Gas system calculations DRAFT

Pressures for use at LBNL

Maximum Operating Pressure

$P_{MOP} := 300psi$

Maximum Allowable Working Pressure

$P_{MAWP} := 350psi$

Stored Energy, U, @ 350 psig MAWP

from PUB3000 , Chapter 7, Appendix E:

$$U = \frac{P_h V_h}{\gamma - 1}\left[1 - \left(\frac{P_l}{P_h}\right)^{\frac{\gamma-1}{\gamma}}\right]$$

where:

$P_h := P_{MAWP} + 14.7psi$ $P_h = 364.7\,psi$ $P_l := 14.7psi$ $\gamma := 1.666$ (for monatomic gases)

System Volume includes vessel, cabling octagon, connectiong spool, recovery bottle, valve and gas system tubing:

$d_{ves} := 7.63in$	$l_{ves} := 13.5in$	main vessel inner dimensions
$d_{LNxt} := 2in$	$l_{LNxt} := 8in$	LN2 extension (cold probe)
$d_{oct} := 8in$	$l_{oct} := 3.0in$	Kimball octagon for cabling
$d_{spool} := 2in$	$l_{spool} := 10in$	connection spool, lid to octagon
$d_{tubing} := 0.5in$	$l_{tubing} := 20ft$	gas system tubing and filters
$d_{valve} := 2in$	$l_{valve} := 4in$	high pressure volume of closed valve and tank stub
$d_{rb} := 4.0in$	$l_{rb} := 36in$	recovery bottle (condensation bottle)

$$V_h := \frac{\pi}{4}\cdot\left(d_{ves}^{2}\cdot l_{ves} + d_{LNxt}^{2}\cdot l_{LNxt} + d_{spool}^{2}\cdot l_{spool} + d_{oct}^{2}\cdot l_{oct} + d_{tubing}^{2}\cdot l_{tubing} + d_{valve}^{2}\cdot l_{valve} + d_{rb}^{2} l_{rb}\right)$$

$V_h = 1.3\times 10^{3}\,in^{3}$ $V_h = 21.9\,L$

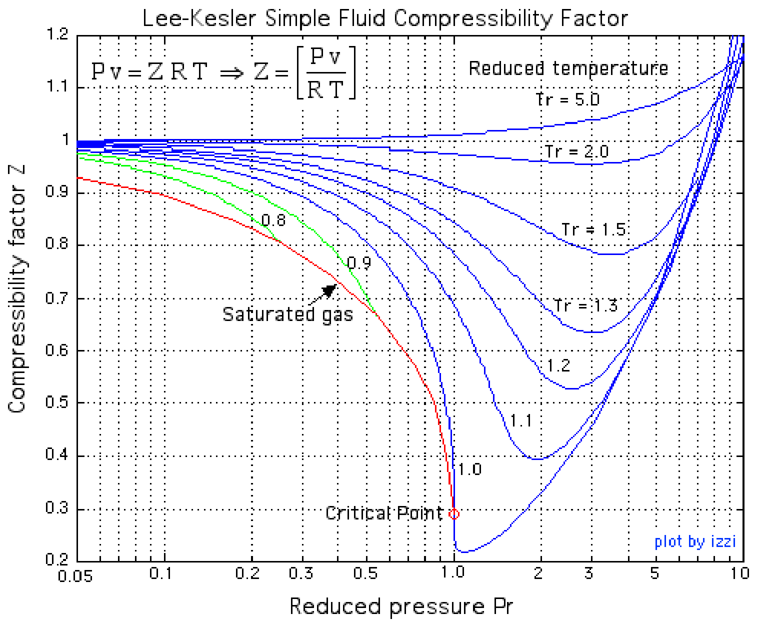
Stored Energy @ 350 psig MAWP:

$$U_v := \frac{P_h\cdot V_h}{\gamma - 1}\left[1 - \left(\frac{P_l}{P_h}\right)^{\frac{\gamma-1}{\gamma}}\right] \qquad U_v = 60\,kJ$$

Mass of Xenon in System at operating pressure

$P_{MOP} = 300\,psi$ $R := 8.314J\cdot mol^{-1}\cdot K^{-1}$ $T_{amb} := 300K$ $M_{a\_Xe} := 131.3gm\cdot mol^{-1}$

For real gases especially those that deviate strongly from ideal behavior the ideal gas law is modified with a compressibility factor Z (where v in chart below is molar density = V/n). For pure gasses (not mixtures) this factor is identical for different compounds when pressure and temperature are expressed in terms of a reduced pressure and temperature (principle of corresponding states), and can be easily found according to the following chart:



ref: A Generalized Thermodynamic Correlation based on Three-Parameter Corresponding States, B.I.Lee & M.G.Kesler, AIChE Journal, Volume 21, Issue 3, 1975, pp. 510-527' (secondary ref. from:http://www.ent.ohiou.edu/~-thermo/

where the reduced pressure and temperature are defined in terms of the critical pressure and temperature respectively:

Critical Pressure, Critical Temperature of Xenon:

$P_{c\_Xe} := 58.40\text{bar}$ $\quad T_{c\_Xe} := 15.6\text{K} + 273\text{K}$

reduced pressure, temperature at operating condition:

$P_r := \frac{315\text{psi}}{P_{c\_Xe}}$ $\quad P_r = 0.361$ $\quad T_r := \frac{T_{amb}}{T_{c\_Xe}}$ $\quad T_r = 1.04$

Compressibility Factor: from chart above:

$Z_{Xe\_20bar} := 0.88$

Number of moles:

$n_{Xe} := \frac{P_{MOP} \cdot V_h}{Z_{Xe\_20bar} \cdot R \cdot T_{amb}}$ $\quad n_{Xe} = 20.642\,\text{mol}$ $\quad \rho_{mol} := \frac{n_{Xe}}{V_h}$ $\quad \rho_{mol} = 0.942\,\frac{\text{mol}}{\text{L}}$

Weight:

$W_{Xe} := M_{a\_Xe} \cdot n_{Xe}$ $\quad W_{Xe} = 2.71\,\text{kg}$

Volume of LXe

density: $\rho_{LXe} := 3.05\,\frac{\text{gm}}{\text{mL}}$ @ boiling, 1 bar, -101.8C

$V_{LXe} := \frac{W_{Xe}}{\rho_{LXe}}$ $\quad V_{LXe} = 0.889\,\text{L}$

Pressure in recovery bottle

Recovery Bottle volume:

$V_{rb} := \frac{\pi}{4} \cdot d_{rb}^{\,2} \cdot l_{rb}$ $\quad V_{rb} = 7.413\,\text{L}$

we need a starting guess for pressure to iterate to find Z

$P_{rb\_guess} := 2.5 \cdot P_{MOP}$ $\quad P_{rb\_guess} = 50.2\,\text{bar}$

then reduced pressure, temperature:

$$P_{r\_rb} := \frac{P_{rb\_guess}}{P_{c\_Xe}} \qquad P_{r\_rb} = 0.86 \qquad T_{hot} := (273 + 50)K \qquad T_{r\_hot} := \frac{T_{hot}}{T_{c\_Xe}} \qquad T_{r\_hot} = 1.12$$

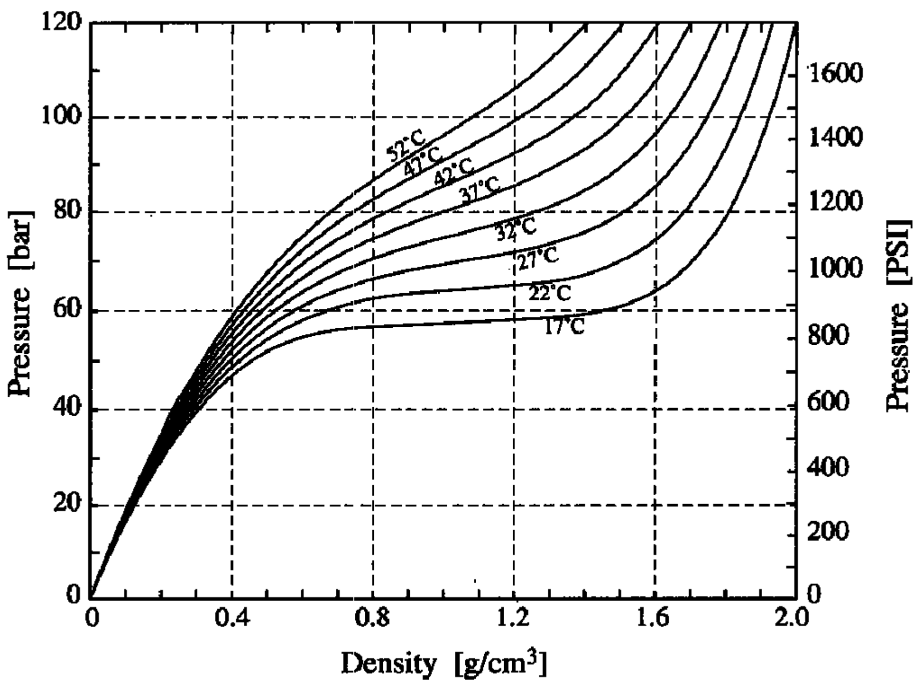
we find from chart:

$Z_{Xe\_rb\_press} := .76$

$$P_{rb} := \frac{n_{Xe} \cdot Z_{Xe\_rb\_press} \cdot R \cdot T_{amb}}{V_{rb}} \qquad P_{rb} = 51.2\,\text{bar} \qquad P_{rb} = 766\,\text{psi}$$

close enough to guess

Alternately, we can use a pressure density curve:



ref :A Portable Gamma Ray Spectrometer using Compressed Xenon Mahler, IEEE Trans. Nuc. Sci. 45(3) p. 1029(1998)

for mass density

$\rho_{mass\_rb} := \rho_{mol\_rb} \cdot M_{a\_Xe}$ $\qquad \rho_{mass\_rb} = 0.366 \frac{gm}{cm^3}$

we find a maximum pressure of

$P_{max\_rb} := 55\text{bar}$ $\qquad P_{max\_rb} = 822\,\text{psi}$

at 50C, which is the maximum temperature we expect to see.
The gas filters have a maximum temperatue of 40C.