

## Heat dissipation in a thin window near the focus of the SEB

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June 1969

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**U.S. Department of Energy**

USDOE Office of Science (SC)

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EP & S DIVISION TECHNICAL NOTE

No. 29

T.E. Toohig  
June 3, 1969

HEAT DISSIPATION IN A THIN WINDOW NEAR  
THE FOCUS OF THE SEB

There are a number of desirable aspects, both from the viewpoint of the AGS Division personnel and of experimenters using secondary beams, to terminating the AGS vacuum in the SEB line with a thin window just upstream of the S93 target. Such advantages as the increased simplicity of targetting in air, the reduced interaction between experimenter-controlled equipment and the AGS vacuum, and reduced multiple scattering in secondary beams might be cited. The greatest question mark in terminating the vacuum at this point is the possibility of rupture of the window by local heating by the concentrated beam spot so close to focus. For simplicity we will calculate this heating on the assumption of an aluminum window. Beryllium or titanium might also be used with factors of two in either direction relative to aluminum.

The ionization energy loss,  $dE/dx$ , in aluminum is 4.37 MeV/cm or  $4.25 \times 10^{-16}$  cal/mil/proton. Assuming a beam spot size of 40 mils x 100 mils the heating due to ionization in the thin window is given by:

$$\frac{\Delta Q}{\Delta t} = \frac{dE}{dx} \times I_0 \times \frac{1}{t} \left/ \rho \frac{dV}{d\ell} \right.$$

where:

$$\frac{dE}{dx} = \text{energy loss/unit length}$$

$$I_0 = \text{incident beam intensity/pulse}$$

$$\frac{1}{t} = \text{machine pulse rate}$$

$$\rho \frac{dV}{d\ell} = \text{mass per unit length in which energy is deposited.}$$



$$\frac{dQ}{dt} = \frac{4.25 \times 10^{-16} \frac{\text{cal}}{\text{mil-proton}} \times 10^{13} \frac{\text{protons}}{\text{pulse}} \times \frac{1 \text{ pulse}}{2 \text{ sec.}}}{4.43 \frac{\text{g}}{\text{in}^3} \times 4 \times 10^{-6} \text{ in}^3}$$

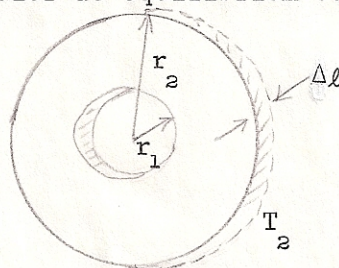
$\frac{dQ}{dt} = 12.0 \text{ cal/g/sec.}$	for 1 mil
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If the  $\Delta Q$  for one pulse were all deposited instantaneously, the resultant temperature rise would be

$\Delta T$  (Al) = 110°C/pulse  
 similarly  $\Delta T$  (Be) = 55°C/pulse  
 $\Delta T$  (Ti) = 150°C/pulse

using  $c_p$  (Al) = 0.215 cal/g C°  
 $c_p$  (Be) = 0.436 cal/g C°  
 $c_p$  (Ti) = 0.125 cal/g C°

In estimating the effectiveness of heat conduction by the window in dissipating the heat generated by the beam we consider the vacuum pipe an infinite sink in good thermal contact with the window. To first approximation we average the beam energy over the 2 sec cycle of the AGS and consider a steady state solution with this continuous source at the center of the window. We consider a disc of thickness  $d\ell$  with a source disc of 37 mils radius at equilibrium temperature  $T_i$ .



For the steady state approximation:

$$\frac{dQ}{dt} = C = \frac{-kA_1}{\Delta\ell} \frac{dT_1}{dr_1} = \frac{-kA_2}{\Delta\ell} \frac{dT_2}{dr_2}$$

where  $\frac{dQ}{dt}$  = heat input per unit thickness

$A_i$  = the area of the disc edge at radius  $r_i$

$$= 2\pi r_i ds$$

$k$  = conductivity

$T_i$  = steady state temperature at radius  $r_i$ .

$C$  = constant



$$\frac{dQ}{dt} = C = - \frac{2\pi r \Delta l}{\Delta l} \frac{dT}{dr}$$

$$dT = - \frac{c}{2\pi k} \frac{dr}{r}$$

$$T_2 - T_1 = \Delta T = - \frac{c}{2\pi k} \ln \frac{r_2}{r_1}$$

$$\Delta T = \frac{2.15 \times 10^{-3} \frac{\text{cal}}{\text{sec-mil}} \times \ln \frac{1.5 \text{ in.}}{.037 \text{ in.}}}{2\pi \times 1.22 \times 10^{-3} \frac{\text{cal}}{\text{sec-mil-C}^\circ}}$$

$$\Delta T \approx 1^\circ\text{C}$$

This first order temperature rise due to radiative loss by  $10^{13}$  protons in the end window is small enough so more exact calculations do not seem warranted.

A 3-mil Al window on the 3-inch vacuum pipe upstream of the S-93 target seems to be a reasonable vacuum termination even at conversion intensities of  $10^{13}$  protons/pulse.

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