SHIP MOTION TRIALS OF USCGC TAMAROA
AND USCGC CHEROKEE

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U. S. Coast Guard Research and Development Center
Avery Point Groton, Connecticut 06340

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Technical Director
U.S. Coast Guard Research and Development Center
Avery Point, Groton, Connecticut 06340
This report documents the results of ship motion trials performed on the 205-foot WMEC’s USCGC TAMAROA and USCGC CHEROKEE. The trials were conducted in April 1981. Roll motions are presented together with pitch motions in head seas. The trials were run using six orientations to the principal wave direction and three different ship speeds. The results of the trials between the two ships are compared.

There appears to be no measurable difference in the roll response characteristics of the two vessels, one of which was ballasted and one unballasted. Test personnel who rode both vessels could detect no ride difference as well.
## METRIC CONVERSION FACTORS

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*1" = 2.54 cm exactly. For someexact temperatures and more detailed tables, see NBS News, Publ. 284, United States Metric Association, Price 12.25, 60 Catalog No. C13.10.239.*
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1.0 INTRODUCTION

Seakeeping and dynamic stability tests were conducted on two 205' cutters, USCGC CHEROKEE and USCGC TAMAROA during April of 1981. These tests are a portion of the Coast Guard's advanced marine vehicle and ship trials program, one objective of which focuses on documenting and analyzing ship motion data for the various classes of Coast Guard vessels. The 205's were the first class to be tested under this program. This report presents the results of those tests.

Two vessels were instrumented and tested in this class in order to draw a comparison between the recently ballasted TAMAROA and the unballasted CHEROKEE. The objectives of the test program were:

a. To determine the response amplitude operators of the vessel to waves in as many as six degrees of freedom (i.e., roll, pitch, yaw, heave, sway and surge).

b. To determine the significant H \( \frac{1}{3} \) wave height and the corresponding average of the \( \frac{1}{3} \) highest vessel motions.

2.0 TESTING AND INSTRUMENTATION

2.1 General

The motion data was collected at three different vessel speeds (1-2 kts, 5 kts, 10 kts) and six headings relative to the prevailing seas (90\(^\circ\), 270\(^\circ\) beam seas) (0\(^\circ\) and 180\(^\circ\) head and following seas) (45\(^\circ\) and 225\(^\circ\) bow quartering and following quartering seas). Two different sea states (a low H \( \frac{1}{3} \) of approximately 4 feet and a high H \( \frac{1}{3} \) of 10-15 feet) were desired. For each ship test, two series of data were recorded; however, the wave heights ranged from 4-8 feet during both. Each course was run for 20 minutes while recording the data. The data collected for each run consisted of:

a. wave height versus time
b. vessel motion versus time (roll; pitch; yaw; heave, surge, and sway accelerations)
c. water depth
d. operating configuration
e. shaft rpm
f. apparent wave direction
g. vessel course
h. draft and trim of vessel
i. wind speed and direction

Appendix A lists the wave direction, wind direction, ship headings and operating configuration information for the vessels for each test run. Time and loading information is also given in Appendix A.
2.2 Instrumentation

The instrumentation used for measuring the motion data consisted of a gyro stabilized platform having a reference to the horizontal and to a fixed horizontal angle. A 14-channel analog tape recorder was used to record the data. Ship angular motions (roll, pitch, yaw) were measured relative to the fixed reference. The linear motions (heave, sway, surge accelerations) were measured in g's using the same fixed reference. For both vessels, the motion package was placed as close to the vertical and horizontal center of gravity as physically possible. For the CHEROKEE, this was on the deck just forward of the main switchboard in B-2 engine room. On the TAMAROA, the package was placed on the deck aft of the main switchboard. For both vessels, the package was hard wired to the recording equipment located in the machine shop. Figure 2 shows the locations of the motion package during both tests.

Wave data (height) was measured and transmitted to the test vessel by a Datawell waverider buoy. Each run began or ended in the vicinity of the buoy in order to increase the validity of the correlation between wave measurements and ship motions. Also, since the buoy was free floating, this minimized the chances of losing the buoy.

Data on the motions and wave height was recorded in FM analog form by a 14-channel magnetic tape recorder. A strip chart recorder was also used for the wave height information. This provided a ready visual means of determining proper buoy transmission.

3.0 ANALYSIS OF DATA

Wave data and ship motion data for roll were analyzed for each run. Pitch data was also analyzed for the runs made with head seas. None of the other data collected was studied. A total of 72 test runs were made.

The data was converted from the time versus amplitude representation on the analog tape to an amplitude versus frequency form using a Hewlett-Packard 5420A digital signal analyzer. A Hanning windowing function was used. The data were recorded at 1-7/8 inches/second and analyzed at 30 inches/second. The data were then converted by a Hewlett-Packard 9835B computer to the proper frequency and amplitude and plotted. The analysis was performed using a bandwidth of 32 Hz which corresponds to 2 Hz real time. Coupling between the tape recorder and analyzer was D.C. to avoid loss of data due to the A.C. coupling capacitor's roll-off in the frequency range being analyzed.

Calibration factors were entered into the digital signal analyzer to convert the voltage signal on the analog tape into the correct engineering units. Because the analyzer gives results as RMS voltage, a correction was used to obtain peak voltage results. The calibration factors were computed as follows:
Factor = \( C_1 \times C_2 \times C_3 \times \sqrt{2} \)

where

\( C_1 \) = Motion package (wave buoy) engineering units/V
    e.g., 90/V for roll
\( C_2 \) = Tape recorder attenuation, e.g., 5 volts in/1 volt out
\( C_3 \) = Units conversion, e.g., meters to feet
\( \sqrt{2} \) = Converts RMS voltage to peak voltage

Data for roll, pitch, and wave height has been plotted in the form of energy spectral density; that is, the area under the curve between two frequencies is proportional to the roll, pitch, or wave energy between those frequencies. The wave spectrum has been corrected to frequency of encounter using the ship speed and direction.

Response amplitude operators (RAO's) were computed by dividing the respective roll or pitch energy spectrums by the corresponding wave energy spectrum. The RAO's should be used with caution because they were not obtained in a theoretically correct manner. The primary problem is that the waves were not unidirectional. However, the data was collected at corresponding ship speeds and direction to the waves on the USCGC CHEROKEE and the USCGC TAMAROA.

The averages of the 1/3 and 1/10 highest waves and vessel roll motions are included in Tables 1 and 2. These were obtained from measuring the actual wave and motion heights. These values can also be estimated from the value of energy given on the plots using the following formula:

\[
H_{1/3} = 2.83 \text{ (Energy)}^{1/2} \\
H_{1/10} = 3.60 \text{ (Energy)}^{1/2}
\]

A Rayleigh distribution is assumed. Figure 1 shows a comparison between the actual wave height data for one run of the USCGC TAMAROA and the Rayleigh distribution corresponding to the energy for this run. The values of \( H_{1/3} \) are noted on this figure.

4.0 RESULTS

Data plots are given in Appendix B. The test results vary widely. This is even true between runs made on different days on the same ship. The cause of the wide variation is not known for certain. However, some of the contributing factors are that the waves were not unidirectional and that the wave buoy was not located at the bow of the vessel. In head or stern seas there should theoretically be no roll motion if the waves are unidirectional and there are no motion coupling effects. The fact that the figures show a substantial RAO value for head and stern seas shows the influence of non-unidirectional waves. Also, the waves at the buoy location may be somewhat different from those at the vessel. In other words, the spatial distribution of energy in the area may not be uniform.
Because of the wide variation in data on the individual vessels, it is difficult to see any significant differences between the TAMAROA and the CHEROKEE. Both ships had similar RAO amplitude ranges and the frequency of roll on both ships was very close. The CHEROKEE had possibly the lower roll frequency (0.105 Hz versus 0.112 Hz for the TAMAROA).

In general, there is no roll motion difference between the two ships apparent as a result of these tests. Pitching motion RAO's on the CHEROKEE were slightly higher than those of the TAMAROA.
USCGC TAMAROA (Run No. 12)
Data from Wave Rider Buoy

Data 4/14/81
Data measured by
hand
Rayleigh Dist.
Significant Hits

FIGURE 1
205' WMEC

* TAMAROA - MOTION PACKAGE LOCATION IS ON THE C' OF SHIP

* CHEROKEE -

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APPENDIX A

DATA FORMS
DATA FORM 13A
MOTION IN WAVES

VESSEL NAME CHEROKEE

DATE 4/4/81

RECORER LEROY COOK

OPERATING CONFIGURATION N.A.

RPM 30

SPEED 2 KTS

DRAFT FORWARD 14'-4"

DRAFT AFT 14'-8"

APPARENT WAVE DIRECTION 220

TRUE

WIND SPEED 11 KTS

WIND DIRECTION 180°

TRUE

WATER DEPTH 450 FATHOMS

LOCATION OF MOTION PACKAGE FWD B-2

<table>
<thead>
<tr>
<th>RUN NUMBER</th>
<th>VESSEL COURSE</th>
<th>DIRECTION TO WAVES</th>
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<tbody>
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<td>3</td>
<td>310</td>
<td>Beam (Port)</td>
<td>0940</td>
<td>1000</td>
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<td>4</td>
<td>130</td>
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<td>175</td>
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<td>6</td>
<td>355</td>
<td>Stern QTR (Port)</td>
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DATA DISK/TAPE NUMBER CHEROKEE #1
DATA FORM 13A
MOTION IN WAVES

VESSEL NAME CHEROKEE
DATE 4/14/81

RECORDER LCDR COOK

OPERATING CONFIGURATION N.A.

RPM 55
SPEED 5.5

DRAFT FORWARD 14' -4''
DRAFT AFT 14' - 8''

APPARENT WAVE DIRECTION 220
TRUE

WIND SPEED 15
WIND DIRECTION 210
TRUE

WATER DEPTH 450 FATHOMS

LOCATION OF MOTION PACKAGE FWD B-2

<table>
<thead>
<tr>
<th>RUN NUMBER</th>
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<th>DIRECTION TO WAVES</th>
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<tr>
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<td>040</td>
<td>Stern</td>
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DATA DISK/TAPE NUMBER CHEROKEE #1 #2
DATA FORM 13A
MOTION IN WAVES

VESSEL NAME  **Cherokee**
RECORER  **LCDR COOK**
OPERATING CONFIGURATION  **N.A.**

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<th>RPM</th>
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<td>14' - 4&quot;</td>
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<th>FWD, B-2</th>
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<td>STEERN</td>
<td>1450</td>
<td>1510</td>
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<td>15</td>
<td>155</td>
<td>BOW QTR (STBD)</td>
<td>1512</td>
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<td>16</td>
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DATA DISK/TAPE NUMBER  **Cherokee #2**
DATA FORM 13A
MOTION IN WAVES

VESSEL NAME CHEROKEE
DATE 4/6/81

RECOR D COR COUR
OPERATING CONFIGURATION NA

RPM 20 SPEED 2 KTS

DRAFT FORWARD 14' 4"
DRAFT AFT 14' 8"

APPARENT WAVE DIRECTION 180° TRUE

WIND SPEED 11 WIND DIRECTION 280° TRUE

WATER DEPTH 125 FEET

LOCATION OF MOTION PACKAGE TWO B-2

<table>
<thead>
<tr>
<th>RUN NUMBER</th>
<th>VESSEL COURSE</th>
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<td>1010</td>
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DATA DISK/TAPE NUMBER CHEROKEE # 2 & # 3
DATA FORM 13A
MOTION IN WAVES

VESSEL NAME **CHEROKEE**
DATE  **4/6/81**

RECORER **LCDR. COOK**

OPERATING CONFIGURATION **N.A.**

RPM **50/1 ENGINE**

SPEED  **5 KTS**

DRAFT FORWARD  **14' 4"**

DRAFT AFT  **14' 8"**

APPARENT WAVE DIRECTION  **180°**

TRUE

WIND SPEED  **12 KTS**

WIND DIRECTION  **300°**

TRUE

WATER DEPTH  **125 FEET**

LOCATION OF MOTION PACKAGE  **Fwd 8-2**

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<th>DIRECTION TO WAVES</th>
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<td>225</td>
<td>Bow Qtr (Port)</td>
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<td>090</td>
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DATA DISK/TAPE NUMBER **CHEROKEE #3**
DATA FORM 13A
MOTION IN WAVES

VESSEL NAME  CHEROKEE  DATE  4/6/81

RECORER  LCOR COOK

OPERATING CONFIGURATION  N.A.

RPM  80  1/2 ENGINES  SPEED  10

DRAFT FORWARD  14' 4"  DRAFT AFT  14' 8"

APPARENT WAVE DIRECTION  180  TRUE

WIND SPEED  12 KTS  WIND DIRECTION  300°  TRUE

WATER DEPTH  125 FEET

LOCATION OF MOTION PACKAGE  FWD 6-2

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<th>VESSEL COURSE</th>
<th>DIRECTION TO WAVES</th>
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DATA DISK/TAPE NUMBER  CHEROKEE  #3  &  #4

* PRIMARY SEA STATE CHANGED TO SEAS FROM 270°, TRUE WIND 270° @ 14 KTS
** PRIMARY SEAS BACK TO 180
**DATA FORM 13A**

**MOTION IN WAVES**

**VESSEL NAME** TAMAROA  
**DATE** 4/4/81

**RECORDER** LCDR Cook

**OPERATING CONFIGURATION** N.A.

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**DATA DISK/TAPE NUMBER** TAMAROA #1
DATA FORM 13A
MOTION IN WAVES

VEssel NAME TAMAROA

DATE 4/14/81

REcORDER LCDR COOK

OPERATING CONFIGURATION N.A.

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DRAFT FORWARD 13'  DRAFT AFT 14'

APPARENT WAVE DIRECTION 110  TRUE

WIND SPEED 21 KTS  WIND DIRECTION 110  TRUE

WATER DEPTH 1600 FATHOMS

LOCATION OF MOTION PACKAGE AFT B-1

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DATA DISK/TAPE NUMBER TAMAROA #1 & #2
DATA FORM 13A
MOTION IN WAVES

VEssel NAME TAMAROA
REcORDER LCO
OPERATING CONFIGURATION N.A

RPM 85  SPEED 10
DRAFT FORWARD 13'  DRAFT AFT 14'

WIND SPEED 21  WIND DIRECTION 110 TRUE
WATER DEPTH 1600 FATHOMS

LOCATION OF MOTION PACKAGE AFT B-1

<table>
<thead>
<tr>
<th>RUN NUMBER</th>
<th>VESSEL COURSE</th>
<th>DIRECTION TO WAVES</th>
<th>START TIME</th>
<th>FINISH TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>135</td>
<td>HEAD</td>
<td>1457</td>
<td>1517</td>
</tr>
<tr>
<td>14</td>
<td>315</td>
<td>STERN</td>
<td>1524</td>
<td>1544</td>
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<td>15</td>
<td>180</td>
<td>BOW QTR (PORT)</td>
<td>1550</td>
<td>1610</td>
</tr>
<tr>
<td>16</td>
<td>000</td>
<td>STEERN QTR (STBD)</td>
<td>1613</td>
<td>1633</td>
</tr>
<tr>
<td>17</td>
<td>225</td>
<td>BEAM (PORT)</td>
<td>1643</td>
<td>1659</td>
</tr>
<tr>
<td>18</td>
<td>045</td>
<td>BEAM (STBD)</td>
<td>1700</td>
<td>1720</td>
</tr>
</tbody>
</table>

DATA DISK/TAPE NUMBER TAMAROA #2
DATA FORM 13A

MOTION IN WAVES

VESSEL NAME **TAMAROA**

DATE **4/15/81**

RECORD **LCDE Cook**

OPERATING CONFIGURATION **N.A.**

---

RPM **80**

SPEED **10**

DRAFT FORWARD **13'**

DRAFT AFT **14'**

APPARENT WAVE DIRECTION **000°** TRUE

WIND SPEED **22 KTS**

WIND DIRECTION **000°** TRUE

WATER DEPTH **14 FATHOMS**

LOCATION OF MOTION PACKAGE **AFT 8-1**

---

<table>
<thead>
<tr>
<th>RUN NUMBER</th>
<th>VESSEL COURSE</th>
<th>DIRECTION TO WAVES</th>
<th>START TIME</th>
<th>FINISH TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>090</td>
<td><strong>BEAM (PORT)</strong></td>
<td><strong>1516</strong></td>
<td><strong>1536</strong></td>
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<tr>
<td>2</td>
<td>270</td>
<td><strong>BEAM (STBD)</strong></td>
<td><strong>1541</strong></td>
<td><strong>1601</strong></td>
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<tr>
<td>3</td>
<td>180</td>
<td><strong>STERN</strong></td>
<td><strong>1603</strong></td>
<td><strong>1623</strong></td>
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<tr>
<td>4</td>
<td>000</td>
<td><strong>HEAD</strong></td>
<td><strong>1627</strong></td>
<td><strong>1647</strong></td>
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<tr>
<td>5</td>
<td>045</td>
<td><strong>BOW QTR (PORT)</strong></td>
<td><strong>1648</strong></td>
<td><strong>1708</strong></td>
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<td>6</td>
<td>225</td>
<td><strong>STERN QTR (STBD)</strong></td>
<td><strong>1713</strong></td>
<td><strong>1733</strong></td>
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</tbody>
</table>

DATA DISK/TAPE NUMBER **TAMAROA TAPE # 3**
DATA FORM 13A
MOTION IN WAVES

VESSEL NAME TAMAROA

DATE 4/15/81

RECORDER LCDB COOK

OPERATING CONFIGURATION N.A.

RPM 45 SPEED 5 KTS

DRAFT FORWARD 13' DRAFT AFT 14'

APPARENT WAVE DIRECTION 000 TRUE

WIND SPEED 18 WIND DIRECTION 000 TRUE

WATER DEPTH 15 FATHOMS

LOCATION OF MOTION PACKAGE AFT 8-1

<table>
<thead>
<tr>
<th>RUN NUMBER</th>
<th>VESSEL COURSE</th>
<th>DIRECTION TO WAVES</th>
<th>START TIME</th>
<th>FINISH TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>090</td>
<td>BEAM (PORT)</td>
<td>1736</td>
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<td>8</td>
<td>270</td>
<td>BEAM (STBD)</td>
<td>1802</td>
<td>1822</td>
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<td>9</td>
<td>045</td>
<td>BOW QTR (PORT)</td>
<td>1830</td>
<td>1850</td>
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<tr>
<td>10</td>
<td>225</td>
<td>Stern QTR (STBD)</td>
<td>1856</td>
<td>1916</td>
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<td>11</td>
<td>180</td>
<td>Stern</td>
<td>1918</td>
<td>1938</td>
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<tr>
<td>12</td>
<td>000</td>
<td>Head</td>
<td>1946</td>
<td>2006</td>
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</table>

DATA DISK/TAPE NUMBER TAMAROA #3 & #4
DATA FORM 13A
MOTION IN WAVES

VESSEL NAME Tamaroa

DATE 4/15/81

RECORER LCDR COOK

OPERATING CONFIGURATION N.A.

RPM 35
SPEED 2 KTS

DRAFT FORWARD 13'
DRAFT AFT 14'

APARENT WAVE DIRECTION 000
TRUE

WIND SPEED 9 KTS
WIND DIRECTION 350
TRUE

WATER DEPTH 15 FATHOMS

LOCATION OF MOTION PACKAGE AFT 8-1

<table>
<thead>
<tr>
<th>RUN NUMBER</th>
<th>VESSEL COURSE</th>
<th>DIRECTION TO WAVES</th>
<th>START TIME</th>
<th>FINISH TIME</th>
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</thead>
<tbody>
<tr>
<td>13</td>
<td>000</td>
<td>HEAD</td>
<td>2010</td>
<td>2020</td>
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<td>14</td>
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<td>Stern</td>
<td>2039</td>
<td>2059</td>
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<td>15</td>
<td>270</td>
<td>Beam (Stbd)</td>
<td>2103</td>
<td>2123</td>
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<td>16</td>
<td>090</td>
<td>Beam (Port)</td>
<td>2128</td>
<td>2148</td>
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<td>17</td>
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<td>Bow QTR (Port)</td>
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<td>18</td>
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<td>Stern QTR (Stbd)</td>
<td>2218</td>
<td>2238</td>
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DATA DISK/TAPE NUMBER TAMAROA #4
## LIQUID LOADING DATA

<table>
<thead>
<tr>
<th>Vessel</th>
<th>CHEROKEE</th>
<th>Date</th>
<th>4/3/81</th>
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</thead>
<tbody>
<tr>
<td>Draft Fwd</td>
<td>14' 4&quot;</td>
<td>Aft</td>
<td>14' 8&quot;</td>
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<table>
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<th>TANK</th>
<th>GALS</th>
<th>TANK</th>
<th>GALS</th>
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<tbody>
<tr>
<td>A-1-W</td>
<td>10,686 F.W</td>
<td>C-402-W</td>
<td>6,108 F.W</td>
</tr>
<tr>
<td>A-404-W</td>
<td>4,532 F.W</td>
<td>A-405-W</td>
<td>4,532 F.W</td>
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<tr>
<td>A-410F</td>
<td>3,596</td>
<td>A-409-F</td>
<td>3,279</td>
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<tr>
<td>B-202-F</td>
<td>612</td>
<td>B-201-F</td>
<td>920</td>
</tr>
<tr>
<td>B-902-F</td>
<td>Full F.W</td>
<td>B-901-F</td>
<td>Full F.W</td>
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<tr>
<td>B-904-F</td>
<td>Full F.W</td>
<td>B-903-F</td>
<td>Full F.W</td>
</tr>
<tr>
<td>S-905-F</td>
<td>Full F.W?</td>
<td>B-905-F</td>
<td>Full F.W</td>
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<tr>
<td>S-908-F</td>
<td>Full F.W</td>
<td>B-907-F</td>
<td>Full F.W</td>
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<tr>
<td>C-2-F</td>
<td>5991</td>
<td>C-1-F</td>
<td>6,352</td>
</tr>
<tr>
<td>C-302-F</td>
<td>2,636 L.O.</td>
<td>C-301-F</td>
<td>2,335 L.O.</td>
</tr>
<tr>
<td>C-4-F</td>
<td>516</td>
<td>C-3-F</td>
<td>3001</td>
</tr>
<tr>
<td>C-304-F</td>
<td>516</td>
<td>C-303-F</td>
<td>X</td>
</tr>
<tr>
<td>C-6-F</td>
<td>542</td>
<td>C-5-F</td>
<td>5917</td>
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<td>C-8-F</td>
<td>500</td>
<td>C-7-F</td>
<td>4,573</td>
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A-13
<table>
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<td>A-410F</td>
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<td>B-202-F</td>
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<tr>
<td>B-902-F</td>
<td>Full FW</td>
<td>B-901-F</td>
<td>Full FW</td>
</tr>
<tr>
<td>B-904-F</td>
<td>Full FW</td>
<td>B-903-F</td>
<td>Full FW</td>
</tr>
<tr>
<td>B-906-F</td>
<td>Full FW</td>
<td>B-905-F</td>
<td>Full FW</td>
</tr>
<tr>
<td>B-908-F</td>
<td>Full FW</td>
<td>B-907-F</td>
<td>Full FW</td>
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<tr>
<td>C-2-F</td>
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<td>1960 L.O.</td>
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<td>Dirty Oil</td>
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<td>1134</td>
<td>C-3-F</td>
<td>24</td>
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<td>C-304-F</td>
<td>197</td>
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<td>Sewage</td>
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<td>482</td>
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<td>C-8-F</td>
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## LIQUID LOADING DATA

**Vessel** TAMAROA

**Date** 4/16/81

<table>
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<th>TANK</th>
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<tr>
<td>B-202-F</td>
<td>900</td>
<td>B-201-F</td>
<td>900</td>
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<tr>
<td>B-902-F</td>
<td>3343 FW</td>
<td>B-901-F</td>
<td>3543 FW</td>
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<td>B-904-F</td>
<td>4046 FW</td>
<td>B-903-F</td>
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<tr>
<td>B-905-F</td>
<td>2722 FW</td>
<td>B-905-F</td>
<td>2722 FW</td>
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<tr>
<td>B-908-F</td>
<td>3228 FW</td>
<td>B-907-F</td>
<td>3228 FW</td>
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<tr>
<td>C-2-F</td>
<td>3797</td>
<td>C-1-F</td>
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<td>C-302-F</td>
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<td>C-301-F</td>
<td>1085 DIRTY OIL</td>
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<td>1134</td>
<td>C-3-F</td>
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<td>C-304-F</td>
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<td>C-7-F</td>
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</table>
USCGC CHEROKEE
Tested 4/4/81

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC CHEROKEE
Tested 4/4/81

Run No. 1
Head Sea
Speed 2 kts
Calibration 23.1931

Energy = 2.650

USCGC CHEROKEE
Tested 4/4/81

Run No. 1
Head Sea
Speed 2 kts
Calibration 25.4550

Energy = 3.307
USCGC CHEROKEE
Tested 4/4/81

Roll Response Amplitude Operator

USCGC CHEROKEE
Tested 4/4/81

Energy = 3.022

Wave Energy Spectrum

USCGC CHEROKEE
Tested 4/4/81

Energy = 20.439

Roll Energy Spectrum
USCGC Cherokeee
Tested 4/4/81

Run No. 14
Stern Seas
Speed 10 kts
Calibration 9.2795

Energy = 3.077

Wave Energy Spectrum

USCGC Cherokeee
Tested 4/4/81

Run No. 14
Stern Seas
Speed 10 kts
Calibration 25.4550

Energy = 29.461

Roll Energy Spectrum
USCGC CHEROKEE
Tested 4/4/81

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC CHEROKEE
Tested 4/4/81

WAVE ENERGY SPECTRUM

Energy = 4.204

USCGC CHEROKEE
Tested 4/4/81

ROLL ENERGY SPECTRUM

Energy = 7.105
USCGC CHEROKEE
Tested 4/6/81

ROLL RESPONSE AMPLITUDE OPERATOR

ROLL ENERGY SPECTRUM

USCGC CHEROKEE
Tested 4/6/81

HOUR ENERGY SPECTRUM

Run No. 1
Head Sea
Speed 2 kts
Calibration 0.2795

Energy = 3.070

Run No. 1
Head Sea
Speed 2 kts
Calibration 12.2279

Energy = 11.351
USCGC CHEROKEE
Tested 4/6/81

**ROLL RESPONSE AMPLITUDE OPERATOR**

Run No. 4
Beam Seas (Port)
Speed 2 kts

**WAVE ENERGY SPECTRUM**

Energy = 2.620

**ROLL ENERGY SPECTRUM**

Energy = 48.450
USCGC CHEROKEE
Tested 4/6/81

ROLL RESPONSE AMPLITUDE OPERATOR

Energy = 13.401

WAVE ENERGY SPECTRUM

Energy = 51.607

ROLL ENERGY SPECTRUM
USCGC CHEROKEE
Tested 4/6/81

Roll Response Amplitude Operator

Run No. 7
Stern Sea
Speed 5.0 kts

Energy = 0.305

Wave Energy Spectrum

Run No. 7
Stern Sea
Speed 5.0 kts
Calibration 3.7235

Energy = 13.004

Roll Energy Spectrum
USCGC CHEROKEE
Tested 4/6/81

ROLL RESPONSE AMPLITUDE OPERATOR

Run No. 8
Head Speed 5 kts
Calibration 0.2795

Energy = 3.558

WAVE ENERGY SPECTRUM

USCGC CHEROKEE
Tested 4/6/81

Run No. 8
Head Speed 5 kts
Calibration 25.4558

Energy = 6.401

ROLL ENERGY SPECTRUM
USCGC CHEROKEE
Tested 4/6/81

Run No. 8
Head Sea
Speed 5.0 kts

PITCH RESPONSE AMPLITUDE OPERATOR

USCGC CHEROKEE
Tested 4/6/81

Run No. 8
Head Sea
Speed 5.0 kts
Calibration 12.7279

Energy = 3.947

PITCH ENERGY SPECTRUM
USCGC CHEROKEE
Tested 4/6/01

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC CHEROKEE
Tested 4/6/01

Energy = 3.662

WAVE ENERGY SPECTRUM

USCGC CHEROKEE
Tested 4/6/01

Energy = 35.099

ROLL ENERGY SPECTRUM
USCGC CHEROKEE
Tested 4/6/81

ROLL RESPONSE AMPLITUDE OPERATOR

Energy = 4.946

USCGC CHEROKEE
Tested 4/6/81

Energy = 58.591
USCGC CHEROKEE
Tested 4/6/81

Run No. 12
Beam(Port)
Speed 5 kts
Calibration 9.2795
Energy = 5.322

WAVE ENERGY SPECTRUM

USCGC CHEROKEE
Tested 4/6/81

Run No. 12
Beam(Port)
Speed 5 kts
Calibration 23.4558
Energy = 45.337

ROLL ENERGY SPECTRUM
USCGC CHEROKEE
Tested 4/6/81

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC CHEROKEE
Tested 4/6/81

RUN NO. 13
Aft Qtr (Stbd)
Speed 18.8 kts

Energy = 5.130

WAVE ENERGY SPECTRUM

USCGC CHEROKEE
Tested 4/6/81

RUN NO. 13
Aft Qtr (Stbd)
Speed 18 kts
Calibration 25.4558

Energy = 24.088

ROLL ENERGY SPECTRUM
USCGC CHEROKEE
Tested 4/6/81

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC CHEROKEE
Tested 4/6/81

Wave Energy Spectrum

USCGC CHEROKEE
Tested 4/6/81

Roll Energy Spectrum

Energy = 6.864

Energy = 9.508
USCGC CHEROKEE
Tested 4/6/81

ROLLE RESPONSE AMPLITUDE OPERATOR

USCGC CHEROKEE
Tested 4/6/81

WAVE ENERGY SPECTRUM

Energy = 7.327

USCGC CHEROKEE
Tested 4/6/81

ROLL ENERGY SPECTRUM

Energy = 30.153
USCGC CHEROKEE
Tested 4/6/81

ROLL RESPONSE AMPLITUDE OPERATOR

Energy = 6.901

Wave Energy Spectrum

Energy = 3.666

Roll Energy Spectrum
USCGC TAMAROA
Tested 4/14/81

Energy = 8.419

USCGC TAMAROA
Tested 4/14/81

Energy = 10.100

WAVE ENERGY SPECTRUM

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/14/81

Run No. 1
Head Speed 3 kts

FREQUENCY OF ENCOUNTER (Hz)

PITCH RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/14/81

Run No. 1
Head Sea Speed 3 kts
Calibration 12.7279

Energy = 12.096

PITCH ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/14/81

Run No. 2
Stern Seas
Speed 3.8 kts

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/14/81

Run No. 2
Stern Seas
Speed 3 kts
Calibration 9.2795

Energy = 8.364

WAVE ENERGY SPECTRUM

Energy = 56.787

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/14/01

ROLL RESPONSE AMPLITUDE OPERATOR

Run No. 5
Beam Sea (Port)
Speed 3 kts

ROLL ENERGY SPECTRUM

USCGC TAMAROA
Tested 4/14/01

Run No. 5
Port Beam Sea
Speed 3 kts
Calibration 5.277

WAVE ENERGY SPECTRUM

Energy = 9.676

Energy = 43.485
USCGC TAMAROA
Tested 4/14/81

**Roll Response Amplitude Operator**

**USCGC TAMAROA**
Tested 4/14/81

Run No. 6
Beam Scan (Sidb)
Speed 3 kts

**Energy** $= 8.150$

**Wave Energy Spectrum**

**USCGC TAMAROA**
Tested 4/14/81

Run No. 6
Sidh Beam Scan
Speed 3 kts
Calibration $23.455$

**Energy** $= 42.916$

**Roll Energy Spectrum**
USCGC TAMAROA
Tested 4/14/81

Run No. 7
Head Sea
Speed 5 kts

Pitch Response Amplitude Operator

Energy = 12.643

Pitch Energy Spectrum
USCGC TAMAROA
Tested 4/14/81

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/14/81

WAVE ENERGY SPECTRUM

Energy = 0.057

ROLL ENERGY SPECTRUM

Energy = 58.145
USCGC TAMAROA
Tested 4/14/81

Run No. 10
Hft Qtr (Std) 
Speed 5.0 kts

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/14/81

Run No. 10
Apd Qtr Sess (Std) 
Speed 5 kts 
Calibration 3.2755

Energy = 7.565

WAVE ENERGY SPECTRUM

USCGC TAMAROA
Tested 4/14/81

Run No. 10
Hft Qtr Sess (Std) 
Speed 5 kts 
Calibration 25.4330

Energy = 56.344

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/14/01

ROLL RESPONSE AMPLITUDE OPERATOR

WAVE ENERGY SPECTRUM

Energy = 7.738

USCGC TAMAROA
Tested 4/14/01

Roll No. 11
Plug Beam Sea
Speed 5 kts
Calibration 25.4558

Energy = 44.988

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/14/81

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/14/81

Run No. 13
Head Seas
Speed 10 kts
Calibration 9.2755

Energy = 6.841

WAVE ENERGY SPECTRUM

USCGC TAMAROA
Tested 4/14/81

Run No. 13
Head Seas
Speed 10 kts
Calibration 25.4558

Energy = 10.782

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/14/81

Run No. 13
Head
Speed 10 kts

PITCH RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/14/81

Run No. 13
Head Sea
Speed 10 kts
Calibration 12.2279

Energy = 7.981

PITCH ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/14/01

Run No. 16
Aft Qtr Seax(Stbd)
Speed 10.0 kts

Energy = 7.031

WAVE ENERGY SPECTRUM

RUN RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/14/01

Run No. 16
Aft Qtr Seax(Stbd)
Speed 10.0 kts
Calibration 9.2793

Energy = 36.043

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/14/81

ROLL RESPONSE AMPLITUDE OPERATOR

Energy = 7.330

Energy = 21.249

WAVE ENERGY SPECTRUM

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/14/81

Run No.: 10
Beam Sway (Std)
Speed: 10 kts

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/14/81

Run No.: 10
Std Beam Sway
Speed: 10 kts
Calibration 5.2795

Energy = 7.035

WAVE ENERGY SPECTRUM

USCGC TAMAROA
Tested 4/14/81

Run No.: 10
Std Beam Sway
Speed: 10 kts
Calibration 25.4558

Energy = 52.714

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/15/81

Run No. 3
Stern Seam
Speed 18 kts
Calibration 9.2795

Energy = 2.962

USCGC TAMAROA
Tested 4/15/81

Run No. 3
Stern Seam
Speed 18 kts
Calibration 23.4558

Energy = 9.205

WAVE ENERGY SPECTRUM

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/15/81

Run No. 4
Head Seas
Speed 18.0 kts

PITCH RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/15/81

Run No. 4
Head Seas
Speed 18 kts
Calibration 12.7279

Energy = 2.399

PITCH ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/13/81

ROLL RESPONSE AMPLITUDE OPERATOR

USCGC TAMAROA
Tested 4/13/81

Energy = 2.851

USCGC TAMAROA
Tested 4/13/81

Energy = 10.081

WAVE ENERGY SPECTRUM

ROLL ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/15/91

Run No. 12
Heave Seas
Speed 5.0 kts

\[ \gamma_e (t) = 0.6 \gamma_s \]

PITCH RESPONSE AMPLITUDE OPERATOR

Energy = 1.211

USCGC TAMAROA
Tested 4/15/91

Run No. 12
Heave Seas
Speed 5 kts
Calibration 12.7279

PITCH ENERGY SPECTRUM
USCGC TAMAROA
Tested 4/15/81

Run No. 14
Stern Sea
Speed 2.0 kts

ROLL RESPONSE AMPLITUDE OPERATOR

Frequency of Encounter (Hz)

-1.1
-1.0
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3

Energy = 0.159

Energy = 1.170

USCGC TAMAROA
Tested 4/15/81

Run No. 14
Stern Sea
Speed 2.0 kts
Calibration 25.4550

WAVE ENERGY SPECTRUM

Energy = 1.170

Energy = 0.159

ROLL ENERGY SPECTRUM