ORNL/CP-102359

ENERGY DISSIPATION IN THE TARGET STATION OF THE SPALLATION NEUTRON SOURCE

Felix C. Difilippo and Lowell A. Charlton
Computational Physics and Engineering Division*
Oak Ridge National Laboratory
P. O. Box 2008, Bldg. 6025
Oak Ridge, Tennessee 37831-6363
fcd@ornl.gov; lac@ornl.gov

Paper to be presented at the *American Nuclear Society's International Conference on Mathematics and Computation, Reactor Physics and Environmental Analysis in Nuclear Applications*, Madrid, Spain, September 27–30, 1999.

---

*Research sponsored by the Oak Ridge National Laboratory managed by Lockheed Martin Energy Research Corporation for the U.S. Department of Energy under contract No. DE-AC05-96OR22464.

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Energy Dissipation in the Target Station of the Spallation Neutron Source

Felix C. Difilippo and Lowell A. Charlton
Computational Physics and Engineering Division
Oak Ridge National Laboratory
P. O. B. 2008
Oak Ridge, Tennessee 37831-6363 (USA)
fcd@ornl.gov; lac@ornl.gov

Abstract

The heat distributions within the components of the target station of the Spallation Neutron Source were calculated using the Monte Carlo codes HETC, LAHET and MCNP to track the cascade of events after the introduction of 1 GeV protons in the mercury target. The boundaries of the model are the proton window and the external reflectors and includes such components as the stainless steel container, the water coolant, the thermal and cold neutron sources and the beam tubes. The calculations show that detailed heat distributions are sensitive to the proton beam profile and the curvature of the surface penetrated by the proton beam.

1 Introduction

The Spallation Neutron Source (SNS) project (AccApp, 98) is currently under development in several national laboratories of the Department of Energy of the US government. The pulsed neutron source is to be driven by a beam of 1 GeV protons making impact in a target of mercury. The neutrons, produced by the spallation reactions of the protons with the nucleus of the target and by the evaporation processes in excited residual nuclei, are then moderated by water and liquid hydrogen to produce an intense pulse of thermal and cold neutrons. The target is surrounded by a massive lead neutron reflector which is cooled with heavy water that improves the neutron economy and acts as a partial shield. A shower of neutral and charged particles follows the injection of the protons, and as the energy of the original protons is transported by the shower, heat is dissipated in the different components of the target station. Cooling requirement and an especially precise knowledge of the thermal-hydraulic conditions in the mercury target make necessary a detailed analysis of the distribution of heat.

2 Description of the Target Station

The proton beam, of approximately 7×20-cm cross section, hits the mercury target, which occupies a region ~ 8×40×70-cm. At the top of the target two liquid hydrogen moderators generate the cold neutrons which are extracted by 3 beam channels and 6 beam tubes; a similar arrangement is at the bottom of the target for the thermal neutron source with water as moderator. A massive lead reflector, 180-cm radius and 200-cm height, surrounds the target region. Figures 1 and 2 produced by Sabrina (VanRiper, 95) and the MCNP input, show a general view of the target station and details of the target and moderators.

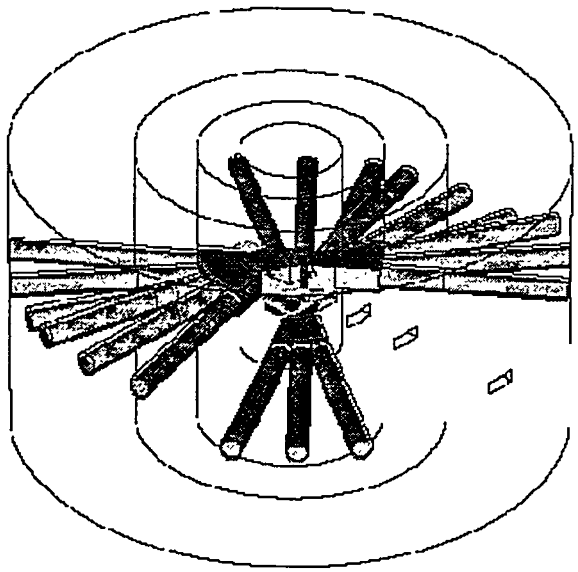

Figure 1. General view of the target station. The lead reflector is etched to allow the view of the beam channels and tubes, the mercury target and the two cold (at the top) and two thermal (at the bottom) neutron moderators. The windows in the reflector indicate the path of the proton beam.

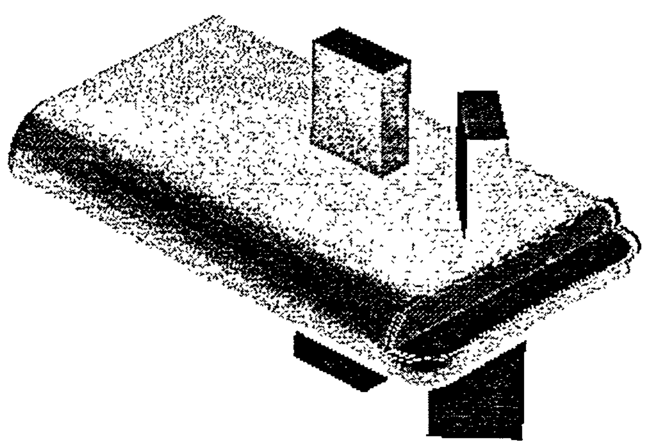

Figure 2. Mercury target and liquid hydrogen (top) and water (bottom) moderators. The stainless steel jacket of the target is shown opened to allow the view of the internal structure. The cold mercury flows mainly in two lateral cylindrical channels, mixes at the internal nose where it receives the impact of the proton beam and flow back through the inner part of the container. In another loop, the upper and lower small channels in Figure 2, mercury also flows, this time to form a few millimeter thick film (external nose) that is the first mercury to interact with the beam.

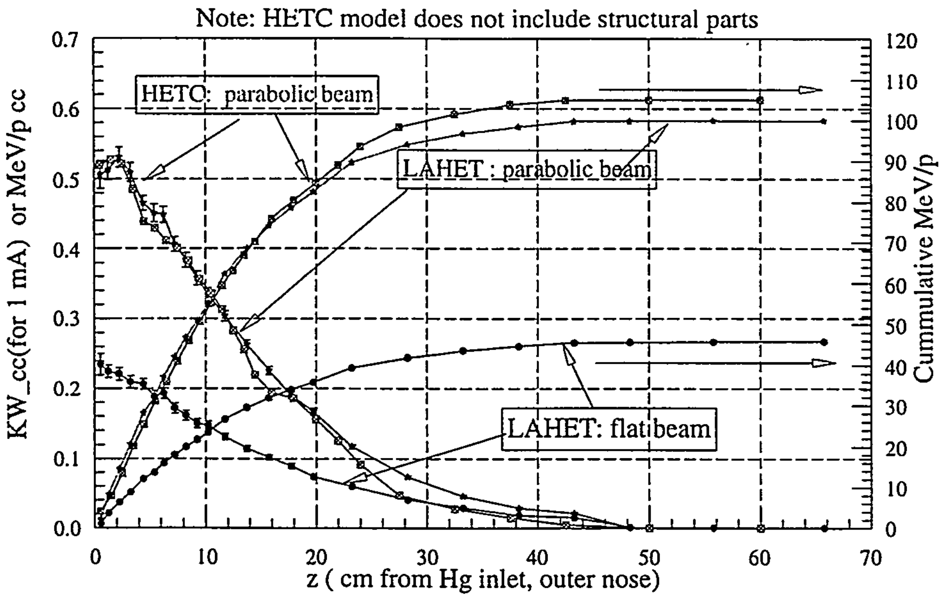

Figure 3. Heat distributions calculated with HETC (smoothened data) and LAHET with different proton beam profiles both calculations correspond to a 2×6 cm rectangular mercury cylinder located at the center of the beam and correspond to a target with a curved nose. Note that HETC model does not include structural parts.

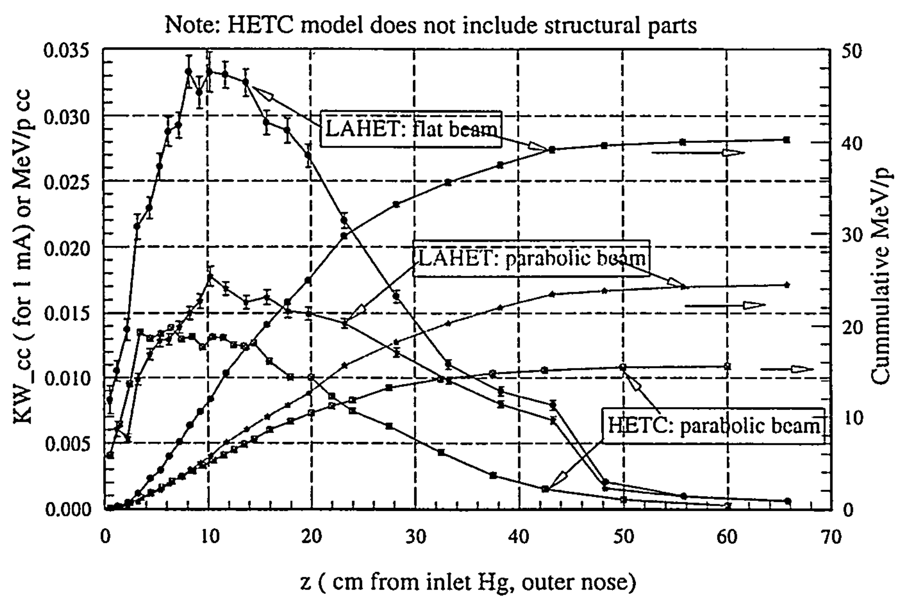

Figure 4. Heat distributions calculated with HETC and LAHET with different proton beam profiles. Both calculations correspond to a 8×24.3-cm rectangular mercury "shell " cylinder (i.e., minus its 7×20.3 cm inner part) located at the center of the beam and correspond to a target with a curved nose. This region is not directly illuminated by the beam.

Calculations were also done with a flat (i.e., no semicylindrical nose) mercury target illuminated by a 7×20-cm uniform beam to investigate the nature of the heat distribution at the immediate vicinity of the injection of the proton beam. As Figure 5 shows, the heat distribution

Table 1. Target design 10-22-98 energy distribution (per 1 GeV proton) uniform beam 7×20 cm

Mat #	Description	Vol. (L)	Mass (kg)	kW (for 1 mA) or MeV/p (all E)	Error kW or MeV	MCNP/total
1	Hg target	23.163	315.020	578.105	1.064	0.099
2	SS jacket of target	8.375	66.330	63.017	0.066	0.156
3	Water in SS	2.958	2.930	5.650	0.061	0.612
3	Water moderator	1.798	1.778	2.695	0.091	0.744
4	Al Th/cold source	1.293	3.491	1.487	0.040	0.350
5	He cold sources	0.167	0.025	0.038	0.001	0.880
6	Cd Th/cold sources	0.158	0.875	37.464	0.161	0.997
8	Liquid H2	1.798	0.121	1.141	0.011	0.893
9	Gd Th/cold sources	0.004	0.021	0.027	0.001	0.883
10	Pb 15.85 vol% D2O	400.800	3891.771	82.430	0.452	0.598
11	Pb 9.91 vol% D2O	1691.389	17336.737	69.081	0.391	0.778
12	Pb 4.95 vol% D2O	3913.200	42409.310	45.932	0.250	0.882
13	Fe 4.23 vol% D2O	13767.240	105418.510	45.831	0.233	0.946
	Total	19812.343	169446.919	932.896	1.776	0.320

5 Conclusions

Calculations of the heat distributions in the different components of the target station of the Spallation Neutron Source were presented. Particular details in the mercury around the region of the injection of the proton beam are important for thermal-hydraulic calculations of the moving mercury. The details depend on the beam profile and the curvature of the surface of penetration.

References

AccApp, 2nd *International Topical Meeting on Nuclear Application of Accelerator Technology*, American Nuclear Society, Gatlinburg, TN, September 20–23, 1998. See also web site http://epmnas.epm.ornl.gov/pgm-nsns.html

Briemeister, J. F., Editor, "MCNP: A General Monte Carlo N-Particle Transport Code," Los Alamos National Laboratory, LA-12625-M (March 1997).

Gabriel, T. A., Bishop, B. L., Alsmiller, F. S., Alsmiller, R. G., Johnson, J. O., "CALOR98: A Monte Carlo Program Package for the Design and Analysis of Calorimetric Systems," Oak Ridge National Laboratory, ORNL-TM-11185.

Prael, R. E., Lichtenstein, H., "User Guide to LCS: The Lahet System," Los Alamos National Laboratory, LA-UR-89-3014 (September 1989).

VanRiper, K. A., " Sabrina™ User's Guide," Los Alamos National Laboratory, LA-UR-93-3696 (April 1995).