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Extreme Values of Motion from RO/RO Discharge Facility Experiments and Trials

By

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Several predictions, model experiments, and trials concerning the absolute and relative motion of various components of a Roll-On/Roll-Off (RO/RO) ship offshore off loading system have been reviewed. The results of each report have been compared to similar results of other reports. A table of estimated extreme motion values for the RO/RO ship and causeway platform motions in Sea State 3 was determined from appropriate existing data. Recommendations are presented for future work to improve motion predictions.

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ABSTRACT

Several predictions, model experiments, and trials concerning the absolute and relative motion of various components of a Roll-On/Roll-Off (RO/RO) ship offshore off loading system have been reviewed. The results of each report have been compared to similar results of other reports. A table of estimated extreme motion values for the RO/RO ship and causeway platform motions in Sea State 3 was determined from appropriate existing data. Recommendations are presented for future work to improve motion predictions.

ADMINISTRATIVE INFORMATION

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INTRODUCTION

The Department of Defense is in the process of developing a system for rapid deployment of equipment, supplies, and vehicles to shore in support of any major DOD operation. As part of the Containers Over the Shore (COTS) and Fleet Logistics Readiness Technology (FLRT) programs, a number of studies, experiments and trials have been conducted to develop and evaluate systems to accomplish this objective. One of these systems is intended to offload cargo from RO/RO ships anchored in the stream. This system is being developed in two stages, the first is a near term calm water capability and the second a Sea State 3 capability.

Development and testing of the near term calm water capability took place in the early 1980's. During 1982 and 1983, full scale evaluations of the calm water RO/RO Discharge Facility (RO/RO DF) were conducted. The results of those trials verified the capability of the RO/RO DF to operate in Sea States 1 to 2. Operations were discontinued when waves approached Sea State 3 for fear of damaging equipment and danger to personnel.

The FLRT program will develop and evaluate concepts to meet the Sea State 3 requirement. Model tests were conducted in 1984 to evaluate the effect of Sea State 3 on the calm water RO/RO DF.

The purpose of this investigation is to define motions and relative motions of ship/ramp/barge systems in Sea State 3 for use in concept design and evaluation. Available data from past tests, projects, and demonstrations will be examined to determine how they are related and what data is applicable to the current system configuration when used in Sea State 3.

SYSTEM DESCRIPTION

The evaluation of the RO/RO DF operation is complicated by the large number of variables in the system. For example, any causeway platform configuration must be able to interface with all types of landing support craft, several Causeway Ferry (CWF) configurations, all types of cargo ships, and at least three ramp configurations. This does not include the wind, current and wave amplitude, and direction variations.

Current plans call for the Causeway Platform Facility (CPF) configuration to consist of six barges attached in an arrangement two long and three wide. As a first cut, this investigation is limited to this CPF configuration married to a ship with a stern ramp. This configuration appears most promising and was included in the 1982 Joint Logistics Over-the-Shore II (JLOTS II) trials.

EXISTING DATA

Several seakeeping model experiments and trials with a few of the many configurations are reported in References 1 through 7. References 8, 9, and 10 present the results of seakeeping predictions for several system configurations.

The 2 x 3 barge arrangement of the CPF was included in the trials reported in References 2 and 4 and in the model experiments reported in References 1 and 6.

The model experiment reported in Reference 1 did not include the RO/RO ship. Results of Reference 6 (page 17) indicate motions of the system are significantly different with and without the RO/RO ship and ramp connection. Also the wind, wave and current disturbance caused by the RO/RO ship has a significant effect on CPF and CWF motions. Therefore, the results of Reference 1 are not recommended for use in assessing JLOTS system operation performance.

The full-scale trials reported in References 2 and 4 did not include any operations in waves higher than Sea State 2. Conversations with trial personnel indicated that trials were suspended in Sea State 3 because of the higher risk of equipment damage and personnel injury.

Apparently most of the landing craft have a limited capability to operate in Sea State 3. The photograph of the wave buoys stowed on the CPF in Figure 15 of Reference 2 show a significant spray and wetness problem with the CPF in waves. The waves in the photograph were not measured.

The model experiments in Reference 6 with configuration 2 appear to be very similar to the configuration and sea conditions of interest. The CWF and CPF were not modeled accurately but the differences are acceptable. The model of the RO/RO ship was small compared to the scale of the CPF and CWF; however, the results of these experiments are probably the more indicative of the selected system than other available data. A standard fully developed long-crested theoretical wave spectra was used for the experiments. It remains to be seen if this is the most appropriate wave condition in the proposed operational areas.

TRIALS RESULTS VERSUS MODEL EXPERIMENT RESULTS

By using a very flexible definition of "the same" and overlooking all the differences previously discussed, there were trials presented in References 2 and 4 and model experiments in Reference 6 with the "same" ship-CPF-CWF configuration. How does this data compare?

Very little similar data exists for both model experiments and trials. If we ignore the fact that the CWF is attached to the CPF at a different location, configuration of Reference 2 is similar to configuration 2 of Reference 6. Only statistical information for the Sea State 2 waves is available from the trial (Reference 2). This information is not directly comparable to the statistical information for the Sea State 3 waves used in the model experiment (Reference 2).

Response Amplitude Operators (RAOs) were obtained in the model experiment but were not presented for the trial. Because of the nature of wave measurement during trials, it is not recommended to obtain RAO's from the trial results. The RAO's obtained for the trials would be suspect and of little value.

Useful measurements were reported in each reference. However, pitch and roll of the CPF are the only two measurements reported in both Reference 2 and 6. If the definition of "the same" is widened to include configuration 2 of Reference 1, the pitch and roll results of that model experiment can be included. Figure 1 shows a modified copy of Figure 26 of Reference 2. This figure presents the significant pitch and roll results in head waves from References 2, 4, and 6. As seen in the figure, none of the data is for the same sea condition but the data indicates a smooth and sharp increase in pitch and roll response with increased wave height. This is a reasonable trend to expect. The large amount of scatter in the data from Reference 2 is believed to be the result of moving traffic. The wave induced roll in head waves should be quite small.

A comparison of results with other JLOTS configurations was considered. The only compatible data found had already been compared in Figure 27 of Reference 2. Nothing more could be added.

WAVES

One of the most difficult problems in comparing model experiment and trial results is finding comparable wave spectra. From conversations with observers during the trials, it is apparent that the waves during the trial were long crested like those of the model experiments.

Figures 2 and 3 show a comparison of wave spectra from model experiments of Reference 1 and the trials of Reference 2. Taking into account the great differences in significant wave height, these spectra indicate a promising trend. The spectra of the higher model waves have a peak value at higher frequency than those from the trials. Considering trends shown from the Pierson-Moskowitz family of wave spectra, the peak of the wave spectra will move to higher frequency and the frequency band of the spectra will increase as the wave height increases. Therefore the spectra from the trials can be "expected" to grow into spectra "similar" to those used in the model experiments. This trend deserves further measurement investigations.

MOTION COMPUTER PREDICTIONS

References 8, 9, and 10 present rigid body motion computer prediction techniques and the resulting motion estimates for various system configurations and components. None of these techniques account for the interaction effects between the ship, the CPF, and the CWF. Also, these prediction techniques are not sufficiently validated. Most were designed for ship type hull forms.

The predictions in Reference 10 include the RO/RO ship with stern ramp, and CPF composed of only three barges. The predictions include effects of wave swells and extreme value statistics on the motions of components of the system. It is not out of the question to use these results to obtain "ball park" estimates of the motions. It is interesting to note that the resuls indicate swell could be the dominate factor in motion determination. In Reference 10 the period of wave swell was chosen such that motions were maximum. The resulting motions from such a wave swell spectrum were almost as much as four times those from wind wave spectra. In Reference 6 a reasonable period of wave swell was used in the experiments. The resulting motions were only slightly higher than those from wind waves.

SUMMARY

As a results of this study of the model experiments, trials and motion predictions for the system, the following conclusions are apparent:

1. The configuration with the stern ramp onto a CPF composed of a 2 long x 3 wide matrix of barges and CWF attached is most common.

2. None of the same measurements were made on any of the trials or model experiments for the same sea conditions.

3. Results that could be pieced together indicate all data is reasonable and very loosely compatible.

4. From the limited wave spectra obtained during the trials, the wave spectra from the model experiments appear reasonable. Waves are important and should be investigated further. Wave measurements in typical operation areas and the development of typical wave spectra to be expected in discharge loctions should be obtained.

5. Computer prediction techniques are missing several important interaction effects between components of the overall system, do not accurately model the system or the CPF, and have not been sufficiently validated for such applications.

6. The computer predictions indicate: (a) the importance of wave swell in determining motions of the system, and (b) the proper use of extreme value statistics to identify design motion amplitudes.

7. The model experiments presented in Reference 6 appear to be best estimates for motion of the system in Sea State 3 in spite of the fact that the models are not accurate.

RECOMMENDATIONS

Results from either Reference 6 or Reference 10 could be used with appropriate factors of safety to obtain criteria information. The model experiment results of Reference 6 appear to be the most realistic and are preferred. However, where information from the model experiment is lacking, the results from Reference 10 could be used to fill in.

The extreme value statistics recommended in Reference 11 and used in Reference 10 are a good way to estimate motion amplitudes for design purposes.

DESIGN MAXIMUM VALUES

Tables 1 and 2 show the significant double amplitudes (4.0*rms) of motions from Reference 6. Table 1 is for wind driven waves and Table 2 includes wave swell. The head, bow and beam columns in the tables refer to relative wave headings of 180, 150, and 90 degrees, respectively. Table 3 shows a conservative estimate of maximum double amplitudes of motion recommended for design as derived from Tables 1 and 2. Table 3 was derived as follows:

The extreme value technique could not be applied directly to the model experiment results because the equation for extreme value requires both the 0th and 2nd moments of each motion of interest. Only the 0th moments are available from Reference 6. Reference 11 anticipated this problem and provided a graph, reproduced here as Figure 4, showing the effects of the square root of the ratio of moments. As seen in the figure, the effect of the ratio on the extreme value is not large. To be safe, the values for a ratio of 1.0 are recommended and used in Table 3.

The extreme value is also dependent on the operation time. Assuming the same operation times of 24 and 72 hours as Reference 10, the extreme value is approximately 5.3 times the rms in 24 hours and 5.6 times the rms in 72 hours. To be safe, 5.6 times rms is recommended and used in Table 3.

The effects of swell are not so large in the model experiments. In general, the most severe motions were in swells, but occasionally not. Therefore, to be safe the larger of the values in Tables 1 and 2 were used for Table 3.

The extreme values presented in Table 3 represent a conservative estimate of the amplitude of motion such that the probability of that motion amplitude being exceeded in 72 hours is 0.01.

For the extreme values of motions not included in the model experiment, the values in Reference 10 are recommended.

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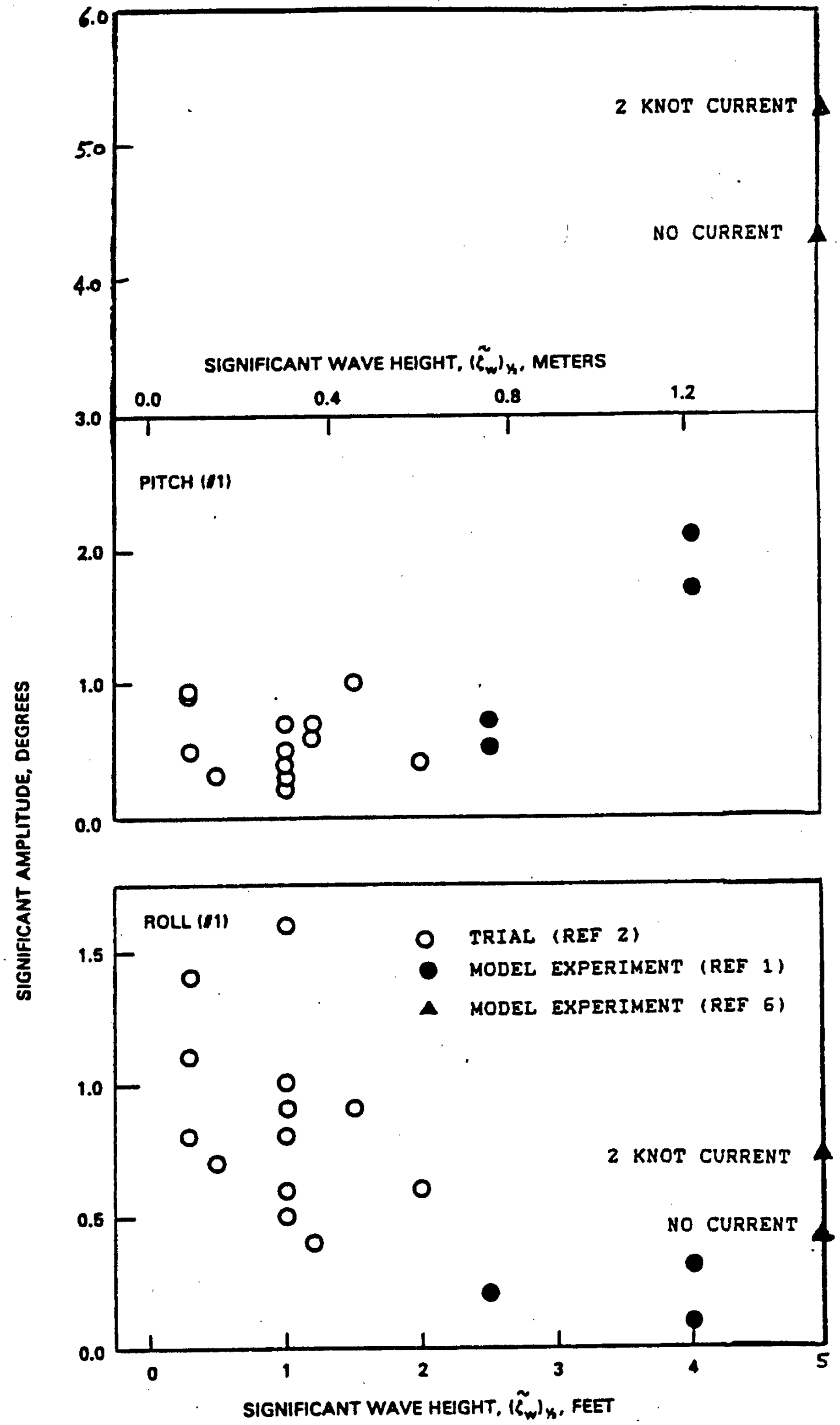

Figure 1 - Absolute Causeway Platform Facility Motions Comparing MS CYGNUS Interface Trial and Model Experiment Results

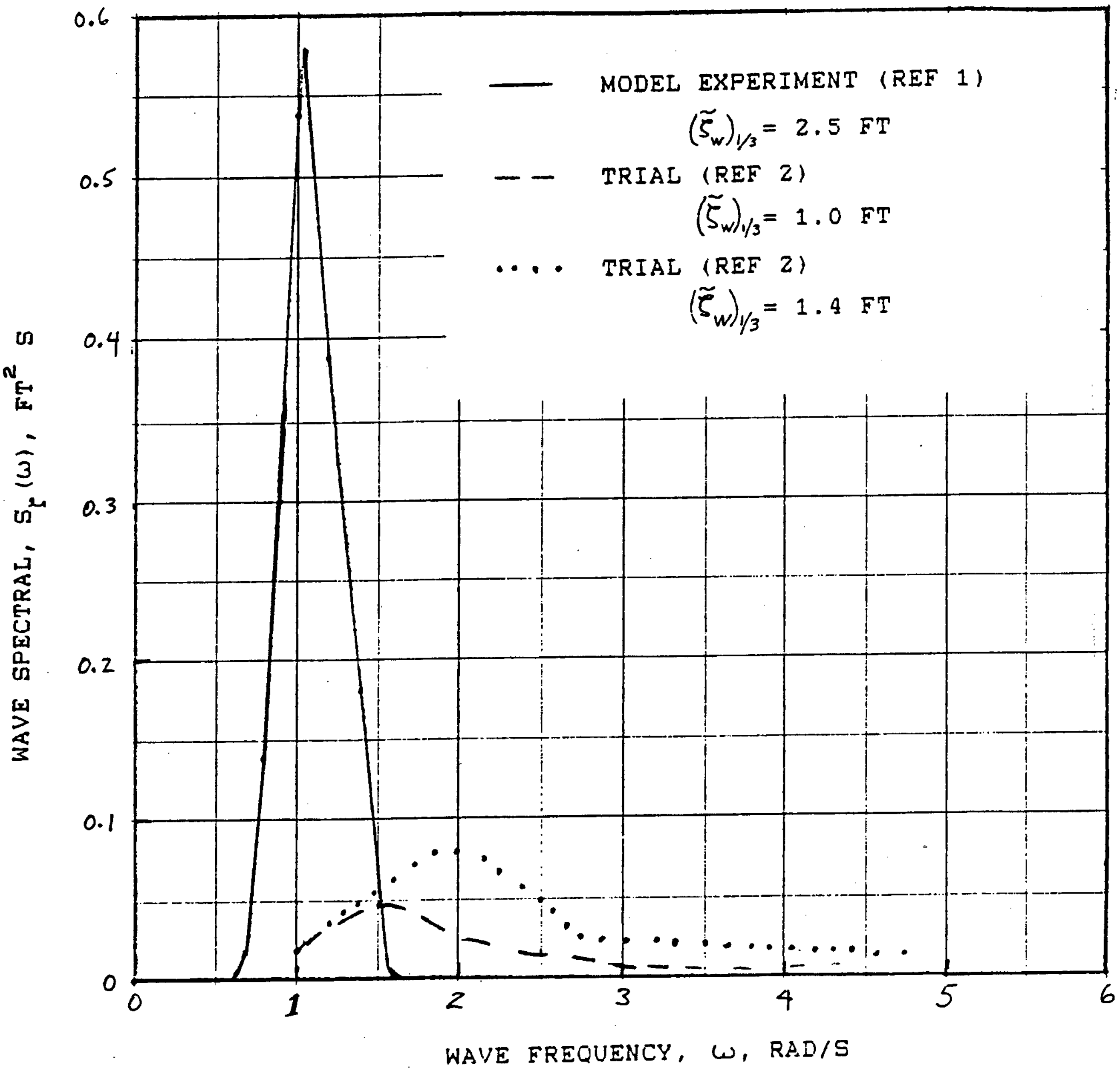

Figure 2 - Comparison of Typical Wave Spectra from Trials and Model Experiments

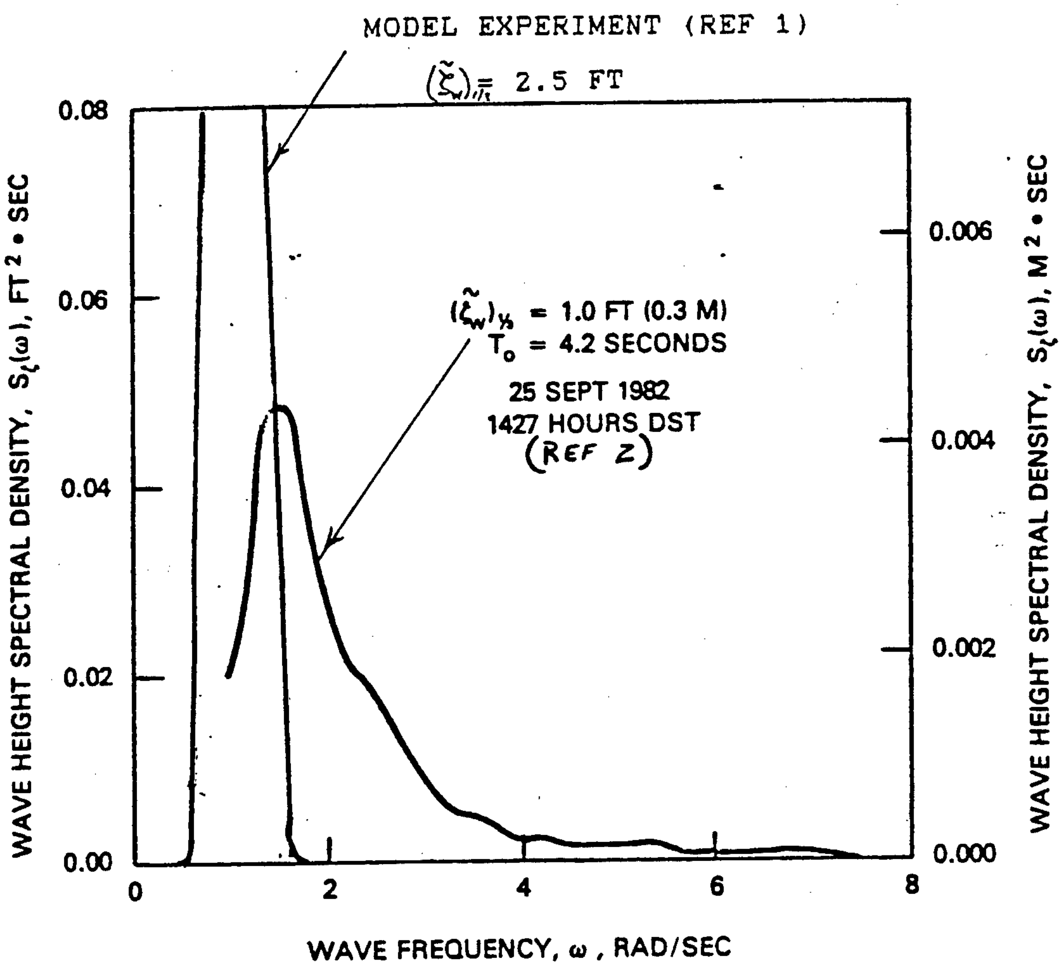

Figure 3 - Typical Wave Spectra Obtained during the MS CYGNUS Interface Compared with spectrum from Model Experiment (Ref 1)

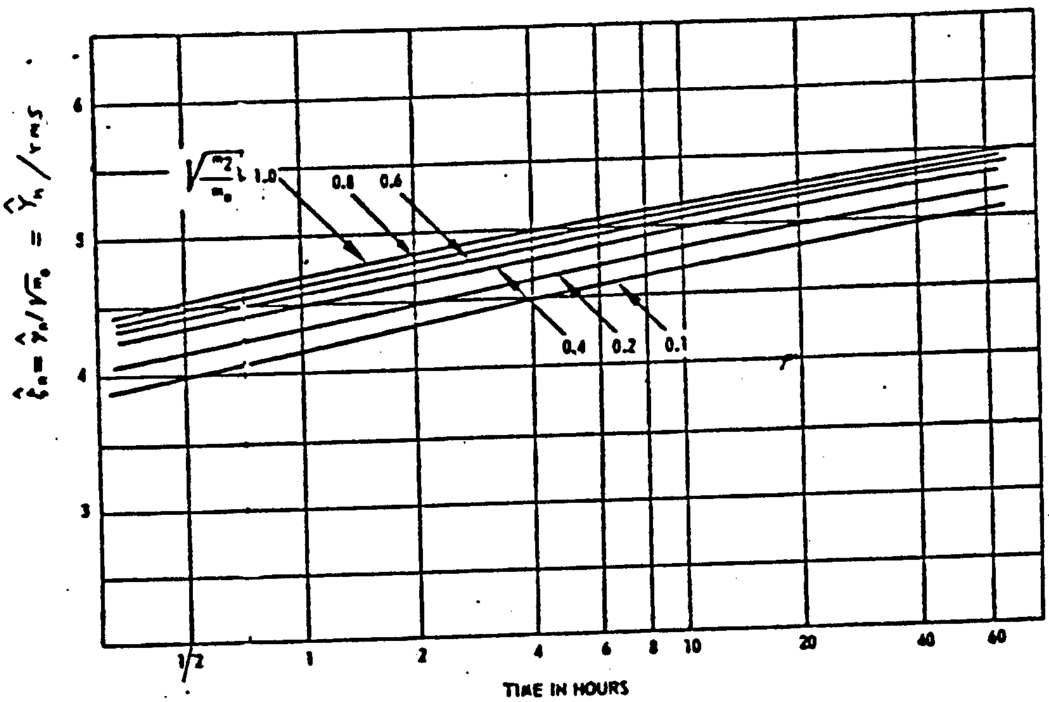

Figure 4 - Extreme value $\hat{\xi}_n$ (amplitude) as a function of time for various values of parameter, $\sqrt{m_2/m_0}$ ($\alpha = 0.01$)

(Figure 5, Ref 11)

TABLE 1 - SIGNIFICANT DOUBLE AMPLITUDES IN SEA STATE 3 WITH 2 KNOTS CURRENT
(From Reference 6)

Abbreviation	Description		Head Waves	Bow Waves	Beam Waves*
RVD	Relative vertical displacement between the stern of the RO/RO Ship and the bow of the center-forward CPF section	ft	5.4	6.0	2.4
CPF ROLL	Roll of the center-forward section of the CPF	deg	0.7	0.8	4.4
CPF PITCH	Pitch of the center-forward section of the CPF	deg	5.2	5.7	1.5
CPF RA1	Relative angle at the port longitudinal junction of the CPF	deg	1.6	2.8	9.5
CPF RA2	Relative angle at the starboard longitudinal junction of the CPF	deg	2.2	2.5	13.5
CPF RA3	Relative angle at the transverse junction of the CPF	deg	8.2	9.5	2.0
RO/RO ROLL	Roll of RO/RO	deg	0.7	1.5	5.4
RO/RO PITCH	Pitch of RO/RO	deg	1.0	1.0	0.8
RO/RO HEAVE	Heave of RO/RO	ft	0.9	-	-
RAMP RA1	Relative angle between the off-loading ramp and the RO/RO Ship	deg	2.3	2.8	2.0
RAMP RA2	Relative angle between the off-loading ramp and the center-forward CPF section	deg	4.9	5.4	2.0

*Estimated

TABLE 2 - SIGNIFICANT DOUBLE AMPLITUDES IN SEA STATE 3 WITH SWELL AND 2 KNOTS CURRENT
(From Reference 6)

Abbreviation	Description		Head Waves	Bow Waves	Beam Waves*
RVD	Relative vertical displacement between the stern of the RO/RO Ship and the bow of the center-forward CPF section	ft	6.3	6.6	1.5
CPF ROLL	Roll of the center-forward section of the CPF	deg	0.5	0.9	4.0
CPF PITCH	Pitch of the center-forward section of the CPF	deg	6.4	6.8	0.6
CPF RA1	Relative angle at the port longitudinal junction of the CPF	deg	1.9	2.9	8.8
CPF RA2	Relative angle at the starboard longitudinal junction of the CPF	deg	2.6	2.5	14.5
CPF RA3	Relative angle at the transverse junction of the CPF	deg	10.8	12.2	1.0
RO/RO ROLL	Roll of RO/RO	deg	0.7	1.7	4.4
RO/RO PITCH	Pitch of RO/RO	deg	0.7	2.4	0.8
RO/RO HEAVE	Heave of RO/RO	ft	0.9	-	-
RAMP RA1	Relative angle between the off-loading ramp and the RO/RO Ship	deg	1.7	2.5	1.6
RAMP RA2	Relative angle between the off-loading ramp and the center-forward CPF section	deg	6.0	5.8	1.6

*Estimated

TABLE 3 - ESTIMATE OF THE EXTREME MOTION DOUBLE AMPLITUDE SUCH THAT THE PROBABILITY OF BEING EXCEEDED IN 72 HOURS IS 0.01

Abbreviation	Description		Head Waves	Bow Waves	Beam Waves*
RVD	Relative vertical displacement between the stern of the RO/RO Ship and the bow of the center-forward CPF section	ft	17.6	18.4	6.8
CPF ROLL	Roll of the center-forward section of the CPF	deg	2.0	2.6	12.4
CPF PITCH	Pitch of the center-forward section of the CPF	deg	18.0	19.0	4.2
CPF RA1	Relative angle at the port longitudinal junction of the CPF	deg	5.4	8.2	26.6
CPF RA2	Relative angle at the starboard longitudinal junction of the CPF	deg	7.2	7.0	40.6
CPF RA3	Relative angle at the transverse junction of the CPF	deg	30.2	34.2	5.6
RO/RO ROLL	Roll of RO/RO	deg	2.0	4.8	15.2
RO/RO PITCH	Pitch of RO/RO	deg	2.8	6.8	2.2
RO/RO HEAVE	Heave of RO/RO	ft	2.6	-	-
RAMP RA1	Relative angle between the off-loading ramp and the RO/RO Ship	deg	6.4	7.8	5.6
RAMP RA2	Relative angle between the off-loading ramp and the center-forward CPF section	deg	16.8	16.2	5.6

*Estimated