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Spallation Neutron Source Beam Dump Radiation Shielding Analysis

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ACRONYMS

SNS	Spallation Neutron Source

EXECUTIVE SUMMARY

Preliminary shielding calculations were performed to establish the dimensions of the radiation shielding surrounding the three Spallation Neutron Source (SNS) beam stops. Steel shielding thicknesses were sized to give dose levels of 1, 2, and 5 mrem/h at the top of the shield, and, to provide enough shielding along the sides and bottom of the beam dump so that soil activation is not a problem. It was concluded that 144 in. of steel shielding is needed above the beam stop. The thickness of the concrete floor in the service building above the dump was not a part of these calculations. This shielding design is current as of January 2000.

1. INTRODUCTION

There are three beam dumps in the Spallation Neutron Source (SNS) facility. The Linac Dump (33 kW) allows full energy pulses to be produced by the Linac for tuning without beam being transported to the ring. This dump is limited to a 10% duty cycle. The Ring Injection Dump (200 kW) accepts a fraction of the beam from the ring that is not trapped in the ring during injection. This dump operates anytime that the facility is producing beam. The Ring Extraction Dump (33 kW) allows the ring to be tuned with full pulses and is operated for tuning pulses or when the target station is not able to accept beam. It operates with a 10% duty cycle. The Linac and extraction beam stops are made of steel and the injection beam stop is made of copper. The beam stops must have adequate shielding to assure that radiation dose levels are within acceptable limits and to prevent significant activation of soil or groundwater.

The shielding for the linac dump must be designed to allow maintenance personnel in the ring during operation of this dump. Two significant remote maintenance operations have been identified for the three beam dumps, namely, vacuum window replacement and replacement of the beam stops. Cooling water and helium utility systems are located in a service building above the beam dump stops. The utilities will be positioned and shielded to permit hands-on access to the equipment. Personnel will be permitted access to the service buildings during accelerator operation. Replacement of the highly activated beam stops will be performed remotely using special purpose shielded transfer containers and an external portable crane system. There is a removable hatch in the roof to allow crane hook access to the beam stop for removal.

A preliminary shielding analysis was conducted to establish the size of the steel radiation shielding surrounding the beam stop.

2. DESCRIPTION OF BEAM DUMP

A common design is used for all dumps. The layout and design for all three dumps are generally the same. Figure 1 shows a simplified representation of the building and dump vessel. The ring injection beam stop for the beam is a water-cooled assembly of copper disks contained in a 316 SS shell. This beam stop is ~0.30 m in diam. The beam stop is enclosed in a 1.5 m rectangular enclosure that also contains water-cooled steel shielding and contains a helium atmosphere. The bulk shielding outside the enclosure is composed of steel shield blocks to make a cube ~5 to 6 m long on each side. This shielding is made from 10 ton blocks of steel 52 in. × 52 in. × 26 in. arranged in an array of 7 × 14 × 7 with an opening for the vessel offset from the center by ~2 ft in the upstream beam direction. These blocks are assembled within an 18 in.-thick concrete enclosure, lined with steel to contain leaks and to hold the potentially activated air atmosphere.

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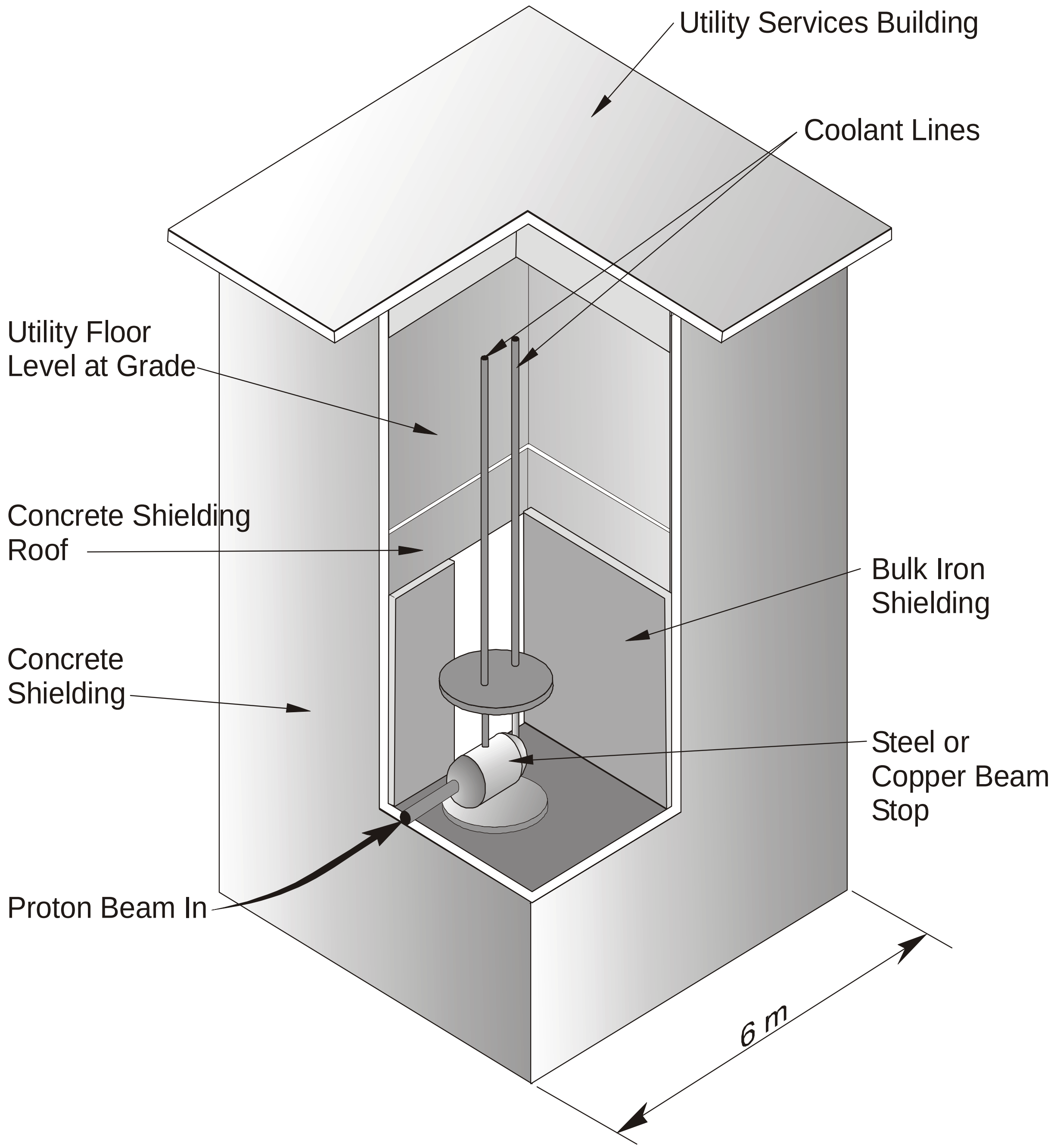

Fig. 1. General beam dump building and assembly.

3. CALCULATION SOURCE MODEL

The radiation source was modeled as a 30 cm diam × 75 cm long water-cooled copper cylinder (80% copper). The neutron flux spectrum was scored in the following five angular bins for use in 1-D ANISN calculations:

- 0–20°
- 20–45°
- 45–90°
- 90–135°
- 135–180°

The source files utilized for this analysis were from the SNS Conceptual Design Report analysis. The sources were normalized to the number of neutrons in these angular bins for 200 kW operation and 33 kW operation. Within the uncertainty of this analysis, a water-cooled copper source is a reasonable assumption for modeling the 33 kW steel beam stop.

4. CALCULATIONS

The following is a description of calculations done during June 1999.

ANISN computer code calculations were run using the 0–20 source, the 45–90 source, and the 135–180 source. For the 200 kW dump, the initial steel shielding was assumed to be water cooled (5% water); 100 cm in the forward direction (0–20°), 75 cm in the side directions (45–90°), and 50 cm in the back direction (135–180°). No water cooling was included in the 33 kw dump analysis for this preliminary analysis. One foot (30 cm) of concrete was assumed to surround the side and top of the steel, and 150 cm was assumed to represent the foundation.

Based on conversations with Eric Pitcher at Los Alamos National Laboratory, a maximum neutron flux of 1×10^5 n/cm^2/s will begin to produce tritium in the soil at levels of regulatory concern. There was no discussion of the water content of the soil in reference to this number. Therefore, for this analysis, the beam dump shielding size for a neutron leakage flux of 10^3, 10^4, and 10^5 n/cm^2/s was estimated on every surface except the top. For the top, the shielding for 1, 2, and 5 mrem/hr was estimated. The dimensions in the following table do not include the concrete floor of the dump utility service building, currently 24 in.- thick. However, the dose and flux values are for the contact surface between the concrete and the soil.

Table 1 is for the 200 kW dump. Since the only difference between this dump and the 33 kW dump is the factor of 6 reduction in power level, the steel thicknesses can be reduced by ~30 cm to obtain the equivalent dump size needed for the 33 kW dump. However, steel shielding block thicknesses come in fixed dimensions of 52 × 52 × 26 in. So, no advantage is taken of the smaller shielding thicknesses permitted by lower power beam stops. No consideration was taken for the hours of operation since the dump is sized for a flux level and not dose rate. This analysis did not evaluate the activation of the soil for these dump sizes.

Figure 2 gives the design that resulted from these shielding calculations. The figure is taken from SNS design drawing number M3E087000K00 Rev 0. Because a neutron flux of 10^5 is where tritium formation begins to be a problem, to be conservative, a neutron flux leakage of only 10^4 was allowed in setting the side and bottom dimensions of the shielding. Then, in the upward direction, shield thicknesses were determined for 1.0, 2.0, and 5.0 mrem/h. A steel shielding thickness of ~374 cm, corresponding to the 1.0 mrem/h dose rate, was used in the upward direction.

Table 1. 200 kW ring injection dump radiation dose for various steel shield thickness (Does not include concrete wall thickness)

n flux level ($n/cm^2/s$)	10^3	10^4	10^5
Forward direction			
Dose (R/h)	2.47×10^{-2}	2.44×10^{-1}	2.02
Steel (cm)	346	306	266
Backward direction			
Dose (R/h)	1.79×10^{-2}	2.11×10^{-1}	1.81
Steel (cm)	248	218	188
Sideward direction			
Dose (R/h)	2.15×10^{-2}	2.31×10^{-1}	2.01
Steel (cm)	328	290	252
Upward direction			
Dose (R/h)	4.94×10^{-3}	1.93×10^{-3}	1.03×10^{-3}
Steel (cm)	350	368	374
Downward direction			
Dose (R/h)	6.54×10^{-2}	4.70×10^{-1}	2.83
Steel (cm)	223	193	163

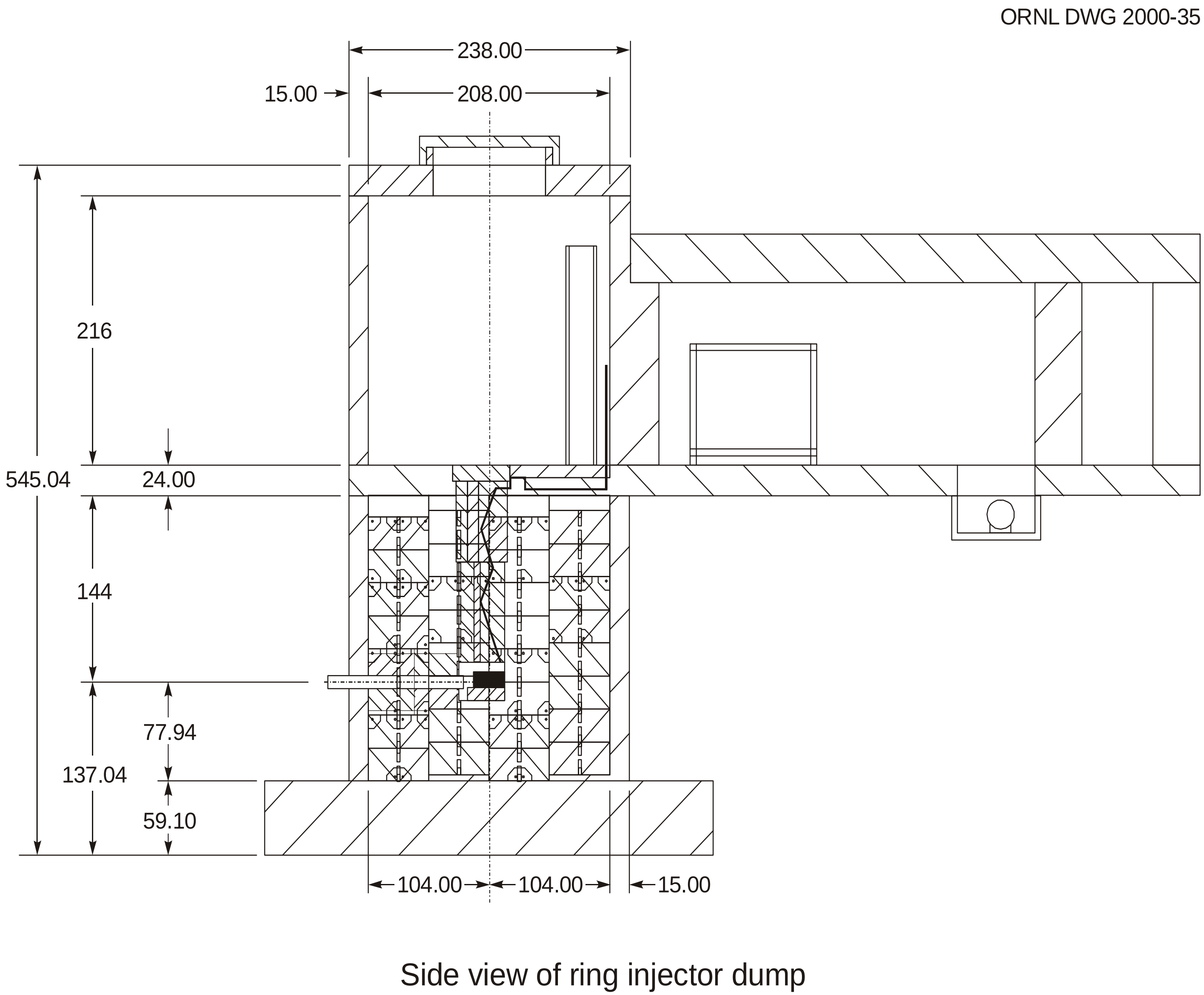

Fig. 2. Side view of ring injection dump (all dimensions in inches).

5. FURTHER WORK

These numbers are preliminary. We are in the process of running beam dump optimization calculations for the dumps now with different power levels and design assumptions. We are also trying to determine the cooling requirements, water activation, and component activations for these dumps. At this later stage, we will be able to calculate ground activation products. The ground activation analysis may allow the beam dump shielding sizes to be reduced further.