

**Application For
Permit to Sidetrack**

ENGINEERING CALCULATIONS

**OCS-G-16942
Walker Ridge Block 29
“Big Foot #3 ST2”**

ENSCO 7500

**CHEVRON USA
DEEPWATER EXPLORATION AND PROJECTS**

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I. TEST PRESSURE CALCULATIONS

A. CALCULATION METHOD

For casing and liner tests several pressures are calculated and considered. The first criteria is based on the MMS regulations for 70% of casing burst or on the maximum allowable wellhead pressure (MAWP). The second criteria are based on initial and future liner lap pressures or formation integrity/leak off test pressures.

MASP Based on Bottom Hole Pressure

The first method of calculating maximum anticipated surface pressure is the pore pressure at the next casing shoe less the gas/mud gradient to the surface:

$$\text{MASP}_{\text{BHP}} = \text{BHP} - (\gamma_{\text{equiv}}) (\text{TVD}_{\text{next}})$$

Where the gradient is equivalent to an 80%/20% gas/mud gradient:

$$\gamma_{\text{equiv}} = (20\%) (\rho_{\text{mud}}) (0.052) + (80\%) (\gamma_{\text{gas}})$$

For depths greater than 10,000 ft, a 50% gas/mud gradient is used. The average gas gradient is calculated based on the Nagy/Young correlation. The pore pressure at the next casing shoe is:

$$\text{BHP} = (\rho_{\text{pore}}) (0.052) (\text{TVD}_{\text{next}})$$

MASP Based on Fracture Gradient

The second method of calculating maximum anticipated surface pressure is the fracture pressure at the current casing shoe, less the mud/gas gradient to the surface:

$$\text{MASP}_{\text{Shoe}} = P_{\text{frac}} - (\gamma_{\text{equiv}}) (\text{TVD}_{\text{shoe}})$$

Where the gradient is equivalent to an 80%/20% gas/mud gradient:

$$\gamma_{\text{equiv}} = (20\%) (\rho_{\text{mud}}) (0.052) + (80\%) (\gamma_{\text{gas}})$$

For depths greater than 10,000 ft, a 50% gas/mud gradient is used. The average gas gradient is calculated based on the Nagy/Young correlation.

Where the fracture pressure at the current casing shoe is:

$$P_{\text{frac}} = (\rho_{\text{frac}}) (0.052) (\text{TVD}_{\text{shoe}})$$

Maximum Anticipated Wellhead Pressure

The maximum anticipated wellhead pressure is the maximum anticipated surface pressure at the next casing shoe plus the gas/mud gradient from the mud line to the surface:

$$\text{MAWP} = \text{MASP} + (\gamma_{\text{equiv}}) (\text{TVD}_{\text{water}})$$

Where MASP = Minimum of $[\text{MASP}_{\text{BHP}}]$ or $[\text{MASP}_{\text{frac}}]$

$$\text{MAWP}_{\text{Surf}} = \text{MAWP} - (\rho_{\text{mud csg test}}) (0.052) (\text{TVD}_{\text{ML}})$$

Casing Test Pressure

The casing test pressure is based on the maximum of:

1. Minimum of the MAWP or 70% of burst (of the weakest exposed casing/liner):

$$P_{\text{test1}} = \text{Minimum of: [MAWP + 500 psi]} \\ \text{or: } [70\% P_b - (\rho_{\text{mud}} - \rho_{\text{pore}}) (0.052) \text{ TVD}]$$

2. Maximum of the shoe test or liner lap:

$$P_{\text{test2}} = \text{Maximum of: [P}_{\text{test shoe}} + 200 \text{ psi]} \\ \text{or: } [P_{\text{test liner}}] + 500 \text{ psi}$$

3. $P_{\text{testcsg}} = \text{Max [P}_{\text{test1}}, P_{\text{test2}}]$

Liner pressure tests are based on the maximum of the shoe test or the liner lap.

Casing Test Pressure at the Shoe

The test pressure at the shoe is the formation integrity/leak off equivalent mud weight minus the mud gradient difference:

$$P_{\text{test shoe}} = (\rho_{\text{frac}} - \rho_{\text{mud}})(0.052)(\text{TVD}_{\text{shoe}})$$

Liner Lap Test Pressure

The test pressure at the liner top that will exceed the fracture pressure of the previous casing or liner shoe (calculated for each liner):

$$P_{\text{test liner}} = (\rho_{\text{frac}} - \rho_{\text{mud}})(0.052)(\text{TVD}_{\text{liner}})$$

Ram Test Pressure at Surface

The ram test pressure at surface is based on the MASP, plus 500 psi:

$$P_{\text{test RAM}} = \text{MASP} + 500 \text{ psi}$$

Annular Test Pressure at Surface

The annular test pressure at surface is the lesser of the ram test pressure or 50% of the annular BOP working pressure:

$$P_{\text{test ANN}} = \text{Minimum of [P}_{\text{test RAM}} \text{ or } 50\%P_{\text{ANN WP}}]$$

All test pressures are rounded up to the nearest 100 psi.

B. APD CALCULATIONS FOR BIG FOOT #3

22" Casing Calculations (below 16" liner hanger)

$$70\% P_b (\text{casing})_{WH} = (0.7)(3580) - (8.6 - 8.6)(0.052)(8551) = \underline{\underline{2506 \text{ psi}}}$$

$$70\% P_b (\text{rupture disk})_{WH} = (0.7)(2600) - (8.6 - 8.6)(0.052)(5782) = \underline{\underline{1820 \text{ psi}}}$$

$$\begin{aligned} \text{MASP}_{BHP} &= (14000)(10.5)(0.052) - (10.8)(14000)(0.052)(50\%) - (0.1193)(14000)(50\%) \\ &= \underline{\underline{2875 \text{ psi}}} \end{aligned}$$

$$\begin{aligned} \text{MASP}_{shoe} &= (8531)(12.5)(0.052) - (8531 - (14000)(50\%))((10.8)(0.052) - (14000)(50\%) \\ &\quad (0.1197)) = \underline{\underline{3847 \text{ psi}}} \end{aligned}$$

$$\text{MASP} = \text{Minimum} (\text{MASP}_{BHP}, \text{MASP}_{shoe}) = \underline{\underline{2875 \text{ psi}}}$$

$$\text{MAWP} = 2875 + (5304)(0.1197) = \underline{\underline{3510 \text{ psi}}}$$

$$\text{MAWP}_{surf} = 3510 - (8.6)(0.052)(5304) = \underline{\underline{1138 \text{ psi}}}$$

$$P_{test 1} = \text{Minimum} (\text{MAWP}_{surf} + 500 \text{ or } 70\% P_b_{WH}) = \underline{\underline{1638 \text{ psi}}}$$

$$P_{shoe} = (12.0 - 10.8)(0.052)(8551) + 200 = \underline{\underline{733 \text{ psi}}}$$

$$P_{testcsg} = \text{Maximum} (P_{test 1} \text{ or } P_{shoe}) = \underline{\underline{1700 \text{ psi}}}$$

16" Casing Calculations

$$70\% P_b = (0.7)(7860) - (11.4 - 8.6)(0.052)(5548) = \underline{\underline{4694 \text{ psi}}}$$

$$\begin{aligned} \text{MASP}_{BHP} &= (27100)(12.0)(0.052) - (12.5)(27100)(0.052)(50\%) - (0.1335)(27100)(50\%) \\ &= \underline{\underline{6294 \text{ psi}}} \end{aligned}$$

$$\begin{aligned} \text{MASP}_{shoe} &= (20500)(14.2)(0.052) - (20500 - (27100)(50\%))((12.5)(0.052) - (27100)(50\%) \\ &\quad (0.1335)) = \underline{\underline{8811 \text{ psi}}} \end{aligned}$$

$$\text{MASP} = \text{Minimum} (\text{MASP}_{BHP}, \text{MASP}_{shoe}) = \underline{\underline{6294 \text{ psi}}}$$

$$\text{MAWP} = 6294 + (5304)(0.1335) = \underline{\underline{7002 \text{ psi}}}$$

$$\text{MAWP}_{surf} = 7002 - (11.8)(0.052)(5304) = \underline{\underline{3748 \text{ psi}}}$$

$$P_{test 1} = \text{Minimum} (\text{MAWP}_{surf} + 500 \text{ or } 70\% P_b) = \underline{\underline{4248 \text{ psi}}}$$

$$P_{test shoe} = (14.0 - 11.4)(0.052)(14000) + 200 = \underline{\underline{2093 \text{ psi}}}$$

$$P_{test 2} = \underline{\underline{2545 \text{ psi}}} \text{ (13 5/8" W/11.8 ppg) or } \underline{\underline{2938 \text{ psi}}} \text{ w/ 11.4 ppg}$$

(Adjusted for the 16" casing seat and test mud weight.)

$$P_{testcsg} = \text{Maximum} (P_{test 1} \text{ or } P_{test 2}) = \underline{\underline{4300 \text{ psi}}}$$

13 5/8" Liner Calculations

$$P_{test shoe} = (14.0 - 11.8)(0.052)(20500) + 200 = \underline{\underline{2545 \text{ psi}}}$$

$$P_{test liner} = (14.8 - 11.8)(0.052)(14000) + 500 = \underline{\underline{2684 \text{ psi}}}$$

$$P_{test 2} = \text{Maximum} (P_{test shoe} \text{ or } P_{test liner}) = \underline{\underline{2684 \text{ psi}}}$$

(Adjusted for the 13 5/8" casing seat and test mud weight.)

$$P_{testcsg} = \text{Maximum} (P_{test 1} \text{ or } P_{test 2}) = \underline{\underline{2700 \text{ psi}}}$$

11 7/8" Liner Calculations

$$P_{\text{test shoe}} = (13.3 - 11.8)(0.052)(23,272) + 200 = 2015 \text{ psi}$$

$$P_{\text{test liner}} = (13.3 - 11.8)(0.052)(18,726) + 500 = 1960 \text{ psi}$$

$$P_{\text{test 2}} = \text{Maximum } (P_{\text{test shoe}} \text{ or } P_{\text{test liner}}) = 2015 \text{ psi}$$

(Adjusted for the 11 7/8" casing seat and test mud weight.)

$$P_{\text{testcsg}} = \text{Maximum } (P_{\text{test 1}} \text{ or } P_{\text{test 2}}) = 2050 \text{ psi}$$

BOPE Test Pressures

$$P_{\text{test RAM}} = 7329 + 500 = 6800 \text{ psi}$$

$$P_{\text{test ANN}} = (50\%)(10000) = 5000 \text{ psi}$$

C. NOMENCLATURE

BHP	=	Bottom hole pressure, psi
MASP	=	Maximum Anticipated Surface Pressure, psi
MASP _{BHP}	=	Maximum Anticipated Surface Pressure based on pore pressure, psi
MASP _{shoe}	=	Maximum Anticipated Surface Pressure based on fracture pressure, psi
MAWP	=	Maximum Anticipated Wellhead Pressure, psi
MAWP _{surf}	=	MAWP Surface Pressure with casing test mud weight, psi
P _b	=	Casing burst pressure, psi
P _{frac}	=	Fracture pressure, psi
P _{test1}	=	Casing test pressure based on criteria 1, psi
P _{test2}	=	Casing test pressure based on criteria 2, psi
P _{testcsg}	=	Casing test pressure, psi
P _{test shoe}	=	Equivalent casing test pressure at current casing shoe, psi
P _{test liner}	=	Equivalent casing test pressure at liner top, psi
P _{test ANN}	=	Annular BOP test pressure at surface, psi
P _{ANN WP}	=	Annular BOP working pressure, psi
P _{test RAM}	=	Ram BOP test pressure at surface, psi
TVD _{next}	=	True vertical depth of next casing shoe, ft
TVD _{shoe}	=	True vertical depth of casing shoe, ft
TVD _{liner}	=	True vertical depth of liner top, ft
TVD _{water}	=	Water depth, ft
γ _{equiv}	=	Equivalent gradient of gas/mud mixture, psi/ft
γ _{gas}	=	Gas gradient, psi/ft
ρ _{mud}	=	Mud weight, lb/gal
ρ _{pore}	=	Equivalent mud weight of pore pressure, lb/gal
ρ _{frac}	=	Fracture pressure expressed as equivalent mud weight, lb/gal

II. CASING DESIGN CRITERIA

String	Conductor & Surface Casing				Intermediate Casing/Liner		
Criteria	Loading	Tubular strength	Design factor		Loading	Tubular strength	Design factor
Burst	1. Gas kick Internal: 80% gas column on top of 20% mud column calculated from OH TD to RKB. If OH > 10,000' a 50/50 gradient will be used. (gas gradient 0.10 psi/ft) External: Formation pressure 2. Pressure test Internal: Test pressure plus test fluid column (see Casing & Liner Test Pressure Calculations.doc) External: formation pressure	1. Sweet-service* API burst rating or Heavy-wall burst rating 2. Sour-service** API burst rating or VME burst rating	1. Sweet-service 1.10 2. Sour-service 1.20		1. Gas Kick Internal: 50% gas column on top of 50% mud column calculated from OH TD to RKB (gas gradient by Young-Nagy equation) External: formation pressure 2. Pressure test Internal: Test pressure plus test fluid column (see Casing & Liner Test Pressure Calculations.doc) External: formation pressure 3. Shoe fracture Internal: Frac. Pressure at shoe with mud to surface External: formation pressure	1. Sweet-service* API burst rating or Heavy-wall burst rating 2. Sour-service** API burst rating or VME burst rating	1. Sweet-service 1.10 2. Sour-service 1.20
Collapse	1. Lost return Internal: Full seawater column to surface, a gradient higher than SW may be used (equivalent to the drilling MW column drop to balance the lowest exposed pore pressure). External: Drilling mud 2. Cementing Internal: Drilling mud External: Cement slurry in place	API collapse rating or approved high collapse rating	1.00 or 0.85 for good cement section		1. Lost return Internal: Full seawater column to surface, a gradient higher than SW may be used (equivalent to the drilling MW column drop to balance the lowest exposed pore pressure). External: Drilling mud 2. Cementing Internal: Drilling mud External: Cement slurry in place	API collapse rating or approved high collapse rating	1.00 or 0.85 for good cement section
Tension	1. Running in hole : Buoyant weight	The lesser of API pipe tension rating or connection tension rating	1.60		1. Running in hole : Buoyant weight	The lesser of API pipe tension rating or connection tension rating	1.60

String	Production Casing/Liner				Tubing		
Criteria	Loading	Tubular strength	Design factor		Loading	Tubular strength	Design factor
Burst	1. Tubing leak near surface Internal: Tubing leak pressure from production shut-in External: Open hole - formation pressure. Cased hole - mud weight the production liner/casing was run in.	1. Sweet-service* API burst rating or Heavy-wall burst rating 2. Sour-service** API burst rating or VME burst rating	1. Sweet-service 1.10 2. Sour-service 1.20		1. Service Load Internal: Max. pressure from production shut in (equal to initial flowing pressure) External: Packer fluid	1. Sweet-service* API burst rating or Heavy-wall burst rating 2. Sour-service** API burst rating or VME burst rating	1.20
Collapse	1. Fluid Drop Internal: Fluid drop equivalent to abandonment pressure. Internal fluid gradient equal to produced oil or gas gradient. External: Drilling mud 2. Cementing Internal: Drilling mud External: Cement slurry in place	API collapse rating or approved high collapse rating	1.00 or 0.85 for good cement section		1. Full void pipe Internal: Fluid drop equivalent to abandonment pressure. Internal fluid gradient equal to produced oil or gas gradient. External: Packer fluid	API collapse rating or approved high collapse rating	1.00
Tension	1. Running in hole: Buoyant weight	The lesser of API pipe tension rating or connection tension rating	1.60		1. Running in hole: Buoyant weight	The lesser of API pipe tension rating or connection tension rating	1.60