proj: **NEXT-1-LBNL**
Quartz window
title: **Quartz Window Pressure Safety** **DRAFT**

The NEXT1-Xenon/TMA test chamber requires pressure resistant VUV transparent windows mounted to CF40 flanges for several 1"dia photomultiplier tubes (PMTs) to be optically coupled to on the outside of the chamber. Suprasil (highly pure synthetic) quartz is the strongest material available with the desired VUV transmission. Each PMT will be housed in a light-tight enclosure attaching to the window flange, which also provides a backup fragment containment in case a window breaks. There will be gas vent line leading from each can to a fume hood; no isolation is possible, and the PMT enclosure cannot become pressurized through slow leakage of Xe through seals. The vent line is sized to avoid large pressure buildup in case of window failure. Thus the windows do not present a direct safety hazard and the highest safety factor of 8 is not appropriate.

Stress-thickness function:

for thickness t, radius a, pressure q, Poisson's ratio ν, and assume simple edge support condition (rotation allowed, no extra plate material past support), maximum stress is in the radial direction, and is found at center.

Center Moment:

$$M_{rc} := \frac{3+\nu}{16} q\, a^2$$

and maximum stress is, at center of plate

$$\sigma := 6\frac{M}{t^2}$$

ref. 1: Roark's Formulas for Stress and Strain, 6th ed. table 24 case 10a, simple supports, plate thickness <1/4 least transverse dimension (=2a)

or:

$$\frac{t^2}{a^2} := 6\cdot\frac{3+\nu}{16}\cdot\frac{q}{\sigma} \qquad t := \sqrt{\frac{3}{8}\cdot(3+\nu)\cdot\frac{q}{S_{max}}\cdot a^2}$$

Window pressure radius and maximum operating pressure

$a := 0.55\text{in}$ $q := 150\text{psi}$

Maximum allowable stress :

Average flexural design strength for Suprasil quartz is:

$S_{f\_Suprasil} := 67\text{MPa}$ Heraeus brochure, most grades, including commercial

Poisson's ratio $\nu := 0.17$

Quartz and other brittle materials are not well characterized by a single number for ultimate, yield or flexural strength. Unlike metals, there is much more scatter in the data and failure is a strong function of total stressed area or volume and surface condition, as well as other variables. For this reason large safety factors are often used:

LBNL safety manual (PUB-3000) required factors of safety on maximum stress:

FS>=8 required by PUB-3000 for brittle high hazard, for no personnel barrier, FS>=4 with a barrier. We have a barrier, so:

$FS := 4$

$$S_{max} := \frac{S_{f\_Suprasil}}{FS} \qquad S_{max} = 16.75\,\text{MPa} \qquad S_{max} = 2429\,\text{psi}$$

For the small number of windows we will need, plus the lack of a compelling need to fully minimize the thickness, statistical analyses such as Weibull distribution, or fracture mechanics approaches are not warranted. Therefore, minumum window thickness is:

$$t := \sqrt{\frac{3}{8}\cdot(3+\nu)\cdot\frac{q}{S_{max}}\cdot a^2} \qquad t = 3.785\,\text{mm}$$

for FS=8 $t_{fs8} := \sqrt{\frac{3}{8}\cdot(3+\nu)\cdot\frac{q}{0.5S_{max}}\cdot a^2}$ $t_{fs8} = 5.352\,\text{mm}$

It is recommended that a high surface polish specification, e.g. scratch/dig 20/10 be used, as this improves average strength