

Surface Pressure Calculations

These calculations are used to calculate the MMS BOP Ram Test and the MMS Casing Test.

For the preceding cases, the MMS BOP Ram Test is based on Maximum Anticipated Surface Pressure (MASP) and the MASP will be the minimum of a MASP calculated on Pore Pressure ($MASP_{Pore}$) or a MASP calculated on Fracture Gradient ($MASP_{Frac}$). The Ram Test will be the MASP plus 500 psi for a safety margin.

The MMS Casing Test is based on Maximum Anticipated Wellhead Pressure (MAWP) and the MAWP will be the minimum of a MAWP calculated on Pore Pressure ($MAWP_{Pore}$), a MAWP calculated on Fracture Gradient ($MAWP_{Frac}$), or a MAWP calculated on the weakest exposed casing ($MAWP_{Weak}$). This minimum will be rounded off to the next 100 psi.

Liner pressure tests and (liner-laps) are based on the pressure equal to or greater than the anticipated pressure to which the liner will be subjected during the formation pressure-integrity test below that liner shoe, or subsequent liner shoes if set. The liner and liner lap will be tested to this anticipated pressure plus 500 psi. This will also satisfy the criteria for a production liner test.

While these calculations are not required for the MMS Application for Permit to Drill, they are included here for future reference in case a change to test pressures is needed.

MASP Based on Pore 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:

$$\text{MASP}_{\text{pore}} = P_{\text{p next}} - (\gamma_{\text{equiv}}) (\text{TVD}_{\text{next}})$$

Where the gradient is equivalent to a 70%/30% gas/mud gradient:

$$\gamma_{\text{equiv}} = (30\%) (\rho_{\text{mud}}) (0.052) + (70\%) (\gamma_{\text{gas}})$$

The gas gradient here is 0.1 psi/ft. For depths greater than 16,000 ft we use a 60%/40% gas/mud mixture with a 0.1 psi/ft gas gradient. For depths greater than 20,000' we use a 60%/40% gas/mud mixture with a 0.15 psi/ft gas gradient and for depths greater than 22,000 ft we use a 50%/50% gas/mud mixture with a 0.15 psi/ft gas gradient.

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

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 gas gradient to the surface:

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

Where the fracture pressure at the current casing shoe is:

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

We take the lesser of $\text{MASP}_{\text{pore}}$ or $\text{MASP}_{\text{frac}}$:

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

Maximum Anticipated Wellhead Pressure

The maximum anticipated *wellhead* pressure, based on pore pressure, is the pore pressure at the next casing shoe, less the gas/mud gradient to the mud line, less the seawater gradient:

$$\text{MAWP}_{\text{pore}} = P_{\text{pore}} - (\gamma_{\text{equiv}}) (\text{TVD}_{\text{next}} - \text{TVD}_{\text{water}}) - (8.6) (0.052) (\text{TVD}_{\text{water}})$$

Likewise, the maximum anticipated wellhead pressure, based on the *fracture* pressure, is the fracture pressure at the current casing shoe, less the gas gradient to the mud line, less the seawater gradient:

$$\text{MAWP}_{\text{frac}} = P_{\text{frac}} - (\gamma_{\text{gas}}) (\text{TVD}_{\text{shoe}} - \text{TVD}_{\text{water}}) - (8.6) (0.052) (\text{TVD}_{\text{water}})$$

The maximum anticipated wellhead pressure is the *lesser* of MAWP based on pore pressure or fracture pressure:

$$\text{MAWP} = \text{Minimum of } [\text{MAWP}_{\text{pore}} \text{ or } \text{MAWP}_{\text{frac}}]$$

Casing Test Pressure at Wellhead

The test pressure at the wellhead is based on the MAWP, or 70% of burst (of the weakest exposed casing/liner), whichever is less:

$$P_{\text{test WH}} = \text{Minimum of:} \\ [MAWP + 500 \text{ psi}] \\ \text{or:} \\ [70\% P_b - (\rho_{\text{mud}} - 8.6) (0.052) \text{ TVD}_{\text{water}}]$$

Casing Test Pressure at Surface

The surface test pressure is the minimum of the wellhead test pressure less the mud/seawater gradient difference or 70% of burst of the weakest exposed casing/liner at the deepest exposed depth:

$$P_{\text{test surf}} = \text{Minimum of:} \\ P_{\text{test WH}} \text{ or} \\ [70\% P_b - (\rho_{\text{mud}} - 9.0) (0.052) \text{ TVD}_{\text{weak}}]$$

This value is usually rounded up to the nearest 100 psi for simplicity.

Casing Test Pressure at the Shoe

Similarly, the equivalent test pressure at the shoe is the surface test pressure plus the mud/pore pressure gradient difference:

$$P_{\text{test shoe}} = P_{\text{test surf}} + [(\rho_{\text{mud}} - P_{\text{pore}}) (0.052) \text{ TVD}_{\text{shoe}}]$$

This value is for reference and is not used in any further calculations.

Liner Test Pressure at Surface

The surface test pressure applied to a liner will be at minimum of 500 psi over the fracture pressure at that shoe less the mud weight in the hole during the test:

$$P_{\text{test surf}} = P_{\text{frac}} - (\rho_{\text{mud}}) (0.052) \text{ TVD}_{\text{shoe}} + 500 \text{ psi}$$

This value is usually rounded up to the nearest 100 psi for simplicity.

Ram Test Pressure at Surface

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

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

This value is usually rounded up to the nearest 100 psi for simplicity.

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:

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

Nomenclature

MASP =	Maximum Anticipated Surface Pressure, psi
MASP _{pore} =	Maximum Anticipated Surface Pressure based on pore pressure, psi
MASP _{frac} =	Maximum Anticipated Surface Pressure based on fracture pressure, psi
MAWP =	Maximum Anticipated <i>Wellhead</i> Pressure, psi
MAWP _{pore} =	Maximum Anticipated <i>Wellhead</i> Pressure based on pore pressure, psi
MAWP _{frac} =	Maximum Anticipated <i>Wellhead</i> Pressure based on fracture pressure, psi
P _b =	Casing burst rating, psi
P _p =	Pore pressure, psi
P _{p next} =	Pore pressure at next casing shoe, psi
P _{test surf} =	Casing test pressure at surface, psi
P _{test WH} =	Equivalent casing test pressure at wellhead, psi
P _{test shoe} =	Equivalent casing test pressure at shoe, 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 _{weak} =	True vertical depth at maximum depth of weakest exposed casing
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

22" Casing Calculations Shoe @ 7857' md/tvd. Next casing @ 10500' (18" liner)

$$\text{MASP}_{\text{pore}} = (10.5)(0.052)(10500) - [(0.3)(10.7)(0.052) + (0.7)(0.1)] * 10500 = \underline{3245 \text{ psi}}$$

$$\text{MASP}_{\text{frac}} = (11.2)(0.052)(7857) - (0.1)(7857) = \underline{3790 \text{ psi}}$$

$$\text{MASP} = \text{Minimum of } [\text{MASP}_{\text{pore}}] \text{ or of } [\text{MASP}_{\text{frac}}] = \underline{3245 \text{ psi}} = \underline{3300 \text{ psi}}$$

Ram Test Pressure = MASP + 500 psi = 3300 + 500 = 3800 psi (However, we will test to 18" Ram Test Pressure of 6000 psi)

$$\text{MAWP}_{\text{pore}} = (10.5)(0.052)(10500) - [(0.3)(10.7)(0.052) + (0.7)(0.1)] * (10500 - 4619) - (8.6)(0.052)(4619) = \underline{2274 \text{ psi}}$$

$$\text{MAWP}_{\text{frac}} = (11.2)(0.052)(7857) - (0.1)(7857 - 4619) - (8.6)(0.052)(4619) = \underline{2187 \text{ psi}}$$

$$\text{MAWP} = \text{Minimum of } [\text{MAWP}_{\text{pore}}] \text{ or of } [\text{MAWP}_{\text{frac}}] = \underline{2187 \text{ psi}}$$

$$70\% P_{b \text{ WH}} = (0.7)(6364) - (8.6 - 8.6)(0.052)(4619) = \underline{4455 \text{ psi}}$$

$$70\% P_{b \text{ weak}} = (0.7)(6364) - (10.2 - 9.0)(0.052)(7857) = \underline{3965 \text{ psi}} \quad (22" \text{ shoe : } 12.5 \text{ in csg \& tst w/ seawater} = 10.2)$$

$$P_{\text{test WH}} = \text{Minimum of MAWP} + 500 \text{ or } 70\% P_{b \text{ WH}} = \text{Min}((2187 + 500), (4455)) = \underline{2687 \text{ psi}} = \underline{2700 \text{ psi}}$$

$$P_{\text{test surf}} = \text{Minimum of } P_{\text{test WH}} \text{ or } 70\% P_{b \text{ weak}} = \text{Min}(2700, 3965) = \underline{2700 \text{ psi}}$$

Casing Test Pressure = 3100 psi with sea water

18" Drlg Liner Calculations Shoe @ 10500' md/tvd Next casing @ 17838' md/tvd

$$\text{MASP}_{\text{pore}} = (12.5)(0.052)(17838) - [(0.4)(13.7)(0.052) + (0.6)(0.1)] * 17838 = \underline{5441 \text{ psi}}$$

$$\text{MASP}_{\text{frac}} = (14.3)(0.052)(10500) - (0.1)(10500) = \underline{6758 \text{ psi}}$$

$$\text{MASP} = \text{Minimum of } [\text{MASP}_{\text{pore}}] \text{ or of } [\text{MASP}_{\text{frac}}] = \underline{5441 \text{ psi}}$$

$$\text{Ram Test Pressure} = \text{MASP} + 500 \text{ psi} = 5441 + 500 = \underline{5941 \text{ psi}} = \underline{6000 \text{ psi}}$$

$$\text{MAWP}_{\text{pore}} = (12.5)(0.052)(17838) - [(0.4)(13.7)(0.052) + (0.6)(0.1)] * (17838 - 4619) - (8.6)(0.052)(4619) = \underline{4969 \text{ psi}}$$

$$\text{MAWP}_{\text{frac}} = (14.3)(0.052)(10500) - (0.1)(10500 - 4619) - (8.6)(0.052)(4619) = \underline{5154 \text{ psi}}$$

$$\text{MAWP} = \text{Minimum of } [\text{MAWP}_{\text{pore}}] \text{ or of } [\text{MAWP}_{\text{frac}}] = \underline{4969 \text{ psi}}$$

$$70\% P_{b \text{ WH}} = (0.7)(6364) - (10.7 - 8.6)(0.052)(4619) = \underline{3950 \text{ psi}}$$

$$70\% P_{b \text{ weak}} = (0.7)(6680) - (10.7 - 9.0)(0.052)(10500) = \underline{3748 \text{ psi}}$$

$$\text{Liner Calc} = (14.3 - 10.7) (0.052) (10500) + 500 = \underline{2466 \text{ psi}}$$

$$P_{\text{test WH}} = \text{Minimum of } (\text{MAWP} + 500) \text{ or } (70\% P_{b \text{ WH}}) = \underline{3950 \text{ psi}}$$

$$P_{\text{test surf}} = \text{Minimum of } P_{\text{test WH}} \text{ or } (70\% P_{b \text{ weak}}) \text{ or } (\text{Liner Calc}) = \underline{2466 \text{ psi}} = \underline{2500 \text{ psi}}$$

Casing Test Pressure = 2500 psi with 10.7 ppg mud

13 5/8" Casing Calculations Shoe @ 17838' md/tvd, with 2 liners below (11-7/8" @ 22178' tvd, 9-7/8" @ 25258' tvd, TD @ 28768' tvd)

$$\text{MASP}_{\text{pore}} (\text{@ } 11\text{-}7/8 \text{ shoe}) = (14.5)(0.052)(22178) - [(0.5)(14.6)(0.052) + (0.5)(0.15)] * 22178 = \underline{\underline{6640 \text{ psi}}}$$

$$\text{MASP}_{\text{pore}} (\text{@ TD}) = (15.3)(0.052)(28768) - [(0.5)(15.5)(0.052) + (0.5)(0.15)] * 28768 = \underline{\underline{9137 \text{ psi}}}$$

$$\text{MASP}_{\text{frac}} = (15.5)(0.052)(17838) - (0.1)(17838) = \underline{\underline{12594 \text{ psi}}}$$

$$\text{MASP} = \text{Minimum of } [\text{MASP}_{\text{pore}}] \text{ or of } [\text{MASP}_{\text{frac}}] = \underline{\underline{6640 \text{ psi @ next casing point, or } 9137 \text{ psi @ TD}}$$

Ram Test Pressure Minimum = MASP + 500 psi = 6640 + 500 = 7140 psi = 7200 psi for APD

Planned = 9137 + 500 = 9637 psi = 9700 psi will be needed for final hole section to TD.

$$\text{MAWP}_{\text{pore}} = (15.3)(0.052)(28768) - [(0.5)(15.5)(0.052) + (0.5)(0.15)] * (28768 - 4619) - (8.6)(0.052)(4619) = \underline{\underline{9278 \text{ psi}}}$$

$$\text{MAWP}_{\text{frac}} = (15.5)(0.052)(17838) - (0.1)(17838 - 4619) - (8.6)(0.052)(4619) = \underline{\underline{10990 \text{ psi}}}$$

$$\text{MAWP} = \text{Minimum of } [\text{MAWP}_{\text{pore}}] \text{ or of } [\text{MAWP}_{\text{frac}}] = \underline{\underline{9278 \text{ psi}}}$$

$$70\% P_{b \text{ WH}} = (0.7)(11147) - (13.7 - 8.6)(0.052)(4619) = \underline{\underline{6578 \text{ psi}}}$$

$$70\% P_{b \text{ weak}} = (0.7)(11147) - (13.7 - 9.0)(0.052)(17838) = \underline{\underline{3443 \text{ psi}}} \text{ (13 5/8" weak point at 17838' TVD)}$$

$$P_{\text{test WH}} = \text{Minimum of MAWP} + 500 \text{ or } 70\% P_{b \text{ WH}} = \underline{\underline{6578 \text{ psi}}}$$

$$P_{\text{test surf}} = \text{Minimum of } P_{\text{test WH}} \text{ or } 70\% P_{b \text{ weak}} = \underline{\underline{3443}} = \underline{\underline{3500 \text{ psi}}}$$

Casing Test Pressure = 3500 psi with 13.7 ppq mud

11-7/8" Drilling Liner Calculations Shoe @ 22178' tvd. Next liner @ 25258' tvd, TD @28768' tvd

$$\text{MASP}_{\text{pore}} (\text{ @ 9-7/8 shoe}) = (14.0)(0.052)(25258) - [(0.5)(14.2)(0.052) + (0.5)(0.15)] * 25258 = \underline{7168 \text{ psi}}$$

$$\text{MASP}_{\text{pore}} (\text{ @ TD }) = (15.3)(0.052)(28768) - [(0.5)(15.5)(0.052) + (0.5)(0.15)] * 28768 = \underline{9137 \text{ psi}}$$

$$\text{MASP}_{\text{frac}} = (15.5)(0.052)(22178) - (0.15)(22178) = \underline{14549 \text{ psi}}$$

$$\text{MASP} = \text{Minimum of } [\text{MASP}_{\text{pore}}] \text{ or of } [\text{MASP}_{\text{frac}}] = \underline{7168 \text{ psi (9137 psi at TD)}}$$

Ram Test Pressure Minimum = MASP + 500 psi = 7168 + 500 = **7668 psi = 7700 psi for APD**

Planned = 9137 + 500 = 9637 psi = **9700 psi** will be needed for final hole section to TD.

$$\text{MAWP}_{\text{pore}} = (15.3)(0.052)(28768) - [(0.5)(15.5)(0.052) + (0.5)(0.15)] * (28768 - 4619) - (8.6)(0.052)(4619) = \underline{9279 \text{ psi}}$$

$$\text{MAWP}_{\text{frac}} = (15.5)(0.052)(22178) - (0.1)(22178 - 4619) - (8.6)(0.052)(4619) = \underline{14054 \text{ psi}}$$

$$\text{MAWP} = \text{Minimum of } [\text{MAWP}_{\text{pore}}] \text{ or of } [\text{MAWP}_{\text{frac}}] = \underline{9278 \text{ psi}}$$

$$70\% P_{b \text{ WH}} = (0.7)(11910) - (14.6 - 8.6)(0.052)(4619) = \underline{6896 \text{ psi}}$$

$$70\% P_{b \text{ weak}} = (0.7)(11910) - (14.6 - 9.0)(0.052)(22178) = \underline{1879 \text{ psi}} \quad (80\% P_{b \text{ weak}} = 3070 \text{ psi})$$

$$\text{Liner Calc} = (15.5 - 14.6) (0.052) (22178) + 500 = \underline{1538 \text{ psi}}$$

$$P_{\text{test WH}} = \text{Minimum of } (\text{MAWP} + 500) \text{ or } (70\% P_{b \text{ WH}}) = \underline{6896 \text{ psi}}$$

$P_{\text{test surf}} = \text{Minimum of } P_{\text{test WH}} \text{ or } (70\% P_{b \text{ weak}}) \text{ or } (\text{Liner Calc}) = \underline{1538 \text{ psi}} = \underline{1600 \text{ psi}}$ minimum, however the 9-7/8" liner will require testing to a higher pressure...

Casing Test Pressure = 2700 psi with 14.6 ppq MW (from 9-7/8" calcs)

9-7/8" Drilling Liner Calculations Shoe @ 25258' tvd, TD @28768' tvd

$$\text{MASP}_{\text{pore}} (\text{@ TD}) = (15.3)(0.052)(28768) - [(0.5)(15.5)(0.052) + (0.5)(0.15)] * 28768 = \underline{\underline{9137 \text{ psi}}}$$

$$\text{MASP}_{\text{frac}} = (16.0)(0.052)(25258) - (0.15)(25258) = \underline{\underline{17226 \text{ psi}}}$$

$$\text{MASP} = \text{Minimum of } [\text{MASP}_{\text{pore}}] \text{ or of } [\text{MASP}_{\text{frac}}] = \underline{\underline{9137 \text{ psi}}}$$

$$\text{Ram Test Pressure} = \text{MASP} + 500 \text{ psi} = 9137 + 500 = \underline{\underline{9637 \text{ psi}}} = \underline{\underline{9700 \text{ psi for APD}}}$$

$$\text{MAWP}_{\text{pore}} = (15.3)(0.052)(28768) - [(0.5)(15.5)(0.052) + (0.5)(0.15)] * (28768 - 4619) - (8.6)(0.052)(4619) = \underline{\underline{9279 \text{ psi}}}$$

$$\text{MAWP}_{\text{frac}} = (16.0)(0.052)(25258) - (0.15)(25258 - 4619) - (8.6)(0.052)(4619) = \underline{\underline{15853 \text{ psi}}}$$

$$\text{MAWP} = \text{Minimum of } [\text{MAWP}_{\text{pore}}] \text{ or of } [\text{MAWP}_{\text{frac}}] = \underline{\underline{9279 \text{ psi}}}$$

$$70\% P_{b \text{ WH}} = (0.7)(13594) - (14.2 - 8.6)(0.052)(4619) = \underline{\underline{8171 \text{ psi}}}$$

$$70\% P_{b \text{ weak}} = (0.7)(13594) - (14.2 - 9.0)(0.052)(25258) = \underline{\underline{2686 \text{ psi}}}$$

$$\text{Liner Calc} = (16.0 - 14.2) (0.052) (25258) + 500 = \underline{\underline{2864 \text{ psi}}}$$

$$P_{\text{test WH}} = \text{Minimum of } (\text{MAWP} + 500) \text{ or } (70\% P_{b \text{ WH}}) = \underline{\underline{8171 \text{ psi}}}$$

$$P_{\text{test surf}} = \text{Minimum of } P_{\text{test WH}} \text{ or } (70\% P_{b \text{ weak}}) \text{ or } (\text{Liner Calc}) = \underline{\underline{2686 \text{ psi}}} = \underline{\underline{2700 \text{ psi}}}$$

$$\text{Casing Test Pressure} = \underline{\underline{2700 \text{ psi with 14.2 ppg mud weight}}}$$