LA-UR -85-1737

RECEIVED BY OSTI JUN 07 1985

CONF-850504--113

LA-UR--85-1737

DE85 012723

TITLE BEAM LINE WINDOWS AT LAMPF

AUTHOR(S) R. D. Brown, D. L. Grisham, and J. E. Lambert

SUBMITTED TO Particle Accelerator Conference
May 13-16, 1985
Vancouver, British Columbia

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

BEAM LINE WINDOWS AT LAMPF

R. D. Brown, D. L. Grisham, and J. E. Lambert
Los Alamos National Laboratory
P. O. Box 1663, Group MP-7, MS H840
Los Alamos, New Mexico 87545

Abstract

The A-6 main beam-line window at LAMPF separates the vacuum of the main beam line from the isotope production station, proton irradiation ports, and the beam stop, which operate in air. This window must withstand the design beam current of 1 mA at 800 MeV for periods of at least 3000 hours without failure. The window is water cooled and must be strong enough to withstand the 2.1 MPa (300 psig) cooling water pressure, as well as beam-induced thermal stresses. Two designs have been used to meet these goals, a stepped-plate window and a hemispherical window, both made from a precipitation-hardened nickel base alloy, Alloy 718. Calculations of the temperatures and stresses in each of these windows are presented.

Window Design

There are two primary sources of stress in beam line windows: the cooling water pressure (2.1 MPa), which imposes an essentially static stress, and the variable thermal stresses resulting from the beam heating. Keeping the window thin in the region hit by the beam reduces beam heating and consequently thermal stresses. For the first window designed (Fig. 1(a)) a flat plate was reduced in thickness in two steps so as to provide as thin as possible a window that can withstand the stresses produced with the beam on. The second, hemispherical design (Fig. 1(b)) can be somewhat thinner in the center because of lower stresses allowed by this design. The material chosen for the window should have high strength at the operating temperature, so as to allow a margin of safety under normal operating conditions. Materials with high thermal conductivity are preferred, as this minimizes the temperature rise in the window, and consequently, the thermal stresses. In addition, the window material should not be susceptible to corrosion from the cooling water, which is dissociated by the proton beam and should not exhibit large reductions in ductility at the high radiation fluences reached following several thousand hours of operation.

Window Material

To achieve sufficient strength in a flat plate window, we chose Alloy 718. A nickel-base precipitation-hardened alloy, its strength (1030 MPa, 150000 psi at room temperature) drops gradually up to about 923 K,[1] providing a useful safety margin relative to the design conditions. This alloy is quite corrosion resistant. It displays rather sluggish precipitation kinetics and can thus be welded

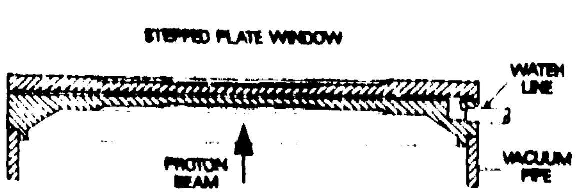

Fig. 1(a). The stepped-plate window.

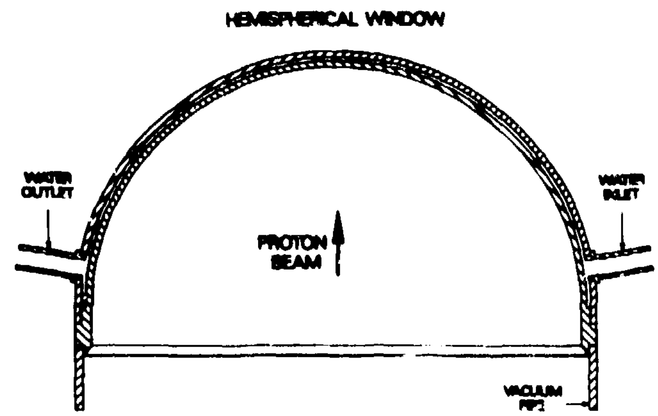

Fig. 1(b). The hemispherical window, also of 20 cm diameter.

with less risk of locally reducing its strength than is the case for many other such alloys. This is particularly useful in that our window design calls for two circumferential welds, one to join the two plates together, the second to join the window to the vacuum pipe. Neutron irradiation testing of this alloy has shown that for samples irradiated at temperatures below 811 K and tensile tested below 700 K, the total elongation, while reduced, remains about 5%.[2] This is certainly adequate for this application. Irradiation effects on strength depend strongly on temperature. As might be expected for a precipitation-hardened material, the tensile strength may decrease. A study[3] comparing crack propagation rates in unirradiated control samples and samples irradiated to high displacement-per-atom levels at 811 K showed that with sinusoidal loading at 0.1 Hz, growth rates of cracks were the same in both cases. Crack growth rates in irradiated samples exceeded those in unirradiated samples by a factor of ten when one minute tensile holds were added to the loading cycle. Alloy 718 is thus less susceptible to large changes in fatigue crack growth rate than are many other high strength alloys.

Calculations and Measurements

The two-dimensional AYER finite element code[4] is used to calculate temperatures as a function of position for a given geometry. Important input parameters include the power deposition as a function of radial position, the heat transfer coefficient to the cooling water, and a temperature-dependent thermal conductivity. The power deposition is typically assumed to be of Gaussian shape with a fullwidth at half maximum of about 47 mm. This code produces a listing of temperatures at each node point, which can then be graphed as shown in Fig. 2 for the two window designs. In both cases, the zero of the abscissa in Fig. 2 corresponds to the window center. The stepped-plate window temperatures are plotted vs radius, while the temperatures for the hemispherical window are plotted vs arc length.

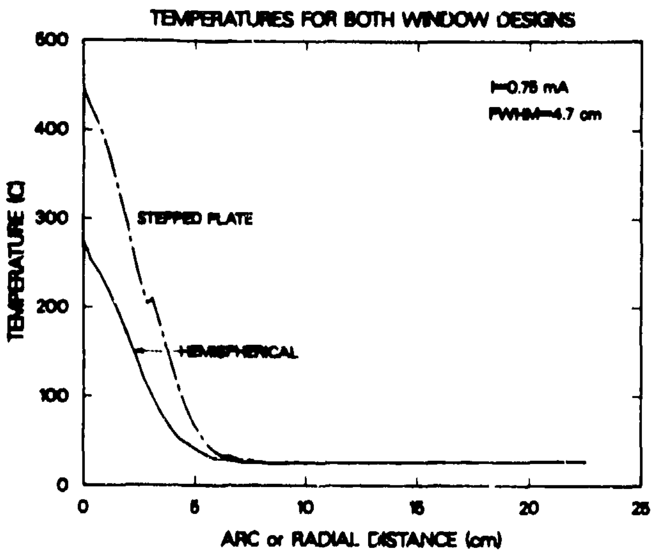

Fig. 2. Temperatures for the two window designs are compared. The hemispherical window is 2.4 mm thick at center, the stepped-plate window, 3.2 mm.

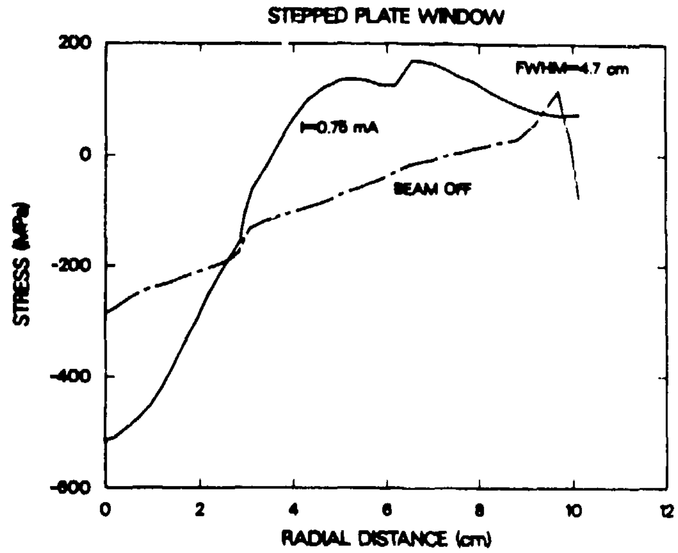

Fig. 3(a). Stresses vs position for the stepped plate window.

To monitor window temperatures, sheathed thermocouples are spot welded to the window faces using 1 cm square weld pads. This means that the temperature read from the thermocouple exceeds that of the window face by as much as several hundred degrees for thermocouples located nearest the beam centroid. When comparing calculated with measured temperatures we separately model the thermocouple and weld pad to determine the temperature increment to be added to the calculated window temperature. When this is done, we find that the two values are typically within 50 C of each other.

Having calculated the temperatures, the TSAAS code[5] is then used to calculate the thermal stresses in the window. Further input to this code is required to specify the thermal expansion coefficient and elastic modulus as a function of temperature. Additional information can be supplied as to the static water pressure and external restraints acting on the window, thus allowing full specification of the boundary conditions. The TSAAS code computes the stresses and strains, which may then be graphed for easy comparison as the design of the window is changed. Figures 3(a) and (b) show the stresses calculated for the stepped plate and the hemispherical windows. As summarized in Table I, the thinner hemispherical window shows both lower static stresses and a lower cyclic stress amplitude.

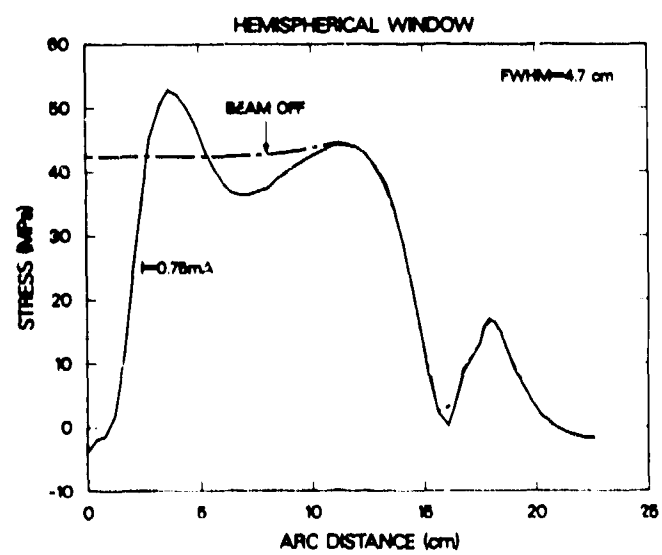

Fig. 3(b). Stresses vs position for the hemispherical window.

Table I

A-6 WINDOW OPERATING CONDITIONS

Window Design*	Beam Current mA	Temperature at Center C	Stress at Center MPa	psi	Cyclic** Stress Amplitude MPa	psi
Stepped-Plate	0.75	448	-517	-75000	-	
	0	20	152	22000	334	48500
Hemispherical Window	0.75	282	-4	-500	-	
	0	20	42	6100	46	6600

*Stepped-plate window is 3.2 mm thick at center; the hemispherical model is 2.4 mm thick.

**Cyclic stress amplitude = (Maximum stress-minimum stress)/2.

Conclusions

Finite element calculations have been used to examine the temperatures and stresses in two beam line window designs. A hemispherical design has the advantages of lower static and cyclic stresses and is currently used at LAMPF.

References

1. Huntington Alloys, Inconel Alloy 718, third edition, 1978.

2. A. L. Ward, J. M. Steichen and R. L. Knecht, "Irradiation and Thermal Effects on the Tensile Properties of Inconel-718," Irradiation Effects on the Microstructure and Properties of Metals, ASTM STP611, American Society for Testing and Materials, 1976, pp. 156-170.

3. D. J. Michel and H. H. Smith, "Effect of Neutron Irradiation on Fatigue and Creep-Fatigue Crack Propagation in Alloy 718 at 427 C," J. Nucl. Mater. 122+123, 153 (1984).

4. R. G. Lawton, The AYER Heat Conduction Computer Program," Los Alamos National Laboratory report LA-5613-MS (May 1974).

5. R. V. Browning, D. G. Miller, and C. A. Anderson, "TSAAS: Finite Element Thermal and Stress Analysis of Axisymmetric Solids with Orthotropic Temperature-Dependent Material Properties," Los Alamos National Laboratory report LA-5500-MS, Revised (February 1982).