

LANSCE FAIL-SAFE RADIATION SHUTTER DESIGN FOR ISOTOPE PRODUCTION FACILITY*

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Abstract

Dose rate modeling and post irradiation measurements of the Isotope Production Facility (IPF) beamline, at the Los Alamos Neutron Science Center (LANSCE) accelerator have determined that a radiation shielding shutter is required to protect personnel from shine from irradiated targets for routine beam tunnel entries. This paper will describe radiation dose modeling, shielding calculations, and the fail-safe mechanical shutter design.

INTRODUCTION

A high radiation area in which dose equivalent rates exceed one rem per hour may be present in the IPF beam tunnel as a result of decay gamma radiation emitted from a target in the lowered position where it receives beam (Figure 1). Exposure rates in the beam pipe on the order of Roentgen per hour could be present beyond the shield wall separating the IPF beam tunnel from the accelerator tunnel twenty meters upstream of the target. DOE Order 10 CFR 835 requires specific physical controls for the protection of workers from high radiation areas where dose rates exceed one rem per hour. A beamline shutter was designed that will shield workers in the IPF tunnel and beam line from a target in the lowered position when the tunnel is accessible.

Targets are lowered from the IPF hot cell into the beam line 12 meters below. The section of beam line receiving targets includes the beam window, plumbing for target cooling water, and a graphite beam stop. This assembly inserts into the target shield at the end of the beam tunnel.

MODELING

A model of the assembly and the target shielding was prepared for input to the Monte Carlo radiation transport code MCNPX [1]. Figure 2 is a plan view plot of the model, including a shutter installed as the first beamline component upstream of the target irradiation insert. The initial design objective was for a shutter that would eliminate the potential for high radiation areas in the IPF tunnel, i.e. 30-centimeter dose rates less than 100 millirem per hour. It was found that a beam line shutter alone could not accomplish this unless it was very near or within the target shielding due to radiation scattering around it. Engineering alternatives that satisfied the objective included redesign of the insert or addition of shielding around the portion of the insert that protrudes into the beam tunnel. These were opted against and the design objective was reconsidered.

It is planned that under normal circumstances targets would be raised into the hot cell before tunnel entries for ALARA reasons. It would be abnormal that one would remain in the lowered position while the tunnel was occupied. A Radiological Control Technician (RCT) makes all initial entries following beam operations to survey and post the tunnel accordingly. Provided the shutter can ensure dose rates are less than one rem per hour if a target is left in the lowered position no further physical controls are required, however if dose rates are found that exceed 100 millirem per hour at 30 centimeters the tunnel would become a high radiation area.

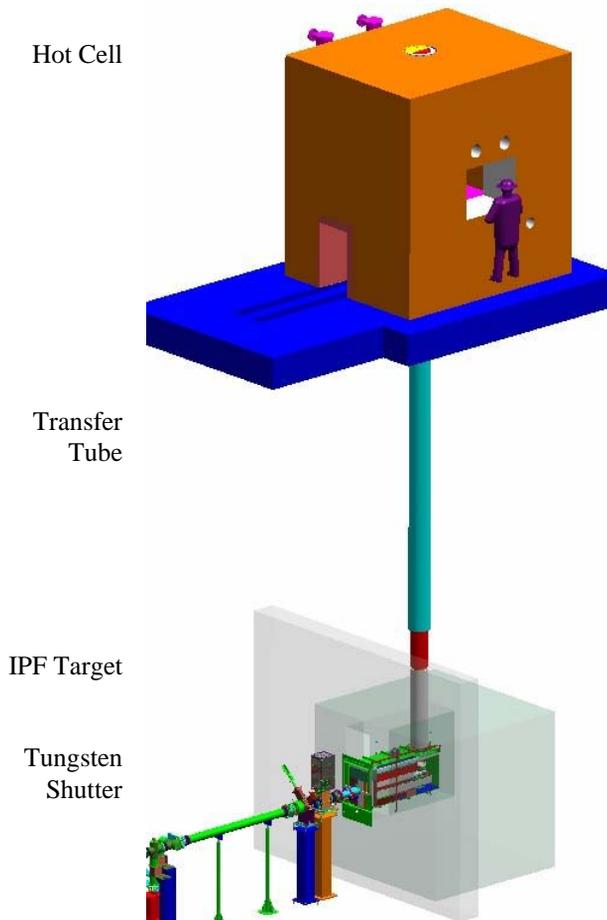


Figure 1: IPF Hotcell, target and shielding

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MCNPX radiation transport calculations were run to study the shutter design. The radiation source assumed was the same photon spectrum specified for the hot cell design. The unshielded, one meter, point source dose rate is approximately 1000 rem per hour for this source. Tungsten was chosen as the shutter shielding material for its high Z and density. Regardless of the shutter installation maximum dose rates 30 centimeters from the sides of the insert were about 300 millirem per hour, assuming ICRP 21 flux-to-dose rate conversion factors. A tungsten length of 152 millimeters was specified to ensure downstream dose rates on the beam line were also 300 millirem per hour at 30 centimeters. A tungsten diameter of 114 millimeters was modeled covering the beam pipe aperture. For mechanical design, a greater diameter (127 millimeters sleeved) is required to account for alignment tolerance. Figure 3 is a mesh tally plot of the photon dose rates at the end of the IPF tunnel, assuming the design basis photon source is in the target position.

Model dimensions were passed on for mechanical design of the shutter. These included minimum and maximum dimensions for the tungsten cylinder and the shutter vacuum box. Minimum dimensions were specified where if, decreased, dose rates would rise, and maximum dimensions were specified where if, increased, dose rates would rise. These specifications ensure that the mechanical design will perform as well as modeling indicated.

SHUTTER DESIGN

The shutter housing is constructed of 304 stainless steel with metal seals used for all vacuum joints. Figure 4 shows an isometric view of the entire mechanism. The upper insertion mechanism is designed to be maintained in the beamline if necessary.

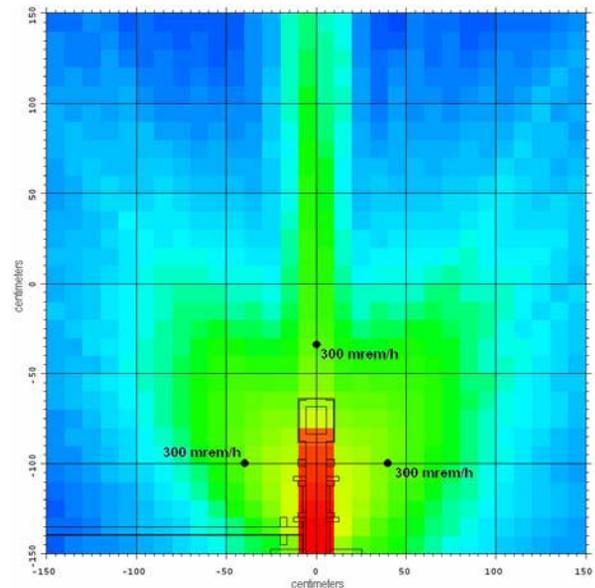


Figure 3: MCNPX dose rate mesh tally plot for design basis target in lowered position.

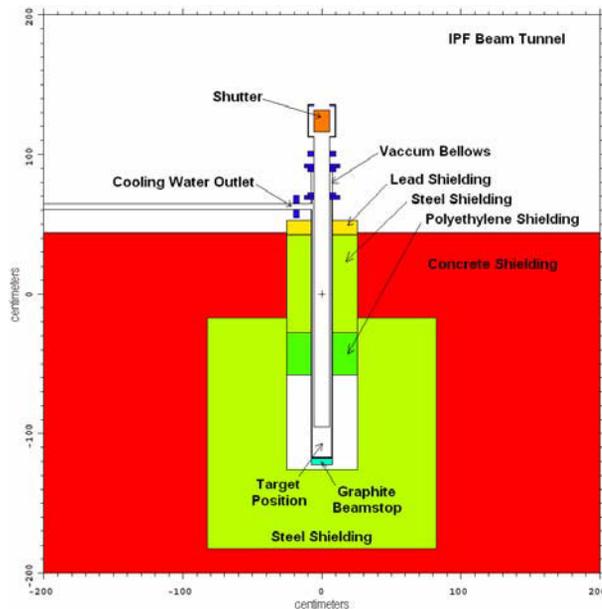


Figure 2: MCNPX model of IPF target insert and shielding with shutter.

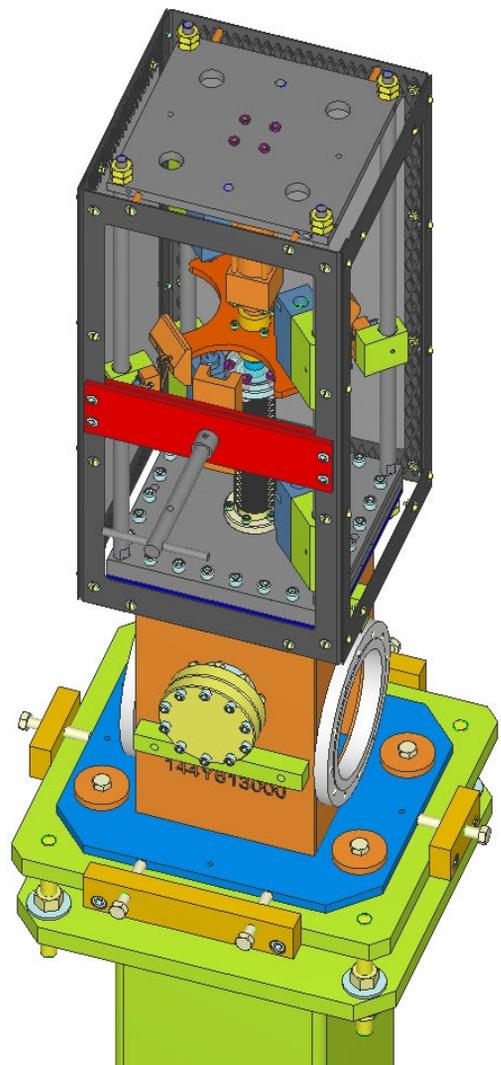


Figure 4: Isometric view of shutter mechanism.

The shutter may also be manually locked in place. This accommodates target mechanism failures and insures management control of the high radiation area under any circumstance. A cross section of the shutter and mechanism may be seen in figure 5. The air cylinder has radiation resistant ethylene propylene rubber (epr) seals. The shutter will fail closed as a result of a loss of air to the cylinder or a power outage. The 114 millimeter diameter, 152 millimeter long, tungsten shutter is sheathed in a 127 millimeter diameter, 304 stainless steel cylinder with integral attachment points to the welded, bellow, vacuum-sealed support and insertion shaft.

The entire assemble is placed on an alignment stand with three axis alignment ability. The vacuum housing is tooled for alignment positioning on the beam line with a laser tracker or standard optical equipment. The shutter position is indicated by fail-safe, doubly redundant, qualified limit switches. The limit switch position information will be hard-wired into the LANSCE Accelerator Radiation Security System (RSS). The RSS is an engineered safety system which automatically terminates transmission of accelerated ion beams in response to pre-defined abnormal conditions. The RSS includes personnel access control systems, beam spill monitoring systems, and beam current level limiting systems. It is a stand-alone system with redundant logic chains. A fault of the RSS will cause the insertion of fusible beam plugs in the accelerator low-energy transport. The RSS system is described in detail in reference 2.

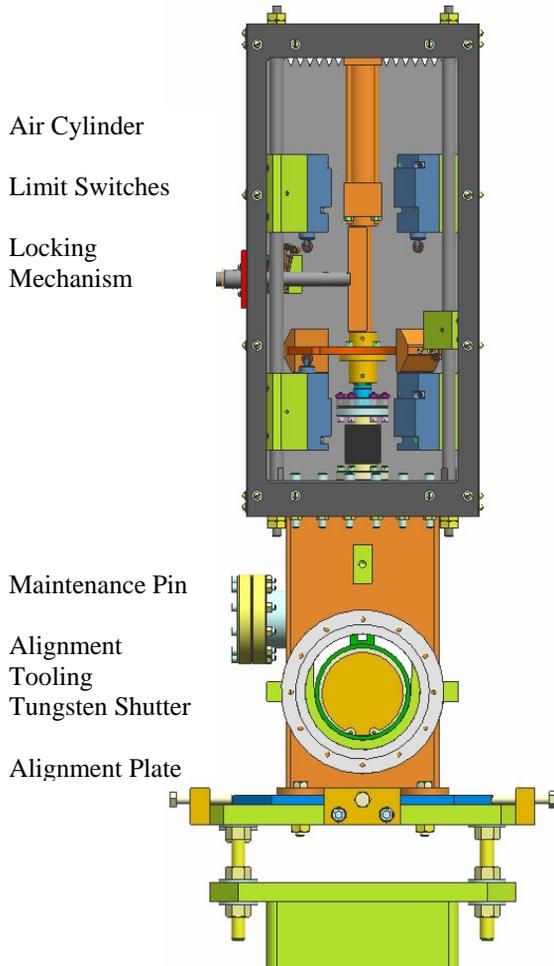


Figure 5: Cross section of shutter mechanism

The inserted shutter may be supported by an externally positioned pin. The pin allows maintenance of the air cylinder; limit switches and cabling while maintaining radiation shielding. The tungsten shutter is insured to be aligned within the vacuum housing to within 0.5 mm by stainless steel guides welded inside the housing.

SUMMARY

A tungsten shutter has been constructed for use in the IPF. The assembly will be installed during the 2008 maintenance period. The mechanism will ensure that radiation levels within the beam line tunnel area are maintained as low as reasonably achievable.

REFERENCES

- [1] D.B. Pelowitz (ed.), MCNPX User's Manual Version 2.5.0, LA-CP-05-0369, Los Alamos National Laboratory, April 2005.
- [2] F. R. Gallegos, LANSCE Radiation Security System (RSS), Health Physics Society 30th Midyear Topical Meeting, 5-8 January 1997, San Jose, California.