After the A_2: Experiences with a Multi-Energy Approach for Type B Package Shielding – 14325

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ABSTRACT

Contents specifications for Type B packages that are used to transport radioactive general radioactive waste and byproduct materials have historically been written to specify maximum content limits in terms of multiples of A_2 and heat load. Pre-shipment radiological surveys were performed to demonstrate compliance with the normal conditions of transport (NCT) package dose limits of US Title 10 Code of Federal Regulations Part 71 Section 47 (10 CFR 71.47). In April 2013, the U.S. Nuclear Regulatory Commission (NRC) released Regulatory Issue Summary (RIS) 2013-04 which describes the position that the NRC staff typically will not accept pre-shipment measurements as an appropriate 10 CFR 71.35(a) evaluation method for determining NCT dose rate compliance with the requirements of 10 CFR 71.47. Thus, applicants for new package certificates or certificate amendments may be considering more elaborate shielding analyses that include the additional detail necessary to demonstrate compliance with 10 CFR 71.47 in light of the NRC staff's position as detailed in RIS 2013-04. This paper describes the experience of Energy*Solutions* during and after the certificate amendment process for the 8-120B package. The 8-120B package has been and continues to be a widely used package for transportation of radioactive waste in the U.S. With its diverse user-base comes the challenge of deploying the more complex qualification requirements without adding significant burden to the users. The paper also discusses the techniques and challenges of rolling out the new radiological qualification requirements in the post-A_2 world.

THE 8-120B: A U.S. INDUSTRY WORKHORSE

The 8-120B (Figure 1) was licensed in 1982 by Chem Nuclear Systems, later to become Energy*Solutions*. The current user-base includes over 80 customers. Energy*Solutions* operates two 8-120B units, which are in continuous use and ship approximately 100 times a year from operating nuclear plants, research facilities, cleanup and decommissioning projects, and medical facilities. 8-120Bs have provided safe service for thousands of hauls totaling over 3 million miles of travel, making them one of the greatest workhorses of the industry. Because of the heavy user demand, and since licensing delays will keep similar casks from shipping until late 2014, Energy*Solutions* is tripling its 8-120B fleet in early 2014.

Figure 1. The 8-120B Cask

The package consists of a steel-lead-steel radial shield, steel top and bottom shields, a two-part bolted lid closure, top and radial thermal shields, lifting and tie-down fixtures, and a set of top and

bottom foam impact limiters. A family of liner products is available, making the package suitable for a wide range of payloads, including resins and filters, activated metals, solidified waste, and isotope sources. TABLE I lists the current cask specifications.

TABLE I. 8-120B Specifications [1, 2]

Certification	USA/9168/B(U)-96
Drum Capacity	8 drums (55 gal)
Internal Dimensions	152∅ x 190 cm (62∅ x 75 in)
External Dimensions	259∅ x 336 cm (102∅ x 132 in)
Shielding	Lead: 8.5 cm (3.4 in) Steel: 5.7 cm (2.3 in)
Max. Gross Weight	33,500 kg (74,000 lb)
Max. Payload Weight	6,400 kg (14,150 lb)
Payload Specifications	Byproduct, source, or special nuclear material, activated metals or metal oxides • 3000 A_1/A_2 max. • 200 W max. thermal

RADIOLOGICAL PAYLOAD QUALIFICATION: IN THE A_2 ERA

Until 2012, contents qualification for the 8-120B package involved confirming that the payload met the Certificate of Compliance (CoC) requirements for physical form, mass, heat generation, fissile restrictions, and that the radiological content was under the A_2 (or, as appropriate, A_1) limit. The pre-shipment radiological survey was the final step in assuring that the radiological source strength of the contents was suitable for shipping.

The shielding safety analysis presented in the Safety Analysis Report (SAR) and reflected in the associated CoC [3, 4] modeled a Co-60 point source to determine whether normal conditions of transport (NCT) or hypothetical accident conditions (HAC) was the governing condition. The analysis concluded that NCT governed, and therefore the pre-shipment survey was determined to be valid for verifying that payloads met regulatory requirements.

From the cask user standpoint, the radiological payload qualification was usually a straightforward matter. A_2 values were obtained by hand or using existing shipping software, and the radiation measurements were readily obtained per the typical pre-shipment surveys.

RADIOLOGICAL PAYLOAD QUALIFICATION: IN THE POST-A_2 ERA

During the process of upgrading the CoC to the -96 designation (i.e. compliant with the 10 CFR 71 regulations addressing the 1996 Edition of the IAEA Regulations for the Safe Transport of Radioactive Material), Energy*Solutions* was required to provide sufficient details on content descriptions and a corresponding shielding evaluation that represents or bounds all proposed contents. This guidance would later become the subject of a NRC Regulatory Issue Summary on the same topic [5]. A comprehensive shielding analysis was prepared using the Monte-Carlo computer code MCNP [6] to demonstrate per 10 CFR 71.35(a) that any approved contents would conform to the requirements of 10 CFR 71.74. As a result, the 8-120B shielding analysis now covers a wide scope of energies, physical size, and shoring configurations to rigorously demonstrate compliance without relying on measurements. The radiological acceptance criteria are now expressed as a series of allowable source terms by gamma energy for each of five physical payload configurations. Sources may be qualified either by their absolute strength or by the source-density where credit is taken for mass attenuation within the payload material.

During the preparation of the new shielding analyses and throughout the review process, several issues arose that would later prove to have significant consequences on cask payload capacity, and/or user experience.

- Secondary containers were not credited as shielding because they are not standardized for all shipments, and thus not part of the certified packaging (i.e., the 8-120B ships with various steel or polyethylene secondary containers of varying thicknesses).
- The payload shielding models that included credit for self-shielding were assumed to have the minimum mass attenuation properties for any common material over each of the energy ranges studied.
- Bremsstrahlung radiation must be considered for significant beta emitters (e.g., Sr-90).

The resulting radiological specification in the Revision 19 CoC and associated SAR [7, 8] included five columns of contents limits, in gammas/sec or gammas/sec·g, over a range of energy bands. In order to qualify a payload for shipment, the cask user must determine which column applies to the shipment, then convert the payload Curie inventory into gammas/sec (or gammas/sec·g) including Bremsstrahlung contributions, bin the gamma energies, and perform a sum of fractions to determine acceptability. Pre-shipment measurements would still be required, but they would no longer be the basis for qualification.

EXPERIENCES WITH ROLLING OUT THE NEW RADIOLOGICAL QUALIFICATIONS

Resin Capacity Impacts

Approximately 80% of 8-120B shipments are resins from operating nuclear facilities. Preliminary evaluations showed that, using the new CoC Revision 19 radiological limits, approximately 30% of the more active resin payloads that had been successfully shipped for three decades would no longer qualify for shipment. The reasons for the loss of capacity were conservatisms in the shielding methodology including the treatment of mass attenuation factors, and the round-up conservatisms inherent in the energy-band approach. An additional cause was determined to be a minor imbalance in the cask shielding thicknesses: the 8-120B was slightly under-shielded in the downward direction at the 1.2 MeV energy range (i.e., Co-60). The shielding imbalance was never understood well due to the relative simplicity of the early shielding analyses. A minor cask modification was designed to balance, or "tune" the cask shielding and recover some of the capacity that was lost due to the new methodology's conservatisms. Energy*Solutions* submitted a revised shielding analysis and NRC issued Revision 20 of the CoC in December 2013. The design modifications have been made to the four existing casks, and the capacity has been restored for this most common type of shipment.

User Feedback: The Energy Method

Customer feedback regarding the new 8-120B radiological qualification methodology identified several opportunities for improvement. Shippers who had relied on simple pre-shipment measurements for decades now found themselves required to perform sometimes extensive calculations in order to demonstrate compliance with the radiological qualification criteria. The most common concerns included:

- The qualification methodology was perceived to be unnecessarily complex.
- Payloads often contain 20 or more isotopes, each of which may have several gamma emissions. The process of converting Curies to gamma emissions, calculating

Bremsstrahlung gamma emissions for pure beta emitters, energy-binning the results and finally performing the sum of fractions calculations was time-consuming and was unlike any previously required evaluations.

To address these concerns, a source qualification tool was developed and made available to the 8-120B user community that performs all gamma conversion, Bremsstrahlung calculations, and energy-binning for over 300 radioisotopes. The qualification tool expresses Curie limits for each radionuclide in each of the five columns from the SAR, leaving the user with the much simpler task of selecting the proper column for the subject shipment, then performing a simple sum of fractions directly using the payload Curie content as the sole input. The tool was introduced in late 2013 and has been widely used for shipments.

Case Study: Zion Plant Decommissioning

The Zion Nuclear Station was permanently shut down in 1998. In 2010, the NRC approved the transfer of Exelon's license in preparation for decommissioning project. The 8-120B cask was scheduled to ship Type B quantities of dismantled reactor internals for disposal. With a budget on the order of 1 billion dollars, the 8-120B waste shipments are a key component in the successful execution of this complex project. Plans for 8-120B shipments were suspended in the fall of 2013, however, when Revision 19 of the CoC became effective and it was discovered that many of the planned payloads could not be qualified for shipment because they did not meet the new radiological requirements.

Payloads that had previously shipped successfully, with measured cask dose rates well within the regulatory limits, could not be qualified under Revision 19 of the CoC. The improved limits in Revision 20 of the CoC were not improved enough to qualify the shipments. MCNP evaluations were performed that determined the most significant causes to be:

- Thick steel liners (Figure 2) are used to store the waste underwater prior to cask loading. The liners are inserted into the 8-120B and then used again to handle the waste at the disposal facility. Whereas the shielding provided by the liners "counted" before (it reduced the measured exposure rates), it was not credited in the shielding safety analyses, and therefore the allowable Curies of Zion source was reduced by over 60%. Because the contents of each of the payloads had been carefully planned to minimize the number of required shipments (and hence the occupational and public exposure), this effect alone caused disruption of shipments with substantial impact to the project.

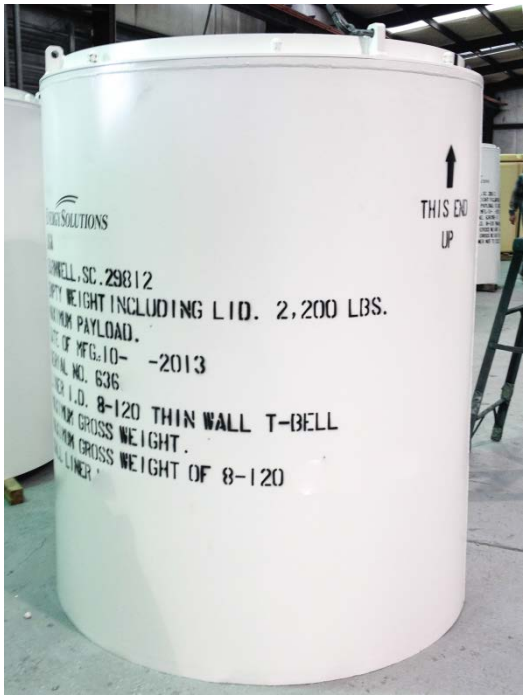

Figure 2. Zion 8-120B Liner

- The shielding safety analyses were performed using the mass attenuation for zirconium over the Co-60 (dominant)

energy range, which was required for conservatism. The payload was actually steel, however, which is a more efficient attenuator than zirconium. The allowable Curies of source were reduced by an additional 6% due to mass attenuation factor conservatism.

- Any conservatism in the waste source characterization would have "washed out" if qualifications were based on measurements alone. But with the new qualification methodology, any conservatism in deriving the waste source terms will carry through to the payload qualification, resulting in a potential loss of capacity.

Energy*Solutions* has applied for a certificate amendment to include targeted payload configurations to handle special cases like irradiated hardware shipments with fewer sources of unnecessary conservatisms. It is anticipated that the Zion irradiated hardware shipments will be able to resume when the new limits are available.

CONCLUSIONS

Applicants for new Type B package certifications and those requesting shielding amendments to existing certificates must address the issues in RIS 2013-04. Pre-shipment measurements were a convenient basis in the past for radiological payload qualification, but A_2 values have limited usefulness for radiological qualification. Applications based on A_2 values do not provide the NRC staff sufficient details to determine compliance with the regulations. The additional assurance has come, however, with a high price to be paid by real-world shipments.

The experience gained with the 8-120B teaches us that the layers of additional conservatisms resulting from non-credited shielding, source term derivations, and the safety analyses assumptions and methodology may manifest themselves in additional exposure to operating personnel and the public due to the additional shipments required, and significant negative impacts to planned shipments resulting in potential disruptions to cost and schedule for both operating and shut down reactors. In addition, applying the more complex qualification procedures has presented challenges for practical deployment in the field.

Energy*Solutions* has obtained or submitted two license amendments to regain the capacity to ship payloads that have successfully shipped for, in some cases, three decades. Additionally, a qualification tool has been developed and deployed which eases the qualification burdens on the 8-120B user community and will result in more consistent, reliable qualifications in the future.

REFERENCES

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5. "NRC Regulatory Issue Summary 2013-04 – Content Specification and Shielding Evaluations for Type B Transportation Packages," U.S. Nuclear Regulatory Commission (April 2013).

6. “MCNP5: Monte Carlo N-Particle Transport Code System,” ORNL RSICC Code Package CCC-710, Oak Ridge National Laboratory (2003).
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