Ship Response Statistics"

to the

Ship Structure Committee

PRELIMINARY ANALYSIS OF BENDING-MOMENT DATA FROM SHIPS AT SEA

by

D. J. Fritch
F. C. Bailey
and
N. S. Wise

Lessells and Associates, Inc.

under

Department of the Navy
Bureau of Ships Contract NObs-77139

Washington, D. C.
U. S. Department of Commerce, Office of Technical Services
December 27, 1963

ABSTRACT

Data playback, manual reduction and analysis techniques, and the automatic system to be used for future analysis are presented. Examples are given of some forms of presentation of long-term trends.

Useful data have been obtained on over 85% of voyages representing three ship-years of operation of a C-4 dry cargo vessel on North Atlantic trade routes. Two complete voyages have been analyzed using manual techniques and the results of this analysis are presented. The maximum observed peak-to-peak variation of wave-induced stress was 8300 psi which occurred during a Beaufort 11-12 Sea. A prediction based on the limited amount of long-term data available from the two analyzed voyages yielded an extreme value of 10,290 psi for a year of operation of this ship type on North Atlantic route. Stress variations on the order of 9,000 psi have been observed during the dry docking of the two instrumented ships.

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INTRODUCTION

"An Unmanned System for Recording Stresses and Accelerations on Ships at Sea", presents the background and objectives of Ship Structure Committee Project SR-153, "Ship Response Statistics" and describes the recording systems now in use. This report will briefly present the theoretical background for the reduction and analysis of data of this type, describe the playback, manual reduction and analysis of some of the data obtained to date, and, finally will describe the automatic data reduction system to be used in future analysis.

It should be clearly understood that data acquisition, reduction, and presentation are the tasks of this investigation; interpretation must be left to the Naval Architect. The overall objective in the portion of the program described herein has been to evolve techniques for future data reduction and presentation which will permit independent analyses by others and the prediction of long term trends and extreme values. In addition, this report will provide some preliminary information on long term trends, based on clearly stated assumptions and analytical techniques, only to demonstrate some possible forms of presentation.

THEORETICAL CONSIDERATIONS

General

It is not the intention, in this report, to perform complete derivations of the statistical bases for the reduction, analysis, and extrapolation of the bending-moment (stress) data. However, in summarizing the theoretical aspects, it is quite necessary that the present state of the art be placed in proper context, since the basis for the analysis is good, but has not definitely been proven to be exact. The discussion to follow in this section is based largely on the work of Bennet[1-3] and Jasper.[2-3]

The presentation will be based on consideration of peak-to-peak stress variation, x, (the vertical distance from crest to adjacent trough or trough to adjacent crest on an oscillographic record of stress signals). See Figure 1. Similar arguments can be used if the analysis is to be based on stress amplitudes (the vertical distance from mean to crest and mean to trough). The mean stress in this case would represent the still-water stress (or bending moment). However, since the sagging moment in a seaway is ordinarily greater than the hogging moment, the average value or mean level of an oscillograph record of the stress would be displaced in the sag direction. Since it is not practical to obtain the still-water stress at any given instant in time, and an extra operation is required to establish the average value, it is most convenient to deal with the peak-to-peak variations of stress.

All of the mathematical models applied to the statistical analysis of wave-induced bending moment in ships are identical to those used in describing wave systems. This is based on the theoretically reasonable, and increasingly well-documented assumption of linear dependence of bending moment on wave height. Most of the basic theory has therefore been the fruit of the oceanographers' efforts, but can be applied to wave-induced ship response (bending moment, acceleration, motions, etc.) with equal assurance.[1-2-3]

In dealing with the statistical description of ocean waves, it is convenient first to confine the analysis to a given wave system, i.e., a specified wind-generated sea. The statistical presentation of peak-to-peak wave-height variation can be thought of either as representing the variation at a certain point at different times in a specified (short) interval, or the distribution of peak-to-peak variations at a given instant in an area of the ocean where wind direction and strength are constant. In treating bending moment in a similar manner, it is necessary to add that direction and speed of the vessel must be constant, as well as the wave systems. The bending-moment data thus treated will be referred to as "short-term data". Data which embrace a variety of ship speeds, headings relative to the sea and/or wind, and sea states, will be considered "long-term data". The statistical basis for dealing with long-term data is more empirical than for short, but no less satisfactory on the basis of investigations to date.

For the purposes of this investigation, data obtained during a single recording interval (minimum of 30 minutes) will be assumed to qualify as "short-term data".

Short-Term Data

Figure 2 and Eq. 1 represent the basic Rayleigh distribution:

$$p(x) = \frac{2x}{E} e^{\frac{-2x}{E}} \qquad x \geq 0 \qquad (1)$$

where

$p(x)$ = probability density of x

x = the magnitude of a data sample (peak-to-peak stress or bending moment variation)

E = mean-square variation = $\frac{\Sigma x^2}{N}$

N = number of samples

The above expression for E assumes that all values of x are considered independently in the calculation of the mean square value of the variation. A more practical method of calculating E is to group the data samples into ranges of amplitude. The samples which fall in each range are then considered to have a magnitude equal to the mean value of the range into which they fall. Then,

$$E = \frac{\Sigma n_i X_i^2}{N}$$

where

X_i = the mean value of the i th range

n_i = the number of data samples which fall within the i th range.

N = the total number of samples = Σn_i

The Rayleigh Distribution is a single parameter distribution, since when E is known, the complete distribution can be established. This is the basic expression to be used in analysis of short-term data, with the following points in mind:

1. It is known that bending-moment (and sea) data do not exactly fit the Rayleigh distribution, nor is there a reason why they should.

2. The departure from the Rayleigh curve is slight.

3. A large amount of wave-height and bending-moment data show good agreement with Eq. (1).

In connection with the last comment above, it should be noted that the agreement becomes progressively less satisfactory at large values of the variate, for which proportionately less information is available. There thus appears to be every reason to justify the use of the Rayleigh function in the analysis of bending-moment data as long as the agreement is satisfactory, and/or until an equally satisfactory distribution (from the point of view of simplicity and ease of manipulation), which fits the data better, is developed.

The cumulative distribution of Eq. (1) is given by:

$$P(x) = 1 - e^{\frac{-x^2}{E}} \qquad (2)$$

where

$P(x)$ = Probability of the variation being less than x in the time interval.

The most probable maximum value (x_{MAX}) in a sample of N variations[4] is:

$$x_{MAX} = \sqrt{E \ln N} \qquad (3)$$

when N is large. For all samples to be considered in this investigation, this will be the case.

Long-Range Predictions

To have practical significance in ship design, it is apparent that time intervals will have to be considered which are far greater than the relatively short periods for which any given Rayleigh distribution will apply. Two approaches to the prediction of long-range extreme values have been suggested.

The first of these is proposed by Jasper.[2] He suggests, on the basis of data on waves and on ship response, that the log-normal distribution satisfactorily represents long-range ship response. Data from a variety of operating conditions for a given vessel, seem to fit this distribution well, but a fundamental difficulty exists. If the distribution is to be developed on the basis of about one ship year of operation, a total of more than a million counts would have to be stored and evaluated.

A simpler method uses the mean-square values from a number of short-term distributions as the basic units in developing a long-term distribution.[3] Studies to date indicate that a long-term collection of mean-square values of stress variation seem to follow the normal or log-normal distribution, with a better fit to the log-normal. It is therefore possible to plot the E values and, using appropriate risk factors and estimating the ship operating life, an "extreme" value of E is determined. From this E the most probable maximum value of stress can be established on the basis of an assumed or calculated period of time during which the extreme conditions exist.

A number of variations on this approach are discussed by Bennet and Jasper.[3] The variations involve the method of predicting the extreme value of stress or bending moment; in all cases the E values for a long period are compared to a log-normal distribution. The log-normal distribution is, of course, a two-parameter distribution and can be described in terms of the mean value of the logarithms of the values in the sample and the standard deviation of the logarithm. Since, in practice, the rms value of E is commonly used, the probability density would be given by:[2]

$$p(\sqrt{E}) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\log\sqrt{E} - \mu)^2}{2\sigma^2}} \qquad (4)$$

μ = mean value of log $\sqrt{E}$

σ = standard deviation of log $\sqrt{E}$

At the present time, it is felt that a log-normal comparison is the best starting point for long-range analysis. Initial attempts to compare the present data with the log-normal distribution will indicate if the log-normal assumption is justified or if some other distribution must be sought. Of course, the results will be most accurate only when a large amount of data has been compiled over a long period of time. Based on a limited amount of reduced data, this report attempts to point the direction toward a solution to the problem of long-range predictions.

Summary and Limitations

The statistical relationships in this report are summarized as follows:

FORMULAS

1. $p(x) = \frac{2x}{E} e^{\frac{-2x}{E}}$ (Describes the basic Rayleigh Distribution)

where

$p(x)$ = probability density of x

x = the magnitude of a data sample (peak-to-peak stress or bending moment variation)

E = mean-square variation = $\frac{\Sigma x^2}{N}$

(for classified data; $E = \frac{\Sigma n_i X_i}{N}$ where

X_i = mean value of the i range

n_i = number of samples in "i th" interval

N = total number of samples in all intervals ($=\Sigma n_i$)

2. $P(x) = 1 - e^{-x^2/E}$ (Is the cumulative distribution of 1)

where

$P(x)$ = probability of the variation being less than x in the time interval

3. $x_M = \sqrt{E \ln N}$

where

x_M = the most probable maximum value in a sample of N variations

N = total number of variations in the sample

4. $p(\sqrt{E}) = \frac{1}{x\sigma\sqrt{2\pi}} e^{\frac{-(\log\sqrt{E} - \mu)}{2\sigma^2}}$

(Describes the log-normal distribution of $\sqrt{E}$)

where

μ = mean value of log $\sqrt{E}$

σ = standard deviation of $\log \sqrt{E}$

5. $v^2 = \frac{x^2}{E}$

where

v = the normalized stress value

x = the peak-to-peak stress variation

E = the mean-square stress variation

6. $\sigma = \frac{1}{p} \sqrt{\frac{P(1 - P)}{N}}$

where

σ = the standard deviation

p = probability density

P = the cumulative probability

N = the sample size

7. $v_M = \frac{x_M}{\sqrt{E}}$

where

v_M = the normalized extreme value of stress

x_M = maximum peak-to-peak stress variation

$\sqrt{E}$ = root-mean-square (rms) stress variation

In the presentation of the data and analyses the following observations, reservations, limitations and/or premises should be borne in mind:

1. Environmental conditions (wave system, ship speed and heading, wind speed and direction, etc.) are assumed constant during each thirty-minute interval that data are being collected.

2. Average midship vertical bending-moment stress can be linearly related to midship bending moment by means of either a deduced or a calculated section modulus. Stress is the dependent variable on which data is obtained; bending moment is the variable of practical interest.

3. A Rayleigh distribution satisfactorily characterizes the distribution of stress levels in each recording interval. This will be verified from time to time, with particular emphasis on the character of the fit at the extreme of any given distribution, and on the distribution in intervals of very low or very high seas.

4. Low-frequency seaway-induced moments only are considered; slamming (whipping) stresses are excluded from the analysis.

5. The long-term distribution of E for a given ship on a given route is specifically applicable only to that ship (or ship-type) and route, and assumes that the data cover a truly representative sample of weather conditions on the route.

METHODS AND RESULTS OF MANUAL DATA ANALYSIS

General

Data have been gathered and analyzed from two C4-S-B5 dry-cargo vessels, the S. S. HOOSIER STATE and the S.S. WOLVERINE STATE, operated by the States Marine Line, Inc. of New York. The voyages of ships considered in this report took place on the North Atlantic. From all of the information obtained, two round-trip voyages and a portion of a third voyage have been selected and manually reduced to show the types of presentation that can be extracted from the data in forms useful for further analysis.

The completed data logs for voyage 124 of the S. S. HOOSIER STATE and voyages 170, 171, 172 and 173 of the S. S. WOLVERINE STATE are shown in Tables 1, 2, 3 and 4. (Note correction on voyage numbers in "Notes on Stress Data Reduction and Presentation" in the Appendix). Complementing the data log are results from the manual stress data reduction shown in Tables 5, 6 and 7.

Methods

Four forms of data presentation which are of special interest are extracted from the tabularized stress data. These are:

1. The experimental histogram and its associated Rayleigh distribution for several "short-term" data intervals.

2. The cumulative probability function for a "short-term" data interval.

3. The statistical scatter plot of normalized extreme-value data.

4. The log-normal plot for "long-term" stresses based on the two round-trips of the S. S. WOLVERINE STATE.

The methods for reducing the data to these forms are as follows:

Procedure for manual reduction of the stress data to histogram and Rayleigh distribution form

a. Using a graphic recorder (oscillograph), produce a visible record of the tape recorded data on which individual stress cycles can be observed. The calibration signal recorded on the tape provides the scale factor for the oscillogram.

b. Measure the peak-to-peak amplitudes of the individual stress cycles in a record period, and tabulate them in ranges. In the examples presented, ranges of 500 psi were used between 0 and 10,000 psi full scale. Note that in all intervals except the first, the range is indicated by its mean value so that the range of say 1500 psi extends from 1250 to 1750 psi, etc. The first range (500 psi) covers 0-750 psi.

Note: The peak-to-peak amplitude, or variation, of a stress cycle is defined as the vertical distance from a maximum positive value to the maximum negative value which follows a crossing of the mean level. Other small inflections are ignored, as well as any high-frequency components which might result from the ship's response to slamming.

c. Calculate the probability density of a given range in percent per 1000 psi by computing the percentage occurrence and multiplying this result by the ratio of the unit being considered (1000 psi = 1 Kpsi) to the range interval (500 psi).

$$\text{Probability Density} = \left(\frac{\text{Number of Counts in Range } (n_i)}{\text{Total Counts in Record (N)}}\right) \cdot \left(\frac{\text{Unit of Measurement}}{\text{Range Interval}}\right)$$

For example,

$$p = \frac{48}{354} \text{ X } \frac{1000}{500} = 0.135 \times 2 = 0.270 \text{ or } 27\% \text{ per Kpsi}$$

d. Tabulate the values of probability density in % per Kpsi for the corresponding ranges.

e. Plot the probability density against the corresponding range in the form of a bar graph. This is the required histogram for the record period being examined.

(i) The mean-square value and RMS (root-mean-square) values for a record period are calculated as follows:

(a) Calculate the mean-square value from the tabulation obtained under b above using the following formula:

$$E = \frac{\Sigma\, n_i X_i^2}{N}$$

where

E = Mean-Square Value

$\Sigma n_i X_i^2$ = Sum of the products of mean value within a range squared, multiplied by the number of counts in that range.

$= n_1 X_1^2 + n_2 X_2^2 + n_3 X_3^2 + \ldots.$

where

n_1 = number of counts in range 1

X_1 = mean stress level of range 1

N = total counts in record period = $\Sigma\, n_i$

Example:

Range (Kpsi)	Range^2 (Kpsi)	Counts	$n_i X_i$ (Kpsi)^2
0.5	.25	1	.25
1.0	1.0	2	2.0
1.5	2.25	4	9.0
2.0	4.0	2	8.0
2.5	6.25	1	6.25
3.0	9.0	0	0

$\Sigma n_i = N = 10 \qquad \Sigma\, n_i X_i = 25.50 \text{ (Kpsi)}^2$

$$E = \frac{\Sigma n_i X_i^2}{N} = \frac{25.5}{10} = 2.55 \text{ (Kpsi)}^2$$

(b) Calculate RMS value by extracting square root of mean-square value. Example:

RMS value = $\sqrt{E} = \sqrt{2.55} = 1.60$ Kpsi

(ii) The probability-density curve for the Rayleigh distribution may be calculated by substituting values for x in the formula

$$p(x) = \frac{2x}{E} e^{-x^2/E}$$

where E is the mean-square value calculated from the recorded data under (i)a above, e is the base of natural logarithms, and x is expressed in the same units of measurement employed above. The resultant values of the probability density p (x) will have units of percent per Kpsi in the examples given, and may be superimposed on the histogram produced above. In this manner, the actual stress distribution may be compared with that which would be obtained in a true Rayleigh distribution.

(iii) The maximum amplitude of variation for a record period may be picked off the oscillogram for the period. The most probable value of the maximum amplitude of variation for a given record period may be calculated using the approximate formula developed by Longuet-Higgins (On the Statistical Distribution of the Heights of Sea Waves, Journal of Marine Research, Vol. XI, No. 3, 1952, pp. 245-266):

$$x_M = \sqrt{E}\ \sqrt{\log_e N}$$

where E is the mean-square value developed above.

$\log_E N$ is the natural logarithm of the total number of counts in the record.

This approximate formula applies when N is large, e.g. N = 50 or greater. Figures 3 through 12 are the histograms and their associated Rayleigh function for 10 intervals of voyage 124 of the S. S. HOOSIER STATE developed by the above methods.

Procedure for presentation of cumulative probability for "short-term" statistical data

The cumulative probability distribution function offers an alternative method of presentation of the reduced statistical data. The values of probability density (p) and mean-square value E which were previously calculated in reducing the data to histogram form are used to calculate points on the cumulative distribution function. These points are then normalized and plotted along the normalized cumulative distribution function for all theoretical Rayleigh distributions. The normalized theoretical cumulative distribution function for a Rayleigh distribution can be represented by a straight line on semi-log graph paper.

Points can then be calculated from which curves representing confidence limits can be added to the presentation.

The procedures for calculating the normalized data points and applying the confidence limits are presented below.

As an example, the data used in developing Fig. 9 are reworked and presented in the form of points on a normalized Rayleigh cumulative distribution function along with curves representing 90% confidence limits. See Fig. 13.

(i) Steps in development of the cumulative-distribution function presentation.

(a) Given (from calculations used in developing histogram of Fig. 9).

$E = 7.61\ (\text{KPSI})^2$ Range Interval = 0.5 KPSI

Values of experimental probability density (p) in per KPSI for each range interval (X).

(b) Form the table on page 7. Enter the given values of range interval and probability density in the first and second column.

(c) Calculate values for third column by multiplying each value of p by the range interval 0.5. 0.5 x .046 = .023, etc. This quantity is available directly in the manual data reduction process as

$$\frac{\text{Number of Counts in Interval } (n_i)}{\text{Total Counts in Record } (N)}$$

(d) Calculate the values of the experimental cumulative probability (P) for column 4 by stepwise addition of the values in column 3. .023 + .166 = .189, .189 + .156 = .345, etc.

(e) Square each value in column 1 and

S. S. HOOSIER STATE

VOYAGE 124

RECORD INTERVAL 14-15 $E = 7.61\ (KPSI)^2$

X Range	Probability Density (per KPSI)	Ratio of Occurrence	P Cumulative Probability	X^2	$V^2 = \frac{X^2}{E}$ Normalized Variable
0.5	.046	.023	.023	0.25	.033
1.0	.332	.166	.189	1.0	.131
1.5	.312	.156	.345	2.25	.296
2.0	.292	.146	.491	4.0	.526
2.5	.280	.140	.631	6.25	.821
3.0	.288	.144	.775	9.00	1.28
3.5	.132	.066	.841	12.25	1.61
4.0	.118	.059	.900	16.00	2.10
4.5	.080	.040	.940	20.25	2.66
5.0	.052	.026	.966	25.00	3.28
5.5	.022	.011	.977	30.25	3.98
6.0	.028	.014	.991	36.00	4.73
6.5	.008	.004	.995	42.25	5.55

S. S. HOOSIER STATE

VOYAGE 124

RECORD INTERVAL 14-15 $E = 7.61\ (KPSI)^2$

X	V^2	p'	P	σ	1.65	$X+1.65\sigma$	$X-1.65\sigma$	$\frac{(X+1.65\sigma)^2}{E}$	$\frac{(X-1.65\sigma)^2}{E}$
0.5	.033	.127	.02	.0515	.085	.585	.415	.045	.0225
1.0	.131	.230	.12	.0675	.111	1.11	.888	.162	.104
1.5	.296	.295	.25	.0700	.115	1.62	1.38	.345	.250
2.0	.526	.312	.40	.0747	.123	2.12	1.88	.590	.465
2.5	.821	.288	.56	.0842	.139	2.64	2.36	.915	.732
3.0	1.28	.242	.725	.09	.1485	3.15	2.85	1.30	1.070
3.5	1.61								
4.0	2.10	.130	.877	.123	.203	4.20	3.80	2.32	1.9
4.5	2.66								
5.0	3.28	.048	.963	.187	.309	5.31	4.69	3.70	2.88
5.5	3.98								
6.0	4.73	.014	.991	.322	.531	6.53	5.47	5.60	3.93
6.5	5.55								

enter the result in column 5.

(f) Divide the values in column 5 by E to obtain the normalized variable $V^2 = X^2/E$ (column 6). 0.25/7.61 = .033.

(g) Plot the values of P (column 4) expressed as percentages against the normalized variable V^2 (column 6) on the normalized Rayleigh cumulative distribution (See Fig. 13).

(ii) Steps in development of confidence limits to be applied to the cumulative distribution. (In this example 90% confidence limits will be calculated.)

(a) Given (from calculations used in developing theoretical Rayleigh distribution of Fig. 2). E = 7.61 $(KPSI)^2$. Values of theoretical probability density (p') corresponding to values of X selected during calculation of points for theoretical Rayleigh curve. Plot of theoretical Rayleigh cumulative distribution function on semi-log paper.

(b) Form the table on page 7 by entering values for X and V^2 from the table developed in Section (i).

(c) Enter given values of p' in column 3.

(d) Enter in column 4 values of P' read from given semi-log theoretical Rayleigh plot corresponding to values of V^2 in column 2. Transform percentages to decimal equivalents.

(e) Calculate the standard deviation (σ) for each value of normalized variable V^2 by substituting in the formula,

$$\sigma = \frac{1}{p'} \sqrt{\frac{P'(1-P')}{N}}$$

The quantity N is the total number of counts in the data sample and is 422 for the record interval in this example.

$$\sigma = \frac{1}{.127} \sqrt{\frac{.02(1-.02}{422}} = .052$$

(f) Multiply the values (column 5) by 1.65 and enter in column 6. 1.65 X .052 = .086, etc.

Note: For other confidence limits the value of this multiplier will change, for example:

Confidence Limits (%)	Multiplier	Limits of X
67	1.0	$X \pm \sigma$
90	1.65	$X \pm 1.65\ \sigma$
95	1.96	$X \pm 1.96\ \sigma$
99	2.58	$X \pm 2.58\ \sigma$

(g) Form X + 1.65 σ and X - 1.65 σ, the upper and lower limits for the variable X, and enter these results in Columns 7 and 8 respectively.

$X + 1.65\ \sigma = 0.5 + .086 = .586$, etc.

$X - 1.65\ \sigma = 0.5 - .086 = .414$, etc.

(h) Normalize the values in Column 7 by squaring each value and dividing this result by E. Enter the results in Column 9.

$$\frac{(X + 1.65\ \sigma)^2}{E} = \frac{(.586)^2}{7.61} = \frac{.343}{7.61} = .045, \text{ etc.}$$

(i) Repeat Step E for the values in Column 8 and enter the results in Column 10.

$$\frac{(X - 1.65\ \sigma)^2}{E} = \frac{(.414)^2}{7.61} = \frac{.171}{7.61} = .0225$$

(j) Plot the normalized upper and lower limits (values in Columns 9 and 10) against the corresponding values of the theoretical cumulative probability (P' in Column 4) on Fig. 1. The result will be a number of points on either side of the theoretical Rayleigh line.

(k) Pass a smooth curve through the points to the left of the theoretical Rayleigh line. This forms the curve of the lower 90% confidence limit.

(l) Pass a smooth curve through the points to the right of the theoretical Rayleigh line to form the upper 90% confidence limit.

<u>Procedure for Obtaining Statistical Scatter Plots of the Normalized Extreme Value Data</u>

(a) The normalized extreme value (v_M) is calculated from the expression:

$$v_M = \left[\frac{(\text{Extreme Stress Variation})^2}{\text{Mean Square Stress Variation}}\right]^{\frac{1}{2}}$$

$$v_M = \frac{x_M}{\sqrt{E}}$$

This calculation of v_M is made for each interval.

(b) Plot v_M versus n, where n is the total counts for the v_M interval. The plot is constructed in the manner of Reference 3, Page IV-37. Figures 14 and 15 show the Statistical scatter for voyages 170 and 171 and voyages 172 and 173 of the S. S. WOLVERINE STATE, respectively.

<u>Procedure for Obtaining the "Long-Term" Cumulative Distribution of RMS Stresses in Log-Normal Form</u>

(a) The log-normal plot is developed on probability versus log scales where the ordinate is the probability (1-P), of exceeding a stated value in percent and the abscissa is the stated value of RMS stress $\sqrt{E}$ in Kpsi.

(b) To construct the plot, arrange the $\sqrt{E}$ values in order of ascending magnitude for all intervals of the various voyages.

(c) Select an $\sqrt{E}$ value and find the number of intervals containing this value or greater. Then, determine the ratio of this number of intervals to the total number of intervals in the population. This quantity x 100% is the probability (1-P) for the selected $\sqrt{E}$.

Example: From voyages 172 and 173 of the S. S. WOLVERINE STATE: RMS stress $\sqrt{E}$ was equal to or exceeded 2.0 Kpsi for 21 intervals (of 30 min each). The total number of intervals for the voyages (where satisfactory data were obtained) was 106, therefore

$$(1-P) = \frac{21}{106} \times 100\% = 19.8\% \text{ at } \sqrt{E} \geq 2.0 \text{ Kpsi}$$

In this manner the points are determined. For the log-normal plots presented here a best straight line was fitted to the points. A more rigorous method is to fit the line analytically and to truncate the data at a lower limit which may be determined by statistical methods.

Note that the probability, (1-P), distribution of $\sqrt{E}$ value is developed on the basis of time intervals rather than cycle counts. This is done for convenience since all the intervals considered are of equal length and because over a long period the operating conditions are more meaningfully described on a time basis.

Figures 16 and 17 are the long-term distribution in log-normal form for voyages 170 and 171 and voyages 172 and 173, respectively. Figure 18 is a plot of the data of both these voyages continued.

<u>Discussion</u>

In general, the results agree with the previously conducted studies.[1-3] The Rayleigh distributions fit the experimental histograms quite well. The scatter of the normalized extremes values are distributed within the confidence limits in a manner similar to the data of other investigations as reported in Ref. 5. The long-term data fit the log-normal line in about the same manner as Jasper and Bennet (See Ref. 3).

In practical utilization of the data, the Rayleigh distribution alone does not provide a great deal of usable information since it is representative of a small part of the whole picture, generated under a very specific set of constraints. It is useful though, as a building block in determining the form of long-term distribution from which maxima can be obtained.

To appreciate the manner in which the reduced data can be used to determine the most probable maximum value of peak-to-peak stress to be encountered during a given period, consider the following example:

Assume that a ship sails 24 hours per day, 20 days per month, which is a total time of 5760 hours in a year. During this year, the worst single variation of peak-to-peak stress that the ship encounters will be expected to occur during one of the four-hour periods represented by a 30-minute data sample. The probability of occurrence is then:

4/5760 = .00694 or .0694%

From the long-term data, for the combined voyages 170-173, of the S. S. WOLVERINE STATE (Figure 18), at (1-P) = .069%, $\sqrt{E}$ is 3.7 KPSI.

From the relationship,

$$x_M = \sqrt{E}\ \sqrt{\ln N}$$

x_M, the most probable maximum value can be determined. It remains then to calculate the value of N. From Ref. 3 and 4,

$$N = \frac{Y \cdot D \cdot 24 \cdot 3600 \cdot (1-P)}{T}$$

where

Y is the number of years

D is the number of days at sea per year

T is the period or mean between the periods of the shortest and longest waves

For 1 year,

$$N = (2.07 \times 10^7) \quad \frac{(1-P)}{T}$$

where

$(1-P) = 4/5760 = .000694$

The period T, is calculated from the relationship,

$$T^2 = \frac{L}{5.12}$$

where L is determined from,

$$\frac{1}{\sqrt{2}}\ \text{LBP} \le L \le \sqrt{2}\ \text{LBP}$$

(LBP is the Length Between Perpendiculars, in feet, of the ship.)

The LBP for the S. S. WOLVERINE STATE is 496.0 feet, then,

$$351 \le L \le 702$$

and from the above

$$8.26 \le T \le 11.8$$

or

$$T = \frac{11.8 + 8.26}{2} \approx 10 \text{ seconds}$$

then

$$N = \frac{(2.07 \times 10^7) \quad (6.94 \times 10^{-4})}{10} = 1435$$

With N and E determined, the most probable maximum value is,

$$x_M = \sqrt{E}\ \sqrt{\ln N} = 9.95 \text{ KPSI (PEAK-TO-PEAK)}$$

This indicates, on the basis of the limited data available, that a C-4 type ship sailing in the North Atlantic for 1 year will probably not encounter a peak-to-peak stress variation greater than 9.95 Kpsi. From the two months of data that have been reduced, representing two of the worst months of the year, maximum observed value of stress was 8.30 Kpsi in interval 61-62 of voyage 173 of the S. S. WOLVERINE STATE during a Beaufort sea state of 10-12. During drydocking, the S. S. HOOSIER STATE was subjected to a change of stress of 9.0 Kpsi from the still water value to dry-on-blocks condition. The predicted maximum value is, for the set of conditions under which these data were gathered, about 1.2 times greater than the maximum encountered during the voyages and about 1.1 times the stress encountered during drydocking operations.

The calculation of N above is based on the assumption that the worst stress is induced by waves of length about equal of ship length (.707 to 1.414 times ship length). Based on experience to date, the number of wave encounters has, in general, been greater than the N predicted above. For instance, during the interval cited (61-62, Voyage 173), 908 cycles of stress occurred during 80 minutes of recording time. This would imply a total of 2700 cycles in 4 hours.

Using $N = 2700$, and $\sqrt{E} = 3.7$ Kpsi

$$x_M = 10.29 \text{ Kpsi}$$

Even taking $N = 4000$, $x_M = 10.66$ Kpsi.

Thus multiplying the anticipated number of cycles by a factor of nearly 3 results in only a 7% increase in most probable maximum stress variation.

Caution should be exercised in using a value of x_M as the basis for a final design stress, since, as can be seen from Fig. 14 and 15, another probability must be introduced. This is related to the frequency of occurrence of a maximum value as compared to the most probable maximum. One way to side step this issue is to note that the high 99.8% bound in the figures is nearly constant at $\frac{x_M}{\sqrt{E}} = 4.0$. In the above case with $\sqrt{E}$ = 3.7 Kpsi, $x_M(99.8\%)$ = 4(3.7) = 14.8 Kpsi. Care must be used in compounding probabilities, however, a direct approach based on Gumbel's theory of extreme values[6] is being explored. Basically, this method would utilize the maximum variation in each interval as input and permit direct predictions of maxima to be expected over long intervals. The data reduced here are basic examples of the types of presentation that can be obtained from the information gathered. These results represent only a preliminary attempt to show what can be achieved. The studies will be continued to expand accuracies and to provide a more sound basis for long-range predictions.

MACHINE DATA REDUCTION

General

One of the principal reasons for selecting a magnetic tape data recording system was the opportunity of using high-speed computing machines for data reduction and analysis. Such equipment could also perform a number of tasks such as derivation of power spectral density data, which are not practical to obtain using manual data reduction. It was desired that the following information be supplied for each record interval:

1. Probability density of peak-to-peak variations (probably as the number of occurrences in each of a number of preselected ranges).

2. Number of occurrences in the interval.

3. Mean square (E).

4. Duration of interval.

5. Maximum variation in interval.

Early in the program, it was decided that power spectral density should not be given serious consideration in the primary data reduction problem.

Two general types of devices (digital and analog) were available at the time the problem was first considered. The general features of these classes of units will be discussed below. It should be borne in mind that the state of development of both generalized and special purpose digital and analog devices is quite rapid at the present time. Consequently, some of the original considerations were invalid in a short while, and the present picture will undoubtedly be altered in a few months. It has been necessary, however, to reach a decision on data reduction on the basis of the best available information at the time, and to proceed with the acquisition of services or equipment accordingly.

Digital Computer

The use of a generalized digital computer in the analysis of a collection of analog data requires two preliminary steps:

1. The data must be placed in digital form.

2. The digital form must match the format or language of the computer.

Digitizing the data and placing it on punched cards or tape, or magnetic tape, can be accomplished quite readily. Language conversion equipment is not usually available at computing centers. This situation is improving at the present time as techniques are being developed whereby small desk-type computers are being used as language conversion units to prepare data for ingestion by much larger devices.

Although the generalized digital computer possesses the very attractive advantage of complete flexibility in selection of analysis program, it was decided that this class of device was not promising. The greatest objection was the fact that one or more intermediate processing steps, which probably could not be performed at the computing center, would be required. In addition, the total cost of extracting even the basic statistical information from a record interval was excessive.

Analog Computer

Compared to digital computation, the use of analog devices would be expected to result in less precision, higher speed, and, of course, less flexibility in data reduction. Once the device was purchased or constructed, data reduction costs would be quite nominal compared to digital analysis.

A probability distribution analyzer was available on the market at the time this problem was being considered. This instrument was capable of measuring the time interval during which the variable remained above a preset level during a given analysis period and could determine the cumulative probability distribution function of instantaneous value above a reference value. The unit could be adapted by the addition of a "sample and hold" device to determine the peak-to-peak distribution function. The sample and hold device had been supplied for operation on high-frequency data, and with a small amount of development could be adapted to data in the 14 to 50 cps range.

Specialized analog equipments for probability distribution and spectral density analysis of tape recorded data have been built from standard components by the NASA at Langley Field, Virginia. These equipments are described in the paper "Analog Equipment for Processing Randomly Fluctuating Data" by Francis B. Smith, IAS Preprint 545, 1955. Although results are degraded somewhat in precision compared to that attainable with digital computation, this equipment can operate at higher speed with reasonable accuracy based on the statistical nature of the data and at the same time eliminate the need for conversion of the data to digital form.

The use of a larger data sample tends to enhance the accuracy attainable with either computational scheme. In the overall picture, accuracies of 0.1% in the computations are not warranted. Accuracies of 1, 2, 5, or even 10% may be considered to be adequate. On the face of it, analog computation could cut calculation time by a factor of four and possibly more, with equipment which represents a reasonable purchase for a long-term project.

Based on these considerations, the acquisition of a special-purpose analog data reduction unit was recommended. This device, which is scheduled for delivery at the time of this writing, will be briefly described in the section following.

The Sierra Probability Analyzer

The probability analyzer manufactured by Sierra Research Corporation of Buffalo, New York, will accept the output of the present tape reproduction system after filtering to remove slamming signals. By the use of digital peak detectors, level counts would be detected and stored in a series of sixteen counters. Either peak-to-peak, or positive and negative amplitudes can be detected. Storage continues until either the record interval has been completed or until a preset number of peak-to-peak counts has been acquired. At this time the system automatically stops the analysis and provides for a readout cycle directly on a strip-chart recorder.

The information readout on the strip-chart recorder (as sequential signal levels, with appropriate calibrate and zero signals) includes the outputs of the 16 level occurrence counters (thus giving a complete histogram of number of occurrences versus signal level), the total number of counts, the mean value of the peak-to-peak signal level, the mean square value, the time duration of the analysis cycle, and the maximum peak-to-peak amplitude encountered during the interval under investigation. See Fig. 2. The unit then indexes automatically to the beginning of the next succeeding record, proceeds through the analysis portion of the cycle, and moves directly to the readout cycle. The statistical data are therefore available on the chart record in a form which permits a check of the fit of the recorded data with the theoretical distributions, and all other parameters required for future extreme value predictions are immediately available.

One of the biggest advantages of the Sierra unit is that the data will be played back at approximately 50 times real time. Thus, for each 160-hour tape, something over 3 hours of actual data analysis time will be required on the instrument. Estimates indicate that compared to manual or digital computer data reduction, the Sierra unit will pay for itself in the reduction of approximately two channel years of data.

The Sierra unit will be used for the reduction of all data now on hand and forthcoming. Cross checks between the automatic reduction and manual reduction of the voyages reported herein will permit evaluation of both procedures.

ACKNOWLEDGMENT

This project is sponsored by the Ship Structure Committee and is under the advisory guidance of the Committee on Ship Structural Design of the National Academy of Sciences-National Research Council. The assistance of the Project Advisory Committee, with Dr. C. O. Dohrenwend as Chairman, is gratefully acknowledged.

APPENDIX

NOTES ON STRESS DATA REDUCTION AND PRESENTATION

VOYAGE NUMBERS - The shipping line changed the voyage numbers for the first instrumented round trip of the S. S. WOLVERINE STATE after the voyages had been completed. The original numbers were voyages 172 and 173. The new numbers are voyages 170 and 171. Thus, the log book data labeled voyage 172 corresponds to the reduced data labeled voyage 170 and log book data labeled voyage 173 corresponds to the reduced data labeled voyage 171.

INTERVAL NUMBERS - The interval number indicates that the recorded data occurred between the specified two entries in the data log book.

SEA STATE NUMBERS - The sea state numbers are the Beaufort Numbers as described in "Table of Sea States Correspond to Beaufort Wind Scale."

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1. Bennett, R., "Stress and Motion Measurements on Ships at Sea," The Swedish Shipbuilding Research Foundation (Report No. 13), 1958.

2. Jasper, N. H., "Statistical Distribution Patterns of Ocean Waves and of Wave-Induced Ship Stresses and Motion with Engineering Applications," Trans. SNAME, Vol. 64 (1956).

3. Jasper, N. H. et al., "Statistical Presentation of Motions and Hull Bending Moments of Essex Class Aircraft Carriers." Washington, D. C.: David Taylor Model Basin (Report 1251), June 1960.

4. Longuet-Higgins, M. S., "On the Statistical Distribution of the Heights of Sea Waves," Journal of Marine Research, 11:3 (1952).

5. Jasper, N. H. et al., "Response to Wave Loads." Washington, D. C.: David Taylor Model Basin (Report 1537), June 1961.

6. Gumbel, E. J., "Statistical Theory of Extreme Values and Some Practical Applications," National Bureau of Standards (Applied Mathematics Series Report), February 1954.

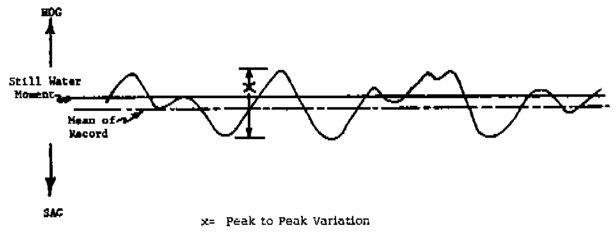

FIG. 1. SKETCH OF TYPICAL BENDING MOMENT RECORD.

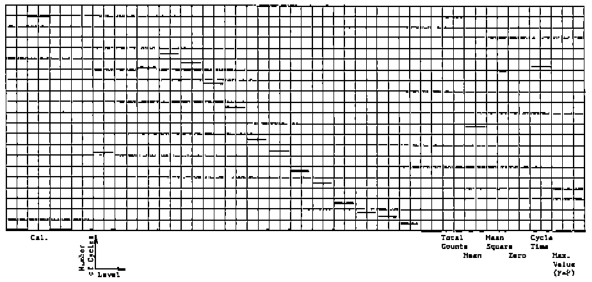

FIG. 2. SKETCH OF DATA READOUT RECORD. (ILLUSTRATING TYPICAL HISTOGRAM)

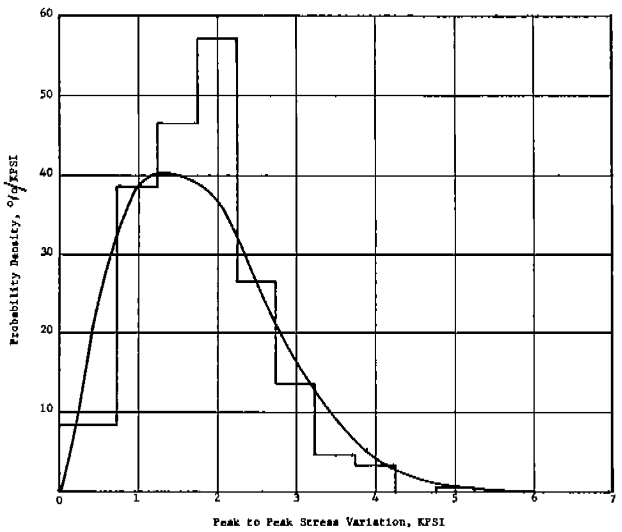

FIG. 3. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 4-5; E = 3.95 (S. S. HOOSIER STATE - VOYAGE 124)

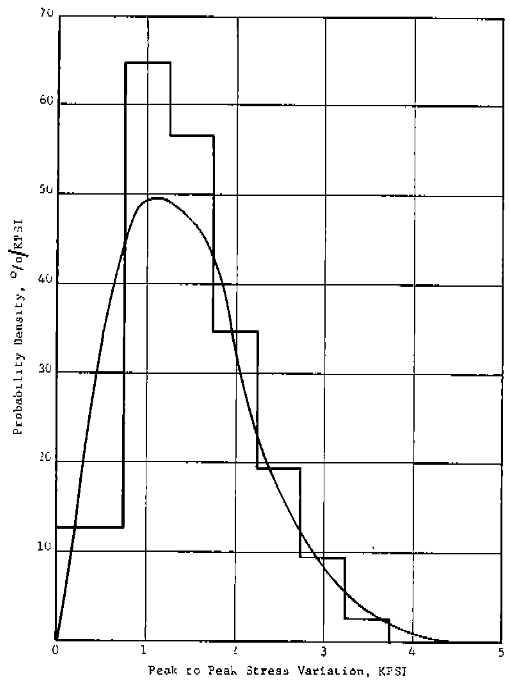

FIG. 4. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 5-6; E = 2.86 (S. S. HOOSIER STATE - VOYAGE 124)

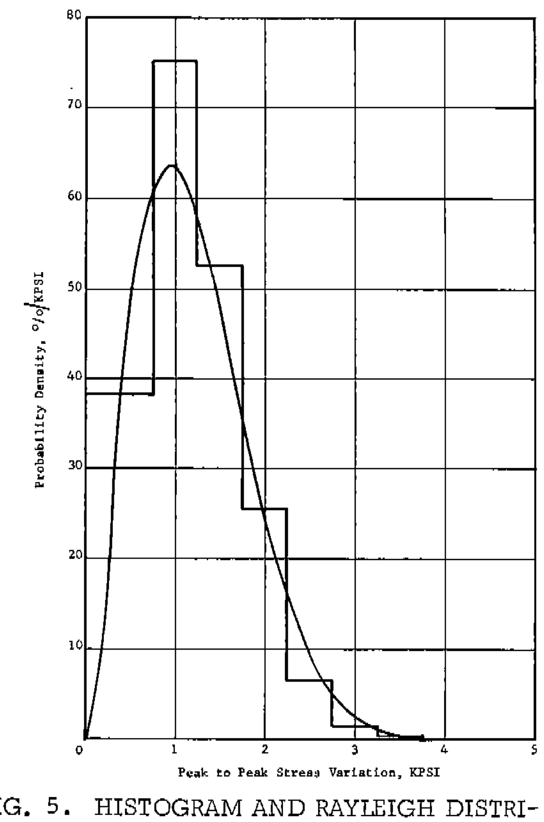

FIG. 5. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 6-7; E = 1.82 (S. S. HOOSIER STATE - VOYAGE 124)

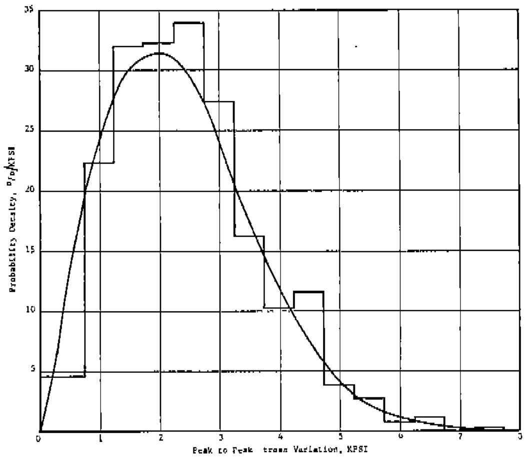

FIG. 6. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 11-12; E = 7.4 (S. S. HOOSIER STATE - VOYAGE 124)

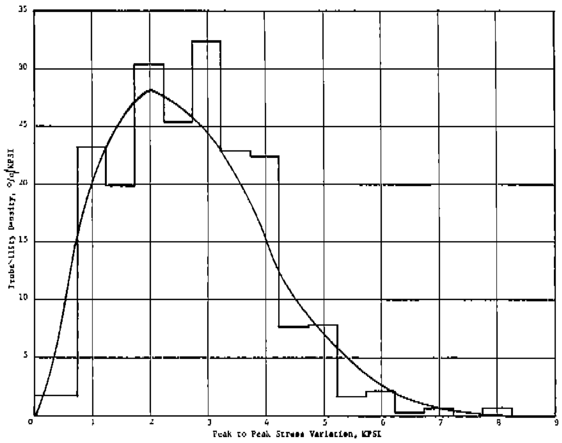

FIG. 7. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 12-13; E = 9.28 (S. S. HOOSIER STATE - VOYAGE 124)

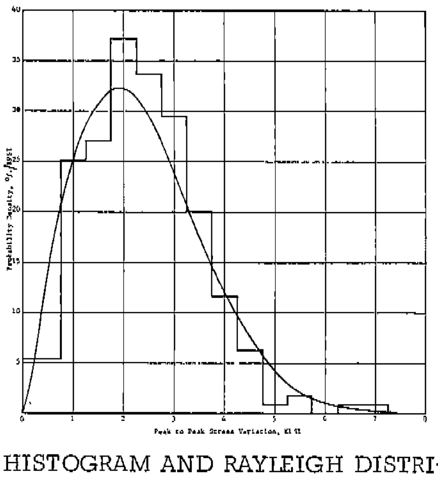

FIG. 8. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 13-14; E = 7.09 (S. S. HOOSIER STATE - VOYAGE 124)

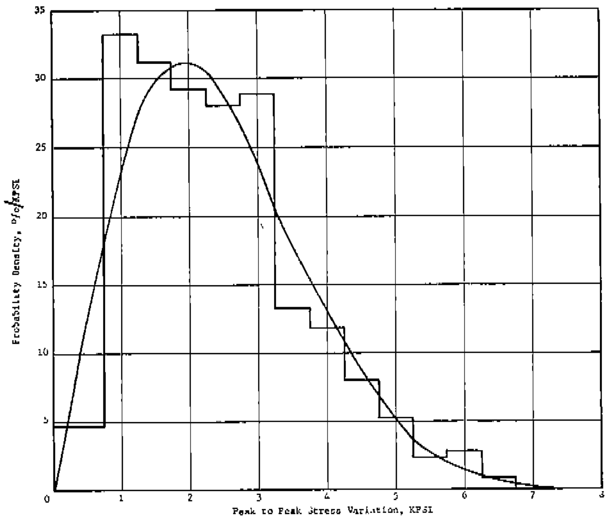

FIG. 9. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 14-15; E = 7.61 (S. S. HOOSIER STATE - VOYAGE 124)

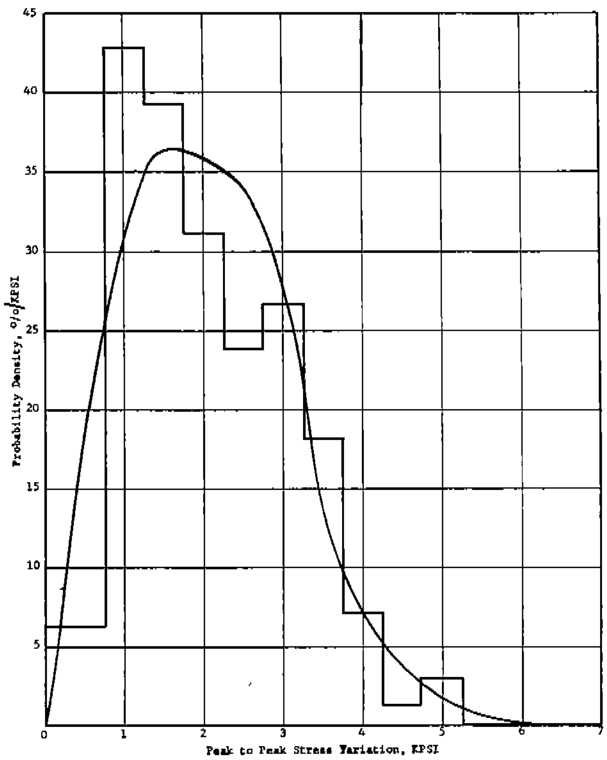

FIG. 10. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 15-16; E = 5.49 (S. S. HOOSIER STATE - VOYAGE 124)

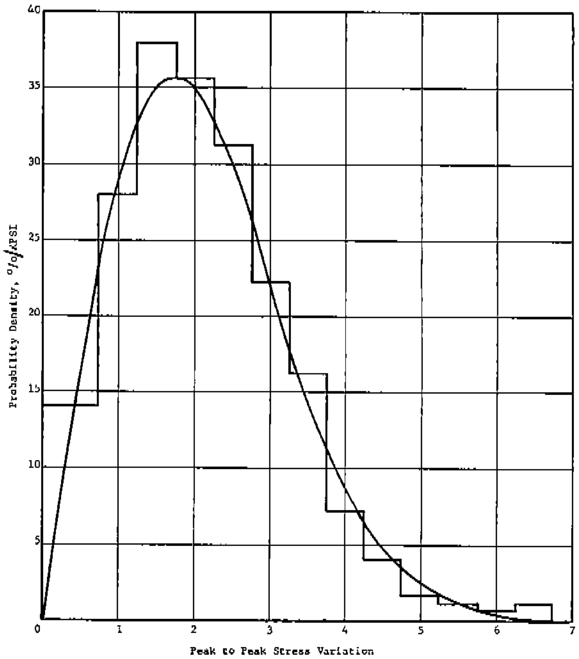

FIG. 11. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 16-17; E = 5.74 (S. S. HOOSIER STATE - VOYAGE 124)

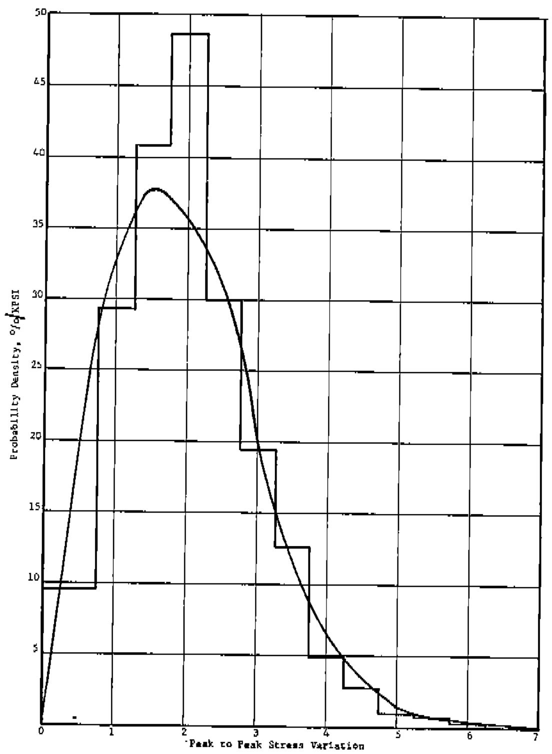

FIG. 12. HISTOGRAM AND RAYLEIGH DISTRIBUTION RECORD INTERVAL 17-18; E = 5.09 (S. S. HOOSIER STATE - VOYAGE 124)

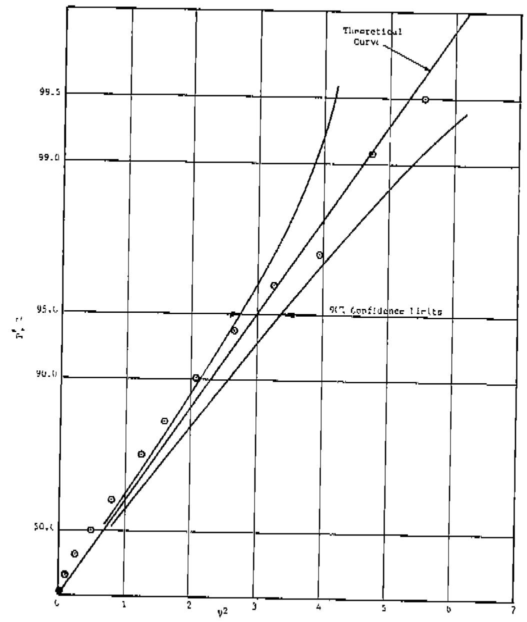

FIG. 13. CUMULATIVE PROBABILITY RECORD INTERVAL 14-15; E = 7.61 (S. S. HOOSIER STATE - VOYAGE 124)

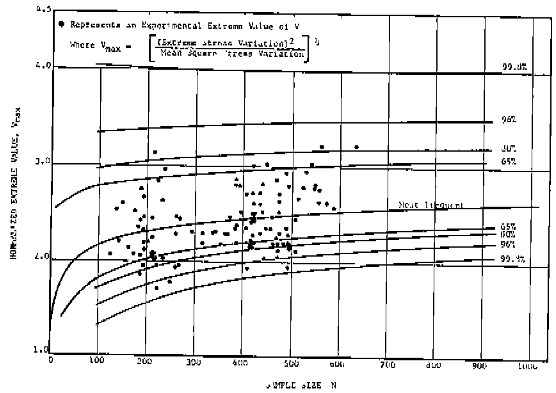

FIG. 14. S. S. WOLVERINE STATE - SCATTER OF OBSERVED EXTREME STRESS VALUES FROM DATA OF VOYAGES 170 and 171.

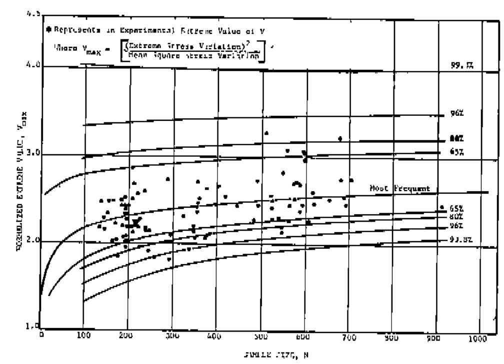

FIG. 15. S.S. WOLVERINE STATE - SCATTER OF OBSERVED EXTREME STRESS VALUES FROM DATA OF VOYAGES 172 AND 173.

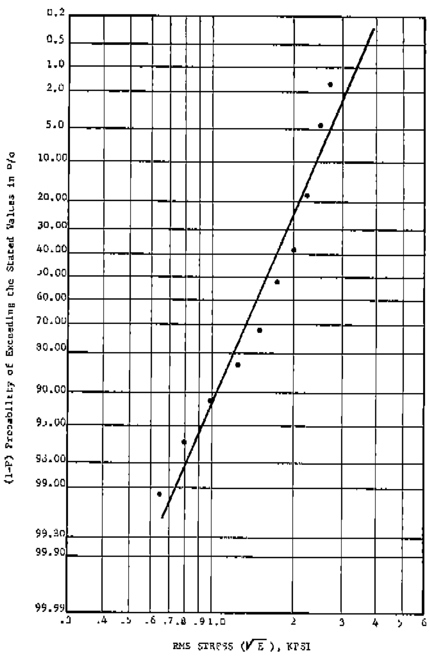

FIG. 16. LOG-NORMAL DISTRIBUTION OF $E^{\frac{1}{2}}$ VALUES (S. S. WOLVERINE STATE - VOYAGES 170 AND 171)

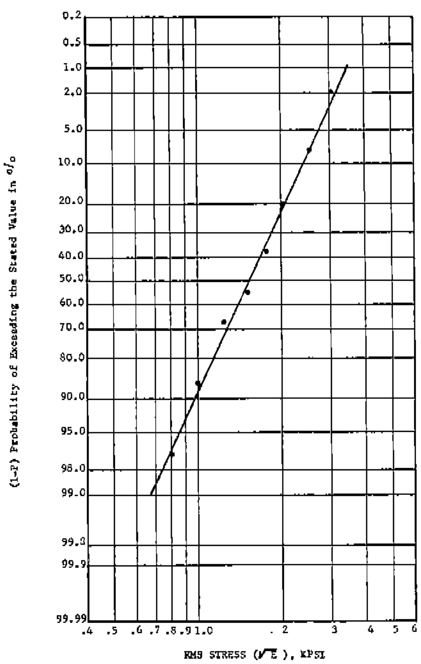

FIG. 17. LOG-NORMAL DISTRIBUTION OF $E^{\frac{1}{2}}$ VALUES (S. S. WOLVERINE STATE - VOYAGES 172-173)

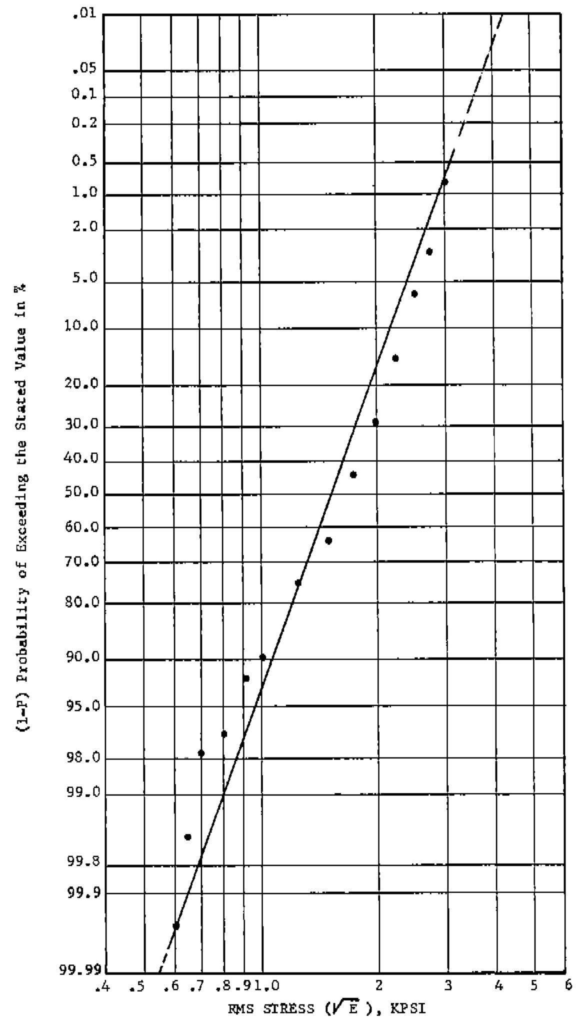

FIG. 18. LOG-NORMAL DISTRIBUTION OF $E^{\frac{1}{2}}$ VALUES (S. S. WOLVERINE STATE - COMBINED VOYAGES 170, 171, 172, 173)

TABLE 1. SS HOOSIER STATE DATA LOG--VOYAGE 124 WEST-SOUTHAMPTON TO NEW YORK/NORFOLK, D

			SHIP							WIND					SEA						
Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	Position (twice daily min.) Lat.	Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	Wind Speed	Wind Dir.	Wind Descr.	Weather	Initials	Sea State	Direction of Advance Rel. Ship	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Swell	Sea Photo No.
1	2000 12-11-60	317	South Hampton		At dock			43	42/41	Lt Airs			O'cast	DD	Calm	alongside dock no sea and [illegible]					
2	0020 12-12-60	0069.7	50.5	2.1	247	17	93.5	51	42/42	2	S	Light Breeze	O'cast rain	DD	Slight	280	2	2	3	nil	
3	0400 12-12	00966	START OF ENGLISH CHANNEL		247	16	94.3	53	45/43	3	SW	"	"	[illegible]	slight	245	2	2	3	0	
4	0900-12-12-60	129.7	49.6 N ENGLISH CHANNEL	5.1 W	247°	16.5	93.6	54	47/45	5	SW	"	LIGHT RAIN OCAST	[illegible]	SLIGHT	340	3	3/5	5	LONG LOW [illegible]	
5	1300-12-12-60	0161.3	49.2 N	6.9 W	247	16.0	89.3	55	51/49	10	NNE	Gentle Breeze	Cloudy	[illegible]	Slight	140	4	4/5	15	long low	
6	1500 12-12	0193.0	48.7 N	8.6 W	247	16.6	92.3	52	52/50	10	NE	gentle Breeze	partly cloudy	[illegible]	slight	045	3	2-5	16	LOW NLY	
7	2100-12-12-60	225.3	48.1 N	9.8 W	225	16.5	94.3	51	51/47	09	SExE		MOSTLY CLOUDY	[illegible]	SLIGHT	270	2	2/5	4	LONG AVERAGE	
8	0100-12-13-60	02670	47.2 N	10.8 W	205	17.0	96.3	52	52/49	18	S	Strong Breeze	Partly Cloudy	[illegible]	rough	345	7	4/6	10	Large SW	
9	0500-12-13	0312.0	46.3 N	11.5 W	205	16	94.1	53	51/50	21	S	Fresh Breeze	Clear	[illegible]	more rough	180	5	5-7	15	Med Wly	
10	0900 12-13-60	03519	45.3 N	12.2 W	205	16	93.9	53	50/49	21	SSW		RAIN O'CAST	[illegible]	MOD	340 TO 090	8	5/7	20	LONG-LOW	
11	1300 12-13-60	03853	44.5	13.1 W	185	16	94.3	55	54/46	47	NW	Strong Gale	Cloudy	[illegible]	High	135	19	10/12	30	Large NW	
12	1700 12-13-60	04160	44.2 N	13.4 W	270	5	72.2	55	60/46	55	NW	FULL GALE	CLOUDY	[illegible]	Very Rough	135	25-30	7-9	30	High NW	
13	2100 12-13-60	0520	43.4 N	13.5 W	185	15.5	84.1	56	51/49	60	NW	WHOLE GALE	RAIN	[illegible]	High	135	25/30	7/9	30	Long HEAVY NW	[illegible]
14	0120 12-14-60	0593.0	42.2 N	13.7 W	195°	15	89.3	56	53/49	49	NNW	Strong gale	Partly Cloudy	[illegible]	High	150	22	11/12	35	Very Large NNW	
15	0440 12-14-60	0628	40.6 N	14.5 W	215	15	89.2	60	53/49	27	N	STRONG BREEZE	partly cloudy	[illegible]	ROUGH	150	15	5-7	20	High Nly	
16	1000-12-14-60	6948	40.8 N	15.2 W	270	14.0	82.1	60	54/50	32	NNE	GALE	CLOUDY RAIN	[illegible]	Very Rough	090	15/18	7	30	LONG Heavy [illegible]	
17	1400 12-14-60	0734.4	40.7 N	16.0 W	252	14.0	88.6	58	56/52	21/32	NNW	Gale	Rain Cloudy	[illegible]	Very Rough to Rough	170	19	10	40	Heavy NNW swell	
18	1800 12-14-60	0778	40.6 N	17.2 W	273	15	82.1	60	56-51	21	N	FRESH BREEZE	SPRINKLES [illegible]	[illegible]	ROUGH	170	15	9	30	HEAVY NNW	

TABLE 2. SS WOLVERINE STATE DATA LOG--VOYAGE 170 EAST-NORFOLK/NEW YORK TO ROTTERDAM, DEC

			SHIP							WIND					SEA						
Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	Noon Position Lat.	~~(in.)~~ Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	Knots Wind Speed	True Wind Dir.		Weather	Initials	Bowditch page 1059 Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Estimate average length in feet & true direction Swell	Sea Photo No.
1	0500 12/19/61	0060.2			075	—	80.1	48	44/42	10	NE		overcast	[illegible]	3	045	3-4	5	50	350/180	
2	0900 12/19/61	0093.3			074	15.0	79.6	54	49/47	9	NExE		Overcast	[illegible]	3	045	3-4	5-6	50	400/180	
3	1300 12/19/61	0127.7			074	16.6	80.1	52	51/48	8	NNE		cloudy	[illegible]	3	025	3/5	5	30	300/180	
4	1700 12/19/61	0161.1	37°47'N	71°38'W	075	16.0	81.2	58	56/53	8	ENE		overcast	[illegible]	3	065	3/5	5/6	50	400/180	
5	2100 12/19/61	0191.5			075	15.5	82.0	64	58/55	8	E		Cloudy	[illegible]	3	090	3/4	5	40	400/030	
6	0100 12/20/61	0226.6			075	15.8	81.2	60	59/56	8	S		partly cloudy	[illegible]	3	180	4/5	5	30	250/200	
7	0500 12/20/61	0258.3			075	16.5	81.1	62	59/57	10	SSE		mostly cloudy	[illegible]	3	155	2/4	5	50	300/180	
8	0900 12/20/61	0291.5			075	16.1	81.1	64	60/58	10	SE		mostly cloudy occ. rain	[illegible]	3	130	2/4	5	30	350/050	
9	1300 12/20/61	0325.5	39°39'N	63°30'W	075	16.6	81.1	70	64/61	21	W		Cloudy [illegible] rain	[illegible]	5	170	4/6	9	40	400/185	

TABLE 2. SS WOLVERINE STATE DATA LOG--VOYAGE 170 EAST-NORFOLK/NEW YORK TO ROTTERDAM, DEC

	SHIP									WIND				SEA						
Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	Noon Position Lat.	Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	Knots Wind Speed	True Wind Dir.	Weather	Initials	Swell/Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Estimate average length in feet and true direction: Swell	Sea Photo No.
10	1700 12/20/61	0356.6			075	16.6	80.9	58	60/55	24	W	Partly Cloudy	[illegible]	6	270	3/5	7	40	350/200	
11	2100 12/20/61	0372.5			075	17.0	82.3	65	60/55	20	W	Partly Cloudy	PW	5	270	4/6	9	45	350/270	
12	0040 12/21/61	0399.7			075	18.0	81.7	62	60/54	18	WxN	Partly Cloudy	R.A.J.	5	285	5/7	9	60	500'/270°	
13	0420 12/21/61	0424.5			075	18.0	81.5	64	59/53	22	WxN	Partly Cloudy	[illegible]	5-6	280	5/8	9-10	60	400/270	
14	0800 12/21/61	0456.2			075	17.2	82.0	64	58/50	23	WxN	Partly Cloudy	PW	6	280°	6/8	9-10	60	500/270	
15	1200 12/21/61	0489.2	41°13'N	55°38'W	075	15.1	81.8	60	55/51	25	W	Partly Cloudy	R.A.J.	6	270°	7/9	9-12	60	500'/290°	
16	1600 12/21/61	0523.3			075	16.0	81.8	62	55/49	23	WxN	Mostly Cloudy	[illegible]	6	260°	7/8	9-12	60	[illegible]/290	
17	2000 12/21/61	0556.5			075	15.2	82.2	54	52/49	22	NW	Mostly Cloudy	PW	6	310°	7/8	9-10	60	500/270	
18	2340 12/21/61	0589.0			075	16.4	81.6	50	46/42	22	NW	scattered clouds	R.A.J.	6	320	5/8	8-10	60	500'/290°	
19	0320 12/22/61	0621.6			075	16.5	81.5	48	45/41	24	NW	Partly Cloudy	[illegible]	6	315°	6/8	9-11	60	500/290	
20	0700 12/22/61	0653.0			075	17.0	81.8	43	40/38	22	WxN	Partly Cloudy	PW	6	280°	6/8	8-10	60	500/290°	
21	1100 12/22/61	0685.7			075	15.5	81.5	42	40/38	22	WxN	Partly Cloudy	R.A.J.	6	280°	5/8	8-10	60	500'/290°	
22	1500 12/22/61	0719.7	42°52'N	46°50'W	075	17.0	81.7	59	45/40	22	WNW	Partly Cloudy	[illegible]	6	290°	6/8	8-10	60	[illegible]/290°	
23	1900 12/22/61	0752.7			075	17.0	81.5	61	47/43	23	W	Mostly Cloudy	PW	6	270°	6/8	8-10	60	500/300	#1 and #2
24	2240 12/22/61	0784.9			075	16.0	81.1	60	48/44	18	WNW	Cloudy	R.A.J.	5	290	5/7	7-9	50	500/[illegible]	
25	0220 12/23/61	0815			076	16.0	81.4	62	48/43	18	WNW	Mostly Cloudy	[illegible]	5	290°	5/7	7-9	50	[illegible]/270°	
26	0600 12/23/61	0848.8			076	16.5	81.6	58	49/44	18	WNW	Mostly Cloudy	PW	5	290°	5/7	7-9	50	500/310°	
27	1000 12/23/61	0881.4			076	16.5	81.2	60	50/45	18	WNW	Cloudy	R.A.J.	5	290°	5/8	7-9	50	550'/320°	
28	1400 12/23/61	0915.3	44°35'N	38°44'W	076	16.5	81.4	62	49/45	18	WNW	Mostly Cloudy	[illegible]	5	290°	6/8	7-9	50	500/320°	
29	1800 12/23/61	0948.8			076	16.1	82.1	56	50/45	22	WNW	Mostly Cloudy	PW.	6	290°	5/8	7-9	50	550/320	
30	2140 12/23/61	0971.5			076	16.5	81.3	58	50/44	25	NW	Partly Cloudy	R.A.J.	6	310°	9/11	10-13	65	600'/290°	
31	0120 12/24/61	0993.2			076	16.5	81.4	58	[illegible]/45	25	NW	Partly Cloudy	[illegible]	6	310°	9/10	10-12	65	600'/290°	
32	0500 12/24/61	1012.7			076	16.9	82.2	57	51/46	27	W	Mostly Cloudy	PW	6	270°	9/10	10-13	65	550/290°	
33	0900 12/24/61	1044.0			076	16.0	[illegible]	56	50/46	30	W	Cloudy Rainsqualls	R.A.J.	7	270	10/15	13-15	70	700'/290°	
34	1300 12/24/61	1076.7	45°58'N	29°40'W	076	16.0	81.3	57	53/49	30	W	Partly Cloudy	[illegible]	7	270	10/13	13-15	70	600'/290°	
35	1700 12/24/61	1110.6			076	17.0	82.1	56	53/49	30	W	Partly Cloudy	PW	7	270°	10/13	13-15	70	700/290	
36	2040 12/24/61	1143.5			076	17.0	81.0	56	51/48	25	WSW	Cloudy! Occ. Rain	R.A.J.	6	250	8/10	9-12	60	850'/275°	
37	0020 12/25/61	1175.7			076	17.0	81.0	56	54/50	28	SW	Partly Cloudy occ. Rain	[illegible]	6	230°	8/10	9-11	60	800/200°	
38	0400 12/25/61	1208.1			076°	17.0	80.5	56	54/50	27	SE	Partly Cloudy	PW	6	130°	9/11	8-10	55	100/270	
39	0800 12/25/61	1239.2			076	15.0	77.6	54	55/50	24	SE	Cloudy	R.A.J.	6	135°	8/10	8-16	55	900'/250°	
40	1200 12/25/61	1271.9	47°26'N	21°07'W	076	16.0	75.7	55	56/51	14	SE	Mostly Cloudy	[illegible]	4	140°	7-9	8-10	50	300'/255°	
41	1600 12/25/61	1305.1			076	11.0	70.9	54	55/50	24	ENE	Partly Cloudy	PW	6	070°	7-9	8-10	50	750/090	
42	1930 12/25/61	1337.7			076	12.0	70.3	54	52/49	22	ESE	Partly Cloudy	R.A.J.	7	080	8-11	9-12	55	600'/090°	

TABLE 2. SS WOLVERINE STATE DATA LOG--VOYAGE 170 EAST-NORFOLK/NEW YORK TO ROTTERDAM, DEC. 19, 1962--JAN. 2, 1963.

Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	SHIP: Noon Position Lat.	Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	WIND: Knots Wind Speed	True Wind Dir.	Weather	Initials	SEA: Beaufort Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Estimate average length in feet and true direction: Swell	Sea Photo No.	Remarks (Changes of Course, Changes of Speed, Changes of Ballasting, Slamming, Rewind Recorder)
43	2320 12/25/61	1370.8			076	9.0	58.5	53	51/48	34	NE	Overcast Lt Rain	RHD	7-8	040°	9-12	9-13	55	600' 090°		Proceeding at reduced speed to ease vessel. Pitching moderate to heavy
44	0300 12/26/61	1403.8			076	6.0	48.8	54	51/49	35	NxE	Overcast Lt Rain	Pw	8	010°	10-12	10-12	55	600 090		Proceeding at reduced speed to ease vessel. Pitching mod. to heavy; rolling easily
45	0700 12/26/61	1434.4			076	8.0	46.2	54	53/51	25	NNE	Rain squalls Cloudy	R.A.Z.	7	010°	8-10	9-12	55	600' 075°		Proceeding at reduced speed to ease vessel. Rolling moderately and pitching heavily
46	1100 12/26/61	1467.0	48°07'N	16°20'W	076	8.0	54.4	54	52/50	28	NNE	Rain squalls Cloudy	RHD	7	025°	8-11	9-12	55	600' 045°		Reduced speed to ease vessel. Pitching mod to heavy. Rolling
47	1500 12/26/61	1500.9			076	9.0	53.5	52	53/50	29	NNE	Rain squalls Cloudy	Pw	7	025°	9-12	9-12	50	550 045°		Reduced speed to ease vessel. Pitching mod to heavy. Rolling mod. 1300 - vessel [illegible]
48	1900 12/26/61	1534.0			076	8.0	50.4	52	51/49	29	NNE	Overcast Intermittent rain	R.A.Z.	7-8	025°	9-14	10-15	65	1500' 045°		Proceeding at reduced speed, rolling and yawing moderately, pitching heavily
49	2300 12/26/61	1566.3			076	8.0	47.4	53	52/50	33	NNE	Overcast Lt. Rain	RHD	7-8	025°	9-14	9-13	60	800' 060°		Proceeding at reduced speed. Pitching heavily. Rolling mod.
50	0300 12/27/61	1598.9			076	6.0	43.8	54	51/48	35	NNE	Overcast Rain squalls	Pw	8	025	9/14	10-15	65	900 045		Proceeding at Reduced Speed. Pitching + Rolling Mod to heavy
51	0700 12/27/61	1630.0			076	6.0	40.6	52	50/48	33	N	Overcast Intermittent rain	R.A.Z.	8	010°	9/14	10-15	65	1500 040°		Proceeding reduced speed to ease vessel. Rolling & pitching heavily, yawing mod.
52	1100 12/27/61	1663.0	48°54'N	12°51'W	076	6.0	46.2	54	51/49	31	NxE	Overcast	RHD	7	010°	9-14	10-15	65	1500' 045°		Proceeding at reduced speed. Pitching and rolling heavily
53	1500 12/27/61	1697.0			083	6.0	46.1	54	51/48	30	NNE	Overcast Occ Rain	Pw	7	25°	9-14	10-15	65	1200 050°		1303 - changed course to 076, 4415 083 True, 7° Acuity. Proceeding at reduced speed. Pitching + Rolling heavily
54	1900 12/27/61	1730.1			083	6.5	47.3	54	50/48	30	NNE	Overcast Intermittent rain	R.A.Z.	7	25°	9-14	10-15	65	1200' 045°		1953 increased to 50 RPM, rolling and pitching heavily, yawing moderately
55	2400 12/27/61	1762.5			083	8.5	55.6	53	51/48	25	NNE	Overcast	RHD	6	25°	8-12	9-13	65	1200' 045°		2111 Increased to 55 RPM. Pitching mod. to heavily
56	0300 12/28/61	1795.1			076	12.0	65.0	54	49/46	19	ENE	Overcast	Pw	5	75°	7-9	8-10	50	700 045		0025 - 60 RPMS, 0309 - 65 RPMS, 0350 Full Throttle. 0350 c/c to 076 Gyro + True.

TABLE 3. SS WOLVERINE STATE DATA LOG--VOYAGE 171 WEST-ROTTERDAM TO NEW YORK, JAN. 2--19, 1963.

Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	SHIP: Noon Position Lat.	Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	WIND: Knots Wind Speed	True Wind Dir.	Weather	Initials	SEA: Beaufort Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Estimate average length in feet and true direction: Swell	Sea Photo No.	Remarks (Changes of Course, Changes of Speed, Changes of Ballasting, Slamming, Rewind Recorder)
1	1100 1/3/62	0003.5	49°39'N	08°08'W	265	17.5	81.4	52	46/42	14	NE	Partly Cloudy	RHD	4	045°	3-5	5-7	35'	500' 360°		Rolling Easily
2	1500 1/3/62	0065.0			265°	16.5	81.9	52	50/44	16	NE	Mostly Cloudy	Pw	5	045°	3-6	6-8	35'	360' 060°		Rolling and Pitching easily. Machine not running - Restarted at 1600
3	1920 1/3/62	0060.5			265	17.5	82.0	52	47/42	16	ENE	Cloudy	R.A.Z.	4	070	3/5	5-7	30'	1600' 045°		Rolling and pitching moderately
4	2340 1/3/62	0083.5			265	17.0	81.3	53	49/45	14	ENE	Mostly Cloudy	RHD	4	025°	3-5	5-7	35'	1600' 045°		Rolling and Pitching Moderately
5	0400 1/4/62	0148.0			265	16.5	81.1	54	50/44	10	WNW	Partly Cloudy	Pw	3	290°	2-4	5-6	30'	800' 030°		Rolling and Pitching Easily
6	0800 1/4/62	0171.3			265	16.0	80.7	52	49/43	5	SE	Partly Cloudy	R.A.Z.	2	135°	1-2	3-5	15'	1200' 045°		Rolling easily and pitching moderately
7	1200 1/4/62	0214.3	49°17'N	18°01'W	205	16.0	81.3	53	54/46	8	SSW	Mostly Cloudy	RHD	3	225°	2-3	4-6	30'	1000' 060°		Rolling Easily. Pitching Mod.
8	1600 1/4/62	0253.3			265	15.5	81.2	54	53/48	25	SW	Mostly Cloudy	Pw	6	225°	6-8	10-12	60'	900' 260		Rolling Mod. Pitching mod. to heavily.
9	2020 1/4/62	0279.3			265	14.0	75.3	54	52/50	28	SW	Overcast	R.A.Z.	7	225	7-10	11-15	65'	1200 [illegible]		1835 reduced speed to 70 RPM to ease vessel. Rolling moderately, pitching moderately to heavily
10	0040 1/5/62	0305.4			265	10.0	52.6	53	54/52	32	SW	Overcast	RHD	7	225°	7-11	12-15	65'	1200' Conf. Wly		2140 Reduced speed to 60 RPM. Rolling Mod - Pitching Mod to heavily
11	0500 1/5/62	0342.8			265	7.0	48.6	54	53/52	35	SW	Overcast occ Lt. Rain	Pw	8	225°	8-12	12-15	65'	1400 Wly		0339 - Reduced speed to 45 RPMS. Rolling + Pitching - mod to heavily
12	0900 1/5/62	0374.0			265	6.5	43.6	53	53/53	30	SSW	Overcast Rain	R.A.Z.	8	200°	10-14	12-15	65'	900' 245°		0710 increased speed to 50 RPM. Rolling moderately, pitching mostly to heavily
13	1300 1/5/62	0406.7	48°59'N	23°12'W	265	7.0	50.8	53	54/53	28	SW	Overcast Rain	RHD		200°	9-12	11-14	65	800' 245°		0940 Increased speed to 55 RPM. Rolling moderately, Pitching Mod

TABLE 3. SS WOLVERINE STATE DATA LOG--VOYAGE 171 WEST-ROTTERDAM TO NEW YORK, JAN. 2--19, 1963.

Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	SHIP: Noon Position Lat.	Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	WIND: Knots Wind Speed	True Wind Dir.	Weather	Initials	SEA: Beaufort Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Estimate average length in feet and true direction: Swell	Sea Photo No.	Remarks (Changes of Course, Changes of Speed, Changes of Ballasting, Slamming, Rewind Recorder)
14	1700 1/5/62	0490.7			265	7.0	53.7	54	54/53	27	SW	Overcast Rain	Pw	6	220°	8-12	10-12	65'	800' 245°		1909 - c/c to 261 gyro, 265 True. Rolling mod. Pitching mod. to heavy.
15	2100 1/5/62	0495.6			265	11.0	68.5	52	54/52	27	SWS	Intermittent drizzle	R.A.J.	6	215°	6-9	7-10	60'	800' 225°		Various speeds, rolling and pitching moderately to heavily
16	0140 1/6/62	0505.7			265	9.0	59.8	54	54/52	34	SSW	Cloudy Drizzle	AHD	8	210°	9-12	8-11	60'	550' 240°		Various speeds. Rolling and pitching moderately to heavily
17	0600 1/6/62	0538.0			265	8.0	49.9	54	50/49	36	SWxW	Cloudy Drizzle	Pw	8	240	9-12	8-12	60'	500 247		0024 c/c to 256 gyro, 265 True. Reduced speed Rolling & Pitching mod. to heavy
18	1000 1/6/62	0569.1			265	7.0	47.1	52	50/49	38	WSW	Partly cloudy Showers	R.A.J.	8	245°	10-14	12-15	85'	800' 260°		Rolling pitching and yawing heavily Proceeding at reduced speed
19	1400 1/6/62	0622.6	48°50'N	27°07'W	265	5.5	44.4	53	54/45	36	W	Partly Cloudy Showers	AHD	7-8	270°	9-13	12-15	65	500' 260°		Rolling pitching & yawing heavily Proceeding at reduced speed
20	1800 1/6/62	0691.9			235	1.8	44.7	54	52/46	34	W	Mostly Cloudy Showers	Pw	8	270°	10-14	12-15	66'	400' 260'		Rolling, Pitching and Yawing heavily 1457 - c/c to 240 gyro, 235 True. Proceeding at reduced speed
21	2200 1/6/62	0724.1			231°	1.8	46.0	52	50/46	32	WSW	Showers Cloudy	R.A.J.	8	250'	14-20	15-18	90'	1800' 260°		Rolling pitching and yawing heavily Proceeding at reduced speed
22	0200 1/7/62	0757.7			265°	2.5	46.4	53	54/45	30	W	Cloudy	AHD	7	270°	18-22	16-21	75'	550' 260°		Rolling pitching and yawing heavily 0032 c/c to 265° gyro and true Proceeding at reduced speed
23	0600 1/7/62	0789.7			265	5.0	45.0	54	47/45	30	WSW	Cloudy Int. Rain	Pw	7	250'	18-20	16-20	80'	600' 260'		Rolling, Pitching, Yawing heavily Proceeding at Reduced Speed.
24	1000 1/7/62	0826.9			265°	6.0	47.5	52	50/47	25	SWW	Showers Cloudy	R.A.J.	7	235	15-18	14-17	75'	1200' 260°		Rolling pitching and yawing heavily Gradual increase to 55 revolutions
25	1400 1/7/62	0853.7	48°35'N	29°20'W	265°	7.5	58.1	52	50/49	28	SW	Mostly Cloudy	AHD	7	225°	14-18	12-15	75'	500 260°		Rolling pitching, yawing heavily Increased to 60 RPM.
26	1800 1/7/62	0857.7			265°	8.0	64.1	54	52/51	34	SWxS	Mostly Cloudy	Pw	8	210°	16-20	14-18	80'	600' 250°		1200 - Increased to 65 RPMs 1540 - Reduced to 60 RPMs Rolling, Pitching, Yawing heavily
27	2200 1/7/62	0920.6			265	5.5	51.8	54	50/48	28	W	Partly Cloudy Showers	R.A.J.	7	270	10-15	12-16	70'	500' Conf. [illegible]		1830 Hand speed to [illegible] removed [illegible] Rolling pitching and yawing heavily
28	0200 1/8/62	0952.8			265	4.0	49.4	54	44/41	28	W	Partly Cloudy Showers	AHD	7	270	10-15	12-14	70'	500' Conf. [illegible]		Rolling pitching, yawing heavily
29	0600 1/8/62	0985.2			250	5.0	45.8	54	43/41	31	WNW	Partly Cloudy Showers	Pw	7	290°	12-16	12-14	75'	500' conf. [illegible]		Rolling, Pitching, Yawing heavily 0031 - c/c to 255 gyro, 250 True
30	1000 1/8/62	1016.5			265	5.5	47.4	52	46/44	25	WW	Cloudy Showers	R.A.J.	6	315	10-12	8-12	60	500' [illegible]		0444 to 265° 0736 increase to 48 revs Rolling pitching and yawing heavily
31	1400 1/8/62	1049.2	48°18'N	33°38'W	265	6.0	60.8	52	47/46	22	W	Cloudy Showers	AHD	6	270	9-12	8-12	60'	500' conf. [illegible]		Rolling & Pitching heavily.
32	1800 1/8/62	1083.1			265	6.0	61.5	54	51/50	21	SW	Overcast Showers	Pw	5	220°	10-12	8-12	55'	400' confused		Rolling & Pitching heavily 1309 - Increase to 60 RPMs 1544 - Increase to 65 RPMs
33	2200 1/8/62	1116.0			265	13.5	77.4	54	56/54	20	WS	Partly Cloudy [illegible]	R.A.J.	5	260	8-12	7-10	40	400' 270°		1654 increased to full throttle 1950 reduced to 75 revs. Rolling moderately, pitching moderately to heavily
34	0200 1/9/62	1148.3			265	10.0	56.9	54	56/54	20	WSW	Overcast	AHD	5	245°	9-13	8-12	55	400' 270°		Rolling & Pitching Mod to Heavy Reduction in speed to 55 RPM
35	0600 1/9/62	1180.8			265	10.0	55.7	54	55/53	19	WxS	Overcast Occ. Rain	Pw	5	265°	9-12	8-10	50'	350' 270°		Rolling & Pitching mod. to heavily 0505 - Increased to 65 RPM 0536 - Reduced to 60 RPM
36	1020 1/9/62	1212.2			265	10.0	59.2	54	56/54	24	W	Cloudy [illegible]	R.A.J.	6	270	9-12	8-10	50	350' 270°		0740 increased to 65 revolutions Rolling and pitching mod to heavy
37	1400 1/9/62	1244.9	48°01'N	37°37'W	265	10.0	62.8	56	56/55	22	WSW	Overcast Showers	AHD	6	245°	9-12	8-10	55'	400' 270°		Rolling and Pitching Mod. to [illegible]
38	1800 1/9/62	1278.8			265	13.5	77.2	58	56/55	24	SWxW	Overcast Rain	Pw	6	240°	9-12	8-10	50'	400' 270°		Rolling mod. Pitching mod. to heavy 1303 - Full Throttle
39	2020 1/9/62	1311.5			265	8.0	70.4	52	52/51	45-55	SWW	Overcast Intermittent Rain	R.A.J.	9	240	15-25	15-20	85'	500' 255°		REMARKS: 1800 to 2000 wind increased from 25 to 45 knots with gusts of 65 knots. Reduced speed in this period from full throttle to 40 [illegible] [illegible] Rolling and pitching [illegible]
40	0240 1/10/62	1348.6			251°	2.0	42.0	50	50/47	45-55	WSW	Overcast Showers	AHD	10	250°	20-26	18-22	85	500' 250°		Rolling, Pitching, Yawing - Heavily Reduced to 40 RPM.
41	0700 1/10/62	1375.8			251°	2.0	47.3	50	47/43	45-55	W	Overcast Showers	Pw	10	270°	20-26	18-22	85	500' 250°		Rolling, Pitching, Yawing heavily
42	1100 1/10/62	1407.0			251°	1.0	46.6	50	46/45	40	W	Part Cloudy [illegible]	R.A.J.	8	270	18-22	15-18	80	550' 270		0[illegible] increased speed to 50 revs Rolling pitching and yawing heavily
43	1500 1/10/62	1439.7	47°45'N	39°46'W	251°	2.0	52.3	53	48/42	40	WNW	Partly Cloudy Showers	AHD	9	290°	20-24	16-20	80	500' 290°		Rolling Pitching and Yawing Heavily
44	1900 1/10/62	1473.5			251°	2.0	54.5	54	46/42	40	WxS	Mostly Cloudy Showers	Pw	8	260°	20-24	16-20	85	500 290		Rolling, pitching & yawing heavily.
45	2300 1/10/62	1506.3			251	4.0	59.1	56	45/41	22	[illegible]	Cloudy	R.A.J.	6	250°	7-10	5-8	40	350' 270°		1815 to 1925 gradually increased speed [illegible] Yawing, rolling and pitching moderately to heavily
46	0300 1/11/62	1537.0			235	4.0	60.4	54	37/34	30	[illegible]	Cloudy Squall Showers	R.A.J.	7	210°	12-18	8-12	65	500' [illegible]		1956 to 235° true and 251° true Rolling & pitching heavily, yawing [illegible]

SS WOLVERINE STATE DATA LOG--VOYAGE 171 WEST-ROTTERDAM TO NEW YORK, JAN. 2--19, 1963.

Time Meter Rdg.	Noon Position Lat.	Noon Position Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	Knots Wind Speed	True Wind Dir.	Weather	Initials	Bowditch page 1059 Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Swell (Estimate average length in feet and true direction)	Sea Photo No.	Remarks (Changes of Course, Changes of Speed, Changes of Ballasting, Slamming, Rewind Recorder)
1607.2			235	10.0	64.2	42	35/31	24	WSW	Cloudy	[illegible]	6	290°	10-16	8-12	65	500' [illegible]		Rolling & Pitching heavily
1634.0			235	10.5	65.5	40	35/30	22	WNW	Cloudy	Pw	6	300°	10-15	8-12	65	500' conf. [illegible]		Rolling and Pitching moderately to heavily
1667.1			235	14.0	77.3	40	35/32	20	NW	Overcast	R.A.J.	5	280°	5-8	5-7	50'	400' 295°		0500 full throttle. Rolling & Pitching moderately
1698.2	45°31'N	45°21'W	235	15.0	82.7	42	36/32	18	W	Overcast	[illegible]	5	270°	5-8	4-7	50'	400' 285°		Rolling & Pitching moderately
1725.7			258°	15.0	81.8	42	35/31	20	W	Overcast	Pw	5	270°	5-8	4-7	50'	400 285		1315 c/c to 260 gyro, 258 true. Rolling & Pitching moderately
1766.3			258'	15.2	82.1	36	35/33	16	W	Overcast	R.A.J.	4	270	4-7	5-7	45	400' 275°		Rolling & pitching easily
1792.2			254	15.5	82.0	34	36/34	14	WSW	Overcast	[illegible]	4	245°	4-7	4-7	45'	400' 260'		VESSEL IN EASY MOTION
1827.0			254	15.5	81.9	34	38/36	16	SWxW	Overcast	Pw	5	240°	4-7	4-7	45'	400 250		Vessel in Easy motion
1864.1			254	14.6	81.6	36	39/38	5-7	Var.	Overcast Intermittent Rain	R.A.J.	2	Confused	1-3	2-4	15'	400' 270		Rolling and pitching easily
1888.0	43°58'N	54°20'W	254	15.6	82.2	39	40/39	10	NE	Overcast Rain	[illegible]	3	050	2-3	2-4	25'	400' 255°		EASY MOTION
1909.3			253	16.5	81.0	50	45/43	21	NE	Overcast Rain	Pw	5	050	4-6	4-5	35'	400' 255°		Vessel in easy motion
1973.5			253	16.0	81.5	40	38/37	35-45	NE	Overcast Rain	R.A.J.	7	045	9-16	7-10	55	450 conf. [illegible]		Rolling, pitching and yawing [illegible]
2005.7			253	14.5	74.9	40	34/31	35-45	NE	Overcast	[illegible]	8	045	14-18	9-13	55	450' conf. [illegible]		Reduced speed due to [illegible]. Rolling and Pitching Moderately
2037.8			253	14.0	59.1	48	34/31	33-35	NNW	Overcast	Pw	7-8	340	14-16	10-12	60'	400 conf. [illegible]		Rolling and Pitching moderately
2071.7			253	12.0	64.7	46	34/31	15	NNW	Cloudy	R.A.J.	4	340	3-5	5	30'	Conf.		Rolling and pitching moderately
2104.8	42°16'N	62°22'W	253	13.0	67.1	46	38/33	10	NW	Partly Cloudy	[illegible]	3	320°	2-4	3-5	35'	400' Conf. [illegible]		VESSEL IN EASY MOTION
2137.2			253	12.0	63.7	42	35/33	10	WxS	Partly Cloudy	Pw	3	260°	2-4	3-5	35'	350 020°		Vessel in easy motion
2169.6			233°	12.9	67.0	40	37/34	05	E	Cloudy	R.A.J.	2	090°	1-2	2-3	15	200' 020°		Vessel riding easily
2201.2			253°	12.8	67.7	44	42/38	12	SSE	Clear	[illegible]	3	225°	2-4	3-5	20	200' 020°		VESSEL IN EASY MOTION
2233.8			253	13.0	66.3	42	44/42	13	S	Partly Cloudy	Pw	4	180°	2-4	3-5	25'	250 020		Vessel in easy motion
2267.7			249	12.4	67.4	42	46/44	09	SE	Cloudy light rain	R.A.J.	3	135°	2-4	3-5	30'	360' 155°		Vessel rolling & pitching easily
2300.6			259	13.0	67.7	43	52/49	17	SSE	Partly Cloudy	[illegible]	5	160°	4-6	3-5	35'	300' 160°		VESSEL ROLLING AND PITCHING EA[SILY]
2333.8			268	13.0	67.0	42	50/48	18	S	Mostly Cloudy	Pw	5	180°	5-7	4-6	35'	300' 170°		Vessel rolling and pitching easily
2339.6			266	12.0	65.1	44	53/52	32	SW	Overcast Rain	R.A.J.	7	225	8-10	6-8	40	Conf.		1810 changed course to 256 gyro 266 true. Vessel rolling moderately pitching [illegible]

SS WOLVERINE STATE DATA LOG--VOYAGE 172, NEW YORK TO ROTTERDAM JAN. 23--FEB. 8, 1963.

Time Meter Rdg.	Noon Position Lat.	Noon Position Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	Knots Wind Speed	True Wind Dir.	Weather	Initials	Bowditch page 1059 Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Swell (Estimate average length in feet and true direction)	Sea Photo No.	Remarks (Changes of Course, Changes of Speed, Changes of Ballasting, Slamming, Rewind Recorder)
000.0	BROOKLYN ARMY TERMINAL			STARTED															
0036.3			181	9.0	—	—	52/51	10	S	Overcast	[illegible]	3	180	2-3	2-4	20'	300' 180°		VESSEL IN EASY MOTION
0068.2			208°	15.0	78.8	38	48	10	SW	Overcast Light [illegible]	Pw	3	220	2-3	2-4	20'	500 180'		Vessel steady
0102.2			270°	15.6	78.6	35	46/43	15	WNW	Cloudy	R.A.J.	4	295°	3-5	4-6	35'	360' 180°		Rolling easily

TABLE 4a. SS WOLVERINE STATE DATA LOG--VOYAGE 172, NEW YORK TO ROTTERDAM JAN. 23--FEB. 8, 1963.

			SHIP							WIND				SEA							
Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	Noon Position Lat.	Long.	Course	Avg. Speed Knots	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	Knots Wind Speed	True Wind Dir.	Weather	Initials	Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Estimate average length in feet and true direction Swell	Sea Photo No.	Remarks (Changes of Course, Changes of Speed, Changes of Ballasting, Slamming, Rewind Recorder)
5	1/25/62 1900	0555.0			Various			—	44°	5	ENE	Clear	fw	3	090°	2-4	3-5	25'	250'/090°		EASY MOTION
6	1/26/62 1300	0795.2			067°	16.0	79.8	44	46/42	10	ENE	Cloudy	RAJ	4	120°	2-5	4-5	25'	250/090		Easy Motion
7	1/26/62 1700	0878.9	39°36'N	72°05'W	067	16.5	81.2	46	41/43	10	E	Overcast	ALD	4	145°	3-5	4-5	25'	250/120°		Rolling easily
8	1/26/62 2100	0911.8			064	16.4	83.1	44	45/44	15	SE×E	mostly cloudy	fw	4	145°	3-5	4-6	25	300'/130°		EASY MOTION
9	1/27/62 0040	0944.3			064°	16.2	82.3	42	45/42	15	S×E	Overcast late rain	RAJ								
10	1/27/62 0420	0978.5			064°	16.2	82.4	44	50/48	15	SE×S	Overcast Lt rain	ALD								
11	1/27/62 0800	1011.6			067°	16.0	82.1	42	49/47	15	SSE	Overcast Lt. Rain	fw	4	160°	3-5	4-6	25'	250/130		Easy Motion
12	1200/1/27/62	1043.5			067	17.4	80.3	42	50/52	20	SW	Overcast Fog	RAJ	5	230°	5-8	6-9	40'	500'/180°		Rolling mostly & pitching easily
13	1100 1/27/62	1077.3	42°03'N	64°19'W	067	16.5	79.1	39	45/42	16	SSW	Overcast	ALD	4	205°	5-7	5-8	35	400'/225°		Rolling easily to moderately
14	2000 1/27/62	1109.5			067°	16.5	82.2	40	41/38	15	WNW	mostly cloudy	fw	4	280°	5-6	5-8	35'	350/280		Rolling Easily
15	2340/1/27/62	1143.1			067	16.5	82.1	39	34/30	18	NW	Partly Cloudy	RAJ	5	315	5-8	7-9	45'	500'/345		Rolling pitching and yawing mostly
16	0320 1/28/62	1177.4			071	16.5	82.6	36	28/25	20	WNW	Partly cloudy	ALD	5	290°	6-9	8-10	50'	500'/275°		ROLLING MODERATELY
17	0700 1/28/62	1210.6			071	16.0	82.3	40	24/22	20	NW×W	Partly Cloudy	fw	5	300°	6-8	8-10	50'	450/290		Rolling moderately.
18	1100/1/28/62	1243.3			071	15.4	81.7	34	20/20	20	NW	Cloudy Sea Smoke	RAJ	5	315	5-8	8-10	50'	500'/270°		0745 reduced to full throttle due to excessive vibration—rolling pitching and yawing moderately
19	1500/1/28/62	1275.9	49°13'N	56°34'W	071	15.7	81.4	38	31/23	18	WNW	Partly cloudy snow	ALD	5	290	5-8	7-9	50'	500'/270°		ROLLING MODERATELY
20	1900 1/28/62	1309.7			071	16.0	80.9	42	21/20	19	NW	Overcast Lt. Snow	fw	5	310	6-8	8-10	50'	400'/290°		Rolling moderately.
21	2300/1/28/62	1341.4			071	16.2	81.2	36	21/21	17	WNW	Overcast light snow	RAJ	5	290	5-8	7-9	45'	500'/290°		Rolling & yawing mostly pitching easily
22	0300 1/29/62	1376.1			071	16.0	81.2	34	25/24	15	WNW	OVERCAST	ALD	4	290	4-7	6-8	45	500'/290°		ROLLING EASILY
23	0700 1/29/62	1409.7			071	16.0	81.0	32	25/24	15	E	Heavy Snowfall	fw	4	090	3-5	4-6	35'			Easy Motion
24	1100/1/29/62	1441.6			071	15.5	80.4	44	28/27	10	E	Overcast Snow	RAJ	3	090	1-3	3-5	20'	450'/270°		Rolling easily
25	1500 1/29/62	1475.4	45°58'N	48°12'W	095	15.0	80.5	32	28/27	20	NE	Overcast snow squall	ALD	5	045	4-6	7-9	45	450'/270°		1130 c/c to 095° ROLLING EASILY
26	1900 1/29/62	1507.5			095	15.0	80.8	36	38/37	11	E	Overcast sleet-Rain	fw	4	090	1-3	4-6	30'	400'/180°		Rolling moderately.
27	2340/1/29/62	1540.7			082	15.5	80.3	40	37/35	15	NW	Overcast Drizzle	RAJ	4	315°	3-5	5-7	40'	600'/[illegible]		1615 c/c 082° true Rolling & yawing mostly pitching easily
28	0230 1/30/62	1552.8			082	15.5	80.4	39	38/36	14	NW	OVERCAST	ALD	4	320°	3-5	4-6	40'	500'/[illegible]		ROLLING MODERATELY
29	0600 1/30/62	1575.1			082	15.5	80.7	42	37/35	14	N	Overcast	fw	4	000°	3-5	4-6	40'	450/[illegible]		Rolling Easily
30	1000/1/30/62	1608.6			082	15.5	81.0	50	40/39	12	NNW	Overcast Haze	RAJ	4	340°	3-4	4-6	40'	800'/180°		Rolling & yawing easy to moderate Pitching easily
31	1400 1/30/62	1640.1	46°38'N	40°16'W	082	15.0	80.7	58	44/41	10	N	OVERCAST DRIZZLE	ALD	3	000	2-4	3-5	35'	600'/180°		ROLLING EASILY
32	1800 1/30/62	1674.4			082	15.0	81.2	56	47/44	13	NW	Overcast	fw	4	310°	3-4	4-6	40'	500/320		Rolling Easily
33	2200/1/30/62	1706.4			082	16.0	80.0	54	46/43	14	NW	Overcast	RAJ	4	315°	3-4	4-6	40'	800'/245°		Rolling pitching and yawing easily
34	0200 1/31/62	1739.7			082	16.0	80.0	53	48/46	10	N	PARTLY CLOUDY	ALD	3	355°	2-4	3-5	30'	600'/350		ROLLING EASILY
35	0600 1/31/62	1774.0			082	16.0	79.1	54	46/44	12	N	Partly cloudy	fw	4	000°	2-4	4-6	35'	450/250°		Rolling Easily
36	1000/1/31/62	1807.4			082	16.0	79.7	52	46/42	10	NNW	Cloudy	RAJ	3	340°	1-3	3-5	25'	450/[illegible]		Rolling pitching and yawing easily
37	1400 1/31/62	1839.2	47°42'N	30°22'W	082°	15.5	80.9	52	48/46	10	NNE	PARTLY CLOUDY	ALD	3	025	1-3	3-5	30	450'/290°		ROLLING EASILY

TABLE 4a. SS WOLVERINE STATE DATA LOG--VOYAGE 172, NEW YORK TO ROTTERDAM JAN. 23--FEB. 8, 1963.

Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	SHIP: Noon Position Lat.	Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M.	Sea Temp.	Air Temp.	WIND: Knots Wind Speed	True Wind Dir.	Weather	Initials	SEA: Beaufort (gross est.) Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Estimate average length in feet and true direction: Swell	Sea Photo No.	Remarks (Changes of Course, Changes of Speed, Changes of Ballasting, Slamming, Rewind Recorder)
38	1800 1/31/62	1872.8			085	16.0	81.7	52	48/42	11	NE	Partly Cloudy	Fw	3	040	2-3	3-5	40'	400/270		1830 - c/c to 085 Gyro + True. Rolling Easily
39	2140 1/31/62	1905.0			085	16.5	80.7	54	48/42	14	E	Partly Cloudy	RDJ	4	090°	3-5	5-7	45'	400' Conf. NE		Rolling & pitching easily
40	0120 2/1/62	1938.5			085	16.3	81.0	53	50/47	16	SE	Overcast	ARD	4	115°	3-5	5-7	45'	350 Conf. Sea		ROLLING EASILY
41	0500 2/1/62	1972.9			085	16.4	81.4	52	50/46	15	SE	Mostly cloudy	Fw	4	125°	3-5	5-7	45'	400 conf. w/s		Rolling Easily
42	0900 2/1/62	2006.3			085	16.2	81.2	54	50/46	10	S	Cloudy	RDJ	3	180°	1-3	3-5	25'	400'/315°		Rolling & pitching easily
43	1300 2/1/62	2038.9	48°15'N	21°17'W	085	16.0	81.2	53	52/47	12	S	Mostly Cloudy	ARD	3-4	180°	2-4	3-5	30'	400'/315°		ROLLING EASILY
44	1700 2/1/62	2071.7			085	16.0	81.7	54	53/48	11	S	mostly Cloudy	Fw	3-4	180°	2-4	3-5	35'	400'/320		Rolling Easily
45	2040 2/1/62	2103.7			085	16.0	81.6	54	52/48	16	SSW	Cloudy	RDJ	3	200'	1-3	3-5	30'	400'/320°		Rolling & pitching easily
46	0020 2/2/62	2131.3			085	16.0	82.1	53	52/48	07	SW	Mostly Cloudy	ARD	2-3	225°	1-3	2-4	30'	400'/320°		ROLLING EASILY
47	0400 2/2/62	2171.8			085	16.0	82.5	53	51/47	06	SW	Mostly cloudy	Fw	2	225	1-2	2-4	20'	350'/320°		Rolling Easily
48	0800 2/2/62	2205.4			085	16.0	81.2	54	51/46	10	W	Overcast	RDJ	2	270	2-4	3-5	20'	350'/320°		Rolling and pitching easily
49	1200 2/2/62	2237.5	48°56'N	11°22'W	085	17.0	82.3	52	53/48	14	NW	Mostly Cloudy	ARD	4	315°	2-4	4-6	30'	400'/315°		ROLLING EASILY
50	1600 2/2/62	2271.3			078°	17.0	82.8	53	51/48	13	NW	Mostly cloudy	Fw	4	315°	2-4	4-6	35'	400/315		1210 - c/c to 078 Gyro + True. Rolling Easily
51	1940 2/2/62	2303.3			078°	17.0	82.6	52	51/48	15	W	Overcast	RDJ	4	270	3-5	4-6	35'	400'/290°		Rolling & pitching easily
1	2320 2/2/62	0026.8			078	16.5	82.9	51	51/48	14	W	OVERCAST	ARD	4	270'	3-5	4-6	35	400'/290°		EASY MOTION
2	0300 2/3/62	0040.0			078	16.9	83.1	52	51/49	9	NW	Overcast	Fw	3	320	2-4	3-5	30'	—		Easy motion
3	0700 2/3/62	0071.8			078	18.2	83.0	50	50/49	10	W	Overcast Rain drizzle	RDJ	3	270	1-3	3-5	20'	Nil		Riding easy
4	1100 2/3/62	0102.1	50°19'N	0°21'W	078	18.0	83.1	48	52/50	07	W	OVERCAST	ARD	2	270'	1-2	2-4	15'	NIL		EASY MOTION
5	1500 2/3/62	0134.0			068	15.5	83.1	47	51/49	09	WSW	Overcast	Fw	3	250°	2-3	2-4	20'	250/250		1342 - c/c to 068 Gyro + True. Easy Motion
6	1900 2/3/62	0169.7			050	14.0	82.6	46	50/48	20	WSW	Overcast	RDJ	4	250	3-5	4-6	30'	Nil		Various courses through Dover Str. Vessel riding easily
7	2200 2/3/62	0199.9			VARIOUS	17.0	83.1	45	47/45	10	WSW	CLEAR	AND	2-3	245	1-3	2-4	20'	NIL		VARIOUS COURSES EASY MOTION
8	0730 2/6/62	0233.4		STARTED	STRESS	MACHINE	-		LEAVING	ROTTERDAM											
9	1100 2/6/62	0262.1	53°42'N	04°19'E	015	14.7	77.2	40	43/42	16	SW	OVERCAST DRIZZLE	AND	4-5	225°	3-5	5-7	40'	450'/225°		ROLLING EASILY.
10	1500 2/6/62	0301.9			Various	15.8	79.6	41	41/44	16	S	Overcast	Fw	4-5	180	3-5	5-7	40'	400/225°		Pilot Cruising - Various courses. Rolling Easily
11	1900 2/6/62	0333.4			Various	16.4	79.2	42	41/39	15	SW	Overcast Mist	RDJ	4	225°	3-5	5-7	40'	050'/225°		North Sea Pilot Buoyed Channels. Rolling easily
12	2230 2/6/62	0361.4			SECURED	STRESS	MACHINE	—		BREMERHAVEN			ANE								
	2300 2/7/62	0367.4			STARTED	STRESS	MACHINE	-	LEAVING	BREMERHAVEN			AND	5	225°	2-3	3-4	35'	Nil		Easy Motion
13	0300 2/8/62	0399.7			262°	15.8	78.8	36	41/40	16	SW	Overcast Lt. Rain	Fw	4	360°	1-3	3-4	20'	250°/270°		North Sea Swept Channels. Rolling easily
14	0700 2/8/62	0433.3			Various	14.8	78.3	46	40/39	09	N	Overcast Rain	RDJ	3	310	1-3	2-4	25'	250°/300		ROLLING EASILY
15	1100 2/8/62	0468.0	52°47'N	03°59'E	220	15.0	79.7	42	45/43	10	NW	PARTLY CLOUDY	ARD	4	000	2-4	3-6	35'	300/360		Rolling Easily
16	1500 2/8/62	0501.7			220	18.0	80.6	42	42/41	12	N	mostly cloudy	Fw	4	035	3-5	5-7	35	300'/360		Approaching Dover Strait. Rolling easily
17	1920 2/8/62	0534.0			Various	15.0	80.4	40	42/38	12	NNE	Partly Cloudy	RDJ	3	000	1-3	2-4	25'	NIL		ENGLISH CHANNEL VESSEL STEADY
18	2340 2/8/62	0568.1			VARIOUS	15.0	80.3	46	42/39	10	N	CLEAR	ARC								

TABLE 4b. SS WOLVERINE STATE DATA LOG--VOYAGE 173, ROTTERDAM TO NEW YORK, FEB. 11--22, 1963.

Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	SHIP: Noon Position Lat.	Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M. (Past four hrs)	Sea Temp.	Air Temp.	WIND: Knots Wind Speed	True Wind Dir.	Weather	Initials	SEA: Beaufort page 1057 Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Estimate average length in feet and true direction: Swell	Sea Photo No.	Remarks (Changes of Course, Changes of Speed, Changes of Ballasting, Slamming, Rewind Recorder)
TEA	2015 2/11/62	0600.6		STARTED	MACHINE	LEAVING				SOUTHAMPTON,		ENG.									
19	0400 2/12/62	0654.4			248°	14.5	83.8	46	47/45	22	W	Overcast	AHD	5-6	265°	5-6	7-9	45'	450'/270°		Various courses. Rolling & pitching easily
20	0800 2/12/62	0669.2			256°	14.0	82.7	49	51/49	22	W	Overcast	Pw	5-6	270°	6-8	8-10	50'	400/270°		0300 C/C to 256 gyro & true. Rolling and pitching easily
21	0800 2/12/62	0702.8			263°	15.0	81.7	50	52/50	20	W	Overcast	R.A.Z.	5	270	~~7-10~~ 5-8	7-10	50'	300'/270°		0815 Decrease speed to 15 knots. 0715 C/C 245°. Pitching moderately
22	1200 2/12/62	0735.0	49°34'N	06°35'W	245°	14.0	78.1	49	52/50	31	W	Overcast	AHD	7	270°	7-10	11-13	65'	400/270°		Full throttle and C/C to 245. Pitching and rolling moderately
23	1600 2/12/62	0769.0			240°	12.5	78.5	50	53/51	33	W	Overcast	Pw	7-8	270°	8-12	12-14	65'	350'/270°		1307 - C/C to 240 T. Pitching moderately, rolling mod. to heavy
24	2020/2/12/62	0801.5			240°	12.5	78.1	43	51/48	29	WSW	Overcast	R.A.Z.	7	280°	8-12	12-14	70'	450'/270°		Rolling heavily. Pitching & yawing moderately
25	0045 2/13/62	0835.2			240°	12.5'	78.4	52	51/48	35	W	Overcast	AHD	8	275°	8-12	12-14	70'	450'/270°		Rolling heavily. Pitching moderately
26	0500 2/13/62	0870.0			240°	12.5	78.2	52	53/50	35	W	Overcast	Pw	8	270°	8-12	12-14	70'	450/westerly		Rolling heavily. Pitching moderately
27	0900/2/13/62	0903.3			240°	12.5	77.8	54	53/50	30	WNW	Cloudy	R.A.Z.	7	295°	10-14	12-18	75'	450'/315°		Rolling heavily, pitching and yawing moderately
28	1300 2/13/62	0935.6	47°01'N	13°37'W	245°	12.5	77.9	52	56/53	32	WNW	Mostly Cloudy	AHD	7	295°	10-14	12-16	75'	450'/315°		Rolling heavily. Pitching moderately
29	1700 2/13/62	0969.5			260°	13.0	78.7	53	54/52	30	WNW	Mostly Cloudy	Pw	7	295°	10-14	12-16	75'	450/315		1310 C/C to 260 True. Rolling heavily, pitching mod.
30	2120/2/13/62	1003.1			260°	14.5	77.2	54	53/50	15	NNW	Cloudy	R.A.Z.	4	340°	4-6	5-7	35'	450/300		1930 increase speed to 14 knots. Vessel rolling, pitching and yawing easy to moderately
31	0140 2/14/62	1035.9			260°	14.5	80.9	52	52/51	16	NNW	Overcast Drizzle	AHD	4	340°	5-7	6-8	40'	450'/310°		Rolling and pitching easily
32	0600 2/14/62	1070.8			260	14.5	81.6	54	53/51	16	NW	Mostly Cloudy	Pw	4	345°	5-7	6-8	40'	400/310		Rolling and pitching easily
33	1000/2/14/62	1104.7			260	15.2	81.7	56	53/50	10	NNW	Cloudy & Showers	R.A.Z.	3	340°	1-3	4-5	25'	350/340°		0720 increase to 18 knots. Rolling and pitching easily
34	1400 2/14/62	1137.1	45°49'N	22°38'W	276	16.0	83.1	55	57/51	07	NNW	Partly Cloudy	AHD	2-3	340°	1-3	3-4	25'	350'/340		1... C/C to 276°. Vessel in easy motion
35	1800 2/14/62	1171.1			276	16.0	83.7	55	55/50	08	NW	Mostly Cloudy	Pw	2-3	320°	1-3	3-4	20'	300/340°		Vessel in easy motion
36	2200/2/14/62	1203.6			276	16.3	83.7	55	53/5	04	W	Cloudy	R.A.Z.	1	270	0-2	2-3	15'	200'/250°		Rolling & pitching easily
37	0200 2/15/62	1237.3			276	17.0	83.8	55	53/50	05	WSW	Mostly Cloudy	AHD	2	250	1-2	2-3	15'	200/240°		Vessel in easy motion
38	0600 2/15/62	1271.8			276	17.0	84.0	56	52/49	10	SW	Mostly Cloudy	Pw	3	230°	1-3	2-4	20'	200'/270°		Vessel in easy motion
39	1000/2/15/62	1305.4			276	17.3	83.8	56	57/50	15	SSW	Overcast	R.A.Z.	4	200	3-5	5-7	30'	450/325°		Pitching easily
40	1400 2/15/62	1337.5	46°30'N	32°24'W	276	16.0	83.5	56	56/52	20	SW	Partly Cloudy	AHD	5	225	4-6	5-8	35'	350'/225°		Pitching easily
41	1800 2/15/62	1371.3			272	15.5	81.4	56	55/53	18	SSW	Mostly Cloudy	Pw	5	200	4-5	5-6	35'	350/220		1218 C/C to 272. Pitching and rolling easily
42	2220/2/15/62	1403.6			272	15.2	80.0	57	56/51	14	S	Clear	R.A.Z.	4	180	3-5	5-7	35'	450'/206°		Rolling & pitching moderately
43	0240 2/16/62	1445.0			272	14.5	79.8	55	54/53	18	SSW	Mostly Cloudy	AHD	4-5	205°	4-6	5-8	35	350/205°		Rolling & pitching moderately
44	0700 2/16/62	1495.5			272	14.5	80.0	56	56/53	18	SxE	Partly Cloudy	Pw	5	170°	5-8	4-7	40'	450'/140°		Rolling mod to heavily. Pitching moderately
45	1100/2/16/62	1513.9			272	14.0	79.5	58	57/54	38	SSE	Cloudy & Hazy	R.A.Z.	8	160	12-16	10-15	80'	Heavy confused		Rolling, pitching & yawing heavily
46	1500 2/16/62	1551.1	46°55'N	39°45'W	Hove To	7.0	60.6	58	56/52	60	SSE	Cloudy	AHD	11	155°	26-28	17-19	100'	Heavy Confused		Hove to on various SW course. Rolling and pitching very heavy
47	1900 2/16/62	1576.5			Hove to	15	41.5	58	58/57	60	SSE	Overcast Lt Rain	Pw	11	160°	26-30	17-20	90'	Heavy confused		Hove to on various SW courses. Rolling - pitching very heavily
48	2300 2/16/62	1625.6			Hove To	2.0	40.2	59	57/55	45	SSE	Overcast Drizzle	R.A.Z.	9	160	18-22	20-25	125'	"		Hove to, Rolling, pitching and yawing heavily
49	0300 2/17/62	1659.0			Hove To	2.0	40.0	54	56/54	40	SSE	Overcast	AHD	9	155°	17-20	18-22	100'	Heavy Confused		Hove to on various SW courses. Rolling & pitching heavily
50	0700 2/17/62	1690.0			260°	4.0	48.9	54	56/54	40	SE¼	Overcast Heavy Rain	Pw	8-9	135°	16-17	16-18	75'	Heavy confused		0735 Full Throttle - Rolling and Pitching heavily

TABLE 4b. SS WOLVERINE STATE DATA LOG--VOYAGE 173, ROTTERDAM TO NEW YORK, FEB. 11--22, 1963.

Index No.	Date (M,D,Y) Time (GMT)	Time Meter Rdg.	SHIP: Noon Position Lat.	Long.	Course	Avg. Speed Knots (Past four hrs)	Avg. Engine R.P.M.	Sea Temp.	Air Temp.	WIND: Knots Wind Speed	True Wind Dir.	Weather	Initials	SEA: Avoided (?) Sea State	True Direction of Advance	Avg. Wave Height Ft.	Avg. Wave Period Sec.	Avg. Wave Length Ft.	Estimate average length in feet and true direction: Swell	Sea Photo No.	Remarks (Changes of Course, Changes of Speed, Changes of Ballasting, Slamming, Rewind Recorder)
51	1100 2/17/62	1715.5			265°	13.0	78.3	58	56/54	28	SW	Overcast Intermittent rain	RDJ	7	226°	8-12	10-12	75'	Heavy confused		0835 to 265° Rolling and yawing heavily, pitching moderately
52	1500 2/17/62	1754.4	45°57'N	43°46'W	265°	13.0	79.5	54	54/51	21	W	Mostly cloudy	ARD	5-6	270	7-11	8-10	60'	450'/270°		Rolling & pitching moderately
53	1900 2/17/62	1782.0			252	15.0			42/39	20	W	Overcast Drizzle	Pw	5	270	8-10	6-9	50'	400/160		1703 c/c to 252° Rolling and pitching moderately
54	2300 2/17/62	1815.3			263	14.0	80.2	44	38/35	28	SW	Overcast Clearing	RDJ	5	315	6-9	8-11	60'	Hard Conf.		1730 to 263° Rolling pitching & yawing moderately
55	0300 2/18/62	1848.8			263	13.5	1?.0	40	33/32	12	NW	Overcast Drizzle	ARD	3-4	320	5-8	8-10	60'	Mod. Confused		Rolling and pitching moderately
56	0700 2/18/62	1881.7			263	14.0	80.4	32	32/31	7	WSW	Overcast Lt. Snow	Pw	2-3	250°	2-3	4-5	30'	500/000		Rolling easily
57	1100 2/18/62	1915.2			263	14.0	80.8	34	31/30	17	SE	Overcast Snow Showers	RDJ	4	285	3-5	5-7	45'	400'/180°		Rolling moderately & pitching easily
58	1500 2/18/62	1947.0	44°57'N	52°05'W	255	16.5	82.7	33	37/36	12	SE	Overcast Lt. Rain	ARD	3-4	130'	2-4	4-6	40'	700/180°		1445 c/c to 255° Rolling easily
59	1900 2/18/62	1980.7			255	15.0	82.1	32	33/30	40	WSW	Overcast Snow Showers	Pw	8	250°	8-10	9-12	40'	350/250		Rolling Easily
60	2320 2/18/62	2027.6			230	2.0	53.7	34	32/31	50	WSW	Overcast Intermittent Snow	RDJ	10	250	18-22	20-25	140'	450/250		Vessel rolling pitching and yawing heavily; 2115 to 2327 gradually reduced speed to 50 RPM; 2215 to 230° ... and steadily ...
61	0340 2/19/62	2096.5			Hove to	1.0	50.8	35	31/30	60-70	WSW	Overcast Sleet Snow	ARD	11-12	250°	26-40	24-28	175'	500'/250°		Rolling & pitching very heavily; hove to on SW course - reduced speed
62	0800 2/19/62	2178.4			Hove to	1.0	50.6	42	28/26	60-70	WSW	Overcast	Pw	11-12	250	30-40	20-25	150'	450/250		Rolling & pitching very heavily; hove to on SW course
63	1200 2/19/62	2221.0			"	1.5	50.5	39	28/27	48	WNW	Overcast Snow Showers	RDJ	10	290	20-25	20-25	180'	2000'/270°		Hove to on 50 RPM; Rolling pitching & yawing heavily
64	1630 2/19/62	2263.2	43°33'N	54°54'W	250°	4.0	52.7	39	27/26	40	WNW	Overcast Lt. Snow	ARD	8	240	14-18	10-15	75'	450/315°		Gradually increased speed to 65 RPM; Rolling & pitching moderately
65	2000 2/19/62	2275.4			250°	8.5	70.7	40	26/24	36	WNW	Overcast	Pw	8	290°	12-16	10-14	90'	500/290°		1208 - 70 RPMs; Rolling and pitching moderately
66	0000 2/20/62	2331.9			252	14.0	72.4	42	27/25	19	SSW	Cloudy	RDJ	5	340	5-8	7-9	60'	750'/315°		1600 to 252° ... full throttle; Rolling pitching and yawing moderately
1	0030 2/20/62	0003.0		NEW	TAPE	INSTALLED		3													
2	0400 2/20/62	0032.5			252	14.5	80.3	42	26/24	10	NNW	Overcast	ARD	3	340	2-4	4-6	40'	500/315°		Easy motion
3	0800 2/20/62	0068.5			252	15.0	82.9	36	30/28	10	S	Overcast	Pw	3	180°	2-4	5-7	40'	400/315		Easy Motion
4	1200 2/20/62	0096.0			252	15.5	80.4	42	42/41	30	SSE	Overcast Snow & rain	RDJ	7	110°	5-8	8-10	65'	350'/135°		Rolling pitching & yawing moderately
5	1600 2/20/62	0127.0	42°17'N	61°47'W	252	15.7	81.3	42	44/41	27	WSW	Mostly Cloudy	ARD	6-7	255	7-9	11-13	80	400/115°		Rolling moderately
6	2000 2/20/62	0159.0			252	14.0	82.5	40	35/33	45	W	Overcast Showers	Pw	9	270	9-14	12-15	90'	350/270		1545 Reduced to 70 RPMs; Rolling & pitching moderately
7	0030 2/21/62	0199.8			242	5.0	59.9	42	38/34	41	WNW	Overcast Snow Showers	RDJ	9	290	12-14	11-15	120'	450'/270°		2115 reduced speed ... 2310 to 242° ... rolling pitching & yawing heavily ... reduced speed ...
8	0440 2/21/62	0234.0			242	5.0	57.2	39	33/31	38	NNW	Overcast	ARD	8	290°	12-14	11-15	140'	450/270°		2133 reduced speed to 55 RPMs; Rolling and pitching heavily
9	0900 2/21/62	0267.5			256	10.5	72.1	40	34/32	21	NW	Overcast Showers	Pw	5	310°	4-6	6-8	70'	300/270°		0315 Full throttle; 0328 c/c to 256°; Rolling easily, pitching moderately
10	1300 2/21/62	0299.3			257	14.0	79.6	42	32/30	18	SW	Overcast	RDJ	4-5	315°	4-6	6-8	70'	400'/290°		Rolling & pitching moderately
11	1700 2/21/62	0336.8	40°55'N	66°35'W	257	14.5	77.6	39	37/35	14	NNW	Partly Cloudy	ARD	4	295°	3-5	5-6	50'	350/290°		Rolling and pitching easily
12	2100 2/21/62	0368.9			258	15.0	83.3	38	34/31	15	WNW	Mostly Cloudy	Pw	4	295°	4-6	6-7	60'	350/290		Rolling and pitching Easily
13	0100 2/22/62	0402.3			267	16.0	8?.8	40	32/31	10	W	Overcast Lt. Rain Snow	RDJ	3	270	1-3	3-5	30'	300'/270°		1915 to 267° true; Vessel riding easily
14	0500 2/22/62	0436.6			267	16.3	83.5	40	37/36	08	W	Overcast Rain	ARD	2-3	270	1-3	2-4	30'	250/270°		Vessel in easy motion
15	0900 2/22/62	0470.0			267	17.0	83.7	42	41/39	10	SE	Overcast Rain, Snow	Pw	3	130°	1-3	2-4	35'	250/130°		Vessel in easy motion
16	1300 2/22/62	0501.0			Various	Various	81.1	36	34/33	10	SSE	Overcast Mist	RDJ	3	070°	1-3	2-4	25'	250'/110°		0712 Arrival Ambrose; Vessel riding easily

COMPLETE MANUAL STRESS ANALYSIS

TABLE 5. SS HOOSIER STATE - - VOYAGE 124 WEST-SOUTHAMPTON TO NEW YORK/ NORFOLK, DEC. 11-14, 1962.

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress ($\sqrt{E}$) (KPSI)	Observed Maximum P-P Stress (X_m)(KPSI)	Calculated Maximum P-P Stress (X'_m)KPSI	% Difference
2-3	30	526	-	-	1.0	1.32	+32
3-4	30	532	-	-	2.15	2.60	+21
4-5	30	598	3.95	1.99	5.23	5.07	- 3
5-6	30	538	2.86	1.69	3.69	4.24	+15
6-7	30	532	1.82	1.34	3.38	3.48	+ 3
7-8	30	494	-	-	2.46	2.56	+ 4
8-9	30	378	-	-	2.54	2.29	- 9
9-10	30	404	-	-	1.77	2.01	+13
10-11	30	636	-	-	2.77	2.54	- 8
11-12	70	912	7.4	2.72	7.69	7.10	- 7
12-13	45	604	9.28	3.05	8.08	7.68	- 5
13-14	60	518	7.09	2.66	6.92	6.60	- 4
14-15	45	422	7.61	2.76	6.46	6.75	+ 4
15-16	45	384	5.49	2.34	5.15	5.72	+11
16-17	45	693	5.74	2.40	6.46	6.09	- 5
17-18	30	666	5.09	2.26	5.92	5.73	- 3

TABLE 6a. SS WOLVERINE STATE - - VOYAGE 170 EAST-NORFOLK/NEW YORK TO ROTTERDAM, DEC. 19, 1962 --JAN 2, 1963.

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress ($\sqrt{E}$) (KPSI)	Observed Maximum P-P Stress (X_m)(KPSI)	Calculated Maximum P-P Stress (X'_m)KPSI	% Difference
3-4	30	217	0.944	0.307	1.65	1.71	+ 4
4-5	30	166	1.15	1.07	2.70	2.40	-11
5-6	30	412	1.31	1.14	2.55	2.79	+ 9
6-7	30	446	1.25	1.12	2.65	2.73	+ 3
7-8	30	406	1.13	1.06	2.00	2.58	+29
8-9	30	332	1.16	1.08	2.50	2.56	+ 2
9-10	50	516	0.710	0.843	1.75	2.11	+20
10-11	30	216	0.860	0.927	1.75	2.15	+23
11-12	30	197	1.04	1.02	2.15	2.35	+ 9
12-13	30	187	2.31	1.52	4.10	3.45	- 9
13-14	30	205	3.88	1.97	4.10	4.49	+ 9
14-15	30	188	3.88	1.97	4.60	4.45	- 3
15-16	30	257	2.93	1.71	3.30	4.02	+22
16-17	30	195	4.26	2.06	5.10	4.73	- 7

TABLE 6a. SS WOLVERINE STATE - - VOYAGE 170 EAST-NORFOLK/NEW YORK TO ROTTERDAM, DEC. 19, 1962--JAN 2, 1963.

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress ($\sqrt{E}$) (KPSI)	Observed Maximum P-P Stress (X_m)(KPSI)	Calculated Maximum P-P Stress (X'_m)(KPSI)	% Difference
17-18	30	248	2.39	1.55	2.80	3.64	+29
18-19	30	191	2.61	1.62	3.15	3.71	+18
19-20	30	311	1.85	1.36	3.20	3.26	+ 2
20-21	30	175	2.21	1.49	3.50	3.38	- 3
21-22	30	214	2.20	1.48	3.00	3.40	+13
22-23	30	167	2.49	1.58	3.25	3.54	+ 9
23-24	30	356	2.14	1.46	3.40	3.53	+ 4
24-25	30	252	2.38	1.54	3.50	3.62	+ 3
25-26	30	292	2.70	1.64	3.85	3.90	+ 1
26-27	30	210	3.01	1.73	3.50	4.00	+14
27-28	30	266	2.83	1.68	4.15	3.96	- 4
28-29	30	208	3.01	1.73	3.90	3.96	+ 2
29-30	30	226	4.17	2.04	4.15	4.71	+14
30-31	30	193	5.36	2.31	5.10	5.29	+ 4
31-32	30	208	6.12	2.47	5.95	5.66	- 5
32-33	30	211	4.08	2.02	4.10	4.63	+13
33-34	30	184	4.36	2.09	3.85	4.72	+22
34-35	30	200	5.43	2.33	5.10	5.36	+ 5
35-36	30	194	4.00	2.00	4.95	4.60	- 7
36-37	30	226	3.60	1.90	5.00	4.39	-12
37-38	30	264	4.05	2.01	3.90	4.74	+21
38-39	30	398	2.35	1.53	3.85	3.75	- 3
39-40	30	496	3.30	1.82	4.00	4.50	+12
40-41	30	486	3.46	1.86	3.60	4.63	+28
41-42	30	435	3.87	1.97	5.05	4.87	- 4
42-43	30	461	4.54	2.13	6.10	5.28	-13
43-44	30	379	3.68	1.91	5.50	4.62	-16
44-45	30	481	3.56	1.89	4.50	4.71	+ 5
45-46	30	509	3.43	1.85	3.90	4.63	+19
46-47	30	491	4.77	2.18	4.70	5.43	+16
47-48	30	466	5.51	2.35	4.85	5.83	+21
48-49	30	423	4.97	2.23	5.00	5.49	+10
49-50	30	362	6.05	2.46	5.65	5.98	+ 6
50-51	30	470	5.51	2.35	6.00	5.83	- 3
51-52	30	506	4.31	2.30	5.60	5.75	+ 3
52-53	30	435	4.33	2.08	5.50	5.14	- 7
53-54	30	433	2.98	1.73	4.75	4.26	-12

TABLE 6a. SS WOLVERINE STATE - - VOYAGE 170 EAST-NORFOLK/NEW YORK TO ROTTERDAM, DEC. 19, 1962--JAN. 2, 1963.

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress ($\sqrt{E}$) (KPSI)	Observed Maximum ρ-ρ Stress (X_m)(KPSI)	Calculated Maximum ρ-ρ Stress (X'_m)(KPSI)	% Difference
54-55	30	584	2.94	1.71	4.35	4.31	- 1
55-56	30	414	0.942	0.307	2.65	2.75	+ 4

TABLE 6b. SS WOLVERINE STATE - - VOYAGE 171 WEST ROTTERDAM TO NEW YORK JAN. 2--19, 1963.

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress ($\sqrt{E}$) (KPSI)	Observed Maximum ρ-ρ Stress (X_m)(KPSI)	Calculated Maximum ρ-ρ Stress (X'_m)(KPSI)	% Difference
1-2	30	294	2.03	1.42	3.60	3.32	- 8
2-3	30	255	1.90	1.39	3.80	3.27	-14
3-4	30	350	1.72	1.31	2.80	3.17	+13
4-5	30	264	2.28	1.50	3.60	3.54	- 2
5-6	30	311	2.00	1.41	3.10	3.38	+ 9
6-7	30	435	1.79	1.34	3.10	3.31	+ 7
7-8	30	380	2.32	1.52	3.60	3.71	+ 3
8-9	30	416	3.98	1.99	4.90	4.90	± 0
9-10	30	464	4.14	2.03	4.60	5.04	+10
10-11	30	460	4.87	2.20	4.85	5.46	+13
11-12	30	395	4.43	2.10	5.90	5.15	-13
12-13	30	471	4.25	2.06	5.40	5.11	- 5
13-14	30	423	2.83	1.68	4.10	4.13	+ 1
14-15	30	519	3.23	1.79	5.00	4.48	- 1
15-16	30	410	3.89	1.97	4.30	4.83	+12
16-17	30	420	5.15	2.27	5.95	5.58	- 6
17-18	30	377	6.90	2.63	7.15	6.42	-10
18-19	90	1143	7.34	2.70	7.50	7.16	- 5
19-20	30	411	6.89	2.62	6.30	6.42	+ 2
20-21	30	420	5.64	2.37	5.95	5.83	- 2
21-22	30	377	6.35	2.52	5.95	6.15	+ 3
22-23	30	437	5.90	2.43	6.85	6.00	-12
23-24	30	336	5.13	2.26	5.15	5.22	+ 1
24-25	30	468	5.28	2.29	5.00	5.68	+14
25-26	30	472	5.13	2.26	5.25	5.60	+ 7
26-27	30	441	6.91	2.62	5.30	6.47	+22
27-28	30	409	5.50	2.36	5.10	5.73	+12
28-29	30	420	4.91	2.22	5.05	5.46	+ 8
29-30	30	371	4.56	2.14	5.30	5.20	- 2
30-31	30	456	3.92	1.98	4.55	4.89	+ 7
31-32	30	419	2.66	1.63	4.90	4.01	-18
32-33	30	554	3.03	1.74	4.80	4.37	- 9

TABLE 6b. SS WOLVERINE STATE - - VOYAGE 171 WEST ROTTERDAM TO NEW YORK JAN. 2--19, 1963.

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress ($\sqrt{E}$) (KPSI)	Observed Maximum P-P Stress (X_m)(KPSI)	Calculated Maximum P-P Stress (X'_m)(KPSI)	% Difference
33-34	30	459	4.04	2.01	4.90	4.96	+ 1
34-35	30	469	4.63	2.15	4.55	5.33	+17
35-36	30	417	4.20	2.05	5.20	5.00	- 4
36-37	30	508	3.75	1.94	5.20	4.77	-10
37-38	30	538	1.92	1.39	4.20	3.49	-17
38-39	30	496	4.92	2.22	5.10	5.48	+ 7
39-40	30	382	5.36	2.32	5.05	5.66	+12
40-41	30	402	7.87	2.81	6.60	6.88	+ 4
41-42	30	403	5.57	2.36	6.40	5.78	-10
42-43	30	417	4.37	2.09	5.20	5.14	- 1
43-44	30	472	4.17	2.04	5.20	5.06	- 3
44-45	30	525	2.84	1.69	4.95	4.23	-15
45-46	30	469	3.95	1.99	4.60	4.94	+ 7
46-47	30	449	4.17	2.04	6.15	5.00	-19
47-48	30	479	3.48	1.87	4.05	4.64	+15
48-49	30	474	2.51	1.58	4.30	3.92	- 9
49-50	30	554	2.60	1.61	4.25	4.04	- 5
50-51	30	495	1.78	1.33	3.70	3.29	-11
51-52	30	549	1.76	1.33	3.70	3.31	-11
52-53	30	547	2.04	1.43	3.95	3.56	-10
53-54	30	570	1.55	1.24	3.25	3.12	- 4
54-55	30	556	1.53	1.24	4.00	3.11	-22
55-56	30	634	1.29	1.14	3.65	2.90	-21
56-57	30	484	0.43	0.65	1.90	1.62	-15
57-58	30	144	2.65	1.63	4.25	3.63	-15
58-59	30	180	4.47	2.11	5.05	4.81	- 5
59-60	30	257	3.78	1.94	4.00	4.58	+15
60-61	30	219	4.00	2.00	5.70	4.64	-19
61-62	30	181	2.44	1.56	3.25	3.56	+10
62-63	30	213	1.90	1.38	4.30	3.19	-26
63-64	30	123	2.42	1.50	3.10	3.26	+ 5
64-65	30	182	1.00	1.00	2.75	2.28	-17
65-66	30	178	0.89	0.94	1.95	2.14	+10
66-67	30	135	0.43	0.65	1.65	1.42	-14
67-68	30	157	0.57	0.75	1.60	1.69	+ 6
68-69	30	136	0.77	0.88	1.95	1.93	- 1
69-70	30	231	0.34	0.58	1.70	1.35	-21

TABLE 7a. SS WOLVERINE STATE - JAN. 23--FEB. 8, 1963. - VOYAGE 172 NEW YORK TO ROTTERDAM

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress $(\sqrt{E})$ (KPSI)	Observed Maximum P-P Stress (X_m)(KPSI)	Calculated Maximum P-P Stress (X'_m)(KPSI)	% Difference
1-2	30	---	----	----	<0.5	----	---
2-3	30	---	----	----	<1.25	----	---
3-4	30	---	----	----	<1.25	----	---
4-5	30	---	----	----	<0.5	----	---
5-6	30	---	----	----	<0.5	----	---
6-7	30	---	----	----	<0.5	----	---
7-8	30	---	----	----	<0.5	----	---
8-9	30	---	----	----	<0.5	----	---
9-10	30	---	----	----	<1.25	----	---
10-11	30	---	----	----	<1.25	----	---
11-12	30	---	----	----	<1.0	----	---
12-13	30	---	----	----	<1.0	----	---
13-14	30	287	1.16	1.08	1.95	2.57	+32
14-15	30	215	1.76	1.33	3.00	3.09	+ 3
15-16	30	195	3.24	1.80	3.50	4.14	+18
16-17	30	204	2.42	1.56	3.50	3.55	+ 1
17-18	30	228	3.08	1.75	3.90	4.04	+ 4
18-19	30	221	5.80	2.40	5.50	5.59	+ 2
19-20	30	204	4.13	2.03	4.55	4.69	+ 3
20-21	30	206	3.87	1.97	4.45	4.50	+ 1
21-22	30	198	4.33	2.08	4.20	4.78	+14
22-23	30	206	2.84	1.69	4.55	4.02	-12
23-24	30	214	4.63	2.15	4.70	4.99	+ 6
24-25	30	198	2.09	1.45	3.45	3.34	- 3
25-26	30	189	1.94	1.39	2.90	3.18	+10
26-27	30	188	1.31	1.14	2.80	2.61	- 7
27-28	30	241	2.47	1.57	3.40	3.67	+ 8
28-29	30	222	3.57	1.89	3.90	4.38	-12
29-30	30	242	3.35	1.83	3.50	4.30	-23
30-31	30	204	2.32	1.52	4.25	3.50	-18
31-32	30	215	2.98	1.73	4.50	4.01	-11
32-33	30	217	2.88	1.70	3.80	3.94	+ 4
33-34	30	201	3.34	1.83	4.05	4.10	+ 1
34-35	30	178	3.93	1.98	5.00	4.51	-10
35-36	30	217	2.47	1.57	3.20	3.64	+14
36-37	30	185	2.77	1.66	4.30	3.78	-12
37-38	30	196	2.55	1.60	3.75	3.68	- 2

TABLE 7a. SS WOLVERINE STATE - - VOYAGE 172 NEW YORK TO ROTTERDAM
JAN. 23--FEB. 8, 1963.

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress ($\sqrt{E}$) (KPSI)	Observed Maximum p-p Stress (X_m)(KPSI)	Calculated Maximum p-p Stress (X'_m)(KPSI)	% Difference
38-39	30	203	2.06	1.44	3.05	3.33	+ 9
39-40	30	164	2.51	1.58	3.55	3.57	+ 1
40-41	30	154	2.08	1.44	3.60	3.31	- 8
41-42	30	205	1.77	1.33	3.45	3.07	-11
42-43	30	189	2.11	1.45	3.25	3.34	+ 3
43-44	30	169	1.34	1.16	2.35	2.62	+11
44-45	30	195	1.47	1.21	2.78	2.65	- 5
45-46	30	131	1.14	1.07	2.35	2.36	+ 1
46-47	30	192	1.51	1.23	2.50	2.82	+13
47-48	30	161	1.31	1.14	2.30	2.57	+12
48-49	30	189	1.53	1.24	2.90	2.84	- 5
49-50	30	200	1.23	1.11	2.70	2.55	- 6
50-51	30	164	1.21	1.10	2.75	2.49	- 9
51-52	30	189	1.41	1.19	2.60	2.73	+ 5
1-2	30	142	0.92	0.96	2.05	2.14	+ 4
2-3	30	150	0.45	0.67	1.55	1.50	- 3
3-4	30	---	----	----	< 1.0	----	---
4-5	30	---	----	----	< 0.5	----	---
5-6	30	---	----	----	< 0.5	----	---
6-7	30	---	----	----	< 0.5	----	---
7-8	30	---	----	----	< 0.5	----	---
8-9	30	---	----	----	< 1.0	----	---
9-10	30	285	0.79	0.89	2.45	2.12	-13
10-11	30	140	0.43	0.66	1.50	1.46	- 3
11-12	30	234	0.48	0.69	1.50	1.62	+ 8
12-13	30	---	----	----	< 0.5	----	---
13-14	30	---	----	----	< 0.5	----	---
14-15	30	---	----	----	< 0.5	----	---
15-16	30	189	0.62	0.79	1.90	1.80	- 5
16-17	30	132	0.70	0.84	1.90	1.85	- 3
17-18	30	---	----	----	< 1.0	----	---
18-18A	30	174	0.65	0.81	1.50	1.85	+23

TABLE 7b. SS WOLVERINE STATE - - VOYAGE 173, ROTTERDAM TO NEW YORK
FEB. 11--22, 1963.

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress ($\sqrt{E}$) (KPSI)	Observed Maximum p-p Stress (X_m)(KPSI)	Calculated Maximum p-p Stress (X'_m)(KPSI)	% Difference
18A-19	30	334	0.46	0.68	1.30	1.61	+24
19-20	30	702	1.05	1.02	2.80	2.61	- 8
20-21	30	675	1.35	1.16	3.20	2.96	- 8
21-22	30	541	2.73	1.65	3.55	4.14	-17
22-23	30	520	3.68	1.92	4.45	4.80	+ 8
23-24	30	506	3.45	1.86	6.10	4.65	-24
24-25	30	581	3.43	1.85	4.40	4.66	+ 6
25-26	30	599	3.35	1.83	5.40	4.63	-14
26-27	30	651	3.03	1.74	4.60	4.43	- 4
27-28	30	574	2.90	1.70	4.60	4.28	- 7
28-29	30	603	2.86	1.69	3.85	4.28	+11
29-30	30	574	2.88	1.70	4.28	4.40	- 3
30-31	30	595	1.84	1.36	4.20	3.44	-18
31-32	30	401	1.36	1.17	3.15	2.87	- 9
32-33	30	318	1.18	1.09	2.50	2.62	+ 5
33-34	30	252	0.75	0.87	2.10	2.04	- 3
34-35	30	398	0.92	0.96	2.15	2.35	+10
35-36	30	351	0.87	0.93	2.55	2.25	-12
36-37	30	350	0.73	0.86	2.00	2.08	+ 4
37-38	30	350	0.72	0.85	2.05	2.06	+ 1
38-39	30	371	0.93	0.97	2.60	2.36	-12
39-40	30	683	1.72	1.31	3.30	3.35	+ 2
40-41	30	594	2.36	1.54	3.70	3.90	+ 5
41-42	30	559	2.07	1.44	3.25	3.63	+12
42-43	30	543	2.09	1.45	4.10	3.64	-11
43-44	30	583	1.97	1.40	3.80	3.53	- 7
44-45	30	515	2.82	1.68	4.30	4.20	- 2
45-46	30	345	3.78	1.94	4.15	4.69	+13
46-47	30	533	5.98	2.45	5.70	6.15	+ 8
47-48	30	357	5.48	2.34	6.05	5.66	- 6
48-49	30	370	5.84	2.42	5.00	5.88	+21
49-50	30	415	4.38	2.09	5.45	5.14	- 6
50-51	30	371	4.33	2.08	4.30	5.05	+17
51-52	30	352	2.85	1.69	4.20	4.09	- 3
52-53	30	375	1.99	1.41	3.00	3.44	+15
53-54	30	476	2.34	1.53	3.50	3.79	+ 8
54-55	30	590	4.44	2.11	6.35	5.34	-16

TABLE 7b. SS WOLVERINE STATE - - VOYAGE 173, ROTTERDAM TO NEW YORK
FEB. 11--22, 1963.

Record Interval	Record Duration (Minutes)	Total Counts (N)	Variance (E) $(KPSI)^2$	RMS Stress $(\sqrt{E})$ (KPSI)	Observed Maximum p-p Stress (X_m)(KPSI)	Calculated Maximum p-p Stress (X'_m)(KPSI)	% Difference
55-56	30	611	2.69	1.64	4.35	4.15	- 5
56-57	30	541	1.02	1.01	2.25	2.54	+13
57-58	30	343	0.69	0.83	1.85	2.01	+ 9
58-59	30	231	1.35	1.16	3.05	2.70	-12
59-60	30	584	7.99	2.83	7.70	7.13	- 7
60-61	60	694	7.86	2.80	6.70	7.17	+ 7
61-62	80	908	11.32	3.36	8.30	8.77	+ 7
62-63	45	521	8.30	2.88	7.20	7.20	0
63-64	30	349	6.91	2.63	5.45	6.36	+17
64-65	30	298	9.01	3.00	6.30	7.17	+14
65-66	30	291	7.81	2.79	5.60	6.64	+19
66-67	30	560	3.27	1.81	5.55	4.56	-18
1-2	30	519	1.37	1.17	2.80	2.92	- 4
2-3	30	---	----	----	<1.25	----	---
3-4	30	219	3.28	1.81	3.50	4.20	+20
4-5	30	231	3.33	1.82	3.95	4.25	+ 8
5-6	30	498	4.42	2.10	5.10	5.23	+ 3
6-7	30	448	6.44	2.54	6.27	6.90	+10
7-8	30	492	4.00	2.00	5.50	4.96	-10
8-9	30	576	2.47	1.57	4.25	3.96	- 7
9-10	30	674	3.51	1.87	6.05	4.77	-21
10-11	30	613	4.27	2.07	5.10	5.24	+ 3
11-12	30	562	1.24	1.11	2.70	2.80	+ 4
12-13	30	---	----	----	<1.0	----	---
13-14	30	---	----	----	<1.0	----	---
14-15	30	---	----	----	<1.0	----	---
15-16	30	---	----	----	<1.0	----	---

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