MPR

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CALCULATION TITLE PAGE

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Project REVIEW OF CALCULATION OF ALLOWABLE MAKEUP TANK PRESSURE VS. LEVEL	Task No. 102075
Title EFFECT OF MAKEUP TANK TEMPERATURE ON MAXIMUM ALLOWABLE MAKEUP TANK PRESSURE	Calculation No. 102075DHH06

Preparer/Date	Checker/Date	Reviewer/Date	Rev. No.
A.L. Harrison 2/13/96	R.C. Landee 2/13/96	R.C. Landee 2/13/96	0

RECORD OF REVISIONS

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102075D4H06	Harrison	R. C. Sanders	

Revision	Description
0	Original Issue

EFFECT OF MAKEUP TANK TEMPERATURE ON MAXIMUM ALLOWABLE MAKEUP TANK PRESSURE

1. PURPOSE:

The purpose of this calculation is to establish the effect of the assumed temperature in the makeup tank on the maximum allowable pressure in the tank. As the temperature is reduced from 135°F as assumed in the base calculation, the solubility increases so there is more inventory of gas in the system; however, the vapor pressure of the water is reduced. This calculation evaluates the maximum allowable pressure in the makeup tank using the method described in Reference 1 for both 100°F and 135°F temperature in the makeup tank.

2. SUMMARY:

Evaluation of maximum allowable makeup tank pressure was done for two different temperatures: 100°F and 135°F. The difference between the two values was found to depend on the level in the makeup tank. The difference is always such that a lower temperature in the makeup tank would allow a higher makeup tank pressure. This shows that the use of a high makeup tank temperature is a conservative basis upon which to set the design curve.

The specific values of this difference (both as pressure and a head of water) are shown in curves on page 8.
At high makeup tank levels the difference between 100°F and 135°F makeup tank temperature can be more than 10 feet.

3. APPROACH

The calculation of reference 1 will be repeated at a temperature of 100°F in the makeup tank and then the difference between this result and that for 135°F from Reference 1 will be calculated.

<u>Input Values for 100°F makeup tank temperature.</u>

See Reference 1, page 20. and Reference 2, page 22

a. Henry's Law Constants

Using Table 1-19 of BAW-1385, Rev. 6, referenced by FPC calculation M94-0053 attach #6, (Reference 4 of MPR calculation 102075DHH03, Reference 2 of this calculation)

$$\text{Temp } 100°F \qquad H_{H_2} = 0.923 \ \frac{psia}{cc/kg}$$

$$H_{N_2} = 1.221 \ \frac{psia}{cc/kg}$$

so convert units as in Reference 2

$$H_{H_2} = \underset{\frac{psi}{\frac{cc(stp)}{kg\,H_2O}}}{0.923} \times \underset{\frac{psfa}{psia}}{144} \times \underset{\frac{lb}{kg}}{2.205} \times \underset{\frac{cc(stp)}{lb\text{-}mole}}{1.01686 \times 10^{7}} = 2.9801 \times 10^{9} \ \frac{psfa}{\frac{lb\text{-}mole\,H_2}{lb\,H_2O}}$$

$$H_{N_2} = 1.221 \times 144 \times 2.205 \times 1.01686 \times 10^{7} = 3.9423 \times 10^{9} \ \frac{psfa}{\frac{lb\text{-}mole\,N_2}{lb\,H_2O}}$$

$$C_{HH_2} = \frac{1}{2.9801} \times 10^{-9} = 3.3556 \times 10^{-10} \ \frac{\frac{lb\text{-}mole\,H_2}{lb\,H_2O}}{psfa}$$

$$C_{HN_2} = \frac{1}{3.9423} \times 10^{-9} = 2.5366 \times 10^{-10} \ \frac{\frac{lb\text{-}mole\,N_2}{lb\,H_2O}}{psfa}$$

b. Saturation Pressure of Water at 100°F.

From Reference , Table 1. @ 100°F

$P_{sat} = 0.94924 \ lbf/in^2 = 136.6906 \ lbf/ft^2$

$v_{sat} = 0.016130 \ ft^3/lbm = 61.9963 \ lbm/ft^3$

c. Densities of Water

$\rho_s = \rho_m = 61.9963 \ lbm/ft^3$

d. Gas Constant, $R_o = 1545.3 \ ft\cdot lbf/lb\text{-}mole \ °R$

e. Absolute temperature of makeup tank.

100°F = 460+100 = 560°R

f. Group of constants (see a, e, c, and d above)

$$D_H = 1545.3 \times 560 \times 61.9963 \times 3.3556 \times 10^{-10} = 1.8003 \times 10^{-2}$$

$$D_N = 1545.3 \times 560 \times 61.9963 \times 2.5366 \times 10^{-10} = 1.3609 \times 10^{-2}$$

Other inputs are the same as in Reference 1 for 135°F tank temperature.

The relations for maximum allowable pressure are evaluated in the same manner as in Reference 1. This is done in Mathcad 6.0, a commercial mathematics program. The inputs, outputs, and processing are shown in the printout on pages 6 through 8.

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Calc 102075DHH06 Preparer: DHarrison Checker:

EVALUATION OF MAKEUP TANK MAXIMUM PRESSURE

PURPOSE:

The purpose of this calculation is to evaluate the maximum pressure in the makeup tank as a function of level in the tank. The expressions are derived in hand calculations. Some parameters are also established by separate hand calculations.

CASE COVERED:

This is the nominal reference case except that the temperature in the makeup tank is assumed to be 100°F instead of 135°F. An expression for the difference in allowable pressure for the two temperatures is derived and evaluated, both as pressure and head.

PARAMETERS:

Vapor pressure of water in the makeup tank at 100°F: $Psat := 0.94924\cdot\frac{lbf}{in^2}$ $Psat = 136.691\cdot\frac{lbf}{ft^2}$

Density of water in the makeup tank at 100 F: $\rho_m := 61.9963\cdot\frac{lb}{ft^3}$

Density of water in the BWST at 100 F: $\rho_s := 61.9963\cdot\frac{lb}{ft^3}$

Acceleration of gravity: $g := 32.17\cdot\frac{ft}{sec^2}$

Minimum level in the BWST: $Lmin := 5.0\cdot ft$

Minimum elevation of the surface in the BWST: $E_s := Lmin + 119.67\cdot ft$ $E_s = 124.67\cdot ft$

Minimum margin between the top of the pipe at the tie-in and and the gas in the makeup tank: $Xm := 2\cdot ft$

Elevation of the top of the 6-in pipe at the tie-in point: $E_d := 104.5\cdot ft + 3\cdot in$ $E_d = 104.75\cdot ft$

Minimum elevation of the level in the pipe from the MUT to the top of the 6-in pipe at the tie-in point: $E_x := E_d + Xm$ $E_x = 106.75\cdot ft$

Mole ratio of Nitrogen to Hydrogen in the MUT cover gas: $\gamma := 0.1$

Pipe flow velocity (in the 6-in pipe) at tie-in point: $u_c := 6.664\cdot\frac{ft}{sec}$

Gage pressure in the BWST: $Psg := -1.0\cdot ft\cdot 62.4\cdot\frac{lbf}{ft^3}$

Absolute pressure in the BWST: $Ps := 14.7\cdot\frac{lbf}{in^2} + Psg$ $Ps = 2.054\cdot 10^3\cdot\frac{lbf}{ft^2}$

Total head loss from the BWST to the tie-in point at the centerline of the 6-in pipe: $\Delta Hac := 11.8704\cdot ft$

Combined Henry's Law and other constants for Hydrogen and Nitrogen, respectively:

$D_H := 0.018003$ $D_N := 0.013609$

The number of calculational steps to reduce the liquid volume in the makeup tank to zero: $k := 20$

EXPRESSIONS USED:

The expressions below for the maximum pressure in makeup tank are derived in hand calculations:

$$R_H(j, vo, \delta v) := \frac{vo + (j-1)\cdot\delta v + D_H\cdot(1 - vo - j\cdot\delta v)}{vo + j\cdot\delta v + D_H\cdot(1 - vo - j\cdot\delta v)} \qquad R_N(j, vo, \delta v) := \frac{vo + (j-1)\cdot\delta v + D_N\cdot(1 - vo - j\cdot\delta v)}{vo + j\cdot\delta v + D_N\cdot(1 - vo - j\cdot\delta v)}$$

$$\Psi(\gamma, vo, k) := \frac{\prod_{j=1}^{k} R_H\left(j, vo, \frac{1-vo}{k}\right) + \gamma\cdot\prod_{j=1}^{k} R_N\left(j, vo, \frac{1-vo}{k}\right)}{1+\gamma}$$

The maximum pressure in the makeup tank as a function of the initial gas volume fraction, vo, is as follows:

$$Pmo(vo, \gamma, k) := Psat + \frac{-\rho_m\cdot g\cdot E_x + \rho_s\cdot g\cdot E_s - (\rho_s - \rho_m)\cdot g\cdot E_d + \rho_s\cdot g\cdot\left(\frac{Ps}{\rho_s\cdot g} - \Delta Hac - \frac{u_c^2}{2\cdot g}\right) - Psat}{\Psi(\gamma, vo, k)}$$

If we now define another quantity, Pxmo, as the allowable pressure at the maximum temperature in the makeup tank of 135°F, we can get the difference between the two pressures.

The saturation pressure at 135°F is: $Pxsat := 2.5375\cdot\frac{lbf}{in^2}$ $Pxsat = 365.4\cdot\frac{lbf}{ft^2}$

The density at 135°F is: $\rho_{mx} := 61.4628\cdot\frac{lb}{ft^3}$

The non-dimensional constants (from hand calculations) are: $Dx_H := 0.01892$ $Dx_N := 0.01246$

Now determine the new terms for the maximum temperature condition as above:

$$Rx_H(j, vo, \delta v) := \frac{vo + (j-1)\cdot\delta v + Dx_H\cdot(1 - vo - j\cdot\delta v)}{vo + j\cdot\delta v + Dx_H\cdot(1 - vo - j\cdot\delta v)} \qquad Rx_N(j, vo, \delta v) := \frac{vo + (j-1)\cdot\delta v + Dx_N\cdot(1 - vo - j\cdot\delta v)}{vo + j\cdot\delta v + Dx_N\cdot(1 - vo - j\cdot\delta v)}$$

$$\Psi x(\gamma, vo, k) := \frac{\prod_{j=1}^{k} Rx_H\left(j, vo, \frac{1-vo}{k}\right) + \gamma\cdot\prod_{j=1}^{k} Rx_N\left(j, vo, \frac{1-vo}{k}\right)}{1+\gamma}$$

The maximum allowable pressure in the makeup tank, Pxmo, as a function of the initial gas volume fraction, vo, is as follows for the 135°F makeup tank temperature is:

$$Pxmo(vo, \gamma, k) := Pxsat + \frac{-\rho_{mx}\cdot g\cdot E_x + \rho_s\cdot g\cdot E_s - (\rho_s - \rho_{mx})\cdot g\cdot E_d + \rho_s\cdot g\cdot\left(\frac{Ps}{\rho_s\cdot g} - \Delta Hac - \frac{u_c^2}{2\cdot g}\right) - Pxsat}{\Psi x(\gamma, vo, k)}$$

The gas volume fraction, vo, is related to the measured level in the makeup tank, in inches, by the following relation (obtained from hand calculations):

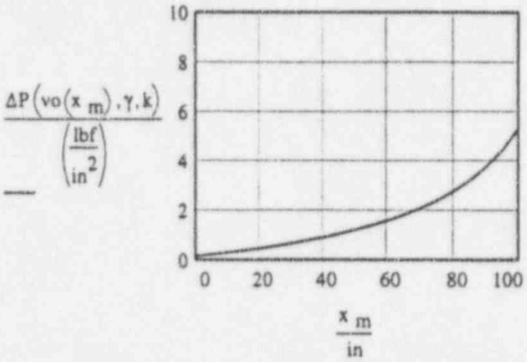
$$vo(x_m) := 0.9089 - 0.0068355\cdot in^{-1}\cdot x_m$$

If we now define the difference between the two allowable pressures as ΔP (where Pmo is the allowable pressure at a makeup tank temperature of 100°F and Pxmo is the allowable pressure for a tank temperature of 135°F):

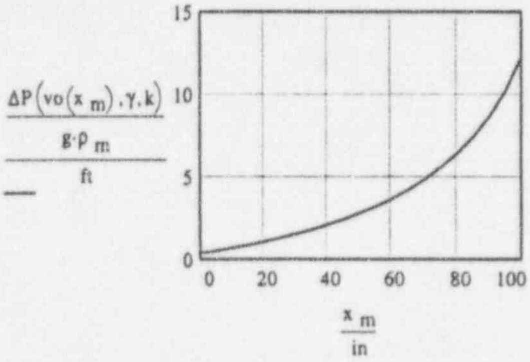
$$\Delta P(vo, \gamma, k) := Pmo(vo, \gamma, k) - Pxmo(vo, \gamma, k)$$

If ΔP is greater than zero, the allowable pressure at the makeup tank temperature of 100°F is greater than the allowable pressure at the 135°F temperature used in the original base calculation and it would show that the assumption of the higher (135°F) temperature is conservative because it results in a lower allowable pressure.

Range of level: $x_m := 0 \cdot in, 5 \cdot in .. 100 \cdot in$



As shown by the curve, the allowable pressure for 135°F is always lower than the allowable pressure at 100°F. This confirms that the use of the higher temperature in the analysis. Furthermore, it shows that the use of the higher temperature involves a substantial additional margin in the calculation. The curve of pressure difference can also be expressed in terms of feet of head as follows:



REFERENCES:

1. MPR CALCULATION: 102075DHH01, Rev. 0 "Maximum Allowable Makeup Tank Pressure." Jan. 11, 1996.

2. MPR CALCULATION: 102075DHH03, Rev. 0 "Makeup Tank Pressure." Jan. 11, 1996.