Transocean Spitsbergen

Dynamically Positioned Semi-Submersible MODU

Norway - Roald Rygg
1290 m Water Depth

Prepared for
Transocean Operations Norway

Revision	Date	Author	Description	Reviewed by
0	23-Feb-15	M. Taha	Initial Release for Review	

Rig No.	Group	Subgroup	PSS Subject	REA/Project No.
8020	**AA**	**422**	**Riser Analysis**	**13923**

EXECUTIVE SUMMARY

This report documents the riser limits and station-keeping of the Transocean Spitsbergen dynamically positioned semi-submersible for operations offshore Norway at Roald Rygg location in 1290-m (4231-ft) water depth.

This report will outline the following:

1. API Riser Buckling Stability Criteria Calculations in accordance with API RP16Q
2. Riser Operability and Drilling Performance
3. Dynamic Wellhead and Casing Bending Loads

Location Description			
Operator	**Statoil**		
Designation	**Roald Rygg**		
Region of Operation	**Norway**		
Water Depth at Well Center	**1290** [meters]	4,231 [feet]	
Applicable Code of Practice	**API RP16Q**		
Anticipated Max.Mud Weight	**1.35** [sg]	11.3 [ppg]	
Maximum Shut-in Pressure	**3,713** [psi]		
Conduct DST Operation	**NO**		

Casing Program	**O.D.** [inches]	**Wall Thickness** [inches]	**Material Yield** [ksi]	**From** [meters]	**To** [meters]	**Weight per foot** [pounds]	**Bending Capacity** [ft-kips]	**Comments**
36-inch Structural Casing	36.00	1.50	56	2.0	70.0	557	6283	100% Yield
Wellhead				2.0	3.1		5700	

Overall conclusions from the analyses indicate the following:

1. For the 1290-m (4231-ft) water depth space-out outlined in this report, the required 1.35 SG (11.3 ppg) mud is achieved with the Transocean Spitsbergen riser and tensioner system. The minimum applied tension for the specified maximum mud weight of 1.35 SG is 652-tonnes (1437-kips) as calculated in accordance with API RP16Q / ISO 13624-1 and LMRP lift-off requirements.

2. Global riser stresses will be generally below 49% yield (67% allowed) for the selected 652-tonnes applied tension in up to the 99%NX conditions.

3. Mean Stroke-out has been found to be the first riser mechanical limit at 6.7% of water depth (86-m) in the 99%NX conditions. The associated Maximum Wellhead bending load is 3563 kip.ft, the associated Maximum Casing bending load is 4922 kip.ft.

4. Mean Stroke-out has been found to be the first riser mechanical limit at 7.7% of water depth (100-m) in the 95%NX conditions. The associated Maximum Wellhead bending load is 3863 kip.ft, the associated Maximum Casing bending load is 5379 kip.ft

5. Seasonal metocean data have been provided for the subject location. Since operations are scheduled to take place in the late February/March time period, the maximum environment from this period was used in this analysis. If the operation schedule changes to outside of late February/March period, the analysis may need to be re-run in order to establish more accurate limits for DP operations.

6. The surface casing configuration consist of 36-inch x 1.5-inch Grade X56 structural casing to approximately 70-m below mud line with a wellhead stickup of approximately 3.1-m. Although actual casing program contains more components, the depth to which the casing is modeled captures the elevation exposed to the highest bending loads in the soil region. The model only utilizes the surface casing (single pipe), inner casing strings were not modeled and are expected to add additional resistance to bending loads.

7. The analysis was performed using the Customer furnished soil data.

8. If the lengths or set depth differ by more than 5-feet, consultation with HQ-engineering should be made to ensure that riser mechanical limits are not altered.

***WD offsets are set in respect to the well center. Negative offsets (-) represent downstream direction and positive (+) are upstream.**

PROPOSED RISER STRING CONFIGURATION

Description	Quantity	Section Length	Depth to Top of Section	Component Weight		Section Weight		Wet/Dry Ratio	
				In Air	In Water	In Air	In Water	BOP	LMRP
	[joints/ea.]	[m]	[m]	[kg]	[kg]	[tonnes]	[tonnes]		
Wellhead		3.0	1286.6						
BOP	1	8.5	1278.1	205933	179162	205.9	179.2		
LMRP	1	6.6	1271	106142	92343	106.1	92.3		
LFJ+Riser Adapter	1	1.3	1270						
Slick w/Fins 21 in x 0.875 in	3	68.6	1201.6	17100	11500	51.3	34.5	80.6%	84.2%
Lower X/O Joint 21 in x 0.875 in	1	22.9	1178.7	14598	12700	14.6	12.7	81.1%	84.3%
Slick w/Fins 21 in x 0.875 in	2	45.7	1133.0	17100	11500	34.2	23.0	78.8%	82.9%
7500 ft 21 in x 0.875 in	3	68.6	1064.4	28219	4881	84.7	14.6	60.9%	71.7%
4500 ft 21 in x 0.875 in	30	685.8	378.6	25674	2951	770.2	88.5	25.0%	35.1%
2000 ft 21 in x 0.875 in	8	182.9	195.8	22100	-1618	176.8	-12.9	20.4%	29.9%
Slick w/Fins 21 in x 0.875 in	6	137.2	58.6	17100	11500	102.6	69.0	24.0%	32.4%
Upper X/O Joint 21 in x 0.875 in	1	22.9	35.7	14598	12700	14.6	12.7	24.7%	32.9%
21in x 0.875in x 10ft	1	3.0	32.7	4140	3257	4.1	3.3	24.8%	33.0%
ROPS 75'	1	22.9	9.8	28736	25000	28.7	25.0	26.1%	34.0%
Estimated Riser Stretch	1	0.4	9.5						
TJ OB & Tension Ring	1	21.0	-11.5	33700	29319	33.7	29.3	27.6%	35.1%
TJ Stroke (IB)	1	**7.9**	-19.5	9072	7893	9.1	7.9	28.0%	35.4%
Spacer Jt, 45 ft	1	13.7	-33.2	11036	9601	11.0	9.6		
Diverter FJ	1	3.2	-36.4	5000	4350	5.0	4.4		
Diverter FJ to RKB	1	4.1	-40.5						

Riser Weights, API Factors and Tension Margins

TJ OB to LFJ Steel Wet Weight	**725** [tonnes]	API Weight Factor	**1.03**
Buoyancy Net Lift	**-423** [tonnes]	API Buoyancy Factor	**0.97**
Total Nominal Riser only Wet Wt.	**302** [tonnes]	API Weight Margin	**34** [tonnes]
TJ OB, Riser, and LMRP Nominal Wet Weight	**394** [tonnes]	API Factored Steel Weight	**747** [tonnes]
TJ OB, Riser, and BOP Nominal Wet Weight	**574** [tonnes]	API Factored Buoyancy Lift	**-410** [tonnes]
		Total API Factored Wet Weight	**337** [tonnes]
		Reserve Tension After Failure	**14** [tonnes]
		Tension Margin for Lift-off	**220** [tonnes]

Lift-off Margin is based on riser recoil analysis in 1354m WD

API 16Q Minimum Tension Requirements & LMRP Lift-off Requirement*

Mud Weight	Total Mud Weight	Min. API/ISO Tension	Tmin Required	Tensioner Pressure	Tvertical @ Tension Ring	Wellhead Tension	LMRP Connector Tension	LFJ Tension	
		Required	@ Cyl. Top		(Tension Setting)			Actual	Effective
[SG]	[tonnes]	[tonnes]	[tonnes]	[bar]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]
1.03	2	421	717	**58.7**	**652**	77	348	380	25
1.08	16	428	717	**58.7**	**652**	62	334	357	69
1.10	23	435	717	**58.7**	**652**	56	327	347	89
1.13	29	443	717	**58.7**	**652**	49	321	337	109
1.15	35	451	717	**58.7**	**652**	43	314	327	130
1.17	42	458	717	**58.7**	**652**	36	308	317	150
1.20	48	466	717	**58.7**	**652**	30	301	306	170
1.22	55	473	717	**58.7**	**652**	23	295	296	190
1.25	61	481	717	**58.7**	**652**	17	288	286	211
1.26	65	485	717	**58.7**	**652**	14	285	281	221
1.29	74	496	717	**58.7**	**652**	4	276	266	251
1.32	81	504	717	**58.7**	**652**	-2	269	255	271
1.34	87	511	717	**58.7**	**652**	-9	263	245	291
1.35	**91**	**515**	**717**	**58.7**	**652**	**-12**	**259**	**240**	**302**
1.38	97	523	717	**58.7**	**652**	-19	253	230	322
1.40	104	531	717	**58.7**	**652**	-25	246	220	342
1.44	113	542	717	**58.7**	**652**	-35	237	204	372
1.46	120	550	717	**58.7**	**652**	-41	230	194	393
1.49	126	557	717	**58.7**	**652**	-48	224	184	413
1.50	129	561	717	**58.7**	**652**	-51	220	179	423
1.53	139	572	717	**58.7**	**652**	-61	211	164	453
1.56	146	580	717	**58.7**	**652**	-67	204	154	473
1.58	152	588	717	**58.7**	**652**	-74	198	143	494
1.60	159	595	717	**58.7**	**652**	-80	191	133	514
1.63	165	603	717	**58.7**	**652**	-87	185	123	534
1.65	172	610	717	**58.7**	**652**	-93	178	113	554
1.68	178	618	717	**58.7**	**652**	-100	172	103	575
1.70	185	626	717	**58.7**	**652**	-106	165	92	595
1.72	191	633	717	**58.7**	**652**	-113	159	82	615
1.75	197	641	722	**59.1**	**657**	-114	157	77	635
1.77	204	648	730	**59.7**	**665**	-113	159	75	655
1.80	210	656	738	**60.3**	**673**	-112	160	72	676
1.82	217	664	746	**60.9**	**680**	-110	161	70	696
1.84	223	671	754	**61.5**	**688**	-109	163	67	716
1.87	230	679	761	**62.2**	**696**	-108	164	65	736
1.89	236	686	769	**62.8**	**704**	-106	165	63	757
1.92	243	694	777	**63.4**	**711**	-105	166	60	777
1.94	249	702	785	**64.0**	**719**	-104	168	58	797
1.96	256	709	793	**64.7**	**727**	-102	169	55	817
1.99	262	717	801	**65.3**	**735**	-101	170	53	837
2.01	269	724	809	**65.9**	**743**	-100	172	50	858
2.04	275	732	816	**66.5**	**750**	-99	173	48	878
2.06	282	740	824	**67.2**	**758**	-97	174	46	898
2.08	288	747	832	**67.8**	**766**	-96	176	43	918
2.11	295	755	840	**68.4**	**774**	-95	177	41	939
2.13	301	762	848	**69.0**	**781**	-93	178	38	959
2.16	308	770	856	**69.6**	**789**	-92	179	36	979

Maximum Allowable Mud Weight calculated in accordance with API RP16Q: **4.4 SG**

* LMRP Lift-off Margin is based on riser recoil analysis in 1354m WD

METOCEAN CRITERIA

Site/Region specific seasonal metocean criteria have been provided by the operator for the subject location and are summarized below.

Since operations are scheduled to take place in the late February/March time period, the maximum environment from this period was used in this analysis. If the operation schedule changes to outside of February /March period, the analysis may need to be re-run in order to establish more accurate limits for DP operations.

The stipulated environmental combinations were assessed with the riser connected and displaced with the maximum anticipated mud weight. It is assumed the current profiles are collinear with wind and waves.

Environment Description (Feb-Mar Statistics)	99% Non-Exceedence [BF 10]	95% Non-Exceedence [BF 9]		
1-hour Wind Speed at 10m	**21.0** [m/s]	**19.0** [m/s]		
1-min Wind Speed at 10m	**25.0** [m/s]	**22.5** [m/s]		
3-hr Significant Wave Height	**9.0** [meters]	**7.0** [meters]		
Mean Spectral Peak Period	**14.3** [seconds]	**13.1** [seconds]		

Current Profiles - Depth Below Mean Water Level

0-ft Depth = Surface Current Speed

99% Non-Exceedence [BF 10]		95% Non-Exceedence [BF 9]					
Depth	Speed	Depth	Speed	Depth	Speed	Depth	Speed
0-m	**0.69-m/s**	0-m	**0.49-m/s**				
20-m	**0.69-m/s**	20-m	**0.49-m/s**				
50-m	**0.67-m/s**	50-m	**0.48-m/s**				
100-m	**0.61-m/s**	100-m	**0.47-m/s**				
200-m	**0.57-m/s**	200-m	**0.44-m/s**				
300-m	**0.48-m/s**	300-m	**0.44-m/s**				
400-m	**0.47-m/s**	400-m	**0.37-m/s**				
500-m	**0.39-m/s**	500-m	**0.37-m/s**				
600-m	**0.34-m/s**	600-m	**0.30-m/s**				
800-m	**0.34-m/s**	800-m	**0.27-m/s**				
1000-m	**0.34-m/s**	1000-m	**0.27-m/s**				
1200-m	**0.33-m/s**	1200-m	**0.26-m/s**				
1312-m	**0.31-m/s**	1312-m	**0.24-m/s**				

Metocean data reference:
"Statoil - Aasta Hansteen FieldMetocean Design Basis / MBM-NKG-RA 0023"

SOIL AND CASING MODEL

Site specific soil data have been provided by the customer for the subject location and were used in this analysis as tabulated below.

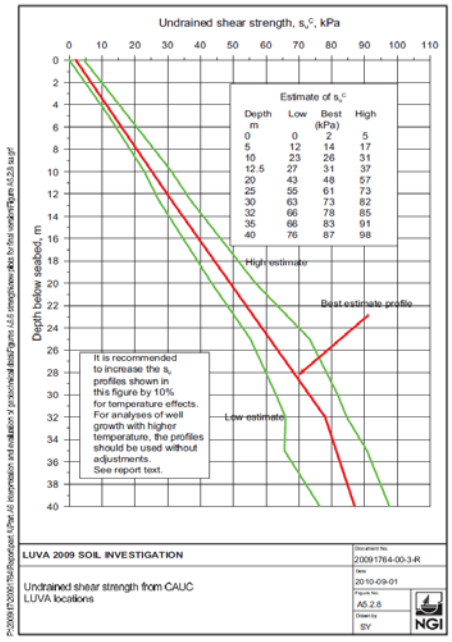
The casing model incorporated 36" x 1.5" X56 casing down to approximately 70 m below mudline. Although the actual casing program contains more components, the depth to which the casing is modeled captures the highest bending loads in the soil region.

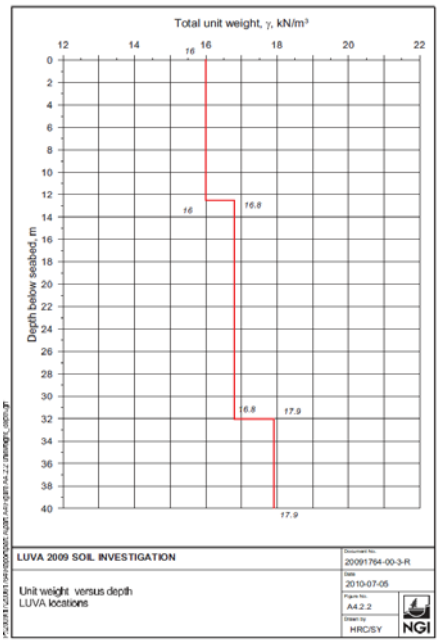
Estimate of Su

Depth m	Low (kPa)	Best (kPa)	High (kPa)
0	0	2	5
5	12	14	17
10	23	26	31
12.5	27	31	37
20	43	48	57
25	55	61	73
30	63	73	82
32	66	78	85
35	66	83	91
40	76	87	98

Estimate of Unit Weight

Depth m	Unit Weight kN/m3
0	16
5	16
10	16
12.5	16
20	16.8
25	16.8
30	16.8
32	16.8
35	17.9
40	17.9





Soil data reference:
"Soil data RE-LUVA-00013-01 Luva Soil Investigation part 1 / 20091764-00-3-R"

RISER ANALYSIS CRITERIA

Design Parameter	Connected Drilling	Connected Not Driling	Riser Disconnected
Mean Flex-joint Angle			
(upper & lower)	2	NA	NA
Max Flex-joint Angle			
(upper & lower)	4	90% Available (1)	90% Available
Stress Criteria (2)	0.67 σy (3)	0.67 σy	0.67 σy
Significant Dynamic Stress Range			
@ SAF 1.5	10 ksi	NA	NA
@ SAF > 1.5	15 / SAF	NA	NA
Minimum Top Tension	Tmin (4)	Tmin	NA
Dynamic Tension Limit	DTL (5)	DTL	NA
Max Tension Setting	90% DTL	90% DTL	NA

Notes:
1) reduce further with drill pipe in hole
2) Method B for Deepwater Analyses
3) σ_y = yield strength of material
4) $T_{min} = T_{SRmin} \times N / [R_f (N-n)]$
5) $DTL = P_A \times A_{cyl} / N_{LF}$

Riser tension requirement is by the following formulation:

T_{min}	=	T_{SRmin} N/[Rf (N-n)]
T_{SRmin}	=	Minimum Slip Ring Tension = $W_s f_{wt} - B_n f_{bt} + A_i [d_m H_m - d_w H_w]$
W_s	=	Submerged Riser Weight above the point of consideration
f_{wt}	=	Submerged Weight Toler weighted)
B_n	=	Net Lift of Buoyancy Material above the point of consideration
f_b=		Buoyancy Loss and Tolerance Factor resulting from elastic compression, long term water absorption, and manufacturing tolerance. (Maximum value = 0.96 unless accurately known by submerged weighing under compression at rated depth)
A_i	=	Internal Cross Sectional Area of Riser including auxiliary fluid lines
d_m	=	Drilling Fluid Weight Density
H_m	=	Drilling Fluid Column to point of consideration
d_w	=	Sea Water Weight Density
H_w	=	Sea Water Column to point of consideration including storm surge and tide
N	=	Number of Tensioners Supporting the Riser
n	=	Number of Tensioners Subject to Sudden Failure
R_f	=	Reduction Factor Relating Vertical Tension at the Slip Ring to Tensioner Setting to account for fleet angle and mechanical efficiency (usually 0.90 - 0.95 for non-drilling and drilling modes)

RISER ANALYSIS METHODOLOGY

The riser dynamic response during the connected mode was computed with features of the DeepRiser program developed by MCS. The method utilized was Frequency Domain dynamic analysis.

Connected Riser Analysis

The connected riser dynamic analyses were performed using Frequency domain. The analysis procedure is as follows:

(1) Represent the riser by a finite element model with appropriate properties: mass, weight, buoyancy, added mass (Cm = 2.0), drag coefficients (CD ~ 0.7-1.2), top tension, flex-joint stiffness, etc.

(2) Specify the metocean and motion parameters:
- Wave height, spectral mean period, and wave energy spectrum (JONSWAP).
- Vessel offset (mean plus low frequency).
- Vessel motion response amplitude operators (RAOs) and phase angles.

(3) Perform static and dynamic analyses to determine the riser maximum lateral displacements, bending moments, and maximum stresses.

The riser and casing are analyzed as a coupled system in this analysis. Soil restoring forces are input as p-y curves at varying soil depths to model the casing as a laterally restrained pile. This approach more accurately captures the lower flex joint angle response and wellhead system loading.

RISER ANALYSIS RESULTS

Riser operability performance was studied for all the environments below with the anticipated 1.35 Specific Gravity (11.3 ppg) maximum mud weight in the riser. Plots of flex joint angle (upper and lower) and Wellhead bending moment and Casing bending moment as a function of offset are provided on the following pages for the connected case.

For drilling operations, 2-degree mean upper and 1.0-degree mean lower flex joints angles (or 4-degree Max) should be maintainable within the following envelopes:

-0.9% and 2.6% (-12-m and 48.9-m) in the 95% Non-Exceedence [BF 9] conditions.
-0.6% and 0.9% (-7.2-m and 11.2-m) in the 99% Non-Exceedence [BF 10] conditions.

Riser stroke-out is estimated based on the following assumptions:

Initial Tensioner Stroke Setting	27.4 [feet]	8.35 [meters]	**6.9-m Stroked-in**
Tidal Change	-3.0 [feet]	-0.91 [meters]	
Error in Stroke Position	-2.0 [feet]	-0.61 [meters]	
Max. Expected Heave due to Storm surge	-3.0 [feet]	-0.91 [meters]	
Usable Mean Tensioner Stroke-out	**19.4** [feet]	**5.92** [meters]	

Wellhead and Casing Loads

The graphs on pages 13 and 14 of this report present the maximum bending moment in the soil region for vessel offset in the environments assessed. Limiting bending moments are shown as horizontal lines in the plot. The results indicate that 100% yield of the casing can occur at above 8.8% WD excursion in the 99%NX [BF10] conditions.

Dynamic Positioning Watch Circle Guidance

Dynamic positioning watch circles should be set to make certain the LMRP can disconnect (lift off) from the well prior to exceeding any mechanical limit of the riser system. From the cases studied here, the limiting vessel point of disconnect for normal drilling operations are estimated as follows:

Limits based on 652-tonnes (1437-kips) Top Tension	**Limit**	**99% Non-Exceedence [BF 10]** [%WD]	[meters]	**95% Non-Exceedence [BF 9]** [%WD]	[meters]
Mean Tensioner Stroke-out	19.4 [feet]	6.7%	85.9	7.7%	99.6
Max Flex Joint Angle	8.0 [degrees]	12.7%	163.4	16.1%	207.8
Wellhead Bending Moment	5700.0 [kip.ft]	12.0%	154.3	12.3%	158.9
Casing Bending Moment *	6282.9 [kip.ft]	8.8%	113.4	9.1%	117.6
Excursion Limit from Well Center		**6.7%***	**85.9***	**7.7%***	**99.6***

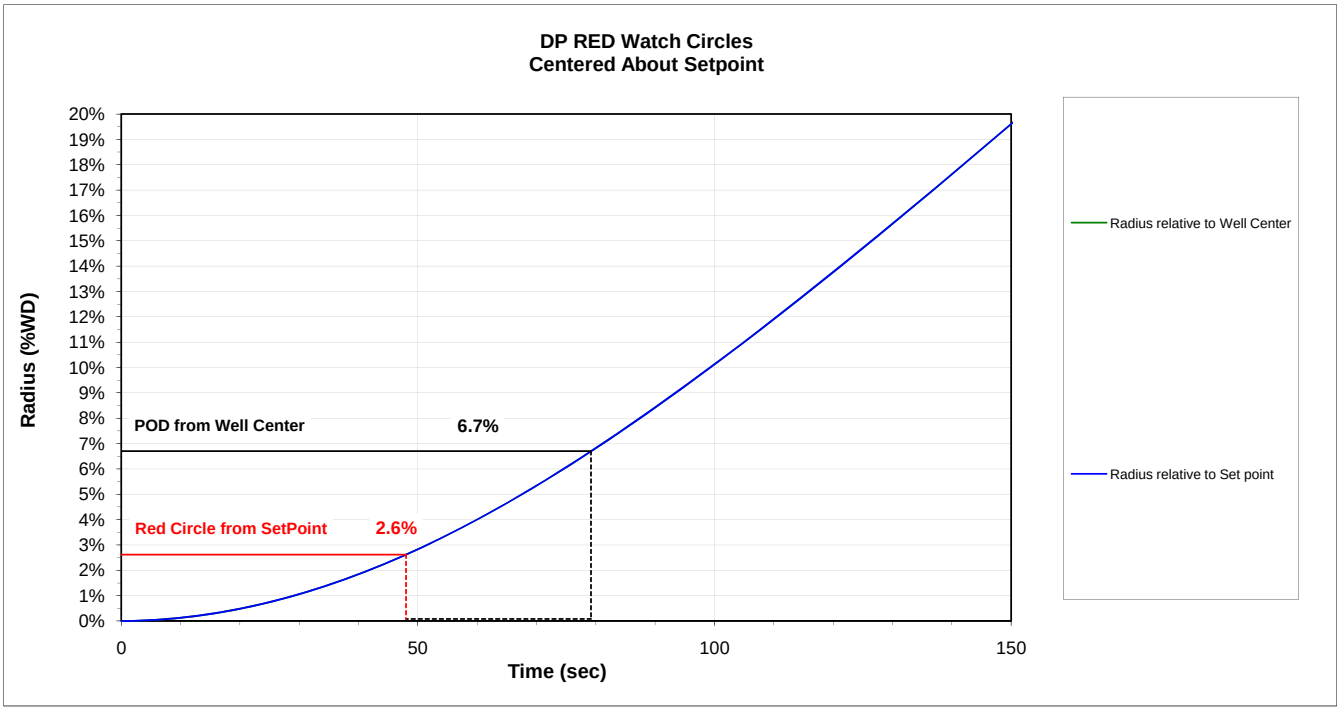
Wellhead and Casing Bending Loads @ POD:

Limits based on Component	**99% Non-Exceedence [BF 10]**		**95% Non-Exceedence [BF 9]**	
Wellhead Bending Moment	3563	[kip.ft]	3863	[kip.ft]
Casing Bending Moment	4922	[kip.ft]	5379	[kip.ft]

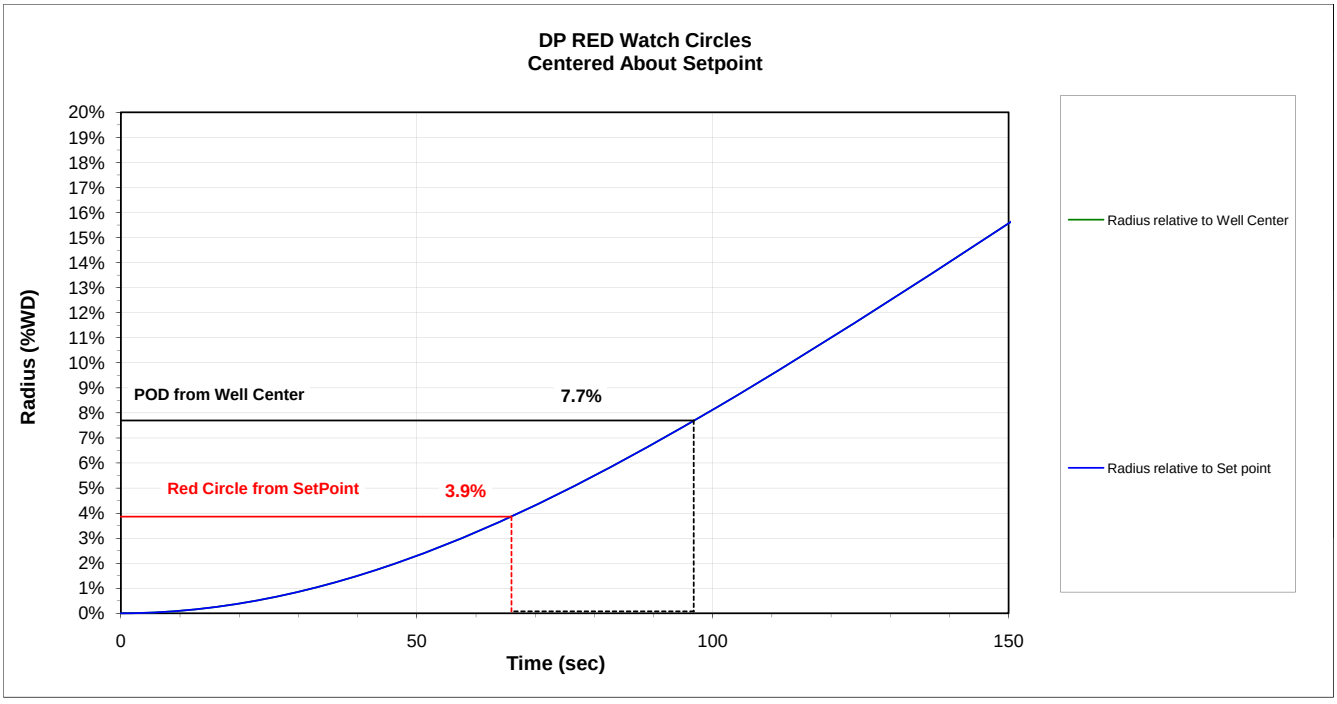
From the results, Mean Stroke-out is predicted to control allowed vessel excursion during a drift off event. This is in some part due to the conservative, omnidirectional collinear environmental loads assumed for the analysis. This offset criterion will be used in the dynamic watch circle calculation program. The program will advise the necessary red watch circle (point to initiate an EDS) to ensure a safe disconnect for the prevailing weather conditions and EDS cycle time.

As an example of reaction time and watch circles with the environment at 15 degrees from the bow the red watch circles and reaction times would be as indicated on the following page.

99% Non-Exceedence [BF 10]



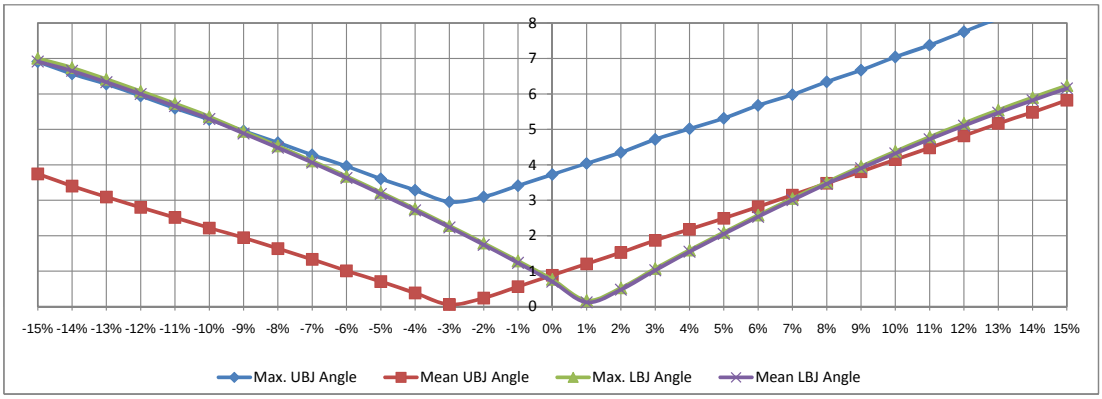
95% Non-Exceedence [BF 9]



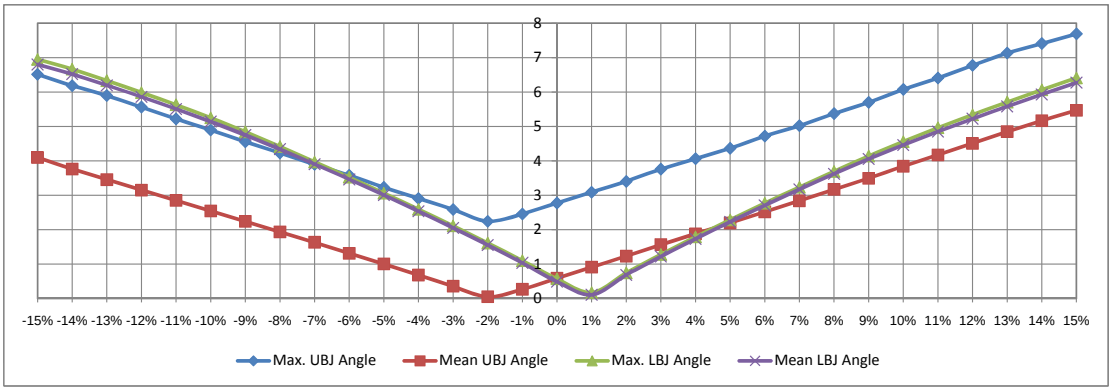
Sequence	EDS Time	POD	Red Circle Radius		Reaction Time	Comment
	[sec]	[%WD]	[%WD}	[meters]	[sec]	
99% Non-Exceedence [BF 10]	31	6.7%	**2.6%**	**34**	**48**	Collinear Environment applied 15-deg off bow, set point @ well center
95% Non-Exceedence [BF 9]	31	7.7%	**3.9%**	**50**	**66**	Collinear Environment applied 15-deg off bow, set point @ well center

Mean Upper and Lower Flex Joint Angle

(a) 99% Non-Exceedence [BF 10] **652-tonnes (1437-kips) Top Tension**

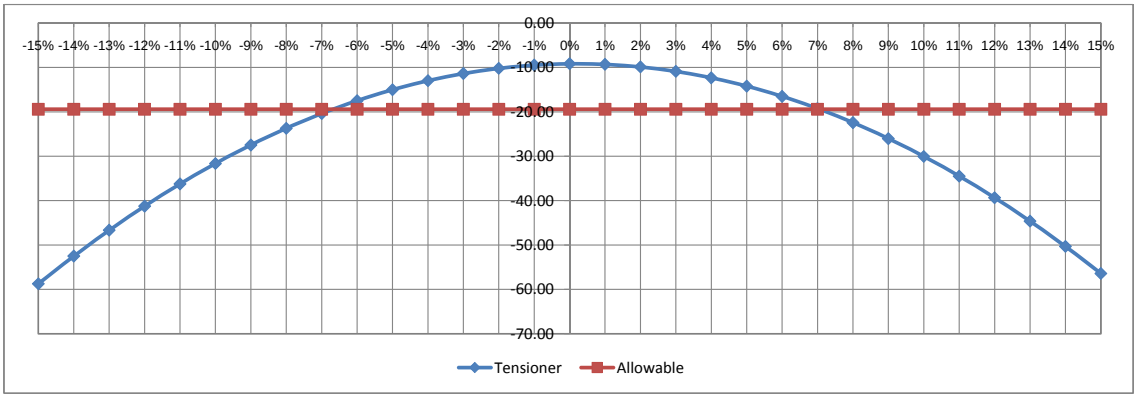


(b) 95% Non-Exceedence [BF 9] **652-tonnes (1437-kips) Top Tension**

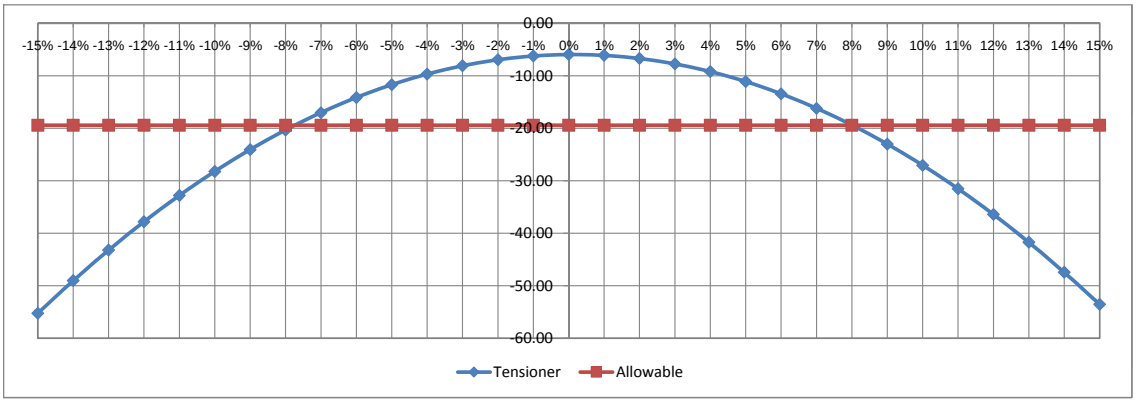


Mean Tensioner Stroke-out

(a) 99% Non-Exceedence [BF 10] **652-tonnes (1437-kips) Top Tension**

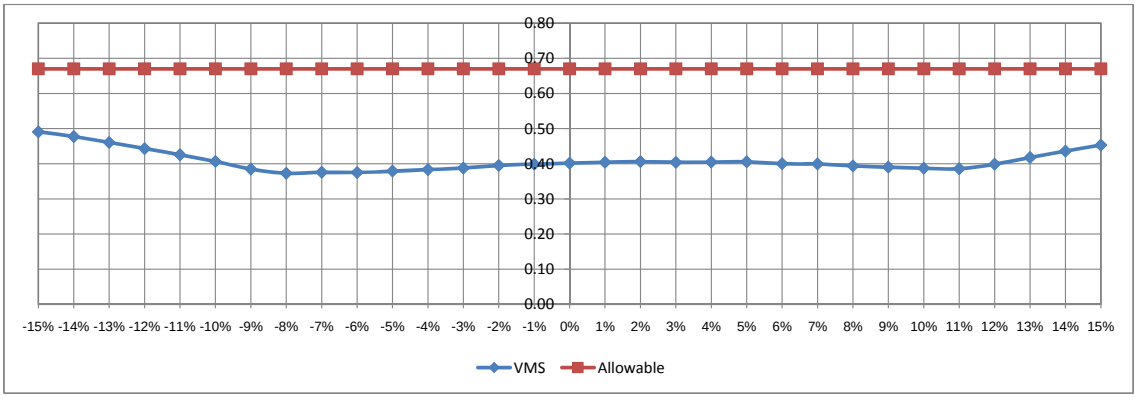


(b) 95% Non-Exceedence [BF 9] **652-tonnes (1437-kips) Top Tension**

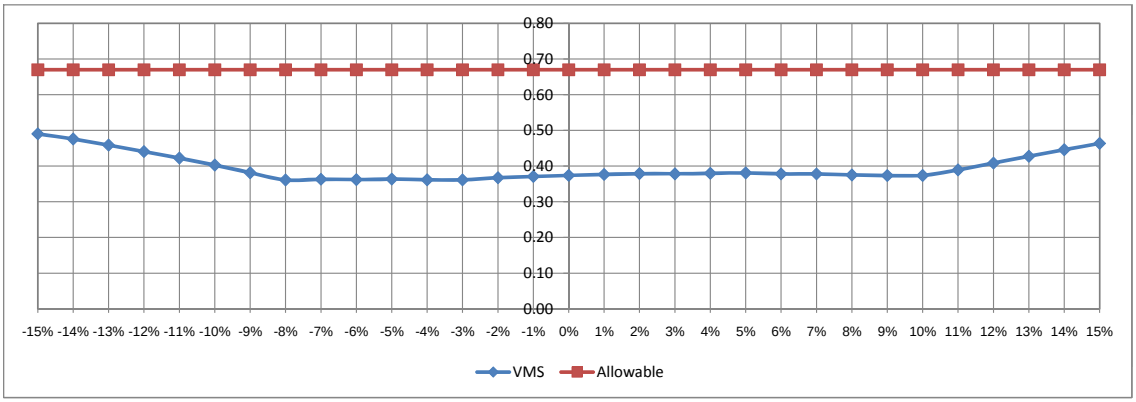


Max Von Mises Stress Along the Riser

(a) 99% Non-Exceedence [BF 10] **652-tonnes (1437-kips) Top Tension**

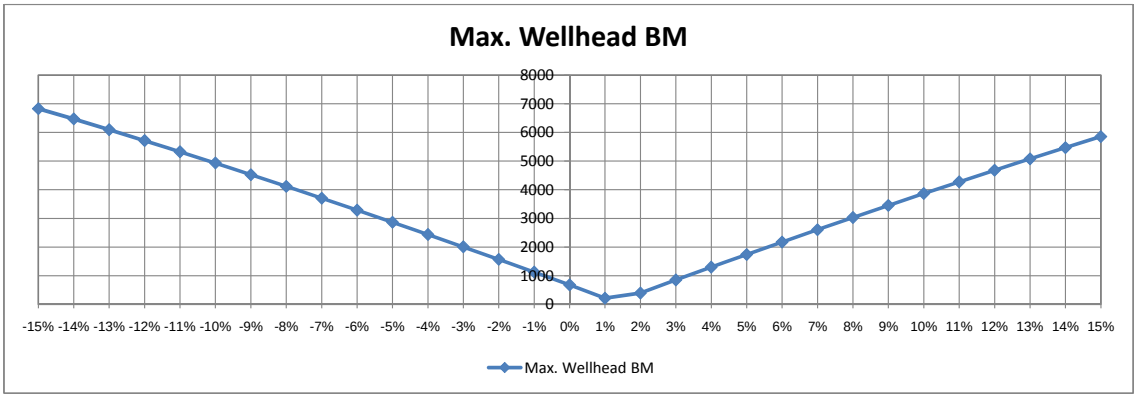


(b) 95% Non-Exceedence [BF 9] **652-tonnes (1437-kips) Top Tension**

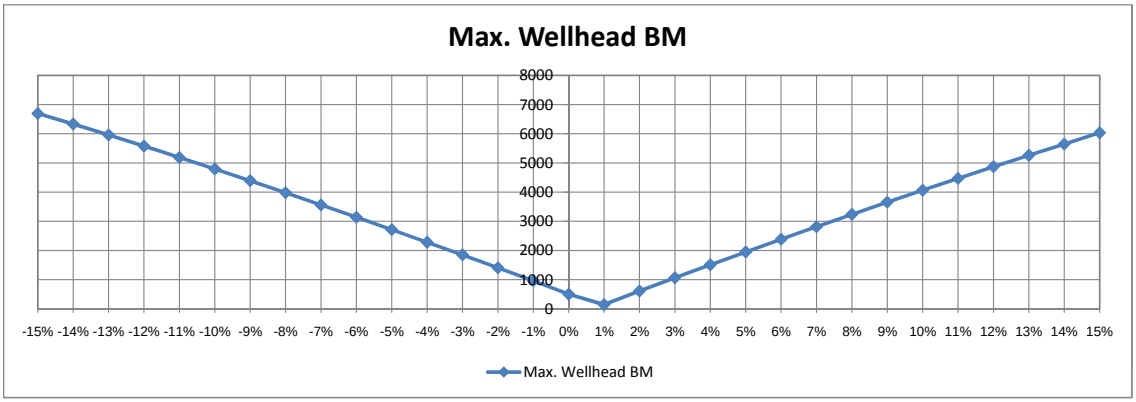


Well Head Bending Moment

(a) 99% Non-Exceedence [BF 10] **652-tonnes (1437-kips) Top Tension**

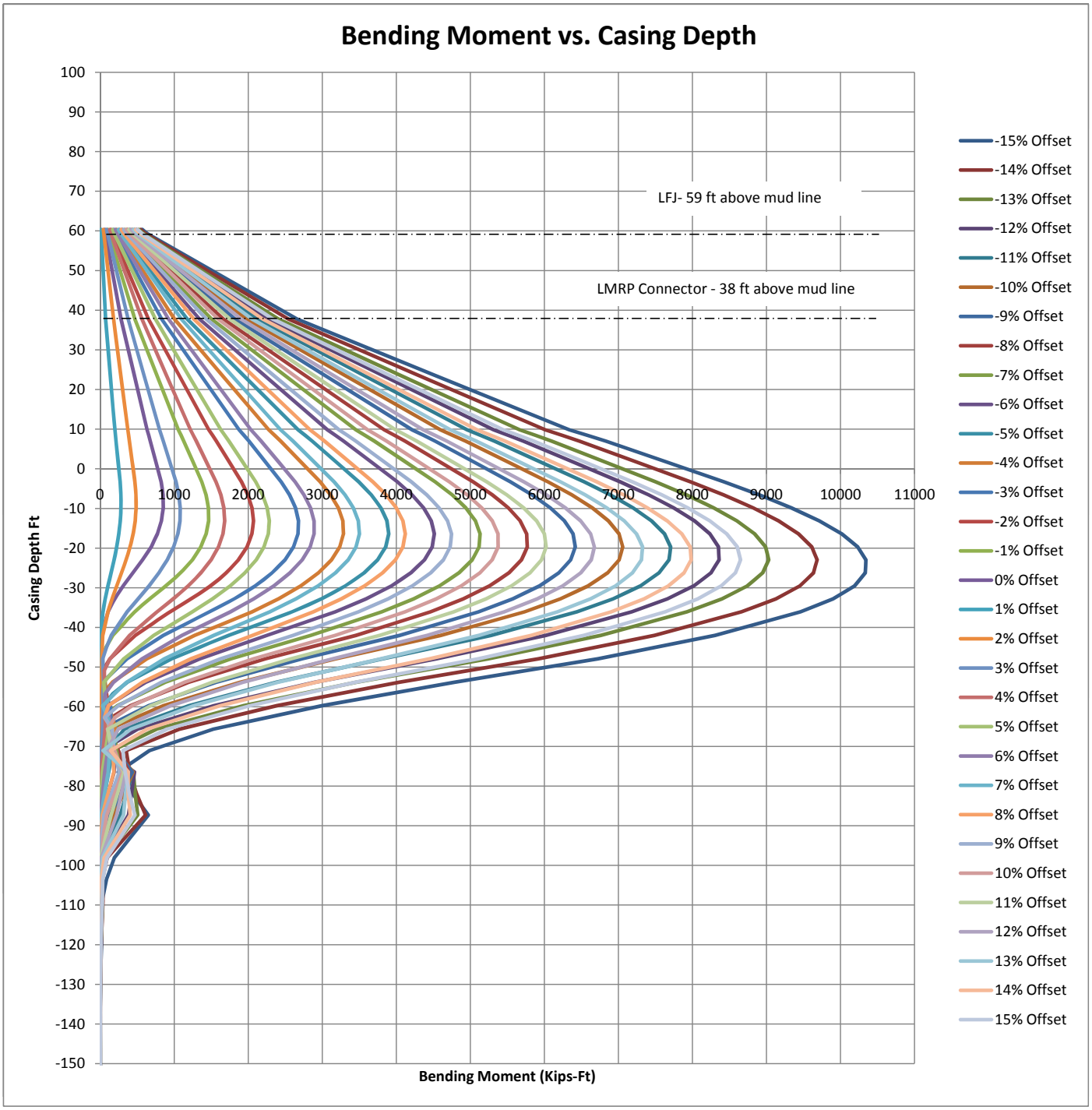


(b) 95% Non-Exceedence [BF 9] **652-tonnes (1437-kips) Top Tension**



Casing Bending Moment

(a) 99% Non-Exceedence [BF 10]



Casing Bending Moment

(a) 95% Non-Exceedence [BF 9]