12 th International Conference on
OFFSHORE MECHANICS AND ARCTIC ENGINEERING
OMAE 1993 - Glasgow, Scotland
June 20 - June 24, 1993

CUIMR-R-93-008 C3

RELIABILITY BASED REQUALIFICATION CRITERIA FOR OFFSHORE PLATFORMS

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ABSTRACT

Reliability methods have become one of the cornerstones of development of criteria for the design of offshore platforms. This paper addresses how such methods can be used to develop rational and reasonable criteria for the requalification of offshore platforms. Results from two requalification case histories are use to demonstrate applications of reliability methods and verify the requalification criteria.

INTRODUCTION

Requalification of offshore platforms is an issue that is of critical importance to the industry and public. With more than 6,000 major platforms offshore today, with about one-third of these platforms reaching the end of their design lives and suffering aging and "technological obsolescence", with the present economic conditions, with the need to continue the development and exploitation of an important natural resource, and with the present political and environmental concerns, there is a pressing need to develop requalification criteria that will be both rational and reasonable.

Figure 1 summarizes a general purpose engineering approach to the requalification of offshore platforms (Bea, Craig, 1993). This approach has evolved from the past decade of research and development efforts on this topic. The initial steps include selection of a platform for reassessment and requalification, performing a condition survey, and then developing an inspection, maintenance, and repair program that will provide the basis for the assessment and requalification.

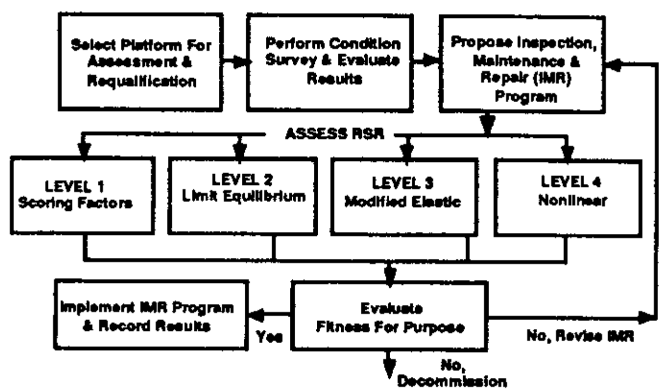

Fig. 1 - Assessment and requalification approach based on evaluation of platform Reserve Strength Ratio (RSR)

The selection of a particular platform can be triggered by either a regulatory requirement or by an owner's initiative following an unusual loading event, an accident, proposed upgrading of the platform operations, or a desire to significantly extend the life of the platform beyond that originally intended.

The condition survey is intended to build a complete and detailed history of the platform including its design, construction, and operation background. Detailed above and underwater inspections must be performed to provide an accurate description of the platform in its present condition (Marine Technology Directorate Ltd., 1989; API 1991). This step is of critical importance because the requalification can only be as effective as the information that is provided for the evaluations.

Given the results of the condition survey, an Inspection, Maintenance, and Repair (IMR) program is developed as the premises for the first round of the requalification process. The inspections include those that will be conducted during the repairs and during the proposed requalification time period. Inspections may also include instrumentation and monitoring systems that are installed on the platform to help improve the knowledge of its performance characteristics. Maintenance includes those measures that will be undertaken to preserve the integrity of the structure including corrosion protection and marine fouling management. Repairs include those items in the structure that will be rehabilitated and those that will be monitored ("judicious neglect").

The loading and capacity characteristics of the of the structure are expressed with the Reserve Strength Ratio (RSR) (Marshall, Bea, 1976; Lloyd, Clawson, 1983; Titus, Banon, 1987; Stewart, Efthymiou, and Vugts, 1988). The RSR is the ratio of the ultimate lateral load capacity of the platform (Ru) to a "reference" lateral loading (S_R):

$$RSR = \frac{Ru}{S_R} \qquad (1)$$

S_R is based on site, platform, and operations specific environmental conditions. The platform loadings are determined according to current design guidelines for new platforms in a given area (Tromans, P. S., et al., 1992; Rozario, et al., 1993; Heideman, Weaver, 1992). An attempt is made to use the best available technology and to eliminate all "biases" in the characterization of conditions and the computation of loadings. The objective is to develop a best estimate evaluation of loadings and loading patterns.

Four "levels" of analyses of increasing detail and difficulty are used to determine the RSR:

- **Level 1 - "scoring" factor analyses** (Bea, 1992d; Marshall, 1992),

- **Level 2 - simplified "limit equilibrium" analyses** (Bea, DesRoches, 1993),

- **Level 3 - modified elastic "state-of-the-practice" analyses** (Fu, et al., 1992), and

- **Level 4 - "state-of-the-art" nonlinear and probability of failure analyses** (Bea, Landeis, Craig, 1992).

The primary objective of this approach is to allow assessment and requalification of platforms with the simplest method. It is intended to identify platforms that are clearly fit for purpose as quickly and easily as is possible and reserve more complex and intense requalification analyses for those platforms that warrant such evaluations. The engineer is able to choose the method that will facilitate and expedite the requalification process. If platform analytical models are already developed and available for Level 3 analyses, then these models can be used in the evaluation process.

There are more stringent Fitness for Purpose (FFP) criteria associated with the simpler methods because of the greater uncertainties associated with these methods, and because of the need to minimize the likelihood of "false positives" (platforms identified to be FFP that are not FFP) associated with the simplified methods.

Evaluations of FFP are based on comparisons of the potential "exposures" associated with the platform operations and the RSR based on a given IMR program (Bea, 1991). If the RSR is acceptable, then the proposed IMR program can be implemented and monitored. If the RSR is not acceptable, then the IMR program can be revised and the process repeated until an acceptable and feasible (based on venture economics) RSR is achieved. If this can not be done, the implication is that the platform should be decommissioned.

DETERMINATION OF THE RSR

Level 1 RSR is based on five factors that address the platform capacity and four factors that address the platform environmental loadings (Table 1):

$$RSR = \frac{[R_1 \ R_2 \ R_3 \ R_4 \ R_5]}{[S_1 \ S_2 \ S_3 \ S_4]} \qquad (2)$$

Guidelines have been developed on how to define the scores for each of the factors for steel, template-type Gulf of Mexico (GOM) platforms (Bea, Craig, 1993). These guidelines have been based on calibrations with results from Level 3 and Level 4 analyses of a wide variety of GOM platforms.

Due to the unique history of each offshore region, scoring guidelines must be developed for each of the regions in which platforms are to be requalified using the Level 1 approach. The Level 1 evaluations are intended to help "screen" large populations of structures, readily identifying those platforms that are not in need of extensive requalification analyses, and readily identifying those platforms that should be investigated in greater detail.

Level 2 RSR is based on a limit equilibrium technique to estimate the platform lateral load capacity (Fig. 2) (Bea, 1992d; Bea, DesRoches, 1993). The estimate is based on the summed capacities of all of the primary lateral load resisting members at a given elevation. Comparisons of the platform shear capacities with the environmental loading shears are used to identify the component (assembly of brace, joint, leg, pile elements) that would fail first. Simplified procedures have been developed to estimate the storm loading profiles including wave crest loadings acting on the lower decks. The environmental loading base shear that would bring the first component to failure defines the static lateral load capacity of the platform (Rus).

Table 1
Level 1 RSR Capacity Scoring Factor Guidelines

FACTOR	GUIDELINE	SCORE
R_1	Structure & foundation design and construction criteria • 1947-1959 • 1960 - 1964 • 1965 - 1975 • 1976 - 1993	 0.5 - 0.8 0.6 - 1.2 0.7 - 1.3 0.9 - 1.5
R_2	Structure condition: corrosion, dented & bent members, dropped objects, fouling, scour • Poor • Good • Excellent	 0.3 - 0.8 0.8 - 1.0 1.0 - 1.2
R_3	Structure and foundation modifications developed during installation, operations, or reassessment that result in increases or decreases in capacity • Decreases • No Changes • Increases	 0.5 - 0.9 1.0 1.1 - 1.5
R_4	Structure & foundation configuration • Low robustness (e.g. caisson) • Moderate robustness (e.g. 4-leg platform non-ductile bracing) • High robustness (e.g. 8-leg platform with ductile bracing) • Very high robustness (e.g. 8-leg plat. with ductile bracing and excess capacity	 1.0 - 1.1 1.2 - 1.3 1.4 - 1.5 1.6 - 2.0
R_5	Loading-capacity effects Factor - Fv • Storm waves • Earthquakes	 1.0 - 1.5 1.0 - 4.0
S_1	Storm loadings design criteria (Ref. 20th Edition API RP 2A) • $(H_{API} / H_{design})^2$ • (Cd_{API} / Cd_{design}) x (dir. spread, shielding, blockage, & current corrections)	 1.0 - 1.5 1.0 - 1.5
S_2	Lower equipment deck elev. (not in design wave loading) • Elev. $_{API}$ / Elev. $_{present}$	 1.0 - 1.5
S_3	Loading modifications: elements added or removed , marine growth management • Area $_{modified}$ / Area $_{design}$	 0.5 - 1.5
S_4	Operating / gravity loading modifications • Weight $_{modified}$ / Weight $_{design}$	 0.5 - 2.0

The ultimate lateral load capacity of the platform (Ru) is determined by multiplying the static capacity by a "loading - capacity effects" factor (Fv) (Bea 1992a - 1992c; Bea, Young, 1993):

Ru = Rus (Fv)..(3)

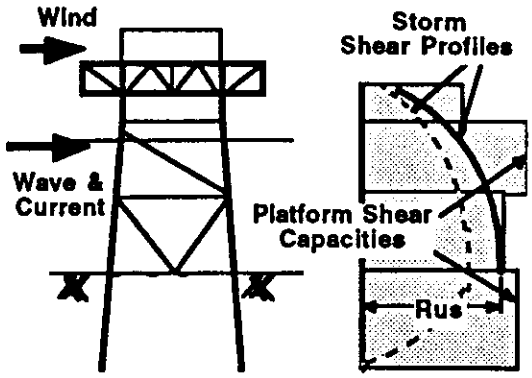

Fig 2: Simplified Capacity Analysis

This loading-capacity effects factor is a function of the magnitude-time characteristics of the different types of environmental loadings (e. g. storm waves, earthquakes, icebergs) and of the ultimate limit state loading resistance-displacement characteristics of the platform itself (Stewart, Moan, Amdahl, Eide, 1993).

Level 3 RSR is based on results from traditional linear elastic analyses for the reference environmental loading. In the case of Working Stress Design procedures, member and element allowable stress ratios are modified to reflect the best estimate ultimate strength of the member. In the case of Load and Resistance Design procedures, the resistance factors are set to unity and the member strength characteristics used as defined by the design procedure (Fu, et al., 1992). The load factors are similarly set at unity. The inverse of the largest allowable stress ratios associated with the primary lateral load carrying members defines a platform load capacity based on the first primary load carrying members "failure" (R_{fm}). As for the loadings characterizations, it is similarly important to use "unbiased" estimates for the capacity characteristics of the platform elements including braces, legs, joints, and foundation piles.

This load capacity is multiplied by a platform configuration "robustness" factor. The robustness factor is intended to recognize post-yield, load-sharing, "system effects" and as such reflects the combined influences of redundancy, ductility, and excess capacity in the primary loading carrying members (Hellan, Tandberg, Hellevig, 1993). Thus, the Level 3 platform static lateral load capacity:

Rus = (R_{fm}) R_4 ....(4)

This capacity is multiplied by Fv to define the ultimate lateral load capacity, Ru.

Level 4 platform loadings and capacities are determined from the results of detailed static or dynamic nonlinear analyses of the platform system. In the case of dynamic nonlinear analyses, the intensity of the loadings is increased until the platform is brought to its ultimate lateral loading capacity. In the case of static nonlinear analyses, a loading pattern appropriate for a given magnitude of lateral loading is defined and imposed on the platform. The loading pattern is modified to be appropriate for a given intensity of environmental conditions and increased until the static maximum lateral capacity of the platform is defined. The static capacity is multiplied by Fv to define Ru. An alternative "full scope" Level 4 analysis developed and applied by the author to a several high consequence platforms involves explicit assessment of the reliability characteristics of the platform (Fig. 3) (Bea, Landeis, Craig, 1992). The reliability considerations include both those of the platform itself and of its associated operations. The focus of this approach is on the total risk management of the platform. Evaluations of uncertainties include those that are natural or inherent (Type I) and those that are due to model, parametric, and state sources (Type II) (Bea, 1992a, 1992b). An example of the "full-scope" Level 4 reliability analysis will be given in this paper.

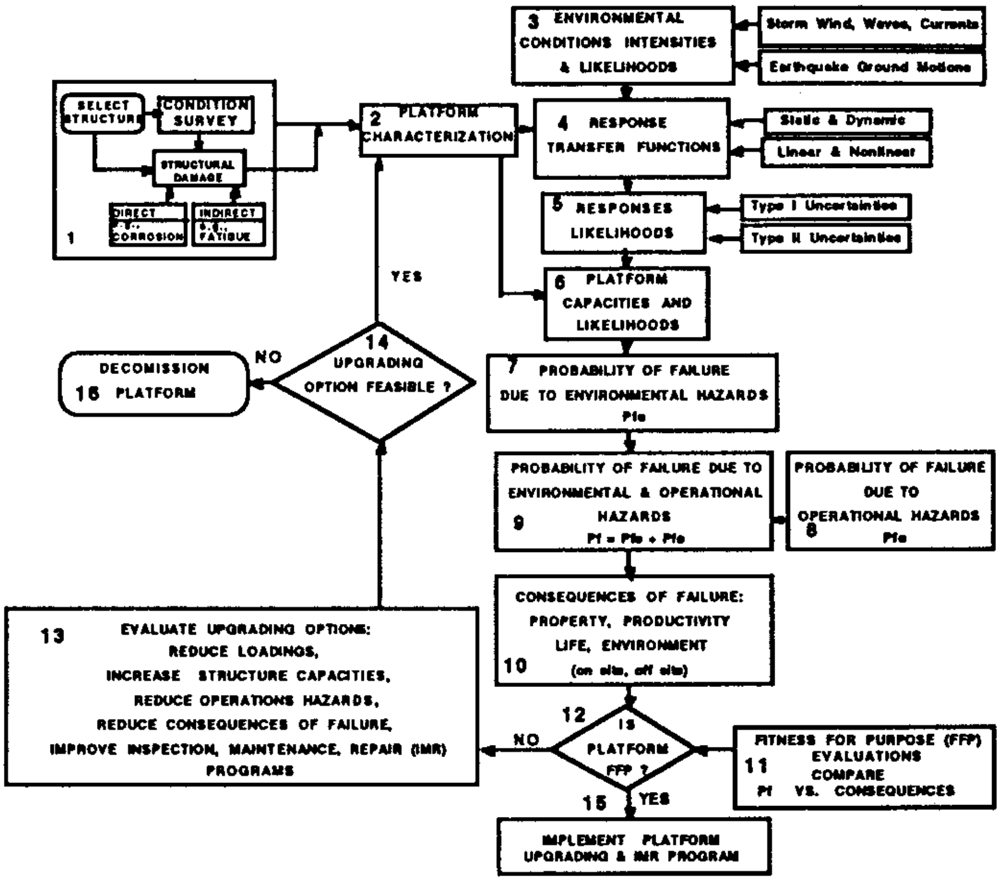

FIG. 3. Full-scope reliability based requalification approach

RELIABILITY BASED GUIDELINES

RSR Fitness-For-Purpose (FFP) evaluations are based on measures of the "exposures" associated with the platform and include property, productivity, personnel, and environmental elements that would be at risk given a catastrophic failure of the platform during an extreme environmental event (Bea, 1991).

Based on reliability considerations, the required RSR can be expressed analytically as follows:

$$RSR = \exp\left(\beta\,\sigma - K\,\sigma_{\ln S}\right) \quad (5)$$

$$K = \Phi^{-1}\left(1 - T_S^{-1}\right) \quad (6)$$

This expression presumes Lognormally distributed loadings and capacities. $\sigma_{\ln S}$ is the standard deviation of the probability distribution of the logarithms of the annual expected maximum lateral loadings. T_S is the return period in years associated with the reference environmental lateral loading. Φ is the Standard Normal Distribution. σ is the resultant uncertainty in the platform capacity and loading ($\sigma^2 = \sigma_{lnR}^2 + \sigma_{lnS}^2$). β is the structural annual Safety Index. β is a normalized measure of the structural probability of failure (Pf = annual likelihood that the platform capacity is exceeded by the environmental loadings, $Pf \approx 10^{-\beta}$).

Exposures associated with potential platform failure are classified into three categories: Low, Moderate, and High. A **Low Exposure Category** structure is represented by a caisson or well protector that might support one to four wells. The wells, risers, and pipelines would be protected with appropriate shut-in equipment. This category is based on $\beta = 1$ to 2.

A **Moderate Exposure Category** structure is represented by a self-contained drilling and production platform that could support six to sixty moderate productivity wells. The platform would be evacuated before intense environmental events. The wells would be protected with subsurface safety valves and the risers and pipelines with emergency shut-down valves. This category is based on $\beta = 2$ to 3.

A **High Exposure Category** structure is represented by a self-contained drilling and production platform that could support six to sixty high productivity wells. The platform would not be evacuated before intense environmental events. Life saving equipment would be provided. The wells, risers, and pipelines would be protected with shut-in equipment. This category is based on $\beta = 3$ to 4.

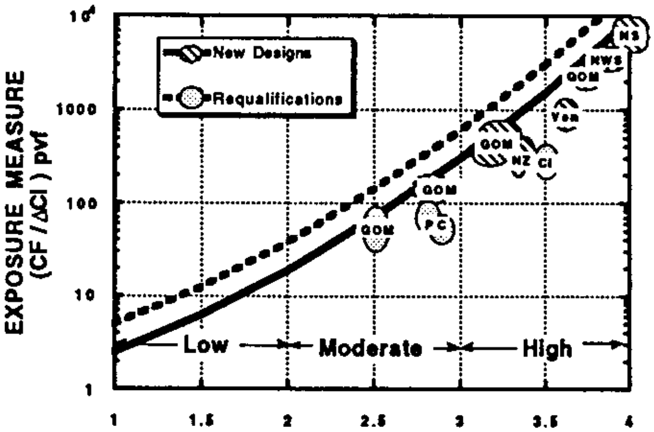

Fig. 5. Exposure categories based on monetary valuations (GOM = Gulf of Mexico, PC = Pacific Coast, CI = Cook Inlet, Ven = Venezuela, NZ = New Zealand, NS = North Sea, NWS = Northwest Shelf Australia)

Fig. 5 characterizes the three categories of exposures in terms of monetary costs. The **Exposure Measure** (EM) is the ratio of the estimated costs associated with failure of the platform (CF) to the costs required to reduce the structural Pf by a factor of ten (Δ Ci) times a present value factor (pvf) (Bea, 1991):

$$EM = \frac{CF}{\Delta Ci} (pvf) \qquad (7)$$

The pvf for long term exposures (L greater than about 20 years) is the reciprocal of the net rate of return on money ($pvf \approx r^{-1}$). The pvf for short term exposures (L less than about five years) is equal to the number of years of the exposure ($pvf \approx L$). It is through the pvf that the proposed "life" of the platform enters the FFP criteria. Longer life systems imply larger EM which results in larger required RSR.

There is a differentiation between the EM for new designs and requalifications of existing platforms. This reflects a willingness to accept lower reliabilities associated with older systems and not to require that these systems have reliabilities that equal those of new systems. Such a willingness can be demonstrated to be true for a variety of engineered systems including commercial aircraft, automobiles, dams, and power plants (Bea, 1991).

Also shown in Fig. 5 are results from recent requalification and design studies of a variety of types and locations of self-contained drilling and production platforms. This information indicates that in general, the standard-of-practice results are more conservative than would be derived from purely economics considerations. These "real life" requalification and design decisions approximate the monetary "optimum" results.

Based on the three general categories of exposures, Fig. 6 and Fig. 7 summarize RSR reliability based FFP guidelines for existing Gulf of Mexico (GOM) and North Sea (NS) platforms. In development of these guidelines, it has been assumed that operating risks and environmental risks are equal.

The GOM guidelines for hurricanes are based on $\sigma_{lnS} = 0.60$, and $\sigma_{lnR} = 0.20$ (Wen, 1988, 1990; Olufsen, Bea, 1990). The NS guidelines for storms are based on $\sigma_{lnS} = 0.30$, and $\sigma_{lnR} = 0.20$ (Olufsen, 1989; Olufsen, Bea, 1990; Haver, 1989). The RSR FFP guidelines are based on a reference or "nominal" storm loading associated with an average return period of $T_S = 100$-years.

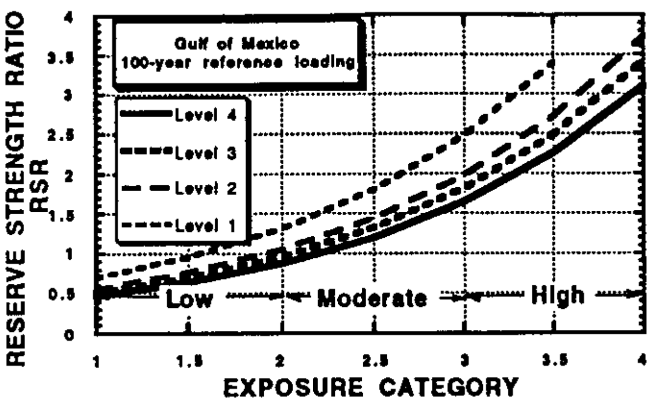

Fig. 6. Gulf of Mexico Hurricane Loadings RSR FFP Criteria

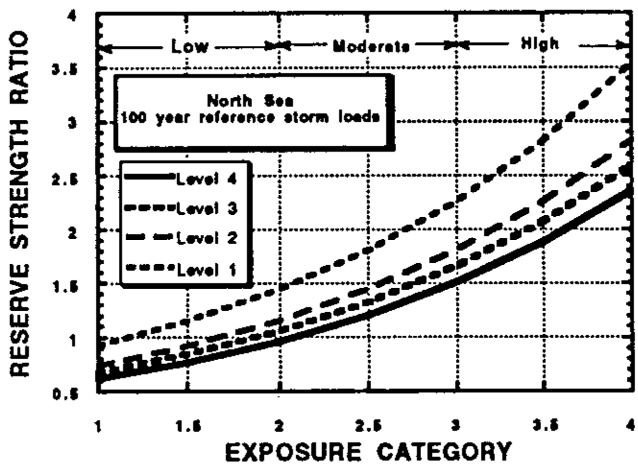

Fig. 7. North Sea storm loading RSR FFP criteria

The larger RSR indicated for the more simplified levels of analysis reflect additional uncertainties associated with the more simplified analyses and the desire to limit false positives. The RSR factor-of-safety for the different levels of analysis were developed as follows:

$$FS_{RSR} = \exp(\beta_{RSR}\, \sigma_{RSR}) \quad (8)$$

The criteria for the different levels were as follows: the likelihood of false positives in Level 1 were 1/100, in Level 2 were 1/20, and in Level 3 were 1/10. The uncertainties associated with the RSR evaluations were $\sigma_{RSR} = 0.3$, = 0.2, and = 0.15 for Levels 1 - 3, respectively. Level 4 was taken as the best estimate of the true RSR. The likelihood of false positives and RSR evaluation uncertainties were estimated based on experience with these various analytical approaches (Bea, Craig, 1993; Nikolaidis, Kaplan, 1991; Olufsen, 1989). The resulting factors of safety for the four levels of analysis were 1.5, 1.2, 1.1, and 1.0, respectively.

It is desirable to retain information sensitivity in the required RSR. As uncertainties are reduced through inspections, monitoring, and improved analyses, there should be a reduction in the required RSR. Fig. 8 illustrates one way in which information sensitivity can be retained. This illustration is based on a reference loading average return period of 100 years, a platform capacity uncertainty of $\sigma_{\ln R} = 0.20$, and a Level 4 RSR analysis. If for a particular platform in a particular region and for a particular category of exposures (reflected in β), it could be demonstrated that the total uncertainty (σ) was different from that assumed to develop the RSR FFP guidelines, then the RSR guidelines could be modified accordingly. For low exposure categories ($\beta \leq 2.5$) there is little sensitivity to the uncertainties.

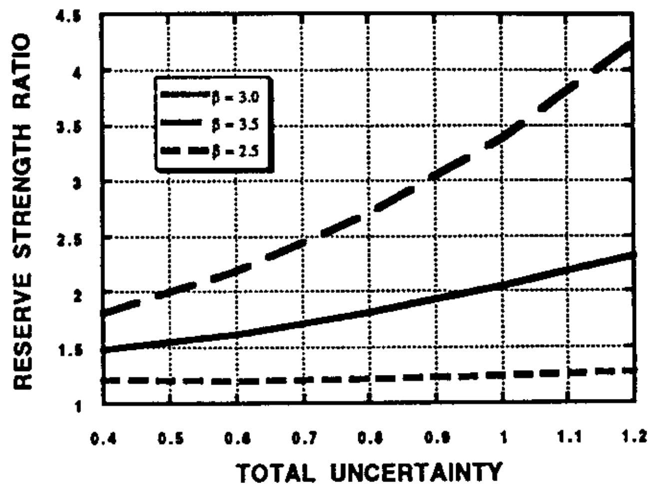

Fig. 8. Information sensitive RSR

The remainder of this paper will illustrate applications of these developments to requalification of two offshore platforms.

PLATFORM 'A'

Platform 'A' (Fig. 9) is a conventional 8-leg self-contained drilling and production platform that was installed in the Main Pass area of the Gulf of Mexico in 1970. The platform was designed according to the first edition API RP 2A guidelines for 100-year storm conditions that included a design wave height $H_D = 17.7$ m, currents (1.1 m/s at surface), an allowance for marine growth, and Cd = 0.6 to 0.7 (function of member diameter).

The platform was constructed of A-36 steel, and had grouted leg-pile annuli and heavy wall joint cans. The foundation soils consisted of dense sands and stiff clays.

The condition survey performed on this platform indicated that the structure was in excellent condition; there was no significant corrosion, cracked joints, or dented-bent members. The platform owner proposed to requalify the platform for another 10 years of service, to perform detailed inspections of the underwater portions of the structure every 5 years, and to perform visual inspections of all primary members every 2 years or after significant loading events.

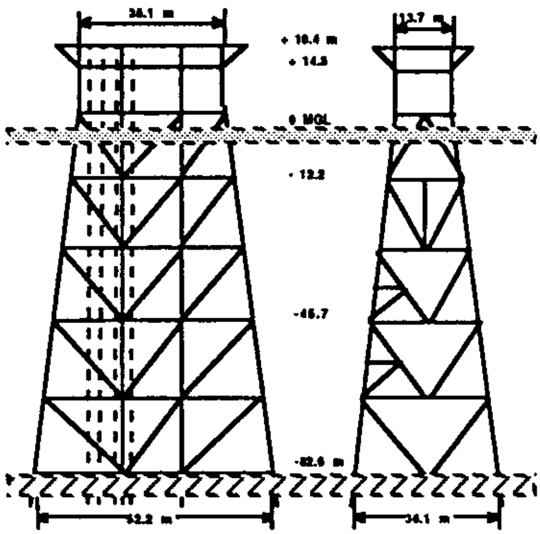

Fig. 9. Elevations of platform 'A'

The Level 1 evaluations of this platform developed the following results (refer to eqn. 2, Table 1):

$$RSR_1 = \frac{1.0 \times 1.0 \times 1.0 \times 1.5 \times 1.2}{1.0 \times 1.0 \times 1.0} = 1.8$$

The Level 2 API reference storm lateral loading shears were determined as a function of elevation and compared with the shear capacities of each of the bays in the jacket and the deck legs (Fig. 10). In this case, because of the vertical diagonal brace framing patterns, the end-on loading capacity was less than the broadside loading capacity. Both capacities were governed by the diagonal brace and leg shear capacities in the fourth level of bracing below the jacket top.

The API reference level force was calculated to be S_R = 10.3 MN (Heideman, Weaver, 1992). The platform lateral static shear capacity was estimated as Rus = 14 MN. Given a natural period of this platform Tn = 1.5 sec, a reference storm wave period of Tw = 11 sec, and a ductility capacity of μ = 2, Fv = 1.2. Thus, Ru = 3,800 kips (17 MN) and RSR_2 = 1.6.

A Level 4 nonlinear push-over analyses of this platform was also performed (Fig. 11). The results indicated that the vertical diagonals and several of the horizontal members in the top four bays of the jacket were involved in the failure mode. The results indicate Rus = 12.5 MN and μ = 2.0. Thus, Ru = 15 MN and RSR_4 = 1.5.

There is no storage onboard the platform, it is evacuated in advance of hurricanes, and the risers and wells are protected with emergency shut-in valves and subsurface safety valves. This platform is indicated to have an EM in the range of 50 to 100 for a 10-year projected life. This would place this platform in the Moderate Exposure Category. Based on the criteria summarized in Fig. 3, and RSR = 1.5 to 1.8 this platform is indicated to be FFP based on all three levels of RSR analyses.

This platform is presently in service.

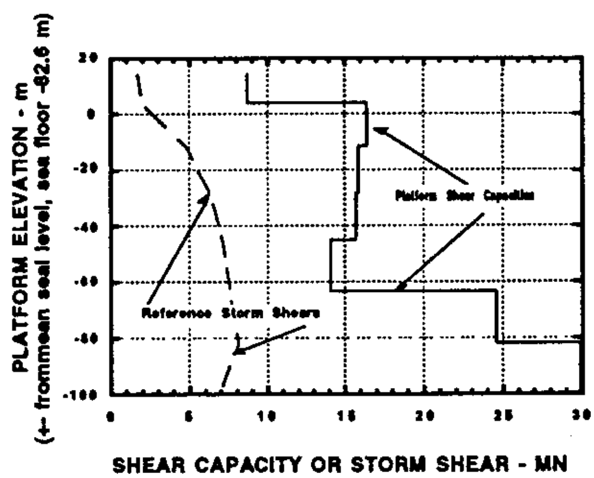

Fig. 10. Platform 'A' 100-year storm shears and platform capacities

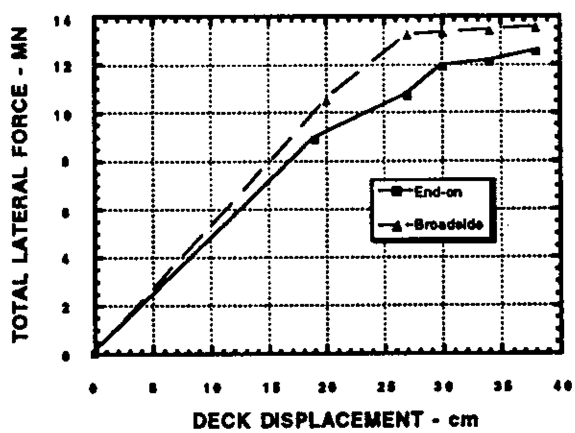

Fig. 11. Platform 'A' push-over analysis results

PLATFORM 'B'

Platform 'B' (Fig. 12) is located two miles offshore California in a water depth of 60 ft (18 m). It is a 12-leg drilling and production platform. It was installed in 1964 and has been well maintained.

The condition survey included extensive above and below water inspections and non-destructive testing of the joints, taking coupons of the structure steel to confirm the yield and ultimate tensile strength, performing a soil boring to define site specific soil characteristics, and performing ambient vibration measurements to define the natural periods (Tn = 0.6 to 0.8 sec) of the structure.

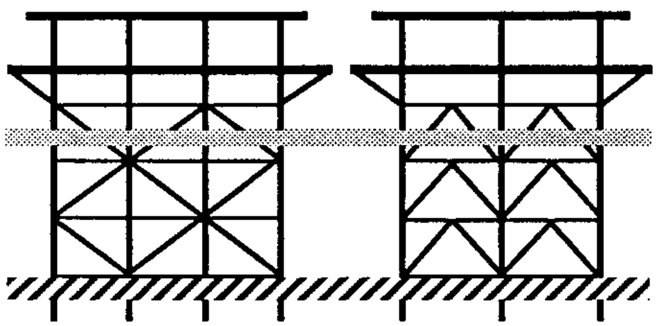

Fig. 12. Platform 'B' elevations

The condition survey indicated significant damage to several underwater primary load path member joints (fatigue cracking). Repairs involving bolted clamps and grouting were engineered and implemented. In addition evaluation of the condition survey results indicated that the pile lateral capacities would likely be less than desirable, so a pile capacity upgrading program consisting of grouting reinforcing steel into the piles in the vicinity of the sea floor was incorporated as part of the IMR program.

The platform owner proposed that the platform will remain in service for another 20 years. Due to the sensitive environment in which this platform operates, the platform owner elected to perform both RSR and reliability based Level 4 evaluations.

State-of-the-art studies were made of the oceanographic and earthquake environments and the performance characteristics of the platform. The storm conditions characterization involved the use of hindcasting models that were calibrated with measured storm conditions in a series of severe storms that have affected this region during the past several years.

The storm wave loading analyses examined the force implications of a subdeck that had been added to the platform and the benefits of marine growth management (Fig. 13). A marine growth management program had substantial benefits in reducing the storm loadings. There were no significant "loading - capacity" effects for this platform (Fv = 1)

The earthquake conditions characterization involved an extensive study of the seismic geology of the site and region including the use of deep geophysics to identify significant seismic sources. Recent recordings of on-land earthquakes in similar seismic settings were used to provide verifications of the source to site attenuation and local site effects characterizations used in the seismic hazard study.

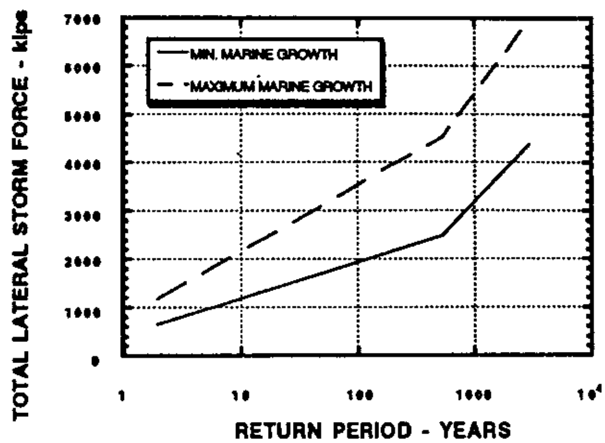

Fig 13. Maximum lateral forces imposed on Platform 'B' by storms

The earthquake loading characterization accounted for the dynamic loading and ductility performance characteristics of the platform. There was a substantial difference between the forces indicated for an elastic system and those for a nonlinear system having load-deformation characteristics similar to those of the platform (Fig. 14).

Comparison of the two loading characterizations indicates that even though this platform is located in an active earthquake region, the loadings from storms were the primary environmental loading hazard.

Damage to the underwater joints which was found during the platform inspections was repaired using advanced grouting and clamping methods. Further strengthening of the structure (deck bracing) and foundation (pile grouting and reinforcement) was accomplished to improve the performance of the platform. Fig. 15 summarizes the results from the Level 4 nonlinear capacity analyses for the platform in its repaired and strengthened conditions. The strengthening measures resulted in a 50 % increase in the platform capacity (12 MN versus 19 MN).

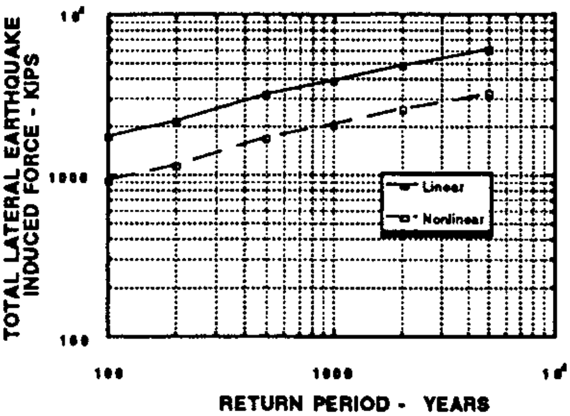

Fig. 14. Maximum lateral forces induced in Platform 'B' by earthquakes

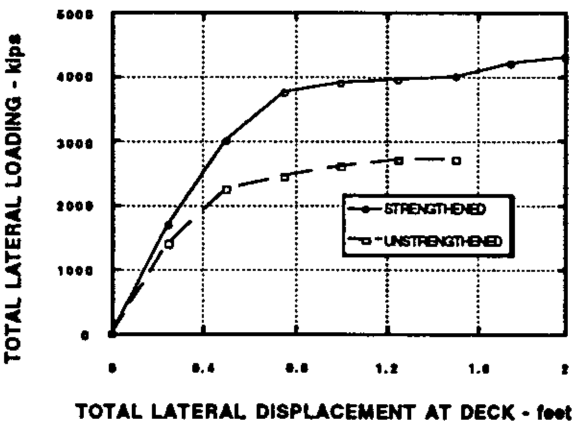

Fig. 15. Platform 'B' substructure load and displacement capacities

Ambient vibration measurements were performed following the repair and strengthening of the platform. The measurements indicated that the strengthening had resulted in a significant decrease in the level of response "noise" (due to repair of the cracked joints) and that there had been a significant decrease in the natural periods (due to the structure and foundation strengthening).

A Level 4 reliability based evaluation (Bea, Landeis, Craig, 1992) was performed for this platform. This evaluation included explicit consideration of natural (Type I) and modeling (Type II) uncertainties, the effects of past loading events (Bayesian updating of platform capacity) and loading "truncations" (e.g. wave height - water depth limits). The influences of topsides operations on the reliability characteristics also were considered.

For the strengthened platform condition, the annual probabilities of platform failure for the storm loadings considering Type I uncertainties were calculated to be Pfs = 6.0 E-3 (no marine growth management) to Pfs = 4.2 E-4 (with marine growth management). Consideration of the additional Type II uncertainties increased these values to Pfs = 1.7 E-2 and Pfs = 2.1 E-3. The probabilities of platform failure due to the earthquake loadings were calculated to be Pfq = 1.3 E-4 (Type I uncertainties) to Pfq = 5.6 E-4 (Types I and II uncertainties). Based on a study of the topsides equipment and operating practices, the operating probabilities of failure were estimated to be Pfo = 6.5 E-5 per year.

The total annual likelihood of loss of serviceability was estimated to be Pf_T = 6 E-3 (maximum marine growth) to Pf_T = 9 E-4 per year (Type I uncertainties). Consideration of Type II uncertainties increased these values to Pf_T = 1.8 E-2 (maximum marine growth) to Pf_T = 3 E-3 per year. For the unrepaired case, Pf_T = 5 E-2 (Type I uncertainties) to Pf_T = 9 E-2 (Types I and II uncertainties). The platform repair and strengthening measures were extremely effective in developing significant reductions in risks caused by environmental loading effects.

This platform is only intermittently manned. The wells have low flow potentials and are protected with subsurface safety valves. There is no onboard storage and the risers and pipelines are protected with emergency shutdown valves. Evaluations of the exposure associated with this platform indicated EM = 50 to 100, placing this platform in the Moderate Exposure Category. The total estimated costs associated with failure of the platform are estimated to be in the range of $30 to $60 millions (U. S.).

Based on economics based FFP criteria (eqn. 7, Fig. 16), the platform strengthening and marine growth management programs are clearly justified.

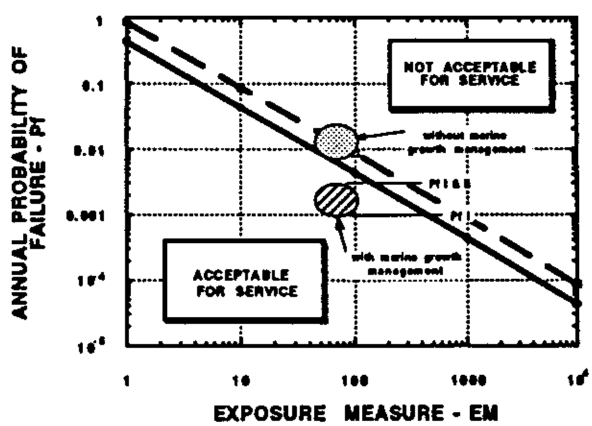

Fig. 16. Economics based evaluation of FFP

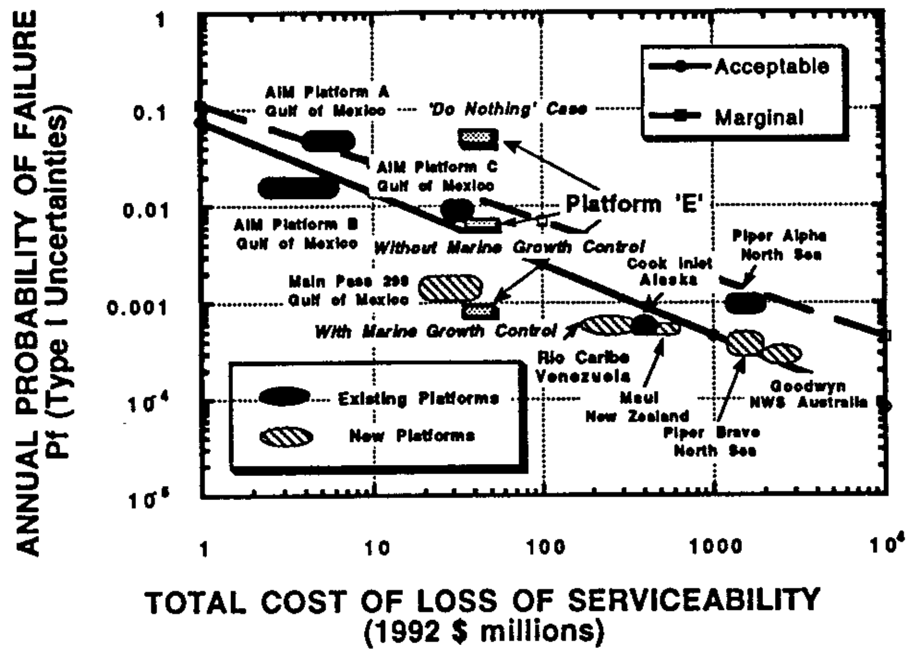

Fig. 17. Standard-of-practice based fitness for purpose evaluation

Based on a standard-of-practice FFP criteria (Fig. 17) (Bea, Landeis, Craig, 1992; Bea, 1992c), the platform would be acceptable in the strengthened condition without a marine growth management program.

This platform is presently in service.

CONCLUSIONS

A practical and general engineering procedure has been developed for the assessment and requalification of existing offshore platforms. The procedure involves four levels of analysis of increasing detail and difficulty so that platforms can be requalified for service at the simplest possible level. Reliability based fitness for purpose guidelines have been developed that recognize differences in property, environmental, and life exposures of different offshore platforms in different locations, the platform loading and capacity characteristics, and the uncertainties in these characteristics.

This procedure has been verified through applications to a variety of requalifications ranging from moderate exposure evacuated platforms to high exposure manned self-contained drilling and production platforms. The procedure has proven to be able to produce consistent and sensible results.

ACKNOWLEDGMENTS

This paper is the result of a research project conducted at the University of California at Berkeley with funding provided by the National and California Sea Grant College Program, the Minerals Management Service, the California State Lands Commission, Phillips Petroleum Co., Chevron Corp., and UNOCAL Corp. Without this support, this work could not have been undertaken and completed.

This paper is funded in part by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, under grant number NA89AA-D-SG 138, project numbers R/OE-11 and R/OE-19 through the California Sea Grant College, and in part by the California State Resources Agency. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its sub-agencies. The U. S. Government is authorized to reproduce and distribute for governmental purposes.

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