2010-108-01

BOEMRE Comparison of Offshore Standards - M10PC00108 – TA&R Project No. 677

Progress Meeting No. 4

28 April 2011

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Agenda

- Introductions
- Work To-date
- Tasks and Schedule
- Summary/Recap

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Work to-date

- Review of standards and TA&R reports
- Comparison - fixed structures:
  - Environmental criteria and loading recipe
  - Member and joint design
  - Foundation design
  - Seismic
  - Fatigue
  - In-service inspection and maintenance (underway)
- Comparison - floaters:
  - Environmental criteria and loading recipe
  - Fatigue
  - In-service inspection and maintenance (underway)
- Jacket case study final results
- Calculation Sheets Developed for Member and Joint Checks
- Floater case study TLP/SPAR (?)

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Tasks

1. Environmental Load Recipes	☑
2. Loading Conditions	☑
3. Structural Steel Design	☑
4. Connections	☑
5. Fatigue	☑
6. Foundation Design	☑
7. In-service inspection and maintenance	
8. Assessment of existing platforms and floaters	
9. Fire, blast and accidental loadings	
10. Installation, Temporary Conditions, and Case Studies	
11. Reporting	
12. Project Management	

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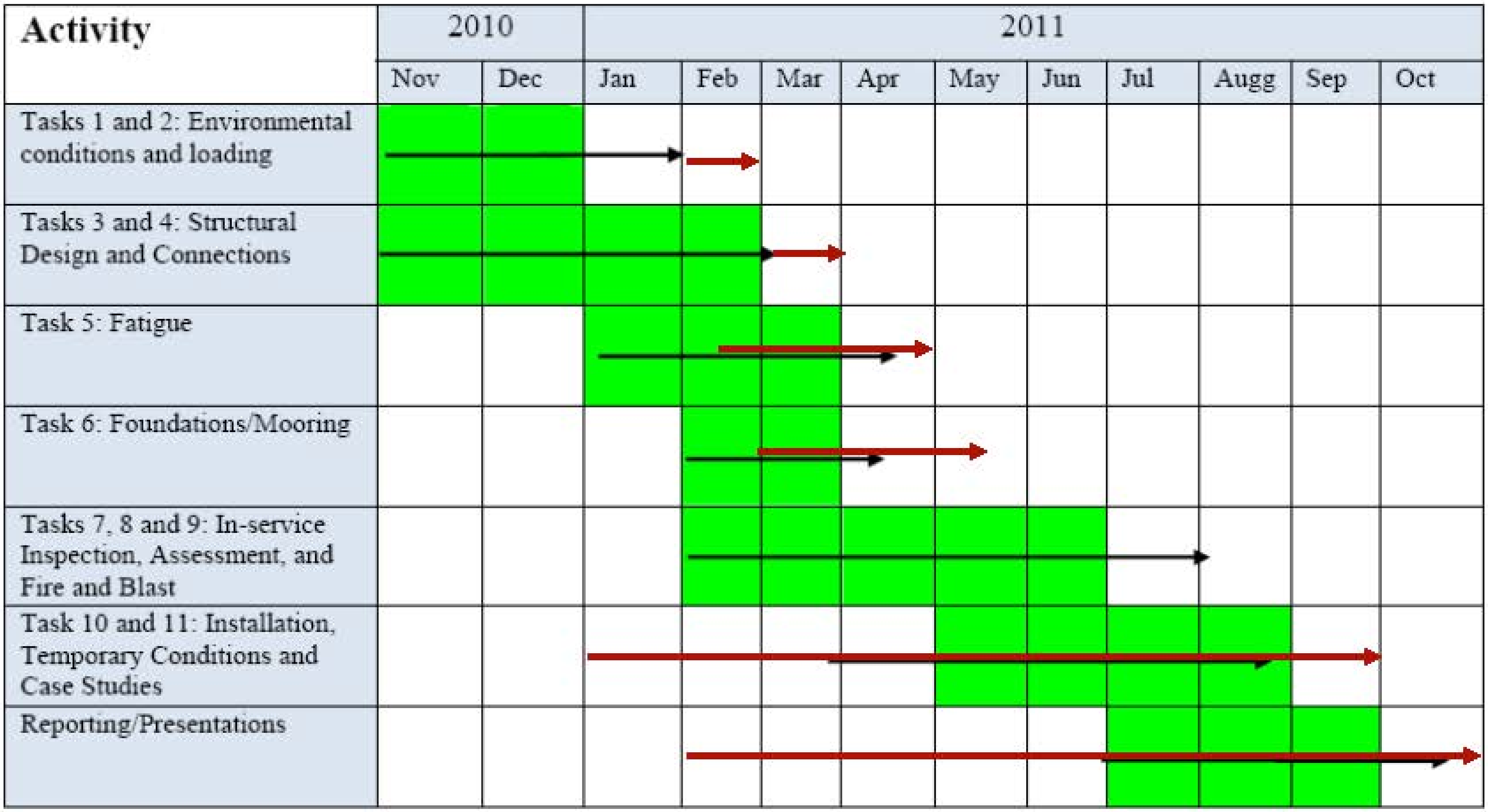
Schedule



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Scope for Floater Case Study

High Level Scope of Case Study for TLP/SPAR:

- Verify the computer model in SESAM suite of programs to ensure imported model is ready for analysis
- Run inplace analysis for extreme (survival) load case
- Run analysis to verify acceptance with criteria as set in API RP-2T/2FPS, ISO 19904-1, and NORSOK N-004
- Compare the results of the analyses
- Summarize the results

Assumptions:

- The case study is intended to be an exercise in acceptance criteria for primary structural members of the hull. Topsides, tendons and foundations are not included as part of this evaluation.

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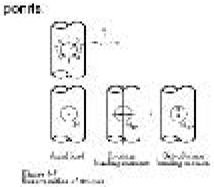
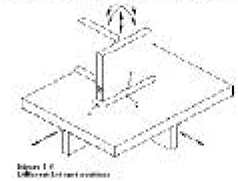
Code Comparison

- Fatigue

	API RP 2A WSD	ISO 19902/19904	Norsok N 004/DNV RP C203
Validity	The fatigue assessment of welded joints is based on the assumption that the connection has full penetration single or double sided welding.	The requirements in the ISO are applicable to the fatigue design of new structures as well as the fatigue assessment of existing structures. However, they only relate to fatigue evaluations of "uncracked" locations; therefore, in the case of existing structures, the proviso is that there be no crack already present. -The fatigue assessment of welded joints is based on the assumption that the connection has full-penetration single or double sided welding, unless otherwise stated.	In this standard, the requirements in relation to fatigue analyses based on fatigue tests and fracture mechanics. Reference is made to DNV RP C203 for more details with respect to fatigue design. DNV RP C203 1) It is valid for steel materials in air with yield strength less than 960 MPa. For steel materials in seawater with cathodic protection or steel with free corrosion the RP is valid up to 550 MPa. It may be used for stainless steel. 2) This RP is valid for material temperatures of up to 100°C. For higher temperatures the fatigue resistance data may be modified with a reduction factor.
Loading	The wave force calculations should follow the procedures described in Section 2.3.1 with the following exceptions: - Current - may be neglected and considerations for apparent wave period and current blockage are not required; - For the Gulf of Mexico a steepness between 1:20 and 1:25 is generally used. A minimum height equal one foot and a maximum height equal to the design wave height should be used. - Wave kinematics factor = 1.0 - Conductor shielding factor = 1.0	- In determining stress variations for a fatigue analysis the partial action factors shall be taken as 1.0. - The partial resistance factor on the fatigue assessment shall also be taken as 1.0.	- In determining stress variations for a fatigue analyses the partial action factors shall be taken as 1.0. - The partial resistance factor on the fatigue assessment shall also be taken as 1.0. - Fatigue analysis can normally be conducted with no current. - Wave kinematics factor = 1.0 - Conductor shielding factor = 1.0 - For small waves with KC referred to the mean water level in the range 1.0<KC<6, the hydrodynamic coefficients can be taken to be: Cd = 0.65 and Cm = 2.0 (smooth member); Cd = 0.80 and Cm = 2.0 (rough members) - In lack of site specific data, the wave periods shall be determined based on a wave steepness of 1/20. For a deterministic fatigue analysis, it is important to select periods such that response amplifications and cancellations are included. Also selection of wave periods in relation to the platform fundamental period of vibration is important. The number of periods included in the analysis should not be less than 20, and be in the range from 1 – 2 s to at least 1 – 20 s.
Stress Range	hot spot stress and hot spot stress range (HSSR) - A minimal of eight stress range locations need to be considered around each chord-brace intersection in order to adequately cover all relevant locations. These are: chord crowns (2), chord saddles (2), brace crowns (2) and brace saddles(2). - HSS for saddle and crown are given by: $HSS_{sa} = SCF_{ax,sa} f_{ax}$ +/- $SCF_{opb} f_{opb}$ $HSS_{cr} = SCF_{ax,cr} f_{ax}$ +/- $SCF_{ipb} f_{ipb}$ +CE where f = nominal stress sa = saddle cr = crown ax = axial ipb = in-plane bending opb = out of plane bending CE = the effect of nominal cyclic stress in the chord	geometric stress (GS) and geometric stress range (GSR) - Tubular Joints - A minimum of eight stress range locations need to be considered around each chord/brace intersection weld in order to adequately cover all relevant locations. These are: the chord sides at two crown positions, the brace sides at two crown positions, the chord sides at two saddle positions and the brace sides at two saddle positions. The GSRs for the chord and the brace side of the weld are determined. $\sigma_{HS,c}(t) = C_{ax,c}\sigma_{ax}(t)$ +/- $C_{ipb,c}\,\sigma_{ipb}(t)$ $\sigma_{HS,s}(t) = C_{ax,s}\sigma_{ax}(t)$ +/- $C_{opb,s}\,\sigma_{opb}(t) + \sigma_{ch,s}(t)$ where σ_{HS} = the geometric stress on the chord or the brace side of the weld between chord and brace σ_{ax} = the nominal axial stress in the brace (or stub) σ_{ipb} = the nominal in plane bending stress in the brace (or stub) σ_{opb} = the nominal out of plane bending stress in the brace (or stub) $\sigma_{n,c}$ = the nominal stress in the chord (or chord can) at the crown position C_{ax} = the stress concentration factor for axial brace stress C_{ipb} = the stress concentration factor for in-plane bending stresses in the brace C_{opb} = the stress concentration factor for out of plane bending stresses in the brace t = time s = the subscript denoting the saddle position c = the subscript denoting the crown position The effect of nominal variable stresses in the chord member can be covered by including the stress due to axial forces in the chord can member, combined with an axial SCF of 1.25, i.e. $\sigma_{ch,c}(t) = 1.25\,\sigma_{n,c}(t)$ Other than tubular joints	hot spot stress and hot spot stress range - Tubular Joints and Members The stresses are calculated at the crown and the saddle points. [illegible] (3.3.1)  - Welded connections other than tubular joints In plated structures, three types of hot spots at weld toes can be identified: a) at the weld toe on the plate surface at ending attachment b) at the weld toe around the plate edge of an ending attachment c) along the weld of an attached plate (weld toes on both the plate and attachment surface) 

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Examples of Code Comparison Table

Stress Concentration Factor (SCF)

SCF = HSSR at location (excluding notch effect) / Nominal Brace Stress Range:
1. The SCF should include all stress raising effects associated with the joint geometry and type of loading, except the local (microscopic) weld notch effect, which is included in the S-N curve.
2. The geometric stress or strain is defined as the total range that would be measured by a strain guage adjacent to the toe of the weld and oriented perpendicular to the weld [illegible] Typical geometric strain gauges are [illegible] within 5 mm to 0.1(rt)$^{0.5}$ from the weld toes with a guage length of 3 mm. r and t refer to the outside radius and thickness of the member instrumented, whether chord or brace.
3. The Efthymiou equations (in Tables C5.5.5-1 to C5.5.5-4) are recommended because this set of equations is considered to offer the best option for all joint types and load types and is the only widely [illegible] overlapped K and KT joints. The validity ranges for the Efthymiou parametric SCF equations are as follows:

- β = d/D from 0.2 to 1.0
- τ = t/T from 0.2 to 1.0
- γ = D/2T from 8 to 32
- α = L/2D (length) from 4 to 40
- θ from 20 to 90 degrees
- ζ = g/D (gap) from -0.6β/sin(θ) to 1.0

4. For all welded tubular joints under all three types of loading, a minimum SCF of 1.5 should be used.
5. SCFs for internally ring-stiffened joints can be determined by applying the Lloyds reduction factors to the SCFs for the equivalent unstiffened joint. For ring-stiffened joints analyzed by such means, the minimum SCF for the brace side under axial or OPB loading should be taken as 2.0. A minimum value of 1.5 is recommended for all other locations.

SCF = the range of the GS at a particular location of the intersection weld (excluding notch effect) / the range of the nominal brace stress

1. The recommended S-N curves and SCF equations used in ISO are based on European definition and are consistent.
2. The Efthymiou equations are recommended because this set of equations is considered to offer either the best option or a very good option for all joint types and types of brace forces and is the only set which covers overlapped K and KT joints.
3. The validity ranges for the Efthymiou parametric SCF equations are as follows:

- β = d/D from 0.2 to 1.0
- τ = t/T from 0.2 to 1.0
- γ = D/2T from 8 to 32
- α = L/2D (length) from 4 to 40
- θ from 20 to 90 degrees
- ζ = g/D (gap) from -0.6β/sin(θ) to 1.0

4. Increasing the chord wall thickness is an effective way of reducing stress concentrations. For T/Y and X joints, a doubling of the chord wall thickness reduces the saddle SCFs by a factor of 4; crown SCFs reduce [illegible]

SCF = hot spot stress range/nominal stress range
- The local weld notch effect is excluded by using stress values just outside the weld notch region and extrapolating these (linearly) to the weld toe. The European definition is based on maximum principal stress, i.e. the stress components are extrapolated to the weld toes and then used in Mohr's Circle to establish the maximum principal stress at the toe. The stress normal to the weld toe, used in the US definition, is somewhat lower than this, but for the all-important saddle location the two are virtually identical.

Tubular Connections

The basic tubular joint S-N curve has been derived from an analysis of data on tubular joints manufactured using welds conforming to a standard [illegible] profile given in AWS.
The basic design S-N curve is of the form:

$Log_{10}(N) = Log_{10}(k1) - mLog_{10}(S)$ (5.4.1.1)

where N = the predicted number of cycles to failure under stress range S,
k1 = a constant,
m = the inverse slope of the S-N curve

The basic design S-N curve is of the form

$log_{10}(N) = log_{10}(k1) - mlog_{10}(S)$ (16.11-1)

where N = the predicted number of cycles to failure under constant amplitude stress range S.
k1 = a constant, (k1 = N for S = 1)
m = the inverse slope of the S-N curve
S = the constant amplitude stress range, which is the geometrical stress range

The basic design S-N curve is of the form

$log_{10}(N) = log(a) - mlog_{10}(\Delta\sigma)$ (2.4.1 DNV RP C203)

where N = the predicted number of cycles to failure under constant amplitude stress range Δσ,
m = negative inverse slope of the S-N curve
Δσ = stress range
log $\bar{a}$ = log a - 2s intercept of log N-axis by S-N curve
a = constant relating to mean S-N curve
s = standard deviation of log N

Table 5.5.1-1 - Basic Design S-N Curves

Curve	$log_{10}(k1)$ S in ksi	$log_{10}(k1)$ S in MPa	m
Welded Joints (WJ)	9.85 11.92	12.48 15.13	3 for N < 10^7 5 for N > 10^7
Cast Joints (CJ)	11.80 13.00	15.17 17.21	4 for N < 10^7 5 for N > 10^7

- The basic design S-N curves given in Table 5.5.1-1 are applicable for joints in air and submerged coated joints.
- These S-N curves are based on welds with yield strength less than 72 ksi (500 MPa)
- The WJ curve is based on 5/8 in (16mm) reference thickness. For material thickness above the reference thickness, the following thickness effect should be applied for as-welded joints.

$S = S_0(t_{ref}/t)^{0.25}$

where t_{ref} = the reference thickness, 5/8 inch (16mm),
S = allowable stress range
So = the allowable stress range from the S-N curve
t = member thickness for which the fatigue life is predicted
- The material thickness effect for castings is given by
$S = So (t_{ref}/t)^{0.15}$
where the reference thickness t_{ref} = 1.5 in (38 mm)
- For Welded Joints in seawater with adequate cathodic protection, the m = 3 branch of the S-N curve [illegible]

Table 16.11-1 - Basic representative S-N curves for air and sea water

Curve	Air: $log_{10}(k1)$ S in MPa	Air: m	Sea water with adequate corrosion protection: $log_{10}(k1)$ S in MPa	Sea water with adequate corrosion protection: m
Welded Joints (WJ)	12.48 16.13	3.0 for N≤10^7 5.0 for N>10^7	12.18 16.13	3.0 for N≤1.8 x 10^6 5.0 for N>1.8 x 10^6
Cast Joints (CJ)	15.17	4		
Other joints (OJ)				
B	15.01 17.01	4.0 for N≤10^7 5.0 for N>10^7	14.61 17.01	4.0 for N≤10^6 5.0 for N>10^6
C	13.63 16.47	3.5 for N≤10^7 5.0 for N>10^7	13.23 16.47	3.5 for N≤4.68 x 10^6 5.0 for N>4.68 x 10^6
D	12.18 15.63	3.0 for N≤10^7 5.0 for N>10^7	11.78 15.63	3.0 for N≤10^6 5.0 for N>10^6
E	12.02 15.37	3.0 for N≤10^7 5.0 for N>10^7	11.62 15.37	3.0 for N≤10^6 5.0 for N>10^6
F	11.80 15.00	3.0 for N≤10^7 5.0 for N>10^7	11.40 15.00	3.0 for N≤10^6 5.0 for N>10^6
F_2	11.63 14.71	3.0 for N≤10^7 5.0 for N>10^7	11.23 14.71	3.0 for N≤10^6 5.0 for N>10^6

Table 2-1 S-N Curve in Air and Table 2-2 S-N curve in seawater with cathodic protection

S-N Curve	Air: log $\bar{a}$ S in MPa	Air: m	Sea water with adequate cathodic protection: $log_{10}(k1)$ S in MPa	Sea water with adequate cathodic protection: m
T	12.164 15.606	3.0 for N≤10^7 5.0 for N>10^7	11.764 15.606	3.0 for N≤10^6 5.0 for N>10^6
C	12.592 16.320	3.0 for N≤10^7 5.0 for N>10^7	12.192 16.320	3.0 for N≤10^6 5.0 for N>10^6
Other joints (OJ)				
B1	15.117 17.146	4.0 for N≤10^7 5.0 for N>10^7	14.917 17.146	4.0 for N≤10^6 5.0 for N>10^6
B2	14.885 16.856	4.0 for N≤10^7 5.0 for N>10^7	14.685 16.856	4.0 for N≤10^6 5.0 for N>10^6
C1	12.449 16.081	3.0 for N≤10^7 5.0 for N>10^7	12.049 16.081	3.0 for N≤10^6 5.0 for N>10^6
C2	12.301 15.835	3.0 for N≤10^7 5.0 for N>10^7	11.901 15.835	3.0 for N≤10^6 5.0 for N>10^6
D	12.164 15.606	3.0 for N≤10^7 5.0 for N>10^7	11.764 15.606	3.0 for N≤10^6 5.0 for N>10^6
E	12.010 15.350	3.0 for N≤10^7 5.0 for N>10^7	11.610 15.350	3.0 for N≤10^6 5.0 for N>10^6

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Examples of Code Comparison Table

- Inspections

TABLE 1

API RP 2A WSD/LRFD 14. SURVEY	ISO 19902	NORSOK N-005
14.3 SURVEY LEVELS **LEVEL I** Below water verification of performance of the cathodic protection system (i.e. dropped cell), and an above water visual survey to determine the effectiveness of corrosion protection system, detect deteriorating coating systems, excessive corrosion, and bent, missing and damaged members. General examination of all structural members in splash zone and above water, concentrating on condition of the more critical areas such as deck legs, girders, trusses, etc. Survey should identify indications of obvious overloading, design deficiencies, and use inconsistent with the platform's original purpose. If above water damage is detected, NDT should be used when visual inspection can't fully determine the extent of damage. Should Level I survey indicate that underwater damage could have occured, a Level II inspection **LEVEL II** General underwater visual inspection by divers or ROV to detect presence of [illegible] accidental or environmental overloading, scour and seafloor instability, fatigue damage, design or construction deficiencies, presence of debris, and excessive marine growth. The survey should include measurement of cathodic potentials of pre-selected critical areas. Detection of significant structural damage during Level II survey should become the basis for initiation of Level III survey, which should be conducted as soon as conditions permit. **LEVEL III** An underwater visual inspection of [illegible], based on results of Level II survey, areas known or suspected damage. Such areas should be sufficiently cleaned of marine growth to permit thorough inspection. FMD can provide an acceptable alternative to close visual inspection (CVI). CVI for corrosion monitoring should be included as part of Level III survey. Detection of significant structural damage during Level III survey should become the basis for initiation of Level IV survey, where CVI alone can't not determine the extent of damage. Level IV survey, if required, should be conducted as soon as conditions permit. **LEVEL IV** An underwater NDT of preselected areas and/or, based on results of Level III survey, areas known or suspected damage. Level IV survey should also include detailed inspection and measurements of damaged areas. A Level III and/or Level IV survey of fatigue-sensitive joints and/or areas susceptible to cracking could be necessary to determine if damage has occured. Monitoring fatigue-sensitive and/or reported crack-like indications, can be an acceptable alternative to analytical verification.	**23 IN-SERVICE INSPECTION AND SIM** **LEVEL I** Below water verification of performance of the cathodic protection system (i.e. dropped cell), and an above water visual survey to determine the effectiveness of corrosion protection system, detect deteriorating coating systems, excessive corrosion, and bent, missing and damaged members. General examination of all structural members in splash zone and above water, concentrating on condition of the more critical areas such as deck legs, girders, trusses, etc. Survey should identify indications of obvious overloading, design deficiencies, and use inconsistent with the platform's original purpose. If above water damage is detected, NDT should be used when visual inspection can't fully determine the extent of damage. Should Level I survey indicate that underwater damage could have occured, a Level II inspection **LEVEL II** General underwater visual inspection by divers or ROV to detect presence of [illegible] accidental or environmental overloading, scour and seafloor instability, fatigue damage, design or construction deficiencies, presence of debris, and excessive marine growth. The survey should include measurement of cathodic potentials of pre-selected critical areas. Detection of significant structural damage during Level II survey should become the basis for initiation of Level III survey, which should be conducted as soon as conditions permit. **LEVEL III** An underwater visual inspection of [illegible], based on results of Level II survey, areas known or suspected damage. Such areas should be sufficiently cleaned of marine growth to permit thorough inspection. FMD can provide an acceptable alternative to close visual inspection (CVI). CVI for corrosion monitoring should be included as part of Level III survey. Detection of significant structural damage during Level III survey should become the basis for initiation of Level IV survey, where CVI alone can't not determine the extent of damage. Level IV survey, if required, should be conducted as soon as conditions permit. **LEVEL IV** An underwater NDT of preselected areas and/or, based on results of Level III survey, areas known or suspected damage. Level IV survey should also include detailed inspection and measurements of damaged areas. A Level III and/or Level IV survey of fatigue-sensitive joints and/or areas susceptible to cracking could be necessary to determine if damage has occured. Monitoring fatigue-sensitive and/or reported crack-like indications, can be an acceptable alternative to analytical verification.	
14.4 SURVEY FREQUENCY Frequency of surveys are dependent upon the exposure categories of the platform for both life-safety and consequence of failure considerations. Survey Intervals (see Survey Intervals table below) * survey should be performed if required based on Level I inspection findings. Time interval between surveys for fixed platforms should not exceed the intervals shown in table above, unless [illegible] justified. Justification for changing guideline survey intervals should be documented and retained by operator. Following factors, which either increase or decrease survey intervals, should be taken into account:	**23.7 DEFAULT PERIODIC INSPECTION REQUIREMENTS** In absence of an in-service structural inspection strategy, following default requirements shall apply. These requirements address only the concerns of safeguarding life and protecting the environment. Additional inspections can be needed to meet statutory requirements, owner's corporate policy or industry standards/practices. Compliance with default requirements does not guarantee structural reliability or fitness-for-purpose. Survey Intervals (see Survey Intervals table below) * determined from Level II inspection results	**4.3 CONDITION MONITORING PRINCIPLES** Operator shall monitor the condition of operated offshore installation in systematic manner. This may include development of an overall philosophy and strategy for condition monitoring, establishing in-service inspection systems and long-term inspection programs, etc.

API RP 2A WSD/LRFD – Survey Intervals

Exposure Category Level	Survey Level I	II	III	IV
L-1	1 yr	3-5 yrs	6-10 yrs	*
L-2	1 yr	5-10 yrs	11-15 yrs	*
L-3	1 yr	5-10 yrs	*	*

ISO 19902 – Survey Intervals

Exposure Level	Inspection Level I	II	III	IV
L-1	Annual	3 yrs	5 yrs	*
L-2	Annual	5 yrs	10 yrs	*
L-3	Annual	5 yrs	not required	not required

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Examples of Code Comparison Table

- Inspections (cont'd)

1. Original design/assessment criteria 2. Present structural condition 3. Service history of platform 4. Platform structural redundancy 5. Criticalness of platform to other operations 6. Platform location 7. Damage 8. Fatigue sensitivity **Special Surveys** Level I survey should be conducted after direct exposure to a design environmental event. Level II survey should be conducted after severe accidental loading that could lead to structural degradation (e.g., boat collision, dropped objects), or after an event exceeding the platform's original design/assessment criteria. Areas critical to the structural integrity of the platform, which have undergone structural repair, should be subjected to a Level II survey approximately one year following completion of the repair. A Level III survey should be performed when excessive marine growth prevents visual inspection of the repaired areas. Level II scour surveys in scour prone areas should take account of local experience, and are usually more frequent than intervals indicated in table above. **14.5 PRE-SELECTED SURVEY AREAS** During initial platform design and any subsequent reanalysis, critical members and joints should be identified to assist in defining requirements for future platform surveys. Selection of critical areas should be based on such factors as joint and member type, stresses, stress concentrations, structural redundancy, and fatigue lives determined during platform design/assessment.	Inspection requirements less than default can be justified when an inspection strategy is developed and maintained. **Special inspections** Special inspections shall be undertaken to assess performance of repairs undertaken to ensure the fitness for purpose of structure, conducted approximately 1 yr after completion of the repair, and to monitor known defects, damage, local corrosion, scour, or other conditions which could potentially affect the fitness for purpose of the structure **Unscheduled inspections** An inspection shall be conducted as soon as practical after the occurrence of an environmental event exceeding that for which structure was designed or assessed, or one significant accidental action. The minimum scope shall include the following: a visual inspection without marine growth cleaning that provides full coverage from sea floor to top of structure, conductors, risers, and various appurtenances, and which includes checking the general conditions of appurtenances and looking for debris and damage.	
14.6 RECORDS Records of all surveys should be retained by the operator for the life of the platform. Such records should contain detailed accounts of survey findings, including video tapes, photographs, measurements, and other pertinent survey results. Records should also identify the survey levels performed. Descriptions of detected damage should be thoroughly documented and included with survey results. Any resulting repairs and engineering evaluations of the platform's condition should be documented and retained.	**23.2 DATA COLLECTION AND UPDATE** Records of all original design analyses, fabrication documentation, installation and in-service inspections, engineering evaluations, repairs, and incidents shall be retained by the owner for the life of the structure and transferred to new owners as necessary	**6.4 INSPECTION RECORD** Operator shall maintain an up to date filing system for results and evaluations from condition monitoring programme throughout the lifetime of installation. The data may include video tape, inspection log, first hand inspection report, evaluation and recommendations. Such data records should also include tools/techniques employed, planned and actual scope of work and description of findings and any anomalies discovered.

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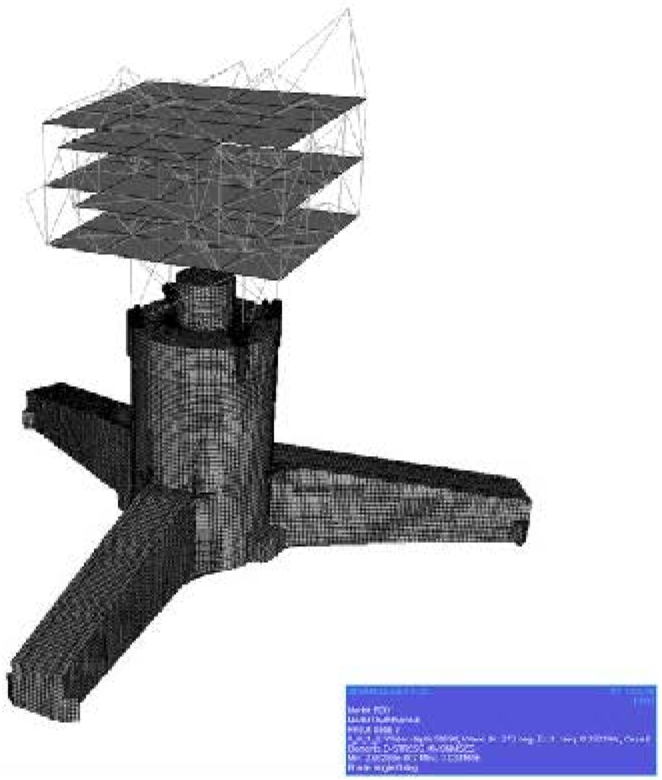
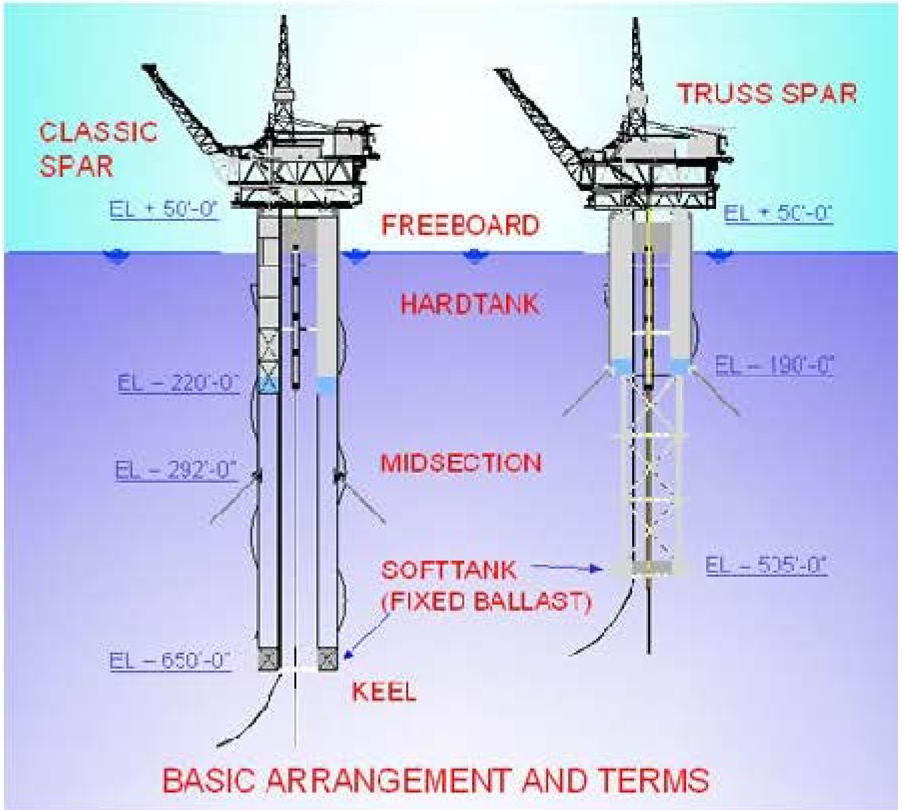
TLP/SPAR for Floater Case Study (?)





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Summary

- Comparison progress to date
- Case studies status
- API, ISO, and NORSOK Standards applied to a Jacket platform case study results presented.
- Tasks 7, 8, 9 and 10 Underway
- Next deliverable: Monthly Progress Report
- Next Progress GoToMeeting – June 1st, 2011.

Further comments

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