PAPER #303

# OPERATING PERFORMANCE OF OFFSHORE TRANSFER RAMPS

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## ABSTRACT

The present paper is related to the study performed on ocean systems composed of floating or fixed structures transfer ramp and a supply boat, with the purpose to determine the dynamic behavior on operating conditions.

The methodology consists on model tests performed on the Towing Tank followed by statistical analysis of those variables relevant to the design and operation of the transfer ramp such as displacements, accelerations and forces.

Curves showing probabilities of exceedance of those variables are obtained as results of the study.

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## 1. INTRODUCTION

The problem related to the acess from/to offshore structures through supply boats is directly associated to sea states occuring at a particular site during the lifetime of the plataform. The usual way to transfer people and cargo consists to utilize nylon baskets hanging from overhead-cranes. This procedure is quite slow due to size limitations. Furthermore, oscillatory motions induced by waves on the boats increase the risk of accidents and the time during transfer. Depending on motion amplitudes, this kind of operation has to be halted and the boats submitted to long waiting periods of time near the platforms before resuming operations.

In case of a high dayly flux of workers, total transfer time can be substantially high. In this context the articulated ramp can be an alternative solution to people transfer probably decreasing time and risk of accidents.

The transfer ramp has to be a light, flexible and articulated structure in order to allow freedom of heave, pitch, sway and yaw motions of the boats connected to it. In normal operationg condition (see fig. 1) the ramp restricts surge motions of boats. Depending on the ramp torsional stiffness, roll motions of supply-boats can be reduced.



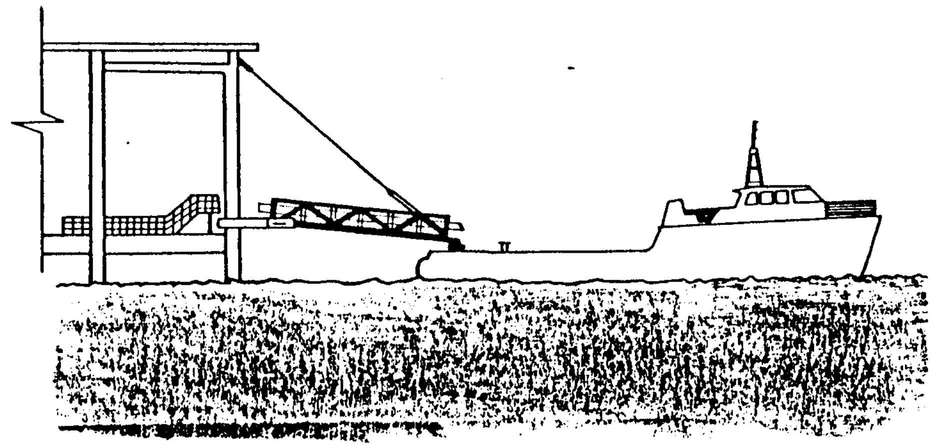


Figure 1 — Transfer Ramp in Operation on a Fixed Plataform.

The advantages on the utilization of transfer ramps as opposed to conventional systems can be summarized as follows:

- to reduce roll motions of supply-boats during transfer operations;
- to keep a safe distance between boats and platforms, reducing the risk of collision;
- to reduce total transfer time;
- to allow transfer operations during severe sea states, reducing waiting time;
- to increase the safety of transfer operations.

However, the use of this system depends on the maximum dynamic loads that fixed or floating offshore structures may support. These loads increase with the roughness of the sea and there is a limit for which the boats have to be disconnected, or the structures will be overstrained.

Analogously the edge of the ramp connected to the boat is exposed to accelerations induced by the motions of the boat which can limit the traffic on the ramp for safety reasons.



## 2. STATISTICAL CHARACTERISTICS OF MOTIONS AND RAMP STRENGHT VARIABLES

### *2.1. Sea Spectrum*

During transfer ramp's life time many sea states may occur in the system operation area so that motions and structural stresses will be induced on boats and platforms. Sea states observed on a given geographical area is normally originated from local wind action on the sea surface and from the propagation effect of surface waves generated by storms in remote areas. The mathematical representation of sea states commonly adopted for dymanic analysis of ocean systems is the spectral density of wave energy $S(\omega)$.

Each geographic region of the planet is characterized by typical intensities and frequencies associated to sea conditions. They are obtained by means of field measurements and observations carried out at the site of interest. However, local spectra, in the absence or shortage of field data, can be estimated by empirically formulated spectra.

In this study the spectrum recommended by the ISSC (International Ship Structures Congress) is employed, having the following expression:

$$S(\omega) = \frac{1,25}{4} \frac{\omega_m^4}{\omega^5} H_s^2 \exp\left[- 1,25\left(\frac{\omega_m}{\omega}\right)^4\right] \qquad (1)$$

Such spectral bi-parametric formulation depends on 2 parameters $H_s$ - i.e, significant wave height - and the modal frequency $\omega_m$, which ought to be recorded or assessed for the particular geographical area of interest. Hence, for a given significante wave height Hs, the spectrum shape takes on the function of the modal period. Such fact allows a certain flexibility to reproduce different sea conditions for the study of the system dynamic response.

## *2.2. Relevant Variables for the Problem*

For this analysis, it has been chosen as relevant variables those which could restrict the system operational capability. These are: the ramp torsional moment, the roll motion of the supply boat as well as the upright and horizontal acceleration amplitudes of the boat deck. The first variable tends to limit the ramp operation due to structural integrity, in the case of large amplitudes being achieved. The others are related to the user's safety to access the ramp.

Taking the sea action as an excitation of random nature, which is defined by the sea spectra, those variables shall be regarded as dynamic responses of the system in question, which are typically represented by time series, according to figure 2.

In view of the random nature of these time series, which represent the history of those variables, it becomes necessary for engineering purposes a statistical treatment of the extreme values of the series, associating to them probabilities of exceedance.



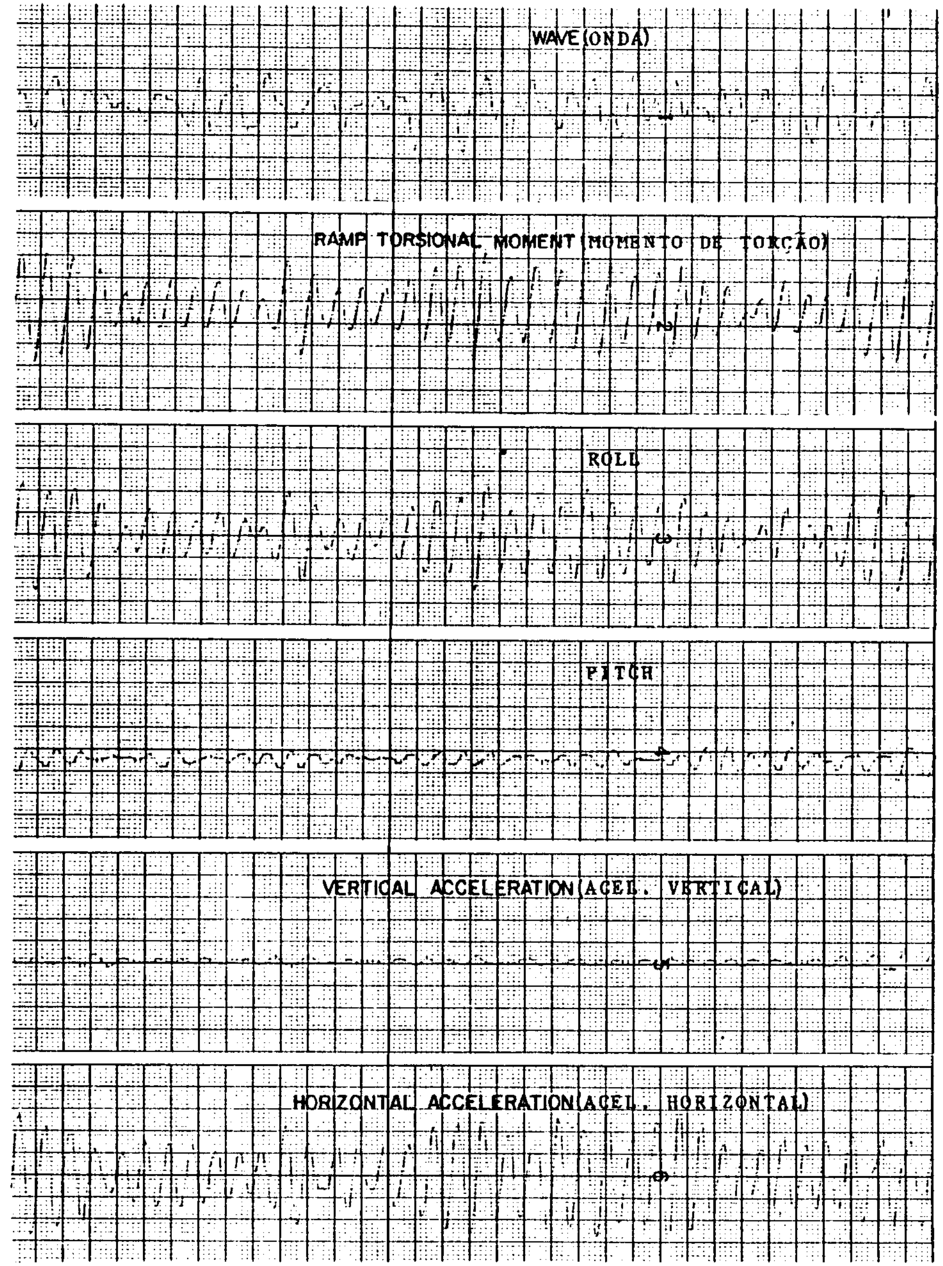



Figure 2 — Test Record of Irregular Waves Incidence Angle 90°

## 3. METHODOLOGY OF ANALYSIS

For long periods of time, the sea can be represented by a power spectrum. Within the assumption of stationarity, the response spectrum of the system can be obtained if the transfer function (RAO) is known. Considering that the response, likewise the excitation, is a stochastic process, the variables of interest can be regarded as random variables.

In the case of oceanic system designs, on of the most important statistics is that related to the extreme values of the time series of measured variables.

Based on the order statistics a useful expression can be derived which will be termed as the design extreme value $\hat{y}_n(\alpha)$ given by:

$$\hat{y}_n(\alpha) = \sqrt{2 \ \ell n \left\{ \frac{(60)^2 t}{2\pi\alpha} \sqrt{\frac{m_2}{m_o}} \right\}} \cdot \sqrt{m_o} \qquad (2)$$

This expression gives extreme value $\hat{y}_n(\alpha)$ which shall not be exceeded with a reliable factor $(1 - \alpha)$ during the time interval in which the system undergoes the action of a particular sea condition. The parameters $m_o$ and $m_2$ are the zeroth and second - order moments obtained from the sea spectra response for the "y" variable.

### 3.1. *Long-term Statistics Analysis*

The oceanic systems have in general an intense regime of operation, and a lifetime of many years which turns them subject to the action of different sea spectra, which repeats themselves as time goes by, with a given frequency.



The long-term statistics analysis is therefore associated with the prediction of the behavior of certain variables for long periods of time of the order of years.

The wave heights prediction is obtained from periodical observations and records taken over several years with a subsequent statistical treatment of this population to determine yearly extreme values. Some probability distribution functions have been utilized for the statistical description of these populations such as Frechet, and Weibull, which allows the extrapolation of the observed results for years to come(example: the centenary wave).

If one is a interested on the behavior of a random variable and there is lack of direct observations, the analysis can be carried ou based on the study of the system response to standard spectra and the associated probability of its occurence in a given period of time.

### 3.2. *Long - Term Statistical Analysis Based on the Short - Term Statistics*

The method proposed by Ochi (1) is based on the fact that for a determined geographic area, period and significant wave height can be regarded as random variables with a log - normal joint probability distribution function.

Thus, by using the pattern spectrum give by expression (1) it is possible to generate a family of spectra, each element having a proper shape and a certain probability of occurrance. Crossing the transfer function with a spectrum from the family provide the desirable spectrum of response of the random variable y (t).

The short-term statistical analysis allows to determine the extreme design value $\hat{y}_n(\alpha)$, given by expression (2). The time t in the expression is further discussed in item 3.3.

In practice for each significant wave height seven periods is assumed, each one associated with a given confidence interval. There fore, for a confidence coefficient of 0.95, it can be established a lower value and a upper value for the period, in such a way that there is only 5% of chances that modal period, associated with that significant wave height will be out of those limits.

The final outcome of such procedure is the determination of a region characterized by an upper-bound curve and a lower-bound curve (see figure 3) where possibility of occurence of extreme values $\hat{y}_n(\alpha)$ has 95% of chances.

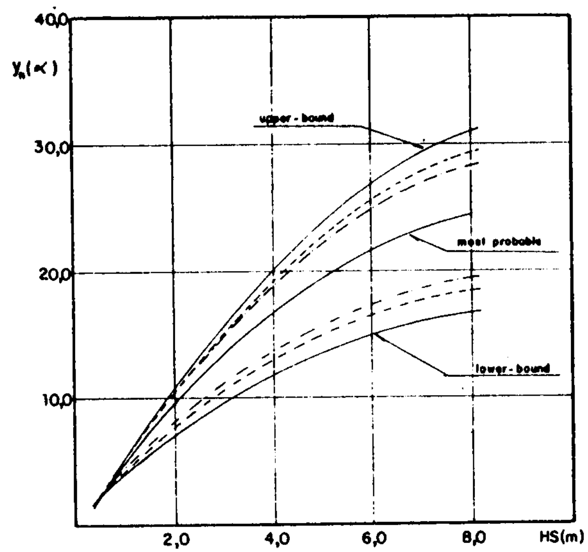



Figure 3- Region of Occurence of Extreme Values $\hat{y}_n(\alpha)$

*3.3. Determination of the Total System Exposure Time to a Particular Spectrum*

When calculating the extreme design values by expression (2), time t can be assessed by the duration time T of the considered sea spectrum multiplied by the probability of the



system being exposed to that particular spectrum during its lifetime.

The time duration of the spectra can be obtained from figure 15 of reference (1), reproduced below, as a function of the significant wave height.

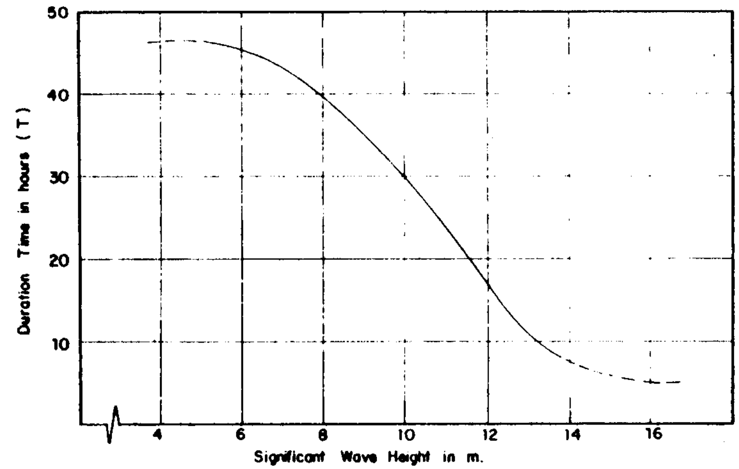



Figure 4 — Spectra Durations

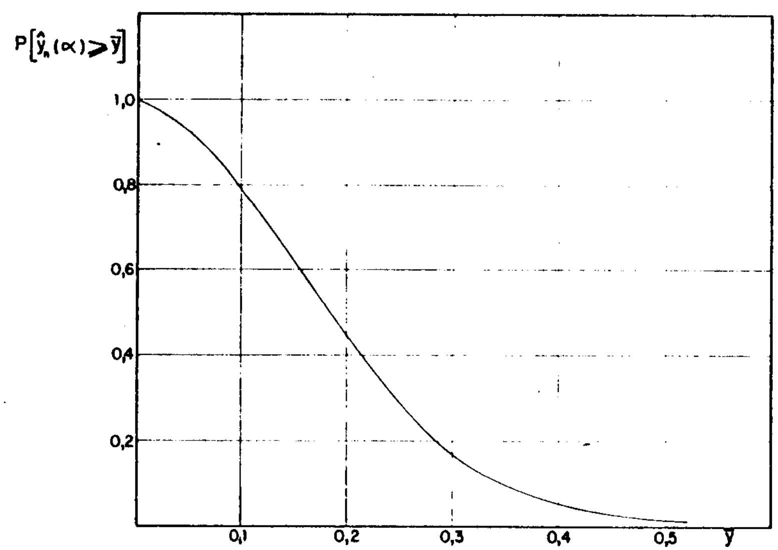
The frequency of occurence of sea spectra for a period of"n"years can be obtained by means of long-term statistics for waves referred to a certain region.

In situations where the system effective operating time is a fraction of the system lifetime, total time t for use in expression (2) reduces to t = KT, (3), where K is the expected number of times the system will see a particular spectrum during its lifetime, taking into consideration the utilization factor of the system.

*3.4. Results Utilization*

In the case of ocean system designs, a number "n" of variables can be relevant to component design and to define the operation of the system in actual sea conditions. Using this method it is possible to associate a probability distribution function to each design variable $\hat{y}_n(\alpha)$.

Therefore, for a given value $\bar{y}$ of a design variable a probability value can be associated to it such that $\bar{y}$ will not be exceed during the system lifetime with a risk coefficient $\alpha$ for each sea state, figure 5.




Figre 5 — Probability Curve of Exceedance $\bar{y}_n(\alpha)$



## 4. METHODOLOGY APPLIED TO THE TRANFER RAMP

The results shown in this paper have been obtained through model tests at IPT and long-term statistics prediction of the extreme values associated to the response of the mentioned system. They have been gathered in such way to evaluate the operationality of the proposed system through probabilistic calculations of the number of days/year which the transfer ramp could be operated never exceeding critical limits for those variables related to the integrity of the structures and users safety.

Model tests allowed the estimation of transfer functions (RAO) of those variables which were utilized in the statistical prediction of extrema, according with the proposed methodology in 3.2.

### *4.1. Tests Outline*

Model tests have been carried out for a supply boat connected to a fixed production platform through the articulated ramp. The system has been submitted to regular waves with three distinct directions of incidence, in such way to reproduce a broad range of probable situations likely to occur during the ramp lifetime.

The supply boat considered in this study was the Ouro Preto tug, 1910t displacement. The ramp model was considered rigid to bending and fitted with a mechanism to simulate the torsional stiffmess of the structure. A transducer to measure torsional moments on the ramp model was develoned for this study, as shown is Figure 6.

Figure 7 shows schematically the incident directions of waves which have been used.

Figure 8 shows a typical test record contening the exciting wave and several response variables which have been measured.

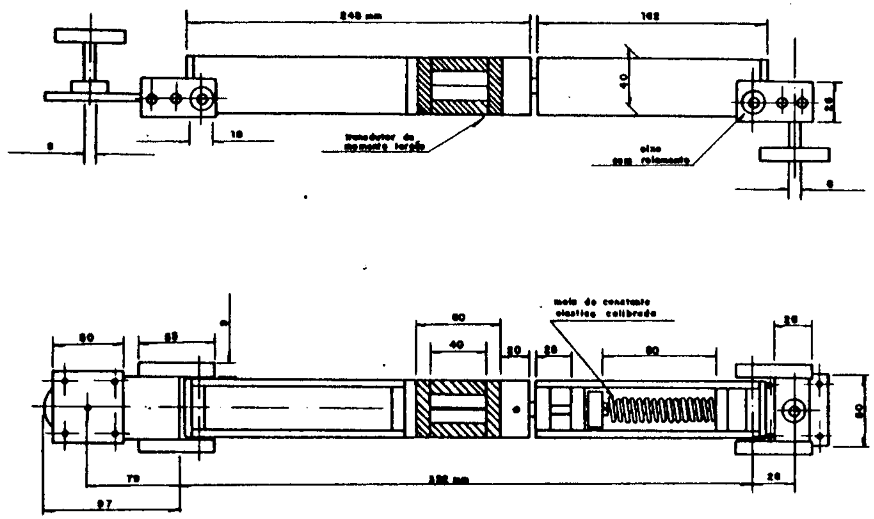



Figure 6 — Schematic Drawing of the Ramp Model

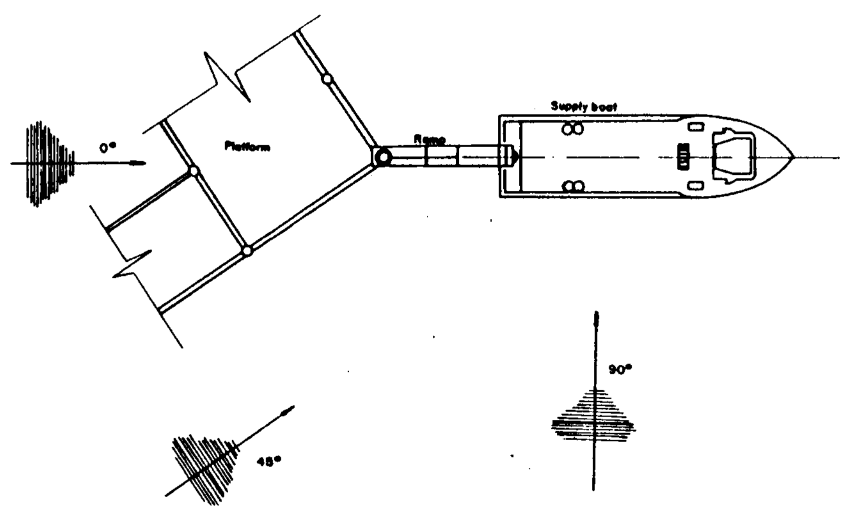



Figure 7 — Wave Incident Directions on the Ramp-Supply Boat System



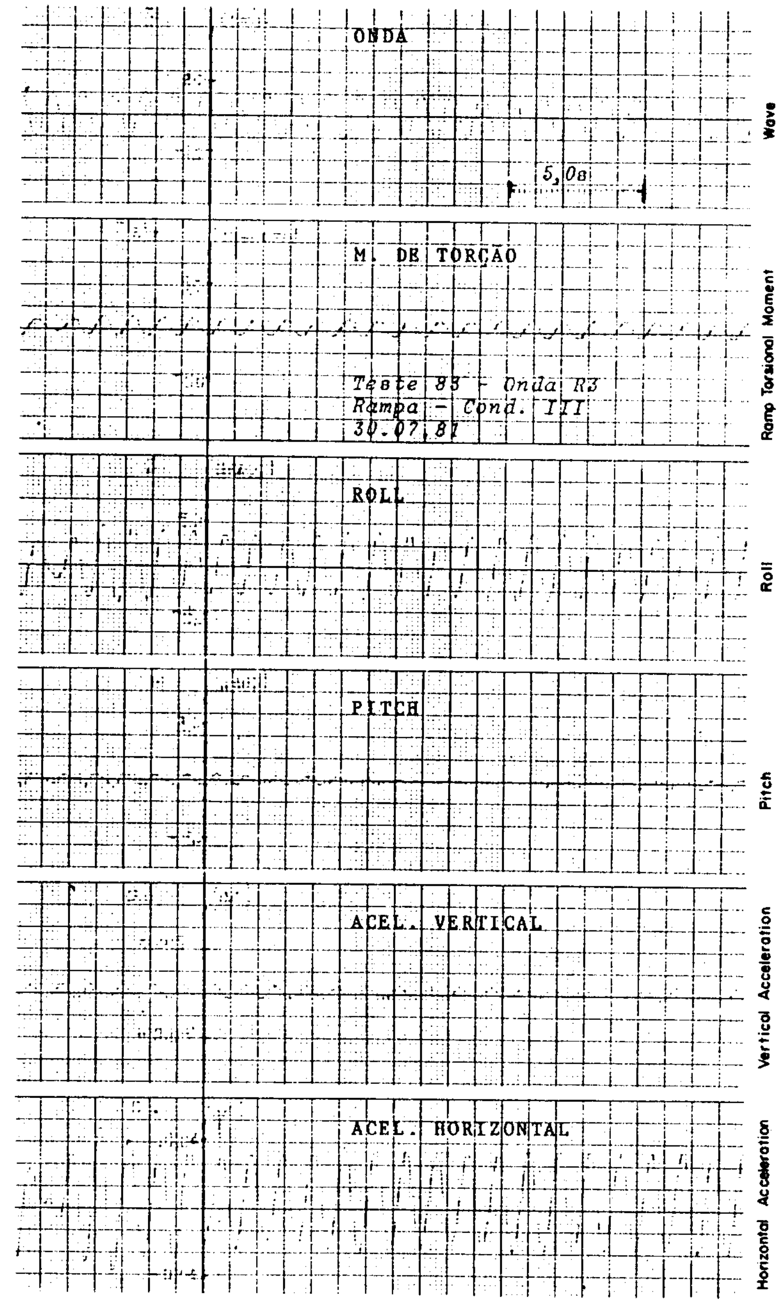



Figure 8 — Test Record of a Regular Wave Incidence Angle 90°

### 4.2. *Environmental Data*

Wave height and period observations used in the study have been borrowed from ref. (2).

The data used correspond to region 40 of such publication in which Campos (RJ) coastline is inserted. Figure 9 presents the results obtained after such data have treated on, showing curves of modal periods ($T_m$) as functions of corresponding significant wave heights ($H_s$). For each $H_s$ value seven modal periods have been obtained corresponding to the mean value, lower and upper bounds for confidence coefficients of 75%, 85% and 95%.

Such results originate families of response spectra of design variables and the resulting calculated design extreme values.

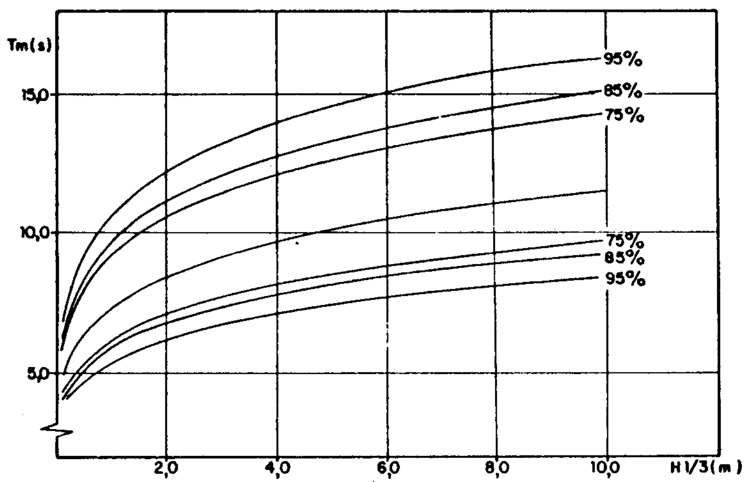



Figure 9 — Significant Wave Heights and Modal Periods for Region 40 (Campos R.J.)

### 4.3. *Assumptions Associated to the Statistical Prediction*

Some assumptions have been used for calculation purposes, mainly those associated to data unavailable for the brazilian coastline.



They are:

- The probability distribution is not affected by the wave incident direction;

  This assumption allowed the use of data from ref(2), for region 40 of Brasil's coastline, and the calculation of extreme values of design variables for several distinct wave directions. The results obtained so far have to be regarded with caution until more precise information with respect to probability distribution of incident waves become available.

- After the installation of the platform the ramp will be operating 20% of the time (4,8 hours per day);

  Such assumption is related to the time of exposure of the system to different sea states which occurs through the years.

### 4.4. *Results Presentation*

Being function of random variables $H_s$ and $T_m$, and having its region of occurance defined by families of sea spectra, $\hat{y}_n(\alpha)$ is also a random variable. Its distribution function is obtained assuming a given conditional probability density function related to H . In the present case the choice was for a uniform distribution function between the upper and lower bounds, because a more accurate distribution would demand the generation of a large sample for each $\hat{y}_n(\alpha)$ variable.

Therefore, knowing $f(H_s)$ and $f(\hat{y}_n(\alpha)/H_s)$, the cumulative distribution function $F(\hat{y}_n(\alpha) < \hat{y})$ is obtained by integration of the product of the probability density function (p. d.f.) mentioned, in the region defined by the upper and lower bounds, tha is:

$$P[\hat{y}_n(\alpha)] = \int_{\text{"lower bound" curve}}^{y} \int_{0}^{\infty} f(H_s)\, f(\hat{y}_n(\alpha)/H_s)\, dH_s\, d\hat{y}_n(\alpha) \qquad (3)$$

## 5. CONCLUSIONS

Figure 10 shows curves of probability of exceedance related to four design variables: torsional moment on the ramp, boat roll motion, vertical and horizontal accelerations on the boat deck close to the ramp-boat connection. Those values are valid under the following assumptions: 10 years lifetime and ramp utilization of 4.8 hours per day.

The probability curves are parametric with the incidence angles on the system, which is an important feature of the way the results is being presented because each structure will be installed in a particular site subjected to different predominant wave directions.

The direction of wave incidence on the boat reveals that the design of such ramps should avoid transfer operations with a beam sea. In this situation, the supply boat is subjeted to large motions and accelerations, and simultaneoresly the articulated ramp is submitted to large torsional moments.

Extreme values of such variables will not be very high if the supply boat is allowed to align with the wave direction ($\psi = 0^{o}$).

As an example, extreme values for 95% probability of nonexceedance, 10 years of sea operation and $\psi = 0^{o}$ incident angle are shown betow:

- boat roll amplitude.......................... $\emptyset = 1.6^{o}$
- ramp torsional moment.......................... $\bar{M}_t = 45$ t*m
- horizontal acceleration...................... $\bar{a}_H = 0.18g$
- vertical acceleration........................ $\bar{a}_v = 0.008g$



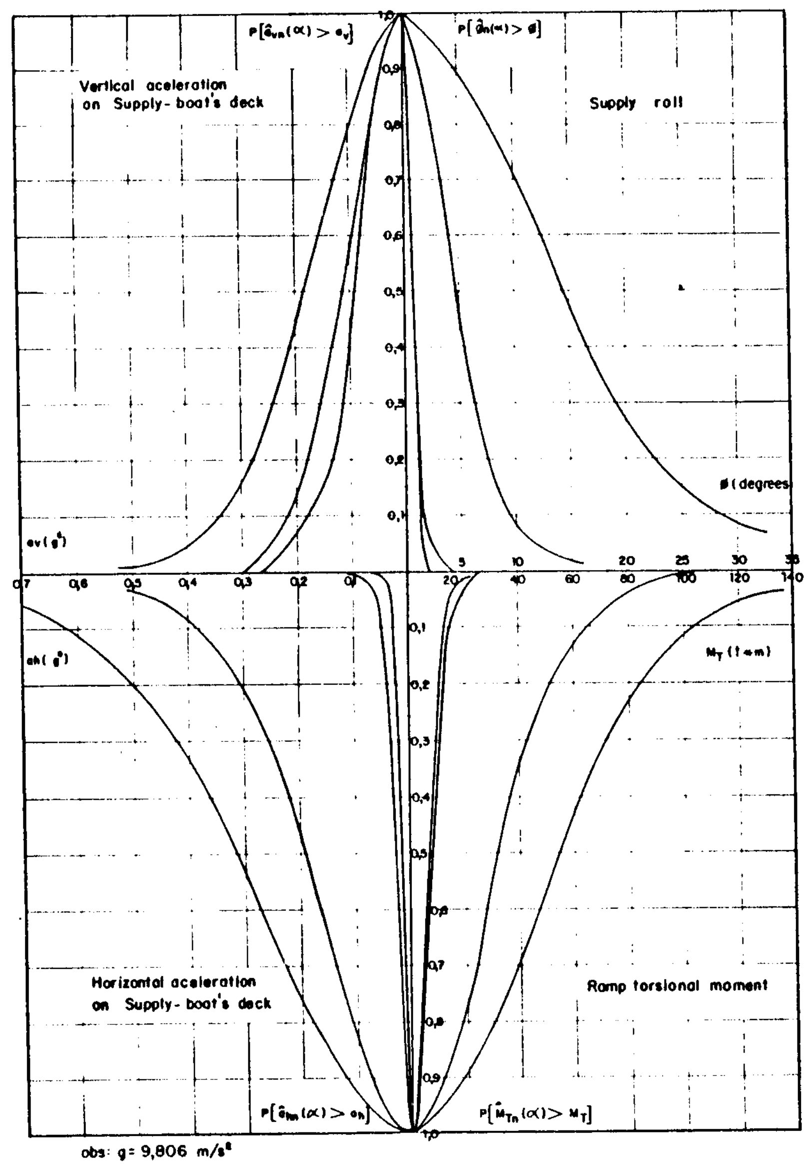



Figure 10 — Probability Curves of Exceedance of Relevant Design Variables

It can be verified that extreme values resulting from such situation are relatively low, showing that a high utilization factor of such system can be expected if the system is allowed to keep $\psi = 0^{o}$ incident angle.

Because the system has a mechanism which allows the ramp to rotate about a vertical axis located on the structure, the alignment with the incident wave is always possible, being limited only by the main structure. In the case of a fixed production platform, a rotation limit of a $180^{o}$ sector will be easily achieved.

Any restriction imposed by the main structure to the boat aligmment with the incident direction will reduce the utilization factor of the transfer ramp.

As an example, we considered systems with different aligmment capabilities and calculated the respective utilizations factors.

Let us assume the following limit values:

- supply boat roll amplitude.................. $\phi = 10^{o}$
- ramp torsional moment...................... $M_T = 45$ t*m
- horizontal acceleration..................... $\bar{a}_H = 0.20$ g
- vertical acceleration....................... $\bar{a}_v = 0.25$ g

For $90^{o}$, $180^{o}$, $270^{o}$ e $360^{o}$ aligmment capabilities and 10 years lifetime, the resulting utilization factors are obtained (Table 1).



Table 1 - Transfer ramp utilization factor example.

| STRUCTURE STUDIED | ALIGMMENT CAPABILITY | | | |
|---|---|---|---|---|
| | $90^{o}$ | $180^{o}$ | $270^{o}$ | $360^{o}$ |
| Fixed Platform. | 23,75 % 866 days | 47,5% 1733 days | 71,25 % 2600 days | 95% 3467 days |

Two aspects are of fundamental importance for the the design of such systems: to collect data of probability distribution of incident wave directions at the operation site, and the mechanical design of the ramp rotation should allow a reasonable aligmment of the boat for a broad range of wave directions.

The first aspect will help to define for each structure the best location to install the ramp. The second aspect will keep high utilization factors during the system lifetime.

## 6. REFERENCES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