TEST PRESSURE CALCULATIONS
"ST MALO 3" – OCS-G 18753 WR 677 #001

A. CALCULATION METHODOLOGY

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:

$$MASP_{BHP} = BHP - (\gamma_{equiv})\ (TVD_{next})$$

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

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

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:

$$BHP = (\rho_{pore})\ (0.052)\ (TVD_{next})$$

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 gas gradient to the surface:

$$MASP_{Shoe} = P_{frac} - (\gamma_{equiv})\ (TVD_{shoe})$$

Where the fracture pressure at the current casing shoe is:

$$P_{frac} = (\rho_{frac})\ (0.052)\ (TVD_{shoe})$$

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:

$$MAWP = MASP + (\gamma_{equiv})\ (TVD_{water})$$

Where MASP = Minimum of [$MASP_{BHP}$] or [$MASP_{frac}$]

$$MAWP_{Surf} = MAWP - (\rho_{mud\ csg\ test})\ (0.052)\ (TVD_{ML})$$

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_{test1} = Minimum of: [MAWP + 500 psi]
   or: [70% P_b - (ρ_{mud} - ρ_{pore}) (0.052) TVD]

2. Maximum of the shoe test or liner lap:

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

3. $P_{testcsg}$ = Max [P_{test1}, P_{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:

$$P_{test\ shoe} = (\rho_{frac} - \rho_{mud})(0.052)(TVD_{shoe})$$

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):

$$P_{test\ liner} = (\rho_{frac} - \rho_{mud})(0.052)(TVD_{liner})$$

Ram Test Pressure at Surface

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

$P_{test\ RAM}$ = MASP + 500 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:

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

All test pressures are rounded to the nearest 100 psi.

B. APD CALCULATIONS FOR "ST MALO 3" – OCS-G 18753 WR 677 #001

22" Casing Calculations

$70\%\ P_{b\ WH} = 70\%\ P_b - \{(\rho_{mud} - \rho_{pore})\ (0.052)(TVD)\}$

$= (0.7)(3580) - \{(8.6 - 8.6)(0.052)(6{,}981)\} =$ **2506 psi**

$MASP_{BHP} = BHP - (\gamma_{equiv})\ (TVD_{next})$

$= (16{,}177)(10.0)(0.052) - \{[(10.5)(0.052)(0.5)+(0.1125)(0.5)][16{,}177]\}$

= **3,086 psi**

Based on 16" casing point, weakest pipe exposed (22" 0.75" wall)

Where $\gamma_{equiv} = (50\%)\ (\rho_{mud})\ (0.052) + (50\%)\ (\gamma_{gas})$

$= (10.5)(0.052)(0.5)+(0.1125)(0.5)$

$=$ 0.32925 psi/ft

$MASP_{shoe} = P_{frac} - [(\gamma_{equiv})(TVD_{shoe})]$

$= (9{,}108)(13.1)(0.052) - [(0.32925)(9{,}108)]$

= **3,205 psi**

$MASP = Minimum\ (MASP_{BHP,}\ MASP_{shoe}) =$ **3,086 psi**

$MAWP = MASP + (\gamma_{equiv})\ (TVD_{water})$, where MASP = Min of $[MASP_{BHP}]$ or $[MASP_{frac}]$

$= 3{,}086 + (0.1125)(6{,}981) =$ **3,871 psi**

$MAWP_{surf} = MAWP - (\rho_{mud\ csg\ test})\ (0.052)\ (TVD_{ML})$

$= 3{,}871 - (8.6)(0.052)(6{,}981) =$ **749 psi**

$P_{test\ 1} = Minimum\ (MAWP_{surf} + 500$ or $70\%\ P_{b\ WH}) =$ **1,249 psi**

$P_{test\ shoe} = (\rho_{frac} - \rho_{mud})(0.052)(TVD_{shoe})$

$= (13.1\text{-}8.6)(0.052)(9{,}108) =$ **2,131 psi**

$P_{testcsg} = Maximum\ \{P_{test\ 1}$ or $(P_{test\ shoe} + 200)\} =$ **2,400 psi w/ 8.6 ppg seawater**

16" Casing Calculations

$70\%\ P_b = 70\%\ P_b - \{(\rho_{mud} - \rho_{pore})\ (0.052)(TVD)\}$
$= (0.7)(7{,}860) - \{(10.5 - 10.0)(0.052)(16{,}177) =$ **5,081 psi (at 16" shoe)**

$MASP_{BHP} = BHP - (\gamma_{equiv})\ (TVD_{next})$, *Based on TD of well of 28,472' MD/TVD*
$= (28{,}472)(13.9)(0.052) - \{(0.5518)(28{,}472)\}$
$=$ **4,869 psi**

Where $\gamma_{equiv} = (50\%)\ (\rho_{mud})\ (0.052) + (50\%)\ (\gamma_{gas})$
$= (0.5)\ (14.3)\ (0.052) + (0.5)(0.36)$
$= 0.5518$ psi/ft
With $\gamma_{gas} = \gamma_{mud} = 0.36$ psi/ft (Oil gradient used based on Jack #2 Welltest)

$MASP_{shoe} = P_{frac} - [(\gamma_{equiv})(TVD_{shoe})]$
$= (16{,}177)(15.3)(0.052) - [(0.5519)(16{,}177)]$
$=$ **6,502 psi**

$MASP = Minimum\ (MASP_{BHP}, MASP_{shoe}) =$ **4,869 psi**

$MAWP = MASP + (\gamma_{equiv})\ (TVD_{water})$,
$= 4{,}869 + (0.36)(6{,}909) =$ **7,356 psi**
where $\gamma_{equiv} = 0.36$ psi/ft based on depth of interface, fluid should be oil

$MAWP_{surf} = MAWP - (\rho_{mud\ csg\ test})\ (0.052)\ (TVD_{ML})$
$= 7{,}356 - (10.5)(0.052)(6{,}981) =$ **3,544 psi**

$P_{test\ 1} = Minimum\ (MAWP_{surf} + 500\ or\ 70\%\ P_b) =$ **4,044 psi**

$P_{test\ shoe} = (\rho_{frac} - \rho_{mud})(0.052)(TVD_{shoe})$
$= (14.2 - 10.5)(0.052)(16{,}177) =$ **3,129 psi**

$P_{test\ liner} = (\rho_{frac} - \rho_{mud})(0.052)(TVD_{liner})$
$= (11.7 - 10.5)(0.052)(7{,}314) =$ **456 psi**

$P_{liner\ (future)} =$ **5,641 psi** (13 5/8") and **4,824 psi** (11 7/8")
(Adjusted for the 16" casing seat of 16,177' TVD and test mud weight of 10.5 ppg.)

$P_{test\ 2} = Maximum\ (P_{liner}, P_{liner\ (future)}, or\ P_{shoe}) =$ **5,641 psi**
$P_{testcsg} = Maximum\ (P_{test\ 1}\ or\ P_{test\ 2}) =$ **5,700 psi**

13 5/8" Liner Calculations

$70\%\ P_b = 70\%\ P_b - \{(\rho_{mud} - \rho_{pore})\ (0.052)(TVD)\}$
$= (0.7)(10{,}030) - \{(11.5\text{-}11.1)(0.052)(23{,}647)\} =$ **6,529 psi**

$MASP_{BHP}$ = **4,869 psi**, *Based on TD of well of 28,472' MD/TVD*
MAWP = **7,356 psi,** *Based on TD of well of 28,472' MD/TVD*

$MAWP_{surf} = MAWP - (\rho_{mud\ csg\ test})\ (0.052)\ (TVD_{ML})$
$= 7{,}356 - (11.5)(0.052)(6{,}981) =$ **3,181 psi**

$P_{test\ shoe} = (\rho_{frac} - \rho_{mud})(0.052)(TVD_{shoe})$
$= (14.2 - 11.5)(0.052)(23{,}647) =$ **3,320 psi**

$P_{test\ liner} = (\rho_{frac} - \rho_{mud})(0.052)(TVD_{liner})$
$= (14.2 - 11.5)(0.052)(15{,}877) =$ **2,229 psi**

$P_{liner\ (Future)}$ = **4,759 psi** (11 7/8")
(Adjusted for the 13 5/8" casing seat and test mud weight.)

$P_{test\ 2}$ = Maximum $\{(P_{test\ shoe} + 200)$ or $(P_{test\ liner} + 500)$ or $P_{liner\ (Future)}\}$ = **4,759 psi**

$P_{test\ csg}$ = Maximum ($P_{test\ 1}$ or $P_{test\ 2}$) = **4,800 psi**

11 7/8" Liner Calculations

$70\%\ P_b = 70\%\ P_b - \{(\rho_{mud} - \rho_{pore})\ (0.052)(TVD)\}$
$= (0.7)(8{,}660) - \{(13.5\text{-}13.3)(0.052)(26{,}670)\} =$ **5,784 psi**

$MASP_{BHP}$ = **4,869 psi**, *Based on TD of well of 28,472' MD/TVD*
MAWP = **7,356 psi,** *Based on TD of well of 28,472' MD/TVD*

$MAWP_{surf} = MAWP - (\rho_{mud\ csg\ test})\ (0.052)\ (TVD_{ML})$
$= 7{,}356 - (13.5)(0.052)(6{,}981) =$ **2,455 psi**

$P_{test\ shoe} = (\rho_{frac} - \rho_{mud})(0.052)(TVD_{shoe})$
$= (15.0 - 13.5)(0.052)(26{,}670) =$ **2,080 psi**

$P_{test\ liner} = (\rho_{frac} - \rho_{mud})(0.052)(TVD_{liner\ top})$
$= (14.1 - 13.5)(0.052)(23{,}347) =$ **728 psi**

$P_{test\ 2}$ = Maximum {($P_{test\ shoe}$ + 200) or ($P_{test\ liner}$+ 500)} = **2,280 psi**

$P_{testcsg}$ = Maximum ($P_{test\ 1}$ or $P_{test\ 2}$) = **2,300 psi**

BOPE Test Pressures

Ram Test Pressure at Surface

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

= 4,869 + 500

= **5,400 psi**

Annular Test Pressure at Surface

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

= **5,000 psi***

*Request Waiver to test Annular BOPE to lower test pressure

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

I. 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