NEXT-100 DIMENSIONS D. Shuman 1/25/11 100 kg active volume 15 bar

Mass of Xenon in Vessel at Maximum Operating Pressure (absolute):

Assume we have 100 Xe in active volume of gas inside a cylinder inscribed within the QT/WLS assembly array), and we make up any extra to fill plumbing and interstitial spaces:

$$M_{Xe\_100} := 100kg$$

Maximum Operating pressures (absolute):

$$P_{MOPa\_100} := 15bar$$

Operating Temperature, physical constants:

$T_{amb} := 293K$ $R := 8.314J \cdot mol^{-1} \cdot K^{-1}$ $M_{a\_Xe} := 136gm \cdot mol^{-1}$

Critical Pressure, temperature of Xenon:

$P_{c\_Xe} := 58.40bar$ $T_{c\_Xe} := 15.6K + 273K$ $T_{c\_Xe} = 288.6K$

reduced pressure:

$$P_{r\_100} := \frac{P_{MOPa\_100}}{P_{c\_Xe}} \qquad P_{r\_100} = 0.257$$

reduced temperature

$$T_r := \frac{T_{amb}}{T_{c\_Xe}} \qquad T_r = 1.015$$

Compressibility Factor: from chart for pure gasses shown below

$$Z_{Xe\_15bar} := .93$$

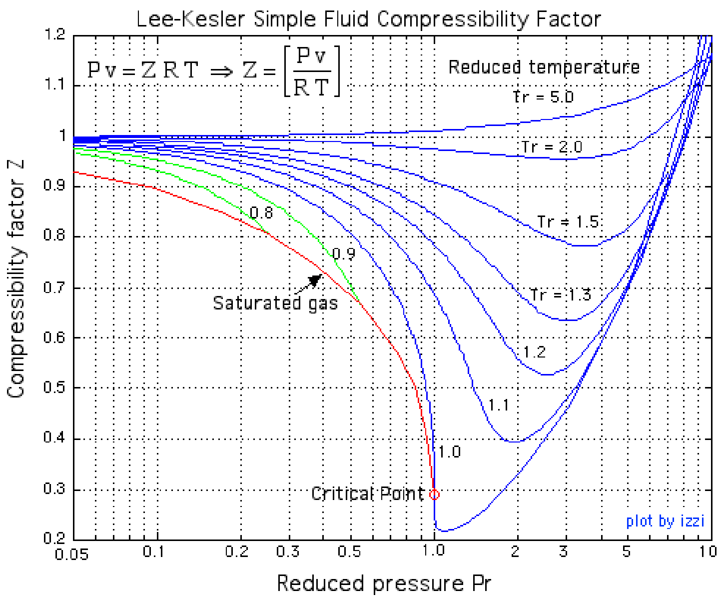

Fig. 6 Compressibility Factor, pure gasses

ref: <u>A Generalized Thermodynamic Correlation based on Three-Parameter Corresponding States</u>, 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/

Number of moles:

$$n_{Xe\_100} := \frac{M_{Xe\_100}}{M_{a\_Xe}} \qquad n_{Xe\_100} = 735.294\,\text{mol}$$

Volume required:

$$V_{Xe\_100} := \frac{n_{Xe\_100} \cdot Z_{Xe\_15bar} \cdot R \cdot T_{amb}}{P_{MOPa\_100}} \qquad V_{Xe\_100} = 1.096 \times 10^{3}\,\text{L}$$

$$n_{Xe} := n_{Xe\_100} \qquad V_{Xe} := V_{Xe\_100} \qquad P_{MOPa} := P_{MOPa\_100}$$

molar, mass, volumetric density:

$$\rho_{mol} := \frac{n_{Xe}}{V_{Xe}} \qquad \rho_{mol} = 0.671\,\frac{\text{mol}}{\text{L}}$$

$$\rho_{Xe} := \rho_{mol} \cdot M_{a\_Xe} \qquad \rho_{Xe} = 0.091\,\frac{\text{gm}}{\text{cm}^3}$$

$$v_{Xe} := \rho_{Xe}^{-1} \qquad v_{Xe} = 10.957\,\frac{\text{cm}^3}{\text{gm}}$$

We desire active length to be = 1.25x active diameter. then:

Active volume radius: $r_{Xe\_exact} := \sqrt[3]{\frac{V_{Xe}}{2.5\pi}}$ $\qquad r_{Xe\_exact} = 0.5186425\,\text{m}$

then: $l_{Xe\_exact} := 2.5 r_{Xe\_exact}$ $\qquad l_{Xe\_exact} = 1.296606\,\text{m}$

Round up to:

$$r_{Xe} := 0.519\text{m} \qquad l_{Xe} := 1.30\text{m} \qquad \pi r_{Xe}^{2} \cdot l_{Xe} = 1.1\,\text{m}^3$$

Quartz Tube (QT) length:

items using up qt length (full length qt is needed):

shield: $l_{shld} := 20\text{cm}$

Si PMT plane: $l_{SiPMT} := 1\text{cm}$

QT length:

$$l_{qt} := l_{Xe} + \left(l_{shld} + l_{SiPMT}\right) \qquad l_{qt} = 1.51\,\text{m}$$

Maximum available quartz tube length is over 2m so we are OK.

QT tube outer radius:

$$r_{qt} := 21\text{mm}$$

QT/WLS sys. nom radius (at QT axis)

$R_{wls} := r_{Xe} + r_{qt}$ $\quad R_{wls} = 0.54\,m$

QT dimensional tolerances

bow:

$tol_{bow} := 1.5\frac{mm}{m}\cdot l_{qt}$

$tol_{bow} = 2.265\,mm$

OD (+/-)

$tol_{OD} := 1mm$

ovality

$tol_{ov} := 0.5tol_{OD}$

$tol_{ov} = 0.5\,mm$

total tolerance:

$tol_{tot} := tol_{bow} + tol_{OD} + tol_{ov}$ $\quad tol_{tot} = 3.765\,mm$ OK, should be less than tube-to-tube spacing s_{qt} below

Number of QT's

$N_{qt} := 72$

Angle of QT spacing $\quad \theta_{qt} := \frac{360deg}{N_{qt}}$ $\quad \theta_{qt} = 5\,deg$

Tangential QT spacing (nominal):

$s_{qt} := R_{wls}\cdot\sin(\theta_{qt}) - 2r_{qt}$ $\quad s_{qt} = 5.064\,mm$ check that $s_{qt} > tol_{tot}$ $\quad tol_{tot} = 3.765\,mm$OK

Xenon vessel inner radius, min.:

$R_{i\_Xev\_min} := r_{Xe} + 2r_{qt} + tol_{tot}$ $\quad R_{i\_Xev\_min} = 0.56477\,m$

Set Xenon vessel inner radius to:

$R_{i\_Xev} := 0.57m$ $\quad$ this gives: $R_{i\_Xev} - R_{i\_Xev\_min} = 5.235\,mm$ clearance for a PTFE reflecting liner, if desired

Note that this assumes there is no cylindrical reflector and gas distribution annulus outside the QT/WLS array and Xenon gas distribution pipes (PTFE) are located in the interstitial spaces behind the QTs.

Xenon Vessel wall thickness

$t_{Xev} := 1cm$ $\quad$ Note, this is likely a practical minimum which allows sealing and fastener attachment at flange; wall thickness can be thinner elsewhere (see below), and some outward extension past this at the cathode may be permissible.

Buffer gas annulus thickness, at main service flange

$t_{bg} := 8cm$ $\quad$ Though this is far higher than needed (see below), we still have much uncertainty which needs to be verified by testing. In addition we might need good pumping and a wide annulus will allow larger ports. The EL "cathode" grid HV will be near the flange and will have a substantial voltage (~30 kV), and the HV cable feeding the EL cathode grid will enter in through this annulus and has a finite width, of perhaps 7mm; something like 3 cm annulus would be sufficient for this purpose.

Pressure Vessel inner radius:

$R_{i\_pv} := R_{i\_Xev} + t_{Xev} + t_{bg}$ $\quad R_{i\_pv} = 0.66\,m$