

ENGINEERING CALCULATIONS



**Jack 3 Prospect
OCS-G 17015 # 002
Walker Ridge 758
ENGINEERING CALCULATIONS**

- 1) The casing design was evaluated with the "Stess Check" design software program.
- 2) The attached sheets define:
 - MASP, MAWP, Casing Test & BOP Test Calculations
 - Example calculations
 - Devon Deepwater Load Cases for Casing Design
 - Walker Ridge Block 758 – Casing Design Summary



Jack 3 Prospect
OCS-G 17015 # 002
Walker Ridge 758

MASP, MAWP, Casing Test, & BOP Test Calculations

Water Depth 6964 ft
Mudline Temp 38
RT-ELEV. 86 ft

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Inputs

INPUT INFORMATION								
Section	1	2	3	4	1	1	1	1
Casing Size	22	22	22	22	16	13 5/8	11 7/8	10 1/8
Weight ppf	328	224.28	224.28	170.2	97	88.2	58.8	79.22
Grade	X80	X-80	X-80	X-60	HP-Q125	HCQ-125	HCQ-125	HCQ-125
Type	Conductor	Conductor	Conductor	Conductor	Drig Liner 1	Drig Liner 2	Drig Liner 3	Prod Liner 1
Connection	H90D QT/MT	S90 QT/MT	S90 QT/MT	S60 QT/MT	SLSF	SLSF	Hydnl 511	SLSF
Burst Rating	9,545	6,360	3,000	3,580	8,660	10,030	8,050	18,160
Collapse Rating	9,457	3,870	3,000	1,820	2,990	5,930	3,760	17,650
Pipe Body Tension	7,728,000	5,278,000	5,278,000	3,004,000	3,761,000	3,190,300	2,105,000	2,912,500
Joint Strength	3,740,000	2,120,000	2,120,000	1,410,000	2,360,000	2,393,000	1,169,500	2,039,000
Set Depth (TVD)	7,579	9,456	7,684	10,009	20,114	23,745	26,144	29,014
Set Depth (MD)	7,579	9,456	7,684	10,009	20,338	24,224	26,792	29,863
Top of Casing String (TVD)	7,050	7,579	7,679	9,456	7,579	19,920	23,494	23,394
Top of Casing String (MD)	7,050	7,579	7,679	9,456	7,579	20,135	23,956	23,848
Length of Casing	529	1,877	5	553	12,759	4,089	2,836	6,015
MW Casing Set In (utilized for CTP Calculation)	9.90	9.90	9.90	9.90	11.70	11.80	13.40	14.20
Depth of Deepest Exposed Shoe (TVD)	10,009	10,009	10,009	10,009	20,114	23,745	26,144	29,014
Depth of Deepest Exposed Shoe (MD)	10,009	10,009	10,009	10,009	20,338	24,224	26,792	29,863
Predicted FG of Deepest Exposed Shoe	12.20	12.20	12.20	12.20	12.50	14.10	14.90	15.30
Estimated Pore Pressure at Previous Deepest Exposed Shoe	8.60	8.60	8.60	8.60	9.30	9.50	11.30	13.20
Deepest Open Hole Depth (TVD)	20,114	20,114	20,114	20,114	23,745	26,144	29,014	29,014
Deepest Open Hole Depth (MD)	20,338	20,338	20,338	20,338	24,224	26,792	29,863	29,863
Pore Press (EMW) @ DOHD	10.60	10.60	10.60	10.60	11.30	13.10	14.00	14.00
MW Nxt Hole @ DOHD	11.70	11.70	11.70	11.70	11.80	13.40	14.20	14.20
Planned FIT/LOT	12.20	12.20	12.20	12.20	12.40	13.90	14.80	15.10
Fracture Gradient Anticipated Surface & Wellhead Pressures (MASP _{FG} & MAWP _{FG})								
Fracture Pressure of Deepest Exposed Shoe	6,350	6,350	6,350	6,350	13,074	17,410	20,256	23,084
Gas Gradient for Frac Grad A.S.P. (0-10Kft = 0.1, >10Kft = 0.15)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Fracture Pressure with gas to surface								
MASP _{FG}	4,848	4,848	4,848	4,848	10,057	13,848	16,335	18,731
Fracture Pressure with gas to mudline								
MAWP _{FG}	5,906	5,906	5,906	5,906	11,115	14,906	17,392	19,789
BHP Anticipated Surface & Wellhead Pressures (MASP _{BHP} & MAWP _{BHP})								
Deepest Open Hole Depth (TVD)	20,114	20,114	20,114	20,114	23,745	26,144	29,014	29,014
% Gas Replacement based on Deepest Open Hole Depth (TVD)	50%	50%	50%	50%	50%	50%	50%	50%
Gas / Mud Interface (TVD)	10,057	10,057	10,057	10,057	11,873	13,072	14,507	14,507
Mud Column (TVD)	10,057	10,057	10,057	10,057	11,873	13,072	14,507	14,507
Gas Gradient for BHP A.S.P. (0-10Kft = 0.1, >10Kft = 0.15)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Pore Pressure (psi) @ Deepest Open Hole Depth (TVD)	11,087	11,087	11,087	11,087	13,953	17,809	21,122	21,122
MASP _{BHP} with % Gas Replacement	3,460	3,460	3,460	3,460	4,887	6,740	8,234	8,234
MAWP _{BHP} with % Gas Replacement	4,517	4,517	4,517	4,517	5,944	7,797	9,292	9,292
Pressure @ Gas / Mud Interface	4,968	4,968	4,968	4,968	6,668	8,701	10,410	10,410
Casing Test and FIT/LOT Pressures								
MMS MASP (Lesser of MASP _{FG} or MASP _{BHP})	3,460	3,460	3,460	3,460	4,887	6,740	8,234	8,234
MMS MAWP (Lesser of MAWP _{FG} or MAWP _{BHP})	4,517	4,517	4,517	4,517	5,944	7,797	9,292	9,292
70% of Internal Yield (MMS CFR 250.423 requirement)	6,682	4,452	2,100	2,506	6,062	7,021	5,635	12,712
Test Mud Weight	9.90	9.90	9.90	9.90	11.70	11.80	13.40	14.20
CTP ₇₀ = (70% of MIYP - (Pi (Test Mud Weight) - Po (external backup assumed as pore pressure at previous shoe))	6,169	3,813	1,581	1,829	3,552	4,181	2,780	11,203
CTP _{70 1st liner} = 70% of MIYP of Casing Liner Hung-In - (Pi (Test Mud Weight) - Po (external backup assumed as pore pressure at previous shoe)) at Liner Top TVD	N/A	N/A	N/A	N/A	N/A	3,472	1,815	986
CTP _{70 2nd liner} = 70% of MIYP of Long Casing String First Liner Hung-In - (Pi (Test Mud Weight) - Po (external backup assumed as pore pressure at previous shoe)) at First Liner Top TVD	N/A	N/A	N/A	N/A	N/A	N/A	2,256	1,304
CTP _{70 long string} = 70% of MIYP of Long Casing String First Liner Hung-In - (Pi (Test Mud Weight) - Po (external backup assumed as pore pressure at previous shoe)) at First Liner Top TVD	N/A	N/A	N/A	N/A	5,460	5,420	4,790	4,474
FIT/LOT Pressure	1,197	1,197	1,197	1,197	732	2,593	1,903	1,000
FIT/LOT Pressure Eqv w/ First Drig Liner Hung in Full String	1,442							
FIT/LOT Pressure Eqv w/ Second Drig Liner Hung in First Drig Liner	1,481				2,697			
FIT/LOT Pressure Eqv w/ Third Drig Liner Hung in Second Drig Liner	3,283				3,664	3,858		
FIT/LOT Pressure Eqv w/ Prod Liner Hung in Second Drig Liner	2,695				3,590	3,920		
Packoff or Liner Hanger Pressure Capabilities	N/A				6,500	6,000	6,000	6,000
Differential on Packer - Initial Pressure Test					4,000	4,000	2,000	1,000
Differential on Packer - 1st Subsequent Liner Pressure Test					4,039	3,657	1,977	
Differential on Packer - 2nd Subsequent Liner Pressure Test					2,670	3,486		
Differential on Packer - 3rd Subsequent Liner Pressure Test					1,985			
CTP Casing Test Pressure		1,581			3,664	3,920	1,903	1,000
CTP Casing Test Pressure Rounded		1,600			4,000	4,000	2,000	1,000
BOP Test Pressures								
Test Pressure (MMS MASP + 500 psi)	3,960	3,960	3,960	3,960	5,387	7,240	8,734	8,734
Mud Weight used for BOP Test	8.55	8.55	8.55	8.55	11.70	11.80	13.40	14.20
Mud Weight vs SeaWater Hydrostatic Difference	-	-	-	-	1,141	1,177	1,756	2,046
Surface Test Pressure not to exceed 70% of Annular Rating at Seafloor Conditions	7,000	7,000	7,000	7,000	5,859	5,823	5,244	4,954
Surface Test Pressure not to exceed 100% of Ram Rating at Seafloor Conditions	15,000	15,000	15,000	15,000	13,859	13,823	13,244	12,954
Ram BOP and ancillary equipment Test Pressure	4,000	4,000	4,000	4,000	5,400	7,300	8,800	8,800
Annular BOP Test Pressure	4,000	4,000	4,000	4,000	5,400	5,900	5,300	5,000
APD RAM BOP AND ANCILLIARY EQUIP TEST PRESSURE		4,000			5,400	7,300	8,800	8,800
APD ANNULAR BOP TEST PRESSURE		4,000			5,400	5,900	5,300	5,000
APD RAM STUMP TEST PRESSURE =								
MMS MASP + 500 psi + MW vs SW Hydrostatic Difference	10,780	11,000						7,000
APD ANNULAR STUMP TEST PRESSURE =								
70% of Rated Working Pressure								

Example Calculations			
<u>Gas Gradient</u> < 10,000' 0.10 psi/ft ≥ 10,000' 0.15 psi/ft	<u>Gas Replacement</u> < 12,000' 70% Gas / 30% Mud 12,000' to 15,000' 60% Gas / 40% Mud ≥ 15,000' 50% Gas / 50% Mud		
22" Casing String MASP			
$MASP_{FG} = (0.052 \times FG \text{ at shoe} \times \text{Casing Seat TVD}) - (\text{Gas Grad} \times \text{Casing Seat TVD})$ $= (0.052 \times 12.20 \times 10,009) - (0.15 \times 10,009)$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 4,848 psi</div>			
$MASP_{BHP} = \text{Hole Depth TVD} \times ((0.052 \times \text{Pore Press}) - (\text{Gas Grad} \times \text{Gas \%}) - (0.052 \times \text{Mud Weight} \times (1 - \text{Gas \%})))$ $= 20,114 \times ((0.052 \times 10.6) - (0.15 \times 0.50) - (0.052 \times - 0.5))$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 3,460 psi</div>			
$MMS \text{ MASP} = \text{lesser of } MASP_{FG} \text{ or } MASP_{BHP} = \boxed{= 3,460 \text{ psi}}$			
22" Casing String CTP			
$CTP_{70} = (70\% \text{ of MIYP} - ((Pi - Po) \times \text{Casing Seat TVD} \times .052))$ <p>Pi = Test MW (MW casing set in) Po = Pore Pressure from Previous Casing Seat</p> $= (0.7 \times 3,000) - ((9.9 - 8.6) \times 7,684 \times 0.052)$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 1,581 psi</div>			
$CTP = \text{lesser of } MASP_{FG}, MASP_{BHP} \text{ or } CTP_{70} = 1,581 \text{ psi} \Rightarrow \boxed{= 1,600 \text{ psi}}$			
11 7/8" Liner MASP			
$MASP_{FG} = (0.052 \times FG \text{ at shoe} \times \text{Casing Seat TVD}) - (\text{Gas Grad} \times \text{Casing Seat TVD})$ $= (0.052 \times 14.90 \times 26,144) - (0.15 \times 26,144)$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 16,335 psi</div>			
$MASP_{BHP} = \text{Hole Depth TVD} \times ((0.052 \times \text{Pore Press}) - (\text{Gas Grad} \times \text{Gas \%}) - (0.052 \times \text{Mud Weight} \times (1 - \text{Gas \%})))$ $= 29,014 \times ((0.052 \times 14.0) - (0.15 \times 0.50) - (0.052 \times - 0.5))$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 8,234 psi</div>			
$MMS \text{ MASP} = \text{lesser of } MASP_{FG} \text{ or } MASP_{BHP} = \boxed{= 8,234 \text{ psi}}$			
11 7/8" Liner CTP			
$CTP_{70} = (70\% \text{ of MIYP} - ((Pi - Po) \times \text{Casing Seat TVD} \times .052))$ <p>Pi = Test MW (MW casing set in) Po = Pore Pressure from Previous Casing Seat</p> $= (0.7 \times 8,050) - ((13.4 - 11.3) \times 26,144 \times 0.052)$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 2,780 psi</div>			
$CTP_{70 \text{ 1st liner}} = (70\% \text{ of MIYP}_{1st \text{ liner}} - ((Pi - Po) \times \text{TOL Depth TVD} \times .052))$ <p>Pi = Test MW (MW casing set in) Po = Pore Pressure from Previous Casing Seat</p> $= (0.7 \times 8,660) - ((13.4 - 09.3) \times 19,920 \times 0.052)$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 1,815 psi</div>			
$CTP_{70 \text{ 2nd liner}} = (70\% \text{ of MIYP}_{2nd \text{ liner}} - ((Pi - Po) \times \text{TOL Depth TVD} \times .052))$ <p>Pi = Test MW (MW casing set in) Po = Pore Pressure from Previous Casing Seat</p> $= (0.7 \times 10,030) - ((13.4 - 09.5) \times 23,494 \times 0.052)$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 2,256 psi</div>			
$CTP_{70 \text{ long string}} = (70\% \text{ of MIYP}_{\text{long string}} - ((Pi - Po) \times \text{TOL Depth TVD} \times .052))$ <p>Pi = Test MW (MW casing set in) Po = Pore Pressure from Previous Casing Seat</p> $= (0.7 \times 9,545) - ((13.4 - 08.6) \times 7,579 \times 0.052)$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 4,790 psi</div>			
$P_{FIT/LOT} = (FIT - \text{Test MW}) \times \text{Casing Seat TVD} \times .052$ $= (14.8 - 13.4) \times 26,144 \times 0.052$ <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;">= 1,903 psi</div>			
$CTP = P_{FIT/LOT} \text{ not to exceed } CTP_{70}, CTP_{70 \text{ 1st liner}}, CTP_{70 \text{ 2nd liner}} \text{ or } CTP_{70 \text{ long string}} = 1,815 \text{ psi} \Rightarrow \boxed{= 2,000 \text{ psi}}$			

Devon Deepwater Load Cases for Casing Design			
String	Burst	Collapse	Tension
	Criteria	Criteria	Criteria
Conductor, Surface, Intermediate & Drilling Liners	•Gas Kick: 0.5 ppg and 50 bbls for development or 70 bbls for exploration. •Lost Returns with Water: Frac at shoe with water column to surface. •Frac at shoe with 1/3 BHP above. •Pressure Test. •Cement Pressure Test. •Maximum Anticipated Surface Pressure	•Cementing: cement slurry in place. •Full Sea water Replacement •Lost Returns w/Mud Drop: partial evacuation to balance lowest pore pressure.	•Running in Hole: include shock loads at 3-4 ft/sec. •Overpull while Running: suggest 100 kips. •Green Cement Pressure Test: large piston loads. •Service Loads: loads due to combined effects in burst and collapse.
Production	•Tubing leak near surface applied to packer fluid. •Pressure test: based on anticipated SITP plus safety margin.	•Cementing: cement slurry in place. •Partial Evacuation: balance with depleted reservoir, i.e. abandonment pressure. •Full evacuation for dry gas wells.	•Running in Hole: include shock loads at 2-3 ft/sec •Overpull while Running: suggest 100 kips. •Green Cement Pressure Test: large piston loads. •Service Loads: loads due to combined effects in burst and collapse.
External pressure profile (All Strings)	•C.S. & I: mud weight to TOC, cement mix water gradient TOC to previous shoe, pore pressure in open hole. •Prod: mud fluid density (note1) to TOC, cement mix-water gradient to outer shoe and pore pressure to TD.	•Mud weight the string was set in.	N/A

Notes; 1) Consider mud deterioration if fluid has poor lon term solids suspension properties.

2) Not every load was utilized on every string.

Casing Design Summary						
String	OD/Weight/Grade/Connection	MD Interval (Ft)	Minimum Safety Factor (Abs)			
			Burst	Collapse	Axial	Triaxial
Conductor	22" 382.3 ppf, X-80, H90D QT/MT	7,050 - 7,579	1.61	3.29	2.8	1.84
	22" 224.28 ppf, X-80, S90D QT/MT	7,579 - 9,456	1.37*	3.03	2.27	2.82
	22", 170.20 ppf, X-60, S60D QT/MT	9,456 - 10,009	1.66	1.3	(1.29)	1.71
Drilling Liner	16", 97 ppf, Q-125 HP SLSF	7,579 - 20,335	1.34	1.01	1.76	1.51
Drilling Liner	13 5/8", 88.20 ppf, HC Q-125, SLSF	20,135 - 24,224	1.21	1.25	(3.59)	1.51
Drilling Liner	11 7/8", 58.80 ppf, HC Q-125, Hydril 511	23,999 - 26,774	1.34	1.62	1.87	1.83
Prod Liner	10 1/8", 79.22 ppf, HC Q-125, SLSF	23,798 - 29,868	1.43	1.06	(1.54)	1.3

Note: () in axial column denotes compression.

Note: Equal or better casing may be substituted pending availability/inventory.

Note: *Due to 3000 psi Burst Disk subs for APB mitigation installed in this section below 16" Supplemental Adapter.