TRANSPORTABILITY
ENGINEERING ANALYSIS

LOAD FACTORS FOR
CARGO RESTRAINT
DURING
MARINE TRANSPORT

Prepared by:
MR. JOHN T.H. GERMANOS

MILITARY TRAFFIC MANAGEMENT COMMAND
TRANSPORTATION ENGINEERING AGENCY
720 THIMBLE SHOALS BLVD, SUITE 130
NEWPORT NEWS, VIRGINIA 23606-2574
COMMERCIAL (804) 599-1113
AUTOVON 927-4646

DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimited
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>EXECUTIVE SUMMARY</td>
<td>1</td>
</tr>
<tr>
<td>II.</td>
<td>BACKGROUND</td>
<td>1</td>
</tr>
<tr>
<td>III.</td>
<td>ANALYSIS</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>A. Acceleration Equations</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>B. Load Factor Equations</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>C. Assumptions and Rationale</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>D. Findings</td>
<td>8</td>
</tr>
<tr>
<td>IV.</td>
<td>CONCLUSION</td>
<td>10</td>
</tr>
<tr>
<td>V.</td>
<td>RECOMMENDATIONS</td>
<td>12</td>
</tr>
<tr>
<td>APPENDIXES</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. MSC Memorandum on Effects of G-Forces During Marine Transport</td>
<td>A-1</td>
</tr>
<tr>
<td></td>
<td>B. Load Factor Example Calculation</td>
<td>B-1</td>
</tr>
<tr>
<td>GLOSSARY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DISTRIBUTION</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
I. EXECUTIVE SUMMARY

This analysis establishes up-to-date load factors for use in establishing tiedown procedures for military equipment during marine transport. These load factors apply to all ships currently listed on the Computerized Deployment System (CODES) database.

II. BACKGROUND

Prior to this study, load factors specifically for use in determining marine tiedown procedures had never been documented. The American National Standards Institute (ANSI) lists load factors imposed on containers during marine transport as follows:

"It is assumed that the combined effect of a vessel's motions and gravity results in an equivalent 1.8 times gravity vertical acceleration, an equivalent 0.6 times gravity transverse acceleration and an equivalent 0.4 times gravity longitudinal acceleration." \(^1\)

However, these factors are primarily used to influence the design of containers. They are not supported by any rationale, such as sea conditions and/or ship design. As a result, Military Traffic Management Command Transportation Engineering Agency (MTMCTEA) had always based marine tiedown procedures on the acceleration data in Army Technical Bulletin (TB) 55-100, which states:

"...cargo and its restraining system should be capable of sustaining an environment occasioned by a seaway-induced loading on a transport ship consequent to twenty days of Beaufort sea state condition 12." \(^2\)

The data from TB 55-100 used to establish the guidance for sustaining the above environment is shown by figure 1. These data are a plot of an envelope of the maximum values of vibrations in the frequency range of 0 to 15 cycles per second. Figure 1 also shows a time history envelope of the maximum shock environment measured. It indicates that the maximum accelerations for a C-2 general cargo ship would be 1.5g in the vertical and lateral directions. Longitudinal accelerations are not addressed, so we typically used 1.0g as a "rule of thumb." Experience gained from Operation Desert Shield/Storm indicates that these data are outdated and inappropriate for today's fleet of larger roll-on/roll-off (RORO) and breakbulk ships that were used to deploy Army equipment to Southwest Asia (SWA). In addition, inconsistent and often excessive tiedown procedures were required by ship's officers because we did not have any published restraint criteria to use for guidance. This resulted in wasted time, money, materials, and manpower hours, especially when lashing gangs were forced to break down and redo lashings to satisfy varying "gut instincts" of ship officers. For example, at the port of Jacksonville, we witnessed one lashing gang being directed by ship officers to tie down 5-ton trucks three different ways on three successive vessels. This led to frustration and wasted valuable time.

\(^1\) American National Standard, Requirements for Closed Van Cargo Containers, ANSI MH5.1M-1979.
Figure 1. Load factor data from TB 55-100.
Recognizing the need for reliable marine tiedown guidance, the Commander, MTMC requested that we establish tiedown criteria that would be adequately conservative, yet enable us to reduce the time and cost of deployment. To initiate this effort, we had to establish some realistic load factors that could serve as the common reference for tiedown criteria and procedures. Initially, we requested that the Military Sealift Command (MSC) provide us with these load factors. MSC's response to our request (app A) recommended that we use DOD-STD-1399 to calculate the load factors. The following analysis accomplishes this task and provides the foundation for the development of a consolidated marine lifting and tiedown handbook that will effectively standardize sealift procedures.

III. ANALYSIS

The load factors presented herein are dimensionless numbers that account for the component accelerations imposed on military equipment by ship motion and attitude during storm sea conditions. When multiplied by the equipment's weight, these load factors give design loads that the equipment tiedown assembly must be able to withstand in the longitudinal (X), transverse (Y), and vertical (Z) directions. We do not intend this study to be a primer in naval architecture; however, the following equations and assumptions must be addressed, since they provide the foundation for our analysis.

A. Acceleration Equations

The motion of a floating object has six degrees of freedom, as shown by figure 2. To determine the accelerations imposed on cargo by ship motion and attitude, we must consider static and dynamic contributions. Static contributions are dictated by the ship attitude and include list, heel, and trim. Dynamic contributions, shown in figure 2, include angular (roll, pitch, and yaw) and linear (surge, sway, and heave) motions. When combined with the components of the gravitational acceleration on the equipment, the terms for these static and dynamic motions are summed to determine the net accelerations in the X, Y, and Z directions as described by the following formulas.

1. \[ A_x = g \sin \Theta + s + k_1 \Theta X + k_1 Z \]
2. \[ A_y = g \sin \Phi + \frac{1}{2} k_1 X + k_2 \Phi Y + k_2 Z \]
3. \[ A_z = g \pm [h + k_1 X + k_2 Y] \quad ("+" \text{ is up, "-" is down}) \]

---

2 Memorandum, MTMCTEA, ATTN: MTTE-TRV, 6 Nov 90, subject: G-Forces Encountered During Marine Transport.
Where,

4. \[ k_1 = 4\pi^2 \Theta / T_r^2 \quad (T_r = (CB) / GM) \]

and,

5. \[ k_2 = 4\pi^2 \Phi / T_r^2 \]

The variables and symbols used in the above equations are defined as follows:

\[ A_x = \text{component acceleration in the longitudinal direction} \]
\[ A_y = \text{component acceleration in the transverse direction} \]
\[ A_z = \text{component acceleration in the vertical direction} \]
\[ \Theta = \text{maximum pitch angle (rad)} \]
\[ \Phi = \text{maximum roll angle (rad)} \]
\[ s = \text{surge acceleration (m/s}^2\text{ or } \text{ft/s}^2) \]
\[ h = \text{heave acceleration (m/s}^2\text{ or } \text{ft/s}^2) \]
\[ g = \text{acceleration caused by gravity (m/s}^2\text{ or } \text{ft/s}^2) \]
\[ T_p = \text{pitch period (sec)} \]
\[ T_r = \text{roll period (sec)} \]
\[ GM = \text{maximum metacentric height (m or ft)} \]
\[ B = \text{maximum beam at or below the waterline (m or ft)} \]
\[ C = \text{roll constant (s/ft)} \]
\[ X = \text{longitudinal distance from CG (m or ft)} \]
\[ Y = \text{transverse distance from CG (m or ft)} \]
\[ Z = \text{vertical distance above CG (m or ft)} \]

Note: \( X, Y, \) and \( Z \) define the stowage location farthest from the ship's center of gravity (CG).

Many of the above symbols and/or terms appear in the Glossary. In addition, figures 3 and 4 illustrate the two most significant dynamic motions (rolling and pitching) along with some appropriate symbols.
\( \overline{WL} = \text{initial waterline} \)

\( \overline{W_1L_2} = \text{waterline after rolling } \phi \text{ degrees} \)

\( G = \text{center of gravity} \)

\( M = \text{metacenter} \)

\( B = \text{center of buoyancy} \)

\( GM = \text{metacentric height} \)

**Figure 3.** End view of a vessel upright and after rolling \( \phi \) degrees.

\( \overline{WL} = \text{initial waterline} \)

\( \overline{W_1L_1} = \text{waterline after pitching } \theta \text{ degrees} \)

\( G = \text{center of gravity} \)

\( B = \text{center of buoyancy} \)

**Figure 4.** Side view of a vessel upright and after pitching \( \theta \) degrees.
B. Load Factor Equations

Once the component accelerations have been calculated as shown above, determination of the load factors is relatively simple. The following equations define these load factors.

1. $L_{L} = A_{L}/g$  longitudinal load factor
2. $L_{T} = A_{T}/g$  transverse load factor
3. $L_{V} = A_{V}/g$  vertical load factor

C. Assumptions and Rationale

To conduct our analysis for a “worst case” scenario, we made the following assumptions. Rationale is included where appropriate.

1. The vessel is on a transoceanic voyage under storm sea conditions equivalent to sea state 8 (up to 45-foot wave height). Sea state 8 is the worst case presented in DOD-STD-1399, section 301A, and it is used here to represent a “winter North Atlantic” environment. Therefore, we are considering maximum sea-induced accelerations in our load factor equations. Interviews with ship officers returning from SWA during Desert Shield/Storm revealed that the worst sea encountered was sea state 4. This implies we have been adequately conservative in assuming sea state 8. Table 1 relates sea state to significant wave height.

<table>
<thead>
<tr>
<th>Sea State Number</th>
<th>Significant Wave Height</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Meters</td>
</tr>
<tr>
<td>0-1</td>
<td>0.00 - 0.10</td>
</tr>
<tr>
<td>2</td>
<td>0.10 - 0.50</td>
</tr>
<tr>
<td>3</td>
<td>0.50 - 1.25</td>
</tr>
<tr>
<td>4</td>
<td>1.25 - 2.50</td>
</tr>
<tr>
<td>5</td>
<td>2.50 - 4.00</td>
</tr>
<tr>
<td>6</td>
<td>4.00 - 6.00</td>
</tr>
<tr>
<td>7</td>
<td>6.00 - 9.00</td>
</tr>
<tr>
<td>8</td>
<td>9.00 - 14.00</td>
</tr>
<tr>
<td>&gt;8</td>
<td>&gt;14.00</td>
</tr>
</tbody>
</table>
2. Greatest initial emphasis must be placed on the transverse load factor. It is typically the largest factor and contributes the most to overall restraint requirements. This is because that ships have a greater tendency to rotate about their longitudinal axis (roll). Figure 5 illustrates how load factors vary with increasing sea state for the Fast Sealift Ship (FSS). The transverse load factor is always the highest for cargo restraint/tiedown considerations. Note that only negative vertical load factor values (up or down) contribute to restraint requirements. The positive values shown in figure 5 are actually load factors for determining the "g-load" on the deck, not a "g-load" that must be accounted for by the cargo tiedown assembly.

3. The load being restrained is at the stowage location farthest from the ship's CG. Since the acceleration induced by ship motion is proportional to the distance from the ship's CG, the load will experience the greatest accelerations and corresponding load factors at the farthest location from the CG.

4. Ships analyzed were partially loaded to create a notional worst case metacentric height (GM). An ideal GM usually corresponds to a fully loaded vessel riding relatively low in the water, since this condition is less inclined to promote rolling. As the load lightens, the vessel rides proportionally higher in the water, and the GM increases. As it rides higher in the water, the vessel tends to "bob" and is more inclined to roll; hence, a worst case is introduced.

5. A roll constant \((C)\) of 0.4 \(\text{s/rt}\) was used to represent the ships in this study. The roll constant is based on experimental results from similar vessels. Per DOD-STD-1399, \(C\) varies from 0.38 to 0.49. Lower values of \(C\) reflect a worst case; however, varying \(C\) over the full range of possible values yields a maximum transverse load factor change of 0.05, or about 3 percent. This variation is relatively insignificant and supports our contention that \(C = 0.4\) is adequately conservative. The transverse load factor is the most sensitive to variations in \(C\).

6. The ships used in our calculations represent an acceptable sample of vessels in the CODES database for use in determining a generic set of load factors. We wrote a computer program that varied all components of the load factor equations for the FSS to see which tended to have the most detrimental effect on the transverse load factor. We compared these results with the CODES ship database and files to produce a list of smaller RORO and breakbulk ships with characteristics that would result in the highest load factors (worst case).

7. Generally, a correlation exists between overall ship size and load factors. Larger vessels tend to be more stable in rough seas; therefore, their corresponding load factors tend to be less than that of smaller vessels.

D. Findings

Based on these equations and assumptions and the ship data provided by MSC and Maritime Administration, we calculated load factors for each ship. Table 2 compiles the data and results for the ships analyzed. As expected, the load factors for the FSS because of its relative size and stability, are significantly less than for the "other ships" analyzed. Therefore, we have chosen to treat the FSS as a special case, independent of smaller RORO and breakbulk ships in the CODES database. From table 2, the highest load factors correlate to the smallest vessels, with the container/breakbulk being the notional worst case. This observation lends credence to our sixth and seventh assumptions. In all cases, our calculated load factors
FIGURE 5
LOAD FACTORS VERSUS SEA STATE FOR THE FAST SEALIFT SHIP
## TABLE 2
Data and Results for the Ships Analyzed

<table>
<thead>
<tr>
<th>DATA CATEGORY</th>
<th>DATA SUMMARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship Name</td>
<td>Fast</td>
</tr>
<tr>
<td></td>
<td>Scaflift</td>
</tr>
<tr>
<td>Ship Type</td>
<td>RORO</td>
</tr>
<tr>
<td>MA #</td>
<td>n/a</td>
</tr>
<tr>
<td>Length Between</td>
<td>840.5</td>
</tr>
<tr>
<td>Perpendicular, LBP (ft)</td>
<td></td>
</tr>
<tr>
<td>Beam, B (ft)</td>
<td>105.5</td>
</tr>
<tr>
<td>Metacenter Height, GM (ft)</td>
<td>8.41</td>
</tr>
<tr>
<td>Max. Longitudinal Distance from Ship's CG, X (ft)</td>
<td>317.0</td>
</tr>
<tr>
<td>Max. Vertical Distance from Ship's CG, Z (ft)</td>
<td>21.45</td>
</tr>
<tr>
<td>Max. Horizontal Distance from Ship's CG, Y (ft)</td>
<td>26.4</td>
</tr>
<tr>
<td>Roll Constant, C (sec/ft)</td>
<td>0.40</td>
</tr>
<tr>
<td>Roll Angle, ( \phi ) (rad)</td>
<td>0.54</td>
</tr>
<tr>
<td>Pitch Angle, ( \Theta ) (rad)</td>
<td>0.087</td>
</tr>
<tr>
<td>Roll Period, ( T_r ) (sec)</td>
<td>14.55</td>
</tr>
<tr>
<td>Pitch Period, ( T_p ) (sec)</td>
<td>8</td>
</tr>
<tr>
<td>Heave Acceleration, ( h ) (ft/sec^2)</td>
<td>6.43</td>
</tr>
<tr>
<td>Surge Acceleration, ( s ) (ft/sec^2)</td>
<td>3.215</td>
</tr>
<tr>
<td>Transv. Acceleration, ( A_y ) (ft/sec^2)</td>
<td>28.696</td>
</tr>
<tr>
<td>Long. Acceleration, ( A_z ) (ft/sec^2)</td>
<td>8.66</td>
</tr>
<tr>
<td>Vert. Acceleration (up), ( A_{z1} ) (ft/sec^2)</td>
<td>5.992</td>
</tr>
<tr>
<td>Vert. Acceleration (down), ( A_{z2} ) (ft/sec^2)</td>
<td>58.307</td>
</tr>
<tr>
<td>Transv. Load Factor, ( L_y )</td>
<td>0.89</td>
</tr>
<tr>
<td>Long. Load Factor, ( L_x )</td>
<td>0.269</td>
</tr>
<tr>
<td>Vert. Load Factor (up), ( L_{z1} )</td>
<td>0.186</td>
</tr>
</tbody>
</table>
were significantly less than those historically used by MTMC for planning marine restraint/tiedown procedures. Table 3 compares our results with the load factors previously used and shows the percent reduction resulting from our study. Appendix B contains an example calculation for the vessel, Aide, since it presented the worst case load factors. Similar calculations were done for each vessel analyzed by using the equations in paragraphs III A and B. Our calculations and results were sent to MSC for approval in February 1991. MSC concurred with our results, stating that “These factors are considered conservative and satisfactory for ship cargo loadings.”

These load factors provide the common base required for developing general tiedown procedures for marine transport. Once developed, these procedures will be incorporated into MTMCTEA Pamphlet 55-22, Marine Terminal Lifting and Tiedown Guidance. We published similar pamphlets for rail tiedown (MTMCTEA Pam 55-19) and marine lifting (MTMCTEA Pam 56-1). These pamphlets were used extensively during Desert Shield/Storm operations. MTMCTEA Pam 55-22 will consolidate the revision of MTMCTEA Pam 56-1 (lifting manual) with the newly developed tiedown guidance, to produce a comprehensive marine terminal reference that military and commercial shippers did not have in the past. The net result will be more efficient loading operations at the ports.

IV. CONCLUSION

Prior to this study, appropriate load factors for determining marine restraint criteria did not exist. Marine tiedown procedures typically varied for different vessels, subject to the discretion of the individual inspecting the load. This often led to excessive lashing and wasted time, money, and manpower hours, particularly when lashing gangs were required to breakdown and redo tiedowns to satisfy a particular individual. This study provides the baseline for establishing uniform tiedown procedures on all ships in the CODES database. The load factors we established are adequately conservative and have been approved by MSC. The following summarizes these load factors for the FSS and all “other ships” in the CODES database:

<table>
<thead>
<tr>
<th>Ship</th>
<th>Transverse Load Factor</th>
<th>Longitudinal Load Factor</th>
<th>Vertical Load Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSS</td>
<td>0.9</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Other</td>
<td>1.2</td>
<td>0.7</td>
<td>0.4</td>
</tr>
</tbody>
</table>

We will use these load factors to develop general marine tiedown guidance that will be consolidated into the new MTMCTEA Pam 55-22, Marine Terminal Lifting and Tiedown Guidance. This pamphlet will promote uniform lifting and tiedown procedures, to ensure commercial and military shippers share a common reference during future deployment.

5 Memorandum, MTMCTEA (MTTE-TRS), 04 Feb 91, subject: Revised Load factors for Restraint During Marine Transport.
TABLE 3
Actual Load Factor Reductions:

<table>
<thead>
<tr>
<th>SHIP</th>
<th>DIRECTION</th>
<th>CURRENT LOAD FACTOR</th>
<th>REDUCED LOAD FACTOR</th>
<th>PERCENT REDUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSS</td>
<td>TRANSVERSE</td>
<td>1.5</td>
<td>0.9</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>LONGITUDINAL</td>
<td>1.0</td>
<td>0.3</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>VERTICAL *</td>
<td>1.5</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>OTHER</td>
<td>TRANSVERSE</td>
<td>1.5</td>
<td>1.2</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>LONGITUDINAL</td>
<td>1.0</td>
<td>0.7</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>VERTICAL</td>
<td>1.5</td>
<td>0.4</td>
<td>73</td>
</tr>
</tbody>
</table>

*Only the absolute value of negative vertical load factors contributes to the restraint requirements. Since the FSS does not induce negative "g's" on its cargo at sea state 8, a vertical load factor is not necessary. In reality, however, the geometry of the tiedown assembly will always provide a minimum of 0.2 g’s in the vertical (up) direction.

V. RECOMMENDATIONS

MTMCTEA should:

A. Proceed with the development of marine tiedown guidance based on the load factors presented herein.

B. Assess the feasibility of establishing optional, less conservative load factors and subsequent tiedown requirements for:

1. Different ship classes, that is, Cape D’s, Cape H’s, and so forth.

2. Varying sea states, that is, sea states 4 through 8, versus sea state 8 exclusively, to give the captain an option when he expects the ship to encounter sea state 8 or less (as was the case during Desert Shield/Storm).

3. Stowage locations closer to the ship’s CG since locations closest to the CG will require little or no restraint.
C. Coordinate all future related progress and findings extensively throughout DOD and the commercial shipping industry.

Note: For ships not in the CODES database, ships with unusual ship loading configurations, and/or ship's with extraordinary dimensions, load factors should be calculated on a case-by-case basis to ensure they are less than or equal to those presented in this analysis. MTMCTEA will be happy to assist and/or perform these calculations on a request basis.

In addition, questions and/or suggestions pertaining to this study should be addressed to:

    Director, MTMCTEA
    ATTN: MTTE-TRV (Mr. John Germanos)
    720 Thimble Shoals Blvd - Suite 130
    Newport News, VA 23606-2574
APPENDIX A

MSC Memorandum on Effects of G-Forces During Marine Transport
From: Commander, Military Sealift Command
To: Commander, Military Traffic Management Command
Transportation Engineering Agency

Subj: EFFECTS OF G-FORCES DURING MARINE TRANSPORT

Ref: (a) MTMCTEA ltr Ser MTTE-TRV (70-47a) of 6 Nov 90
(b) Phonecon J. Cassidy (MTMC)/A. Attermeyer (N741) of 9 Nov 90
(c) Army Technical Bulletin 55-100, "Transportability Criteria: Shock and Vibration", 18 Apr 64

Encl: (1) MIL-STD-1399 Sect. 301A, "Ship Motion and Attitude", July 86

1. References (a) and (b) requested that Military Sealift Command (MSC) provide the g-forces Army equipment can experience during Marine transport. Reference (a) also indicated that reference (c) is presently used to determine the cargo restraining system. The restraint criteria of reference (c), i.e., a minimum of 1.5g in lateral and vertical directions, is considered by MTMC to be excessive, time consuming and costly. The comments below address specific issues and questions of reference (a).

2. Reference (c) addresses the required tie-down procedures of equipment to resist shock and vibration loads while in transit (rail, sea, or air). Although these loads are important variables in the design of equipment and tie-down procedure, they are separate issues from seakeeping forces induced by ship motions.

3. Reference (a) requests restraint criteria (g-forces) for different ship size or type, cargo location on board the ship, and sea states in transit. All of these concerns are addressed in enclosure (1) which is provided for your use. Enclosure (1) is the Navy's manual for determining general ship motions and provides appropriate equations for forces (called "load factors") in both moderate and storm seas. It is recommended that enclosure (1) be utilized for tie-down designs to resist ship motion forces as described in the document.

4. References (a) and (b) expressed the desire to reduce tie-down restraints due to the use of larger ships on shorter (Mediterranean) voyages. Ship motions, while generally lower on larger ships, are a complex combination of sea conditions and ship characteristics and are not a strict linear function of overall ship size. Also, high accelerations can still occur at the extreme distances of cargo on larger ships from the centers of rolling and pitching. Therefore, a reduction in tie-down restraint cannot be provided due to ship size alone. Concerning shorter voyages, although sea states are generally lower in the Mediterranean Sea, wave heights can reach up to 30 feet during the month of January, corresponding to sea state 7. Enclosure (1) may also be
Subj: EFFECTS OF G-FORCES DURING MARINE TRANSPORT

utilized to determine appropriate loading forces in the Mediterranean on a case-by-case basis. However, any voyage originating on the East Coast (U.S.) but transiting through the Mediterranean should have cargo restraint for an ocean voyage.

Thomas W. Allen

P.M. Allen
By Direction
APPENDIX B

Load Factor Example Calculation

Ship Name: Aide  Type: Container/Breakbulk  MA#: C3-S-38a

Physical Characteristics:

\[ \text{LBP} = 470 \text{ ft}; \quad \text{GM} = 3.40 \text{ ft}; \quad B = 73 \text{ ft}; \quad C = 0.40 \text{ sec/} \sqrt{\text{ft}}; \]
\[ X = 189 \text{ ft}; \quad Y = 30 \text{ ft}; \quad Z = 44 \text{ ft} \]

\[ T = \frac{(B)(C)}{\text{GM}'} = 15.8 \text{ sec} \]

\[ \phi = 37^\circ \left( \frac{\pi}{180^\circ} \right) = 37\pi/180 \text{ rad} \]

\[ \theta = 7^\circ \left( \frac{\pi}{180^\circ} \right) = 7\pi/180 \text{ rad} \]

\[ T_p = 6 \text{ sec} \]

\[ h = (0.50)(32.15 \text{ ft/sec}^2) = 16.1 \text{ ft/sec}^2 \]

\[ s = (0.25)(32.15 \text{ ft/sec}^2) = 8.04 \text{ ft/sec}^2 \]

Using equation 2 in paragraph III A,

\[ A_y = (32.15) \sin \left( \frac{37\pi}{180} \right) + \frac{1}{2} \left[ \frac{4\pi^2}{36}(7\pi/180)(189) \right] + \left( \frac{4\pi^2}{(15.8)^2} \right) \left( \frac{37\pi}{180} \right)^2 (30) + \frac{4\pi^2}{(15.8)^2} \left( \frac{37\pi}{180} \right)(44) \]

Therefore,

\[ A_y = 38.45 \text{ ft/sec}^2 \]

And, using equation 2 in paragraph III B,

\[ L_y = 38.45/32.15 = 1.196 \]

Substituting similar of values in equations 1, 3, and 6 of paragraph III A and equation 3 of paragraph III B yields the following:

\[ A_x = 20.94 \text{ ft/sec}^2 \]

\[ L_{tx} = 0.651 \]

And,

\[ A_z \ (\text{up}) = -12.30 \text{ ft/sec}^2 \]

\[ L_{t\alpha} \ (\text{up}) = -0.382 \]

B-1
1. Angular motions - the oscillatory motions of roll, pitch, and yaw.

2. Attitude, ship's - defined by a ship's list, trim, and heel; the net inclination of a ship in the water.

3. Beam - the extreme width of a ship at or below the waterline.

4. Design load - the force applied to cargo at a given location in the ship, determined by multiplying the cargo mass by the load factor(s). This is the load the tiedown assembly must be capable of restraining.

5. "g-load" or "g-force" - acceleration caused by gravity (9.807 m/sec² or 32.15 ft/sec²).

6. Heave - the up and down motion of a ship along the vertical (Z) axis.

7. Heel - the nonoscillating angular displacement of a ship about the longitudinal (X) axis caused by steady externally imposed loads (that is wind, control surface, and so forth).

8. Length between perpendiculars - the length of a ship measured from the forward perpendicular to the after perpendicular.

9. Linear motions - motions contributed by heave, surge and sway along the respective axes.

10. List, also called "heel" - the inclination of a ship about the longitudinal (X) axis caused by either lateral separation between the center of gravity and the center of buoyancy or by steady externally imposed loads (that is wind or control surface).

11. Load factor - a calculated number in terms of gravitational and dynamic acceleration, which, when multiplied by the mass of cargo, determines the design load that the cargo tiedown assembly must restrain in the longitudinal, transverse, and vertical directions as a result of the accelerations of gravity and ship motions.

12. Metacentric height - distance from the ship's center of gravity to the metacenter; a measure of the vessel's stability in the upright or nearly upright condition.

13. Pitch - the oscillatory motion of a ship about the transverse (Y) axis.

14. Roll - the oscillatory motion of a ship about the longitudinal (X) axis.

15. Sea state - a measure of the severity of the sea conditions, to include wave height, period, energy distribution with wave frequency, and direction.

16. Ship's motion - the motions defined by the six degrees of freedom of a floating vessel (roll, pitch, yaw, surge, sway, and heave).
17. Surge - fore and aft motion of a ship along the longitudinal (X) axis.

18. Sway - the lateral motion of a ship along the transverse (Y) axis.

19. Tiedown assembly - all components of the restraint system that must secure the cargo to the design load requirements dictated by the respective load factors; includes cargo tiedown provisions, chains, load binders, shackles, deck tiedowns, and so forth.

20. Trim - the inclination of a ship about the transverse (Y) axis caused by longitudinal separation of the center of gravity and the center of buoyancy.

21. Yaw - the oscillatory motion of a ship about the vertical (Y) axis.
Lykes Bros. Steamship Co., Inc., 300 Poyvas St., New Orleans, LA 70130
Maersk Line, Limited, Giralda Farms, Madison Ave, P.O. Box 884, Madison, NJ 07940-0884
Maritime Overseas Corp., 511 Fifth Ave., New York, NY 10017
Matson Navigation Company, Inc., P.O. Box 7452, San Francisco, CA 94120
Transportation Institute, 5201 Auth Way, Camp Springs, MO 20746
Marine Center Equipment Certification Corporation, 160 Squankum Yellowbrook Rd, Farmingdale, NJ 07727
Peck and Hale, Inc., 180 Division Ave, West Springfield, NY 11796
American National Standards Inst., 11 West 42nd Street, New York, NY 10036
International Cargo Gear Bureau, 17 Battery Place, New York, NY 10004
Commander, MSC Pacific, Naval Supply Center, Oakland, CA 94625
Commander, MSC Europe, Box 3, FPO New York 09510-5300
Commander, MSC Far East, FPO Seattle 98760
Commander, MSC Mediterranean, P.O. Box 23, FPO New York 09521
Commander, MSC Southeast Asia, Box 11 FPO San Francisco, CA 96651-2600
Commander, MSC Middle Atlantic, Bldg Y100A, Naval Supply Center, Norfolk, VA 23512-5000
NAVCHAPGRU NSC Cheatham Annex, Williamsburg, VA 23185-8792
COMSCLANT Military Ocean Terminal, Bldg 42, Bayonne, NJ 07002
CG FMFEUR (DESIGNATE), ATTN: G-4, U.S. Naval Act., United Kingdom, Box 33, FPO New York 09510
CG 1ST MARDIV, Embarkation Officer, Camp Pendleton, CA 92055-5501
CG 2D MARDIV, Embarkation Officer, Camp Lejeune, NC 28542-5501
CG 3D MARDIV, Embarkation Officer, FPO San Francisco 96602-8601
CG 4th MARDIV USMCR, 4400 Dauphine St, New Orleans, LA 70146-5400
CG 1st MAW, Embarkation Officer, FPO San Francisco 96603-8701
CG 2d MAW, Embarkation Officer, MCAS, Cherry Point NC 28533-6001
CG 3d MAW, Embarkation Officer, MCAS, El Toro, Santa Ana 92709-6001
CG 4th MAW MARTC, 4400 Dauphine St, New Orleans, LA 70146-5500
CO 1st FSSG, Embarkation Officer, Camp Pendleton, CA 92055-5701
CG 2d FSSG, Embarkation Officer, Camp Lejeune, NC 28542-5701
CG 3d FSSG, (ATTN: DC/S OPS-EMBARK), FPO San Francisco 96604-8801
CG 1st Marine Brigade, Embarkation Officer, FPO San Francisco 96863-5501
CG 4th MEB (EMBO), FPO New York 09502-8404
CG 5th MEB, Camp Pendleton, CA 92055-5405
CG 6th MEB (EMBO), Camp Lejeune, NC 28542-5406
CG 7th MEB, ATTN: G4/EMBARK, MCAGCC 29 Palms, CA 92278-5407
CG 9th MEB (EMBO) FPO San Francisco 96606-8409
CO LFTCPAC, Embarkation Section, NAB, Coronado, San Diego, CA 92155-5034
CG LFTCLANT, Embarkation Branch, NAB, Little Creek, Norfolk, VA 23521-5350
HQ 265th Engr Grp, ATTN: CPT Heath, P.O. Box 7747, Marietta, GA 30065-1747
16th Engineer Command, ATTN: AFRC-ENIL-LG, 4454 W. Cermak Rd, Chicago, IL 60623-2991
HHD, 28th Trans Bn, ATTN: S-3 (MAJ Ron Ellis), APO AE 09166
G4/DTO 25ID (L), ATTN: CPT F. K. Gates, Schofield Barracks, HI 96858
234th Base Supt Bn, ATTN: AET-HVG-XO (MAJ John Christensen), Unit 20911, APO AE 09169
3997 Leach Lake Way, ATTN: CPT Joe Crowley, Fort Irwin, CA 92310
29th DTO, ATTN: CPT Michael K. LaViolette, Fort Belvoir, VA 22060
Commander, 5th Inf Div (M), ATTN: G4 (CPT Cale), Fort Hood, TX
Commander, 10th Mountain Division, ATTN: G4, DTO (MAJ McNulty), Fort Drum, NY 13602