GRAPHITE TARGETS AT LAMPF

R. D. Brown and D. L. Grisham
Los Alamos National Laboratory
Los Alamos, NM 87545

Summary

Rotating polycrystalline and stationary pyrolytic graphite target designs for the LAMPF experimental area are described. Examples of finite element calculations of temperatures and stresses are presented. Some results of a metallographic investigation of irradiated pyrolytic graphite target plates are included, together with a brief description of high temperature bearings for the rotating targets.

Introduction

Graphite targets have been used for many years to produce secondary particles from the primary proton beam at the Clinton P. Anderson Meson Physics Facility (LAMPF). As shown in table 1, the power deposited in the targets is quite high.[1] Two basic target designs have been developed, as shown in figure 1 a and b. Rotating targets are about 0.3m in diameter and rotate at 27 rpm. Their rotation allows the beam to step around the circumference of about 1m, while the target radiates its heat to the target box. Stationary targets made of pyrolytic graphite lose about 95% of their heat by conduction through the a-b planes of the graphite to the water cooling tubes.

Thermal Analysis of Targets

Finite element codes (AYER[2], TSAAS[3]) are used to analyze temperatures, stresses, and strains. Figures 2 and 3 show several stages of this procedure for the rotating polycrystalline and stationary pyrographite targets, respectively. In figure 3, (a) displays the mesh used, (b) shows temperature contours, and (c) shows the resulting stress contours.

Both target styles have in practice survived many hours at beam currents of 0.5 ma and above, in keeping with the predictions of the calculations, which show the principal stresses to be less than the tensile strength[4] for either material.

Deterioration Of Stationary Pyrolytic Targets

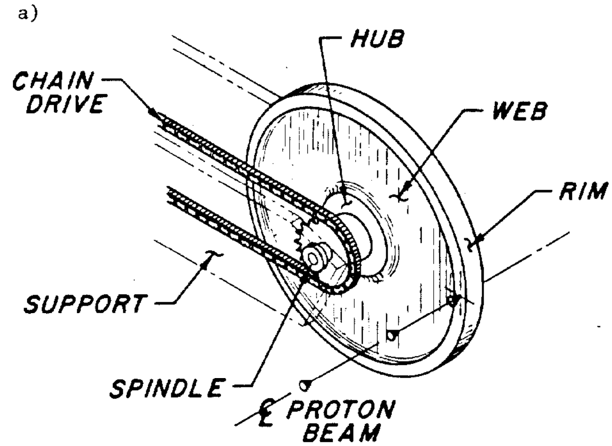
Thermal stresses in the pyrolytic graphite target are a significant fraction of the tensile strength in the a-b plane. Together with radiation damage, which accumulates in the irradiated area with time, this produces delaminations between the a-b planes, which is observed as a macroscopic thickening of the pyrographite plates. To better understand the deterioration of the target plates, plates were cut from irradiated targets in a hot cell and examined metallographically. Figure 4 shows the swelling and delamination which occurs in a target which ran for 330,000 μA x hr. ($2x10^{25}$ P/m^2). In addition to the delaminations, which run parallel to the face of the plate (parallel to the a-b planes), cracks are observed running through the plate. These are more harmful to the target than delaminations, since they prevent the heat generated from being conducted to the cooling water and thereby cause overheating of the pyrographite. Rectangular samples were cut from the plates as indicated in figure 4a. These were ground and polished to produce sections at varying depths from the original edge of the plate. Figure 4c and d show the delaminations revealed by photomacrographs of a section near the beam

TABLE I

PROTON BEAM HEATING

LAMPF Target Area	Beam Size (FWHM,mm)	Heat Generated (kw @I ma)	Target Style
A-1	3.2 V 3.9 H	13 I=1	Rotating Wheel
A-2	5.3 V 6.5 H	14 I=.92	Rotating Wheel
A-5	5.3 V 8.9 H	40 I=.75	Water Cooled

a)



b)

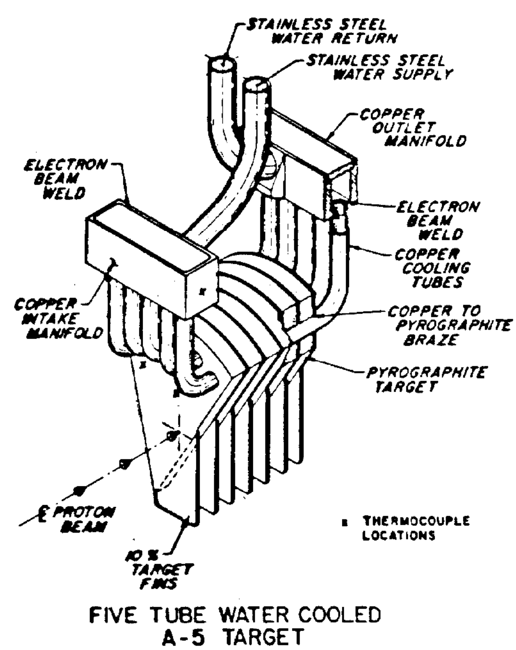


Figure 1 a) Polycrystalline graphite rotating target.
b) Pyrographite stationary target.

0018-9499/83/0800-2801$01.00© 1983 IEEE

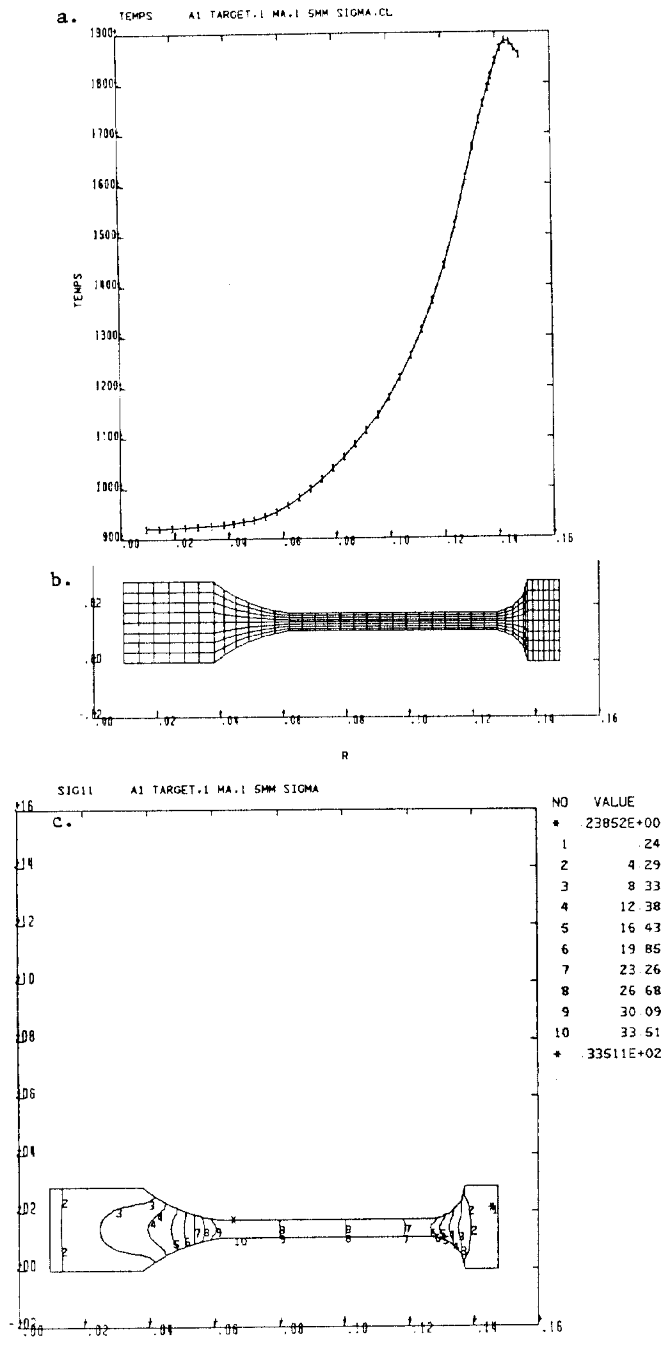


Fig. 2 Polycrystalline graphite rotating target.
a) Centerline temperatures.
b) Finite element mesh of a radial section.
c) Calculated stresses.
Temperatures in Kelvin
Stresses in MPa

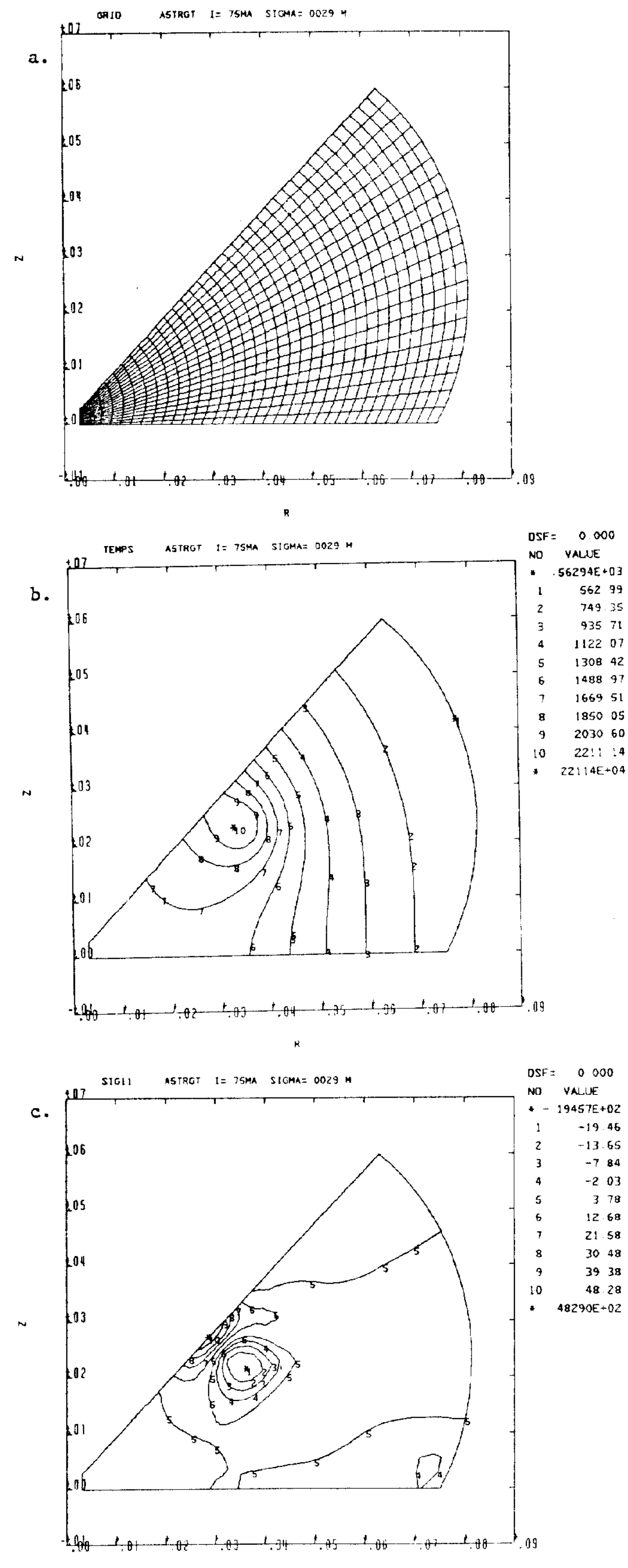


Fig. 3 Temperatures and stresses calculated for the stationary pyrographite target.
Temperatures in Kelvin
Stresses in MPa

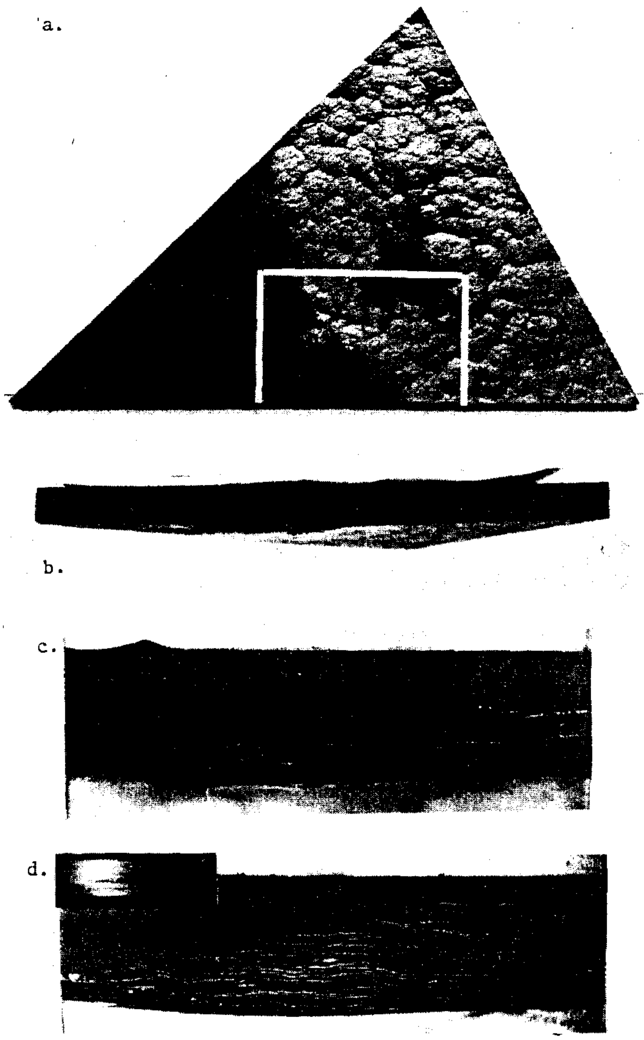


Fig. 4 a. Pyrolytic graphite plate, sectioned from an irradiated target.
b. Edge view of the plate.
c. Polished section from sample outlined in a) showing delaminations and cracks.
d. Section from the irradiated area.

center. An autoradiograph is included to show the distribution of the ^{7}Be which marks the beam location. At the temperatures calculated for this material, it must be assumed that the ^{7}Be has diffused outward from the area irradiated by the proton beam. The cracks running through the plates develop at proton fluences above about 2×10^{25} P/m^2. Plates from targets irradiated to about 0.5 of this fluence show extensive delamination, but lack the macroscopic cracks across the a-b planes. These results indicate that pyrolytic graphite is very susceptible to delamination, as would be expected from the low tensile strength in the c direction. All of these results are for pyrographite plates produced by the substrate nucleation process. In one target, plates produced by the continuous nucleation process were intermixed with those of the usual type, so that all plates received the same fluence of about 10^{25} P/m^2. On metallographic examination, it was found that the continuously nucleated plates showed little delamination compared to the substrate nucleated material, but had cracked completely through the plate thickness, leading to overheating of these plates. For our application, the substrate nucleated pyrographite is preferred.

Bearings For Rotating Targets

Temperatures in the shaft of the rotating targets were found to be approximately 700 K at a beam current of .36 mA. The stainless steel ball bearings used under these conditions seized resulting in erratic target rotation. A search for bearings to operate at high temperatures and in vacuum led to two possibilities, both sleeve bearings. The first used a graphite sleeve, the second, a sleeve of a proprietary powder metallurgy product containing MoS_2. Although both appeared acceptable based on testing at temperatures in vacuum, higher than expected loading led to rapid wear of the graphite sleeves. They were replaced with the sleeves containing MoS_2, which have given good service.

References

1. J. B. Donahue, "Power Deposition of LAMPF Proton Beam in Various Materials," Los Alamos National Laboratory, Group MP-7 Technical Note MP-7-TN-14 (August 1980).

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

3. 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).

4. W. V. Kotlensky and H. E. Martens, "Tensile Properties of Pyrolytic Graphite to 5000°F," Jet Propulsion Laboratory, California Institute of Technology, J. P. L. Report No. 32-71 (1961).