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Title: DESIGN OF AN OGIVE-SHAPED BEAMSTOP

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# DESIGN OF AN OGIVE-SHAPED BEAMSTOP

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### Abstract

This paper addresses the evolution, design, and development of a novel approach for stopping cw (continuous-wave), non-rastered proton beams. Capturing the beam in vacuo within a long, axisymmetric surface of revolution has the advantages of spreading the deposited energy over a large area while minimizing prompt neutron backstreaming and reducing shield size and mass. Evolving from a cylinder/cone concept, the ogive shape avoids abrupt changes in geometry that produce sharp thermal transitions, allowing the beam energy to be deposited gracefully along its surface. Thermal management at modest temperature levels is provided with a simple, one-pass countercurrent forced-convection water passage outside the ogive. Hydrophone boiling sensors provide overtemperature protection. The concept has been demonstrated under beam conditions in the CRITS (Chalk River Injector Test Stand) facility.

## 1 INTRODUCTION

The Accelerator Production of Tritium (APT) program requires several commissioning beamstops [1]. This paper discusses the first of these, which will be used to commission the RFQ and the first section of the CCDTL in the Low Energy Demonstration Accelerator (LEDA) presently being built at LANL (Los Alamos National Laboratory) [2]. The first LEDA beamstop must accommodate a 0.1 A proton beam in cw operation at energy levels of up to 6.7 MeV. Early studies showed that conventional beamstop approaches (e.g., plate-type with beam rastering to spread the heat flux) would result in a large, costly, immobile installation with significant radiation back-streaming issues—attributes which would severely complicate the job of developing and maintaining the Linac. These issues are addressable with an approach that minimizes the beamstop footprint orthogonal to the beam.

Eliminating rastering reduces the footprint to that of the beam spot size but requires management of sharply higher energy fluxes imposed by the Gaussian beam. The circular spot shape of the beam suggests a conical impact surface for the beamstop, a concept

which has been successfully used on other Linac applications.

Even smaller footprints result when the conical geometry is combined with an upstream cylindrical scraper section that exploits the divergent qualities of the beam to spread the heat flux. The conical end section then would capture the central portion of the beam while the wings of the Gaussian distribution are deposited in the cylindrical section. The cone/cylinder beamstop proportions are governed by the practical combination of radius and length that captures the beam within a minimum radius without spillage, typically resulting in a long, thin structure, with a re-entrant configuration that inherently minimizes both the back-streaming potential and the radial shield thickness requirement. The circular cross-section also minimizes edge effects which could produce hot spots.

The concept evolved to an ogive shape after analyses confirmed the need to smooth out the geometric transition between the cone and cylinder to reduce thermal gradients. The graceful, continuous inflection obtained with an ogive shape is a logical solution to this problem.

## 2 THE OGIVE CONCEPT

The ogive shape addressed here is generated by revolving a circular arc about a centerline to produce a surface of revolution, as shown in Figure 1. The ogive

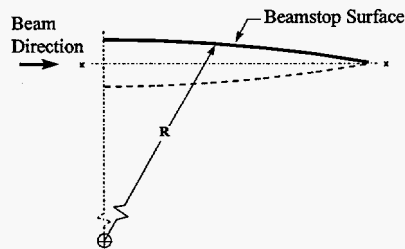


Figure 1: Ogive Shape

contour adjusts the angle of incidence as needed to accommodate the variable power density of the diverging beam: the greatest angles occur where the power density is lowest, and vice versa, resulting in a smooth, relatively mild heat flux profile on the beamstop surface.

### 3 DESIGN CONSIDERATIONS

Table 1 summarizes the LEDA beamstop design, which is based on the ogive concept.

Table 1: LEDA Beamstop Design

<b>BEAM CHARACTERISTICS</b> Energy x Current Operation	6.7 MeV x 0.1 A, Gaussian 1 Hz to cw (~6 mos. At cw)
<b>PHYSICAL FEATURES</b> Overall Dimensions Beam Centerline Height Target Geometry Target Dimensions Target Material Coolant Coolant Flow Arrangement	~ 109-in Height x 133-in Length 72-in Axisymmetric; Tangent Ogive 6-in ID x 92-in L x 0.1-in Thick Electroformed Nickel Water outside (vacuum inside) 1-Pass Forced Convection, Counterflow to Beam Direction
Neutron Shield Neutron Shield Tank Material Gamma Shield	Water Aluminum 1-in Lead Wall on Upstream Face
<b>THERMAL MANAGEMENT</b> Heat Removal Peak Heat Flux Peak Wall Temperatures Water Conditions	670 kW 250 W/cm <sup>2</sup> incident to surface 250 F waterside; 400 F beamside 305 gpm, 60 F/75psig in; 35 psid

The ogive beamstop is integrated into a simple, replaceable water-cooled cartridge that connects directly to the upstream beam ducting. In the arrangement shown in Figure 2, a flow shroud around the ogive creates an annular passage for once-through, forced-convection water cooling.

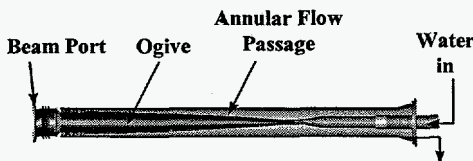


Figure 2: Ogive Beamstop Cartridge

The shielding advantages of the ogive approach are evident in Figure 3, which presents a cutaway view of

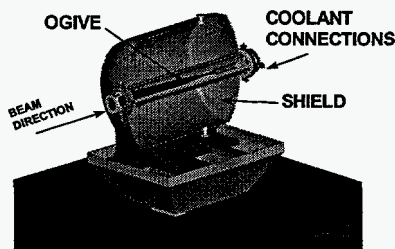


Figure 3: Integrated Beamstop Arrangement

the integrated beamstop assembly. The deposition of the beam energy deep within the small-diameter ogive makes it possible to have a near-4-pi, minimum-size neutron shield. The gamma shield wall is not shown.

#### 3.1 Thermal Management

The thermal design is based on the quasi-Gaussian beam characteristics predicted for the LEDA linac, including the location and severity of hot spots produced by beam focus and steering errors. Figure 4 shows the mild axial heat flux and waterside temperature profiles predicted for the 6.7 MeV LEDA ogive at the nominal operating condition. The beam direction is from left to right.

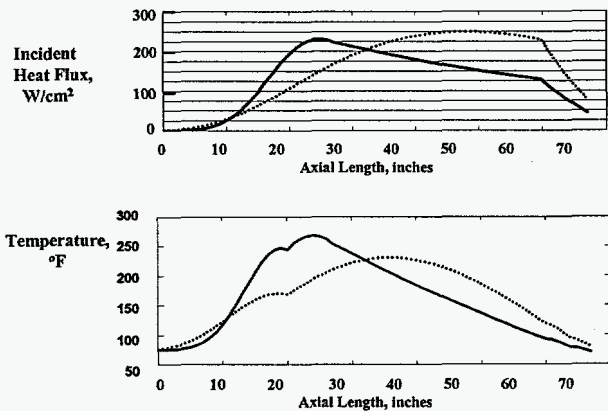


Figure 4: The heat flux normal to the ogive surface is a small fraction of that normal to the beam, resulting in modest temperatures

The thermal design is based on cooling with high-velocity water flow under sufficient static pressure to suppress boiling. Since the flow passage near the tip of the ogive is a venturi, care must be taken to ensure that the static pressure in this region will remain above the boiling limit.

#### 3.3 Structural Design

The ogive structural analysis considered buckling, flow-induced vibration, thermal stress due to heat flux, thermal bowing due to misaligned beam, and the potential for thermal/flow feedback instability. Figure 5 is an example of the analytical sophistication needed to confirm structural adequacy.

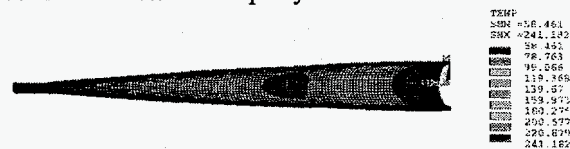


Figure 5: Temperature Distribution of Ogive Coolant for One Case of Beam Misalignment

## 4 DEVELOPMENT

Although the LEDA beamstop has not yet gone into service, valuable experience has already been obtained on the fabricability and performance of the ogive concept.

### 4.1 CRITS Beamstop Testing

By happy coincidence, an adjunct proton Linac program at LANL urgently needed a new beamstop just as the LEDA design was being finalized, affording the opportunity to test out the ogive concept under actual cw, beam-on conditions similar to those of LEDA, but at reduced power levels. The water-cooled copper 6.5-in ID x 42-in long ogive, shown in Figure 6, was designed to accommodate a 1.25 MeV proton beam at 75 mA. With a proton energy well below the

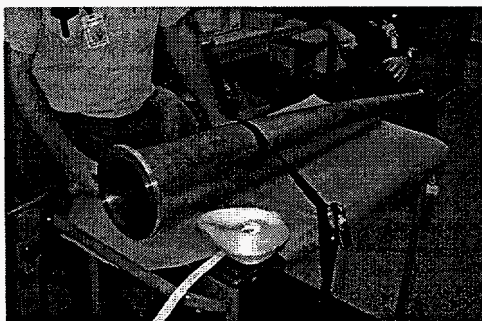


Figure 6: CRITS Ogive

2.2 MeV neutron activation threshold for copper, shielding was not required. The ogive easily met design performance, permitting the CRITS linac to reach the highest cw 1.25 MeV beam power ever demonstrated [3]. During this testing calorimetry performed on the ogive cooling water circuit helped verify the beam power measurements. The excess cooling capacity in the beamstop design defeated attempts to confirm the functionality of the hydrophone boiling sensors installed on the ogive flow shroud.

### 4.2 LEDA Beamstop Fabrication

Unlike its CRITS predecessor, which was spun from a copper cylinder, the nickel ogive for LEDA was produced by electroforming. This plating method produced a robust, one-piece, seamless, near-net shape ogive section to which a machined nose was added, using the same process. Figure 7 shows the completed LEDA ogive beamstop before it was inserted into its cartridge (see Figure 2).

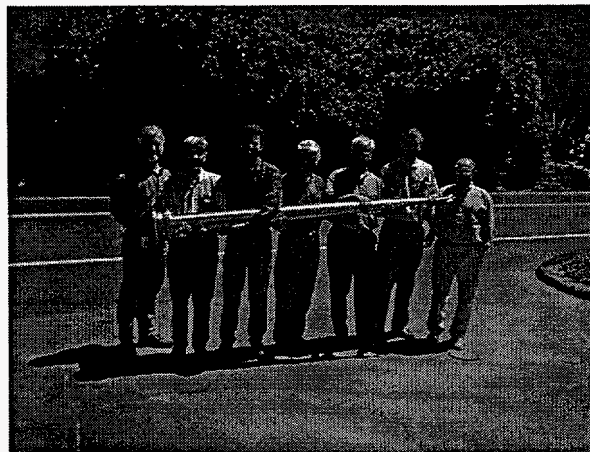


Figure 7: Electroformed Ogive for LEDA

The 6.7 MeV LEDA beamstop has been installed at LANL and is now undergoing precommissioning checkouts. Testing should begin later this year.

## 5 CONCLUSIONS

The CRITS and LEDA experience gained to date have validated the ogive approach, which is now being applied to the design of the beamstops needed to commission the low to intermediate energy sections of the APT.

## 6 ACKNOWLEDGMENTS

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## 7 REFERENCES

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