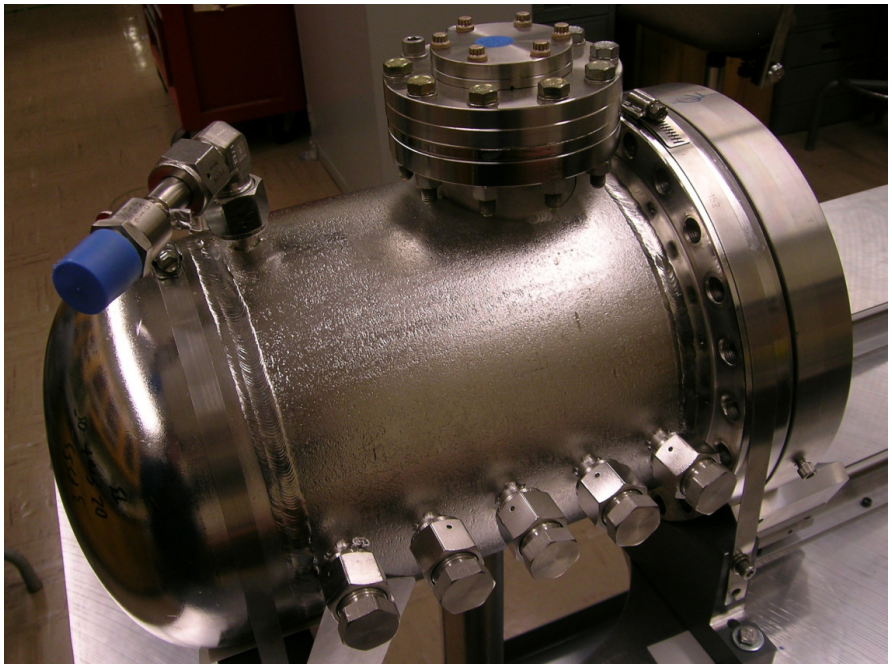
proj: **XENON TPC**

Xenon Pressure Chamber

DRAFT

title: **Pressure Safety Note**

This Safety Note covers a pressure vessel recently acquired by LBNL, from LLNL, for a physics research experiment involving neutrinoless double beta decay, and possibly dark matter. The pressure vessel will enclose a small Time Projection Chamber (TPC) with Xenon gas used as both the drift volume and electrical insulation. The vessel was designed by LLNL, and used at LLNL from 2000-2009 for a similar purpose. LLNL Safety Note MESN99-020-OA (1999) contains the vessel design calculations, performed in accordance with ASME Pressure Vessel code Section VIII (1995), and is included here in the Appendix. It includes pressure testing procedures andrequirements. The vessel has not been modified from its original design. The associated gas handling system is composed of small diameter high pressure metal tubing, filters, valves, and pumps; it is similar to what was used at LLNL. This note is to assure that the Vessel meets LBNL Safety requirements of PUB-3000. It does not cover the associated gas handling system. The chamber is shown below:



The pressure vessel is approximately 8 inches in diameter and 14 inches long, (inside volume). It will be operated at LBNL at a 350 psig maximum operating pressure (MOP), with a maximum allowable pressure of 406 psig (MAWP). It was designed for operation up to 850 psig MOP, with a section of the chamber operated at LN2 temperature. It will be used with inert gases only, mainly Xenon and Argon, as well as high vacuum. The gas system is used primarily to scrub the Xenon gas to a high purity state, and the Argon is for initial flushing of air, H20, etc. when the vessel is first assembled. The stored energy is 30 kJ for both of these monatomic gasses @MAWP=406psig. There are no toxic, flammable, biological, or radioactive gasses or materials inside the vessel with the exception of some small low intensity sealed gamma sources. The inside instrumentation is composed of common metals, Teflon, mylar, Kapton and PEEK polymers, glass, signal calbing and some semiconductor ICs. There will be high voltage components inside, operating as high as +/-20 kV, but there will be no organic liquids, gases, or aerosols, and no oxygen present when operating, so there is no explosion hazard. There will be people present near the vessel when it is under full pressure. Accordingly, it is classified under PUB3000 as a High Hazard Pressure System. An AHD is not required.

The chamber is constructed from Schedule 80 316L S.S. pipe and the flanges and heads are 304 S.S. (if not 304L). There are no brittle materials used. Welds were made by ASME certified welders according to the LLNL Note. Welds were designed with an efficiency factor of 0.7 to eliminate the need to radiograph welds.

It has a Maximum Operating Pressure (MOP) of 850 psig when used with a specially made blank flat head which seals against the vessel flange with a C-type face gasket. Maximum allowable Pressure (MAWP) is 976 psig with this head. This vessel and head combination has been pressure tested to 1.5xMAWP=1467 psig. However there is no plan to operate the vessel at LBNL using this head.

It has an MOP of 350 psig when used with a different specially made flat head (labeled AAA- 99-104240-00) which has a number of openings for instrumentation, and seals with a CF-type (conflat) flange. This flange is not a standard CF type flange but has increased thickness and uses double the number of clamping bolts. Maximum allowable Pressure (MAWP) is 406 psig. It has been pressure tested to 1.5xMAWP = 609 psig with this head (openings blanked off).

The Vessel can only and will only be used at LBNL only with the 350 psig MOP head. There are a number of valves, pipes and electrical feedthru's that will attach to the head and vessel; all will be either rated by the manufacturer for 350 psig operation, and, if not, will be analyzed for presssure safety and pressure tested, either in conjunction with this vessel or separately. The strength of this vessel and head have no dependency on any attached components, nor do any attached components rely on this vessel or head for strength.

There are no toxic, flammable, biological, or radioactive gasses or materials inside the vessel with the exception of some small low intensity sealed gamma sources. Argon gas will be used as a purge gas, most likely at low pressure but perhaps up to the MOP. There is a cold probe welded to the main tank vessel which is used to condense Xenon, using a surrounding dewar of LN2, however, there are no plans at LBNL to use this feature.

There are new components which will be attached to the chamber, some of which pressure rated by the manufacturer, some which are not rated by the manufactrue but which are suitable for safely holding pressure, aand some which will be designed and built by LBNL. These latter two categories will be analyzed for sufficient strength and proof tested separately

LLNL Safety Note MESN99-020-OA (1999) shows calculations performed in accordance with ASME Pressure Vessel Code Section VIII-1-1997. The analysis appears to be fairly complete and correct with respect to ASME Pressure Vessel Code Section VIII-1-2007, which this author has access to. There is an analysis of the 350 psi MOP head which uses a non-ASME method involving stress concentration factors, however there is also an analysis based on ASME methods.

Stored Energy 406 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:

$P_h := (406 + 14.7)\text{psi}$ $\quad d_v := 7.63\text{in}$ $\quad l_v := 12.6\text{in}$ $\quad V_h := \frac{\pi}{4} d_v^{\,2} \cdot l_v$ $\quad V_h = 576.115\,\text{in}^3$

$P_l := 14.7\text{psi}$

$\gamma := 1.666$

$$U_v := \frac{P_h \cdot V_h}{\gamma - 1}\left[1 - \left(\frac{P_l}{P_h}\right)^{\frac{\gamma-1}{\gamma}}\right] \qquad U_v = 30.36\,\text{kJ}$$

Valve calcs

(c) Cylindrical Shells. The minimum thickness or maximum allowable working pressure of cylindrical shells shall be the greater thickness or lesser pressure as given by (1) or (2) below.

(1) Circumferential Stress (Longitudinal Joints). When the thickness does not exceed one-half of the inside radius, or *P* does not exceed 0.385*SE*, the following formulas shall apply:

$$t = \frac{PR}{SE - 0.6P} \quad \text{or} \quad P = \frac{SEt}{R + 0.6t} \qquad (1)$$

(2) Longitudinal Stress (Circumferential Joints).[16] When the thickness does not exceed one-half of the inside radius, or *P* does not exceed 1.25*SE*, the following formulas shall apply:

$$t = \frac{PR}{2SE + 0.4P} \quad \text{or} \quad P = \frac{2SEt}{R - 0.4t} \qquad (2)$$

MAWP Maximum allowable stress Weld efficiency

$P_{MAWP} := 406\text{psi}$ $S_{304SS} := 16500\text{psi}$ $E_w := 0.7$

wall thickness inner radius

$t_{neck} := .065\text{in}$ $R_{i\_neck} := 1.0\text{in}$

$$t_{neck\_min\_circ} := \frac{P_{MAWP} \cdot R_{i\_neck}}{S_{304SS} \cdot E_w - 0.6 \cdot P_{MAWP}} \qquad t_{neck\_min\_circ} = 0.036\,\text{in} \quad \text{OK}$$

$$t_{neck\_min\_long} := \frac{P_{MAWP} \cdot R_{i\_neck}}{2S_{304SS} \cdot E_w + 0.4P_{MAWP}} \qquad t_{neck\_min\_long} = 0.017\,\text{in} \quad \text{OK}$$

Spool tube calcs

$t_{spool} := .125in$ $R_{i\_spool} := 0.75in$ $E_w = 0.7$

$$t_{spool\_min\_circ} := \frac{P_{MAWP} \cdot R_{i\_spool}}{S_{304SS} \cdot E_w - 0.6 \cdot P_{MAWP}} \qquad t_{spool\_min\_circ} = 0.027\,in \quad \text{OK}$$

$$t_{spool\_min\_long} := \frac{P_{MAWP} \cdot R_{i\_spool}}{2S_{304SS} \cdot E_w + 0.4P_{MAWP}} \qquad t_{spool\_min\_long} = 0.013\,in \quad \text{OK}$$

CF flange calcs

$kJ := 10^3 J$