

ENGINEERING CALCULATIONS



**Chuck Prospect
OCS-G 18675 # 001
Walker Ridge 278
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 278 – Casing Design Summary

**Chuck Prospect****OCS-G 18675 # 001****Walker Ridge 278****MASP, MAWP, Casing Test, & BOP Test Calculations****Water Depth 6475 ft**
Mudline Temp 38 ft
RT-ELEV. 85.5 ft**Rev Date: 15-Jun-07****15:49****INPUTS**

INPUT INFORMATION								
Section	1	1	2	1	1	2	1	1
Casing Size	22	18	17 7/8	16	14	13 5/8	11 7/8	9 7/8
Weight ppf	224	94	93.5	96	113	88.2	71.8	62.8
Grade	X80	X-80	HCN-80	HCP-110	HCQ-125	HCQ-125	HCQ-125	HCQ-125
Type	Conductor	Drig Liner	Drig Liner	Drig Liner	Intermediate	Intermediate	Drig Liner	Drig Liner
Connection	RL4S/H90 MT	HydriL 521	HydriL 521	HydriL 511	HydriL 523	HydriL SLX	HydriL SLX	HydriL SLX
Burst Rating	6,360	3,890	3,920	6,664	12,500	10,030	10,720	13,840
Collapse Rating	3,870	1,400	1,270	2,920	9,430	5,970	7,160	13,050
Pipe Body Tension	5,278,000	2,199,000	2,183,000	3,065,000	4,147,000	3,191,000	2,581,000	2,270,000
Joint Strength	2,650,000	1,416,000	1,380,000	1,916,000	3,060,000	2,438,000	1,867,000	1,795,000
Set Depth (TVD)	8,100	10,700	12,500	17,000	6,581	21,725	26,585	30,240
Set Depth (MD)	8,100	10,700	12,500	17,000	6,581	21,902	27,034	31,451
Top of Casing String (TVD)	6,561	7,500	10,700	7,400	6,561	6,581	21,343	26,219
Top of Casing String (MD)	6,561	7,500	10,700	7,400	6,561	6,581	21,500	26,634
Length of Casing	1,540	3,200	1,800	9,600	21	15,321	5,534	4,817
MW Casing Set In (utilized for CTP Calculation)	8.60	10.00	10.00	12.10	13.10	13.10	14.30	14.40
Depth of Deepest Exposed Shoe (TVD)	8,100	12,500	12,500	17,000	21,725	21,725	26,585	30,240
Depth of Deepest Exposed Shoe (MD)	8,100	12,500	12,500	17,000	21,902	21,902	27,034	31,451
Predicted FG of Deepest Exposed Shoe	10.60	13.30	13.30	14.70	15.70	15.70	15.30	16.00
Estimated Pore Pressure at Previous Deepest Exposed Shoe	8.60	8.60	8.60	9.80	11.40	11.40	12.30	14.00
Deepest Open Hole Depth (TVD)	12,500	17,000	17,000	21,725	26,585	26,585	30,240	34,085
Deepest Open Hole Depth (MD)	12,500	17,000	17,000	21,902	27,034	27,034	31,451	36,145
Pore Press (EMW) @ DOHD	9.80	11.40	11.40	12.30	14.00	14.00	14.10	14.30
MW Nxt Hole @ DOHD	10.00	12.10	12.10	13.10	14.30	14.30	14.40	14.70
Planned FIT/LOT	10.50	13.20	13.20	14.30	15.00	15.00	15.00	15.60
Fracture Gradient Anticipated Surface & Wellhead Pressures (MASP _{FG} & MAWP _{FG})								
Fracture Pressure of Deepest Exposed Shoe	4,465	8,645	8,645	12,995	17,736	17,736	21,151	25,160
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}	3,250	6,770	6,770	10,445	14,478	14,478	17,163	20,624
Fracture Pressure with gas to mudline MAWP _{FG}	4,234	7,754	7,754	11,429	15,462	15,462	18,147	21,608
BHP Anticipated Surface & Wellhead Pressures (MASP _{BHP} & MAWP _{BHP})								
Deepest Open Hole Depth (TVD)	12,500	17,000	17,000	21,725	26,585	26,585	30,240	34,085
% Gas Replacement based on Deepest Open Hole Depth (TVD)	60%	50%	50%	50%	50%	50%	50%	50%
Gas / Mud Interface (TVD)	7,500	8,500	8,500	10,863	13,293	13,293	15,120	17,043
Mud Column (TVD)	5,000	8,500	8,500	10,863	13,293	13,293	15,120	17,043
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)	6,370	10,078	10,078	13,895	19,354	19,354	22,172	25,346
MASP _{BHP} with % Gas Replacement	2,645	3,454	3,454	4,866	7,476	7,476	8,582	9,762
MAWP _{BHP} with % Gas Replacement	3,629	4,438	4,438	5,850	8,460	8,460	9,566	10,746
Pressure @ Gas / Mud Interface	3,770	4,729	4,729	6,496	9,470	9,470	10,850	12,318
Casing Test and FIT/LOT Pressures								
MMS MASP (Lesser of MASP _{FG} or MASP _{BHP})	2,645	3,454	3,454	4,866	7,476	7,476	8,582	9,762
MMS MAWP (Lesser of MAWP _{FG} or MAWP _{BHP})	3,629	4,438	4,438	5,850	8,460	8,460	9,566	10,746
70% of Internal Yield (MMS CFR 250.423 requirement)	4,452	2,723	2,744	4,665	8,750	7,021	7,504	9,688
Test Mud Weight	8.60	10.00	10.00	12.10	13.10	13.10	14.30	14.40
CTP ₇₀ = (70% of MIYP - (Pi (Test Mud Weight) - Po (external backup assumed as pore pressure at previous shoe))	4,452	1,944	1,834	2,632	8,168	5,101	4,739	9,059
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	3,906	1,944	3,105	N/A	N/A	3,802	4,641
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	N/A	N/A	N/A	3,691
FIT/LOT Pressure	800	2,080	2,080	1,945	2,146	2,146	968	1,887
FIT/LOT Pressure, If Second Drig Liner Hung in First Drig Liner							1,998	
Packoff or Liner Hanger Pressure Capabilities		4,000	4,000	6,500			5,500	6,500
CTP Casing Test Pressure	2,645	2,080		1,945	5,101		1,998	1,887
CTP Casing Test Pressure Rounded	2,700	2,100		2,000	5,200		2,000	1,900
BOP Test Pressures								
Test Pressure (MMS MASP + 500 psi)	3,145	3,954	3,954	5,366	7,976	7,976	9,082	10,262
Mud Weight used for BOP Test	8.60	10.00	10.00	12.10	13.10	13.10	14.30	14.40
Mud Weight vs SeaWater Hydrostatic Difference	17	488	488	1,195	1,532	1,532	1,936	1,970
Surface Test Pressure not to exceed 70% of Annular Rating at Seafloor Conditions	6,983	6,512	6,512	5,805	5,468	5,468	5,064	5,030
Surface Test Pressure not to exceed 100% of Ram Rating at Seafloor Conditions	14,983	14,512	14,512	13,805	13,468	13,468	13,064	13,030
Ram BOP and ancillary equipment Test Pressure	3,200	4,000	4,000	5,400	8,000	8,000	9,100	10,300
Annular BOP Test Pressure	3,200	4,000	4,000	5,400	5,500	5,500	5,100	5,100
APD RAM BOP AND ANCILLIARY EQUIP TEST PRESSURE		5,400			8,000		9,100	10,300
APD ANNULAR BOP TEST PRESSURE		5,400			5,500		5,100	5,100
APD RAM STUMP TEST PRESSURE =								
MMS MASP + 500 psi + MW vs SW Hydrostatic Difference	12,232	13,000					10,000	7,000
APD ANNULAR STUMP TEST PRESSURE = 70% of Rated Working Pressure								

Example Calculations

Gas Gradient

< 10,000'	0.10 psi/ft
≥ 10,000'	0.15 psi/ft

Gas Replacement

< 12,000'	70% Gas / 30% Mud
12,000' to 15,000'	60% Gas / 40% Mud
≥ 15,000'	50% Gas / 50% Mud

13-5/8" Casing String MASP

$$MASP_{FG} = (0.052 \times FG \text{ at shoe} \times \text{Casing Seat TVD}) - (\text{Gas Grad} \times \text{Casing Seat TVD})$$

$$= (0.052 \times 15.7 \times 21725) - (0.15 \times 21725)$$

$$= 14,478 \text{ psi}$$

$$MASP_{BHP} = \text{Hole Depth TVD} \times ((0.052 \times \text{Pore Press}) - (\text{Gas Grad} \times \text{Gas \%}) - (0.052 \times \text{Mud Weight} \times (1 - \text{Gas \%})))$$

$$= 26585 \times ((0.052 \times 14.0) - (.15 \times .50) - (0.052 \times 14.3 \times (1 - .5)))$$

$$= 7476 \text{ psi}$$

$$MMS \text{ MASP} = \text{lesser of } MASP_{FG} \text{ or } MASP_{BHP}$$

=

$$= 7476 \text{ psi}$$

13-5/8" Casing String CTP

$$CTP_{70} = (70\% \text{ of MIYP} - ((Pi - Po) \times \text{Casing Seat TVD} \times .052))$$

Pi = Test MW (MW casing set in)

Po = Pore Pressure from Previous Casing Seat

$$= ((.7 \times 10030) - ((13.1 - 11.4) \times 21725 \times .052))$$

$$= 5101 \text{ psi}$$

$$CTP = \text{lesser of } MASP_{FG}, MASP_{BHP} \text{ or } CTP_{70} = 5101 \text{ psi}$$

=>

$$= 5200 \text{ psi}$$

9 7/8" Liner MASP

$$MASP_{FG} = (0.052 \times FG \text{ at shoe} \times \text{Casing Seat TVD}) - (\text{Gas Grad} \times \text{Casing Seat TVD})$$

$$= (0.052 \times 16.0 \times 30240) - (0.15 \times 30240)$$

$$= 20,624 \text{ psi}$$

$$MASP_{BHP} = \text{Hole Depth TVD} \times ((0.052 \times \text{Pore Press}) - (\text{Gas Grad} \times \text{Gas \%}) - (0.052 \times \text{Mud Weight} \times (1 - \text{Gas \%})))$$

$$= 34085 \times ((0.052 \times 14.3) - (.15 \times .50) - (0.052 \times 14.7 \times (1 - .5)))$$

$$= 9762 \text{ psi}$$

$$MMS \text{ MASP} = \text{lesser of } MASP_{FG} \text{ or } MASP_{BHP}$$

=

$$= 9762 \text{ psi}$$

9 7/8" Liner CTP

$$CTP_{70} = (70\% \text{ of MIYP} - ((Pi - Po) \times \text{Casing Seat TVD} \times .052))$$

Pi = Test MW (MW casing set in)

Po = Pore Pressure from Previous Casing Seat

$$= ((.7 \times 13840) - ((14.4 - 14.0) \times 30240 \times .052))$$

$$= 9059 \text{ psi}$$

$$CTP_{70 \text{ 1st liner}} = (70\% \text{ of MIYP}_{1st \text{ liner}} - ((Pi - Po) \times \text{TOL Depth TVD} \times .052))$$

Pi = Test MW (MW casing set in)

Po = Pore Pressure from Previous Casing Seat

$$= ((.7 \times 10720) - ((14.4 - 12.3) \times 26219 \times .052))$$

$$= 4641 \text{ psi}$$

$$CTP_{70 \text{ long string}} = (70\% \text{ of MIYP}_{\text{long string}} - ((Pi - Po) \times \text{TOL Depth TVD} \times .052))$$

Pi = Test MW (MW casing set in)

Po = Pore Pressure from Previous Casing Seat

$$= ((.7 \times 10030) - ((14.4 - 11.4) \times 21343 \times .052))$$

$$= 3691 \text{ psi}$$

$$P_{FIT/LOT} = (FIT - \text{Test MW}) \times \text{Casing Seat TVD} \times .052$$

$$= (15.6 - 14.4) \times 30240 \times .052$$

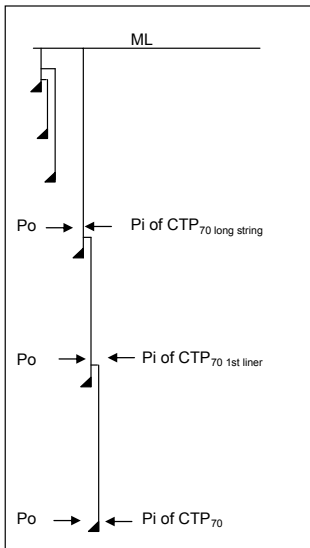
$$= 1887 \text{ psi}$$

$$CTP = P_{FIT/LOT} \text{ not to exceed } CTP_{70}, CTP_{70 \text{ 1st liner}} \text{ or } CTP_{70 \text{ long string}}$$

$$= 1887 \text{ psi}$$

=>

$$= 1900 \text{ psi}$$



Devon Deepwater Load Cases for Casing Design

	Burst	Collapse	Tension
String	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. Pressure Test. Cement Pressure Test. Maximum Anticipated Surface Pressure	Cementing: cement slurry in place. Lost Returns w/Mud Drop: partial evacuation to balance pore pressure. Partial Evacuation. Sea water / Mud drop to balance pore pressure	Running in Hole: includes 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: includes 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 (note ₁) to TOC, cement mix-water gradient to outer shoe and pore pressure to TD.	Mud weight the string was set in.	N/A

Note1: Consider mud deterioration if fluid has poor long-term solids suspension properties.

Casing Design Summary

APD

String	OD/Weight/Grade	Connection	MD Interval (ft)	Drift Dia. (in)	Minimum Safety Factor (Abs)			
					Burst	Collapse	Axial	Triaxial
Conductor Casing	22", 224.28 ppf, X-80	RL4S / H90MT	6,561 - 8,100	19.813	1.43	2.52	3.03	1.76
Surface Drilling Liner	18", 94.00 ppf, X-80	521	7,500 – 10,700	16.813	1.15	1.37	2.60	1.43
	17 7/8", 93.50 ppf, HCN-80	521	10,700 – 12,500	16.687	1.27	1.10	4.53	1.57
Surface Drilling Liner	16", 96.00 ppf, HCP-110	511	7,400 - 17,000	14.663	1.34	1.11	1.73	1.74
Intermediate Casing	14", 113.00 ppf, HCQ-125	523	6,561 – 6,581	12.244	1.74	1.97	1.84	1.96
	13 5/8", 88.20 ppf, HCQ-125	SLX	6,581 – 21,902	12.250	1.40	1.22	1.44	1.54
Intermediate Drilling Liner	11 7/8", 71.80 ppf, HCQ-125	SLX	21,500 – 27,034	10.625	1.60	3.10	2.04	1.84
Intermediate Drilling Liner	9 7/8", 62.80 ppf, HCQ-125	SLX	26,610 – 31,451	8.500	3.53	3.90	2.16 C	2.16

Note: C in axial column denotes compression.

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