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Tritium Extraction Facility ALARA Paper

Marvin Barnett
Joye Brotherton

The primary mission of the TEF is to extract tritium from tritium producing burnable absorber rods (TPBARs) that have been irradiated in a commercial light water reactor and to deliver tritium-containing gas to the Savannah River Site Facility 233-H. The tritium extraction segment provides the capability to deliver three (3) kilograms per year to the nation's nuclear weapons stockpile. The TEF includes processes, equipment and facilities capable of production-scale extraction of tritium while minimizing personnel radiation exposure, environmental releases, and waste generation.

Radiological engineers have been involved from conception through construction insuring that ALARA principles are followed. All aspects of the design have been considered: D&D; monitoring, contamination, shielding, etc. This paper will discuss several ALARA considerations that went into the shielding design.

During irradiation of the TPBARs, the stainless steel is activated to create Co-60. The calculated dose rate 1 ft from a TPBAR basket is approximately 50,000 R/hr. Thus, the TPBAR baskets will create a significant safety risk due to radiation. The baskets will be handled in a remote handling building, with shielding designed to reduce the dose rate to below 0.25 mrem/hr in occupied areas.

Bulk shielding, walls, roofs, shield doors, etc, were the first shielding structures that needed to be determined. Unattenuated dose rates versus distance were determined from a basket of TPBARs. The attenuation factor through various materials, such as concrete and steel, were also calculated. Bulk wall thicknesses were determined by calculating the concrete necessary to attenuate the dose rate from unshielded baskets of TPBARs. Shield doors and walls that shielded scatter radiation were analyzed using Monte Carlo codes.

Penetrations went through several walls to provide cable access, HVAC, etc. To reduce the radiation streaming through the wall, 3-legged penetrations were used. The length of the penetration was determined by the area of the opening; larger penetrations requiring a longer offset. In addition to making the penetration 3-legged, steel was imbedded into the wall. The steel was added to compensate for the concrete removed by putting in a penetration. Steel was added behind the penetration at the opening, around the penetration in the middle, and in front of the penetration at the exit. External steel box were placed around a penetration only when other methods could not reduce the dose rate sufficiently.

Streaming was also a concern around the doors. The doors are not flush against the wall; they have a 0.5 in. gap. Several steps were taken to reduce the streaming around the doors. Where feasible concrete corbels were placed behind the door. Steel lips and labyrinths were used in other areas to reduce the streaming. A significant amount of radiation went into the gap by going through the concrete. Therefore, steel was placed inside the concrete and door overlaps were lengthened.

Dose assessments were performed to determine where additional dose saving could be achieved. Time and motion data was developed in cooperation with the Operations group. The time and motion data was then matched with dose rates for each operation to determine the associated person-rem/operation. Person-rem numbers were converted to dollar values to determine if additional dose reduction beyond the design limit would be warranted. The largest contributor to dose was cask operations. Methods were examined to reduce the time or number of people needed for each operation. The feasibility of long-handled tools and temporary shielding was also examined.

After a design has been constructed, it is necessary to verify the as-built shields. The ANSI/ANS 6.3.1 standard details the principal objectives of a test program, discusses criteria for the selection of locations for measurements, and recommends survey and measurement methods. Two methods were proposed to test the shield structures: 1) bring in a source prior to start-up; 2) use the basket of TPBARs as they arrive.

Method 1 would require bringing in a Co-60 source between 40,000 and 500,000 Ci. The 40,000 Ci would represent the largest source term configuration expected within the facility. As long as dose rates on the personnel side of the shield do not exceed pre-set dose rate limits, the shields are considered sufficient. Disadvantages included the uncertainty associated with performing survey results and receiving no measurable dose rates through shielding structures, due to the fact that there are several factors other than radiation attenuation that could result in a reduced detector response. The 500,000 Ci source would ensure a positive response on survey equipment through the most effective shielding configurations. Advantages to this approach included the ability to confirm that dose rates for the design basis source term do not exceed design dose rates for all shield configurations prior to introduction of TPBARs into the facility. However, these choices were eliminated due to cost and potential for increased radiation exposure through shield structures designed to a lower-activity source term and radiation damage to equipment.

Method 2 uses one of the TPBAR sources as the test source for shield construction. The primary advantage of Method 2 is the fact that the facility is specifically designed to accept TPBAR baskets, and to remotely move them throughout the facility, which eliminates the logistical concerns with assembling non-TPBAR high-activity sources for the shield tests. Also, using the actual source material for the shield tests, for which the facility is designed, eliminates the concerns associated with elevated personnel dose rates and equipment radiation damage that would be experienced with the positive response approach of Method 1. Finally, this option eliminates the costs associated with bringing in a high activity source. Disadvantages to this approach include the potential impact to the operations schedule if a shielding inadequacy is found during TPBAR testing; corrective actions could delay start of operations within the facility. In addition, it is likely that the first few TPBAR baskets may not bound later shipments in terms of dose rate, due to issues such as longer decay times prior to shipment and fewer number of rods per basket. Method 2 was chosen by the project.

The actual validation of the TEF radiation shield design is a three-step program:

Step 1. After completion of construction of the Remote Handling Area (RHA) civil structures, the conservatism in the radiation shielding design was evaluated by comparing design basis shield parameters with the actual installed shield parameters. Small-source field tests on selected shielded penetrations and concrete placements were used to obtain a measure of conservatism in design. Construction records have been reviewed to identify anomalies that may impact radiation shielding properties.

Step 2. During the TEF startup program, specific radiation shield equipment necessary for personnel radiation protection (e.g., shield doors) will be tested and inspected to ensure that they are installed and are operational as designed.

Step 3. Using containers of tritium-producing burnable absorber rods (TPBARs) from a commercial light water reactor (CLWR), a full-scale test verification of shield structures will be performed by moving irradiated TPBARs throughout the RHA not only to verify that shield structures meet the design basis for dose rates throughout the facility, but also to serve as the baseline for operational postings for radiological areas.