RP2T 3rd Edition Workshop

September 2007

Planning, Designing, and Constructing Tension Leg Platforms

API RP2T 3rd Edition

energy API

Agenda

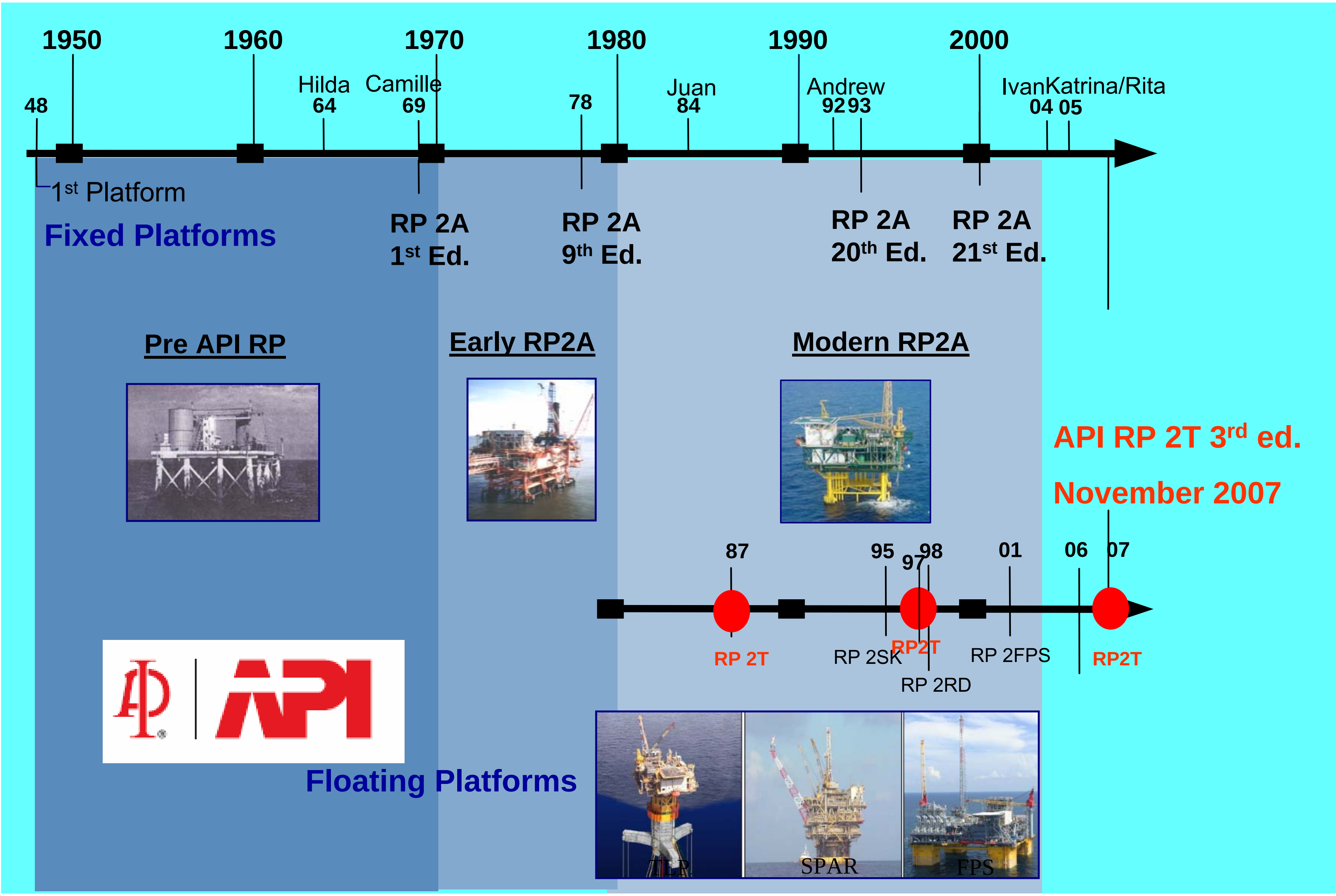
- **Welcome, Safety**
  - **Jaime Buitrago**
- **Introduction and Overview of 3rd Edition**
  - **Steve Leverette**
- **Section Presentations**
  - **All**
- **Question and Answer Panel**
  - **Tommy Laurendine**
- **Conclusion**
  - **Steve Leverette**

Welcome and Safety

Jaime Buitrago

- The Codes/Recommended Practices: API SC2 and ISO
- History of RP2T
- RP2T Committee, 3rd Edition
- TLP History
- Objective of Workshop
- Overview of RP2T 3rd Edition

Standards and Hurricanes



API Series 2 Documents

INTRODUCTION
RP 2GEN/ISO 19900

General Parts

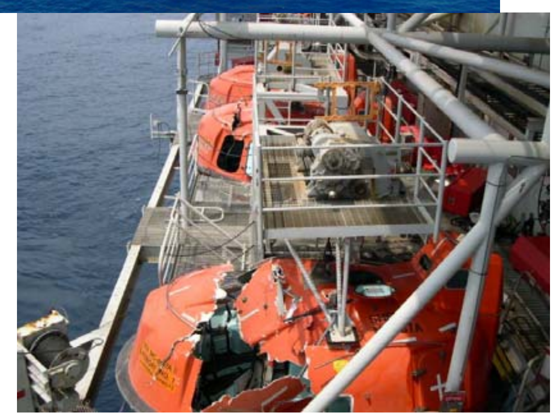
Metocean	Seismic Design	Topsides Design	Geotechnical	Weight Control	Marine Operations	Station Keeping	Fire and Blast	Structural Integrity Management	Plates	Shells
RP 2MET/ ISO 19901-1	RP 2EQ/ ISO 19901-2	RP 2TOP/ ISO 19901-3	RP 2GEO/ ISO 19901-4	RP 2WGT/ ISO 19901-5	RP 2MOP/ ISO 19901-6	RP 2SK-RP 2SM/ ISO 19901-7 RP 2I	RP 2FB	RP 2SIM	2V	2U
							ISO 19901-3	ISO 19902	N/A	N/A

Specific Structures

Fixed steel structures		Concrete Structures	Floating Structures	TLP	Jack-ups	MODUs	Arctic Structures
RP 2A WSD	RP 2A LRFD/ ISO 19902	RP 2CON/ ISO 19903 ?	RP 2FPS/ ISO 19904-1	RP 2T	??	??	RP 2N/ ISO 19906 ?
N/A				N/A	ISO 19905-1	ISO 19905-2	

Existing	Under Revision	Under Development	Not Started	No Plans

Why we have codes,   why we update codes



API RP2T 3rd Edition

- **1st Edition 1987**
  - **2 TLP's Installed**
  - **Consensus document on important issues**
  - **"Do a good job"**
- **2nd Edition 1997**
  - **Update format**
  - **Incorporate Fire and Blast, Wind Spectra Addendums**
- **3rd Edition 2007**
  - **20 years of practice**
  - **Major re-write**
  - **Extended scope**
  - **"Meat on the bones"**
  - **Probabilistic scan**
  - **1000 yr survival criteria**
  - **Robustness checks**

API RP2T 3rd Edition Workgroup Committee

- **Active Members 2007**

• Gail Baxter	Marathon Oil
• Nyle Britton	WorleyParsons Sea
• Debbie Bryant (DB)	BP
• Earl Doyle	Consultant
• Bill Greiner	WorleyParsons Sea
• George Gu	ConocoPhillips
• Steve Hodges	Shell Oil
• Edward Huang	VersaMarine Engr.
• Bob Kipp	WorleyParsons Sea
• Tommy Laurendine	Liberty
• Shihwei Laio	ConocoPhillips
• Craig Lee	ABS
• Steve Leverette	SBM Atlantia (Chairman)
• Rick Mercier	OTRC
• Ron Perego	BHP
• Amal Pradke	ConocoPhillips
• Graeme Ripley	DNV
• Mirza Saadat	Saipem Americas
• Jim Stevens	Mustang Engineering
• Dave Taberner	Total
• Ward Turner	ExxonMobil
• Chunfa Wu	WorleyParsons Sea

API RP2T 3rd Edition Workgroup Committee

USCG Participation

- **from the Marine Safety Center:**
  - Lisa Hecker
  - CDR Charlie Rawson
- **from CG-3PSE-2 (Naval Architecture Div at USCG HQ):**
  - Tom Jordan

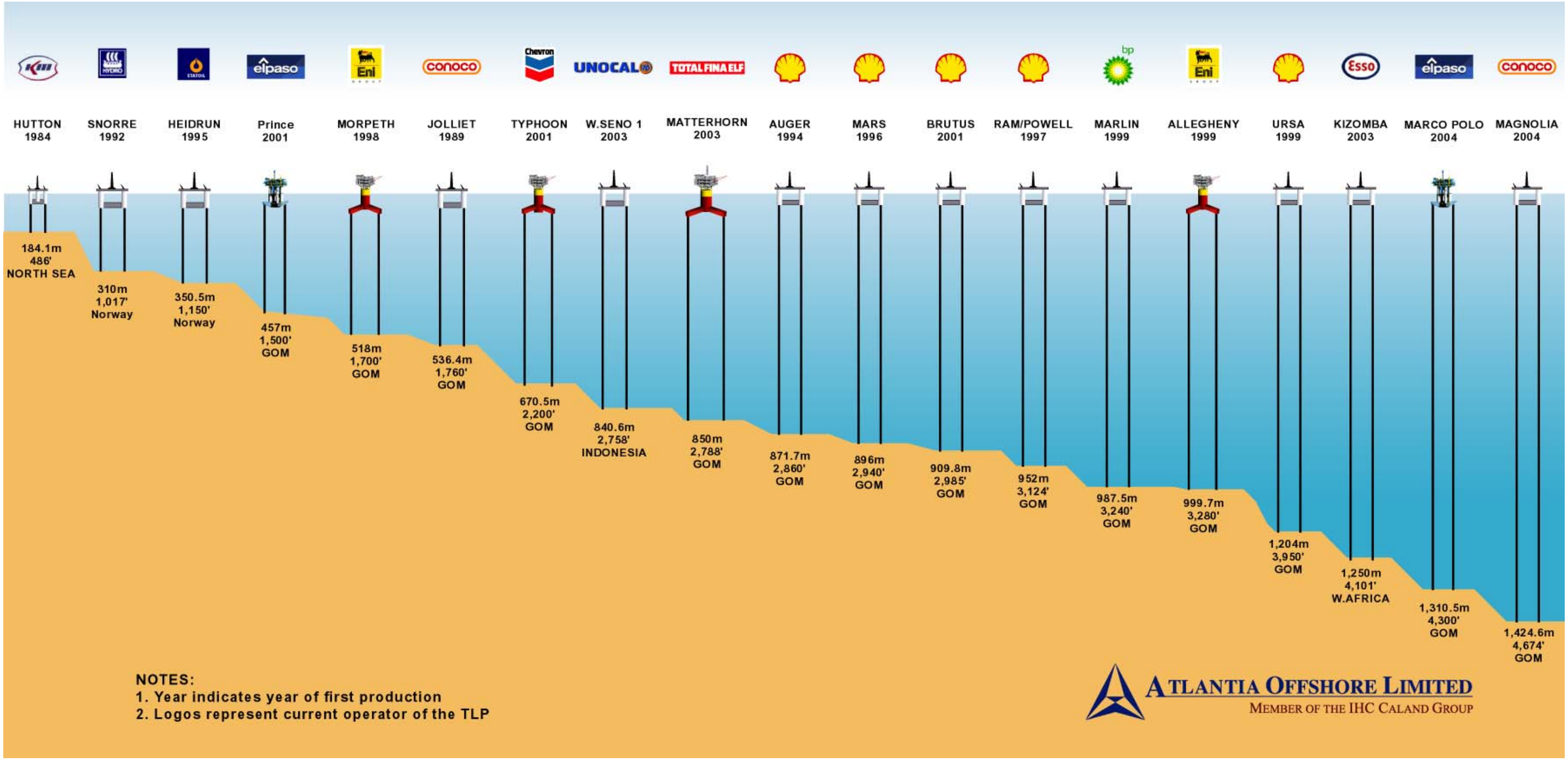
MMS Participation

  - Christy Bohanan
  - Mike Conner

API RP2T 3rd Edition Workgroup Committee

- **41 meetings since 3/21/2001**
- **Hiatus during 2005 following Katrina/Rita**
- **Renewed effort August 2006**
- **Include lessons learned from Katrina/Rita**
- **Delivered to SC2 on 27 July 2007**

25 TLP's
(21 plus Okume 1&2, Neptune, Shenzi)











TLP Evolution

- **25 Existing TLP's installed or in construction**

- **TLP configuration evolution:**
  - **Hutton (6 columns, shallow water)**
  - **Conventional 4 column (Snorre, Shell TLP's, Marlin)**
  - **Jolliet (TLWP)**
  - **Auger (aux. Mooring)**
  - **Heidrun (concrete)**
  - **SeaStar (single col, subsea wells: Morpeth, Allegheny, Typhoon, Neptune)**
  - **Matterhorn (SeaStar with surface wells)**
  - **Moses (4 col. Mini TLP: Prince, Marco Polo)**
  - **W. Seno (tender drilling)**
  - **ETLP (extended pontoons)**

Today's Objective

- Present RP2T 3rd Edition to industry
- Highlight differences from earlier editions
- Discuss new content
- Answer questions
- Feedback from industry to workgroup
- Facilitate Ballot process

  (Note that we are not here to debate content – API Process)

Overview

- **Significance of RP2T 3rd Edition**
  - **Only widely used code to address TLP's**
  - **First edition was prior to experience**
  - **Second edition was minor change and reformatting**
  - **Third edition is finally based on practice and experience**

- **With 3rd Edition change from "primer" to "code"**

- **New areas of coverage, ground breaking issues**
  - **First API RP to include Survival conditions / 1000 yr code checks**
  - **First API RP to give guidance on response based criteria**
  - **First API RP to require probabilistic scan**
  - **First API RP to initiate robustness checks beyond design conditions**
  - **First API RP to include marine systems guidance**
  - **Address Ringing**
  - **Address VIV/VIM**

API Bulletin 2INT-DG

Includes Recommendations from proposed RP2T 3rd ed

- **New airgap check (>0) for 1000 year event (in addition to 5 feet in 100 year).**
- **Deck design to include tripping brackets for local impact.**
- **Addresses 15% crest height add-on for local design**
- **Specifies minimum tendon tension for 100 year (Category B) and 1000 year (Category S).**
- **Robustness check for conditions beyond 100 yr. “extreme” and 1000 yr. “survival”. Emphasis on connector and mechanical component robustness.**
- **Review of downflooding points and hatches during 100 yr. extreme conditions.**

RP2T Overview

Table of Contents

• **1 Scope**	**SL**
• **2 Normative References**	**SL**
• **3 Terms, Definitions**	**SL**
• **4 Planning – issues addressed, key factors**	**SL/WT**
• **5 Criteria**	**SL**
• **6 Forces**	**GG**
• **7 Global**	**SL/RM**
• **8 Structure**	**GB**
• **9 Tendons**	**NB/SH**
• **10 Foundation**	**SL/ED**
• **11 Risers**	**GB/SH**
• **12 Marine Systems**	**JS/DB**
• **13 Corrosion**	**SL/WT**
• **14 Fabrication, Installation & Inspection**	**GB/SH**
• **15 Surveys and Maintenance**	**JF/CL**

API RP2T 3rd Edition
New Material

- **Section 5   Design Criteria**
  - **Safety Categories**
    - A – Operational
    - B – Extreme Conditions
    - S – Survival Conditions (nominal 1000 yr)
    - C – Fatigue Conditions
  - **Stability**
    - Free Floating Stability per MODU code for Free Floating Conditions
    - In-place Stability is Structural – Global Performance Loadcases
  - **Environment**
    - Reference to Bul 2INT-MET and RP 2MET
    - Data selected after consultation with Designer and Metocean Specialist
    - Defined as Response-Based – 100 yr event expected to give 100 yr response
    - Probabilistic scan required

API RP2T 3rd Edition
New Material

- **Section 7 Global Response**
  - **Design options – n-year and Response Based**
  - **Code Equations provided**
  - **Survival case for global performance**
  - **1000 yr for Deck Clearance check**
  - **1000 yr for Minimum Tension check**
  - **Probabilistic Scan Described**
  - **Extensive Commentary**
    - VIV/VIM
    - Ringing and Springing
    - Long Term Prob. Analysis and Response Based Criteria

API RP2T 3rd Edition
New Material

- **Section 9 Tendons**
  - **Code Equation for tension/collapse as “practice”**
  - **Safety Factors as “practice” (much discussion)**
  - **Robustness check for Tendon System**
  - **Single Event Fatigue Limit**
  - **Extensive Commentary**

  - **Strong need for addition test program to improve deep water capabilities**

API RP2T 3rd Edition
New Material

- **Section 10   Foundations**
  - **Latest document from Geophysical Group, latest practice**

- **Section 11   Risers**
  - **Refer to API RP 2RD**
  - **TLP Specific recommendations**

API RP2T 3rd Edition New Material

- **Section 12 Facilities and Marine Systems**
  - **Extensive new material on Marine Systems**
  - **Merging of practice from designers**
  - **Lessons from Thunderhorse**
  - **Interface Checklist**
- **Section 14 Fabrication, Installation & Inspection**
  - **Extensive reference to AWS and API RP2A**
- **Section 15 Surveys and Maintenance**
  - **New Section – major input from ABS**
- **Deleted old section on Structural Materials**
  - **Incorporated in individual sections**

API RP2T 3rd Edition
What is not done - (material for 4th Edition)

- **Reduction in Tendon Safety Factors**
- **Re-Assessment (does not replace Bul. 2INT-EX)**

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September 2007

Section 1-3

- **1 Scope**
  – Planning, Designing, and Constructing Tension Leg Platforms
  – Now includes surveys and maintenance
  – Does not include assessment

- **2 Normative References**

- **3 Terms, Definitions**

Section 4 – Planning

What's Different?

- **Some reorganization, primarily in first 2 sub-sections**
- **Reference to Design Spiral removed**

What's New?

- **Where applicable, design criteria is updated**
- **Expanded discussions and information provided on several topics**

Section 4 Planning - Design Criteria Updates

- **Document adopts API RP2A consequence based design terminology, however all new-build TLPs are designated as having a "high consequence of failure"**
  - **High consequence of failure links to 100-year return period criteria**
  - **Lower return periods are potentially permissible for unmanned platforms, structures not used for hydrocarbon extraction, or reassessments of existing facilities nearing end-of-life**

- **Design Considerations are also include as required:**
  - **Earthquake – two-tier Strength Level Event (SLE) / Ductility Level Event (DLE)**
  - **Matrix of fatigue seastates representing entire range of environments expected (include hurricanes)**
  - **Environmental conditions associated with transportation and installation**

- **Metocean criteria updated for Gulf of Mexico referenced to recent HEAT initiatives and successors**

Section 4 Planning – Expanded Topics

- **Seafloor Surveys and the use of:**
  - **Conventional 3D seismic data**
  - **Mapping products including bathymetry, seafloor renderings, seafloor amplitude, near-seafloor isopach and structure maps**
  - **Deep tow survey equipment and Autonomously Underwater Vehicles (AUV's)**

- **Platform design and layout to additionally consider installation procedures**

- **Foundation type may also consist of individual piles to which individual tendons are directly connected**

- **Platform fabrication methods to also include:**
  - **Modules – deck facilities are installed in the form of stacked modules on top of the hull**
  - **Deck Lifting – deck is constructed in one piece and is lifted and integrated offshore**

- **Operating and In-Service Manuals – the list is greatly expanded and contains a comprehensive recommended list of practice and procedure manuals necessary to safely and efficiently conduct normal operations, maintenance, in-service inspection, and emergency procedures.**

Section 5 Design Criteria

- Safety Categories
  - A - normal
  - B - extreme
  - C - fatigue
  - S - survival
- Operational Requirements
- Stability Requirements
  - In-place (free floating stability does not apply, section 7 global performance)
  - Pre-service (ref. USCG and IMO MODU Code)
  - Weight control (inclining and draft survey, alternates)

Section 5 Design Criteria

- **Environmental Criteria**
  - **Criteria are philosophically response based**
  - **Reference to Bulletin 2INT-MET and API RP-2MET**
  - **N-year or response based for design, probabilistic check required**

- **Design Load Cases**
  - **Intact**
  - **Damaged (1 compartment anywhere, 2 at waterline)**
  - **Tendon Removed (not broken tendon case)**
  - **Design Environments**
    - Extreme
    - Normal
    - Reduced Extreme
    - Survival
    - Marine Operations Environment (also durations, PNR)

Section 5 Project Design Load Cases

Design Load Case	Safety Category	Project Phase	Platform Configuration ‡	Design Environment	Annual Probability of Exceedance
1	B	Construction	Various		
2	B	Load out	Intact	Calm	
3	B	Hull/Deck Mating	Intact	Site Specific	
4	B	Tow / Transportation	Intact / Damaged	Route	varies
5		Installation	Intact	Installation	varies
6	A	In-Place	Intact	1-year Normal	≤1
7	B	In-Place	Intact	100-year Extreme	0.01
8	S	In-Place	Intact	1000-year Extreme	0.001
9	B	In-Place	Damaged - No Compensation	1-year Normal	≤ 0.01*
10	S ** #	In-Place	Damaged - No Compensation	10-year Reduced Extreme	≤ 0.001*
11	B	In-Place	Damaged - Compensation	10-year Reduced Extreme	≤ 0.01*
12	S ** #	In-Place	Damaged - Compensation	100-year Extreme	≤ 0.001*
13	B	In-Place	Tendon Removed	10-year Reduced Extreme	≤ 0.01*
14	S** #	In-Place	Tendon Removed	100-year Extreme	≤0.001*
15	C	In-Place	Intact	Annual Scatter Diagram	1
16	SLE †	In-Place	Intact	SLE Seismic	Varies
17	DLE †	In-Place	Intact	DLE Seismic	Varies

Table is indicative of the types of loadcases to be checked, and is not intended to imply adequate number of loadcases.

***   Probability of exceedance includes nominal probability of damage or tendon removal occurring.**
**** Pile check, if performed, in Survival conditions uses reduced safety factor**
 #   Survival check with damage or tendon removed is against disconnect (not zero tension) and may be response-based.
†   See Section 4 and API RP2A for definition of Strength Level Event (SLE)/ Ductility Level Event (DLE)
‡   In all cases, platform configuration should consider both minimum weight and maximum weight variations.

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Chapter 6 – Environmental Forces

Contributors:

George Gu, ConocoPhillips
Vigleik Hansen, DnV

Amal Phadke, ConocoPhillips

Major Changes from 2nd Edition

- **Reduced Wind Forces section**
  - **Refer to RP2A/RP2MET for Mean Profile, Gusts and Spectra**
  - **Mentioned wind force software**
  - **Modified Current Force equation**

$$F_d = \frac{1}{2} \rho_W C_D \int A_c (V - \dot{x}) | V - \dot{x} | \, dl$$

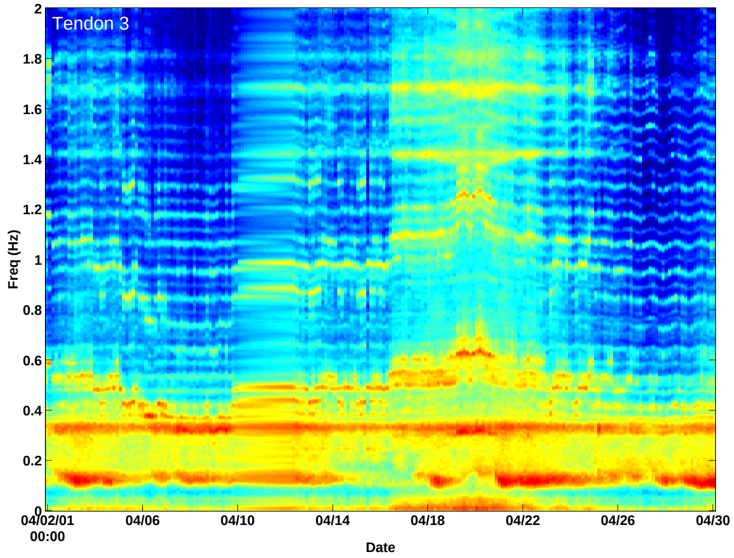
Now the damping effect of current is included

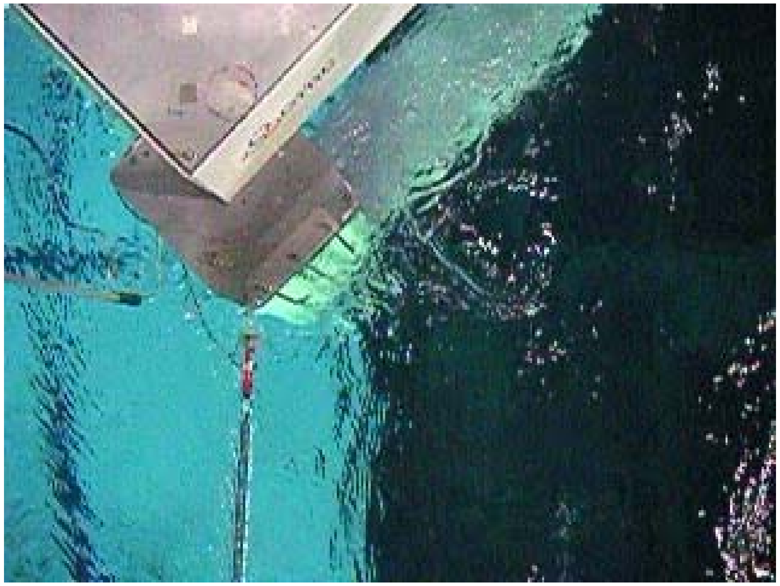
From "Vortex Induced Motions of Semi Submersible with Four Square Columns", O. Rijken, S. Leverette and K. Davies, DOT 2004, New Orleans, USA.

Major Changes from 2nd Edition

- **Expanded Vortex Induced Vibrations Subsection**
  - **Introduced as a major section (6.4)**
  - **Enhanced discussion of tendon/riser VIV**
    - Consequences of tendon/riser VIV.
    - Hull Vortex Induced Motion (VIM).
    - Discussion of Cross-Flow and Inline VIV

  Discussion of wind induced VIV (mostly for topsides).



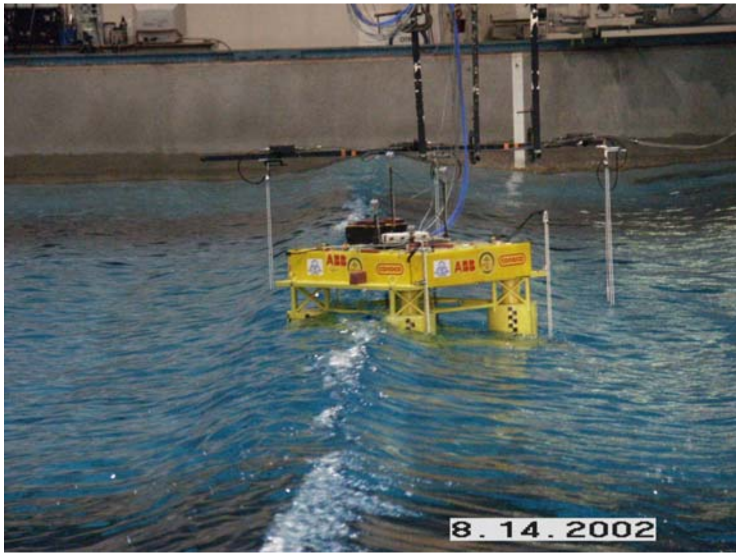


From "Vortex Induced Motions of Semi Submersible with Four Square Columns", O. Rijken, S. Leverette and K. Davies, DOT 2004, New Orleans, USA.

6.5 Wave Forces

- Moved details on Diffraction/Radiation Analysis to Chapter 7
- Moved details of sub- and super-harmonic forces to Chapter 7
- Added a subsection -- Hull Inundation for Low Column Designs
- Added discussion on Drag Amplification due to VIV
- Expanded Force Calculation Method Guidelines

$$\frac{C_D \mid A_y > 0}{C_D \mid A_y = 0} = \begin{cases} 1 + 2.1(A_y / D) & \text{Blevins (1990)} \\ 1 + 1.043(2Y_{rms} / D)^{0.65} & \text{Vandiver (1983)} \\ 1 + 1.16\left\{\left[\left(1 + 2A_y / D\right) f_n / f\right] - 1\right\}^{0.65} & \text{Skop et.al. (1977)} \end{cases}$$



6.6 Wave Impact Forces

- **Updated Wave Impact Forces section to include wave slamming on columns and its effects**

API RP2T 3rd Edition

Global Design and Analysis

Rick Mercier/Steve Leverette

Section 7 – Global Design and Analysis

What's Different

- **Organization of material**
- **Emphasis on probabilistic long term response analysis for design verification**

What's New

- **Explicit criteria for minimum deck clearance and minimum tendon tension**
- **Single event fatigue check**
- **Commentaries on**
  - VIV
  - high frequency TLP responses
  - long term analysis and response-based criteria

Design Verification Philosophy

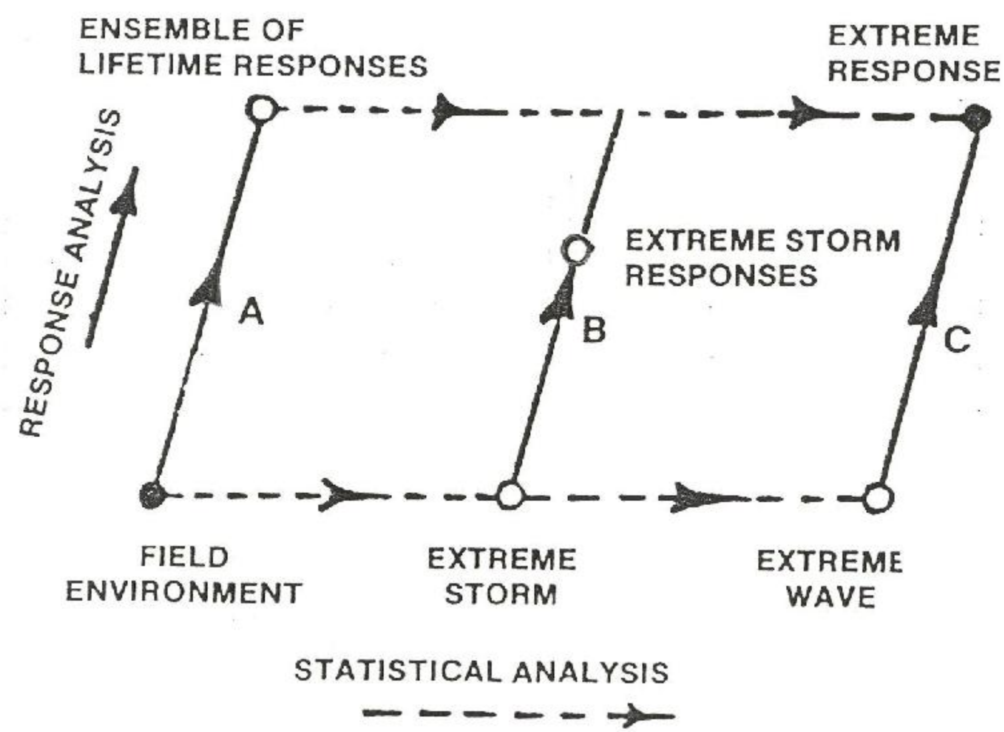
As before…

- **Design checks are structured around the concept of global performance load cases or limit states**
- **Response analysis and design checks are based on working stress design**
- **The "extreme" design load cases are based on appropriate safety factors applied to the estimate of a 100-year return period *response***
- **It is the designer's responsibility to ensure appropriate environmental conditions for a site and for a general TLP configuration**

But now…

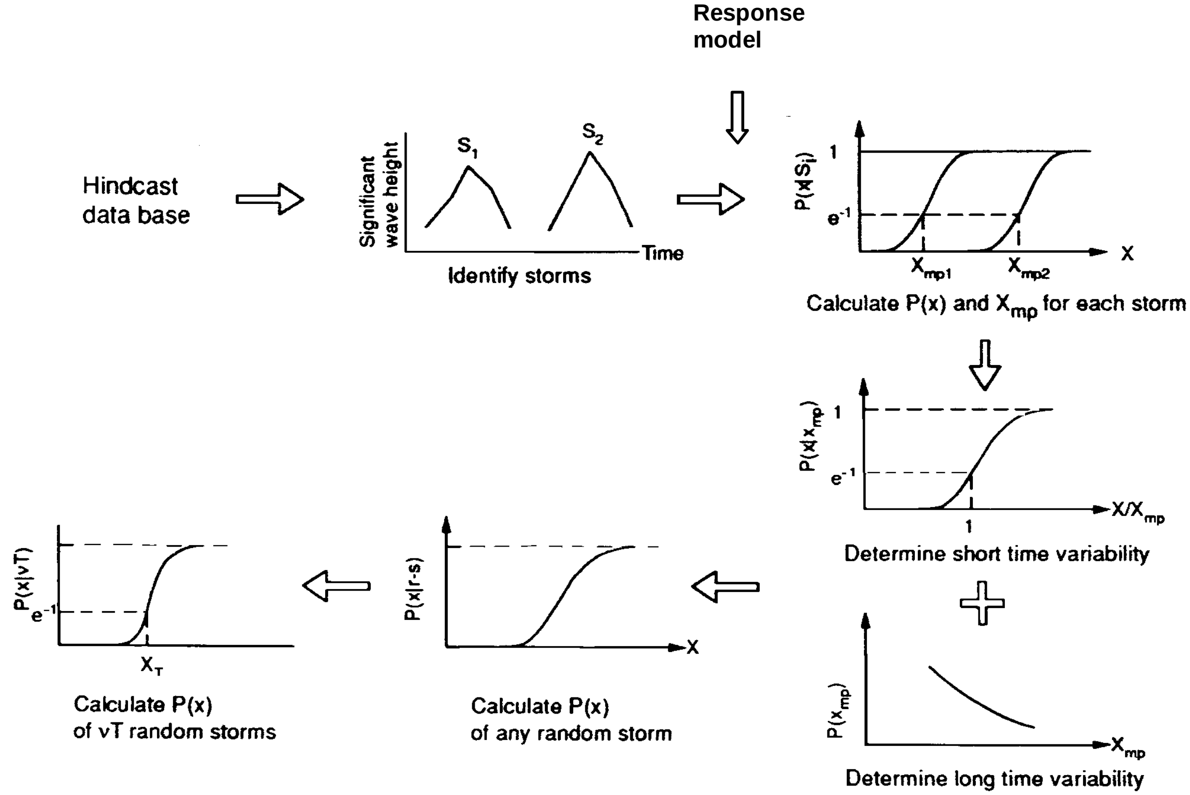
- **Regardless of the way environmental criteria are selected for preliminary design, the adequacy of the environmental criteria should be verified through long term response analysis applied to the final design configuration**

EXTREME VALUE FOR DESIGN



Long Term Response Analysis

Involves developing non-exceedance probability distributions for TLP responses of interest that account for both short-term and long-term variability in sea conditions, and from which design level responses can be identified



Minimum Deck Clearance Criteria

Applies to deck structure that is not intended to be immersed

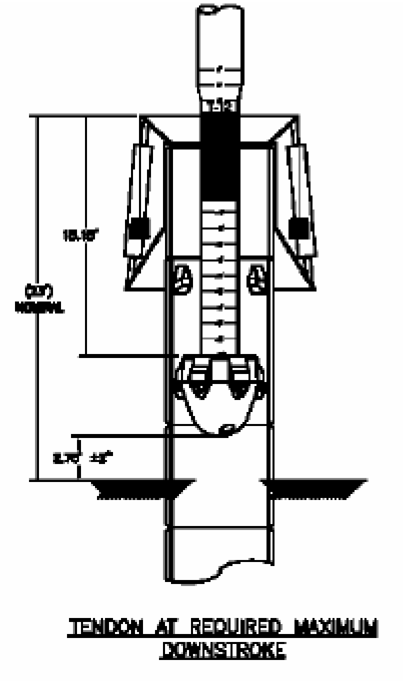
Recommended criteria:

- **At least 5 ft clearance to main steel in extreme (100-yr return period) conditions**
- **Zero or greater clearance in survival (1000-yr minimum return period) conditions**
- **Local wave effects in these conditions can be dealt with by local strength design**

If the designer chooses to allow and design for wave impact, the entire TLP system (including deck, hull, tendons and foundations) should be designed for the anticipated local and global wave forces and resulting responses

Minimum Tendon Tension Criteria

Objective is to prevent unrestrained motions which may lead to tendon disconnect or excessive loads in the structure or tendon system



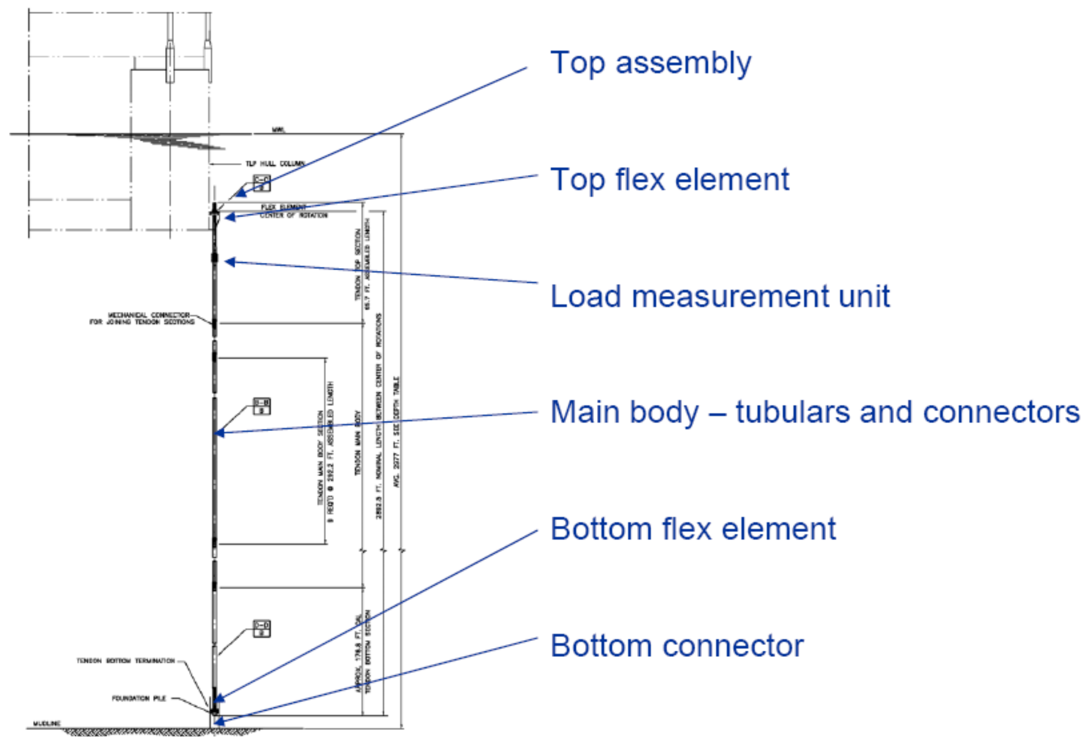
Recommended criteria:

- **For Safety Categories A and B, minimum tendon tension in at least 1 tendon per corner should remain non-negative**
- **For Safety Category S, either**
  - minimum tension in at least 3 corner groups of tendons must maintain non-negative tension in the 1000-yr return period response environment, or
  - a comprehensive coupled analysis of the tendon system performance under loss of tension must be performed to demonstrate proper re-engagement of the bottom connector with the foundation receptacle and adequate robustness against subsequent snatch loading

Single Event Fatigue Check

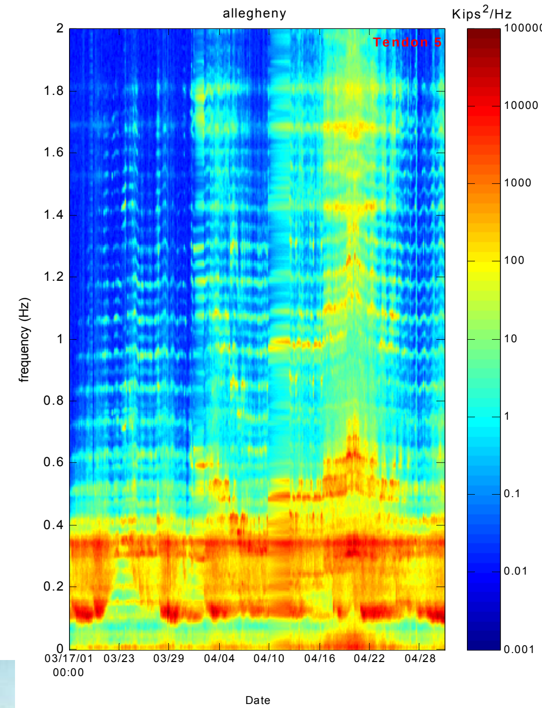
Components that are susceptible to low cycle/high stress fatigue should be analyzed to assess damage accumulation during rare extreme events that may be of extended duration

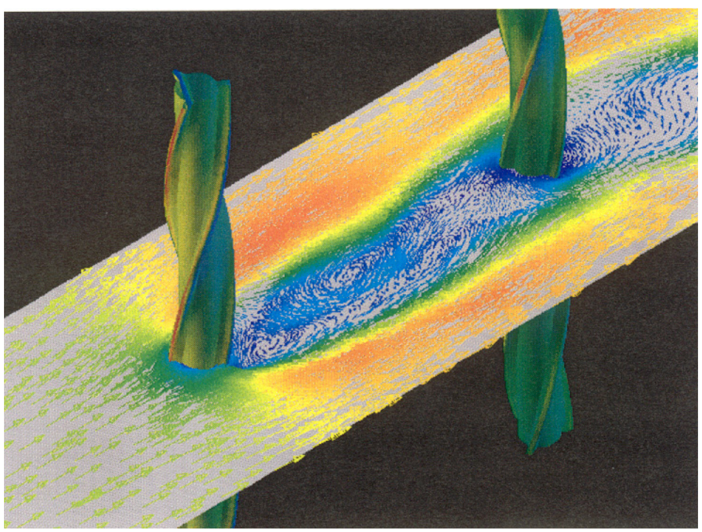
Refer to Section 9 for guidance on single event fatigue analysis for tendon components



Commentary on VIV of Hull, Tendons and Risers

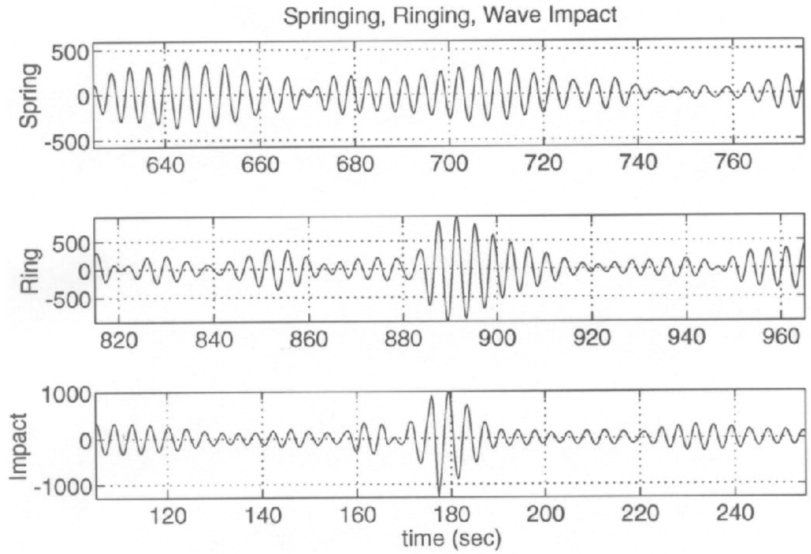
- **Observations**
- **Analysis methods**
- **VIV mitigation**
- **References**





Commentary on High Frequency TLP Responses

- Includes springing, ringing, VIV, deck wave impacts
- Description of
  - Mechanisms
  - Modeling techniques



- Recommended design verification procedure
  - Model testing
  - Extreme value estimation
  - Design recipes
- References

Commentary on Long Term Response Analysis (LTRA) and Response-Based Criteria

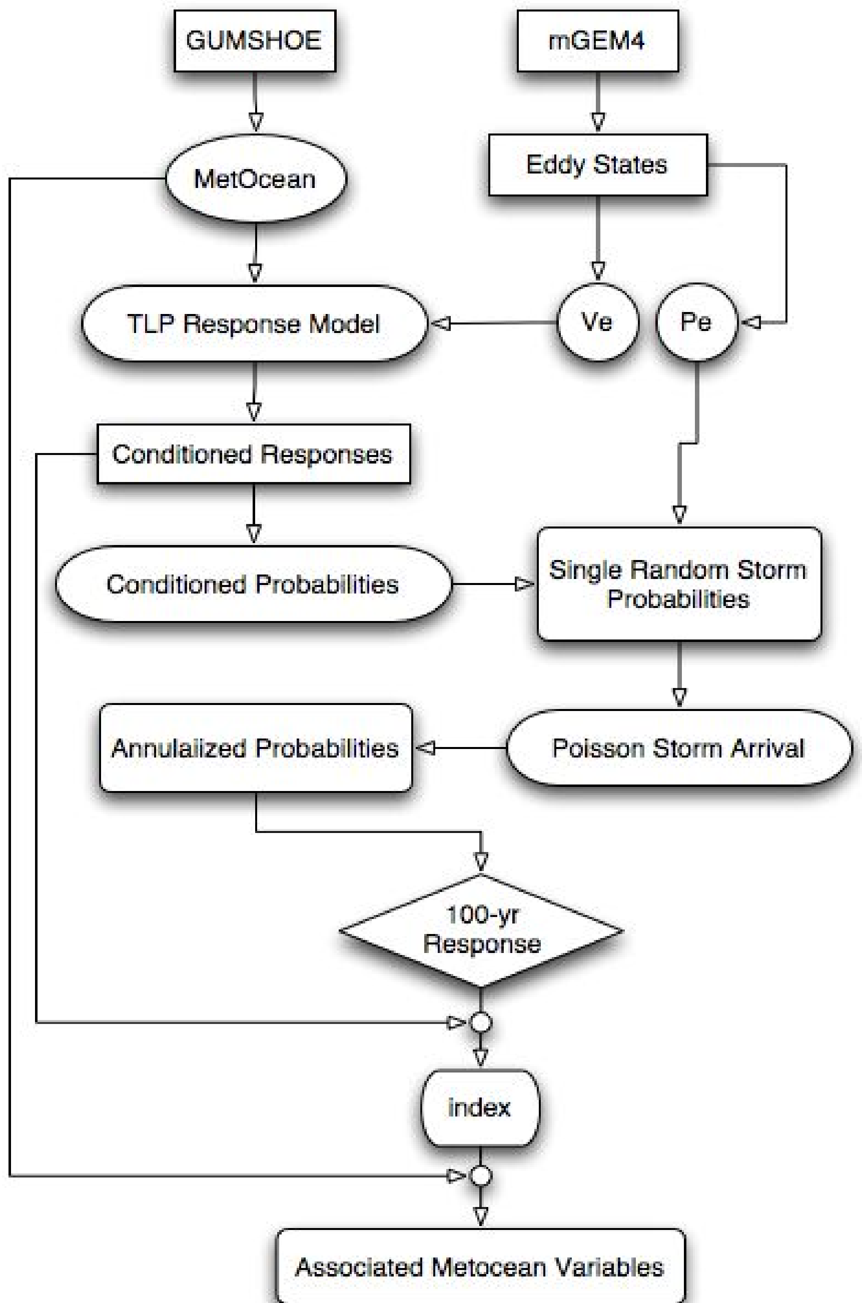
- **There are a number of methods by which LTRA can be performed, and references are provided for the different methods**
- **Requires a sufficiently extensive (hindcast) metocean database to allow extreme value estimation (preferably by interpolation rather than by extrapolation)**
- **Metocean database is processed sequentially using a simplified TLP response model to determine short term extreme response distributions associated with all seastates**
- **Probabilistic combination (weighting) performed in same way as for determining long term probability distributions of metocean parameters**
- **Once design level (100-yr, 1000-yr return period) responses have been identified, response-based criteria are determined as associated seastates which generate the design level responses at a particular short term probability level**

Commentary on Response Based Criteria

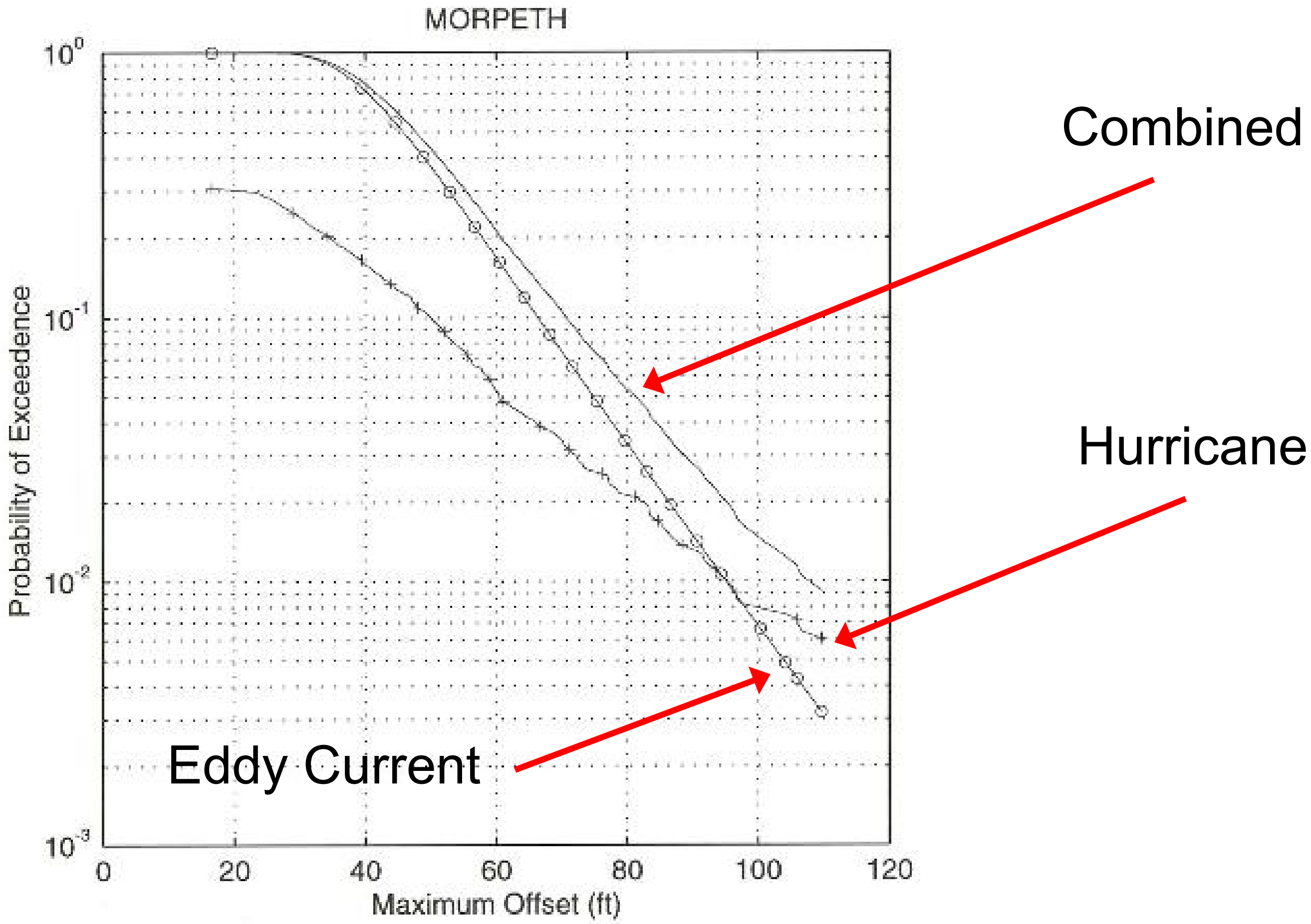
1. Long Term Environment
2. Simulation Model
3. Long Term Response Data
4. Evaluate Design Response
5. Identify Conditions Giving Design Response

- Accounts for sensitivities of structure
- Accounts for site specific conditions
- Gives rational way to combine wind/wave/current
- Identifies combinations not normally considered
- Improved and consistent reliability

Response Based Environmental Criteria



Hurricane / Eddy Combination



Distribution of Maximum Offset

(E)ddies only [o] Hurricanes w/wo E [+] Combined Maxima [-]

70.77 [10] 84.42 [25] 107.7 [100]

Questions?

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Planning, Designing, and Constructing Tension Leg Platforms

Section 8 – Platform Structural Design

Gail Baxter

Section 8 – Platform Structural Design

<u>What's Different?</u>

- **Expanded corrosion guidance**
- **Expanded information on design cases**
- **Expanded structural analysis guidance**
- **Incorporation of structural materials**

<u>What's New?</u>

- **Hydrodynamic structure loading methods**
- **Commentary on tendon porch design**

Section 8 – Platform Structural Design

Corrosion

- Internal hull corrosion protection
- Antifouling coatings
- Splash zone coatings

Section 8 – Platform Structural Design

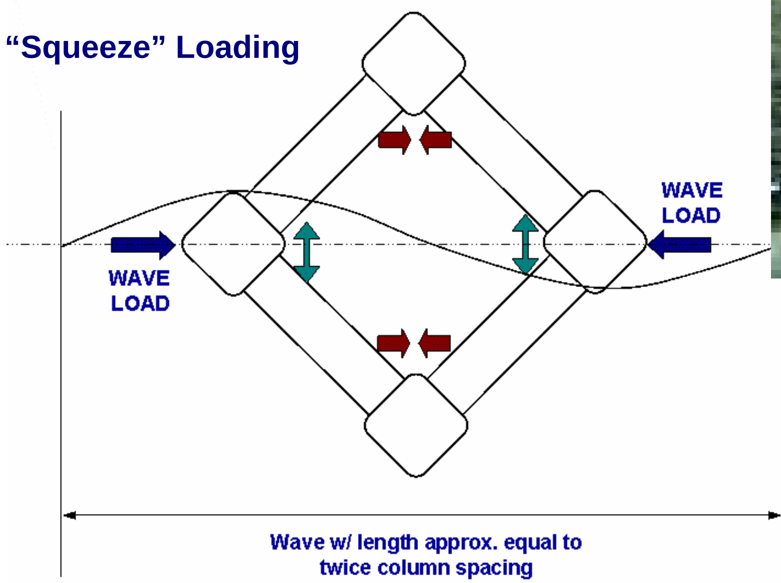
Design Cases

- Intact
  - Permanent + Variable Loads
  - Platform Cranes
  - Drilling Rigs
  - Appurtenance Design
  - Fluid Sloshing
  - Pre-service Loads
- Damaged
  - Compartment Flooded
  - Collisions + Dropped Objects
- Tendon Removed

Section 8 – Platform Structural Design

Hydrodynamic Loads for Hull Design

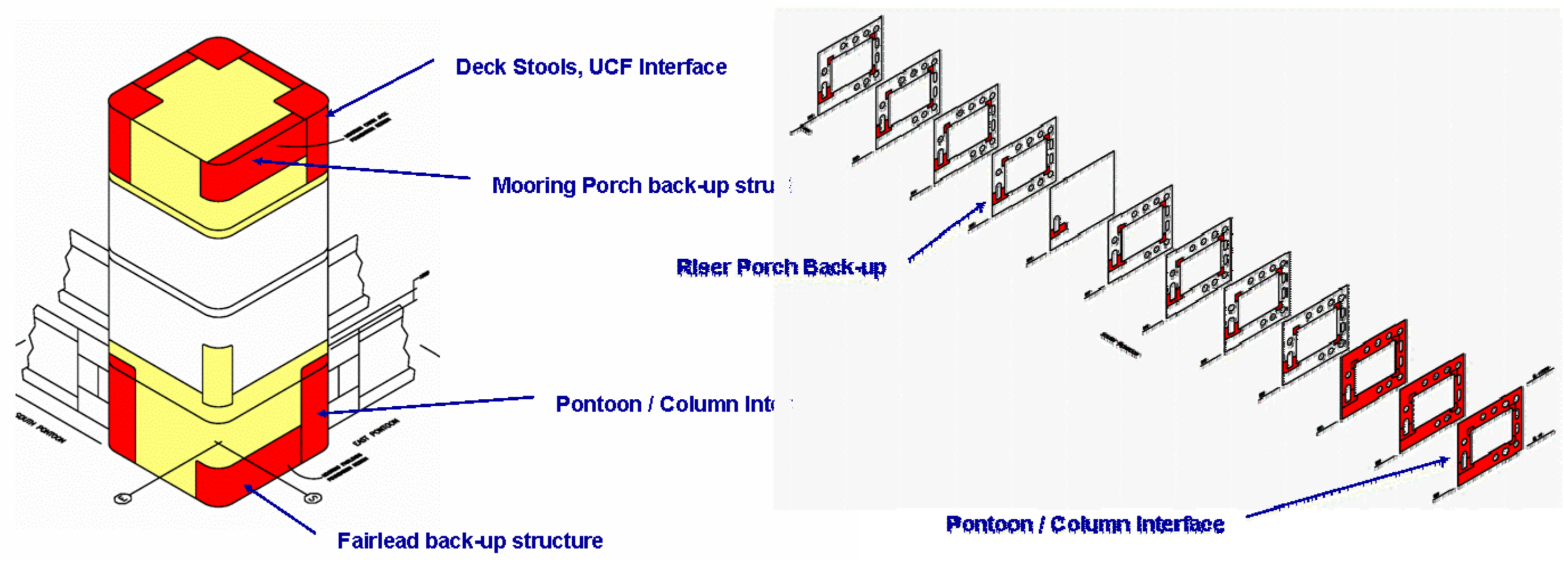
- Hydrodynamic Pressure Load Generation
- Global Hydrodynamic Loads
- Design Wave Cases



Section 8 – Platform Structural Design

Structural Analysis and Design

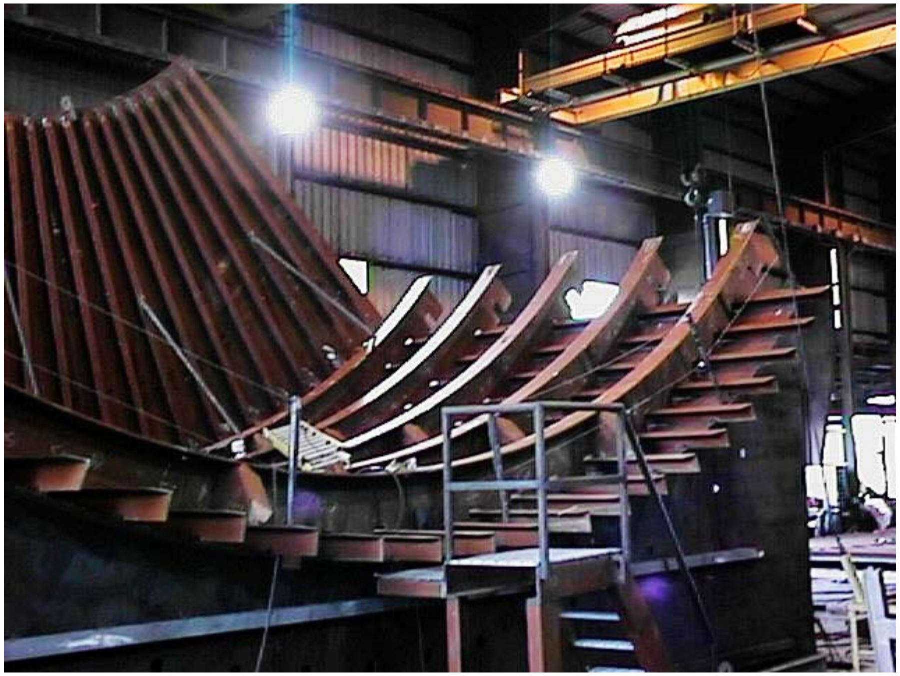
- Pre-service Conditions
- Component strength / stability
- Fatigue Analysis & Design



Section 8 – Platform Structural Design

Structural Materials

- Incorporated relevant information from Section 14, Edition 2.
- Eliminated information duplicated – references other specifications.



Section 8 – Platform Structural Design

Commentary – Tendon Porches

- Design for maximum dynamic tendon loads
- Fatigue – factor of 10
- Ensure that tendon porch failure will not have catastrophic consequences if not designed to tendon breaking strength

Section 8 – Platform Structural Design

- **Questions?**

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Planning, Designing, and Constructing Tension Leg Platforms

Section 9 – Tendon System Design

Nyle Britton

Section 9 – Tendon System Design

Primary Authors

- **Steve Hodges – Shell International Exploration and Production**
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General Contributors

- **Members of the RP2T Workgroup as a whole**

Section 9 – Tendon System Design

▶ *GUIDING PRINCIPLE FOR REVISIONS*

- **Bring 2T into alignment with established design practice**
- **Address lessons learned form recent GoM hurricanes**
- **Do not be over prescriptive.**
- **Maintain an appropriate level of conservatism, while not being excessively conservative.**
- **Incorporate TLP specific information in RP2T rather than rely on reference to other documents which may be subject to change.**
- **Provide clearer guidance to the designer.**

Section 9 – Tendon System Design

What's Different about Section 9

- **Slight changes to the arrangement of contents**
- **Deletion of outdated illustrations**
- **More design guidance incorporated explicitly rather than through reference to other documents**
- **Moved guidance on tendon structural materials**
- **Expanded guidance on fatigue design**
- **Expanded guidance on tendon structural material design**
- **Figures have been updated**
- **Section commentary has been placed at end of Section rather than in an Appendix**
- **References have been placed at end of Section rather than in an Appendix**

Section 9 – Tendon System Design

What's New in Section 9

Subsection 9.1 – General

- Virtually unchanged from 2nd Edition, other than the deletion of a legacy illustration of a Hutton TLP type tendon arrangement

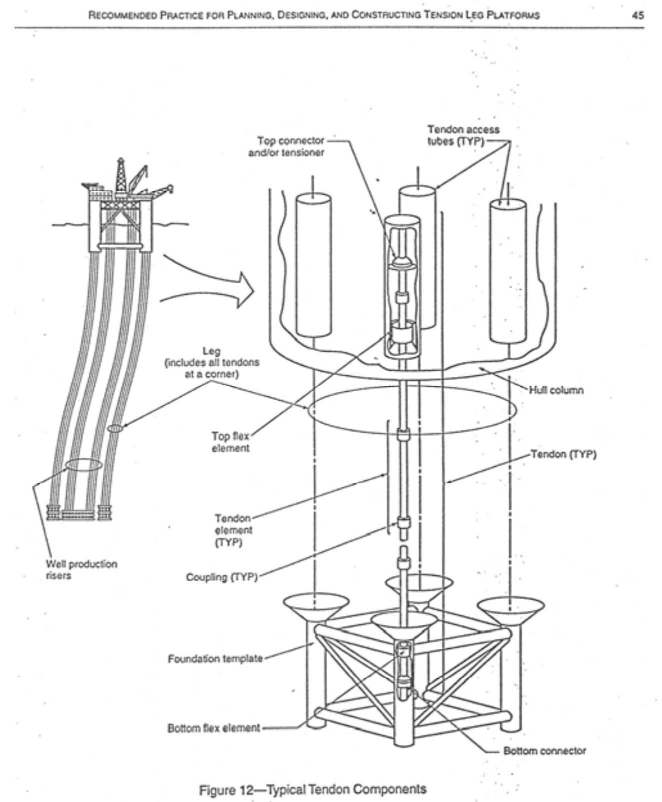


Figure 12—Typical Tendon Components

Deleted Figure

Section 9 – Tendon System Design

What's New in Section 9

Subsection 9.2 – General Design

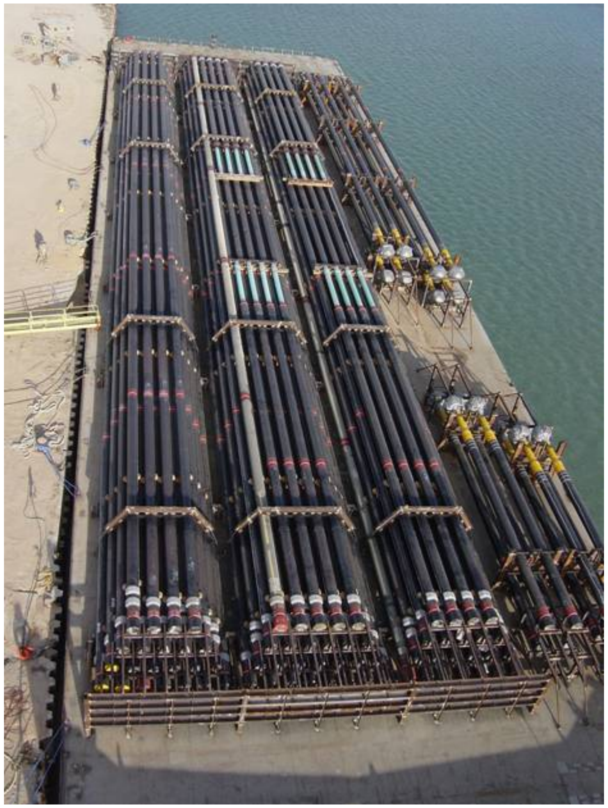
- Moved the Tendon Design Flowchart to end of Section 9
- Moved the discussion of Material Considerations to stand alone as Subsection 9.3
- Moved discussion of Fatigue Design to Subsection 9.2 from Subsection 9.6.4 of 2nd Edition and significantly revised and expanded the discussion

Section 9 – Tendon System Design

What's New in Section 9

Subsection 9.3 – Material Considerations

- Created as a stand alone Subsection to more comprehensively address Material Considerations.
  - Added discussion of Existing Practice
  - Provided guidance on various grades of steel material and on elastomeric material as used in Flex Elements
  - Addressed practical aspects of material availability



Section 9 – Tendon System Design

What's New in Section 9

Subsection 9.4 – Design Loads

– This Subsection is virtually unchanged from the way it appeared as Subsection 9.3 of 2nd Edition entitled "Design Loading Conditions"

Subsection 9.5 – Load Analysis Methods

– This Subsection repeats much of what is currently in Subsection 9.4 of 2nd Edition, also entitled "Load Analysis Methods" with the following exceptions

- Reduced the discussion of tendon dynamic analysis in an effort to be less prescriptive
- Deleted the discussion of Axial Vibrations as not being required
- Deleted the brief mention of Hydrodynamic Loads and Seismic Loads Analysis as being unnecessary in this Subsection.
- Deleted passage regarding modeling multiple tendon at a leg as a single tendon as not generally recommended

Section 9 – Tendon System Design

What's New in Section 9

Subsection 9.6 – Structural Design and Fabrication

This Subsection has a significant amount of new material. It has been built from elements of Subsection 9.5, "Structural Analysis Methods" and Subsection 9.6, "Structural Design Criteria" of 2nd Edition, but has been expanded to be more comprehensive.

<u>Sub-Subsection 9.6.1 – General Considerations</u>

More discussion of current practice in tendon configuration design and the elements of that configuration (i.e. steel tubular tendons)

Discussion includes for the first time a mention of composite materials

What's New in Section 9

<u>Sub-Subsection 9.6.2 – Tendon Pipe</u>

Diameter transitions in the steel tubular tendon receive more attention and design guidance, including figures, recommendation of FEA to evaluate the additional bending and hoop stresses, and presentation of a formula from API RP 2A-WSD for conservative estimation of stresses in a conical transition

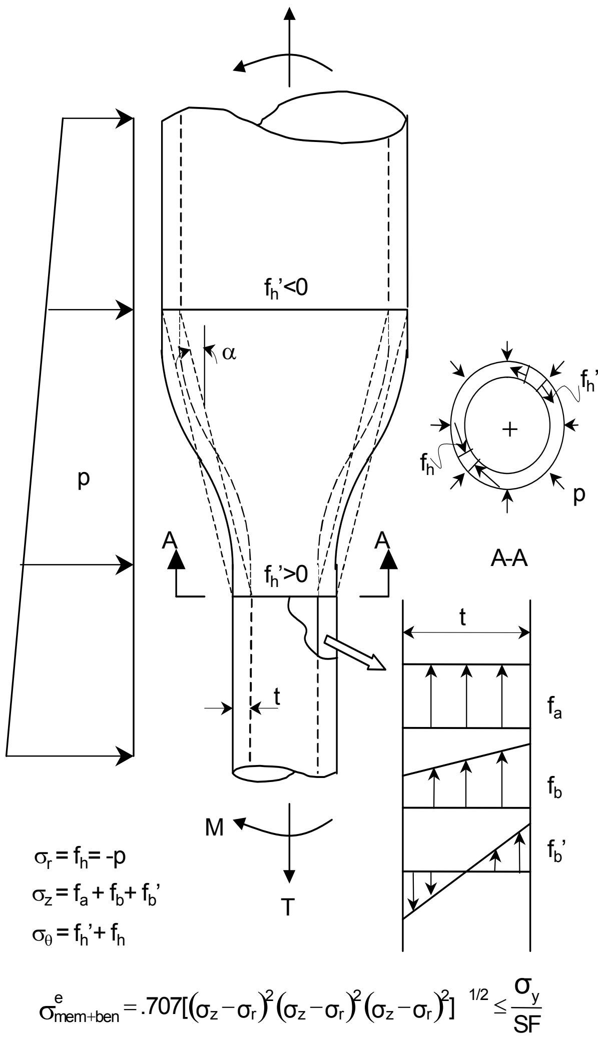


Figure 9-2: Local Stress Check At Tendon Section Transitions

Section 9 – Tendon System Design

What's New in Section 9

Sub-Subsection 9.6.2 – Tendon Pipe (continued)

Pipe Strength Criteria

Current industry practice regarding use of tension/collapse interaction equations developed in API RP 2A-LRFD D.3.3, but with either WSD or LRFD safety factors, is introduced.

Design using Load and Resistance safety factors is put forward.

	SF_t	SF_c
Safety Criteria	**Tensile**	**Hoop**
A (Operating)	**1.67**	**1.63**
B (Extreme)	**1.25**	**1.38**
S (Survival)	**1.11**	**1.25**

Global Tension-Collapse Strength Criteria with WSD Safety Factors as presented in Table 9-1

Design Condition	**Load Factors**			**Resistance Factors**	
	L_1	L_2	L_3	Φ_t	Φ_h
Operating	**1.00**	**1.30**	**1.50**	**0.95**	**0.8**
Extreme	**1.00**	**1.10**	**1.35**	**0.95**	**0.8**
Survival	**1.00**	**1.00**	**1.00**	**0.95**	**0.8**

Global Tension-Collapse Strength Criteria With LRFD Safety Factors as presented in Table 9-2

Where, *L1* is the load factor for the design margin, *L2* is the load factor for the static pretension, *L3* is the load factor for the environmental and inertia loads, Ft is the resistance factor for the axial, bending and shear strength, and Fh is the resistance factor for the hoop buckling strength.

What's New in Section 9

Sub-Subsection 9.6.2 – Tendon Pipe (continued)

Local Pipe Strength Criteria for Diameter Transition and Thickness Transition

Separate Von Mises equivalent stress formulations are presented for Diameter Transitions under tensile hoop stress or compressive hoop stress.

For Thickness Transitions a simplified von Mises equation is given for checking local membrane or net section stress and for combined membrane plus bending stress.

A set of Safety Factors for local pipe strength is then recommended for various Safety Categories.

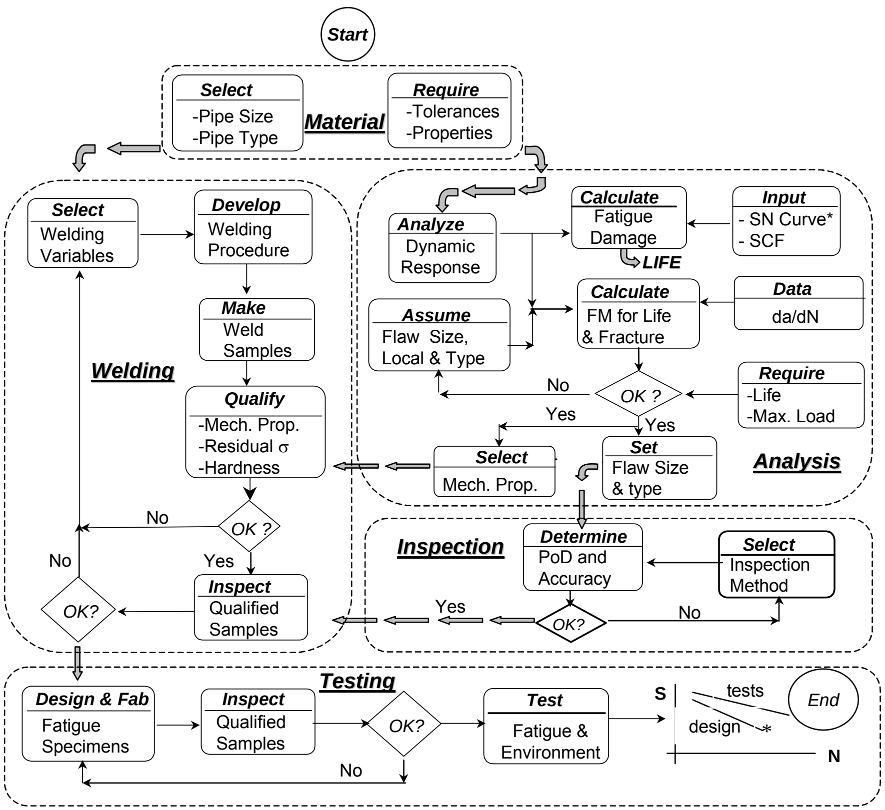
	Safety Factors	
Safety Criteria	**Membrane**	**Membrane + Local Bending**
A (Operating)	1.67	1.11
B (Extreme)	1.25	0.83
S (Survival)	1.11	0.83

Local Pipe Strength Safety Factors

Local stresses developed due to diameter or thickness transitions in the tendon pipe are addressed.

What's New in Section 9

Sub-Subsection 9.6.3 – Tendon Girth Welds



Design, Fabrication, and Verification Process for Fracture Critical Tendon Welds

This Sub-Subsection provides guidance on treatment of Tendon Girth Welds

Addresses:

- Stresses acting on girth welds
- Fatigue design
- Fatigue damage analysis
- Fracture mechanics analysis
- S-N fatigue life
- Design for inspection and for no inspection during service life
- Fabrication
- Weld inspection at the fabrication site
- Weld testing

Section 9 – Tendon System Design

What's New in Section 9

Sub-Subsection 9.6.4 – Tendon Connectors (Top, Bottom and Intermediate)

Significant guidance has been proposed to be added in the 3rd Edition for design of the Tendon Connectors

Strength check criteria and formulation is provided for

- Primary Stress
- Primary plus Secondary Stress
- Shear Stress
- Bearing Stress

Connector fatigue design is discussed, including:

- S-N (Stress Life) Method
- Strain Life Method

Tendon Top Connector

	Safety Factors	
Safety Criteria	**Membrane**	**Membrane + Bending**
A (Operating)	**1.50**	**1.00**
B (Extreme)	**1.25**	**0.83**
S (Survial)	**1.00**	**0.83**

Safety Factors for Primary Stress

Section 9 – Tendon System Design

What's New in Section 9

<u>Sub-Subsection 9.6.5 – Tendon Flex Element</u>

The proposed 3rd Edition provides specific guidance for designing the elastomeric Flex Elements.

The guidance includes:

- Description
- Discussion of the stresses acting on the Flex Element
- Treatment of the steel and elastomeric portions of the Flex Element
- Strength Design
- Fatigue Design

Section 9 – Tendon System Design

What's New in Section 9

Subsection 9.7 – Transportation, Handling and Procedures

- Subsection 9.7 of 2nd Edition entitled "Fabrication" was rolled into the proposed 3rd Edition Subsection 9.6, "Structural Design and Fabrication"

- Subsection 9.7 of the proposed 3rd Edition serves merely to acknowledge the need to consider Transportation, Handling and Procedures in the tendon design, then points to Subsection 9.14 for guidance in that regard.

Section 9 – Tendon System Design

What's New in Section 9

Subsection 9.8 – Operational Procedures

- Subsection 9.8 in 2nd Edition addressed Installation Procedures by directing the reader to Subsection 13. Subsection 9.7 of the proposed 3rd Edition addresses Installation Procedures similarly by directing the reader to Subsection 14.

- Subsection 9.8 of the proposed 3rd is virtually unchanged from that of Subsection 9.9 of 2nd Edition, also entitled "Operational Procedures".

What's New in Section 9

Subsection 9.9 – Corrosion Protection

- Provides guidance on corrosion protection standards to which the designer should refer (NACE or DNV).
- Identifies types of corrosion protection systems to consider
- Recommends consideration of antifouling coatings to reduce the effects of marine growth where applicable

Section 9 – Tendon System Design

What's New in Section 9

Section 9 - Commentary

– Commentary 9.2.5.4	Single Event Fatigue
– Commentary 9.2.6	Robustness of Design
– Commentary 9.6.2.2	Hydrostatic Collapse Criteria
– Commentary 9.6.3.2	Girth Weld Fatigue Damage Analysis
– Commentary 9.6.3.3a	Girth Weld Fracture Mechanics Analysis
– Commentary 9.6.3.3b	Girth Weld Inspection
– Commentary 9.6.4.1	Connector Acting Stresses
– Commentary 9.6.4.2	Connector Strength Criteria
– Commentary 9.6.4.3	Connector Fatigue Initiation Life Method
– Commentary 9.6.5	Tendon Flex Element
– Commentary 9.6.5.3	Tendon Flex Element Fatigue Design

▶Questions?

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Planning, Designing, and Constructing Tension Leg Platforms

Section 10 – Foundation Design

Earl Doyle, Jason Newline

Section 10 – Foundations

- Section written by Earl Doyle and Jason Newlin, with contribution and review by most of geotechnical community. This represents latest methods and procedures within API geotechnical community.

What's Different?

- Axial capacity safety factor (B) recommended to be 1.5

What's New?

- Recommendations on Fatigue design
- Extensive commentary

Section 10 Foundation Analysis and Design

- **Foundation requirements and Site Investigations**
- **Loading**
- **Analysis Procedures**
  - **Reference to RP2A with discussion of differences**
- **Design of Piled Structures**
  - **Reference to RP2A with discussion of differences**
- **Design of Piles**
  - **Skin friction only**
  - **Ignore soil plug**
  - **Factors of Safety**

Load Condition	Safety factor
Extreme environment	1.5 X **B**
Normal environment	2.0 X **B**
Damage (w/reduced extreme env.)	1.5 X **B**
One tendon removed (w/reduced extreme env.)	1.5 X **B**

For GOM, **B** = 1.5

Section 10 Foundation Analysis and Design

- **Design of Shallow Foundations**
  - **Design of gravity foundations references ISO 19901-4**
- **Material Requirements**
- **Fabrication, Installation, and Surveys**
- **Commentary**
  - **Creep of Tension Piles**
  - **Fatigue Design of Driven Piles**
    - D = F1*D1 + F2*D2 (F2=10, F1 may be less than 10)
  - **Discussion on Safety Factors**
  - **Discussion on Large Lateral Pile Deflections**

Section 10 Foundation Analysis and Design

- **Questions and comments to**
  - **Earl Doyle**
  - **Jason Newlin**

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Section 11 – Riser Systems

Steve Hodges / Gail Baxter

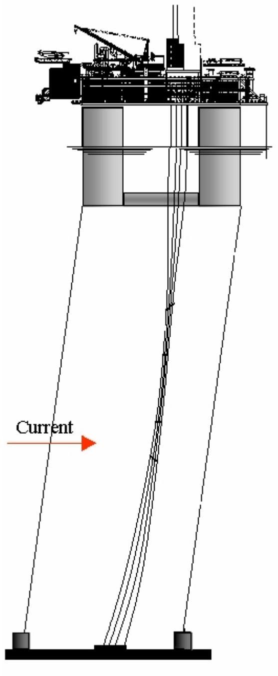
Section 11 – Riser Systems

<u>What's Different?</u>

- **Eliminated replication of material from API RP 2RD**
- **Various clarifications and edits**

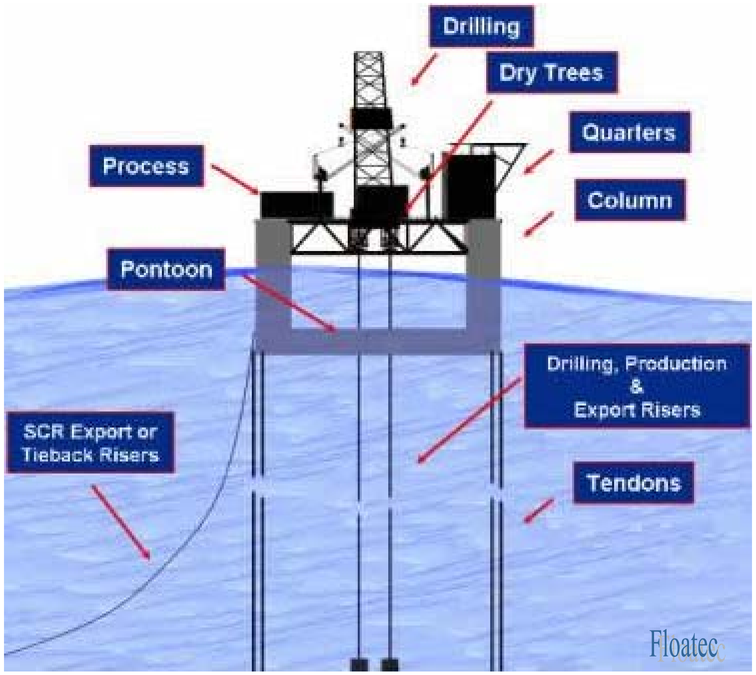
<u>What's New?</u>

- **No substantial changes**



Section 11 – Riser Systems

- **Questions?**



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Planning, Designing, and Constructing Tension Leg Platforms

Section 12

Jim Stevens & Debbie Bryant,

Section 12 – Facilities and Marine Systems Design

– *We are switching gears from the big stuff to another world….*

The world of Marine Systems

- Internal Access Shaft with HVAC duct and tank vent piping.

▶Supports for Marine Systems Piping & Cable Tray

▶Fire Water Casing

Section 12 – Facilities and Marine Systems Design

- Access shaft w/ piping and structural racks

What's Different

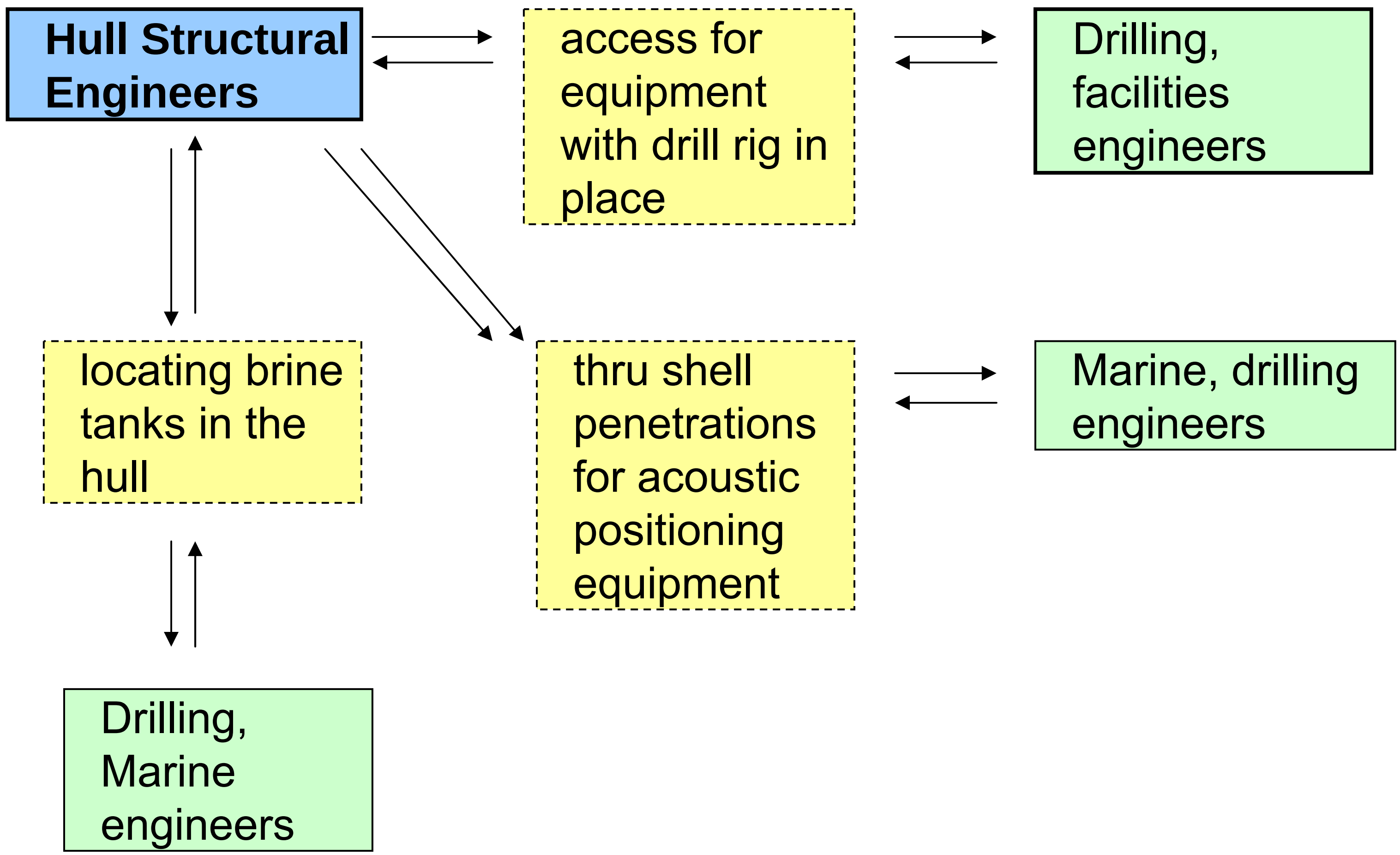
- More concentration on_safe egress.
- Updated ballast rate requirements with consideration for global design and TLP specific requirements.
- Updated/added referenced specifications.
- More platform fire protection considerations.
- ESD philosophy with respect to hull and semi-enclosed moonpools.

Section 12 – Facilities and Marine Systems Design

What's New

- **Drilling-specific considerations**
  - drilling fluids/oil tanks, inert gases in the hull
- **More emphasis on Intrinsically safe design:**
  - prevention of backflow of gases into the hull; hull hazardous areas
  - load cases for bilge pump sizing
  - Pollution prevention equipment in the hull
  - Emphasis on watertight integrity - Recommendations for bulkhead penetrations, including electrical and ventilation penetrations
- **Designing for inspectability – and increased safety during inspection**
- **Designing for necessary ergonomic issues:**
  - Noise
  - Lighting issues due to structural members
- **Emphasis on marine instrumentation systems and support of same**
  - Provision of power during hurricane evacuations
- **Added Interface checklists**

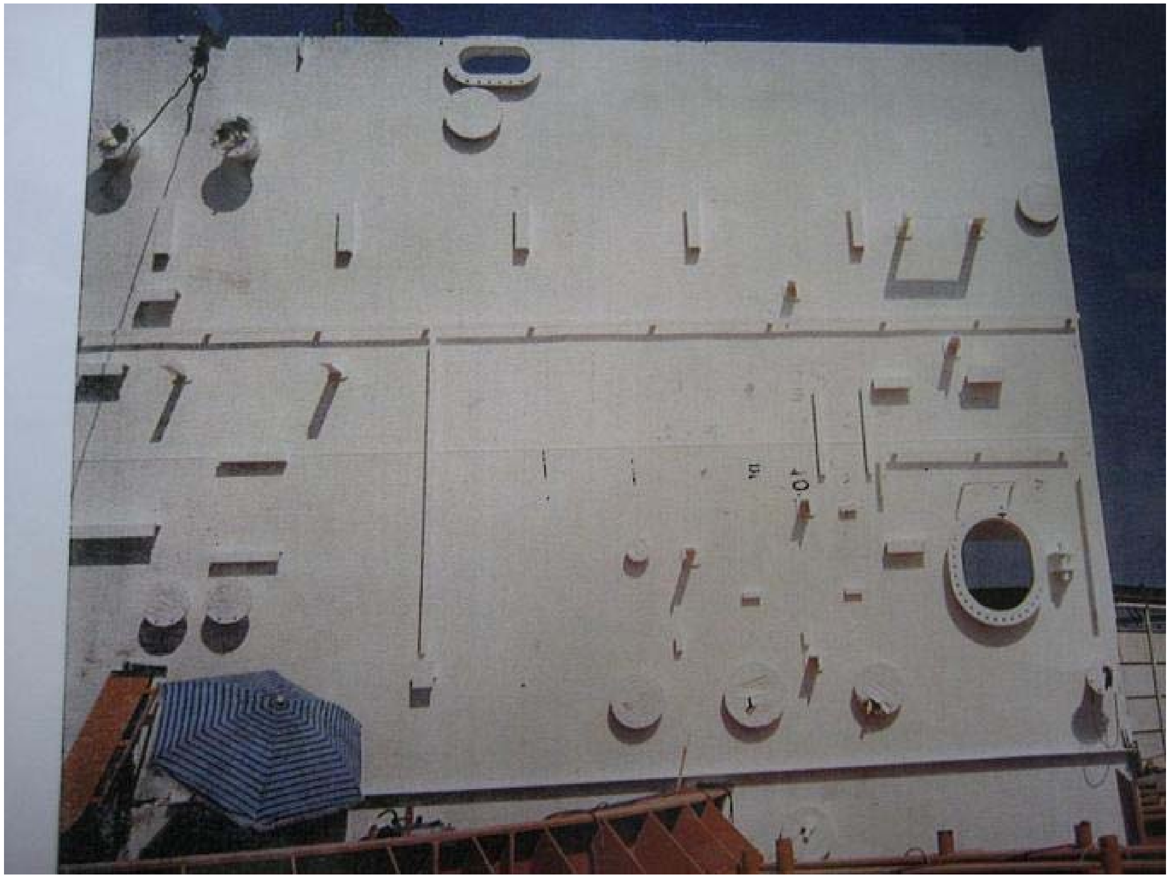
What's New: Interface Checklists ***(Example below)***



Section 12 – Facilities and Marine Systems Design

▶Column Module with Subsea tie back pull tubes

- Bulkhead w/ Piping Penetrations, Cable Tray attachment points & Manway.



New to Section 12 HULL SYSTEMS AND TOPSIDES FACILITY INTERFACE CHECKLIST

- **Structural:**
  - **Extreme wave forces on externally mounted items in the wave zone**
  - **Hull column compression during deck integration**
  - **Access/Egress – Internal and External stairs, ladders, walkways, elevators**
  - **Structural connection alignment (x,y,z tolerances) between hull & deck**
  - **Riser Porches**
  - **Pipeline valves mounted on the hull: placement, access, support.**

- **Facilities:**
  - **Process and Utility piping & Facility fluid loading, storage and transfer within the hull**
  - **Supply of seawater to the facility**
  - **Connections of piping & structures to the hull:**
  - **External production and export riser pipe routing**
  - **External casings, skim piles.**
  - **Routing of cables into hull**
  - **AC and DC power needs**
  - **Ability to Pre-commission hull systems**

- **Marine Information systems (MIS):**
  - **ADCP (Acoustical Doppler Current Profiler for VIV monitoring)**
  - **Tendon Instrumentation Systems**
  - **Draft sensors**
  - **Ability to supply power to MIS during hurricane evacuations**

Added: Interface planning - Internal HULL INTERFACE CONSIDERATIONS:

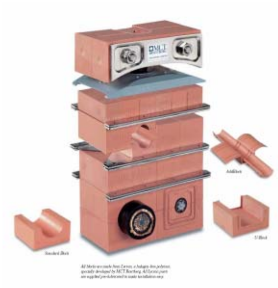
- **Access/Egress**
  - **Internal and External stairs, ladders, walkways.**
- **Platform crane access to**
  - **upper decks**
  - **top of hull**
  - **interior of hull**
- **Injured Personnel removal**
- **Equipment maintenance/removal**
- **Local lifting devices**
- **Sealed Compartment Inspection**
- **Hull statically & dynamically induced forces in internal and external piping.**

Added: Watertight Integrity Design considerations

- ***<u>Required operator action to ensure watertight integrity should be kept to a minimum</u>*.**

- **If seachests are used:**
  - **Stringent inspection requirements needed.**
  - **an exterior means of closure should be provided.**
  - **Review locating the seachest within a ballast tank or consider using external casing pumps as an alternate source of ballast water.**
  - **If located in a normally accessed space (such as a pump room), additional water level monitoring devices should be provided.**

- **Watertight electrical cable penetrations should be carefully chosen:**
  - **Use of pressure testable back-to-back cable transits and/or resin should be considered.**
  - **Single cable transits are typically available for a higher hydrostatic head rating than a multi-cable transit.**
  - **Inspection of the installation is Critical.**



Added: Watertight Integrity Design considerations

Other Penetrations into the hull:

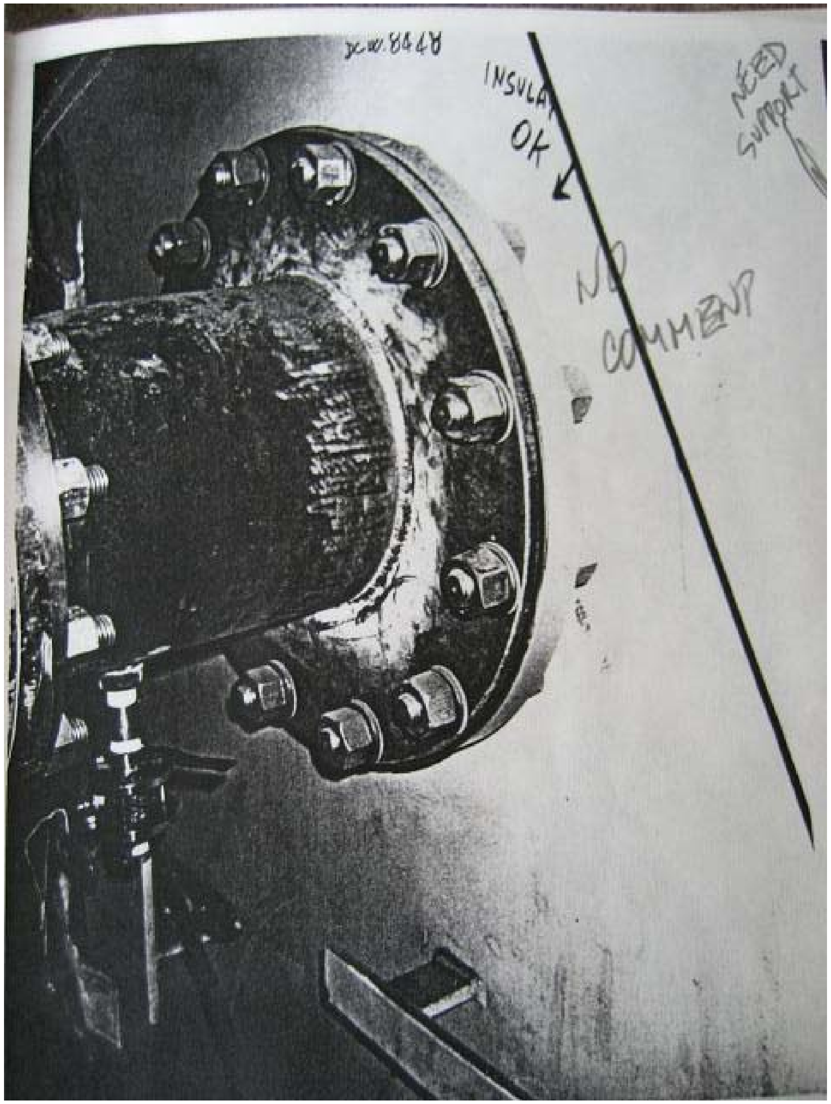
- **HVAC penetrations must be rated to the rating of the bulkhead they pass through.**
  - **Designers should consider the use of a flanged piping penetration piece with a valve in order to maintain watertight integrity.**
- **Exterior watertight hatches should be located above the design storm wave height.**
- **All watertight tanks should be provided with leak detection and level measurement capability**

- **Ratings for <u>all</u> penetrations – topsides facilities or hull – Need to match the fire rating of the bulkhead they pass through.**

Added: Materials & Watertight Integrity

- **Materials for watertight penetrations should be chosen to minimize corrosion**
  - **the piping arrangement should lend itself to in-service inspection and replacement.**
  - **Material characteristics should be considered when specifying antifouling systems to eliminate the possibility of increased brittleness and stress fractures.**
  - **Materials should be chosen to maintain the field life. Strong consideration should be given to the use of corrosion-resistant materials for seawater piping systems.**
    - If carbon steel is used for seawater service, the designer must provide a sufficient corrosion allowance and an accessible means of cleanout. Ballast tank vents should be designed with this in mind, as blockage of vents by rust would impair the platform's ballast transfer ability.
- **Galvanic corrosion should be considered where dissimilar materials exist. Particular emphasis should be given to bulkhead penetrations. Means of isolation should be provided.**

▶Ballast Piping Penetration



Added: Semi-enclosed Moonpools in monocolumn structures

Where a TLP's Moonpool can be considered a semi-enclosed space as defined by API 500, additional systems must be provided. These include:

a. Oil Removal
b. Ventilation
c. Gas detection
d. Firefighting
e. Access
f. Injured personnel rescue

Notes:

- Semi-enclosed Moonpools should be provided with redundant explosion proof sources of ventilation air.
- A minimum of two gas detectors should be provided at opposite sides and at varying elevations within the Moonpool.
- Consideration of whether shutdown of this equipment, upon receipt of a gas signal, actually increases platform safety, should be included.
- Handrails should be provided around semi-enclosed Moonpools. Means of access/egress should be provided. Removal of injured personnel should be a design case when designing access to this area.

Added: 12.9.4 HULL MARINE SYSTEMS OPERATOR TRAINING

- **All operators, not just Marine crew, should have an increased awareness of TLP hull marine systems functionality in order to increase platform safety.**

- **Areas to consider for increased training/awareness:**
  - **where to find emergency response procedures for the TLP hull.**
    - This will benefit the platform in terms of emergency response and in avoidance of incidents during maintenance activities.
  - **hurricane abandonment procedures for the TLP hull as well as for the process facility.**
  - **Operators should be aware of fire & gas shutdowns, alarms, and firefighting equipment within the hull even if they don't normally enter the space.**

Added: 12.10 Volatile Fluid Storage (Flash Point < 60 degrees C

- **The benefits of storing volatile fluids in the hull must be weighed against the design penalties:**
  - **area classification implications**
  - **the need for additional vents**
  - **fire protection**
  - **increased ventilation and gas detection**
  - **Structural design of tanks for the full head of the tower or prevention of overflow – Close communication is needed here.**
- **Inert gas (IG) blanketing of hull volatile fluid tanks should be considered in lieu of natural gas blanketing. However, if used, then IG or Nitrogen system is needed for purging & gas freeing.**
- **Provisions for degassing and ventilation of volatile fluid tanks for personnel entry should be made. Purging/degassing of the tank should be able to be accomplished without opening any manways or connections into adjacent enclosed compartments.**

Added: 12.10 Volatile Fluid Storage (Flash Point < 60 degrees C -- Further Design Considerations:

- **Installation of a crude oil wash (COW) systems should be strongly considered when storing crude oil in hull tanks and COW systems may be a Regulatory (OPA 90) requirement.**
- **For TLP's in U.S. waters with storage of hydrocarbon fluids in the hull, refer to OPA 90 requirements. The applicability of OPA 90 to hydrocarbon-containing production chemicals should be determined early in the design.**
- **The risk and consequences of a boat collision should be considered in the selection of tank locations for volatile fluids**
- **The potential for leakage from volatile fluid tanks into adjacent compartments and methods to detect and remove flammable gas should be considered in the tank layout.**
- **The impact on area classification and the potential for contamination should be accounted for when considering integral hull volatile fluid tanks located next to ballast tanks.**
- **Firesafe valves tested in accordance with API 607 should be used in piping systems within the hull where the fluid flashpoint is < 60 degrees C.**

Added: Typical Tendon/Marine Monitoring Systems for TLP's

- **A monitoring system for a tension leg platform can not be considered a critical system in that it will not change the behavior of the TLP in any way. However the ability of the operator to provide data showing that maximum weather experienced was less than extreme design conditions may avoid expenditure of extra inspection dollars otherwise required. Such systems have taken many forms on the various TLP's in existence to date.**

Items typically monitored are:

1. Tendon tension/load
2. Draft
3. Ballast and void tank liquid levels
4. Local environmental data such as wind speed, air temperature, etc.
5. Current profile
6. An inclinometer (may be provided as a platform installation aid).
7. Riser load

Section 13 Corrosion

- New section included to provide specific guidance on methods and products that can be used to protect steel materials from the effects of corrosion
- Corrosion Protection Systems are to be designed in accordance with DNV or NACE corrosion specifications
- Systems generally include coatings, cathodic protection (CP), corrosion allowances, dehumidification, and corrosion monitoring
- Corrosion Protection for the various subsystems (hull, tendons, foundations, risers, pipelines) should be designed to work together

Section 13 Corrosion - Applications

- **Antifouling - Coatings considered to reduce the effects of marine growth**
- **Splash Zone - Extra wall thickness on steel components and/or special coatings (i.e., epoxies /urethanes, glass flake reinforced coatings, thermally sprayed aluminum)**
- **Internal Surfaces – Systems comprised of Coatings, dehumidification, cathodic protection**
- **Hull External Submerged Surfaces - Cathodic protection systems, sometimes supplemented by coatings**
- **Tendons – System comprised of Coatings (i.e., fusion bonded epoxy, polyethylene, thermally sprayed aluminum) with cathodic protection. Include consideration for the top and bottom connectors and tension monitoring system.**
- **Foundations - Included in the overall corrosion protection design**
- **Cathodic Protection Interaction - Ground all connected systems and ensure that all are sufficiently protected so as not to cannibalize the capacity of other systems**

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Section 14

Fabrication, Installation, & Inspection

energy API

Section 14 –
Fabrication, Installation, & Inspection

<u>What's Different?</u>

- **Combined the sections from the 2nd Edition:**
  - Section 13 – Fabrication, Installation and Inspection
  - Section 14 – Structural Materials
- **Eliminated replication of material from API and AWS**
- **Various clarifications and edits**

<u>What's New?</u>

- **No substantial changes**

Section 14 –
Fabrication, Installation, & Inspection

Fabrication, Welding, & Assembly

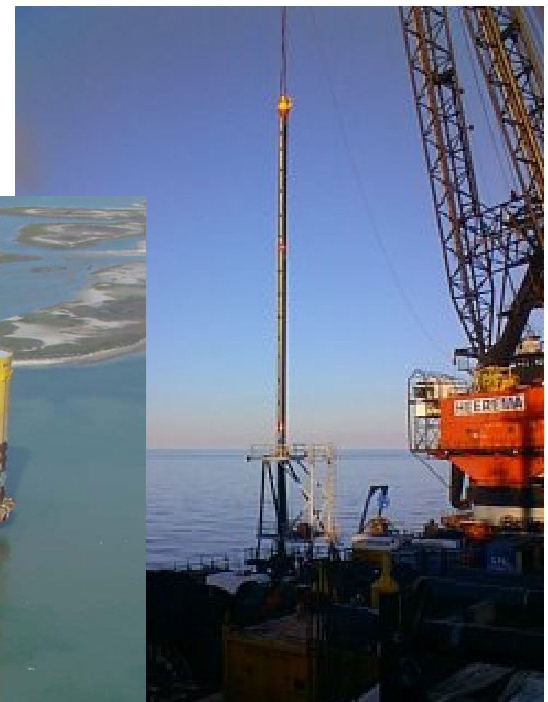
- Reference API RP 2A, Spec 2B, Bul 2U & 2V, + AWS D1.1

Transportation & Installation

- Reference API RP 2A

Inspection & Testing

- Reference API RP 2A



Section 14 –
Fabrication, Installation, & Inspection

- **Questions?**

RP2T 3rd Edition
Section 15
Survey and Maintenance

Dave Forsyth

energy API

Section 15 Surveys and Maintenance

Section 15 consists of five sections

- General
- Personnel
- Survey & Maintenance Planning and Record Keeping
- Survey Frequency
- Survey Requirements

This is an expansion of the In-Service inspection requirements from 13.7.6 of the Second Edition, which did not specify any frequency for inspections and only general recommendations for inspection requirements.

Section 15 Surveys and Maintenance
General

- **In-service surveys**
- **Goal is to safeguard human life, property, environment and prevent loss of natural recourses.**
- **Surveys are to be coordinated with a maintenance program that monitors changing conditions and corrects deficiencies.**

Section 15 Surveys and Maintenance
Personnel

- **Planning**
- **Survey**
- **Maintenance**

Section 15 Surveys and Maintenance

Survey & Maintenance Planning and Record Keeping

- **Survey & Inspection and Maintenance Planning Document**
- **Survey Reports file**
- **Maintenance File**

Section 15 Surveys and Maintenance
Survey Frequency

- **Annual Surveys**
- **Intermediate Surveys**
- **Special Periodical Surveys**
- **Continuous Surveys**
- **Survey after Storm or other Significant Environmental Event**

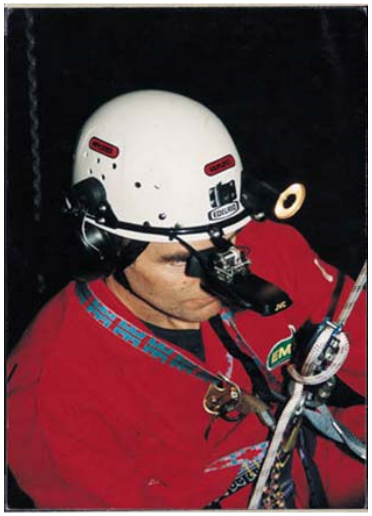
Section 15 Surveys and Maintenance
Survey Requirements - Annual Surveys

Section 15 Surveys and Maintenance

Survey Requirements - **Intermediate Survey & Underwater Inspection**

Section 15 Surveys and Maintenance

Survey Requirements - Special Periodical Survey



Survey Requirements

Survey after Storm or other Significant Environmental Event

Section 15 Surveys and Maintenance

Questions?

RP2T 3rd Edition Workshop

September 2007

Planning, Designing, and Constructing Tension Leg Platforms

Discussion and Questions

Conclusions

Agenda

- **Welcome**
  - **Jaime Buitrago**
- **Overview of 3rd Edition**
  - **Steve Leverette**
- **Section Presentations**
  - **All**
- **Panel Discussion and Questions**
  - **Tommy Laurendine**
- **Conclusion**
  - **Steve Leverette**

Question and Answer Panel : API RP2T 3rd Edition

- **Tommy Laurendine, Moderator**

1. **Scope**
2. **Normative References**
3. **Terms and Definitions**
4. **Planning**
5. **Design Criteria**
6. **Forces**
7. **Global Response**
8. **Structure**
9. **Tendons**
10. **Foundation**
11. **Risers**
12. **Facilities and Marine Systems**
13. **Corrosion**
14. **Fabrication, Installation, Inspection**
15. **Surveys and Maintenance**

Summary: Today's Objective

- Present RP2T 3rd Edition to industry
- Highlight differences from earlier editions
- Discuss new content
- Ask questions
- Feedback from industry to workgroup
- Facilitate Ballot process

Summary

Table of Contents

Path Forward

- **Balloting closes November 7, 2007**
- **Responding to comments**
- **Future updates**
  - **Identified issues**
    - Tension Collapse test data
    - Revise tendon safety factors
    - Assessment guide

THANK YOU!