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E951 Beam Windows Test Plan

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Introduction

The purpose of the window test is to qualify beam windows for use on the inner and outer containment vessels for the mercury tests.

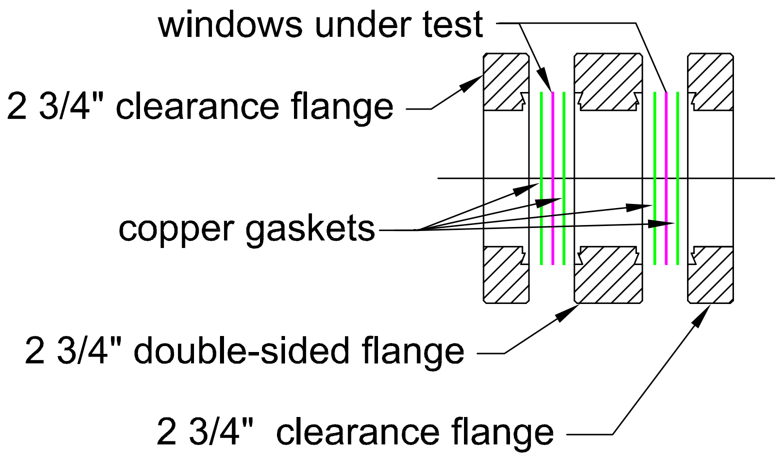
Our design policy of the E951 beam tests is that anything we place in the focus of the A3 beam will be enclosed inside an outer containment vessel.

For these tests, the outer containment box includes 2 beamlines, and hence 4 beam window units, to permit more studies without access into the A3 target cave.

The outer containment vessel is mounted on an x-y mover so that either of the two beamlines of the box can be brought into the proton beamline, or the entire box can be moved out of the proton beam and a beam flag inserted into the proton beam.

Baseline design of a beam window unit

To provide an online measure of beam window integrity, the beam window units will consist of a pair of windows on either side of a 2 3/4″ double-sided conflat flange. Each window will be clamped between a pair of copper gaskets. The small volume between the two windows will be evacuated to about 10 mtorr, and sealed off. A thermocouple vacuum gauge will monitor the pressure. Initial tests indicate that the window units prepared without bakeout and with pumpdown for only 1-2 hours have outgassing rates of $\approx$ 100 mtorr/day $\Rightarrow \approx$ 10 days useful vacuum after pumpdown.



Scope of the window tests

Our primary consideration is the possible failure of a beam window, and consequent dispersal of activated target material, particularly mercury. Our strategy for the window tests is therefore:

1. Expose candidate window materials to a sequence of high intensity pulses, to provide a yes/no answer to the viability of the windows for ≈ 100 such pulses, which number is greater than that desired in the mercury targets tests in April 2001. These candidate materials will include some calculated to have peak stress beyond ultimate for a 5 TP beam pulse, for which failure might be observed during the tests.
2. Make auxiliary measurement of strain and temperature in the window materials to validate the energy deposition calculations.

Materials for the window tests

We plan to test 4 materials:

1. Havar (Co/Cr/Fe/Ni/W/Mo, 42/20/20/13/3/2), 0.011″ thick, measured ultimate strength 279 ksi at room temp.

   This is the strongest metal to which we have access. Even, so, a MARS/ANSYS calculation by N. Simos indicates that a fast, 16 TP, 24 GeV AGS proton beam pulse focused to a spot of 0.5 mm σ radius (the requested design capability of the A3 beamline) would experience a peak stress 95% of ultimate.

   The use of a thin window is desirable to minimize activation.

   However, because windows on the inner containment vessel for the mercury targets may experience impacts from mercury dispersed by the beam, we desire a thicker material suitable for use as a baffle to protect havar, or even as the inner beam window. The best candidate for this is item 2.

2. Inconel 718, 6 mm thick, the optimum thickness calculated for use with 24 GeV AGS proton beam pulses, taken to have a triangular beam profile with 100 ns width at the base.

   This material is calculated to experience a peak stress slightly beyond ultimate strength in a 16 TP pulse, focused to 0.5 mm σ.

3. Inconel 718, 1 mm thick. Calculated to have peak stress about 3 times higher than that in a 6 mm thick sample, due to the unfavorable effect of reflection of the pressure waves.

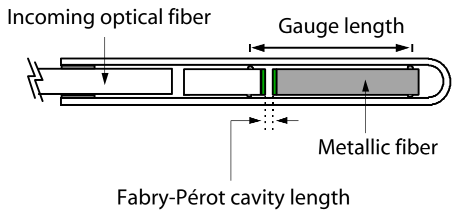
4. 3000 series aluminum 0.010" thick. This material is commonly used in beam windows at the AGS, but is calculated to experience peak stress somewhat beyond ultimate strength for a 5 TP pulse focused to 0.5 mm σ.

Types of window tests

1. Integrity of a pair of windows as monitored by their ability to hold vacuum. This will be monitored by an 8-channel Varian Multigauge controller with setpoints.

2. Strain measured at four points on a window by fiberoptic sensors. Windows separate from those of test 1 will be mounted between a pair of conflat flanges, providing the same clamped boundary conditions as in test 1, and in their eventual use in the mercury tests.

   The strain sensors are miniature Fabry-Perot interferometers as shown in the figure.



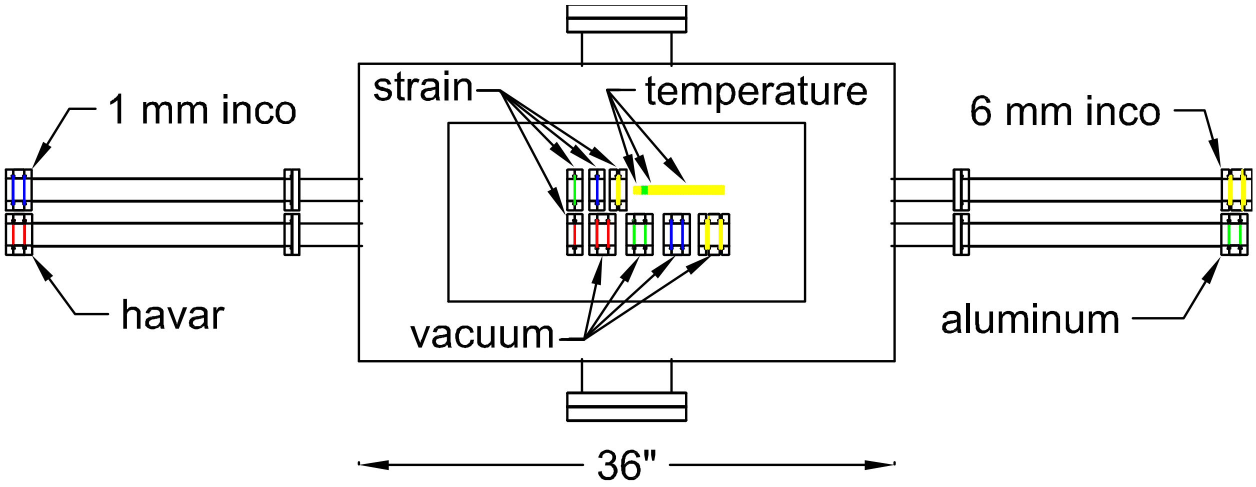
   They are described at http://www.fiso.com/literature/Strain_description.pdf, and their use in carbon target tests at LANSCE is reported at
   http://www.hep.princeton.edu/˜mcdonald/mumu/target/graphite-lansce.pdf

3. Energy deposition in window materials as measured by temperature rise (simple calorimetry with thermocouples). For this it is favorable to use cylindrical samples of thickness and diameter both about 1 cm to minimize the surface to volume ratio, and to contain the proton beam with some margin of error for drift of the beam position.

   In addition, we include a 5″ long, 0.5″ diameter Inconel rod with a sequence of thermocouples along its axis to monitor the hadron shower profile.

Arrangement of the window tests

The samples of window materials will be arrayed in two beamlines:



1. Upper beamline in the figure. 1 and 6 mm Inconel 718 and an 0.010″ aluminum window equipped with strain sensors, plus 0.5″ OD ×0.5″ long calorimeters of aluminum and

Inconel 718 and a 5″ long Inconel calorimeter. This beamline will be exposed to less than 10 proton pulses at maximum beam intensity and minimum beam spot size.

2. Lower beamline in the figure. The double window samples: 0.011″ havar, 0.010″ aluminum, 1 mm Inconel and 6 mm Inconel 718, plus one havar window equipped with strain sensors. This beamline will be exposed to 100 proton pulses at maximum beam intensity and minimum beam spot size.

In addition, the outer containment vessel will have vacuum window units as its beam windows. For the nominal beam tune, these window units are at $\pm 2\beta^*$ from the focus, and hence the beam intensity is 1/5 that at the focus.

At some risk of failure of an outer window unit, we mount all 4 types of material under study on the 4 outer windows of the two beamlines (as shown in the figure above). This would provide information as to the effect of 1/5 of whatever intensity is experience by the material tested at the nominal beam focus.

Sequence of the window tests

The general strategy is to start with pulses with lower numbers of protons and larger spot radii to verify the operation of the readout system, and to end with the pulses of the largest number of protons and smallest focused spot achievable.

The tests should explore a factor of ten variation in pulse intensity, up to whatever maximum is achievable.

To change the spot size in a controlled manner requires verification by taking the target box out of the beam, and inserting the flag. The SWIC just upstream of the test box will provide a measure of possible drift in beam spot and position, with reduced accuracy compared to use of the flag.

As it will take more time to change the spot size than the number of protons, only 3 spot sizes will be studied, $\sigma_r = 1.5$, 1, and 0.5 mm.

If the tests can proceed at the rate of 10 pulses per hour (as limited by radiation safety, and to be verified during commissioning of the A3 beamline), the tests should occupy 2 shifts, and involve about 10 full intensity pulses in the upper beamline in the figure, and 100 full intensity pulses in the lower beamline.

The greatest level of activation will occur in the 6 mm thick Inconel windows, and has been calculated by Al Hanson to be about 200 mCi after 24 hours cooldown (10 mCi after one week).

At the end of the window tests, the outer containment vessel will be removed from the x-y positioning stand and stored on the floor inside the A3 target cave. A similar vessel containing the carbon targets will then be placed on the positioning stand, and mounted with (new) windows of the material most favored by the outcome of the window tests. The carbon target tests should then be conducted during 1-2 shifts prior of 1 April.