EXPERIENCE WITH IPNS TARGETS

J. M. Carpenter and A. G. Hins
Argonne National Laboratory

Abstract

Three targets have operated in the IPNS Neutron Scattering Facility. The first, a depleted Uranium target, served from 1981 until it was replaced in 1988 by the Enriched Uranium Booster Target. The Booster Target had operated for nearly three years when it suffered a cladding leak and was replaced with the retired depleted Uranium target. That target reached its end-of-life after less than one year's further operation, and was replaced with an identical one newly assembled from spare components, which is still operating satisfactorily.

This paper reviews the operating history of the IPNS targets and the findings reached during analysis of the failures. Similarities with ISIS target experience, preliminary conclusions and plans for providing spares and improved targets are discussed. We present some preliminary results from the hot cell examination of the failed depleted Uranium target.

Introduction

Figure 1 shows the design of the IPNS Enriched Uranium Booster Target. The depleted Uranium target is similar, but all disks are nominally 25 mm thick. The core material of both targets is α-phase Springfield adjusted alloy, with HIP bonded 0.5 mm thick Zircaloy-2 cladding. The designs of the targets have been described earlier.(1-4)

Figure 2 shows the average proton current on the IPNS target from turnon in May, 1981 until the present. IPNS ran about 26 weeks per year in the early years and 18 weeks per year in FY 1992, diminishing about linearly in between. For most of this time, the proton energy was 450 MeV. Through 1984, the Neutron Scattering Target received beam 75% of the time; the Radiation Effects Facility received the remaining 25%. The targets suffered between 10 and 100 full thermal cycles each day.

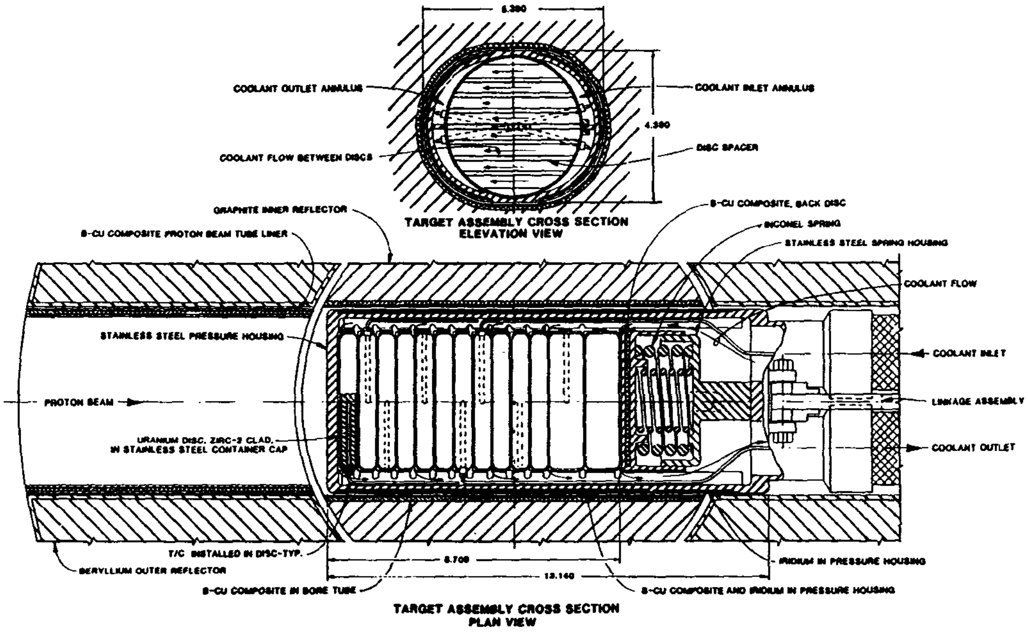

Figure 1 The IPNS Enriched Uranium Booster Target

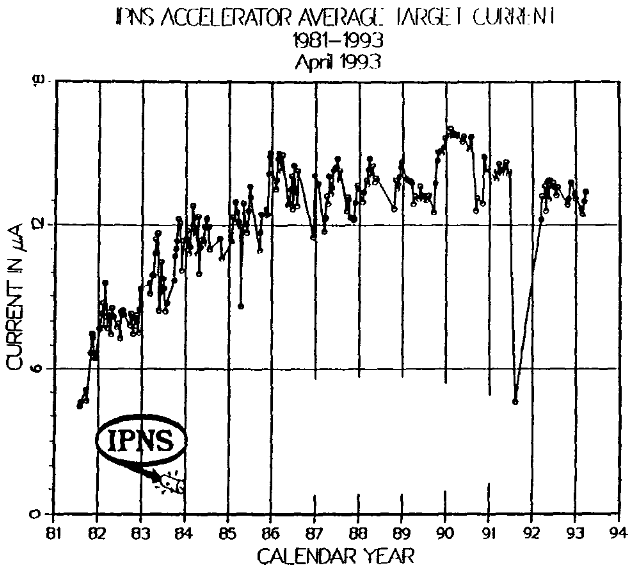

Figure 2 Weekly averaged proton current on the IPNS targets.

The original depleted Uranium target operated in the Neutron Scattering Facility from the beginning until it was replaced in October, 1988 by the Booster Target. In June, 1991, the target monitoring system displayed an increase in the concentration of Xe-135 in the cover gas of the primary coolant surge tanks, indicating a leak in the cladding after nearly three years of trouble-free operation.

Figure 3a shows the counting rate in the monitors (there are two systems, interrogated alternately) around the time of the Booster Target failure. The counting rate rose linearly from its long-term background level up to the conservatively-imposed upper limit where operation terminated.

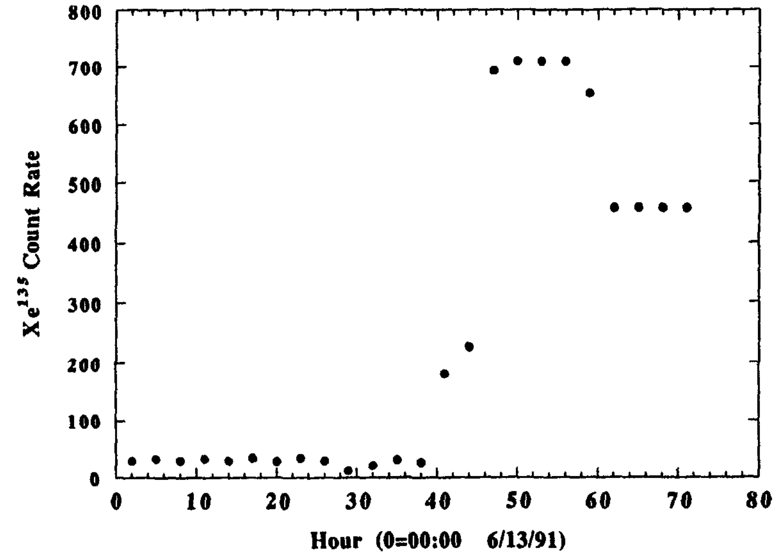

Figure 3 a Counting rate in the Xe-135 monitoring system.around the onset of the Booster Target leak.

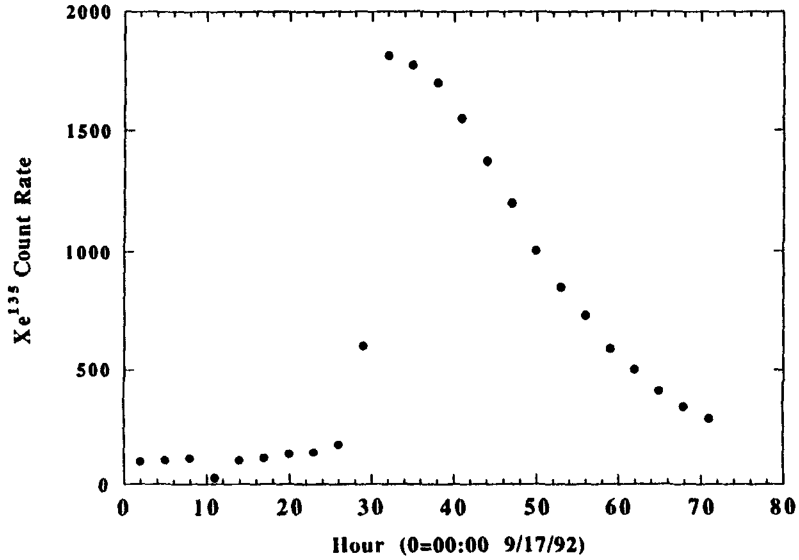

Figure 3 b Counting rate in the Xe-135 monitoring system.around the onset of the depleted Uranium target leak.

Extensive tests followed to establish that the increase was due to Xe-135 leaking from a breach in the cladding and to quantify the leak. After further extensive investigation of the consequences of continuing operation with the leaking clad(5), we concluded that it was necessary to remove the Booster Target and replaced it with the original depleted Uranium target previously operated in the Neutron Scattering Facility. That target ran successfully until August, 1992, when it, too, sprang a leak and Xe-135 was seen in the surge tank cover gas. Figure 3b shows the counting rate around the time of the failure. In this case, the rate increased at first slowly, then more rapidly until it reached the limit where operation was terminated. The target was replaced with a spare which continues to operate normally. We have assembled another spare depleted Uranium target. We are designing a replacement enriched Uranium target, based on U-10%Mo alloy.

Figure 4 shows the specific activity of Xe-135, Xe-133 and La-140 observed in samples of cooling water removed from the cooling system during test operation with the failed Booster (we remain uncertain about the identity of the La-140.) In these tests with the demineralizer connected in the coolant system, we were unable to detect many expected chemically-active fission products. When the demineralizer was isolated from the system, the full range of fission products became observable, as Figure 5 shows in the case of the Iodine isotopes. The demineralizer efficiently removes chemically active elements from the water stream, as demonstrated by the rapid decrease in Iodine activity when it was reconnected to the system. From kinematic model analysis and from data from these and other tests, we could determine the absolute leak rates of various isotopes, and the partitioning of volatile elements between water and cover gas.

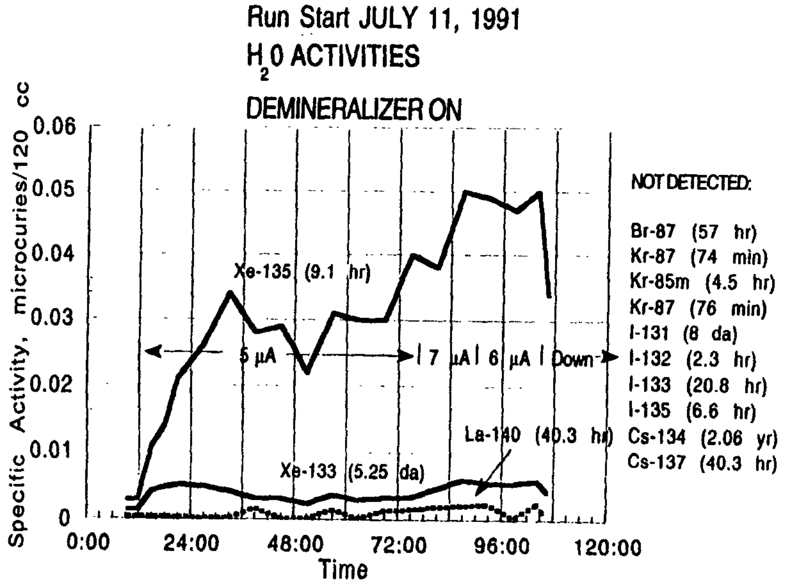

Figure 4 Xe-135 and Xe-133 activities, demineralizer on

We removed the leaky depleted target into a hot cell for destructive examination. Sawing away the vessel, we were easily able to remove the target disks. We have completed a series of preliminary examinations and non-destructive tests. Figure 6 shows the gamma-ray dose rate measured 8 cm from the surfaces of the individual

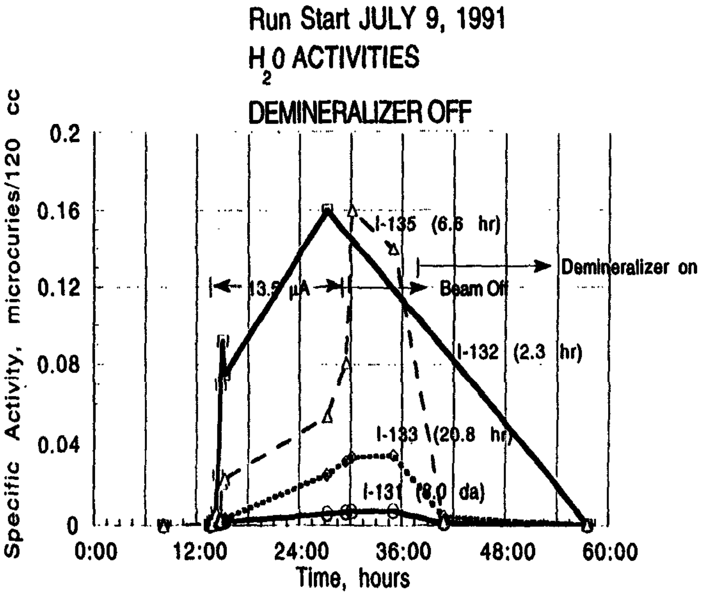

Figure 5 Activities with demineralizer on and off

disks, a measure of their activation by proton irradiation. As expected, the highest activity is confined to the front of the target. The figure also shows the power density calculated for 500 MeV protons. The fall-off at the end of range (13.4 cm of U metal, 11.4 cm for 450 MeV) occurs farther downstream than the fall-off in the measured dose rates; as of the time of writing, we do not understand this.

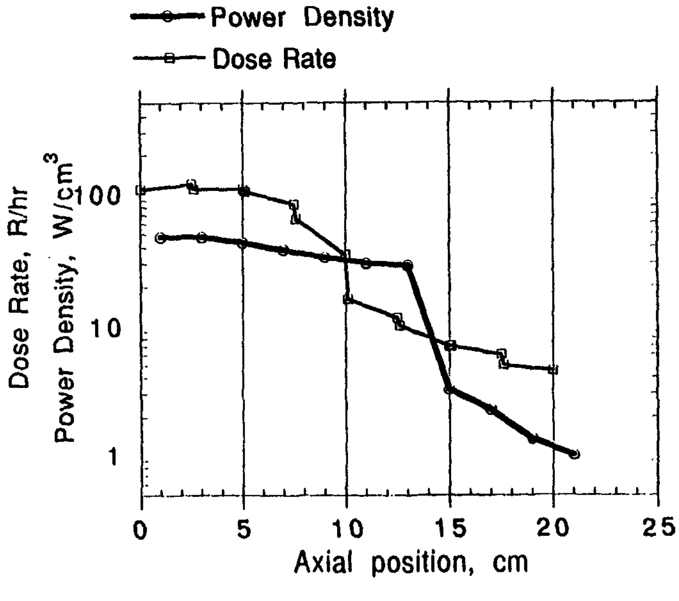

Figure 6 Gamma-ray dose rate as a function of disk position in the depleted Uranium target, and power density calculated for 500 MeV protons.

Progress in Examining Disk Surfaces

After opening the welded vessel, most of the disks, in their flow guides, easily slid down the housing guideways, but the front disk required slight additional manipulation. All eight disks were easily removed from the flow guides by force of gravity, or with a few pounds of force from an extraction fixture. Thermocouples in disks 3, 5 and 7 fell from their wells during the course of handling. The thermocouple in disk #1 remained stuck in the well and later broke off at the disk during repeated handling.

Photographs were taken of both faces of all 8 disks. Angled views provide the best lighting to accentuate disk surface irregularities. Witness of the flow channel guide bars is apparent on the front faces of all disks.

The front face of disk #1 shows a 1-inch long crack running across the approximate center of the disk in the direction of the thermowell tube exit, Figure 7. The crack appears to be imbedded in a narrow depression channel that is visible on the disk surface. The depression channel is more than 2 inches long and extends to the thermowell tube exit point. In the central region of the disk, a pattern of surface undulation and apparent blistering are easily seen. The surface damage pattern apparently outlines target beam location, which is somewhat off-round and off-center. Figure 8 shows a magnified view of the central portion of the disk face.

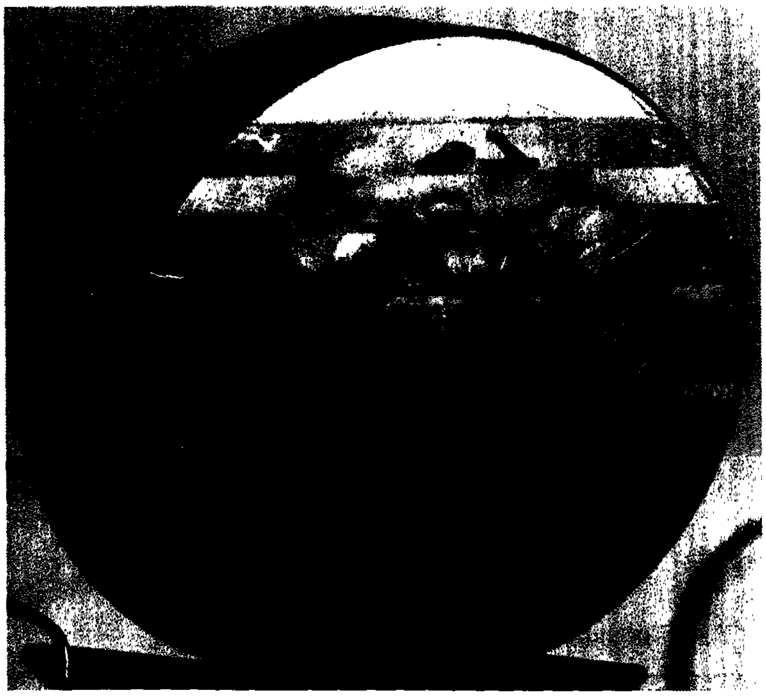

Figure 7 Front face of Disk #1 (ANL photo #283811)

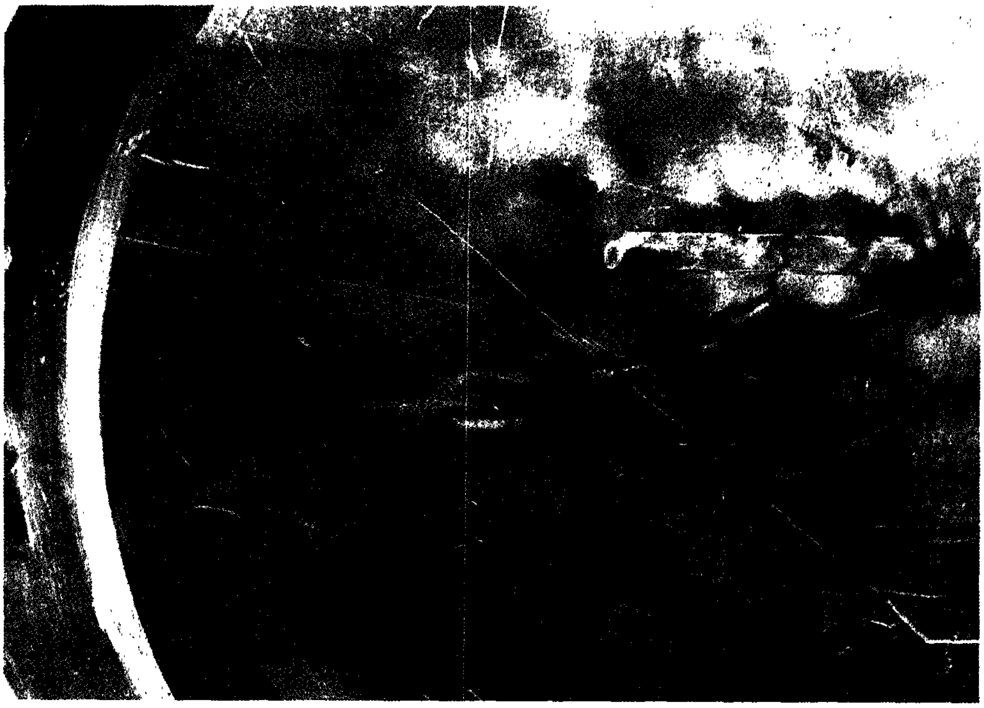

Figure 8 Front face of Disk #1, enlarged view (ANL photo #283895)

Figure 9 shows the rear face of disk #1. In this view the disk is still housed in the flow guide cup. Imprints from the adjacent flow channel guides are

Figure 9 Back face of Disk #1 (ANL photo # 283713)

pronounced in the central region of the disk face. A major elevated surface projection (blister??) has occurred within 1/8" of the center of the face. A 1/8"-long blunt crack can be seen at the midpoint down one slope of the blister. Figure 10 is a 3X magnified view of the disk central region, which shows the blunt crack in detail.

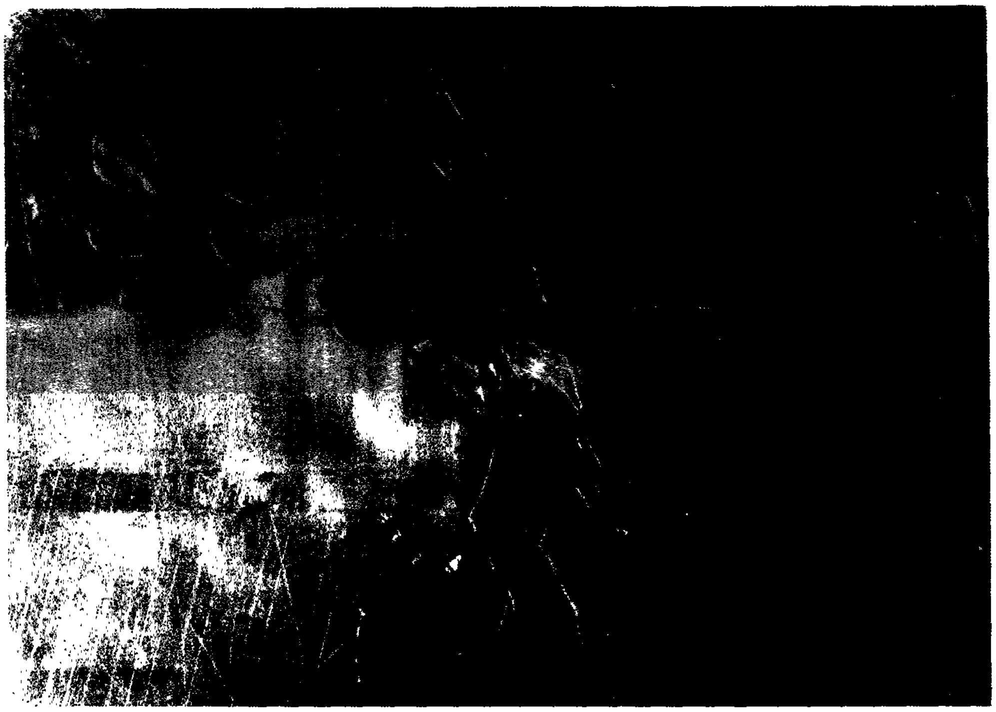

Figure 10 Backface of Disk #1, enlarged view (ANL photo # 283696)

Figure 11 is a profile view of the back face of disk #1 and it shows the elevation of the major blister on that face. By rough measurement, the blister elevation is seen to be about 0.066" from its base. By oblique light, surface rounding (blisters?) can be seen in random areas throughout the face--with some blisters extending nearly to the outside edge of the disk. However, the undulating surface is most pronounced in the central region of the face. Depression channels, generally in line with the axis of the thermowell tube, are seen on this face also.

Disk #2 front face photographs show an obvious elevated surface projection in the central region of the face. This (blister) is nearly opposite the major blister that occurred on the back face of disk #1. No surface crack is visually apparent on this face. The central region of the face shows general surface undulation as does the central region of the back face of disk #2.

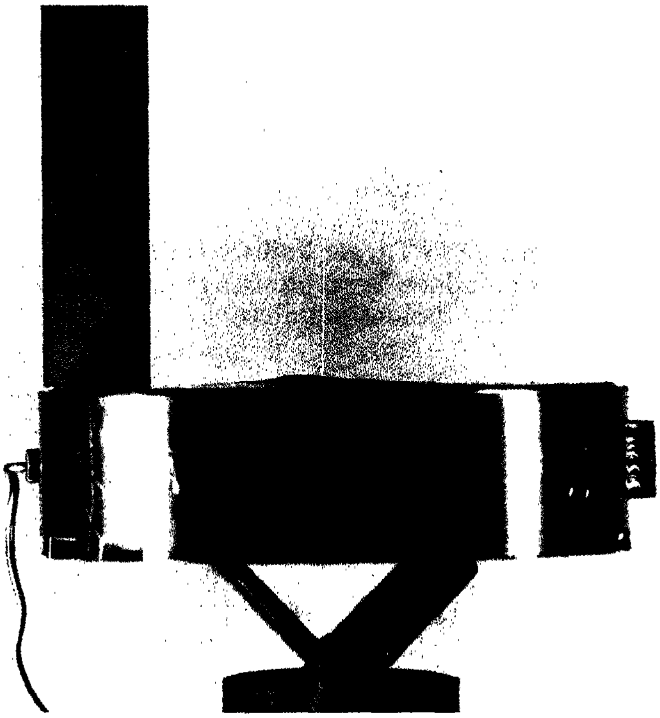

Figure 11 Back face of Disk #1, profile view (ANL photo # 283712)

Both faces of disk #3 and the front face of disk #4 show some visual evidence of surface undulation in the central region. The disk faces farther back in the target stack show very little visual evidence of surface undulation.

We plan destructive metallurgical examination of the disks and cladding to begin in the near future.

Relationship to ISIS Target Experience

Table 1 represents an attempt to relate failure data on ISIS and IPNS targets(6). In many instances, the table entries are only best estimates.

Table 1

ISIS and IPNS Target Failure Data
Thermal cycles to failure, Total protons to failure and
Total fissions to failure

Target	Thermal Cycles	Total Protons, mAhrs	Peak Temperature, °C	Relative Total Number of Fissions
ISIS#1		92.4		0.31
ISIS#2	40000.0	53.1	120.0	0.18
ISIS#3	10389.0	174.9	130.0	0.59
ISIS#4	4147.0	138.8	150.0	0.47
ISIS#5	5074.0	295.6	165.0	1.00
ISIS#6	2628.0	126.1	180.0	0.43
ISIS#7	1805.0	107.2	215.0	0.36
IPNS Depleted#1	89600.0	240.0	225.0	0.39
IPNS Booster#1	28000.0	128.8	175.0	1.07

The data suggest the following observations. The lifetimes of the targets, while variable, are not dramatically different in terms of total protons or fissions. There is much less consistency in the lifetime expressed as thermal cycles. While the statistics are poor, a reduction in target lifetime as the peak temperature increases seems to be indicated. If this is confirmed by future targets then increased lifetime can be achieved by a change of design to give lower peak temperatures, which would, most likely, result in only a small reduction in neutron production .

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