*Trials Joint Industry Project*

# Trial Application of API RP 2A — WSD Draft Section 17

## Volume I — Summary Report


*by*
*PMB Engineering Inc.*
*San Francisco, CA*


*December 1994*

# Final Report

## Trials Joint Industry Project

## Trial Application of the API RP 2A-WSD Draft Section 17

## TRIAL APPLICATIONS

*Prepared for*

**Minerals Management Service and Trials JIP Participants**

*Prepared by*

PMB
ENGINEERING INC.

**PMB Engineering Inc.**

**December 1994**

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# Introduction

## 1.1 BACKGROUND

API Task Group (TG) 92-5 developed a draft guideline called "API RP 2A-WSD 20th Edition, Draft Section 17.0, Assessment of Existing Platforms." The latest version of this document is dated April 29, 1994 with some particular revisions dated June 24, 1994. This document defines an assessment process as shown in Figure 1-1, which varies from that followed for a new design. It is based on a multi-level consequence-based acceptance criteria and follows a three-tiered assessment process consisting of screening checks, design level analysis or ultimate strength analysis.

This draft guideline has not been yet officially endorsed by the API, and has been distributed to interested parties for comments by the TG.

The Minerals Management Service (MMS) and a number of interested participants (21 total) contracted PMB Engineering Inc. (PMB) to manage and coordinate a Joint Industry Project (JIP), called the TRIALS JIP, consisting of two parts as follows:

**Part I**: Trial application of the draft guideline in its entirety by the participants to their selected platforms.

**Part II**: Trial application of the ultimate strength analysis procedure of the draft guideline to a common platform by participants or any other interested organization not participating in Part I, in order to determine the variability in the ultimate strength analysis results.

At the kickoff meeting held for the Part I participants of the Trials JIP project on January 19, 1994 at PMB/Bechtel, Houston offices, a Technical Advisory Committee (TAC) was formed to govern both Part I and Part II of the JIP. All companies participating in Part I of the project nominated one member to the TAC. Each TAC member was given one vote on all project matters.

PMB developed the requirements of Trial Applications and produced a Trial Basis Document in agreement with the TAC. The Trial Basis Document provided the necessary background information for performing the trial applications and specific instructions on the types of analysis and results required of each participant. The Trial Basis Document was provided to the various companies interested in performing the Trial Applications.

This report provides details of Part I of the project. The information contained in the Trial Documents received from 21 participants is summarized in the same order as one would apply the Draft Section 17. The primary focus of review of Participants' submittals was to identify problems experienced by them in complete application of the Section 17 document and also to provide information (results obtained) to the API TG for re-examining (if required) the criteria and the basis used in its development.

## 1.2 OBJECTIVES

The objectives of this portion of the TRIALS JIP were as follows:

- Complete assessment of a platform by each participating company.
- To provide comments and feedback to the API TG on the draft document.
- To provide assessment information for a larger sample of platforms assessed in this project to the TG to review the acceptance criteria, if found necessary
- To provide training (learning the process) to the participating companies

## 1.3 PROJECT PARTICIPANTS

At the kick-off meeting on January 19, 1994, 22 companies (16 operating companies and 6 engineering contractors) showed interest in performing Trial Applications. Nineteen companies (15 operating companies and 4 engineering companies) submitted their assessment to the project by September 15, 1994 (the revised original deadline), and four of these provided or revised their ultimate strength analysis results by November 15, 1994. Two companies submitted their documents by November 1, 1994 (extended deadline for late submittals and new participants). In addition, one company provided an additional document on voluntary basis for a platform located West Africa to demonstrate applicability of the Section 17 process to other regions.

The 21 companies (hereafter called "Trial Participants" or "Participants") submitting documents are identified as follows:

AKER OMEGA
AMERADA HESS
AMOCO
BARNETT & CASBARIAN
CHEVRON
CONOCO
ELF EXPLORATION
EXXON
IDEAS
IMP/PEMEX
LINDER AND ASSOCIATES

MOBIL
MURPHY OIL
NEWFIELD
PENNZOIL
PHILLIPS
SHELL
TEXACO
UNOCAL
WALTER OIL & GAS
ZENTECH

## 1.4 PLATFORMS ASSESSED

A summary of the physical and operational characteristics of the 22 platforms assessed in this JIP is presented in Table 1-1 and Table 1-2. All of these platforms were approved for inclusion in this JIP by the TAC members at the kick-off meeting of January 19, 1994 and through later PMB correspondence with the TAC. The participating companies are identified in this report as A, B, C, etc. to keep their identities confidential. The information presented in these tables is discussed below.

- The 22 platforms evaluated in Part I of this JIP include 16 in the Gulf of Mexico, 2 offshore Southern California, 1 in Cook Inlet, 1 in the North Sea, 1 in the Bay of Campache, and 1 offshore Cameroon. The Gulf of Mexico platforms are located in blocks from East Cameron (Platforms A, B, L) to Main Pass (Platform E).

- The platforms are installed in water depths from 37 ft (Platform J) to 340 ft (Platform I) and their year of original design varies from 1957 (Platforms D and J) to 1982 (Platform G). In three cases (Platforms A, J and H), the platforms were re-used at alternate sites. Platform A, which was first installed in 1964 in 150 ft water depth, was reused and installed in 1969 in a 103 ft water depth. Platform J was salvaged in 1957 from its originally installed location in Ship Shoal, extended by 14 ft. and re-installed in 37 ft of water in a South Pelto block. Platform H was originally installed in 1978 in 133 ft of water and later salvaged, modified and reinstalled in 1989 in 95 ft water depth.

  Platform M, originally designed and constructed in 1964 for a water depth of 196 ft, was installed at its current location in 184 ft in 1968. At its new location, an attempt to push the bottom horizontal framing 12 ft into the mudline was not completely successful, and the bottom braces currently sit at 7.5 ft below the mudline.

- Most of the platforms have either four or eight legs. One platform (D) has 16 legs, consisting of two 8-legged jackets installed and connected together. Platform J has 36 legs, consisting of three 12-leg jackets installed and connected together. Platform T has 6 legs and platforms S and Q have 12 legs.

- The bracing scheme in the vertical frames of platforms primarily included K-braces and diagonals. In five cases (Platforms H, L, R, T, and U), X-braces are provided.

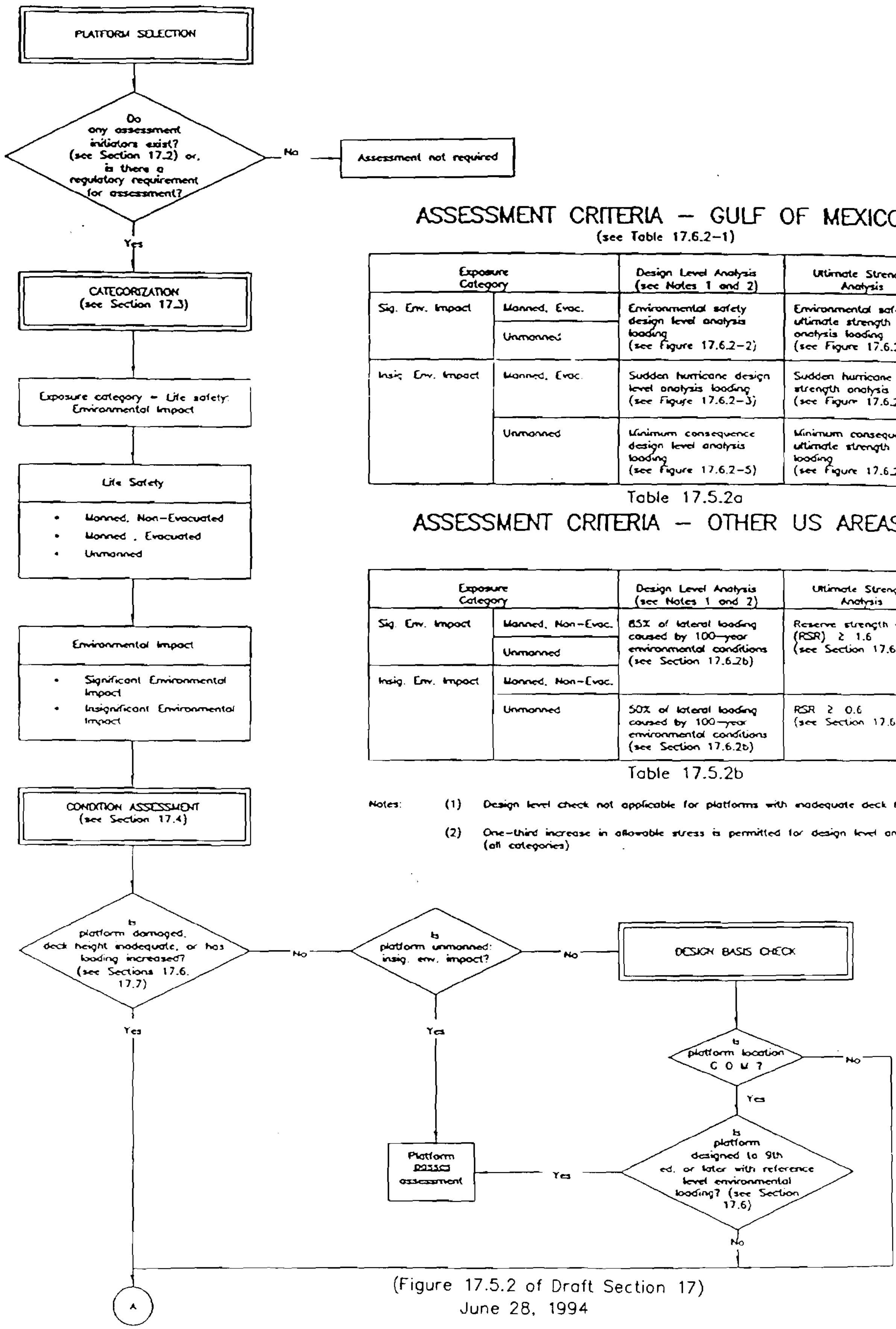
- The damage reported is minimal for most of these platforms. For a majority of platforms, modifications were made from the original design stage or future modifications are under consideration.

- A majority of platforms have Production, Drilling, and Quarters (PDQ) facilities.

- All the "manned" platforms in the Gulf of Mexico are reported to be "evacuated" during storm. Whereas, the three platforms (Q, R, S) located Offshore California and Cook Inlet are "manned" but "not evacuated" during storm.

- The number of wells in these platforms vary from a minimum of three (Platform J) to a maximum of 59 (Platform Q). Platform T has no wells.

The above information indicates that these platforms provide cases with a wide variation of physical and operational characteristics. The assessment information for these platforms provides a useful database for the MMS and the API TG.




## ASSESSMENT CRITERIA – GULF OF MEXICO

(see Table 17.6.2-1)

| Exposure Category | | Design Level Analysis (see Notes 1 and 2) | Ultimate Strength Analysis |
|---|---|---|---|
| Sig. Env. Impact | Manned, Evac. | Environmental safety design level analysis loading (see Figure 17.6.2-2) | Environmental safety ultimate strength analysis loading (see Figure 17.6.2-2) |
| | Unmanned | | |
| Insig. Env. Impact | Manned, Evac. | Sudden hurricane design level analysis loading (see Figure 17.6.2-3) | Sudden hurricane ultimate strength analysis loading (see Figure 17.6.2-3) |
| | Unmanned | Minimum consequence design level analysis loading (see Figure 17.6.2-5) | Minimum consequence ultimate strength analysis loading (see Figure 17.6.2-5) |

Table 17.5.2a

## ASSESSMENT CRITERIA – OTHER US AREAS

| Exposure Category | | Design Level Analysis (see Notes 1 and 2) | Ultimate Strength Analysis |
|---|---|---|---|
| Sig. Env. Impact | Manned, Non-Evac. | 85% of lateral loading caused by 100-year environmental conditions (see Section 17.6.2b) | Reserve strength ratio (RSR) ≥ 1.6 (see Section 17.6.2b) |
| | Unmanned | | |
| Insig. Env. Impact | Manned, Non-Evac. | | |
| | Unmanned | 50% of lateral loading caused by 100-year environmental conditions (see Section 17.6.2b) | RSR ≥ 0.8 (see Section 17.6.2b) |

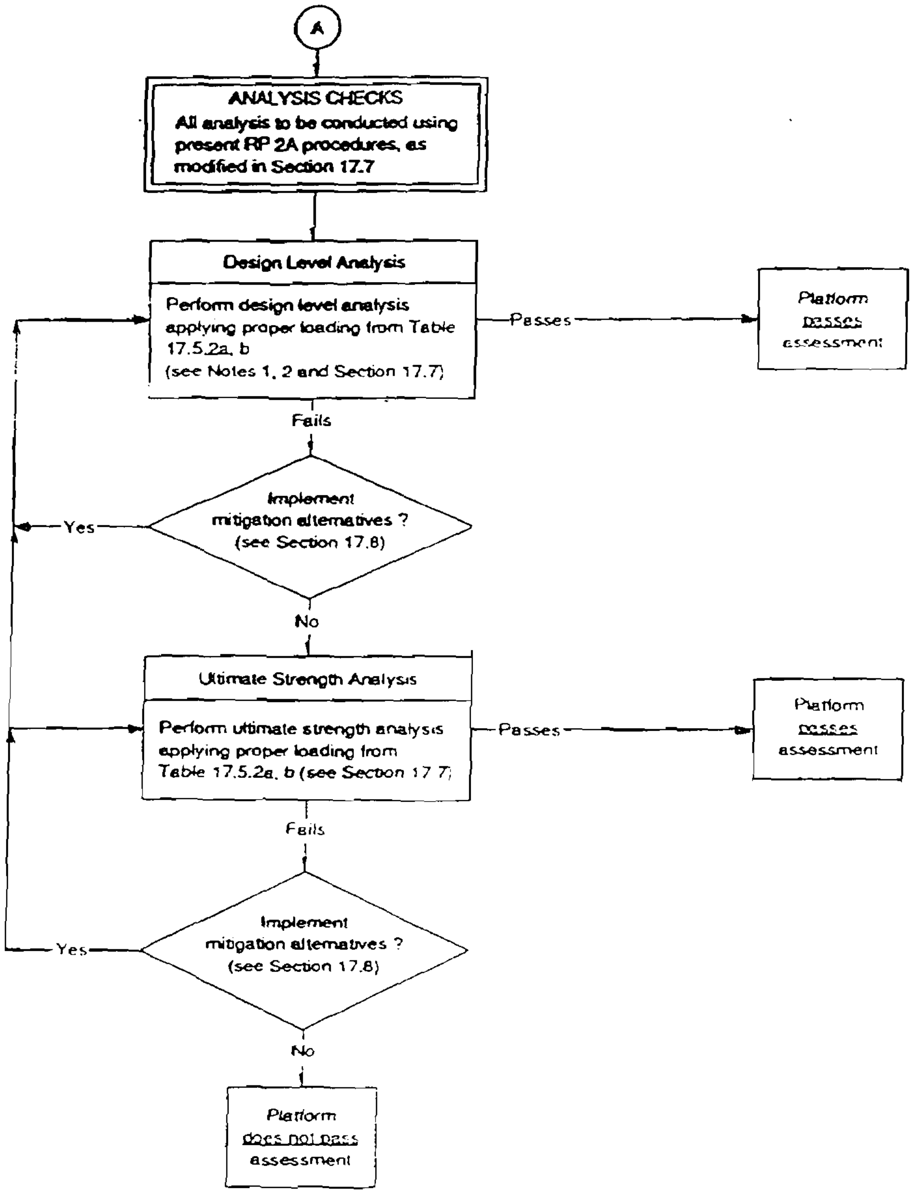
Table 17.5.2b

Notes: (1) Design level check not applicable for platforms with inadequate deck height.

(2) One-third increase in allowable stress is permitted for design level analysis (all categories)

(Figure 17.5.2 of Draft Section 17)
June 28, 1994

**Figure 1-1 Section 17 - Platform Assessment Process Metocean Loading**




(Figure 17.5.2 (continued) of Draft Section 17)
April 29, 1994

**Figure 1-1 Section 17 - Platform Assessment Process Metocean Loading (continued)**

Table 1-1: Summary of Basic Platform Information - Physical Characteristics

| Platform | Location | Water Depth (ft.) | Year of Installation | Year Designed or API Edition | Physical Characteristics: Number of Legs | Number of Piles | Pile Diameter (inch) | Leg/Pile Annulus (#1) | Pile Penetration (ft.) | Brace Type In Vertical Frames | Lowest Deck B.O.S. Elev. (ft.) | Damages to Jacket Primary Members | Platform Modifications Since Original Design |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gulf of Mexico:** | | | | | | | | | | | | | |
| A | East Cameron | 103 | 1969 | 1964(orig.) | 4 | 4 | 36 | Grouted | 230 | K | 52.00 | None | One external well added |
| B | East Cameron | 182 | 1971 | not known | 4 | 4 | 42 | Ungrouted | 255 | K | 46.00 | Not significant | None |
| C | Eugene Island | 255 | 1972 | 1971 | 8 | 8 | 42 | Ungrouted | 312/360 | K & Diagonal | 45.5 (#4) | Minor damage | 3 conductors added |
| D | Grand Isle | 88 | 1957 | 1957 | 16 | 16 | 30 | Grouted | 141 | Diagonal | 44.06 | None | Piles grouted in 1967 |
| E | Main Pass | 247 | 1969 | 1968 | 8 | 8 | 42 | Ungrouted | 240 | K & Diagonal | 47.50 | Not significant | - |
| F | Ship Shoal | 162 | 1970 | 1969-70 | 4 | 4 | 36 | Ungrouted | 355 | K | 27.75 | None Known | Main deck extended, equipment added |
| G | Ship Shoal | 310 | 1984 | 1982 | 8 | 8 | - | Ungrouted | - | X & Diagonal | 52.50 | None | - |
| H | South Marsh | 95 | 1978/1989 | 1977(orig.)/1989 | 4 | 4 | 30 | Ungrouted | 195 | K & X | 52.75 | Undamaged | Upgraded for reuse at alternate site in 1989 |
| I | South Pass | 340 | 1967 | 1966 | 8 | 16 | 48 | Ungrouted | 180 | K | 44.00 | Gen. corrosion, pitting | - |
| J | South Pelto | 37 | 1957 | 1950's | 36 | 36 | 18 | Ungrouted | 132-141 | K | 31.00 | Local damage, corrosion | - |
| K | West Delta | 160 | 1965 | 1964 | 8 | 18 | 30 | Ungrouted | 182 | K & Diagonal | 44.00 | - | - |
| L | East Cameron | 160 | 1970 | 1970 | 4 | 4 | 36 | Ungrouted | 190/227 | X | 47.00 | None | None |
| M | West Delta | 184 | 1968 | 1964 (orig) | 8 | 8 | 36 | (# 2) | 160 | K & Diagonal | 39.00 | None | Gussets @ joints added, leg/pile grouted |
| N | West Delta | 223 | Mid 1960's | 1964 | 8 | 8 | 42 | Ungrouted | 270 | K & Diagonal | 40.00 | None | Minor repairs |
| O | Eugene Island | 300 | 1973 | 1973 | 8 | 12 | 48/42 | Grouted | 320/340 | K & Diagonal | 46.5 (# 3) | Unknown | Unknown |
| P | Eugene Island | 263 | 1973 | 1972 | 8 | 8 | 48 | Grouted | 300 | K & Diagonal | 47.00 | Not Significant | None |
| **Offshore Southern California:** | | | | | | | | | | | | | |
| Q | Santa Barbara | 189 | 1968 | 1968 | 12 | 12 | 40 | Partially grouted | 85 | Diagonal, K | 40.00 | None | None |
| S | Santa Barbara | 155 | 1968 | 1967 | 12 | 12 | 36 | Grouted | not available | Diagonal | 32.00 | None known | Cracked joints, dented/lost braces repaired in 1981/82 |
| **Cook Inlet:** | | | | | | | | | | | | | |
| R | - | 100 | 1968 | 1967 (UBC) | 4 | 32 | 30 | Grouted | 175 | X | 43.00 | None | Larger drill rig in 1992 |
| **North Sea, U.K.:** | | | | | | | | | | | | | |
| T | Southern N. Sea | 118 | 1968 | pre-API | 6 | 6 | 36 | Ungrouted | 105 | X | 42.10 | None | Repair/grouting to leg C1 |
| **Bay of Campache, Mexico:** | | | | | | | | | | | | | |
| U | Nohoch B | 125 | 1979 | 1977 | 8 | 8 | 48 | Ungrouted | 243 | K/X/Diagonals | 47.50 | Minor Damage | Addition of facilities |
| **Offshore Cameroon, West Africa:** | | | | | | | | | | | | | |
| V | Mokoko Abana E | 161 | 1981 | 1981 | 4 | 4 | 36 | Ungrouted | 290 | Diagonals | 32.00 | None | Living quarter removed |

#1: Refers to Main Pile/Leg Annulus, where applicable
#2: Grouting of all legs not confirmed from survey reports
#3: T.O.S. Elevation of Lower Deck

**Table 1-2: Summary of Basic Platform Information - Operational Characteristics**

| Platform | Location | Water Depth (ft.) | Year of Installation | Operational Characteristics: Type of Facility | Operational Characteristics: Manned/ Unmanned Operation & Evacuation During Storm | Operational Characteristics: Number of Wells/ Conductors | Future Modifications Planned or Proposed |
|---|---|---|---|---|---|---|---|
| **Gulf of Mexico:** | | | | | | | |
| A | East Cameron | 103 | 1969 | PDQ | Manned, evacuated | 9(orig.) + 1 | - |
| B | East Cameron | 182 | 1971 | D & Q | Manned, evacuated | 5 | - |
| C | Eugene Island | 255 | 1972 | PDQ | Manned, evacuated | 21 | - |
| D | Grand Isle | 88 | 1957 | PDQ | Manned, evacuated | 14 | - |
| E | Main Pass | 247 | 1969 | PDQ | Manned, evacuated | 14 | - |
| F | Ship Shoal | 162 | 1970 | PDQ | Manned, evacuated | 4 | - |
| G | Ship Shoal | 310 | 1984 | PDQ | Manned, evacuated | 10 | Added 2 conductors and 1 riser |
| H | South Marsh | 95 | 1989 | PDQ | Manned, evacuated | 4 | - |
| I | South Pass | 340 | 1967 | PDQ | Manned, evacuated | 18 | - |
| J | South Pelto | 37 | 1957 | Production | Unmanned | 3 | - |
| K | West Delta | 160 | 1965 | Satellite | Unmanned | 10 (orig.) + 1 | To add up to 8 conductors |
| L | East Cameron | 160 | 1970 | D & P | Manned, evacuated when updated | 8 | New compressors, risers |
| M | West Delta | 184 | 1968 | PDQ | Manned, evacuated | 14 | - |
| N | West Delta | 223 | Mid 1960's | D & P | Manned, evacuated | 12 | - |
| O | Eugene Island | 300 | 1973 | PDQ | Manned, evacuated | 24 | - |
| P | Eugene Island | 263 | 1973 | PDQ | Manned, evacuated | 18 | To add conductors |
| **Offshore Southern California:** | | | | | | | |
| Q | Santa Barbara | 189 | 1968 | PDQ | Manned, non-evacuated | 59 | - |
| S | Santa Barbara | 155 | 1968 | PDQ | Manned, non-evacuated | 39 | May have additional wells |
| **Cook Inlet:** | | | | | | | |
| R | - | 100 | 1968 | PDQ | Manned | 24 | - |
| **North Sea, U.K.:** | | | | | | | |
| T | Southern N. Sea | 118 | 1968 | Production | Manned | 4 gas risers | Additional riser guards |
| **Bay of Campache, Mexico** | | | | | | | |
| U | Nohoch B | 125 | 1979 | PDQ | Manned/Evacuated | 12 | - |
| **Offshore Cameroon, West Africa** | | | | | | | |
| V | Mokoko Abana E | 161 | 1981 | PQ (#1) | Manned Production (#1) | 9 | To add compressors |

#1: Currently only production. Assumed manned for this JIP.

## Table 3-7f: Summary of Ultimate Strength Analysis Results - Other Platforms

| Platform | Water Depth (ft.) | Base Shear: Section 17 Ult. Load S-17 (kips) | Base Shear: 100-year RP Ref. Level Load S-20 (kips) | Analysis Results: Load at Ist Member with Lin. LR.=1.0 S-1 (kips) | Analysis Results: Load at Ist Member with Nlin. Event R-1 (kips) | Analysis Results: Ultimate Capacity, Ru (kips) | Analysis Results: Platform Failure Mode | (#1) Ultimate Capacity/ Ult. Load = Ru/S-17 | Assessment Pass/ Fail at Ult. Strength Analysis | Information to the API TG (#1): Reserve Strength Ratio, RSR = Ru/S-20 | Information to the API TG (#1): Ultimate to Linear Ratio, ULR = Ru/S-1 | Information to the API TG (#1): Load Reduction Factor, LRF = S-1/S-20 | Information to the API TG (#1): Redundancy Factor, RF = Ru/R-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **North Sea, U.K.: 6-Leg Platform** | | | | | | | | | | | | | |
| T (#2) | 118 | 2,093 | - | 359 | 1,414 | 3,116 | Joints/Piles | 1.49 | PASSES | - | 8.68 | - | 2.20 |
| | | 2,495 | - | 630 | 1,716 | 3,693 | Joints/Piles | 1.48 | | - | 5.86 | - | 2.15 |
| **Bay of Campache, Mexico: 8 Leg Platform:** | | | | | | | | | | | | | |
| U (#3) | 125 | 2,212 | 1,843 | 4,366 | 8,490 | 9,237 | Piles/Bracing | 4.18 | PASSES | 5.01 | 2.12 | 2.37 | 1.09 |
| | | 2,169 | 1,785 | 4,157 | 8,058 | 9,225 | Piles/Bracing | 4.25 | | 5.17 | 2.22 | 2.33 | 1.14 |
| | | 2,037 | 1,669 | 3,985 | 6,911 | 7,007 | Bracing | 3.44 | | 4.20 | 1.76 | 2.39 | 1.01 |
| **Offshore Cameroon, West Africa: 4 Leg Platform:** | | | | | | | | | | | | | |
| V (#3) | 161 | 766 | 493 | 405 | 694 | 1,107 | Vertical Digonals | 1.45 | PASSES | 2.25 | 2.73 | 0.82 | 1.60 |
| | | 762 | 515 | 596 | 794 | 1,116 | Vertical Digonals | 1.46 | | 2.17 | 1.87 | 1.16 | 1.41 |
| | | 907 | 592 | 405 | 707 | 1,120 | Vertical Digonals | 1.23 | | 1.89 | 2.77 | 0.68 | 1.58 |

#1: Shaded values indicate minimum ratios for a platform

#2: ULR's are very high because critical jacket components in elastic code check are beta=1.0 for X joints for which API capacity is conservative. Ultimate strength model includes mean strength flexible joints which give even load distribution through X-braced framing such that the piles then limit the overall capacity.

#3: The reference level loads based on new (reduced) metocean data since design.

Table 3-8: Summary of Trial Assessments

| Platform | Assessment Initiator Triggers | Metocean Criteria Category | Does Platform Pass at Condition Assessment Stage ? | Does Platform Pass at Design Basis Check Stage ? | Pass/Fail at Design Level Analysis Stage | Pass/Fail at Ultimate Strength Analysis Stage |
|---|---|---|---|---|---|---|
| **Gulf of Mexico, USA:** | | | | | | |
| A | Damage | Sudden Hurricane | No | No | Fails (brace, joints) | Fails |
| B | None | Sudden Hurricane | No | No | Fails (joint) | Passes |
| C | None | Sudden Hurricane | No | No | Fails (joints) | Passes |
| D | None | Sudden Hurricane | No | No | Fails (braces) | Fails (Marginally) (#1) |
| E | None | Sudden Hurricane | No | No | Fails (joints) | Passes |
| F | Inadequate deck height | Sudden Hurricane | No | No | Passes | Passes |
| G | None | Sudden Hurricane | No | No | - | Passes |
| H | Increase in load, addition of facilities/personnel | Sudden Hurricane | No | No | Fails (braces) | Fails |
| I | Increase in load and damage | Sudden Hurricane | No | No | Passes | Passes |
| J | Inadequate deck height | Minimum Consequence | No | No | Fails | Passes (#2) |
| K | Increase in load | Minimum Consequence | No | No | Fails (joints) | Passes |
| L | Addition of facilities and personnel | Full Population Hurricane | No | No | Fails (braces) | Fails (Marginally) |
| M | Increase in load | Sudden Hurricane | No | No | Passes | Passes |
| N | Inadequate deck height | Sudden Hurricane | No | No | Fails (piles) | Fails |
| O | Omitted inspection report | Sudden Hurricane | No | No | Passes | Passes |
| P | None | Full Population Hurricane | No | No | Fails (braces) | Fails (Marginally) |
| **Offshore Southern California, USA:** | | | | | | |
| Q | Increase in load | Significant Environmental Impact | No | Not Applicable | Fails marginally (storm) | Passes (storm & seismic) |
| S | None | Significant Environmental Impact (#3) | No | Not Applicable | Fails (braces) | Passes |
| **Cook Inlet, USA:** | | | | | | |
| R | Increase in load, addition of facilities and extension of life | Significant Environmental Impact | No | Not Applicable | Passes | Passes |
| **North Sea, U.K.:** | | | | | | |
| T | Increase in load | Extreme Storms | No | Not applicable | Fails (joints) | Passes |
| **Bay of Campache, Mexico:** | | | | | | |
| U | Damage, addition of facilities | Full Population Hurricane + Winter Storm | No | Not applicable | Passes | Passes |
| **Offshore Cameroon, West Africa:** | | | | | | |
| V | High marine growth, scour, addition of facilities | Insignificant Environmental Impact | No | Not applicable | Passes | Passes |

#1: Participant intentionally used full population hurricane wave for ultimate strength analysis

#2: Based on prior exposure

#3: Assumed for the JIP study. May differ in an actual assessment.

# Section 2
# Information to Participants

## 2.1 TRIAL BASIS DOCUMENT

The participants were provided with the Trial Basis Document dated February 24, 1994. The document included details of project organization, analysis and documentation requirements for participation in the project. Two tasks were identified for the participants as follows:

**Task A**: A complete application of the API assessment process up to and including ultimate strength analysis. The screening analysis is optional.

**Task B**: A critical review of the draft guideline, as applicable to the ultimate strength analysis, with emphasis on completeness, clarity, complexity, and suggestions where possible. Any typos or other errors should be identified. This task was voluntary. Participants may suggest alternative approaches for "assessment of existing platforms."

The Trial Basis Document mentioned the following:

- The API assessment process shall be applied in a stepwise manner in its entirety to meet the requirements of this project. In case a platform passes at an early stage, the participant shall identify that stage in their trial document and continue with further application of the assessment process.

- The participant shall provide sufficient documentation to understand how each part of the process was performed and significant results. All the steps leading to the selected assessment criteria shall be clearly given. For items such as Platform Selection and Condition Assessment, a brief written statement of the approach used and results shall be provided.

- For platforms located in other regions (such as the North Sea), for which criteria are not given in Draft Section 17, participants shall define their own criteria which shall be in accordance with those suggested by the draft guideline.

- Analysis results, where possible, shall be presented on platform sketches. No computer outputs should be submitted. Participants are encouraged to provide results in tabular or graphical form, where possible.

- If the optional screening analysis is used in Task A, then the participant shall provide a summary of the approach plus documentation indicating that the approach is more conservative than the design or ultimate strength checks.

- For design level analysis, the relevant information required by the MMS for new platforms should be used as a guideline for the type of data required [Federal Register Rules and Regulations, OCS Report MMS 91-0082, 30 CFR 250, Latest Edition]. Per the MMS, the data should include a summary of pertinent derived factors of safety against failure for major structural members.

- For ultimate strength analysis, the lateral load corresponding to the 100-year environmental condition, the ultimate lateral capacity, and RSR for the platform shall be clearly identified on suggested format for load-displacement plots.

- The lateral load level at which the first component reaches a unity check of 1.0 or the first pile reaches the axial pile capacity (design level) per RP 2A-WSD, 20th Edition, with all safety factors included, shall be determined.

The participants were provided with formats of figures and tables for presentation of their analysis results. Also, they were provided details of the voluntary information, which would be useful to the project.

## 2.2 OTHER INFORMATION

Other information was provided to the participants, including versions and modifications to the Draft Section 17, handouts and minutes of kick-off, progress, and final meetings.

# Section 3
# Summary of Participant Submittals

This section summarizes the platform assessment information obtained from the Participants' submittals.

Nineteen participants provided their documents by September 15, 1994 and were included in the Draft Report of September 1994 and were discussed at the Final Meeting held on October 18, 1994.

Following the Final Meeting several participants provided missing information in the Draft Report, participants G and O provided results for the ultimate strength analysis, and participants D and N submitted updated documents.

Participants T and U submitted their documents by November 1, 1994 (extended deadline for late submittals and new participants). The information from these documents have been included in this report as summarized by these participants in the format of the tables of this report.

The information for the platform V located offshore West Africa, a voluntary submittal, which demonstrates applicability of the Section 17 process to other regions has also been summarized in this section.

The information is summarized in tabular form in Tables 3-1 to 3-8, in the sequence of application of the Draft Section 17 document, and is discussed in the following subsections.

Where the information was not provided by the participants, it is noted by the symbol "-" in the tables. Also, in some cases the participants' computed values (such as RSR or platform pass/fail assessment) differed from that defined per Section 17. Where it was clear that the values were computed incorrectly, corrected values are provided.

## 3.1 PLATFORM SELECTION (SECTION 17.2)

Section 17.2 and Figure 17.5.2 provide six assessment initiators as follows:

- Addition of Personnel
- Addition of Facilities
- Increased Loading on Structure
- Inadequate Deck Height
- Damage Found During Inspections

- Is there a Regulatory Requirement?

The participants' assessments for the initiators (excluding Regulatory Requirement) are summarized in Table 3-1. The information presented indicated the following:

- For Platform L, the manning status will change from "unmanned" to "manned"
- For Platform L, additional facilities (compressors, risers) are planned.
- For five platforms (H, K, M, R, and T), participants estimate that the load level is likely to increase by more than 10%. The reasons for such increase included heavy marine growth, additional conductors, and revised criteria.
- Three platforms (F, J, N) had inadequate deck height.
- In two cases (A, I) corrosion damage was noted with all others noting minor or no damage. Platform U has several dented, bent members and joints with cracks in the splash zone.

Based upon these initiators, fifteen platforms were triggered for assessment and seven were not.

Platform I had mixed initiators: marine growth and corrosion damage. Several participants cited choosing the platforms due to various other reasons, such as installed at an alternate site (M), on life extension (E, R), to evaluate for feasibility of future additions (P, S).

## 3.2 CATEGORIZATION (SECTION 17.3)

The platforms were categorized according to life safety and environmental impact. Based on this, the applicable metocean criteria were selected, including one of the following:

- Full Population Hurricane
- Sudden Hurricane
- Minimum Consequence

Table 3-2 summarizes the information for all platforms. A majority (15) of platforms have Production, Drilling and Quarters (PDQ) facilities. Only one platform was defined as a "satellite" drilling platform.

Two platforms are "unmanned." The manning level of platforms was not available for all cases. For those situations in which it was available, it varied from 3 people (Platform F) to 32 people (Platform B). All the "manned" platform cases in the Gulf of Mexico were defined as "evacuated" during storm events. The three platforms located offshore Southern California and in Cook Inlet were considered "non-evacuated" during extreme loading states.

Platform T is bridge connected to the quarters platform and is categorized manned. Platform U is categorized as manned, evacuated and platform V as manned, non-evacuated for this study.

The number of wells varied from a minimum of three (Platform J) to a maximum of 59 (Platform Q). Production platform T has no wells/conductors but has risers, which have been considered in environmental impact evaluation. The information on oil storage on the deck was not available for all cases, and where it was available, it was noted as being very low and having minimal environmental impact. Information on a platform's proximity to shore was not available for all cases. Participants identified 14 Gulf of Mexico platforms as having "Insignificant Environmental Impact" and two with "Significant Environmental Impact."

Based upon the Life Safety and Environmental Impact classifications, metocean criteria were selected as follows for the Gulf of Mexico platforms:

- Full Population Hurricane – 2 platforms
- Sudden Hurricane – 12 platforms
- Minimum Consequence – 2 platforms

Five platforms located in other regions were identified to have "Significant Environmental Impact" and one to have "Insignificant Environmental Impact" for selection of applicable metocean, seismic and/or ice criteria.

## 3.3 CONDITION ASSESSMENT (SECTION 17.4)

Condition Assessment of platforms per Figure 17.5.2 includes gathering platform information per Section 17.4 and assessing the state of the platform to "screen" the "minimum consequence" platforms without damage, those with adequate deck height, and those without significant (>10 %) increase in loading under "PASSES ASSESSMENT" category. The platforms which do not pass at this stage require either "Design Basis Check" or "Analysis Checks."

Table 3-3 provides a summary of this assessment. The survey level for platforms varied from an above-water Level I to an underwater Level IV (Platforms A, J, and K). Damage was reported on three platforms (Platforms A, I and U). Two platforms E and R had minor damages whereas damage to platform O was unknown. Inadequate deck height was noted for only two cases (platforms F, J), and increase in loading was cited for seven cases (platforms H, I, K, M, R, T, U) and for platform O was unknown.

Based upon these three "screening" criteria, 11 platforms will not meet the criteria and will require "Analysis Checks." These platforms are identified as A, F, H, I, J, K, M, O, R, T, and U. The remaining eleven platforms will need to be screened further based on consequence level.

These remaining platforms do not pass at this stage either due to being "manned" or having "significant environmental impact."

Therefore in an actual assessment, none of these platforms would clearly pass at the "Condition Assessment" stage due to not meeting "screening criteria" or due to inadequate information. They would need to undergo either a "Design Basis Check (for the Gulf of Mexico platforms only)" or an "Analysis Check."

## 3.4 DESIGN BASIS CHECK

The Design Basis Check is applicable only to the Gulf of Mexico platforms. These platforms were further screened based on the API RP 2A Edition used in their design. Table 3-4 provides the information retrieved from the participants' submittals. The information presented indicates that only platforms G and H were designed or re-designed to an API Edition later than the 9th Edition. Participant H indicated overstressed members with the original design criteria. In some cases, participants did not provide an answer to this screening criteria question, but based on their year of design/installation, the project put YES/NO in the table.

Participant G did not provide specific checks in their document. Participant N noted that they omitted this check due to the platform having inadequate deck height.

## 3.5 ANALYSIS CHECKS (SECTION 17.6 AND 17.7)

### 3.5.1 Metocean, Seismic, and Ice Criteria

Metocean Criteria

The metocean criteria selected by the participants for Section 17 Design Level and Ultimate Strength, and Section 2 of the RP 2A, 20th Edition is summarized in Table 3-5 according to the metocean criteria category. The orientation of Platform North varies from N45E to N55W. For some cases, information for one or more criteria were not provided by the participants or were not easily extracted from the submittals.

A comparison of the selected wave heights indicate that for the "Sudden Hurricane" category, the Section 17 design level wave height varies from 41 ft to 47.5 ft for water depths from 88 ft to 340 ft, respectively. The variation of the wave height for the Section 17 ultimate strength criteria is from 50 ft to 61.5 ft for this category. Some inconsistencies are noted among platform cases A, H and D in the lower water depth range. Participant D clarified using intentionally greater wave height and current based on full population hurricane criteria to test procedure for wave acting on deck.

Section 17 provides the 100-year return period metocean criteria for the platforms offshore Southern California and does not require analysis for metocean loads for Cook Inlet structures as ice forces govern.

Participants T, U, and V developed metocean criteria for the design level and ultimate strength analysis for the applicable environmental impact category, following the procedure used in the development of Section 17 parameters for the Gulf of Mexico which is discussed in OTC 7484, 1994.

Seismic Criteria

All three platforms Q, R, S under the "Significant Environmental Impact" category require ultimate capacity assessment using loads associated with the median 1,000-year return period earthquake appropriate at the site. Participants used site-specific spectrum in their analysis.

Participants used 200-year return period spectra to perform design level analysis. However, note that Section 17 does not strictly require design level seismic assessment.

Ice Criteria

The ice loads, applicable to the Platform R, were estimated by the participant per API RP 2N, 1st Edition (100-year return period) as 166 kips/ft leg diameter. The ice loads used in the original design were 120 kips/ft.

### 3.5.2 Screening

None of the participants performed screening analysis before moving on to the "Design Level" or "Ultimate Strength" analysis.

### 3.5.3 Design Level Analysis

Table 3-6 summarizes the design level analysis results for the critical direction for each of the platforms. The information for the Gulf of Mexico is further classified according to the number of platform legs. The number of conductors/J-tubes information is also given in this table to provide reasons for variation in base shear.

The five 4-leg platforms located in the Gulf of Mexico in water depths ranging from 95 ft to 182 ft, have wave heights varying from 41.5 ft to 55 ft. These platforms have 4 to 10 conductors and their base shears vary from 935 to 1,460 kips. Of these, only platform F "PASSES" at this stage and the other 4 platforms (A, B, H, L) fail design level analysis check due to I.R.'s exceeding 1.0 for jacket braces or joints. In the case of platform H, the factor of safety against axial capacity (1.37) was also found to be inadequate.

The nine 8-leg platforms located in the Gulf of Mexico in water depths ranging from 160 to 340 ft have base shears varying from 1,614 to 3,622 kips. Participant G did not provide information in the required format. Of these, only three platforms (I, M, O) pass at this stage. Platform D, a 16-leg platform, and platform J, a 36-leg platform do not pass at this stage.

Per Section 17, design level analysis is not applicable for seismic assessment of platforms. However, both participants with platforms in this region performed this analysis for design level metocean and seismic loading criteria. Platform Q marginally fails its metocean design level assessment, as two piles had factors of safety less than 1.5 (1.44 and 1.46). Under design level seismic loading, 9 of 12 piles had factors of safety less than 1.50. Platform S fails this assessment due to overstressing of four members.

The Cook Inlet structure was analyzed for ice loading. Per participant R, the platform passes its assessment (I.R. = 0.93). The participant also provided results for 200-year return period seismic criteria and found maximum I.R. of 0.98. The participant noted that, per Figure 17.5.2b (Section 17), 85% of the 100-year loading is to be applied for the design level analysis.

The North Sea structures (T) fails, whereas the Bay of Campache (U) and Offshore Cameroon (V) structures pass assessment at the design level analysis stage.

Participants used ASAD, CAP, DAMS, KARMA, MicroSAS, SACS, SESAS, and StruCAD, STRUDL software packages in their analyses.

### 3.5.4 Ultimate Strength Analysis Results (Required)

Tables 3-7a to 3-7f present ultimate capacity analysis results. Participants used various software programs and analysis procedures for this analysis. Participants used ASADS, CAP, KARMA, MicroSAS, SAFJAC, and USFOS software packages for nonlinear analysis. The first three tables provide results for the Gulf of Mexico platforms, and the other three tables address platforms Q to V in other regions.

These tables include base shear values, ultimate capacity analysis results, and various ratios computed for use by the API TG 92-5. The results provided for various storm approach directions (maximum of three) are included, and the discussion of results in this section is limited to the most critical direction for a given platform.

Gulf of Mexico: 4-Legged Platforms

Table 3-7a presents results for 4-legged platform cases in the Gulf of Mexico.

The base shear corresponding to the Section 17 criteria varies from 970 kips (Platform F) to 2,600 kips (Platform L). When the base shear is compared to the 20th Edition criteria, the variation ranges from 955 kips (Platform F) to 2,600 kips (Platform A).

The ultimate capacity of the platforms varied from 990 kips (Platform H) to 3,500 kips (Platform B). The platform failure modes were composed of nonlinear events in jacket framing, pile sections, or inadequate axial capacity of soil. The capacity beyond first member failure (RF) varied from 1.0 to 1.5 for these platforms.

The ratio of ultimate capacity of a platform to the base shear per applicable Section 17 criteria varied from 0.59 (Platform A) to 2.10 (Platform F). Based upon this ratio, platforms A, H, and L fail the ultimate strength analyses, whereas platforms B and F pass.

The ratio of RSR varies from 0.55 (Platform A) to 1.75 (Platform F). Without platform F, the RSR range would become 0.55 to 1.18.

ULR ratio for these platforms varies from 1.03 to 2.07 and the LRF ratio varies from 0.44 to 1.63.

Gulf of Mexico: 8-Legged Platforms

Table 3-7b presents results for 8-legged platform cases in the Gulf of Mexico. The base shear corresponding to the Section 17 criteria varies from 1,840 kips (Platform E) to 6,291 kips (Platform P). Comparing the base shear per 20th Edition criteria, the variation is from 2,176 kips (Platform M) to 5,932 kips (Platform K).

The ultimate capacity of the platforms varies from 3,471 kips (Platform N in 223 ft) to 15,029 kips (Platform O in 300 ft). The platform failure modes were composed of nonlinear events in jacket framing, pile sections, or inadequate axial capacity of soil. The capacity beyond first member failure (RF) varied from 1.0 (Platforms E and P) to 1.55 (Platforms K and G).

The ratio of ultimate capacity of a platform to the base shear per applicable Section 17 criteria varied from 0.85 (Platform N) to 2.16 (Platform M). Based upon this ratio, platform N "Fails" and platform P "Marginally Fails" their ultimate strength analysis, whereas other platforms "Pass." The required Section 17 base shear values were not available for platforms G and O. Hence, it is not clear whether they meet the Section 17 ultimate strength criteria or not. However, based on their RSR values, they will surely "Pass" the Section 17 requirement.

The ratio of RSR varies from 0.60 (Platform N) to 1.56 (Platform M) for most platforms. For platforms G and O higher RSR values, 2.30 to 3.2, have been reported. The ULR ratio varies from 1.2 (Platform N) to 2.84 (Platform M). The LRF ratio varies from 0.43 (Platform K) to 1.22 (Platform O).

Gulf of Mexico: Platforms with More than 8-Legs

Table 3-7c presents results for platforms D and J with more than 8-legs located in the Gulf of Mexico.

Participant D presented results based on the full population metocean criteria for this analysis, whereas the platform was categorized under the "Sudden Hurricane" category. The minimum ultimate capacity of the platform is 2,300 kips and the RSR is estimated as 1.18. The platform fails due to nonlinear events in its jacket framing and pile sections. The ratio of ultimate capacity load to the base shear is 0.94. This would place the platform in the "Fails" category.

The minimum RSR for platform J is 1.46. This platform is classified under the "Minimum Consequence" metocean criteria category, resulting in an ultimate load base shear significantly lower than that per 20th Edition. This platform "Passes" Section 17 ultimate strength requirements.

Participant for platform D provided the following discussion for using different criteria:

"This platform passes the ultimate strength check when it passes the platform assessment initiator check (i.e., when the deck height is adequate).

Participant used the full-population hurricane (significant environmental impact) to test the procedure for wave loading on the deck. Under this scenario, this structure would **NOT PASS** the platform assessment initiator check due to inadequate wave height. This is consistent with the tabulated 0.94 ratio for ultimate strength assessment.

For an actual assessment, the sudden hurricane (insignificant environmental impact) would apply, and the platform would **PASS** the platform assessment initiator check (i.e., deck height is adequate). For the ultimate strength analysis, the Section 17 Ultimate Load becomes 1620 and 1955 kips (was 2340 and 2451) for the two analyzed directions. This results in ultimate capacity/ultimate load ratios of 1.88 and 1.18 (was 1.30 and 0.94) based on the previous capacities; the ratios would increase since the deck is not loaded under this scenario."

Offshore Southern California Platforms

Both of these platforms are classified as "Manned Non-evacuated" and have "Significant Environmental Impact." Per Section 17, the ultimate strength criteria would be set at a median 1000-year return period seismic event.

Participant Q performed a pushover analysis for ultimate wave loading and seismic time history analyses for seismic loading. The pushover analysis results indicate an ultimate capacity of 5,600 kips, with a failure mode due to inadequate soil (axial) capacity. The RSR is computed as 2.43, which is higher than the 1.6 minimum required per Section 17. The seismic criteria (spectra from 1971 San Fernando Earthquake) produced lateral load level of 5,600 kips, which leads to buckling or yielding of several vertical diagonals and horizontal braces. None of the legs and pile sections exhibited hinging for the 1000-year seismic spectra. Eleven out of the 12 piles experienced loading beyond static axial capacity, causing soil degradation in the range of 15 to 35 percent. The participant classified the platform as surviving the 1000-year seismic event due to no collapse mechanism being formed.

Participant S performed a pushover analysis for a load level of 3,355 kips (diagonal direction) corresponding to the Ductility Level Earthquake (DLE) criteria. The ultimate capacity estimate is 9,394 kips with failure of several jacket components. The participant provided an RSR value of 2.8 with a load level corresponding to the Serviceability Level Earthquake (SLE) criteria as the denominator. The Section 17 minimum acceptable RSR criteria of 1.6 is applicable to the metocean and ice criteria and not to the seismic event. Per Section 17, a platform would "pass" when the best estimate of resistance can be shown to withstand loads associated with a median 1000-year return period earthquake event without system collapse.

Participant S mentioned selection of significant environmental impact criteria for this platform for the purposes of the JIP study only and is not necessarily the appropriate selection criteria for this platform in an actual reassessment.

Cook Inlet Platform

This platform is governed by ice forces instead of metocean loads. For the Cook Inlet platforms, Section 17 does not provide specific ice criteria and the platforms' meeting or not meeting requirements is based on the RSR value computed for the reference level load per API RP 2N (1988). The results provided for three directions indicate platform ultimate capacity based upon failure of the jacket bracing or leg column.

The minimum RSR was computed as 2.26 in the Diagonal direction, which exceeds Section 17 requirement of 1.6 for a manned, non-evacuated platform. Therefore, this platform "Passes" Section 17 requirements.

The participant referred to results from an analysis using a 1000-year return period DLE spectrum, which indicated a maximum ductility factor of 2 in the cross bracing. Participant noted this and foundation performance as acceptable.

North Sea, U.K.

The ultimate capacity of 3,116 kips was estimated for this 6-leg platform, with failures in X-joints and piles. The base shear for the ultimate load criteria was estimated as 2,093 kips, resulting in RSR of 1.5. The platform meets Section 17 based criteria for the ultimate capacity.

Bay of Campache, Mexico

For this 8-leg platform with damages noted, the ultimate capacity was determined as 7,000 kips with corresponding ultimate load shear of 2,037 kips, thus passing the Section 17 based criteria. For this direction, the nonlinear events in the bracing dominated the platform capacity estimate. This platform has very low redundancy (RF = 1.0) but very high RSR (= 4.2).

Offshore Cameroon, West Africa

This 4-legged platform with vertical legs have the ultimate load shear of 907 kips and ultimate capacity of 1,120 kips based on nonlinear events in the vertical diagonals, thus passing at this stage. This platform has moderate redundancy (RF= 1.41) and RSR of 1.89.

### 3.5.5 Fatigue

No fatigue assessments were performed in this project.

## 3.6 MITIGATION ALTERNATIVES

Several participants identified the following mitigation alternatives for their platforms to meet Section 17 requirements:

Topside Facilities

- Remove large, unnecessary pieces of equipment (Q)
- Perform future drilling operation using a jack-up rig (K)

Cathodic Protection

- Replace depleted anodes (A, O)

Improved Condition Assessment

- Perform Level III/IV underwater inspection of selected joints K)
- Better define the platform damage level (L, O)
- Investigate platform hydrocarbon safety features to better define metocean criteria classification of platform (L)
- Identify the critical braces and joints for closer review during next inspection (S)

Hydrodynamic/Seismic Load Reduction

- Remove non-producing wells or cut below the wave zone (A, O)
- Remove three plugged and abandoned well conductors (K)
- Remove appurtenances such as boat landing etc. (P)
- Remove unnecessary conductors, risers, caissons, and other appurtenances (Q)
- Continue with the marine growth management program (Q)

Structural Strengthening

- Strengthen K-joints either by adding pup pieces or grouting the joint (A)
- Add jacket bracing members (H)
- Grout the piles (H)
- Install a bracing structure (H)

Before any mitigation measure is considered, some participants suggested further assessment of platform by improved analysis.

Further Analysis

- Further investigation of joint strength and analysis (C, E)
- Improved characterization of element strength (P)

## 3.7 SUMMARY

Table 3-8 summarizes the pass/fail information for all platforms and specifies various reasons requiring assessment at any particular level. This table summarizes results obtained from each assessment level given in Tables 3-1 to 3-7.

In an actual assessment following Figure 17.5.2 (Section 17), a platform could pass at 7 stages, which are identified as follows:

- Platform Selection Stage
- Condition Assessment Stage
- Design Basis Check Stage
- Design Level Analysis Stage
- Implement Mitigation Alternatives and Pass Design Level Analysis
- Ultimate Strength Analysis Stage
- Implement Mitigation Alternatives and Pass Ultimate Strength Analysis

The first three are termed herein as "Screening Checks" and the other four fall under "Analysis Checks."

Table 3-8 indicates that seven platforms (B, C, D, E, G, P, S) would not require complete Section 17 assessment as they pass at the "Assessment Initiator Triggers" stage. However, all of these platforms would require further assessment, when their "Condition Assessment" test is done, primarily due to their being "Manned." Most of these also fail at the "Design Basis Check" and at the "Design Level Analysis" stages. At the "Ultimate Strength Analysis" stage, platforms B, C, E, G and S "Pass", whereas platforms D and P "Marginally fail."

None of the platforms clearly pass at the "Condition Assessment" and "Design Basis Check" stages.

All platforms which passed the "Design Level Analysis" stage, pass at the "Ultimate Strength Analysis" stage.

The above discussion identifies consistency in the assessment per Section 17. All seven platforms with no assessment initiator triggers "Pass" or are "Marginal" cases (D, P) at the ultimate strength analysis stage.

**Table 3-1: Summary of Assessment Initiator Triggers**

| Platform | Addition of Personnel | Addition of Facilities | Increased Loading on Structures > 10 % | Inadequate Deck Height | Damage found during Inspections | Assessment Initiator Triggers |
|---|---|---|---|---|---|---|
| **Gulf of Mexico:** | | | | | | |
| A | No | None | No | No | Corrosion | Damage |
| B | No | None | No | No | None | None |
| C | No | None | No (< 10 %) | No | None | None |
| D | No | None | No | No | None | None |
| E | No | None | No | No | Not significant | None |
| F | No | None | No | Yes | No known | Inadequate deck height |
| G | No | None | No (< 10 %) | No | None | None |
| H | Yes | Yes | Yes | No | Not significant | Increase in load & addition of facilities/personnel |
| I | No | None | - | No | Corrosion | Increase in load and damage |
| J | No | None | No | Yes | None | Inadequate deck height |
| K | No | To add 8 conductors | Yes (#1) | No | None | Increase in load |
| L | Yes | Compressors, risers | No (< 10 %) | No | None | Addition of facilities and personnel |
| M | No | Not significant | Yes | No | None | Increase in load |
| N | No | None | No | Yes | None | Inadequate deck height |
| O | No | None | No | No | No information | Omitted inspection report |
| P | No | None | No | No | None | None |
| **Offshore Southern California:** | | | | | | |
| Q | No | No | New seismic information | No | None | Increase in load |
| S | No | Future Possibilities | No | No | None | None |
| **Cook Inlet:** | | | | | | |
| R | No | Yes | Yes | - | Minor dent | Increase in load, addition of facilities and extension of life |
| **North Sea, U.K.:** | | | | | | |
| T | No | No | Yes | No | No | Increase in load |
| **Bay of Campache, Mexico:** | | | | | | |
| U | No | Yes | No | No | Yes | Damage and addition of facilities |
| **Offshore Cameroon, West Africa:** | | | | | | |
| V | No | Yes | No | No | No | High marine growth, scour, addition of facilities |

#1: Assessment initiated based on increased loading; However analysis later showed loading increase < 10 %

**Table 3-2: Summary of Platform Categorization**

| Platform | Type of Facility | Manning Evaluation | | Environmental Impact Evaluation | | | | Metocean Criteria Category |
|---|---|---|---|---|---|---|---|---|
| | | Number of Men | Manned/ Unmanned Operation & Evacuation During Storm | Number of Wells/ Conductors | Oil Storage on Deck (bbl) | Proximity to Shore (Miles) | Environmental Impact Category | |
| **Gulf of Mexico:** | | | | | | | | |
| A | PDQ | - | Manned, evacuated | 10 | - | - | Insignificant | Sudden Hurricane |
| B | D & Q | 32 | Manned, evacuated | 5 | 142 (drilling) | 79 | Insignificant | Sudden Hurricane |
| C | PDQ | - | Manned, evacuated | 21 | - | - | Insignificant | Sudden Hurricane |
| D | PDQ | None | Manned, evacuated | 14 | None | 20 | Insignificant | Sudden Hurricane |
| E | PDQ | 4 | Manned, evacuated | 14 | None | 30 | Insignificant | Sudden Hurricane |
| F | PDQ | 3 | Manned, evacuated | 4 | pumped down | far away | Insignificant | Sudden Hurricane |
| G | PDQ | - | Manned, evacuated | 10 | not significant | not near | Insignificant | Sudden Hurricane |
| H | PDQ | 4 | Manned, evacuated | 4 | None | 58 | Insignificant | Sudden Hurricane |
| I | PDQ | - | Manned, evacuated | 18 | - | - | Insignificant | Sudden Hurricane |
| J | Production | - | Unmanned | 3 | - | - | Insignificant | Minimum Consequence |
| K | Satellite | - | Unmanned | 11 | 90 | 20-25 | Insignificant | Minimum Consequence |
| L | D & P | Unknown | Manned, evacuated | 8 | - | - | Significant | Full Population Hurricane |
| M | PDQ | 10 | Manned, evacuated | 14 | None | - | Insignificant | Sudden Hurricane |
| N | D & P | - | Manned, evacuated | 12 | - | - | Insignificant | Sudden Hurricane |
| O | PDQ | - | Manned, evacuated | 24 | - | - | Insignificant | Sudden Hurricane |
| P | PDQ | 5 | Manned, evacuated | 18 | 100 | - | Significant | Full Population Hurricane |
| **Offshore Southern California:** | | | | | | | | |
| Q | PDQ | - | Manned, non-evacuated | 59 | - | 5 | Significant | Significant Environmental Impact |
| S | PDQ | 1 to 10 | Manned, non-evacuated | 39 | None | 3.5 | Significant | Significant Environmental Impact (#1) |
| **Cook Inlet:** | | | | | | | | |
| R | PDQ | 5 | Manned, non-evacuated | 24 | Future | - | Significant | Significant Environmental Impact |
| **North Sea, U.K.:** | | | | | | | | |
| T | Production | (#2) | Manned | 4 risers with ESV's | None | 38 | Significant | Extreme Storm |
| **Bay of Campache, Mexico:** | | | | | | | | |
| U | PDQ | 15+ | Manned, evacuated | 12 | Not Significant | 50 | Significant | Full Population Hurricane + Winter Storm |
| **Offshore Cameroon, West Africa:** | | | | | | | | |
| V | P & Q (#1) | 6 to 10 | Manned, non-evacuated | 9 | - | - | Insignificant | Insignificant Environmental Impact (#1) |

#1: Assumed for the JIP study. May differ in an actual reassessment process.

#2: Bridge linked to quarters platform, but also forms part of bridge link from drilling platform to quarters.

**Table 3.3: Summary of Condition Assessment**

| Platform | Survey Level | Last Survey (year) | Is the Platform Damaged? | Is the Deck Height Inadequate ? | Has the Loading Increased ? | Is Platform Manned ? | Does it have Significant Environmental Impact ? | Does Platform Passes Assessment at this Stage ? |
|---|---|---|---|---|---|---|---|---|
| **Gulf of Mexico:** | | | | | | | | |
| A | IV | 1993 | Yes | No | No | Yes | No | No |
| B | II | 1993 | No | No | No | Yes | No | No |
| C | - | - | No | - | No | Yes | No | No |
| D | - | - | No | No | No | Yes | No | No |
| E | II | 1994 | not significant | No | No | Yes | No | No |
| F | II | 1989 | No | Yes | No | Yes | No | No |
| G | II | 1993 | No | No | No | Yes | No | No |
| H | I & II | 1994 | No | No | Yes | Yes | No | No |
| I | III | 1990 | Yes | No | Yes | Yes | No | No |
| J | IV | 1989 | No | Yes | No | No | No | No |
| K | I - IV | 1991 | No | No | Yes | No | No | No |
| L | I & II | - | No | No | No | Yes | Yes | No |
| M | I & II | 1992 | No | No | Yes | Yes | No | No |
| N | No information | - | No | No | No | Yes | No | No |
| O | No information | - | Unknown | No | Unknown | Yes | No | No |
| P | II | in past 5 years | No | No | No | Yes | Yes | No |
| **Offshore Southern California:** | | | | | | | | |
| Q | II | not available | No | No | No | Yes | Yes | No |
| S | II | 1992 | No | No | No | Yes | Yes | No |
| **Cook Inlet:** | | | | | | | | |
| R | II & III | 1993 | Minor | No | Yes | Yes | Yes | No |
| **North Sea, U.K.:** | | | | | | | | |
| T | HSE requirement | 1994 | No | No | Yes | Yes | Yes | No |
| **Bay of Campache, Mexico:** | | | | | | | | |
| U | III | 1993 | Yes | No | Yes | Yes | Yes | No |
| **Offshore Cameroon, West Africa:** | | | | | | | | |
| V | - | 1992 | No | No | No | Yes (#1) | No | No |

#1: Assumed for this JIP

Table 3-4: Summary of Design Basis Checks - Gulf of Mexico Platforms

| Platform | Water Depth (ft.) | Year Designed (Original) | API RP 2A Edition Used | Is Platform designed to 9th Edition or later ? | Original Design Details Available ? | Does it Pass at this Stage |
|---|---|---|---|---|---|---|
| **Gulf of Mexico:** | | | | | | |
| A | 103 | 1964(orig.) | None | No | - | No |
| B | 182 | 1971 | Not known | No | - | No |
| C | 255 | 1971 | Prior to 9th Ed. | No | Yes | No |
| D | 88 | 1957 | None | No | - | No |
| E | 247 | 1968 | None | No | Yes | No |
| F | 162 | 1969-70 | - | No | Yes | No |
| G (#1) | 310 | 1982 | - | - | - | No (Sec. 17 check not performed) |
| H (#2) | 95 | 1977(orig.)/1989(rev.) | 7th(orig.)/16th(rev.) | Yes | Yes | No (#2) |
| I | 340 | 1966 | None | No | - | No |
| J | 37 | 1950's | None | No | - | No |
| K | 160 | 1964 | None | No | No | No |
| L | 160 | 1970 | - | No | No | No |
| M | 184 | 1964 (orig) | None | No | No | No |
| N (#3) | 223 | 1964 | None | No | - | No |
| O | 300 | 1973 | Unknown | No | - | No |
| P | 263 | 1972 | 4th | No | Yes | No |
| **Bay of Campache, Mexico:** | | | | | | |
| U | 125 | 1977 | 9th | Yes | No | No |

#1: "G" didn't provide specific checks in their document
#2: "H" indicated overstressed members with the original design criteria
#3: "N" bypassed this check due to inadequate deck height

## Table 3-5: Summary of Metocean Criteria

| Metocean Criteria Category | Platform | Water Depth (ft.) | Platform Orientation w.r.t. True North | Section 17- Design Level | | Section 17- Ultimate Strength | | | RP2A, 20th Edition or 100yr RP | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Wave Height (ft.) | Current Speed (knots) | Wave Height (ft.) | Current Speed (knots) | Required Deck Height (ft.) | Wave Height (ft.) | Current Speed (knots) |
| **Gulf of Mexico:** | | | | | | | | | | |
| Full Population Hurricane | L | 160 | N30W | 55 | 1.6 | 67.5 | 2.3 | 46 | - | - |
| | P | 263 | N20W | 57 | 1.6 | 72 | 2.3 | 44.3 | 67.5 | 2.1 |
| Sudden Hurricane | D | 88 | N45E | 41 | 1.2 | 58 (#1) | 2.3 | 38.5 | 53.5 | 2.1 |
| | H | 95 | N41W | 41.5 | 1.2 | 51.1 | 1.8 | 38.3 | 56 | 2.1 |
| | A | 103 | N30W | 42 | 1.2 | 49.88 | 1.8 | 38 | 58 | 2.1 |
| | F | 162 | N45E | 45 | 1.2 | 56.5 | 1.8 | - | 59.85 | 2.1 |
| | B | 182 | N10E | 46 | 1.2 | 57.5 | 1.8 | 36.2 | 64.2 | 2.1 |
| | M | 184 | N55W | 46 | 1.2 | 57.5 | 1.8 | 36.5 | 65 | 1.8 |
| | N | 223 | N | 46.3 | 1.2 | 59.9 | 1.8 | 36.3 | 66.3 | 2.1 |
| | E | 247 | N36W | 46.9 | 1.2 | 59.4 | 1.8 | 36.3 | 67 | 2.1 |
| | C | 255 | N10W | 47 | 1.2 | 59 | 1.8 | 36.25 | 67 | 2.1 |
| | O | 300 | N30W | 47 | 1.2 | 61 | 1.8 | 36.5 | 68 | 2.1 |
| | G | 310 | N19E | - | - | - | - | 36.5 | - | - |
| | I | 340 | N30W | 47.5 | 1.2 | 61.5 | 1.45 | 36.6 | 68.3 | 2.1 |
| Minimum Consequence | J | 37 | N32W | 21.5 | 0.9 | 26 | 1 | 24.1 | 33.3 | 1.72 |
| | K | 160 | N2.8E | 37.5 | 0.9 | 46.5 | 1 | 36.4 | 63.1 | 2.09 |
| **Offshore Southern California:** | | | | | | | | | | |
| Significant Environmental Impact | Q (#2) | 189 | - | 34 | 1 | 34 | 1 | 28 | - | - |
| | S (#2) | 155 | - | - | - | 34 | 1 | - | 45 | 1 |
| **Cook Inlet:** | | | | | | | | | | |
| Significant Environmental Impact | R (#3) | 100 | N50W | - | - | - | - | - | - | - |
| **North Sea:** | | | | | | | | | | |
| Extreme Storm | T | 118 | N45E | 46.3 (#4) | 3.3 (#4) | Factored wave profile (ULR => 1.8) | | | 49.5 (#5) | 3.3 (#5) |
| **Bay of Campache, Mexico:** | | | | | | | | | | |
| Combined Hurricane and Winter Storm | U | 125 | N45W | 35.6 | 0.62 | 46.6 | 0.86 | 29.9 | 43.3 (#6) | 0.79 (#6) |
| **Offshore Cameroon, West Africa:** | | | | | | | | | | |
| Insignificant Environmental Impact | V | 161 | - | - | - | 24 | 3.02 | - | 18.4 | - |

#1: "D" intentionally used greater H under SEI to test procedure for wave load acting on deck
#2: Seismic loading also considered
#3: 100-year return period Ice load criteria governs

#4: Elastic/ code check assessment - directional
#5: New design - omnidirectional
#6: API RP 2A (20th Ed.) applied to Bay of Campache

## Table 3-6: Summary of Design Level Analysis Results

| Number of Legs | Platform | Water Depth (ft.) | Number of Conductors/ J-Tubes | Wave Height (ft.) | Maximum Base Shear (kips) | Analysis Results: Maximum I.R. (Primary Members) | Analysis Results: Member Types with Maximum I. R. | Analysis Results: Pile Axial Capacity (F.O.S.) | Assessment Pass/ Fail at Design Level Analysis |
|---|---|---|---|---|---|---|---|---|---|
| **Gulf of Mexico:** | | | | | | | | | |
| 4 | H | 95 | 4 | 41.5 | 935 | 1.32 | Horz. brace | 1.37 | FAILS |
| | A | 103 | 10 | 42 | 1,351 | 1.43 (brace) | Brace & K-joints | 2.78 | FAILS |
| | L | 160 | 8 | 55 | 1,460 | 1.29 | Diagonals | - | FAILS |
| | F | 162 | 4 | 45 | 1,013 | 0.85 | Pile | 1.7 | PASSES |
| | B | 182 | 5 | 46 | 1,113 | 1.15 | Joints | 6.9 | FAILS |
| 8 | K | 160 | 11 | 37.5 | 2,060 | 4.6 | Joint | 1.5 | FAILS |
| | M | 184 | 14 | 46 | 1,614 | 1.22 | Secondary horz. braces | 1.35 | PASSES |
| | N | 223 | 12 | 46.3 | 2,269 | 1.71 | Diagonals/ Pile | 1.6 | FAILS |
| | E | 247 | 14 | 46.9 | 1,863 | 0.99 (#2) | K-braces | 1.99 | FAILS |
| | C | 255 | 21 | 47 | 2,090 | 0.91 (#2) | Hortz. braces | - | FAILS |
| | P | 263 | 18 | 57 | 3,622 | 1.19 | K-braces | 2.29 | FAILS |
| | O | 300 | 24 | 47 | 2,422 | 0.95 | Joint(C.G.frame) | 2.61 | PASSES |
| | G (#1) | 310 | 10 | - | - | - | - | - | - |
| | I | 340 | 18 | 47.5 | 2,879 | 0.89 | - | 2.8 | PASSES |
| 16 | D | 88 | 14 | 41 | 1,261 | 3.4 | Diag. braces | 2.22 | FAILS |
| 36 | J | 37 | 3 | 21.5 | 689 | >> 1.0 | Various types | 2.11 | FAILS |
| **Offshore Southern California:** | | | | | | | | | |
| 12 | Q | 189 | 59 | 34 | 1,960 | 0.75 | Diag. braces | 1.44 | MARGINALLY FAILS (#3) |
| | S (#4) | 155 | 39 | 34 | - | - | - | - | - |
| **Cook Inlet:** | | | | | | | | | |
| 4 | R | 100 | 24 | 100-yr Ice loads | 9,716 | 0.93 | Diagonal braces | 2.23 (Comp.) | PASSES |
| | | | | 200-yr seismic | not calculated | 0.98 | Deck girder tank/ diag. bracing | 2.2 | |
| **North Sea, U.K.:** | | | | | | | | | |
| 6 | T | 118 | 4 risers | 46.3 | 1163 | 3.24 | 12 No. X-joints | 1.55 | FAILS |
| **Bay of Campache, Mexico:** | | | | | | | | | |
| 8 | U | 125 | 12 | 35.6 | 1198 | < 1.0 | None | 2.6 | PASSES |
| **Offshore Cameroon, West Africa:** | | | | | | | | | |
| 4 | V | 161 | 9 + 13 risers | 18.4 | 705 | < 1.0 | None | > 1.5 | PASSES |

#1: "G" provided model and computer outputs, without results summary
#2: Several joints have I.R. greater than 1.0
#3: 2 piles with F.O.S. < 1.5 (1.44 & 1.46), under 85% 100-year storm load
#4: Seismic load governs

Table 3-7a: Summary of Ultimate Strength Analysis Results - Gulf of Mexico 4-Leg Platforms

| Platform | Water Depth (ft.) | Base Shear: Section 17 Ult. Load S-17 (kips) | Base Shear: 20th Ed., Ref. Level S-20 (kips) | Analysis Results: Load at Ist Member with Lin. I.R.=1.0 S-1 (kips) | Analysis Results: Load at Ist Member with Nlin. Event R-1 (kips) | Analysis Results: Ultimate Capacity, Ru (kips) | Analysis Results: Platform Failure Mode | (#1) Ultimate Capacity/ Ult. Load = Ru/S-17 | Assessment Pass/ Fail at Ult. Strength Analysis | Information to the API TG (#1): Reserve Strength Ratio, RSR = Ru/S-20 | Information to the API TG (#1): Ultimate to Linear Ratio, ULR = Ru/S-1 | Information to the API TG (#1): Load Reduction Factor, LRF = S-1/S-20 | Information to the API TG (#1): Redundancy Factor, RF = Ru/R-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gulf of Mexico: 4-Leg Platforms** | | | | | | | | | | | | | |
| H (#2, #3) | 95 | 881 | 1,521 | 793 | 881 | 991 | Jacket | 1.12 | FAILS | 0.65 | 1.25 | 0.52 | 1.12 |
| | | 1,351 | 1,802 | 1,182 | 1,182 | 1,216 | Pile | 0.90 | | 0.67 | 1.03 | 0.66 | 1.03 |
| | | 1,557 | 1,916 | 1,168 | 1,246 | 1,324 | Pile | 0.85 | | 0.69 | 1.13 | 0.61 | 1.06 |
| A | 103 | 2,197 | 2,390 | 1,048 | - | 1,307 | K-joints | 0.59 | FAILS | 0.55 | 1.25 | 0.44 | - |
| L (#2) | 160 | 2,358 | 1,966 | 1,226 | 1,533 | 2,321 | Jacket Collapse | 0.98 | FAILS | 1.18 | 1.89 | 0.62 | 1.51 |
| | | 2,596 | 2,160 | 1,298 | 1,609 | 2,556 | Jacket Collapse | 0.98 | | 1.18 | 1.97 | 0.60 | 1.59 |
| F | 162 | 970 | 955 | 1,840 | 1,840 | 2,035 | Soil Failure | 2.10 | PASSES | 2.13 | 1.11 | 1.93 | 1.11 |
| | | 1,075 | 1,325 | 2,160 | 2,160 | 2,320 | Soil Failure | 2.16 | | 1.75 | 1.07 | 1.63 | 1.07 |
| B | 182 | 1,800 | 1,600 | 1,180 | 2,660 | 2,660 | Diagonal braces | 1.48 | PASSES | 1.66 | 2.25 | 0.74 | 1.00 |
| | | 2,100 | 2,300 | 1,270 | 2,750 | 3,500 | Pile Yielding | 1.67 | | 1.52 | 2.76 | 0.55 | 1.27 |
| | | 1,700 | 2,600 | 1,280 | 2,650 | 2,650 | Diagonal braces | 1.56 | | 1.02 | 2.07 | 0.49 | 1.00 |

#1: Shaded values indicate minimum ratios for a platform
#2: Used simplified approach to ultimate strength analysis
#3: Participants' computed RSR values differed

## Table 3-7b: Summary of Ultimate Strength Analysis Results - Gulf of Mexico 8-Leg Platforms

| Platform | Water Depth (ft.) | Base Shear: Section 17 Ult. Load S-17 (kips) | Base Shear: 20th Ed., Ref. Level S-20 (kips) | Analysis Results: Load at Ist Member with Lin. LR.=1.0 S-1 (kips) | Analysis Results: Load at Ist Member with NLin. Event R-1 (kips) | Analysis Results: Ultimate Capacity, Ru (kips) | Platform Failure Mode | (#1) Ultimate Capacity/ Ult. Load = Ru/S-17 | Assessment Pass/ Fail at Ult. Strength Analysis | Information to the API TG (#1): Reserve Strength Ratio, RSR = Ru/S-20 | Ultimate to Linear Ratio, ULR = Ru/S-1 | Load Reduction Factor, LRF = S-1/S-20 | Redundancy Factor, RF = Ru/R-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gulf of Mexico: 8-Leg Platforms** | | | | | | | | | | | | | |
| K | 160 | 3,150 (#2) | 5,932 | 2,546 | 3,393 | 5,552 | Foundation | 1.76 | PASSES | 0.94 | 2.18 | 0.43 | 1.64 |
| | | 3,150 (#2) | 5,724 | 2,655 | 3,529 | 5,477 | Foundation | 1.74 | | 0.96 | 2.06 | 0.46 | 1.55 |
| | | 3,150 (#2) | 4,721 | 2,635 | 3,210 | 5,381 | Foundation | 1.71 | | 1.14 | 2.04 | 0.56 | 1.68 |
| M | 184 | 1,950 | 2,712 | 1,350 | 3,160 | 4,220 | Foundation (pile) | 2.16 | PASSES | 1.56 | 3.13 | 0.50 | 1.34 |
| | | 2,025 | 2,528 | 1,615 | 3,430 | 4,588 | Foundation(soil/pile) | 2.27 | | 1.81 | 2.84 | 0.64 | 1.34 |
| | | 1,925 | 2,176 | 1,453 | 3,468 | 4,767 | Foundation | 2.48 | | 2.19 | 3.28 | 0.67 | 1.37 |
| N(#3) | 223 | 4,082 | 5,870 | 2,935 | - | 3,522 | Pile, Jacket | 0.86 | FAILS | 0.60 | 1.20 | 0.50 | - |
| | | 4,106 | 5,819 | 2,910 | - | 3,492 | Jacket | 0.85 | | 0.60 | 1.20 | 0.50 | - |
| | | 4,072 | 5,785 | 2,893 | - | 3,471 | Jacket | 0.85 | | 0.60 | 1.20 | 0.50 | - |
| E | 247 | 2,624 | 3,143 | 1,950 | 3,547 | 3,592 | Jacket | 1.37 | PASSES | 1.14 | 1.84 | 0.62 | 1.01 |
| | | 2,482 | 4,044 | 2,330 | 4,339 | 4,470 | Jacket | 1.80 | | 1.11 | 1.92 | 0.58 | 1.03 |
| | | 1,840 | 3,254 | 1,865 | 4,861 | 4,876 | Jacket | 2.65 | | 1.50 | 2.61 | 0.57 | 1.00 |
| C | 255 | 3,161 | 3,736 | 1,997 | 3,856 | 4,425 | Jacket | 1.40 | PASSES | 1.18 | 2.22 | 0.53 | 1.15 |
| | | 2,996 | 4,746 | 2,268 | 5,392 | 5,991 | Jacket | 2.00 | | 1.26 | 2.64 | 0.48 | 1.11 |
| | | 2,893 | 3,314 | 2,019 | 3,789 | 4,338 | Jacket | 1.50 | | 1.31 | 2.15 | 0.61 | 1.14 |
| P | 263 | 6,235 | 5,256 | 3,000 | 6,298 | 6,298 | Jacket braces | 1.01 | FAILS | 1.20 | 2.10 | 0.57 | 1.00 |
| | | 6,291 | 5,232 | 2,600 | 6,108 | 6,587 | Diagonal braces | 1.05 | | 1.26 | 2.53 | 0.50 | 1.08 |
| | | 4,964 | 4,154 | 1,950 | 4,302 | 4,660 | Diagonal braces | 0.94 | | 1.12 | 2.39 | 0.47 | 1.08 |
| O | 300 | - | 4,726 | 5,780 | - | 15,029 | Jacket | - | PASSES | 3.18 | 2.60 | 1.22 | - |
| | | - | 4,288 | 5,344 | - | 13,894 | Jacket | - | | 3.24 | 2.60 | 1.25 | - |
| G | 310 | - | 4,528 | - | 5,886 | 11,320 | Jacket | - | PASSES | 2.50 | - | - | 1.92 |
| | | - | 4,400 | - | 5,280 | 10,120 | Jacket | - | | 2.30 | - | - | 1.92 |
| | | - | 4,539 | - | 8,171 | 12,710 | Jacket | - | | 2.80 | - | - | 1.56 |
| I | 340 | 4,929 | 5,567 | 3,260 | 6,985 | 7,238 | Jacket | 1.47 | PASSES | 1.30 | 2.22 | 0.59 | 1.04 |
| | | 4,857 | 4,738 | 4,071 | 7,965 | 9,100 | Pile | 1.87 | | 1.92 | 2.24 | 0.86 | 1.14 |
| | | 3,657 | 3,307 | 3,623 | 7,112 | 9,140 | Pile | 2.50 | | 2.76 | 2.52 | 1.10 | 1.29 |

#1: Shaded values indicate minimum ratios for a platform

#2: Provided only maximum value for Section 17 load level

#3: Used simplified approach for ultimate strength analysis

Table 3-7c: Summary of Ultimate Strength Analysis Results - Other Gulf of Mexico Platforms

| Platform | Water Depth (ft.) | Base Shear: Section 17 Ult. Load S-17 (kips) | Base Shear: 20th Ed., Ref. Level S-20 (kips) | Analysis Results: Load at Ist Member with Lin. I.R.=1.0 S-1 (kips) | Analysis Results: Load at Ist Member with Nlin. Event R-1 (kips) | Analysis Results: Ultimate Capacity, Ru (kips) | Analysis Results: Platform Failure Mode | (#1) Ultimate Capacity/ Ult. Load = Ru/S-17 | Assessment Pass/ Fail at Ult. Strength Analysis | Information to the API TG (#1): Reserve Strength Ratio, RSR = Ru/S-20 | Ultimate to Linear Ratio, ULR = Ru/S-1 | Load Reduction Factor, LRF = S-1/S-20 | Redundancy Factor, RF = Ru/R-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gulf of Mexico: 16-Leg Platform** | | | | | | | | | | | | | |
| D(#2) | 88 | 2,340 | 1,973 | 726 | 902 | 3,040 | Leg/Pile | 1.30 | FAILS (#3) | 1.54 | 4.19 | 0.37 | 3.37 |
| | | 2,451 | 1,953 | 1,054 | 1,420 | 2,302 | Leg/Pile | 0.94 | | 1.18 | 2.18 | 0.54 | 1.62 |
| **Gulf of Mexico: 36-Leg Platform** | | | | | | | | | | | | | |
| J | 37 | 1,010 | 1,793 | (#4) | 2,244 | 3,568 | Pile | 3.53 | PASSES (#5) | 1.99 | - | - | 1.59 |
| | | 972 | 1,349 | (#4) | 1,399 | 2,083 | Pile | 2.14 | | 1.54 | - | - | 1.49 |
| | | 985 | 2,063 | (#4) | 2,078 | 3,007 | Pile | 3.05 | | 1.46 | - | - | 1.45 |

#1: Shaded values indicate minimum ratios for a platform

#2: Participant miscomputed the RSR's. The values shown in the table are correct for the tabulated analysis results

#3: Participants' statement that the structure passes is incorrect based on the tabulated results

#4: Didn't compute because some of the members fall outside the applicable range of the API equations (e.g., 20" dia. legs with a wall thickness of 0.225" after accounting for corrosion)

#5: Participant mentioned that structure Passes by prior exposure

**Table 3-7d: Summary of Ultimate Strength Analysis Results - Offshore Southern California Platforms**

| Platform | Water Depth (ft.) | Base Shear Section 17 100-year Return Period S-ref (kips) | Analysis Results: Load at Ist Member with Lin. I.R.=1.0 S-1 (kips) | Analysis Results: Load at Ist Member with NLin. Event R-1 (kips) | Analysis Results: Ultimate Capacity, Ru (kips) | Analysis Results: Platform Failure Mode | (#1) Reserve Strength Ratio, RSR = Ru/S-ref | Assessment Pass/ Fail at Ult. Strength Analysis (#2) | Information to the API TG (#1): Reserve Strength Ratio, RSR = Ru/S-ref | Information to the API TG (#1): Ultimate to Linear Ratio, ULR = Ru/S-1 | Information to the API TG (#1): Load Reduction Factor, LRF = S-1/S-ref | Information to the API TG (#1): Redundancy Factor, RF = Ru/R-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Offshore Southern California: 12 -Leg Platform (Metocean Loading)** | | | | | | | | | | | | |
| Q (#3) | 189 | 2,300 | 1,700 | 3,750 | 5,600 | Soils | 2.43 | PASSES | 2.43 | 3.29 | 0.74 | 1.49 |
| | | 2,300 | 1,550 | 3,400 | 5,700 | Soils | 2.48 | | 2.48 | 3.68 | 0.67 | 1.68 |
| **Offshore Southern California: 12 -Leg Platform (Seismic Loading) #3** | | | | | | | | | | | | |
| S (#4) | 155 | 3,355 | 2,264 | 3,690 | 9,394 | Jacket | 2.80 | PASSES | 2.80 | 4.15 | 0.67 | 2.55 |

#1: Shaded values indicate minimum ratios for a platform

#2: Structure under the Significant Environmental Impact category "Passes" Metocean loads when RSR > 1.6.

#3: Participant performed DLE analysis using Time History approach
Pushover analysis performed with wave larger than 100-year wave.

#4: Participant used pushover analysis for DLE assessment

**Table 3-7e: Summary of Ultimate Strength Analysis Results - Cook Inlet Platform**

| Platform | Water Depth (ft.) | Base Shear RP 2N, 1st Ed. Ref. Level (#2) S-ref (kips) | Analysis Results: Load at 1st Member with Lin. I.R.=1.0 S-1 (kips) | Analysis Results: Load at 1st Member with NLin. Event R-1 (kips) | Analysis Results: Ultimate Capacity, (#3) Ru (kips) | Analysis Results: Platform Failure Mode | (#1) Reserve Strength Ratio, RSR = Ru/S-20 | Assessment Pass/ Fail at Ult. Strength Analysis (#4) | Information to the API TG (#1): Reserve Strength Ratio, RSR = Ru/S-20 | Information to the API TG (#1): Ultimate to Linear Ratio, ULR = Ru/S-1 | Information to the API TG (#1): Load Reduction Factor, LRF = S-1/S-20 | Information to the API TG (#1): Redundancy Factor, RF = Ru/R-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cook Inlet: 4-Legged Platform (Ice Loading)** | | | | | | | | | | | | |
| R | 100 | 8,559 | 10,517 | 20,235 | 20,235 | Jacket bracing | 2.36 | PASSES | 2.36 | 1.92 | 1.23 | 1.00 |
| | | 9,716 | 11,516 | 14,900 | 21,910 | Leg column buckle | 2.26 | | 2.26 | 1.90 | 1.19 | 1.47 |
| | | 6,985 | 9,095 | 17,990 | 17,990 | Jacket bracing | 2.58 | | 2.58 | 1.98 | 1.30 | 1.00 |

#1: Shaded values indicate minimum ratios for a platform

#2: Base shear values corresponding to 100-year return period ice loads

#3: Provided ultimate capacity value at first member failure for the 1st and 3rd load cases

#4: Structure under Significant Environmental Impact category "Passes" assessment when RSR > 1.6

## Section 4
## Participants' Inquiries, Review and Feedback to the 92-5

### 4.1 INQUIRIES

Inquiries from participants were received during the course of the project. Several participants provided written comments for discussion at the June 7, 1994 progress meeting. The participants' queries were in four general areas as follows:

- Platform Assessment Process
- Consequence Based Metocean Criteria/ Loads
- Wave-in-deck Force Procedure (Section 17.6.2)
- Structural Analysis for Assessment

While the details of these inquiries are not discussed in this section, a copy of the participants' inquiries and questions is provided in Appendix B. Some of the comments concerning environmental loading were responded to by Dr. Chuck Petrauskas and Mr. Tim Finnigan of Chevron Petroleum. A copy of their response is also included in Appendix B.

Some of the key observations from the discussion held at the progress meeting are noted below (see minutes of meeting):

- One participant noted that "a condition may exist in which a platform is damaged (beyond a 10% "significant" level), but the brace is repaired bringing the platform back to its initial condition. Does this platform have to be assessed per the full process in Section 17?" The API TG noted this concern for possible clarification.

- Another participant stated that all platforms will need to be assessed per Figure 17.5.2. API TG noted that there may be a need for an additional block in Figure 17.5.2 clarifying the API requirements for Gulf of Mexico platforms installed prior to 1977.

- API TG clarified that Section 17 recommends that an existing platform undergo an assessment if one or more of the conditions listed in Section 17.2 exists, and that it is not the intent of the document that all pre-1977 platforms be assessed.

- One participant cited the possible differences in RSR computed using a pushover load profile per Section 17 (used in ultimate capacity analysis) and per RP 2A, 20th Edition. Therefore, the RSR's developed in this JIP may not be directly comparable to the RSR's developed in other studies which were used to establish some of the criteria in Section 17. API TG noted that the differences may not be that significant, particularly for cases with wave below the deck; however, all results will be carefully studied by the TG to ensure that they are properly used in establishing criteria.

Based upon the discussion held at the meeting, the API TG updated Figure 17.5.2 in their June 28, 1994 revision.

## 4.2 REVIEW AND FEEDBACK OF DRAFT SECTION 17 (PART B)

Ten participants provided written comments to the Draft Section 17 for use by the API TG. The comments received through Part B of their Trial Documents are provided in Section 4.2.1. The comments received through Part B of the Benchmark Documents submitted by participants are provided in Section 4.2.2. The comments are summarized per Section 17 subsections, and where comments for a particular section were received from more than one participant, they are differentiated by numbers (1, 2, etc.) under the subsections. The comments are duplicated exactly as provided by participants.

Other comments and questions from participants and typographical errors cited are provided in Section 4.2.3 to 4.2.5.

The response by the API TG 92-5 to the Trial and benchmark participants' comments on Section 17 is provided in Appendix-A. The Appendix-A also includes the "correct" metocean criteria and force calculation procedure for evaluating the Benchmark platform (Part II of Trials JIP), identified by the TG92-5 WG3 members.

### 4.2.1 Trial Participants' Comments on Section 17

#### Section 17.1 – General

1. In the draft document in general, all references should be numbered or labeled and only the reference number/label included in the body of the text. This will make reading the document much easier.

   References to the 20th edition of API-RP2A should be changed to current edition of RP2A. After all, this section will first occur in the 21st edition, and should reference the 21st and not the 20th edition.

   The criteria for Gulf of Mexico platforms passing Ultimate Strength Analysis should be clearly stated in the text. Not only in the flow chart.

2. In general the method of comparing base shear for original vs. modified structure is a good method, particularly when the increase in base shear is less than 10%. It is

questionable, however, since software is not yet available to the majority of engineering companies, whether normal lead time will permit the application of an ultimate strength analysis on a routine conventional platform when the indicators suggest it is necessary.

The use of the word "requirement(s)" should be limited and where possible changed to "recommendation(s)".

3. The purpose of API RP 2A Section 17.0 – Assessment of Existing Platforms (draft) is to provide some practical guideline to the designers in the assessment of existing platforms. The contents of API RP 2A Section 17.0 (draft)have been improved significantly since its early version of November 3, 1993.

**Section 17.2 –Platform Assessment Initiators**

1. The only condition that triggers assessment for this platform is member degradation due to corrosion. If there was no corrosion damage on the platform, we didn't have to go through the assessment process. But as it turns out the platform does not pass assessment when all the analysis checks are made even when the platform damage is neglected. This probably will be true for many old platforms designed prior to 1970. Most of these old platforms were designed for a 25 year storm with no loads due to current used in the design and did not have joint cans. It is our opinion that another trigger to perform assessment should be introduced for platforms designed prior to 1970 (Section 17.2).

   All the triggers to perform assessment should be included in the flow chart of Figure 17.5.2 to make it more complete.

2. Section 17.2 states, "An existing platform should undergo the assessment process if one or more of the conditions noted in Section 17.2.1 through 17.2.4 exists. Sections 17.2.1 through 17.2.4 consider 'Addition of Personnel', 'Addition of Facilities', 'Increased Loading on the Structure', and 'Significant Damage.' Please consider adding that platform assessment may also be required from an MMS initiated assessment.

3. Based on platform initiators of API RP 2A, 20th Edition, Section 17.2 (draft version), this platform is not subject to the assessment process. None of the conditions noted in Sections 17.2.1 through 17.2.5 exist. In addition, underwater inspection (Level II inspection) indicates that the platform is in satisfactory condition. That is, members, as well as joints, do not present any signs of being affected by the environmental conditions to which the platform has been subject during its 25 years of operation. Nevertheless, after completing the analytical platform assessment, the study found that the joints supporting the K-braces at Row 1, Row 2, Row 3, and Row 4 are overstressed. Moreover, the platform was designed, built, and installed before the

release of API RP 2A, 9th edition. All of this discussion leads to the need to include guidelines to check these joints, taking into account that the current joint check procedure has some conservatism built into its equations. As it is understood from the JIP meeting of June 7, 1994, an API committee is currently reviewing the joint check design procedure. The committee performing this revision should consider assessment of existing platforms as one of their key evaluations.

4a. As seen in this trial application, a platform can pass assessment when the jacket joints would be shown to be inadequate in a Design Level Analysis. In this case, the platform passes assessment based on the definition of "significant increased loading" (refer to Sections 17.2.6 and 17.5.2.3). Wave load calculations, the first step in the Design Level Analysis, showed that the increased loading due to conductor additions to the platform was less than 10% or not significant. Therefore, the platform passes assessment at this point. However, if the Design Level Analysis is carried further, results would show that the strength of a number of jacket joints is inadequate and the platform would then fail assessment. Consideration should be given to adding text to address this inconsistency.

4b. Sections 17.2.3 and 17.2.5 with Section 17.2.6 indirectly state that platform damage or increased loading would not be assessment initiators if the cumulative damage or cumulative changes from the design premise were not significant (i.e., less than 10% decrease in capacity or less than 10% increase in loading). It is assumed that the wording in these sections applies to all platforms, regardless of exposure category. However, wording in Section 17.5.2.3 and 17.5.2.4 implies that the "not significant" definition only applies to "minimum consequence" platforms. This should be clarified.

5. In Sections 17.2.1, 17.2.2, 17.2.3 and 17.2.4, is there any significance to interchangeably using the phrases "must be assessed", "shall be assessed", and "should be assessed"?

   In Section 17.2.6, the third line, shouldn't the wording "cumulative damage and the increase in loading" be changed to "cumulative damage or the increased in loading"?

Section 17.2.5 – Damage Found During Inspections

The word "justified" is better replaced with the following language for the last two sentences:

*Minor structural damage may be judged acceptable by appropriate structural analysis without performing a detailed assessment. However, the cumulative effects of damage must be documented and, if not determined to be insignificant, be accounted for in the detailed assessment.*

## Section 17.7.3c and C17.7.3c – Global Inelastic Analysis

Items 3.b and 3.c in Section 17.7.3c do not address the issue of modeling braces that carry significant moments. One example is braces that frame into pile heads.

Item 3.d in Section 17.7.3c does not clearly state what the actual loads or the loads based on the strength that act on joints. Some joint modeling techniques should be stated here with their advantages and disadvantages.

Section 17.7.3c provides instructions on element grouping and this is expanded significantly in the commentary. It is questioned whether the level of guidance in the guideline itself is helpful. It is suggested that the clause should reiterate the intention to use best estimate properties to model components (as stated explicitly for foundations) and indicate that, if required, further guidance on the grouping of similar element for modeling purposes is contained in the commentary.

The discussion regarding the modeling of structural members in the commentary appears to be written with the concepts of an "INTRA" type analysis in view. Other programs which have been developed and validated for ultimate strength analysis have automatic facilities to accommodate large deflection beam column action including the effects of end fixity without requiring the user to select specific K factors or element types before performing an analysis. It is also unnecessary to scrutinize working stress analysis results to establish which element types should be selected for each location "based on the dominant stresses." These software packages make the single step to ultimate strength check increasingly viable from economic and time standpoints.

Perhaps a more general approach would be to state that the modeling should properly account for beam column effects, the potential onset of plasticity, and the effect of frame restraints on buckling capacity, etc. This generality leaves the analyst better able to interpret the guideline and less likely to give inadequate consideration to factors which may cursorily be disregarded as irrelevant.

## Section C17.7.3c – Global Inelastic Analysis

In Item 3.g, it is required that the gap between jacket and conductor be modeled. Clearly this is aimed at realism. However, there is uncertainty in the initial position of the conductor in the slot. For this reason the added complexity may not necessarily lead to an improved representation of the system behavior. Perhaps it need not routinely be modeled but if the criteria are only just met this and other factors such as initial member out-of-straightness etc. should be recommended for inclusion in a sensitivity study.

### 4.2.3 Other Comments

1. Are there any comments on dynamic analysis for deep water platforms (other than fatigue)?

2. The static pushover analysis calls for a description of the load level at which the first component reaches IR = 1.0. This study has assumed that it means the load level at which the first member buckles or yields. A more expanded definition needs to be provided to the definition of this load level.

3. Most of the comments on Draft Section 17 were discussed during the execution of this JIP and corrective measures were taken. One very important comment affecting not only Section 17 but also Sections 2 and 4 is provided to ensure that a corrective measure is considered by the Subcommittee on Fixed Structures.

    - Section 4.1 of API RP 2A states that the "joints develop the strength required by design loads, but not less than 50% of the effective strength of the member.

    - Section 2.3.6e of API RP 2A provides additional guidelines, stating that if the horizontal ground motion is 0.05g or greater, the joints for the primary structural members should be sized for the capacity of the member connected to the joint.

   The approach taken by API has worked well for the Gulf of Mexico where the storm loading controls the design and seismic design is not considered, and for offshore Southern California where the seismic loading controls the design.

   For an area such as the South China Sea or offshore Trinidad, the controlling design condition is the typhoon/hurricane event. However, the structure also needs to be analyzed for seismic loads. While the seismic loading may require that a brace be sized 24-inch diameter with 0.5 in wall thickness, the storm event may require a 1.0 inch wall thickness. Thus, while the correct procedure is to determine the seismic capacity required for strength level seismic design and ensure that the joint is capable of resisting loads associated with full member capacity (i.e., to achieve API's objective; namely prevention of an unzipping effect), Section 2.3.6e may be misinterpreted and the designer/analyst may provide joint resistance for full capacity of the member designed for the extreme storm environment.

   We do not necessarily endorse the 50% rule. We also understand the basis for the two contradictory requirements to be due to both the differences in the recurrence intervals considered for storm (100 versus 500 years) and the earthquake (200 versus 2,000 years)

## Section 17.6 –Metocean, Seismic and Ice Criteria/Loads

### Section 17.6.2 – Metocean Criteria/Loads

1. In the second sentence of the third paragraph of Section 17.6.2a-4a, change the words "of this recommended practice" to "from Section 2.3.4" (change in two places in the sentence). This change will add clarity to the sentence and avoid misinterpretations.

2. It is suggested in Section 17.6.2a-4b, paragraph 3, that the third sentence which currently starts with "For some non-critical directions, the omni-..."be modified to include the notes that are found at the bottom of Table 17.6.2-1 and to explicitly state that if the wave height or current vs. direction calculated for the omni-directional criteria exceeds that required by the ultimate strength analysis the smaller of each wave height or current from both criteria will be used.

3. Criteria and procedures are not discussed for structures in the cross hatched area in the Gulf of Mexico shown in Figure 2.3.4-2 in API RP 2A WSD, 20th Ed.

### Section 17.6.2a – Gulf of Mexico Criteria

1. Figure 17.6.2-4 (P 20) contains a rosette entitled: Sudden Hurricane Wave Directions and Factors to Apply to the Omnidirection Wave Heights in Figure 17.6.2-3a for Ultimate Strength Analysis." Is this for currents also? Does it apply only for deep water?

2a. Table 17.6.2-1 (p. 13). "Gulf of Mexico Metocean Criteria" has provided all information required for both design level and ultimate strength analyses for different exposure categories. For the evaluation of ultimate strength analysis results, it seems to be more meaningful to the engineer to know what RSR value has been achieved than just plain pass or fail the ultimate analysis. For example, if a platform passes the insignificant environmental impact/ manned evacuated metocean criteria (Gulf of Mexico) for ultimate strength analysis, what is the equivalent RSR value? The current text of Section 17.0 (draft) has not mentioned it except implicitly by referring to OTC paper #7482 by Krieger et al. It is suggested that the RSR values (for Gulf of Mexico) should be provided in the text or in the commentary. Alternatively, the RSR values can be inserted in Table 17.5.2a of Figure 17.5.2 (p.6).

2b. Table 17.6.2-1 "Gulf of Mexico Metocean Criteria" "If the wave height or current vs direction exceeds that required for ultimate strength analysis, then the ultimate strength criteria will govern."

The background of using omni-direction wave is not clearly explained in the text or commentary. The mixing of omni-direction and ultimate strength criteria makes sense only if the design level analysis is solely required. Two different metocean criteria must be used to derive the required design wave load in each wave direction. The benefit of using mixed mode (criteria) is not clear.

3. In Section C17.6.2a.1 the API RP 2A, 9th edition metocean criteria may be provided to help in the assessment process.

Section 17.6.2b – West Coast Criteria

1. Deck height check should be as prescribed in 17.6.2a.2, not 17.6.2a.5, which doesn't exist. Concerning lowering of the ultimate strength storm tide from that in Table 17.6.2-2, what can you lower it to? Why not just prescribe an adequate tide to use with the defined wave height?

2. Item 4 – First Para: "---. An ultimate strength check will be needed if the platform does not pass the design level or if the deck height is not adequate."

   Is this statement always true? (see the discussion in item 2b under Section 17.5.1).

**Section 17.7 –Structural Analysis for Assessment**

Section 17.7.2 – Design Level Analysis Procedures

1. It is likely that many older structures with adequate deck heights could pass the Design Level Analysis for member strength and foundation capacity, but fail assessment based on inadequate jacket joint strength. Wording should be added to Section 17.7.2c to state that adequate joint strength can be demonstrated through Level III and/or Level IV inspection of critical joints in conjunction with documentation of prior hurricane exposure.

2. Item 17.7.2d and C17.7.2d. The results of fatigue analysis can provide valuable information to the platform owner / operator to identify any critical joints in the structure which might be known or unknown having potential fatigue problems. This information might be available from the platform's design file or a fatigue analysis compatible with Section 5 should be performed.

   The last sentence of C17.7.2d Fatigue (Commentary) read "The use of analytical procedures for evaluation of fatigue may be adequate if only Level II survey is done." This implies that if you have Level II survey information, it is sufficient to carry out the fatigue analysis. Is there a better word to replace the "only" word in that sentence. You can have Level III or Level IV surveys if you want to (even though that is impractical) before proceeding any fatigue analysis.

Section 17.7.3 – Ultimate Strength Analysis Procedures

1. Sections 17.7.3a and 17.7.3b (p. 26) are not clear. Is a Linear Global Analysis the same as a Simplified Ultimate Strength Analysis? Is a Local Overload Analysis simply considering removing overstressed members and rerunning the Linear Global Analysis? Could these sections please be rewritten?

2a. Static Push-Over Analysis – How many wave directions should be performed? Are three wave directions sufficient?

The static pushover analysis results showed that the reserve strength ratio (RSR) is directionally dependent, as expected. It raises the question about how many wave directions should be considered in the platform assessment to ensure that the platform's reserve strength is properly evaluated? Of course, this is an engineering judgment call. The experiences learned in this JIP – trial applications by all participants might have sufficient data to incorporate the answer to that question in the commentary. In our study four wave directions were selected for the static push-over analysis. The results showed that the range of reserve strength ratio (RSR) is between 1.18 and 1.39.

2b. Reduce Joint Check Conservatism. In the ultimate strength analysis, the mean value of material yield strength (instead of the lower bound value) can be used in the joint check. This is a reasonable approach taken to reduce the conservatism built in the joint check formulas. There are other joint check parameters which should be brought to the task group's attention, such as the chord stress reduction factor, $Q_f$ (see Figure C4.3-3 in API RP 2A 20th edition (see Figure 4-6). Especially for the in-plane load case, the factor $Q_f$ decreased drastically as the factor A approaches 1.0. There were only two test data shown in the $Q_f$ curve (in-plane bending). Is the extrapolation of the result beyond, say A = 0.60 too conservative? (for in-plane bending case)

Section C17.7.3 – Ultimate Strength Procedures

The last sentence under "Lateral Soil Resistance Modeling" in Section C17.7.3c.3.g implies that lateral pile displacements greater than 10% of the pile diameter should only be considered for ultimate capacity analysis. This further implies that lateral pile displacement in elastic design of foundations be limited to 10% of the pile diameter. The wording here may be contested by many platform designers, since this "10% rule" for lateral displacement in the design of pile foundations has not typically been followed. Consideration should be given to revising the wording in this section.

### 4.2.2 Benchmark Participants Comments on Section 17

**Section 17.1 –General**

A philosophical background for Section 17 should be added as introduction (Subsection 17.1) explaining what we are trying to do, so that a user can appreciate why different wave heights (as compared to 100-year waves, 20th Edition) have to be used for design level or ultimate level checks as well as for different exposure categories.

**Section 17.6 –Metocean, Seismic and Ice Criteria/Loads**

Section 17.6.2a – Gulf of Mexico Criteria

Under Item 4b, in Figure 17.6.2-4, the caption should indicate that the directions and factors also apply to currents.

Section C17.6.2 – Wave/Current Deck Force Calculation Procedures

The presentation of deck loading could be open to different interpretation. For example wave loads on the net silhouette area are readily distributed equally to decks above and below. In reality structural members might share the load top to bottom whereas loads incident on equipment/structure standing on the deck will pass loads to the lower level almost exclusively. Should the net area modeling be associated with the net deck area for attracting loads rather than between deck silhouette. Alternatively, the proposed procedure may be adequate but should perhaps be flagged for further investigation in a sensitivity study should the margin beyond the required ultimate strength be small.

**Section 17.7 –Structural Analysis for Assessment**

In 17.7.2b and 17.7.3b it is recommended that the clauses read "software developed and *validated* for that purpose."

Section 17.7.3 – Ultimate Strength Analysis Procedures

Guidelines to select suitable analysis method (linear global, local overload or global inelastic) given in Section 17.7.3a through 17.7.3c should be more clearly stated.

There may be less confusion if after the statement in Section 17.5.2 there was a reference made to see Section 17.6.1.

3a. The assessment process flowchart (Figure 17.5.2) does not reflect a check to determine if platform damage or increased platform loading is significant according to Section 17.2.6. Some analytical work is necessary to determine if the damage or increased loading is significant. The analytical work may show the damage or increased loading to be insignificant and, if no other initiators exist, the platform passes assessment. This process for an alternative design level analysis is discussed in Section 17.5.2.3.

3b. Section 17.5.2.3 states that "an acceptable alternative to satisfying the design level analysis requirement is to demonstrate that the damage or increased loading is not significant relative to the as-built condition, as defined in Section 17.2.6. This would involve **design level analysis of both the existing and as-built structures.**" If a full design level analysis is required for both the existing and as-built structures, then what is the incentive for pursuing this alternative approach? A design level analysis of only the existing or current structure would determine if the structure passes assessment or not. If a design level analysis is performed on the existing structure, then it appears that the design level analysis results for the original or as-built structure would be irrelevant. It is possible that the author of this section was considering wave load increases as they relate to the definition of "significant". Here, a design level wave loading analysis on the existing and as-built structures would determine if the loading increase due to platform changes was significant (a full design level stress analysis for both conditions is not required if the loading increase is not significant. For clarity, wording in this section should be revived to better describe the intent of the alternative approach.

3c. Comment 4 above regarding the alternative approach also applies to the ultimate strength analysis in Section 17.5.2.4. An ultimate strength analysis of only the existing or current structure would determine if the structure passes assessment or not. If an ultimate strength analysis is performed on the existing structure, then it appears that the ultimate strength analysis results for the original or as-built structure would be irrelevant. For clarity wording in this section should be revised to better describe the intent of the alternative approach.

3d. For clarity, it is recommended that the two sentences prior to Section 17.5.2.4 be revised to read as follows (note blank line after first sentence):

> "Significant damage or change in design premise is defined in Section 17.2.6.
>
> For platforms that have significant damage, have an inadequate deck height for their category (Ref. Figures 176.2-2b, 3b, 5b) and/or have experienced significant changes from their design premise, the following applies:"

3e. From the wording under "Design Basis Check" in Section 17.5.2 and the wording in the heading for Section 17.6.2a.3, it appears that a platform can only pass assessment by Design Basis Check if it was designed to API RP 2A, 9th Edition (1977) or later. It is possible that a platform designed prior to 1977 could have been designed to a hydrodynamic loading that meets the reference level forces in the 9th Edition. Could this platform pass assessment by the Design Basis Check? This should be clarified. Further comment: It appears that the design basis check concerns only the magnitude of wave loading used for design of the platform. Are there any other design criteria or design procedure issues that should be addressed?

4a. In Figure 17.5.2 there needs to be a mechanism in the flow chart which allows a termination to the assessment process when it is determined that no personnel or facilities are being added and there is no significant damage or load increase. A proposed revision to the flow chart is attached at the end of this section (see Figure 4-5).

4b. In Section 17.5.2.3, the third sentence says that "requirements are described in Section 17.7.2". Section 17.7.2 is entitled "Design Level Analysis Procedures". The nature of Section 17.7.2 seems to state neither requirements or procedures.

4c. In Section 17.5.2.4, the fifth sentence says that "Requirements are described in Section 17.7.3". Section 17.7.3 is entitled "Ultimate Strength Analysis Procedures."

Section 17.5.3 – Assessment for Seismic Loading

1. In Section 17.5.3.4, the wording "The platforms have been surveyed" should be changed to "The platforms have been surveyed to at least Level II as defined in Section 14.3.2".

2. In Section 17.5.3.6, "screening criteria" is not specifically defined in the text except that the term "screening" appears in Section 17.5 ASSESSMENT PROCESS (p.4). However, in the commentary C17.7.1 General (p. 37), The term "screening" is explained explicitly. Is the "screen criteria" for seismic loading different from that for metocean? If so, probably some further explanation on the "screen criteria" in the text or commentary would be helpful.

Section 17.5.4 – Assessment for Ice Loading

1a. In Section 17.5.4.4 the term "screening criteria" appears twice in this Section.

1b. Same comment as (2) under Section 17.5.3.

Section 17.2.6 – Definition of Significant

In Section 17.2.6, the 10% threshold for defining a "significant load increase" will likely be interpreted as a 10% increase in overall loading on the platform (i.e., the interpretation would be based on global loading with no consideration of local effects). Wording should be added to this section to state that additional loading of less than 10% should be considered significant if the additional loading induces failure of local elements that would, in turn, lead to overall failure of the platform.

**Section 17.3 – Exposure Categories**

Section 17.3.1 – Life Safety

Are bridge-connected structures considered "manned"? Could we add some kind of definition to this section regarding bridge-connected structures, or does an adequate definition exist somewhere else in RP 2A?

Section 17.3.2 – Environmental Impact

1. The difference in lateral load level between a platform being classified as belonging to the Significant Environmental Impact category and a platform in the Insignificant Environmental Impact category is substantial. As Figures 4-1 to 4-3 (see end of this section) indicate, the difference of load can be as high as a factor of 2.0. Nevertheless, the definitions in API RP 2A, Section 17.3.2 and Section C17.3.2, are not clear enough. Section 17.3.2b indicates "that a platform may have potential for liquid hydrocarbon or sour gas release and still be categorized as Insignificant Environmental Impact." The level of hydrocarbon or sour gas release required to still belong in the insignificant impact category must be defined.

2. Last paragraph of Section 17.3.2.a: Except for those cases in which release of hydrocarbons or sour gas would *not* occur, no one factor should be considered alone when performing an environmental impact review.

**Section 17.4 – Platform Assessment Information – Surveys**

"Section 17.4.3. Soil Data." doesn't seem to belong in Section 17.4.

**Section 17.5 –Assessment Process**

Section 17.5.1 – General

1. Assessment through the use of explicit probabilities of failure. Are there any target criteria to satisfy this assessment? Is there a defined scope for all failure probabilities to include (i.e. hurricanes, ship impact, fire, explosions, helicopter crash, etc.)? The language in the commentary is vague.

2a. (p.5) First paragraph and Figure 17.5.2 – Page 2. Implies that if the design level analysis is performed and passed then no ultimate strength analysis is required. In the trial application of the "C" platform for insignificant environmental impact/manned - evacuated metocean criteria, one interesting but not surprising result has been found that unity check ratio of certain members (mainly horizontal members) for design level analysis is less than that of the ultimate strength analysis. This means that the statement mentioned in the text that "the design level analysis is simpler and more conservative check" might be not always the case. This finding is confirmed from the results of wave load base shear calculations. The base shear ratio (Ultimate/Design) is ranging from 0.58 to 1.69 in 10 wave directions considered. It is recommended that this finding should be incorporated, at least, in the commentary.

2b. (p.5) First paragraph read as "------. However, it is permissible to bypass the design level analysis and to proceed directly with an ultimate strength analysis. ----. This option should be reflected in Figure 17.5.2 (continued) – page 7 (see Figure 4-4).

Section 17.5.2 – Assessment for Metocean Loading

1. Figure 17.5.2, Page 6, Note 1: "Design Level Check". It is not clear if what is meant is a "Design Level Analysis" or "Design Basis Check".

2. This Section makes the following statement

   > "For the Gulf of Mexico, design level and ultimate strength Metocean Criteria are explicitly provided, including wave height vs. water depth curves."

   Section 17.6.1 makes a similar but less confusing statement of the criteria given in Section 17.

   > "The criteria/loads to be utilized in the assessment of existing platforms should be in accordance with section 2.0 with the exceptions, modifications and/or additions noted herein as a function of exposure category defined in Section 17.3 and applied as outlined in Section 17.5"

and the characteristics of the applied loading and structure response to the applied loads.

Please consider inserting a statement in Section 2.3.6e, indicating that the recommendation is applicable to members capacities controlled by seismic design.

#### 4.2.4 Questions from Participants

One participant listed questions related to the draft document as follows:

- In Section 17.6.2a-4b which wave period and storm tide are to be used in the Design Level analysis if the Ultimate wave analysis wave height governs. Normally smaller wave periods and smaller storm tides are associated with smaller wave heights.

- For the 184 ft water depth Sudden Hurricane Criteria the Storm tide for ultimate strength analysis (larger wave height) is higher than the storm tide of the Design Level analysis (smaller wave height). Should these two curves be asymptotic with the ultimate strength storm tide always being larger than the design basis storm tide.

- For the same structure in 184 ft of water, the storm tide for the design Level analysis is higher than the storm tide for the API 100-yr extreme environmental criteria.

- By comparing Figure 17.6.2-4 to Figure 2.3.4-4, it can be seen that the factors used for the Ultimate Strength analysis are shifted from the factors used in API 100-yr extreme load criteria by 45 degrees. This will clearly affect the reassessment of structures that in the case of the 335 degree angle, for example, will be assessed for a much higher environmental criteria. Specially in the case of a Manned non-evacuated structure were the 95% of the API 100-yr wave is to be compared to the 100% Full Population Hurricane Load which is already 6 to 7% higher.

#### 4.2.5 Typographical Errors

The following typographical errors were cited by three participants. The contributions are kept separate by sub-sections.

1. Miscellaneous comments (editorial changes, typographical errors, etc.):

    - In Section 17.2.6, change the word "and" to "and/or".

- In section 17.3.1c, insert the word "is" after the word "platform".

- In Section 17.4.1, the title of the paper "An Integrated Approach for Underwater Survey and Damage Assessment of Offshore Platforms" should be italicized.

- In the first paragraph of Section 17.5.2, change "environ-mental" to "environmental".

- In the first paragraph of Section 17.5.3, use a capital "S" for the word "section" (i.e., Section 17.3).

- The headings for Sections 17.5.3.4, 17.5.3.5, 17.5.3.6, 17.5.4.3, 17.5.4.4, and 17.5.4.5 should be in bold type, similar to the headings in Section 17.5.2.

- In Section 17.5.3.4, delete the blank line after the first line of text.

- In Section 17.6.1, use a capital "S" for the word "section" (i.e., Section 17.3).

- In Section 17.6.2a.1, should the words "directional spreading" be replaced with the words "wave kinematics"?

- In the last sentence of the third paragraph of Section 17.6.2a.4.b., should the words "directional spreading" be replaced with the words "wave kinematics"?

- In Section 17.6.2b.1, should the words "directional spreading" be replaced with the words "wave kinematics"?

- The word "actual" in the title of reference 5 under "REFERENCES" should be capitalized (i.e. Actual).

- In Section C17.2.4, change the words "Platform installed in deeper water than design for" to "Platform installed in deeper water than the design depth".

- Change the heading for Section C17.5.3 from "Assessment for Seismic Assessment" to "Assessment for Seismic Loading".

- In Section C17.7.3c.3.d, change "load-defotmation" to "load-deformation".

2. Typo mistakes that were found in reviewing the draft document dated April 1, 1994.

   - Page 5, Section 17.5.2 environmental is written environ-mental.

- Table 17.6.2-1, Design Level Analysis written Design Level Level Analysis. (Level written twice, in two instances).

- In paragraph 3 of section 17.6.2a-4b non- critical should be written non-critical. No space between the hyphen and the letter "c".

- The first paragraph in Section 17.6.2a-4c ends with two periods.

3a. Errata/Enhancements to API RP 2A Section 17.0 (Draft)

In Section 17.6.2a-4b (p. 22): In the last sentence of third paragraph "--- a directional spreading factor of 0.88 --- " should read as "---- a wave kinematics factor of 0.88 -----".

In Section 17.6.2b-1 (p. 23): In the 2nd sentence "--- a directional spreading factor of 1.0 ---" should read as "--- a wave kinematics factor of 1.0 ---".

In Section 17.6.2b-2 (p. 23): In the 1st sentence "--- on the same basis as prescribed in Section 17.6.2a.5 ---" should read as "----- on the same basis as prescribed in Section 17.6.2a.2 ---".

In Section 17.6.3 (p. 24): It is suggested that the term "Ultimate strength criteria" be replaced by "Ultimate strength **seismic** criteria". This applies to the last sentence in this paragraph too.

Section 17.7.3 (p. 25). In the first sentence "----, to insure adequacy for ----" be more appropriate to read as "---, to ensure adequate for ----".

Section C17.5.3 (p. 33): The heading "Assessment for Seismic Assessment" should read as "Assessment for Seismic **Loading**".

3b. Errata/Enhancements to API RP 2A-LRFD Section R (Draft)

The same errata/enhancements given under 3(a) should be applied to the API RP 2A-LRFD version (Section R (draft)).

In Section R.6.2a-4b (p. 12): In the last sentence of third paragraph "--- a directional spreading factor of 0.88 --- " should read as "---- a wave kinematics factor of 0.88 -----".

In Section R.6.2b-1 (p. 13): In the 2nd sentence "--- a directional spreading factor of 1.0 ---" should read as "--- a wave kinematics factor of 1.0 ---".

In Section R.6.2b-2 (p. 13): In the 1st sentence "--- on the same basis as prescribed in Section R.6.2a.5 ---" should read as "----- on the same basis as prescribed in Section R.6.2a.2 ---".

In Section R.6.3-3 (p. 14): It is suggested that the term "Ultimate strength criteria" be replaced by "Ultimate strength **seismic** criteria". This applies to the last sentence in this paragraph too.

In Comment R.5.3 (p. 24): The heading "Assessment for Seismic Assessment" should read as "Assessment for Seismic **Loading**".

3. One Benchmark Participant cited the following:

- Section 17.3.1c "platform *is* not"
- Section 17.5.2 "environmental" – remove space and hyphen
- Section 17.6.2b "Section R.6.2a.2"? There is no Section R.6.2a.5
- Section 17.7.3 "to ensure adequacy"
- Section 17.7.3c "deformation"

## 4.3 OTHER COMMENTS AND OBSERVATIONS FROM PARTICIPANTS

Several participants commented on their results and discussed current limitations of modeling and analysis. Selected discussions from their documents are reproduced in this section.

- Joint Modeling

  One participant discussed the joint modeling issue as follows:

  > "The issue of joint modeling is not easily addressed by most nonlinear pushover analysis software and they do not have the capability to explicitly account for the joint can capacity in the ultimate strength analyses. In previous analyses, we have addressed this issue by degrading the member capacities to match the joint can capacities. However, there are various uncertainties with this procedure. First, our experience is that the API joint can capacity formulation is generally conservative even after the safety factor is removed. Second, obviously as the joint cans fail, this will change the internal load distribution. So until the joint can capacity failure and load

redistribution algorithms are incorporated into the pushover analysis program, the simplified procedures for including the effect of joint can failures are at best first pass approximations. We therefore recommend further research in this area which would allow us to incorporate this capability into the ultimate strength analysis programs."

Another participant discussed the joint modeling issue as follows:

"Modeling joint behavior has been a difficult task. Results from past analyses have shown that some of the techniques used gave questionable results (Andrew JIP, Phase I). It has been proposed that joint modeling techniques should be studied carefully with some experimental backup. For these reasons, the joint behavior wa snot considered in the modeling.

- Wave/Current Loads on the Deck

  One participant computed wave-in-deck loads for higher return periods (see Section 3.5.4) and commented as follows:

  "In this analysis we have found that the ultimate strength for the orthogonal directions could vary significantly depending on how these loads are incremented from the 100-year loads to ultimate failure. In addition, these loads become an increasing component of the total base shear for the higher return periods. Therefore, further validation and calibration of the wave impact load algorithm are also important issues.

## 4.4 MISCELLANEOUS INFORMATION FROM PARTICIPANTS

One participant provided the following information in their Part C of Trial Document.

During the trial application, it became apparent that not all of the information required would be easily attainable. The lack of reliable data could affect the results on the assessment of other platforms. A few areas of concern are:

- **Obtaining complete and readable drawings.** For many older platforms, the quality of drawings is not very good.

- **Determining if a structure is grouted or not.** Whether a structure is grouted or not cannot always be determined from the structural drawings. Other evidence such as grout lines (or lack thereof) may be used to determine if a structure is grouted.

- **Determining the pile penetration**. Without adequate pile driving reports, the pile penetration be determined accurately.

- **Determining the soil profile close to the structure**. Many soil boring information logs are not available.

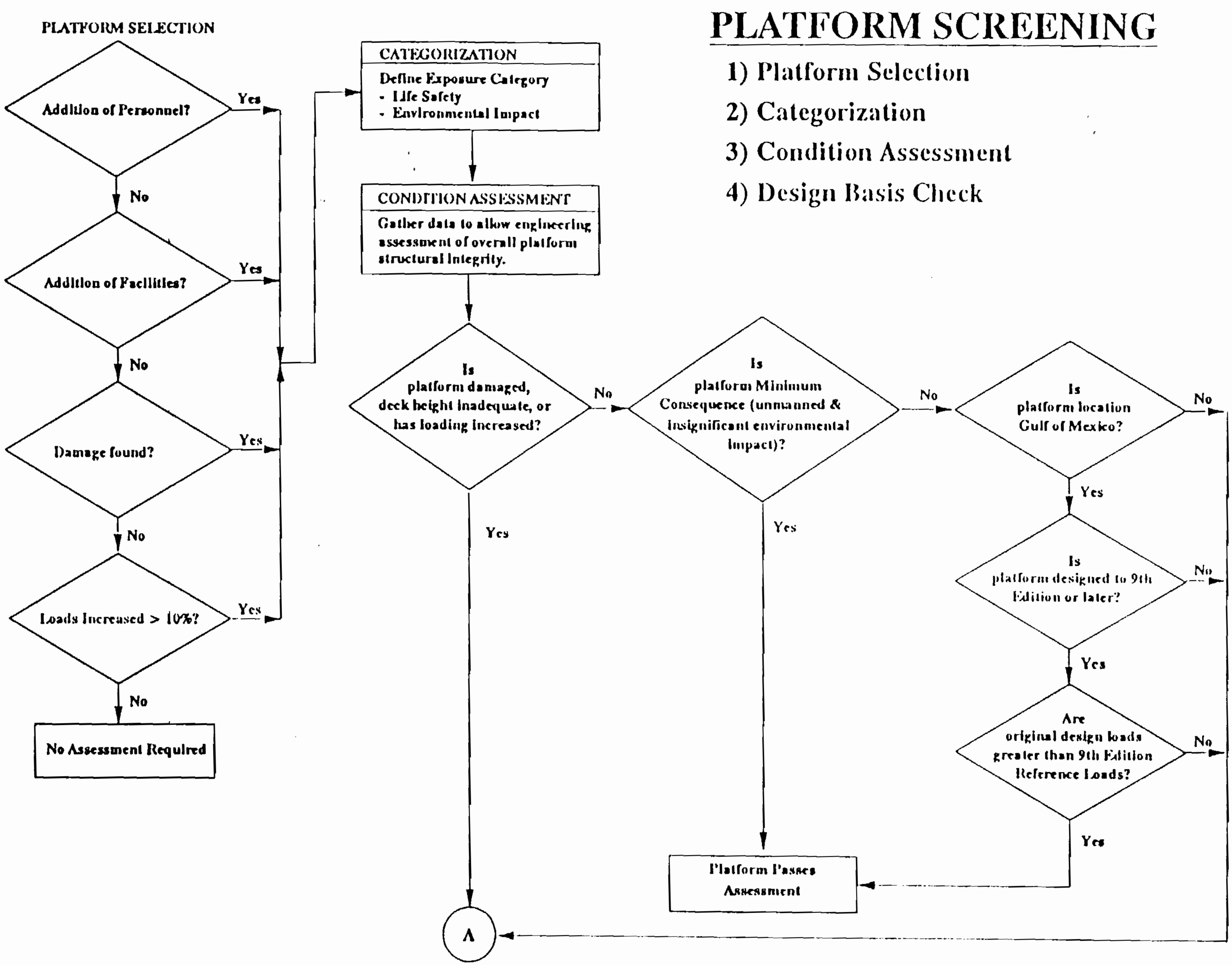

PLATFORM SCREENING
1) Platform Selection
2) Categorization
3) Condition Assessment
4) Design Basis Check
PLATFORM SELECTION
Addition of Personnel?
Addition of Facilities?
Damage found?
Loads Increased > 10%?
No Assessment Required
Yes
No
CATEGORIZATION
Define Exposure Category
- Life Safety
- Environmental Impact
CONDITION ASSESSMENT
Gather data to allow engineering assessment of overall platform structural integrity.
Is platform damaged, deck height inadequate, or has loading increased?
Is platform Minimum Consequence (unmanned & insignificant environmental impact)?
Is platform location Gulf of Mexico?
Is platform designed to 9th Edition or later?
Are original design loads greater than 9th Edition Reference Loads?
Platform Passes Assessment
A

**Figure 4-5**

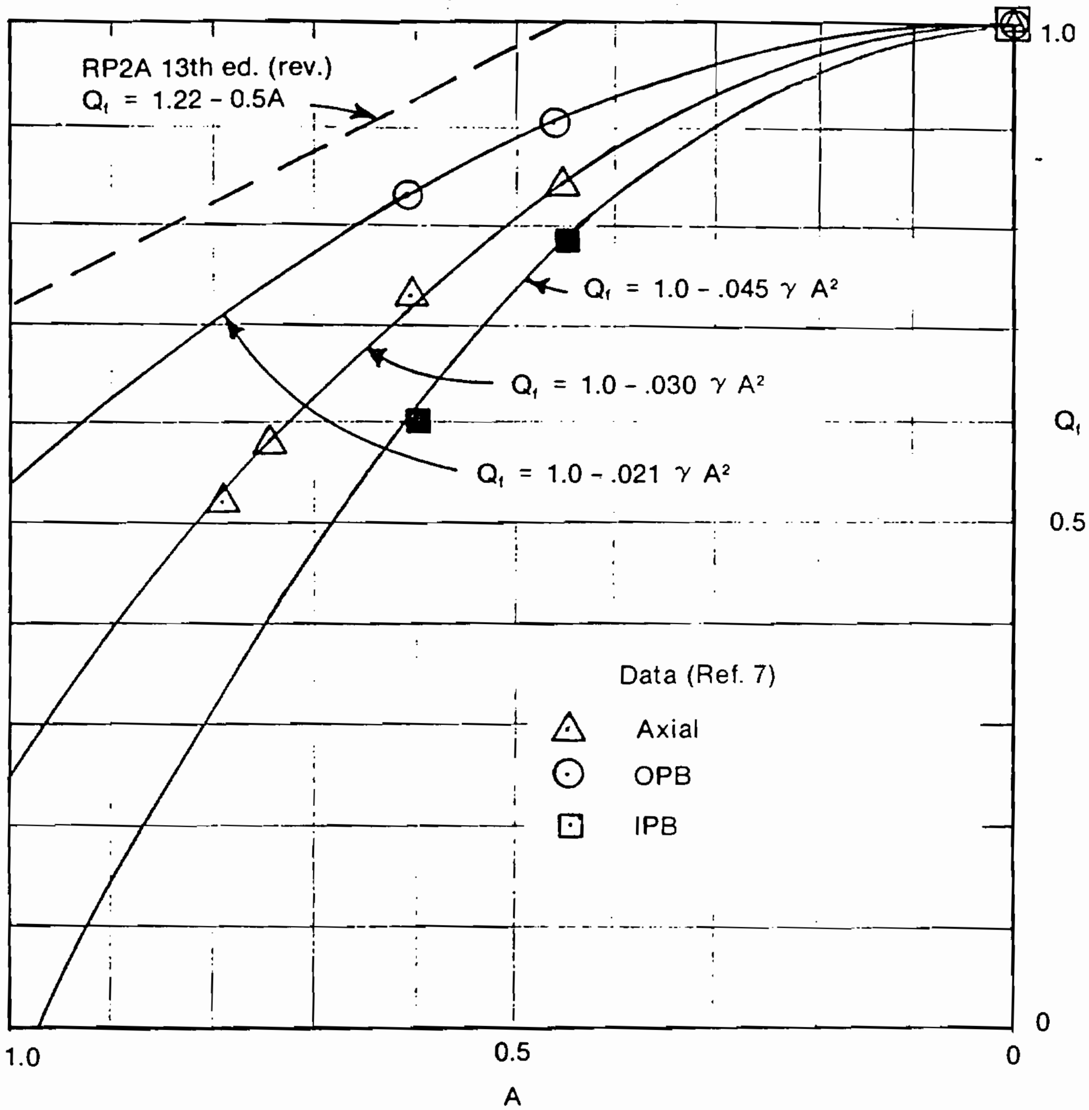
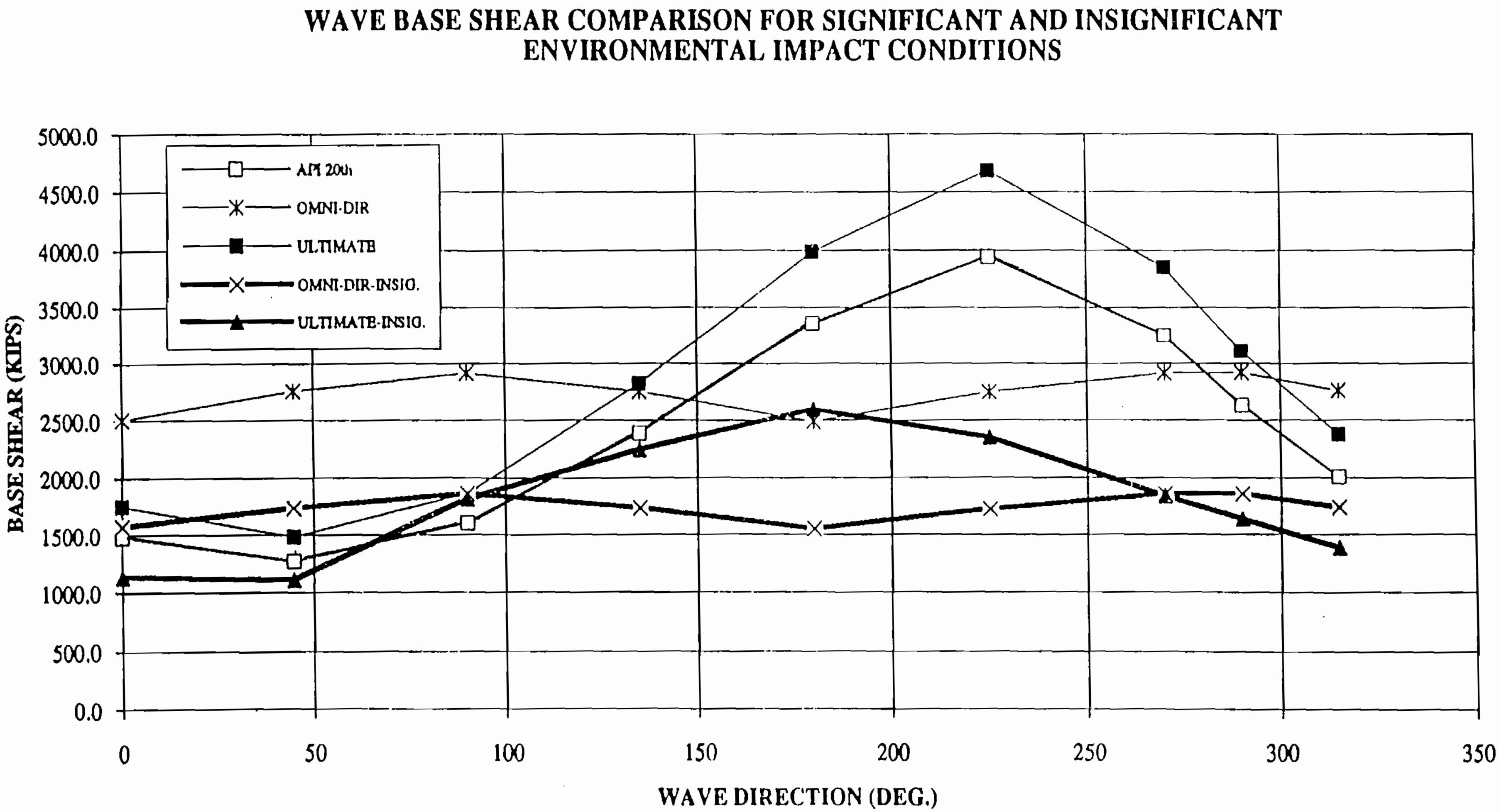



**FIG. C4.3-3**
**CHORD STRESS REDUCTION EFFECTS FOR ALL BRANCH LOAD TYPES WITH SAFETY FACTOR REMOVED**

**Figure 4-6**



WAVE BASE SHEAR COMPARISON FOR SIGNIFICANT AND INSIGNIFICANT ENVIRONMENTAL IMPACT CONDITIONS
BASE SHEAR (KIPS)
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
0
50
100
150
200
250
300
350
WAVE DIRECTION (DEG.)
API 20th
OMNI-DIR
ULTIMATE
OMNI-DIR-INSIG.
ULTIMATE-INSIG.


**Figure 4-1**

WAVE BASE SHEAR RATIO BETWEEN SIGNIFICANT AND INSIGNIFICANT ENVIRONMENTAL IMPACT FOR OMNI-DIRECTIONAL CRITERIA

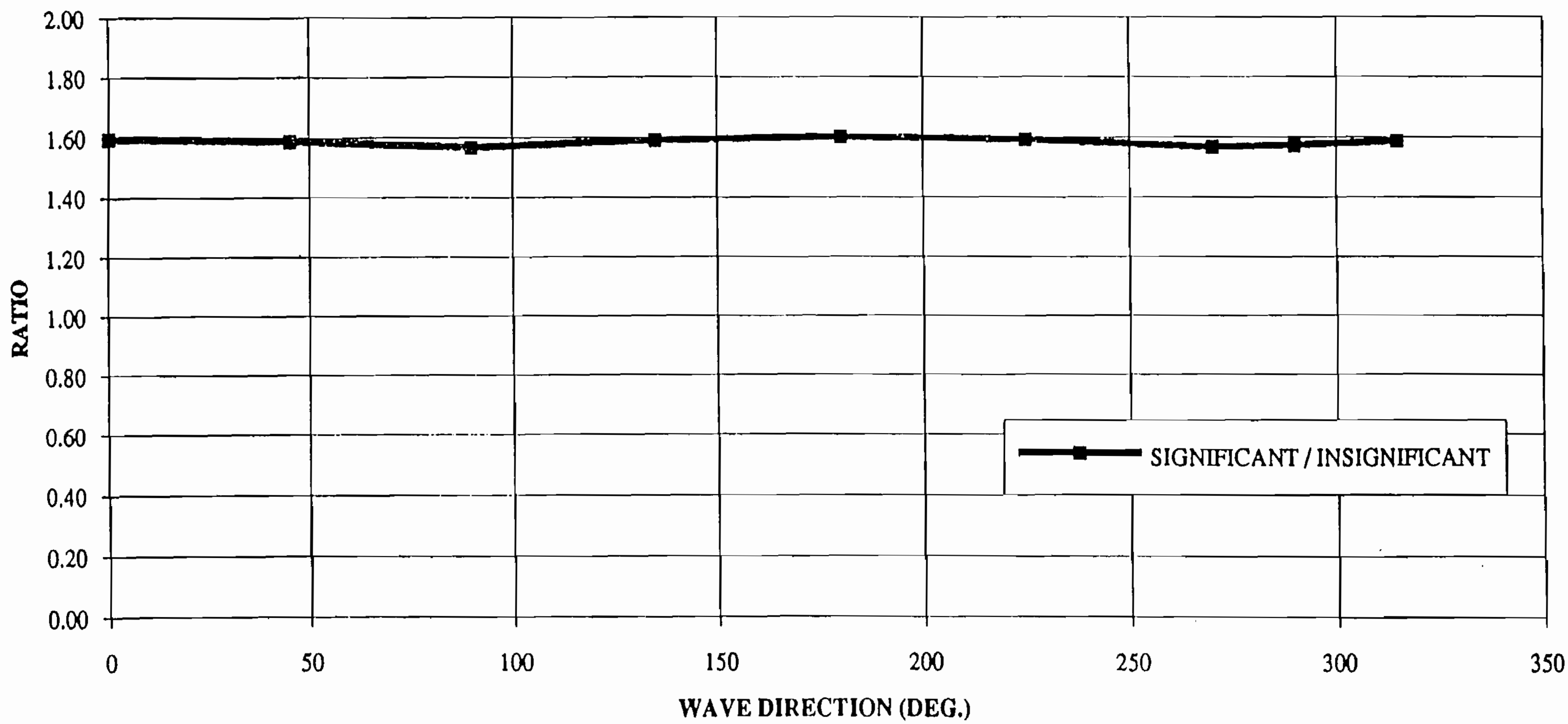



**Figure 4-2**

## WAVE BASE SHEAR RATIO BETWEEN SIGNIFICANT AND INSIGNIFICANT ENVIRONMENTAL IMPACT FOR ULTIMATE STRENGTH CRITERIA

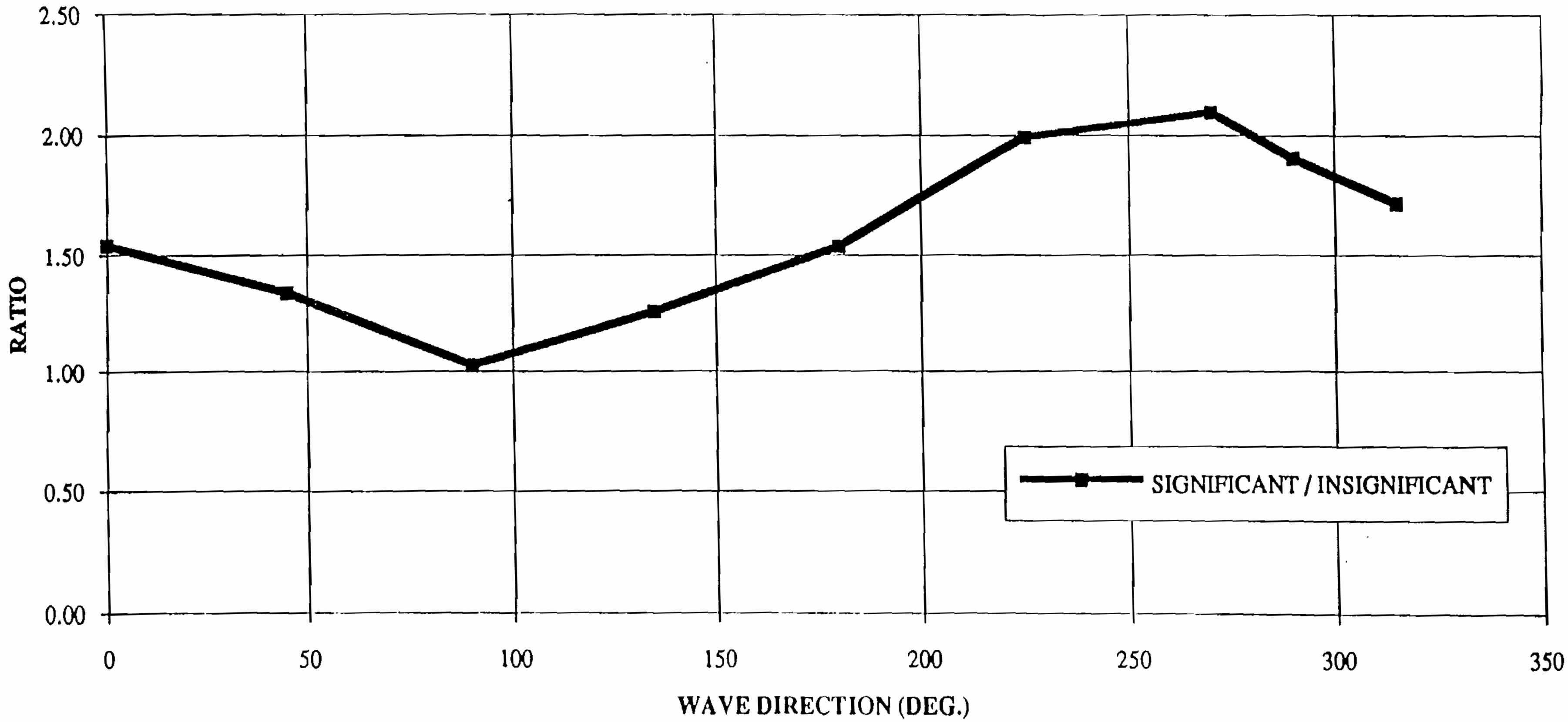



**Figure 4-3**

# PLATFORM ASSESSMENT PROCESS - METOCEAN LOADING

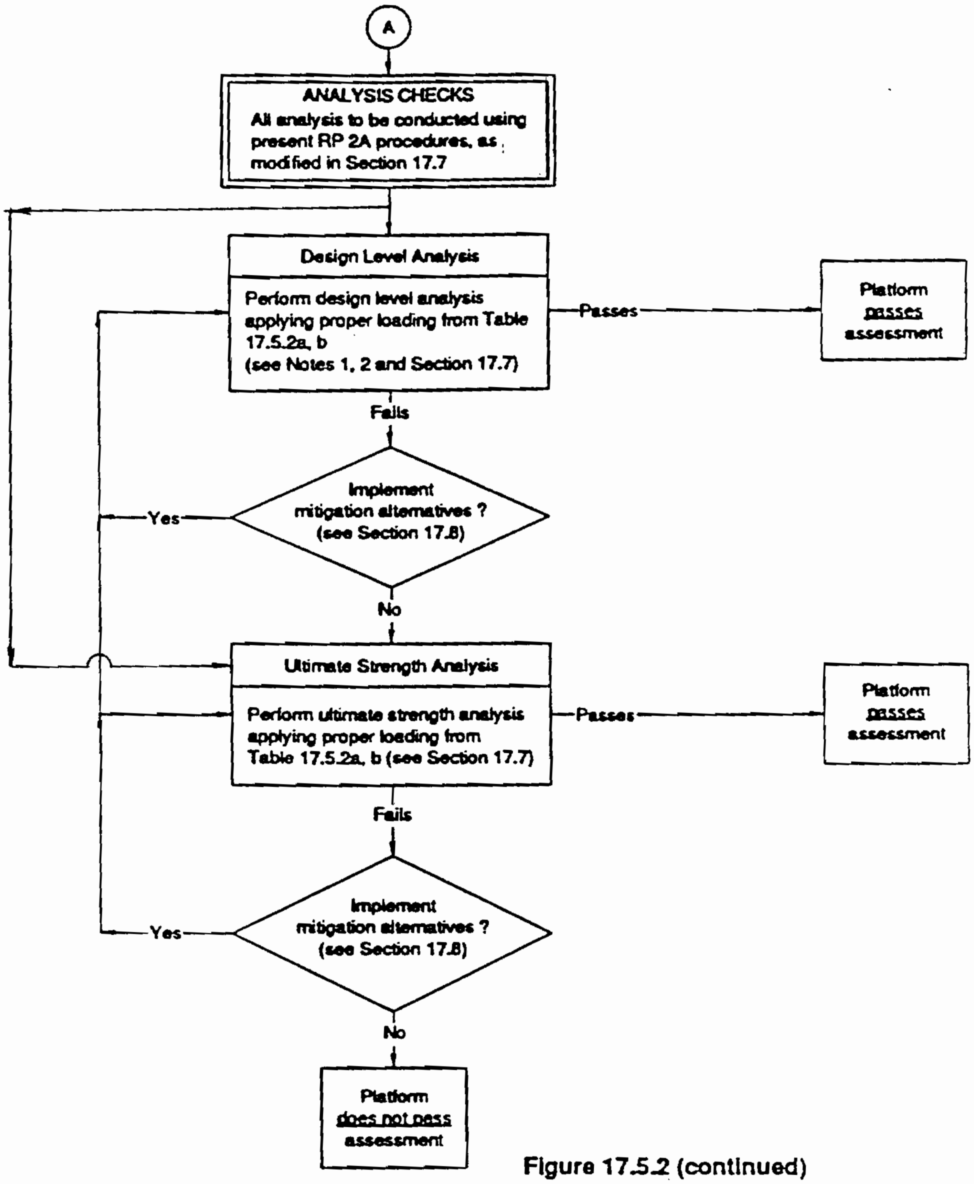



Figure 17.5.2 (continued)

**Figure 4-4**

## Section 5
## Summary and Observations

Twenty two "Trial Application" documents were submitted to the TRIALS JIP. The assessments were performed per API WSD Draft Section 17 and meeting requirements set forth for the Trials JIP. Nineteen platforms (A to S) assessed were located in water depths varying from 37 ft. to 340 ft. and were located in various waters offshore U.S.A., with 16 in the Gulf of Mexico. Their year of original design varied from 1957 to 1982. Three platforms (T, U, V) assessed were in water depths varying from 118 ft. to 161 ft., were installed from 1968 to 1981, and located in other regions, North Sea, Bay of Campache, and Offshore Cameroon. The details of assessment information in the participants submittals were summarized in Section 3.

In general, the project has not attempted to check correctness of the modeling, analysis approach and results. However, where it was clear that an error was made, the values were corrected.

Participants provided a significant amount of written comments to the document as a feedback to the API TG for reviewing and updating the document which are presented in Section 4 in the order of Section 17 sub-sections to facilitate the API TG. The API TG 92-5 response to the participants comments is provided in the Appendix-A. It is organized by Section with no separate comments for Trial and Benchmark participants.

The key observations made from the information presented in the preceding sections are as follows:

**Application of Section 17**

The majority of participants applied Section 17 as required by the project. Design basis checks applicable to the Gulf of Mexico platforms (based on the edition of RP 2A used for the designs) were not provided for platforms G and H, which were designed/redesigned by RP 2A editions later than the 9th edition.

Some participants were not clear of the definition of RSR and used different values in the denominator other than the base shear per the 20th edition reference level criteria.

Some participants were not clear of the pass/fail classification of a platform at the Ultimate Strength Analysis stage. Some of them based it on the RSR (for Gulf of Mexico locations) or the base shear corresponding to the Design Level criteria.

**Selection of Metocean Criteria**

The project did not perform a detailed evaluation of the selected metocean criteria by participants for its correctness. In a few cases, the data provided was not adequate to complete all of the comparison tables contained in this report.

**Hydrodynamic Load Estimates**

The project did not perform a detailed evaluation of the parameters used in development of the hydrodynamic loads. However, Tables 3-7a to 3-7c are presented in such a manner to enable the reader to make general inferences about the pattern of variation of base shear with water depth, number of legs, etc.

The base shear variation among platforms depends upon water depth, wave height, number of legs, conductors, other elements in the wave zone area, and metocean parameters category for a platform. Normally one would expect an increase in base shear with the water depth, but this was not the fact in all cases. This observation indicates that some of the estimates may not be correct.

**Ultimate Strength Analysis**

Various software programs and analysis procedures were used by the participants. Some participants did not use explicit nonlinear pushover analysis programs and instead used conventional linear analysis programs and followed a simplified member replacement approach or only performed analysis up to the failure of first member.

**Pass/Fail Assessment of Platforms**

The final stage pass/fail assessment of a platform for meeting the Section 17 requirements is based on comparison of the Section 17 ultimate load level (consequence dependent) with the ultimate capacity estimate. The ratios of ultimate capacity to the Section 17 ultimate load level are presented in Figure 5-1(a) according to the category of platform.

This figure indicates that three platforms (A, H, and N) clearly do not meet the Section 17 criteria due to their (Ru/S-17) ratio being about 0.59 to 0.85. Platform A is in damaged state.

Three platforms (D, L, P) with (Ru/S-17) ratios between 0.94-0.98 also "fail," but can be said to fall into the "Marginal" category.

Platforms F (4-leg), J (36-leg), K (8-leg), and M (8-leg) have a high ratio (Ru/S-17) exceeding 1.70, and clearly meets Section 17 requirements. The other four platforms (B, C, E, I) have ratio variations between 1.37-1.48 and meet the Section 17 requirements. In these cases only platform B is four-legged and the other three have eight legs.

**Consistency of Pass/Fail Results per Section 17**

The pass/fail information summarized in Table 3-8 for the different assessment levels indicated consistencies in assessment per Section 17. All seven platforms with no assessment initiator triggers "Pass" or are "Marginal cases (D, P)" at the ultimate strength analysis stage.

All platforms that passed the "Design Level Analysis" stage, did pass at the "Ultimate Strength Analysis" stage.

Some participants made their "pass/fail" assessments, which differed from that given in Section 17. Revised wording or additional clarification in the Section 17 document may help reduce such inconsistencies.

**Mitigation Alternatives**

Several participants identified preferred mitigation alternatives for their platforms to improve their meeting Section 17 requirements. Such alternatives included: improved condition assessment of platform, more refined analysis, loading reduction measures, and local and global jacket strengthening measures.

**RSR and Other Ratios for Use by the API TG**

Figure 5-1(b) presents the reserve strength ratios according to the platform category. API TG developed its metocean criteria for different categories based upon specific values of RSR (which are 1.2 for "Full Population" category, 0.8 for "Sudden Hurricane" category, and 0.5 for the "Minimum Consequence" category). For the platforms in seismic areas (offshore Southern California, Cook Inlet) where specific criteria are not given in Section 17, the minimum required RSR against metocean loads or ice loads is 1.6 for the platforms under Significant Environmental Impact category.

This figure indicates that under the Full Population category, two platforms, L (RSR-1.18, 4-leg) and P (RSR-1.12, 8-leg), have RSR's which are marginally lower than 1.2 used by API. Platform P is a special case with a diagonal bracing pattern oriented in the same direction on both longitudinal frames, thus resulting in a lower RSR.

Under the Sudden Hurricane category, only three platforms (A, H, and N) have RSR's lower than 0.8. Four platforms, F (4 legs), M, G, and O (8 legs), have high RSR exceeding

1.5. Platform I has an RSR of 1.3. The RSR varies between 1.0 to 1.2 for four platforms (B with 4 legs; C and E with 8 legs, D with 16 legs).

Under the Minimum Consequence category, platform K (8 legs) has an RSR of 0.94 and platform J (36 legs) has an RSR of 1.46. These are much higher than an RSR of 0.5 on which the criteria was based.

Platform Q (12 leg) being located offshore Southern California has an RSR of 2.4, which is beyond the required minimum of 1.6.

Platform R in Cook Inlet has an RSR of 2.26 against 100-year return period ice loads, thus meeting the required minimum of 1.6.

Tables 3-7a to 3-7e show that most of these platforms have very low redundancy levels with the Redundancy Factor (RF) varying between 1.0 to 1.6. For a majority of platforms the failure of the first member defined the platforms' ultimate capacity estimates for the most critical direction.

**Participants' Feedback to the API TG:**

Significant feedback information was provided by the Trial Applications participants. Participants requested additional clarifications of several terms and further details in some areas. The majority of their comments concerned platform assessment initiators, assessment process, loading criteria, and structural analysis. All of their comments are listed in Section 4.2.1.

Some Benchmark participants who also participated in the Trial Application part gave comments only in one submittal. Therefore, the comments received from all of the Benchmark Analysis participants are included in Section 4.2.2. Other specific observations cited by both participants, such as typographical errors, and miscellaneous information are also provided in Section 4.

Reviewing the participants comments, it seems that further work is required in several areas of the Draft Section 17 and also Section 2 of the API RP 2A (20th edition). The Benchmark Analysis portion of the project indicated a significant inconsistency in selection of the metocean parameters, load and capacity estimates, platform linear stiffness by different companies for a common platform. Inconsistency was also noted is use of terms such as RSR and the resulting "pass/fail" assessments. Revised wording and/or additional clarification in RP 2A may help reduce these problems.

**API TG 92-5 Response to the Participants' Comments**

The response received from the API TG 92-5 (Appendix A) clarifies the various issues raised by the participants. The "correct" metocean criteria and force calculation procedure (Appendix A), identified by the TG92-5 WG3 members, for evaluating the Benchmark platform provides an example and also clarifies some of the participants' questions and comments.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Platform Category | Full Population | 4-Leg | | | L | | | |
| | | 8-Leg | | | P | | | |
| | Sudden Hurricane | 4-Leg | | A, H | | B | | F |
| | | 8-Leg | | N | | E, C, I | | M |
| | | 16-Leg | | | D (#2) | | | |
| | Minimum Consequnce | All | | | | | K | J (#3) |
| | | | <0.5 | 0.5-0.9 | 0.9-1.1 | 1.1-1.5 | 1.5-2.0 | > 2.0 |
| | | | FAILS | | MARGINAL | | PASSES | |

**Ultimate Capacity (Ru) to Section 17 Ultimate Load (S-17) Ratio**

#1: Participants G and O did not provide sufficient information to be included in this figure.
#2: Intentionally used Full Population Critetia for this JIP.
Otherwise, Sudden Hurricane criteria would indicate it in "Pass" category
#3: 36-leg platform

a) Comparison Based on Platform Category, Capacity Ratio and Number of Legs

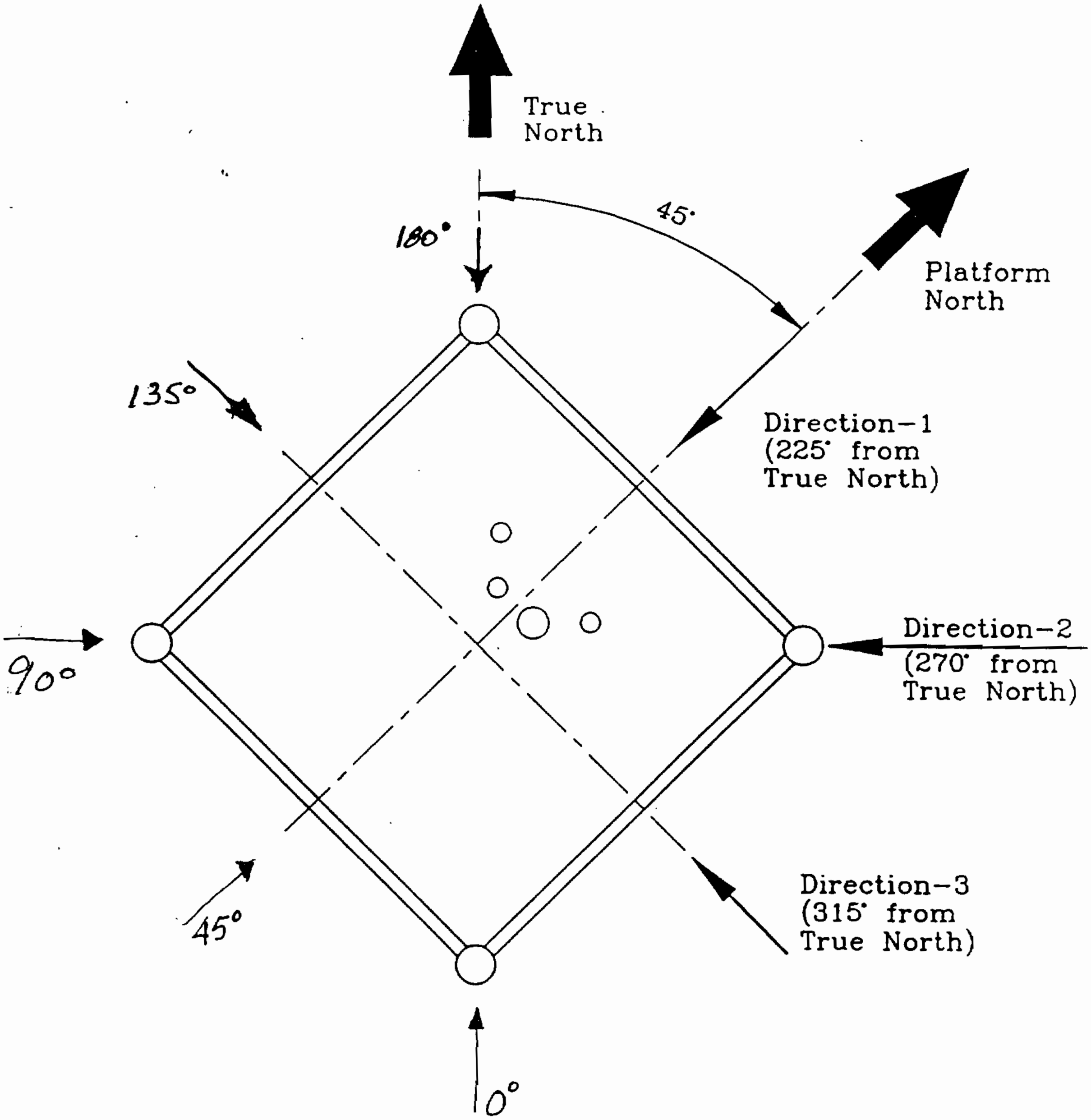
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Platform Category | Full Population | 4-Leg | | | L | | | |
| | | 8-Leg | | | P | | | |
| | Sudden Hurricane | 4-Leg | A | H | B | | F | |
| | | 8-Leg | | N | C, E | I | M | G, O |
| | | 16-Leg | | | D (#1) | | | |
| | Minimum Consequnce | All | | | K | J | | |
| | | | <0.6 | 0.6-0.9 | 0.9-1.2 | 1.2-1.5 | 1.5-1.8 | > 1.8 |

**Reserve Strength Ratio (RSR)**

#1: Intentionally used Full Population Critetia for this JIP.

b) Comparison Based on Platform Category, RSR and Number of Legs

**Figure 5-1: Variations of Minimum RSR and Capacity Ratio for Gulf of Mexico Platforms According to Category**




NOTE: The above three directions are basic directions referred to in the tables and figures. Tables 3-1 to 3-3 indicate normalized directions (with respect to True North) used in participants submittals.

FIG. 1 [redacted] Wave Approach Directions

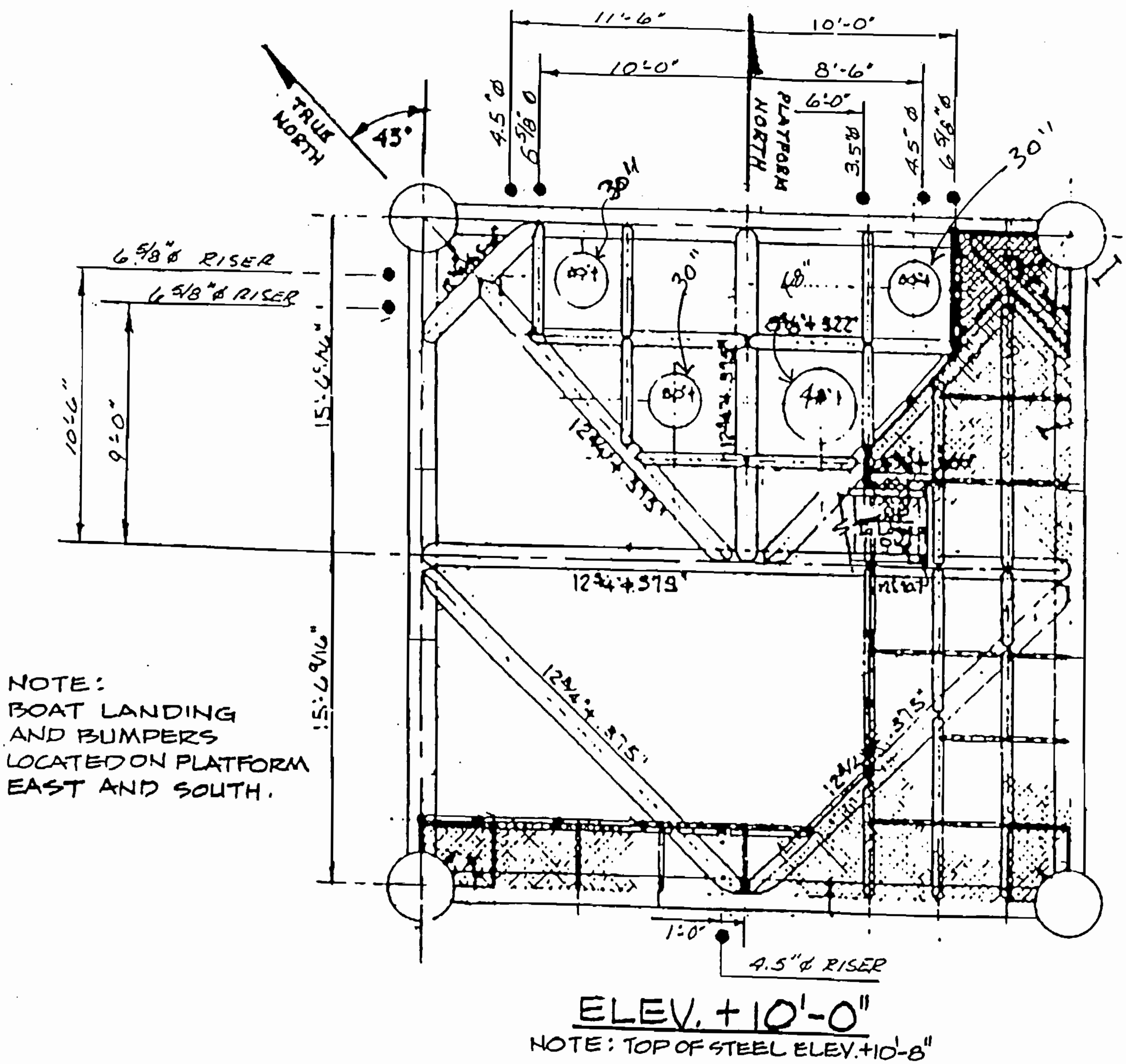



Figure 2[illegible] Key Plan - Benchmark Platform

## Appendix A
## API TG 92-5 Response to Participants' Comments

This appendix provides reponse to the participants' comments summarized in Section 4. The comments received were discussed in brief at the final meeting held on October 18, 1994. The two documents received from the API TG are given in two parts of this Appendix.

Part A.1: API TG 92-5 reply to Trial and Benchmark Participants' Comments on Section 17

Part A.2: Metocean criteria and wave/current force calculation procedures for the Gulf of Mexico PMB Trials JIP Benchmark Platform.

# Appendix A.1

Part A.1: API TG 92-5 reply to Trial and Benchmark Participants' Comments on Section 17

API TG 92-5 REPLY TO
TRIAL AND BENCHMARK PARTICIPANT'S
COMMENTS ON SECTION 17

The Task Group wishes to thank all Participants for their comments and questions. Your input greatly assisted us in finalizing the Draft document and will continue to help in preparing the Final version of Section 17. Our reply is organized by Section with no separate comments for Trial or Benchmark Participants. We have tried to correct all noted typographical errors.

17.1 - GENERAL

1. Section 17 is intended to be and will be an addendum to the 20th Edition of API RP 2A.

2. Participants are directed to the noted references for details on background and philosophy. The main reason for including the complete reference title in the text for this Draft edition is to assist in guiding uses to the right document for any additional information desired.

17.2 - PLATFORM ASSESSMENT INITIATORS

1. The Draft version of Section 17 which will be published by the API shows assessment initiators in Figure 17.5.2 with a question regarding regulatory requirements. The decision to reference assessment initiators, rather than state them explicitly in the flowchart, was based upon space limitations.

2. The question of joint strength is presently being addressed by the API. It is recognized that the API joint strength formulas are in conservative. This was considered in the definition of significant contained in 17.2.6.

3. There is no "defined" significance to the words "must", "shall" and "should".

4. The wording in 17.2.6 is correct.

5. In 17.2.5 we are considering changing the first word "justified" to "judged acceptable" and the phrase "justified as" to "determined to be".

6. The comments regarding Definition of Significant for loading less than 10% which could induce failure of local elements that would in turn lead to overall failure of the platform are being considered for the final version.

17.3 - EXPOSURE CATEGORIES

1. Unmanned bridge-connected structures should not be considered manned unless their failure could be a hazard to any adjacent manned structure. A clarification is planned for the final version.

2. The word not has been added to 17.3.2a.

17.4 - PLATFORM ASSESSMENT INFORMATION - SURVEYS

1. 17.4.3. Soil Data is included here because it is felt that this is one of the important pieces of <u>information</u> required in order to perform an assessment.

17.5 - ASSESSMENT PROCESS

1. The flowchart in Figure 17.5.2 is being changed to read "Design Level Analysis"

2. The statement in 17.6.1 is more precise; however, opinions differ as to the preferred wording. There is currently a reference to Section 17.6 at the end of the first paragraph in 17.5.2.

3. The check to determine if platform damage or increased loading is significant is implicit in the "assessment initiators" diamond, which refers to section 17.2. The comments beginning, "Some analytical work is necessary," are all valid.

4. The criteria for platform assessment, and their basis, are provided in OTC 7482 (1994). For "minimum consequence" platforms, the present practice of accepting undamaged platforms (or platforms with insignificant damage) was adopted. This leads to two levels of acceptance criteria, best explained by example. Referring to Figure 4 in OTC 7482, platform L was found to have a LRF of 0.15. This is less than the 0.30 used as the basis of the US-GOM criteria, per Table 1. Nonetheless, if damage or increased loading was found to be significant relative to the as-built condition (the LRF of 0.15), as a "minimum consequence" platform it would be considered acceptable. This is why a design level analysis of both the existing and as-built structures can be of benefit--checking only against the minimum consequence criteria might result in a platform such as "L" failing the assessment, while checking relative to the "as-built" condition (i.e., performing two design level analyses) may yield the opposite conclusion.

   The advantage of setting an absolute criterion in conjunction with one relative to the as-built condition is that it avoids the following potential inconsistency. If all minimum consequence platforms had to be brought to within 10%, or some other fixed percentage of as-built platform strength, a company could be required to repair platforms that, though damaged, had higher capacity than other older and weaker (though undamaged) platforms. While this might make sense in terms of economic risk, it is not consistent with life or environmental safety assessment.

   This dual basis for acceptance (relative to the as-built condition and to an absolute criterion) is only provided for minimum consequence platforms. Due to changes in design practice over the past forty years, some manned or significant environmental impact platforms which have not suffered either damage or increased loading may fail the design level or ultimate strength assessments. It has been assumed to date that another initiator, either inadequate deck height, a regulatory requirement, or a possible "obsolescence" criterion (being considered) will initiate the assessment of such platforms.

Note: If the only initiator is damage or increased loading which cannot, a priori, be discounted as insignificant, the wording in section 17.2.6 does imply that it would simply be necessary to demonstrate that such changes were in fact "insignificant". However, the intent of those involved with developing acceptance criteria was that all manned or significant environmental impact platforms should meet the criteria in Tables 17.5.2a and b, even if there has been no change in strength from the as-built condition. This could be achieved implicitly, through the design basis check, or explicitly, through design level or ultimate strength analysis.

For increased loading, only a wave loading analysis is necessary. For assessing damage to a platform, structural analysis, at an element level up to a full structural analysis (design level or ultimate strength) is required. Wording in the final version of Section 17 will reflect this.

5. The wording suggested for clarity prior to Section 17.5.2.4 will be incorporated in the final version.

6. Regarding the design basis check; the requirement for platforms to have been designed to the 9th edition or later was based upon both the hydrodynamic loading recipe and the design equations used to ensure adequate member and joint strength. Consequently it is not sufficient just to demonstrate that a platform designed prior to 1977 meets the reference level loading in the 9th edition.

7. The word "requirements" in 17.5.2.3 and 17.5.2.4 refers to the specific requirements listed in the referred procedures (17.7.2 and 17.7.3). There are requirements and exceptions to requirements listed in these procedures.

8. As noted in 17.5.1, the screening of platforms to determine which ones should proceed to detailed analysis is performed by executing the first four components of the assessment process; platform selection, categorization, condition assessment and design basis check. For Seismic and Ice loading this is the screening criteria and is discussed in more detail in OTC 7485 (1994). Greater clarification might have been achieved with the wording "platforms that are not screened out as acceptable for seismic (or ice) loading" may be .....

   Note: Section 17.4 (part of the screening process) requires a Level II survey.

9. Regarding the question on explicit probabilities of failure:

   There are no target criteria specified, nor is there a defined scope for all failure probabilities to include (fire, blast, etc.). The language in the commentary is purposefully vague, placing the burden of justifying the adequacy of criteria upon the owner. The benchmark study has illustrated the variability that can arise when assessing platforms on the basis of estimated ultimate strength, or even based on design level analysis; attempting to provide consistency in assessments based on probability of failure could prove even more challenging. None the less, there are advantages to the probabilistic approach, and there was broad consensus to leave it as an option. However, there was also consensus that probability of failure targets should not be specified without giving extensive guidance as to how the assessment should be performed, and what assumptions are reasonable regarding uncertanity of loading and strength.

## 17.6 - METOCEAN, SEISMIC AND ICE CRITERIA/LOADS

1. Numerous questions regarding metocean criteria were previously addressed by TG 92-5's WG #3 with the answers sent out by PMB in a project update. Those questions and comments will not be addressed here.

2. WG #3 is separately providing the "correct" criteria that should have been used for the benchmark study. This will answer many of the questions noted.

3. Again, Participants are referred to reference #1 from BOSS '94 and OTC papers #7482 and 7485 (1994) for additional details/background on metocean criteria and RSR's.

4. Yes, an ultimate strength analysis is required if the deck height is not adequate. The design level analysis criteria was developed based on experience with structures which did not have any wave in deck loading and is only appropriate for such platforms. The ultimate strength analysis criteria is derived from experience with platforms which experienced wave in deck loading.

## 17.7 - STRUCTURAL ANALYSIS FOR ASSESSMENT

1. Assessment based on prior exposure is allowed for under C17.5.1.3. This method for joint capacity is only appropriate for ultimate strength analysis, not design level analysis.

2. Software validation, while an appropriate desire, is not specifically required in general and is not intended to be a requirement for assessment.

3. The method to be used for ultimate strength analysis is left up to the engineer. If there is any question in his mind as to the adequacy of liniar global analysis or local overload considerations he should proceed to global inelastic analysis. It is likely this Task Group will direct attention to being more specific in some ultimate strength modeling provisions. We felt for this time we had to be general to allow for alternative procedures. With industry experience more guidance will be available, especially in the area of joint capacity.

4. Sufficient static push-over analysis should be performed to determine the MINIMUM RSR.

5. in C17.7.3c.3.g, the phrase "(displacement generally greater than 10% of the pile diameter)" will be deleted in the final version of Section 17.

## Appendix A.2

Part A.2: Metocean criteria and wave/current force calculation procedures for the Gulf of Mexico PMB Trials JIP Benchmark Platform.

Chevron

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P.O. Box 446
La Habra, CA 90633-0446

**API Correspondence**
*TG 95-2 on Platform Assessment*
*WG3 - Environmental Loading*

December 14, 1994

Mr. Frank Puskar
Mr. Rajiv Aggarwal
PMB Engineering Inc.
500 Sansome Street
San Francisco, California 94111

Gentlemen:

Enclosed is a report from WG3 containing the "correct" metocean criteria and force calculation procedures for evaluating the Gulf of Mexico Trials JIP Benchmark Platform. The assessment criteria are based on API RP2A-WSD 20th Edition, Draft Section 17, Assessment of Existing Platforms, June 28, 1994. These criteria have been checked for accuracy by TG 95-2 WG3 members.

Metocean criteria and force calculation procedures are provided for each of eight principal directions (with respect to the platform). The criteria and procedures are for 20th edition design forces, and Section 17 design level and ultimate strength analyses. The method used to arrive at the criteria is described in enough detail so that the basis for the numbers would be clear.

We understand that these criteria will be used by a number of participants to recalculate the base shears in the JIP final report. WG3 asks that each participant highlight the steps where they differ from the given criteria and send comments in writing to WG3, who will then transmit the information to the Wave Force Task Group (being reinstated) for their use in clarifying the 20th edition and Section 17 wave force recipes. Specifically we would like to know what each of the participants used for: (1) wave height, (2) current, (3) storm tide, (4) wave period, (5) wind speed, (6) marine growth, (7) wave kinematics factor, (8) current blockage factor, (9) current profile, (10) drag and inertia force coefficients for both rough and smooth members, (11) wave theory, and (12) conductor shielding factor. Some of this information has been already provided in the JIP report. The Wave Force Task Group would like to receive all pertinent information.

Although there is room for specifying differing criteria because of misinterpretation of intent and acceptable range on parameter values, the effect on base shear should be small and would not result in the large range of base shears that resulted in the JIP. Nevertheless some improvements can be made towards clarification of the procedures. With your information, the Wave Force Task Group will amend the text of the 20th edition and Section 17 to provide for, hopefully, more uniform results on base shear when different personnel use the documents.

Very truly yours,

C. Petrauskas

C. Petrauskas
Team Leader, WG3 of TG 95-2

enc: As noted above

cc w/enc:
- WG3 Members
- Jim Bole (Amoco, Tulsa)
- Kris Digre (Shell Offshore, Houston)
- Allan Reece (Shell Development, Houston
- Roger Thomas (Phillips, Bartlesville)
- Dave Wisch (Texaco, Bellaire)

# METOCEAN CRITERIA AND WAVE/CURRENT FORCE CALCULATION PROCEDURES THE GULF OF MEXICO PMB TRIALS JIP BENCHMARK PLATFORM

**C. Petrauskas (for WG3 of TG 95-2)**

Tue, Dec 6, 1994

## INTRODUCTION

The platform is located in the Gulf of Mexico at 28° 27' N latitude and 91° 20' W longitude (Ref 1). The water depth at the platform location is 157 ft (Ref 2). The platform has four legs, and is oriented so that the diagonal directions are north/south and east/west. Various analyses were required by the Trials JIP using the API RP2A WSD 20th ed wave forces (Ref 3).

This report defines the appropriate metocean criteria and wave force calculation procedures to arrive at the platform base shears that are consistent with the intent of (a) the guideline 20th edition design forces in Ref 3 and (b) Section 17 design level and ultimate strength significant-environmental-impact forces in Ref 4. The results are given for all eight principal platform directions, although only three principal platform directions (Fig 1) were used by most participants.

## API RP2A-WSD 20TH EDITION CRITERIA AND FORCES

### Wave Heights

The platform is located in a region for which 20th ed metocean criteria are applicable (Ref 3, Fig 2.3.4-2). The water depth is assumed to be equal to Mean-Lower-Low-Water (MLLW). The omnidirectional wave height is 63 ft (Ref 3, Fig 2.3.4-3).

Wave heights, as a function of the required (for force calculations) wave direction, are given in Table 1, column 2. The wave heights were obtained by using the guideline design factors given in Ref 3, Fig 2.3.4-4, and taking into account that the factors apply to the guideline design direction ± 22.5° (Ref 3, Sec 2.3.4c3). Interpolation should not be used.

## Storm Tide

The storm tide is 3.5 ft (Ref 3, Fig 2.3.4-7) for all directions. This is the sum of storm surge and astronomical tide. The storm water depth for the benchmark platform is 160.5 ft (157 ft + 3.5 ft).

## Current

The current associated with the wave height for any given direction is a vector quantity and will depend on storm water depth (MLLW + storm tide) and longitude. The depth of 160.5 ft places the current in the "Intermediate Zone" (Ref 3, Sec 2.3.4c4). To obtain the surface current, linear interpolation is needed between the "Shallow Water Zone" and "Deep Water Zone" currents. The procedure for interpolation is given by example in Ref 3, p. 123, "Commentary on Hydrodynamic Force Guidelines, Section 2.3.4". Note that the example only provides the steps for a wave direction of 290°. Such an interpolation has to be carried for all eight required directions given in Table 1. From a practical point of view, the 160.5 ft water depth is sufficiently close to the depth of 150 ft at the shallow-water-zone/intermediate zone boundary, that interpolation may not be necessary. However, for completeness, the interpolation was carried out for all eight directions.

### *"Shallow Water Zone" Current*

The longitude of the platform is 91.33°. The surface current is a vector with a magnitude of 2.1 kts (3.55 fps). Its direction, based on Ref 3, Fig 2.3.4-5, is 280°. For interpolation, the water depth is taken as 150 ft.

### *"Deep Water Zone" Current*

In deep water only the component of the current in the direction of the wave is important, the transverse current is negligible. According to Ref 3, Sec 2.3.4c4 the magnitude of the surface current in the principal wave direction (290°) is 2.1 kts. The magnitudes of the current for the rest of the wave directions, given in Ref 3, Fig 2.3.4-4, are obtained by applying, to the 290° current, the same factor that is applied to the wave heights. This current is assumed to apply to the given direction ± 22.5°. For interpolation, the water depth is taken as 300 ft.

## REFERENCES

1. PMB Engineering, Trials JIP, Benchmark Analysis, Revision 2, April 12, 1994

2. PMB Engineering, Trials JIP, Benchmark Analysis, Draft Final Report, September, 1994

3. American Petroleum Institute, Recommended Practice 2A-WSD (RP 2A-WSD), Twentieth Edition, July 1, 1993

4. American Petroleum Institute, Recommended Practice 2A-WSD (RP 2A-WSD), Twentieth Edition, Draft Section 17, Assessment of Existing Platforms, June 28, 1994

Tables 1 - 3
Figures 1 - 2

## TABLE 1 (revised 11Dec94)

## Guideline Design Metocean and Wave Force Criteria for Gulf of Mexico Benchmark Platform, MLLW=157', Static Analysis, 20th Ed API RP2A

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Wave Dir (deg. towards, clockwise from North) | Wave Height (ft) | Inline Current (kts) | Transverse Current (kts) | Inline Current (kts) | Storm Tide (ft) | Wave Period (sec) | Apparent Wave Period (sec) | Wind Speed (1-hr@10m) (kts) |
| 90.0 | 44.1 | -1.82 | 0.34 | 0.20 | 3.5 | 13.0 | 13.1 | 80.0 |
| 45.0 | 44.1 | -1.02 | 1.60 | 0.20 | 3.5 | 13.0 | 13.1 | 80.0 |
| 0.0 | 53.6 | 0.46 | 1.92 | 0.46 | 3.5 | 13.0 | 13.2 | 80.0 |
| 315.0 | 59.9 | 1.74 | 1.12 | 1.74 | 3.5 | 13.0 | 13.7 | 80.0 |
| 270.0 | 63.0 | 2.07 | -0.34 | 2.07 | 3.5 | 13.0 | 13.8 | 80.0 |
| 225.0 | 56.7 | 1.25 | -1.60 | 1.25 | 3.5 | 13.0 | 13.5 | 80.0 |
| 180.0 | 47.3 | -0.23 | -1.92 | 0.20 | 3.5 | 13.0 | 13.1 | 80.0 |
| 135.0 | 44.1 | -1.50 | -1.12 | 0.20 | 3.5 | 13.0 | 13.1 | 80.0 |

| | |
|---|---|
| Marine Growth | Thickness = 1.5" (from + 1.0 ft to -150.0 ft) |
| Wave Kin. Factor | 0.88 |
| Current Blockage Factor | 0.80 for end-on and tranverse directions<br>0.85 for diagonal directions |
| Current Profile | Uniform over the water column |
| Force Coeff. | If Umo*Tapp/D ≥ 30 use default values, otherwise consult Commentary<br>Umo = maximum horizontal velocity at storm water level<br>Tapp = apparent wave period<br>D = platform leg diameter at storm water level<br>Default values are: Cd(smooth) = 0.65, Cd(rough) = 1.05,<br>Cm(smooth) = 1.6, and Cm(rough) = 1.2 |
| Wave Theory | Select wave theory from Fig. 2.3.1-3, or use appropriate order of other equivalent theory, such as Chappelear or Velocity Potential |
| Conductor Shielding Factor | Use 1.0 because there are only four conductors and the spacing is irregular |

used if an appropriate order of solution is selected.

**Design Level Conductor Shielding Factor**

Ignore shielding (shielding factor = 1.0) because there are only four conductors and the spacing is irregular.

**Ultimate Strength Wave Heights**

The omnidirectional wave height is 68 ft (Ref 4, Fig 17.6.2-2a).

Wave heights, as a function of the required (for force calculations) wave direction, are given in Table 3, column 2. The wave heights were obtained by applying the same factors that were applied to arrive at the 20th ed wave heights.

**Ultimate Strength Storm Tide**

The storm tide is 3.0 ft (Ref 4, Fig 17.6.2-2a) for all directions. This is the sum of storm surge and astronomical tide. The storm water depth is 160 ft (157 ft + 3.0 ft).

**Ultimate Strength Current**

The appropriate surface current is given in Table 3, column 5. The currents were obtained using the same procedure that was used for the 20th ed currents. The current magnitude is 2.3 kts (Ref 4, Table 17.6.2-1) as opposed to the 2.1 kts for the 20th ed.

The current profile is uniform over the water column (Ref 3, Fig 2.3.4-6).

**Ultimate Strength Wave Periods**

Tapp is given in Table 3, column 8. It is based on the inline current in column 5 and is calculated using Ref 3, Fig 2.3.1-2.

**Ultimate Strength Wind Speed**

The one-hour wind speed at an elevation of 10 m is 65 knots (Ref 4, Table 17.6.2-1).

### Ultimate Strength Marine Growth

The thickness is 1.5" and extends from +1 ft to -150 ft (Ref 3, Sec 2.3.4d2).

### Ultimate Strength Wave Kinematics Factor

For hurricanes the wave kinematics factor is 0.88 (Ref 3, Sec 2.3.4d1).

### Ultimate Strength Current Blockage Factor

The platform has four legs and is considered to be a "typical" jacket-type structure. The current blockage factor is 0.80 for end-on and broadside directions and 0.85 for diagonal directions (Ref 3, Sec 2.3.1b4). The blockage factor should be applied to the inline current given in Table 2, column 5.

### Ultimate Strength Force Coefficients

For the Trials JIP benchmark platform, it is assumed that default values of force coefficients apply for all load cases. The default values are: Cd(smooth) = 0.65, Cd(rough) = 1.05, Cm(smooth) = 1.6, and Cm(rough) = 1.2.

The applicability of default values will be further addressed by the API Task Group on Wave Force Commentary and a clarification will be provided for the 21st ed of RP2A.

### Ultimate Strength Wave Theory

The appropriate wave theory should be selected from Ref 3, Fig 2.3.1-3. Other wave theories such as Extended Velocity Potential and Chappelear may be used if an appropriate order of solution is selected.

### Ultimate Strength Conductor Shielding Factor

Ignore shielding (shielding factor = 1.0) because there are only four conductors and the spacing is irregular.

### Wave Theory

The appropriate wave theory should be selected from Ref 3, Fig 2.3.1-3. Other wave theories such as Extended Velocity Potential and Chappelear may be used if an appropriate order of solution is selected.

### Conductor Shielding Factor

Ignore shielding (shielding factor = 1.0) because there are only four conductors and the spacing is irregular.

## SECTION 17 SIGNIFICANT ENVIRONMENTAL IMPACT CRITERIA AND FORCES

### Design Level Wave Heights

The omnidirectional wave height is 55 ft (Ref 4, Fig 17.6.2-2a).

Wave heights, as a function of the required (for force calculations) wave direction, are given in Table 2, column 2. The wave heights were obtained by choosing, for each direction, the lower value of the 55-ft wave height vs the 20th ed wave height.

### Design Level Storm Tide

The storm tide is 3.0 ft (Ref 4, Fig 17.6.2-2a) for all directions. This is the sum of storm surge and astronomical tide. The storm water depth is 160 ft (157 ft + 3.0 ft).

### Design Level Current

The appropriate surface current is given in Table 2, column 5. The currents were obtained by choosing, for each direction, the lower value of 1.6 kts (Ref 4, Table 17.6.2-1) vs the 20th ed current.

The current profile is uniform over the water column (Ref 3, Fig 2.3.4-6).

### Design Level Wave Periods

Tapp is given in Table 2, column 8. It is based on the inline current in column 5 and is calculated using Ref 3, Fig 2.3.1-2.

### Design Level Wind Speed

The one-hour wind speed at an elevation of 10 m is 65 knots (Ref 4, Table 17.6.2-1).

### Design Level Marine Growth

The thickness is 1.5" and extends from +1 ft to -150 ft (Ref 3, Sec 2.3.4d2).

### Design Level Wave Kinematics Factor

For hurricanes the wave kinematics factor is 0.88 (Ref 3, Sec 2.3.4d1).

### Design Level Current Blockage Factor

The platform has four legs and is considered to be a "typical" jacket-type structure. The current blockage factor is 0.80 for end-on and broadside directions and 0.85 for diagonal directions (Ref 3, Sec 2.3.1b4). The blockage factor should be applied to the inline current given in Table 2, column 5.

### Design Level Force Coefficients

For the Trials JIP benchmark platform it is assumed that default values of force coefficients apply for all load cases. The default values are: Cd(smooth) = 0.65, Cd(rough) = 1.05, Cm(smooth) = 1.6, and Cm(rough) = 1.2.

The applicability of default values will be further addressed by the API Task Group on Wave Force Commentary and a clarification will be provided for the 21st ed of RP2A.

### Design Level Wave Theory

The appropriate wave theory should be selected from Ref 3, Fig 2.3.1-3. Other wave theories such as Extended Velocity Potential and Chappelear may be

### *Interpolated Current at Platform Location*

The interpolated inline and transverse currents for a water depth of 160.5 ft is given in Table 1, columns 3 and 4, respectively. A negative inline current means that the inline component of the current opposes the wave. A negative transverse current is the transverse component that is directed clockwise with respect to the inline component.

In performing the interpolation we noted that the example in the Commentary is not consistent with the intent in the main text. Specifically, the check on whether or not the inline current is ≥ 0.2 kts should be performed <u>after</u> interpolation, not <u>prior</u> to interpolation as implied by the Commentary. From a practical point of view the sequence will not be too important for the most forceful waves. However, for consistency, and validity of forces for all directions, the check should be performed <u>after</u> interpolation. The example will be corrected in the upcoming 21st ed.

### *Current for Design Guideline Forces*

The appropriate surface current for calculating the 20th ed design guideline forces is given in Table 1, column 5. This is the same as the inline current in column 3, except it is modified to make sure that the speed is ≥ 0.2 kts (see Ref 3, Sec 2.3.4c4). The current profile is uniform over the water column (Ref 3, Fig 2.3.4-6).

The author believes that it is sufficient to use the inline current for analysis. However it is acceptable to include the transverse component of the current, given in column 4, provided the specified vector current is consistent with the inline component given in column 5. This issue will receive further attention by the API Task Group on Wave Force Commentary and a clarification will be provided for the 21st ed of RP2A.

## Wave Periods

The wave period is 13 sec for all directions (Ref 3, Section 2.3.4c5). This is the period measured at a fixed point. For the purpose of obtaining wave kinematics that may be superimposed on the inline current, the apparent wave period (Tapp, period measured in a coordinate system with the wave) is needed. Tapp is given in Table 1, column 8. It is based on the inline current in column 5 and is calculated using Ref 3, Fig 2.3.1-2.

## Wind Speed

The one-hour wind speed at an elevation of 10 m is 80 knots (Ref 3, Section 2.3.4c7).

## Marine Growth

The thickness is 1.5" and extends from +1 ft to -150 ft (Ref 3, Sec 2.3.4d2).

## Wave Kinematics Factor

For hurricanes the wave kinematics factor is 0.88 (Ref 3, Sec 2.3.4d1).

## Current Blockage Factor

The platform has four legs and is considered to be a "typical" jacket-type structure. The current blockage factor is 0.80 for end-on and broadside directions and 0.85 for diagonal directions (Ref 3, Sec 2.3.1b4). The blockage factor should be applied to the inline current given in Table 1, column 5.

## Force Coefficients

Design waves for the Gulf of Mexico, that are associated with the most forceful directions, are usually sufficiently high so that default values of the force coefficients will apply. For other directions, the waves may be small enough that the force coefficients need to consider wake encounter effects. However, these directions may not control the design.

A simple measure of whether or not default values are applicable is Umo*Tapp/D, where Umo is the maximum horizontal velocity at storm water level and D is the diameter of platform leg at the storm water level (see Ref 3, Sec 2.3.1b7). If Umo*Tapp/D ≥ 30, default values apply; otherwise one needs to consult the Commentary for appropriate coefficients. Default values of the coefficients are: Cd(smooth) = 0.65, Cd(rough) = 1.05, Cm(smooth) = 1.6, and Cm(rough) = 1.2.

**TABLE 2 (revised 11Dec94)**

## Significant Environmental Impact Design Level Metocean and Wave Force Criteria for Gulf of Mexico Benchmark Platform, MLLW=157', Static Analysis

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Wave Dir (deg. towards, clockwise from North) | Wave Height (ft) | Inline Current (kts) | Transverse Current (kts) | Inline Current (kts) | Storm Tide (ft) | Wave Period (sec) | Apparent Wave Period (sec) | Wind Speed (1-hr@10m) (kts) |
| 90.0 | 44.1 | 1.6 | NA | 0.20 | 3.0 | 12.1 | 12.2 | 65.0 |
| 45.0 | 44.1 | 1.6 | NA | 0.20 | 3.0 | 12.1 | 12.2 | 65.0 |
| 0.0 | 53.6 | 1.6 | NA | 0.46 | 3.0 | 12.1 | 12.3 | 65.0 |
| 315.0 | 55.0 | 1.6 | NA | 1.60 | 3.0 | 12.1 | 12.6 | 65.0 |
| 270.0 | 55.0 | 1.6 | NA | 1.60 | 3.0 | 12.1 | 12.6 | 65.0 |
| 225.0 | 55.0 | 1.6 | NA | 1.25 | 3.0 | 12.1 | 12.5 | 65.0 |
| 180.0 | 47.3 | 1.6 | NA | 0.20 | 3.0 | 12.1 | 12.2 | 65.0 |
| 135.0 | 44.1 | 1.6 | NA | 0.20 | 3.0 | 12.1 | 12.2 | 65.0 |

| | |
|---|---|
| Marine Growth | Thickness = 1.5" (from + 1.0 ft to -150.0 ft) |
| Wave Kin. Factor | 0.88 |
| Current Blockage Factor | 0.80 for end-on and tranverse directions<br>0.85 for diagonal directions |
| Current Profile | Uniform over the water column |
| Force Coeff. | Use default values<br>Default values are: Cd(smooth) = 0.65, Cd(rough) = 1.05,<br>Cm(smooth) = 1.6, and Cm(rough) = 1.2 |
| Wave Theory | Select wave theory from Fig. 2.3.1-3, or use appropriate order of other equivalent theory, such as Chappelear or Velocity Potential |
| Conductor Shielding Factor | Use 1.0 because there are only four conductors and the spacing is irregular |

## TABLE 3 (revised 11Dec94)

### Significant Environmental Impact Ultimate Strength Metocean and Wave Force Criteria for Gulf of Mexico Benchmark Platform, MLLW=157', Static Analysis

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Wave Dir (deg. towards, clockwise from North) | Wave Height (ft) | Inline Current (kts) | Transverse Current (kts) | Inline Current (kts) | Storm Tide (ft) | Wave Period (sec) | Apparent Wave Period (sec) | Wind Speed (1-hr@10m) (kts) |
| 90.0 | 47.6 | -2.01 | 0.37 | 0.20 | 3.0 | 13.5 | 13.6 | 85.0 |
| 45.0 | 47.6 | -1.12 | 1.76 | 0.20 | 3.0 | 13.5 | 13.6 | 85.0 |
| 0.0 | 57.8 | 0.50 | 2.11 | 0.50 | 3.0 | 13.5 | 13.7 | 85.0 |
| 315.0 | 64.6 | 1.90 | 1.23 | 1.90 | 3.0 | 13.5 | 14.2 | 85.0 |
| 270.0 | 68.0 | 2.27 | -0.37 | 2.27 | 3.0 | 13.5 | 14.4 | 85.0 |
| 225.0 | 61.2 | 1.37 | -1.76 | 1.37 | 3.0 | 13.5 | 14.0 | 85.0 |
| 180.0 | 51.0 | -0.26 | -2.11 | 0.20 | 3.0 | 13.5 | 13.6 | 85.0 |
| 135.0 | 47.6 | -1.65 | -1.23 | 0.20 | 3.0 | 13.5 | 13.6 | 85.0 |

| | |
|---|---|
| Marine Growth | Thickness = 1.5" (from + 1.0 ft to -150.0 ft) |
| Wave Kin. Factor | 0.88 |
| Current Blockage Factor | 0.80 for end-on and tranverse directions<br>0.85 for diagonal directions |
| Current Profile | Uniform over the water colum |
| Force Coeff. | Use default values<br>Default values are: Cd(smooth) = 0.65, Cd(rough) = 1.05, Cm(smooth) = 1.6, and Cm(rough) = 1.2 |
| Wave Theory | Select wave theory from Fig. 2.3.1-3, or use appropriate order of other equivalent theory, such as Chappelear or Velocity Potential |
| Conductor Shielding Factor | Use 1.0 because there are only four conductors and the spacing is irregular |

## Appendix B
## Participants' Inquiries up to the Progress Meeting

This appendix provides the written inquiries received from the participants up to the Progress Meeting held on June 7, 1994. The inquiries received were re-organized according to the topics and were discussed at the Progress Meeting.

A copy of the response to some of the comments concerning environmental loading provided by Dr. Chuck Petrauskas and Mr. Tim Finnigan of Chevron Petroleum is also included.

For more discussion refer to Section 4.1 of this report.

Part B.1: Participants' Inquiries up to the Progress Meeting.

Part B.2: Response by Dr. Chuck Petrauskas and Mr. Tim Finnigan.

# Appendix B.1

Part B.1: Participants' Inquiries up to the Progress Meeting.

## TRIAL APPLICATIONS

## PARTICIPANT QUERIES

- **Platform Assessment Process**

  — Does Not Clearly Indicate, which platform to assess.

Question

A

  — If deck height is inadequate, it says to do analysis check.

  — Section 17.6: If wave is in the deck, do ultimate capacity analysis directly.

B
- **Consequence Based Metocean Criteria/ Loads**

  — There are 4 Different Wave Heights ?

  — Wave Height be Based on 20th Edition ?

  — Current value same ?

  — Wave Height same for all directions?

C
- **Wave-in-Deck Force Procedure (Section C17.6.2)**

  — What is the basis? Clarifications requested.

  — Cd Values for Wave-in-Deck Case ?

## TRIAL APPLICATIONS - PARTICIPANT QUERIES

## CONSEQUENCE BASED METOCEAN CRITERIA/ LOADS

D 5. Table 17.6.2 -1 specifies the wave height and current to be used for the various analysis types and conditions. For the Design Level, Hurricane condition, the wave height and current is either as specified in the table or API 20th whichever is smaller. Is the case of the wave height this is a fairly straightforward decision. However, for the current no guidance is given for intermediate and shallow water depths regarding direction and magnitude and how to determine which is more critical. To solve this problem, our approach was to vary the 57 ft. and 1.6 kts current around the platform and to compare the wave shears to the corresponding shears for the 20 the Edition, new design cases. The design wave load for each wave direction was chosen based upon the minimum between the Section 17 and new design. Do we need to add further guidance to this section as to how to resolve the current comparison problem?

E 6. Should new design effects such as conductor shielding, current blockage and Doppler shift be used for calculating wave loads on the structure using Section 17 criteria?

# TRIAL APPLICATIONS - PARTICIPANT QUERIES

# CONSEQUENCE BASED METOCEAN CRITERIA/ LOADS

F • Item 3 of Subsection 17.6.2a on Page 12: Based on what wave heights are the wave forces generated for Figure 17.6.2-1? Why are the same wave forces being applied to all exposure categories?

G • Are there any minimum wave height criteria for Figures 17.6.2-2a, 17.6.2-3a and 17.6.2-5a as the water depth approaching zero?

H • Are there any minimum deck height criteria for Figures 17.6.2-2b, 17.6.2-3b and 17.6.2-5b as the water depth approaching zero?

I • Item 4a of Subsection 17.6.2a on Page 22: Please clarify the second sentence of the second paragraph in this page. The statement of "for some non-critical directions" is not clear to us. As we do not know what directions of wave loadings govern the platform integrity, how are they defined as non-critical? It appears that orientations of the structures e.g. tripods would play a critical role in the decision.

J In this same paragraph, it describes that the current profile is given in Section 2.3.4c.4. Please illustrate how this profile could be applied for a water depth of 90 feet.

K • In reference to Table 17.6.2-1 and Figure 17.6.2-4 for wave and current direction, please clarify the recommended procedure to determine the wave heights for wave directions that fall in between those eight principal directions as given in Figure 17.6.2-4.

# TRIAL APPLICATIONS - PARTICIPANT QUERIES

# CONSEQUENCE BASED METOCEAN CRITERIA/ LOADS

Questions and Comments on the draft section 17.0 - Assessment of Existing Platforms

L 1) Section 17.6.2a Gulf of Mexico

4. Design Level and Ultimate Strength Analyses

a. Significant Environmental Impact/Manned, Evacuated or Unmanned

(p. 22)

"For design level analysis, omni-directional criteria are specified. -----"

The definition of "omni-directional criteria" should be further explained. I believe it means that constant wave height will be applied to all directions.

The last sentence of second paragraph of page 22 read as " The wave period, storm tide, and wind speed apply to all directions" but no wave height was mentioned. In reference to OTC paper 7484, Fig 5, it seems that the omni direction means constant wave height in all wave directions.

M 2) Section 17.6.2a Gulf of Mexico

1. Metocean Systems :

(p. 11)

" --- , a directional spreading factor of 0.88 should be used for hurricanes and 1.0 for winter storms"

In RP 2A, the term of "wave kinematics factor" is used instead of "directional spreading factor" (see RP 2A 20th edition page 30). It seems that directional spreading factor implies that the factor is directional dependent, such as shown in Fig.2.3.4-4 of RP 2A 20th edition. To be consistent with RP 2A, the term of "wave kinematics factor" might be used instead of "directional spreading factor" in Section 17.0.

# TRIAL APPLICATIONS - PARTICIPANT QUERIES

## WAVE LOAD IN DECK PROCEDURE

N

Item C17.6.2 on Page 33: Is it correct that the deck force procedure was developed by measuring forces in wave tank tests using deck floors that were "completely framed" with deck stringers of shaped sections? Were the major deck girders built out of wide shape sections as well? Were these deck floors plated or grated? And would there be a difference in their wave force calculations?

O

Item C17.6.2 on Page 34: In the middle of the page, it reads, "For lightly framed sub-cellar deck sections with no equipment, ....". We suggest that it should be revised to read as "For lightly framed sub-cellar deck *or any other deck* sections with no equipment, ....".

In the same paragraph, it mentions that "Deck legs and bracing members below the bottom of the cellar deck should be modeled along with jacket members ......". Where is the bottom of the cellar deck? Does this imply that the members in the cellar deck elevation need not be modeled, and otherwise that would be double dipping?

P

Please confirm that this Subsection C.17.6.2 addresses deck floors that are made up of rolled shape sections or built-up sections. We are also interested to address problems of deck sections that are constructed with tubulars only and which will be submerged into the wave during extreme design wave conditions. Please clarify if lower values given in Table C.17.6.2-1 could be used for "tubular deck framings".

# TRIAL APPLICATIONS - PARTICIPANT QUERIES

# PLATFORM ASSESSMENT PROCESS

Please reference the attached detailed flow chart for the platform assessment process as contained in Section 17 (Metocean loading only). This flow chart represents our best effort at understanding the requirements of Section 17 and your comments are appreciated. In addition we have the following questions:

1. It is our understanding that all existing Gulf of Mexico platforms will be required to undergo a Platform Screening (Ref. Flow Chart, p. 1 of 4). Is this correct?

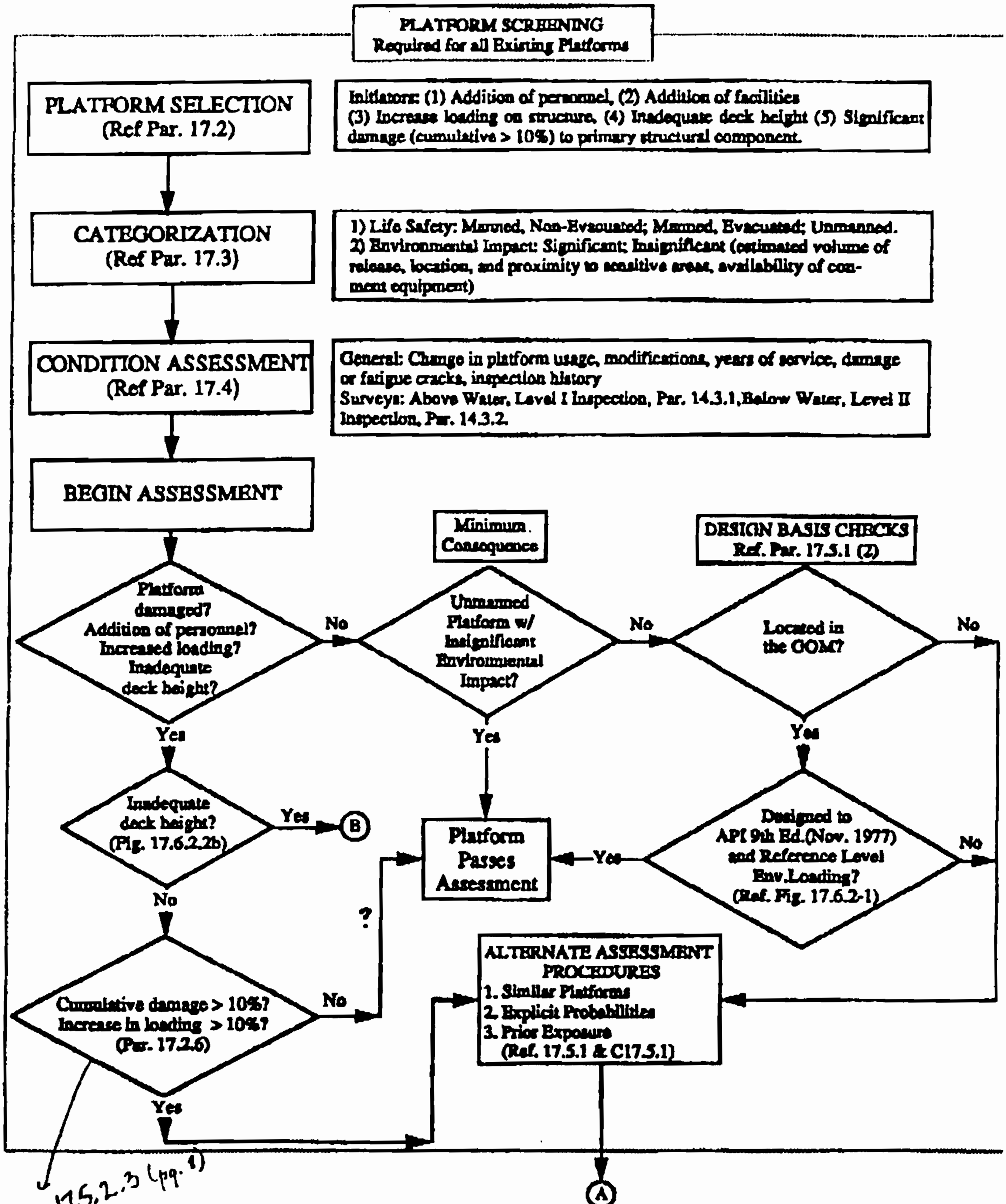
2. Assuming the answer to 1. above is yes, then it appears that it will be necessary to perform a Design Level Check (as a minimum) on all platforms designed prior to API 9th Edition (1977). Is this correct?

3. From Pars. 17.2.6 and 17.5.2(3) it appears that one way of determining if the damage is significant would be to compare the critical wave shear of the as-built platform (no overstresses) to that of the damaged platform (no overstresses) allowing for an adequate reduction in capacity of the damaged member(s). Since other solutions could be proposed for making a comparison, would it be advisable for some wording to be added to Par. 17.2.6 which would clarify the comparison method to be used?

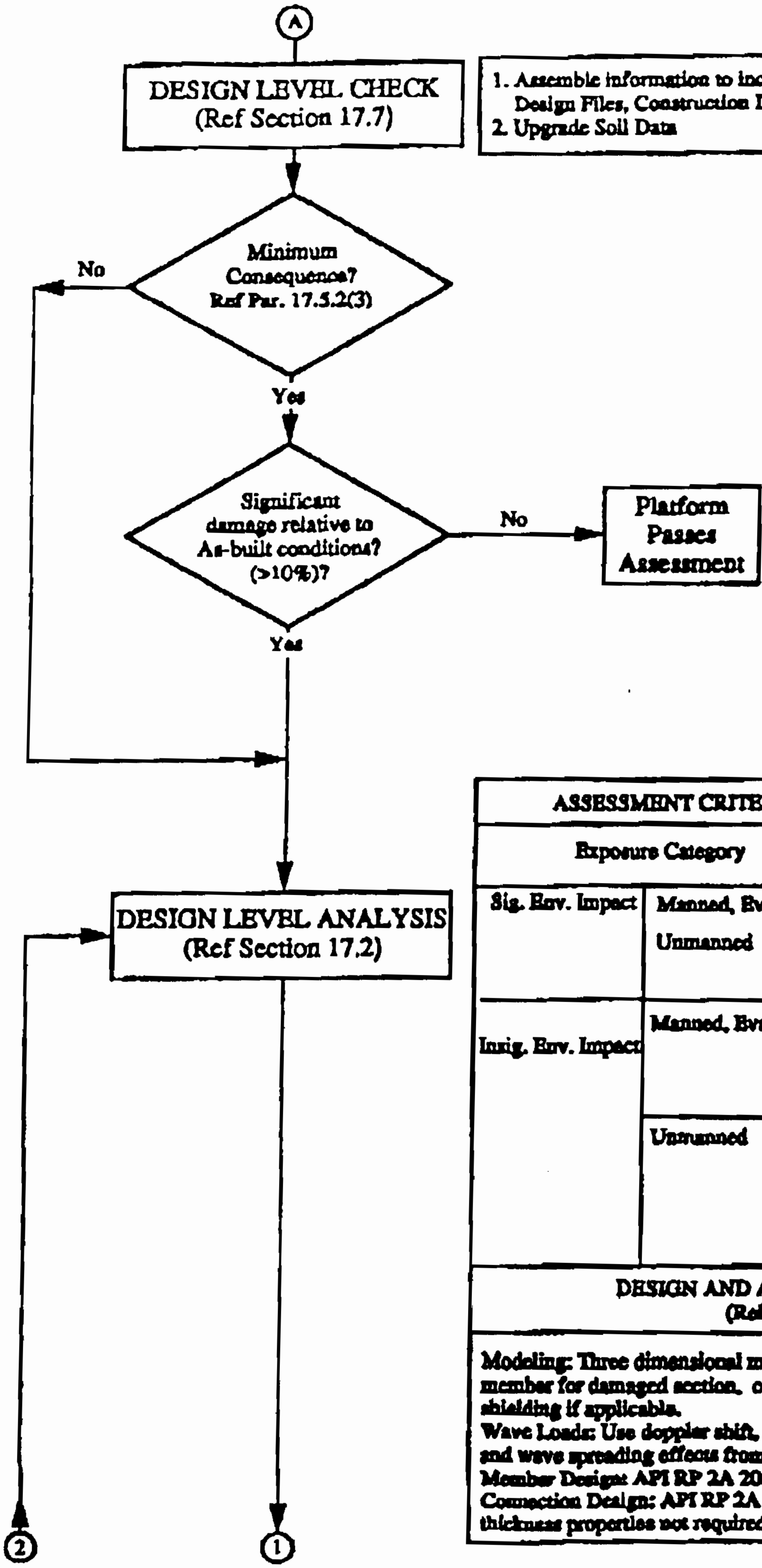
4. Why is it necessary to have a "Significant Damage" check in Par. 17.5.2(3) when this has been covered in the Screening portion? In addition, why is the "Significant Damage" check in Par. 17.5.2(3) limited to Minimum Consequence platforms only? Does this Minimum Consequence rule apply to Par. 17.2.5 as well?

5 For the case where the deck height is to low, Section 17 calls for the designer to proceed directly to an Ultimate Strength Analysis without doing a Design Level Analysis. In this case a fatigue check may be required but at present no wording for a fatigue check is included in the Ultimate Strength Analysis section. Does this need to be included?

# PLATFORM ASSESSMENT PROCESS
# METOCEAN LOADING FLOW CHART
# GULF OF MEXICO




see 17.5.2.3 (pg. 4)

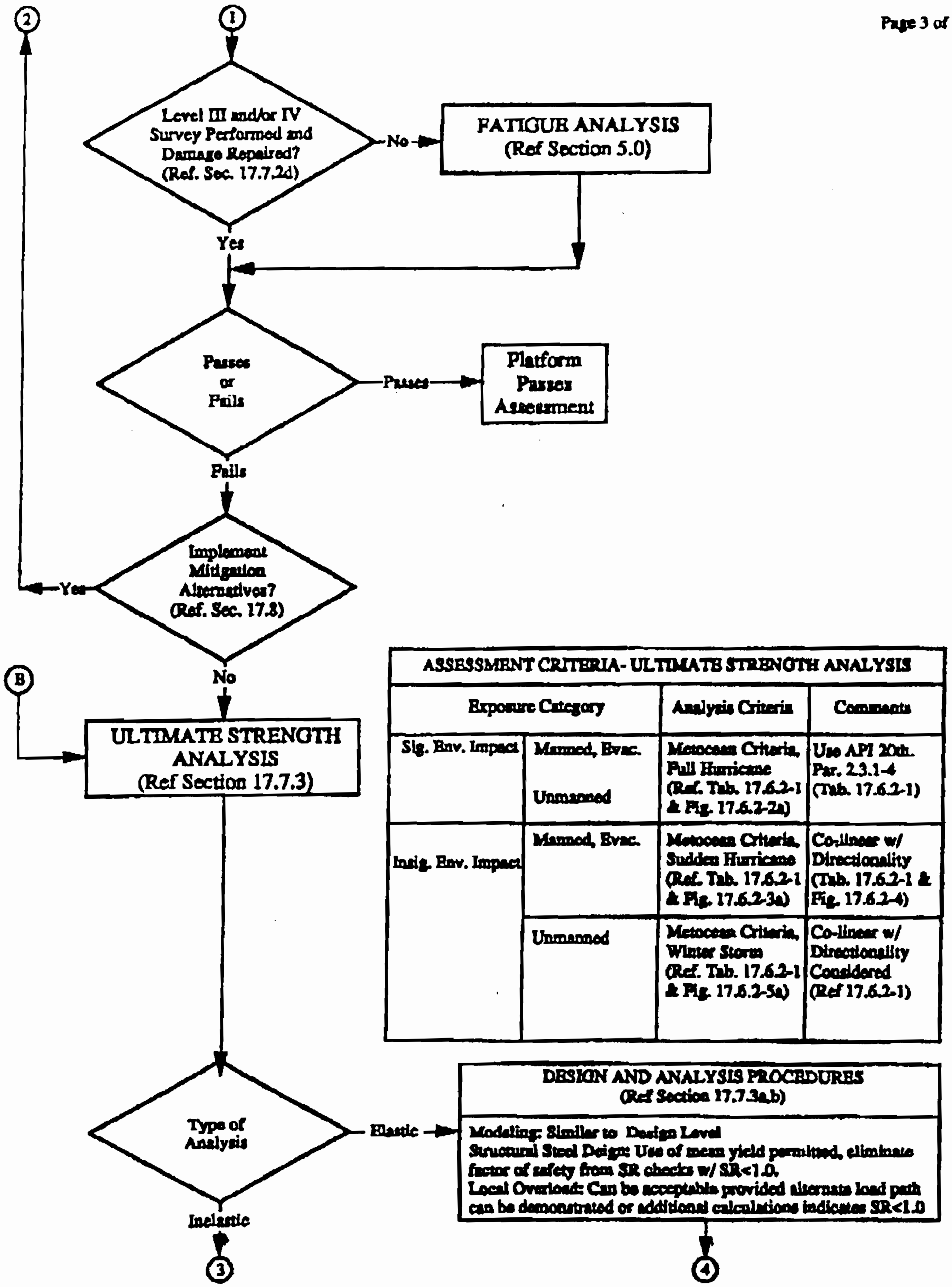



1. Assemble information to include: General Information, Original Criteria and Design Files, Construction Data, Platform History and Present Condition.
2. Upgrade Soil Data

| ASSESSMENT CRITERIA - DESIGN LEVEL ANALYSIS | | | |
|---|---|---|---|
| Exposure Category | | Analysis Criteria | Comments |
| Sig. Env. Impact | Manned, Evac.<br>Unmanned | Metocean Criteria, Full Hurricane (Ref. Tab. 17.6.2-1 & Fig. 17.6.2-2a) | Omni-directional and Co-linear, use 20th if less (Tab. 17.6.2-1) |
| Insig. Env. Impact | Manned, Evac. | Metocean Criteria, Sudden Hurricane (Ref. Tab. 17.6.2-1 & Fig. 17.6.2-3a) | Omni-directional and Co-linear, use Ult. if less (Tab. 17.6.2-1) |
| | Unmanned | Metocean Criteria, Winter Storm (Ref. Tab. 17.6.2-1 & Fig. 17.6.2-5a) | Omni-directional and Co-linear (Tab. 17.6.2-1) |

**DESIGN AND ANALYSIS PROCEDURES**
**(Ref Section 17.7.4)**

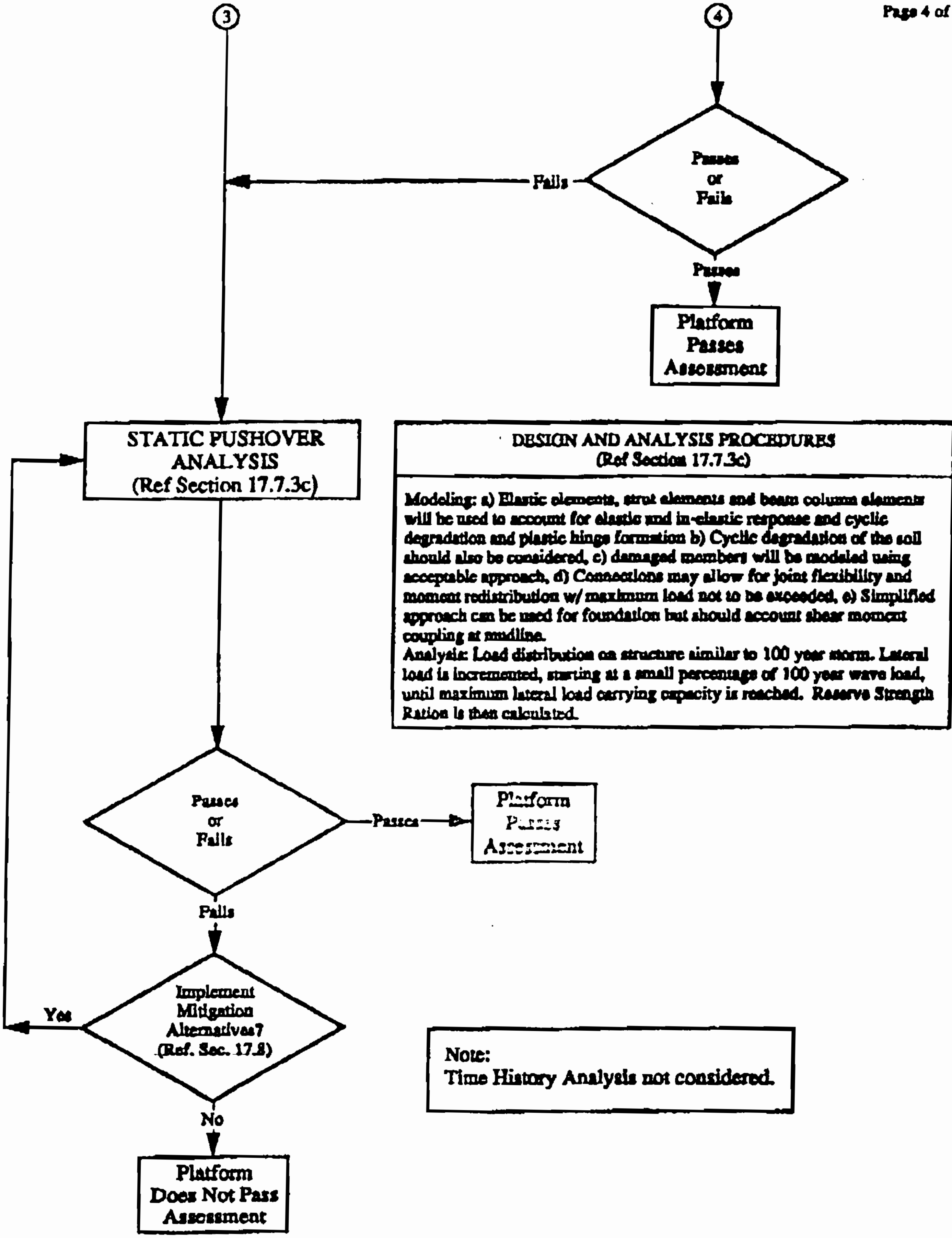
**Modeling:** Three dimensional model, linear elements w/ equivalent member for damaged section. conductors as foundation elements, shielding if applicable.
**Wave Loads:** Use doppler shift, current blockage, conductor shielding, and wave spreading effects from API 20th. (Par 2.3.1-4)
**Member Design:** API RP 2A 20th Edition
**Connection Design:** API RP 2A 20th Edition except 50% checks, through thickness properties not required on joint cans.




| ASSESSMENT CRITERIA- ULTIMATE STRENGTH ANALYSIS | | | |
|---|---|---|---|
| Exposure Category | | Analysis Criteria | Comments |
| Sig. Env. Impact | Manned, Evac.<br>Unmanned | Metocean Criteria, Full Hurricane (Ref. Tab. 17.6.2-1 & Fig. 17.6.2-2a) | Use API 20th. Par. 2.3.1-4 (Tab. 17.6.2-1) |
| Insig. Env. Impact | Manned, Evac. | Metocean Criteria, Sudden Hurricane (Ref. Tab. 17.6.2-1 & Fig. 17.6.2-3a) | Co-linear w/ Directionality (Tab. 17.6.2-1 & Fig. 17.6.2-4) |
| | Unmanned | Metocean Criteria, Winter Storm (Ref. Tab. 17.6.2-1 & Fig. 17.6.2-5a) | Co-linear w/ Directionality Considered (Ref 17.6.2-1) |

**DESIGN AND ANALYSIS PROCEDURES**
**(Ref Section 17.7.3a,b)**

**Modeling:** Similar to Design Level
**Structural Steel Deign:** Use of mean yield permitted, eliminate factor of safety from SR checks w/ SR<1.0.
**Local Overload:** Can be acceptable provided alternate load path can be demonstrated or additional calculations indicates SR<1.0


3
4
Passes
or
Fails
Fails
Passes
Platform
Passes
Assessment
STATIC PUSHOVER
ANALYSIS
(Ref Section 17.7.3c)
DESIGN AND ANALYSIS PROCEDURES
(Ref Section 17.7.3c)
Modeling: a) Elastic elements, strut elements and beam column elements will be used to account for elastic and in-elastic response and cyclic degradation and plastic hinge formation b) Cyclic degradation of the soil should also be considered, c) damaged members will be modeled using acceptable approach, d) Connections may allow for joint flexibility and moment redistribution w/ maximum load not to be exceeded, e) Simplified approach can be used for foundation but should account shear moment coupling at mudline.
Analysis: Load distribution on structure similar to 100 year storm. Lateral load is incremented, starting at a small percentage of 100 year wave load, until maximum lateral load carrying capacity is reached. Reserve Strength Ration is then calculated.
Passes
or
Fails
Passes
Platform
Passes
Assessment
Fails
Implement
Mitigation
Alternatives?
(Ref. Sec. 17.8)
Yes
No
Platform
Does Not Pass
Assessment
Note:
Time History Analysis not considered.

## TRIAL APPLICATIONS - PARTICIPANT QUERIES

## STRUCTURAL ANALYSIS FOR ASSESSMENT

3) Section 17.7.3 Ultimate Strength Analysis Procedures

(p.26)

a. The ultimate strength of undamaged members, joints and piles may be established using the formulas of Sections 3, 4, 6 and 7 with all safety factors removed (i.e. a safety factor of 1.0). ----

In some formulas, the safety factor terms are explicitly shown, therefore, it would not be misinterpreted. However, in other formulas, such as hydrostatic strength check, the safety factors in part implicitly built in the formula. Consequently, it could be subjected to different interpretation by the designers. It is suggested that some guidance should be provided in the commentary to address these problems.

4) Section 17.7.3c. Global Inelastic Analysis

(p.27)

3. Modeling - Element Types

e. Damaged/Corroded Elements : Damaged/corroded members or joints shall be modeled accurately to represent their ultimate and post ultimate strength and deformation characteristics. Finite element and/or fracture mechanics analysis may be justified in some instances.

The research and testing of the capacity of dent members have been undertaken for more than a decade. Especially, the JIP project in Lehigh, which has generated valuable results and presented in OTC papers. It would be appropriate that some guidance should be provided in the commentary (such as residual strength check equations) or refer to some practical papers.

# Appendix B.2

Part B.2: Response by Dr. Chuck Petrauskas and Mr. Tim Finnigan.

**Response to Participants Questions, PMB JIP on Trial Application of API Platform Assessment Procedures**

C. Petrauskas and T. D. Finnigan, Chevron Petroleum Technology Co.

Mon, Jun 6, 1994

The following responses are our own and do not necessarily reflect the consensus of API TG 92-5. The responses are indexed to the questions, copies of which are attached. All responses refer to metocean criteria and wave force questions(see PART B.1).

Responses

A. The two statements with respect to what analysis needs to be done are consistent. The flowchart leads to "analysis check" , which in turn leads to "design level analysis". Note that the "design level analysis" box refers to "Note 1" which states that a design level analysis is not applicable for platforms with an inadequate deck height. This then leads to "ultimate strength analysis", unless mitigation is implemented. In Section 17.6, it simply states that an ultimate strength analysis needs to be done if the deck height is not adequate.

B. All criteria for Gulf of Mexico are defined in Table 17.6.2-1. There are three exposure categories, two sets of criteria for each exposure category, and the criteria are specified for eight wave directions, although for some cases the criteria are omnidirectional. All forces should be calculated using the procedures according to the 20th ed.

C. The basis for wave-in-deck force calculation procedures are a set of wave tank tests on a 1:28 scale model of an offshore platform in which various deck configurations were modeled. See OTC 94 Paper 7484 for further discussion.

D. The use of base shears to arrive at the design level analysis loads is consistent with the intent of the assessment criteria. Arriving at wave heights and currents on the basis of a comparison of 20th ed values vs the omnidirectional values, as defined in Table 17.6.2-1, was meant to be a simplification for the analysis because at most eight load cases need to be run. When a structure barely meets the design level analysis criteria then whether one uses base shear or the metocean criteria as a basis could make a difference. Otherwise, both procedures should lead to the same result as to whether the structure fails or passes. It is important that in the trial JIP all potential inconsistencies be documented with examples so that the need for modifications to the assessment procedure can be properly addressed.

The interpolation procedure for currents is described in the 20th ed, page xxx, Section xxx; an example is provided in the commentary on page xxx. The current for the 20th ed is 2.1 knots. To obtain the current for assessments which call for directional criteria, such as the ultimate strength analysis for full population hurricanes and sudden hurricanes, the same interpolation procedure and current profile applies, except that the current magnitude is different; 2.3 knots for full population hurricanes and 1.8 knots for sudden hurricanes. For omnidirectional criteria the current is the same for all water depths and is used inline with the wave. The profile is specified according to the 20th ed.

E. Yes. All elements of the 20th ed force recipe should be used.

F. As stated in Section 17.6.2a.3, the forces are consistent with reference level forces of the 9th ed, which are based on the reference level wave heights in that edition. The same wave forces are applied to all exposure categories because if the force criteria are satisfied (together with other provisions as defined in Section 17.5.2) then the platform will pass because the assessment metocean criteria for the most severe case is consistent with design loads using the 9th ed.

G and H. No because special studies need to be made to define the storm surge for water depths less than about 30 ft.

I. The critical directions are those that are expected to control the assessment criteria for most structures. We think that the criteria for directions that are ± 90° with respect to the principal wave direction will dominate the assessment process.

J. The mixed layer extends down to -150 ft. Therefore, for a water depth of 90 ft, the current will be uniform with a magnitude as given in Table 17.6.2-1. For directional criteria, the current will be directed along the bathymetric contours, with the same direction as specified in the 20th ed, Figure xxx. For omnidirectional criteria, the current should be assumed to be inline with the wave direction, but should be checked against the inline component of the 20th ed current (for the full population design level analysis) and the inline component of the sudden hurricane ultimate strength current (for the sudden hurricane design level analysis) to make sure that the design level analysis current is appropriate.

K.

Refer to Section 2.3.4c (item 3) of API RP 2A, 20th edition.

L. The wave heights and currents are specified as omnidirectional, but they must not exceed certain values (for consistency purposes) as noted in Table 17.6.2-1 for the design level analyses for the full population and sudden hurricanes.

M. The term "directional spreading factor" should be replaced by "wave kinematics factor".

N. Deck floors were framed and girders were wide flange sections. Floors were plated and grated. The grated floors gave slightly higher lateral loads and the TG 95-2 Metocean/Loads Work Group decided that effect of grating was not significant enough for special consideration.

O. We do not agree that "any other deck with no equipment" should be part of the provisions for "lightly-framed sub-cellar decks". The term "lightly framed" implies light frames such as 4" angle iron that is usually used to support sub-cellar decks. Other decks normally are framed with much larger structural members and should not be considered as "lightly framed".

According to the simplified procedure (the silhouette procedure) the members in the cellar deck need not be explicitly modeled for hydrodynamic loads, otherwise there will be, as the questioner mentions, double-dipping.

The "bottom of the cellar deck" is defined as the bottom of steel that makes up the cellar deck.

P. The silhouette procedure is a simple procedure to obtain an estimate of wave/current deck forces. It cannot address details such as the make-up of deck floors. <u>More detailed procedures are permitted for assessment provided they are verified by model test data or field data.</u>

However, the impact of these details is probably not that important. The questioner raises the issue of deck sections that are constructed of tubular members. The present thinking is that tubular members and wide-flange beams would produce about the same hydrodynamic deck forces because the primary effect is due to flow blockage; and cannot be described through the conventional used of the Morison equation.