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Analysis of a shield design for a DT neutron generator test facility

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Abstract

Independent numerical simulations have been performed using the MCNP5 and SCALE5 radiation transport codes to evaluate the effectiveness of a concrete facility designed to shield personnel from neutron radiation emitted from DT neutron generators. The analysis considered radiation source terms of 14.1 MeV monoenergetic neutrons located at three discrete locations within the two test vaults in the facility, calculating neutron and photon dose rates at 44 locations around the facility using both codes. In addition, dose rate contours were established throughout the facility using the MCNP5 mesh tally feature. Neutron dose rates calculated outside of the facility are predicted to be below 0.01 mrem/h at all locations when all neutron generator source terms are operating within the facility. Similarly, the neutron dose rate in one empty test vault when the adjacent test vault is being utilized is also less then 0.01 mrem/h. For most calculation locations outside the facility the photon dose rates were less then the neutron dose rates by a factor of 10 or more.

Keywords: Neutron generator; Shielding; DT neutron

1. Introduction

One important activity performed at Sandia National Laboratories in Albuquerque, NM, is the design, manufacture and testing of sealed tube neutron generators. These devices are small particle accelerators which exploit either the $^2H+^2H\rightarrow^3He+n+3.3\,MeV$ ($\bar{E}_n=2.5\,MeV$) or $^2H+^3H\rightarrow^4He+n+17.6\,MeV$ ($\bar{E}_n=14.1\,MeV$) fusion reactions to produce fast neutrons. The devices produced at Sandia are similar in many respects to sealed tube neutron generators used elsewhere for neutron activation research and general descriptions of devices similar to those currently being made at Sandia can be found in the literature (Csikai, 1987; Nargolwalla and Przyblowicz, 1973; Marion and Fowler, 1960; Gow and Pollock, 1960; Shope et al., 1983). As a manufacturing facility a major aspect of Sandia's neutron generator production activities is the functional testing of neutron generators for quality control assurance and applied research and development.

In order to test operating neutron generators special test facilities are usually constructed that provide shielding to protect staff personnel from neutron radiation. In principle, radiation protection could be achieved by operating the neutron generators in large open spaces and maintaining a large distance between personnel and the operating neutron generators rather than using shielding; however, limited floor space and difficulty in securing physical access to the generators being tested limits this route in a manufacturing environment. Also, in neutron generator manufacturing facilities there is limited flexibility in reducing the amount of time the neutron generators are operating because of production schedule requirements and research and development testing needs.

Several reports describing custom built shield facilities for neutron generators, including both experiments and simulations, have been described in the literature (Nagorny and Adami, 1972; Angelone et al., 2000; Shin et al., 2005; Shypailo and Ellis, 2005; Litvin et al., 2005). As a reference tool the National Council on Radiation Protection and Measurements (NCRP) has published a report which

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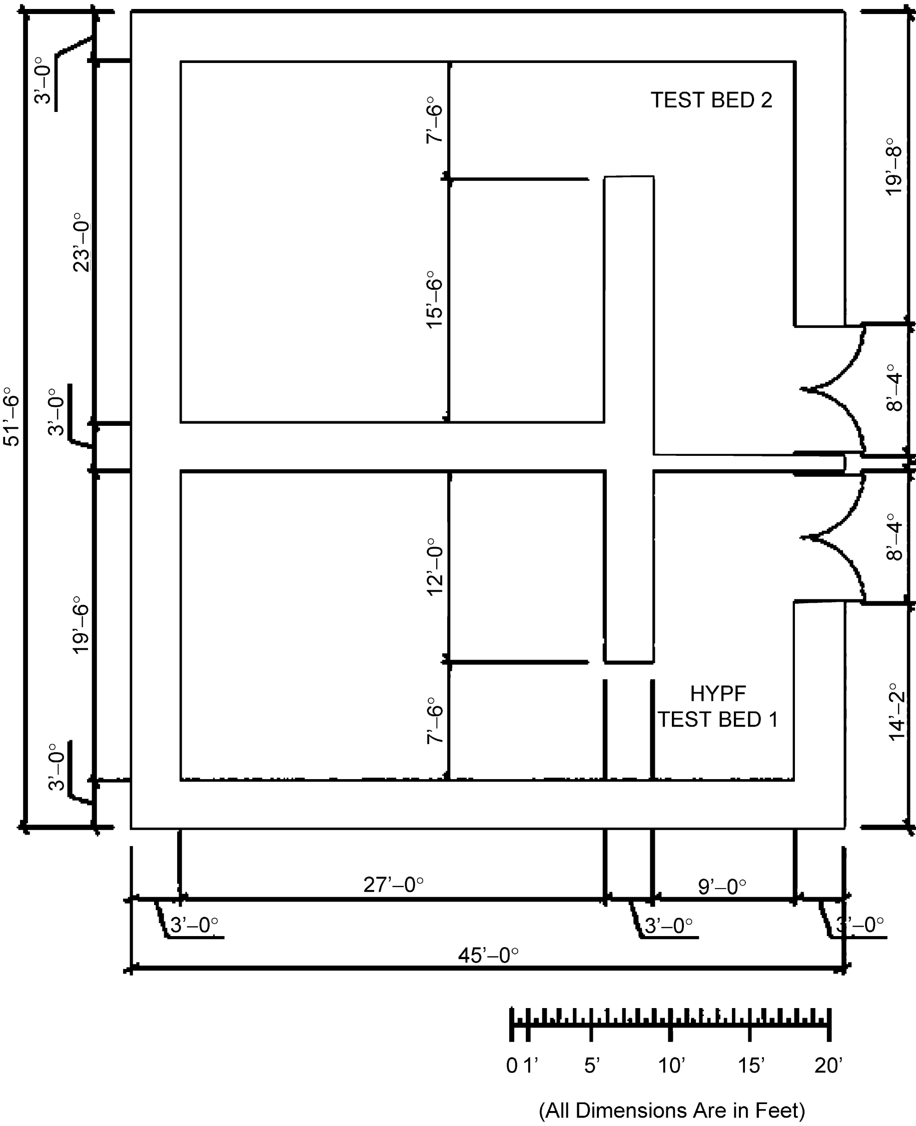

Fig. 1. Floor plan layout of the neutron tube/neutron generator nuclear radiation laboratory.

provides guidance and general rules of thumb for designing neutron generator shields (NCRP, 1983).

Several other references also provide useful guidance for designing and analyzing neutron generator radiation shielding (Csikai, 1987; Nargolwalla and Przyblowicz, 1973; Boggs, 1976; Shultis and Faw, 2000). In most cases, neutron generator shield designers have opted to use concrete for shield facilities because of its relatively modest cost and its structural characteristics in construction. Other materials frequently encountered in neutron generator shields include polyethylene and paraffin (either cast-in-place or as modular blocks, with or without boron) as well as water shielding in large holding tanks (with hollow test chambers inside). When hydrocarbon materials are used the flammability of these materials introduces additional complexities related to fire suppression and ventilation. Of course, the most cost effective shield in most cases is to take advantage of the natural shielding provided by dirt and rock by locating test facilities completely or partially underground in basements or sub-basements, moving dirt over the side walls and roof when possible.

To permit routine functional testing of neutron generators at Sandia National Laboratories a new test facility has been designed and is scheduled for construction. The design of this facility has been performed through an iterative process examining both concrete and hydrocarbon shield materials, investigating several layout schemes including different maze layouts and the use of heavy shielded doors. Important constraints in this process included personnel radiation exposure minimization through ALARA,[1] the design's ability to meet the neutron generator testing mission requirements, construction cost,

[1]ALARA—a health physics acronym for operational efforts keeping personnel radiation exposures at levels which are "As Low As Reasonably Achievable".