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Design and Licensing of Irradiated Uranyl Nitrate Liquid Containers and Applicable Loading and Packaging System

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Abstract

Irradiated uranyl nitrate liquid (UNL) solutions are typically waste materials resulting from the processing of uranium target materials in the production of radioisotopes. Traditionally, these waste materials have been processed and stored at the site of origin, due to the lack of an option for packaging, transportation and disposition. Modern alternatives to process, stabilize, package and dispose of these materials have been developed, but until recently there has not been a viable Type B package solution that could be used to ship these materials in sufficient quantities to justify the cost of an off-site disposition strategy. For this reason, most facilities that generate irradiated UNL materials have implemented on-site storage tanks or containers, resulting in the significant accumulation of UNL inventories worldwide. This paper provides an overview of the design and licensing activities for the development of sealed irradiated UNL transport containers to permit safe transportation of this material in the NAC-LWT cask. A description of the robust UNL container, licensing and fabrication is also presented. In addition, NAC has developed a specialized loading system to optimize the process to load, package and un-package UNL materials to minimize worker exposure during loading, and execute the packaging process efficiently for safe transport and retrieval.

Introduction

This paper provides a general description of the design and technical requirements to transport irradiated uranyl nitrate liquids (UNL) inside sealed containers within the NAC-LWT cask (U.S. NRC CoC 71-9225). These transport containers were designed to accommodate the UNL materials in a safe configuration with suitable interface capabilities for safe and efficient loading and unloading from the NAC-LWT cask. The UNL containers were analyzed to obtain U.S. NRC approval for transport certification as approved contents within the current licensing basis of the NAC-LWT transportation cask system. In addition, considerations for fissile material accountability requirements and for the safe transfer of the UNL liquid were also addressed in the container's design and operational interfaces.

Licensing

The NAC-LWT Safety Analysis Report (SAR) was amended and a revision to the cask Certificate of Compliance (CoC) was issued by the U.S. NRC on 29 December 2014. In support of the SAR amendment, structural, thermal, containment, criticality, and shielding analyses were performed, and operation procedures and fabrication and maintenance documentation developed to demonstrate that 10 CFR 71 requirements were fully satisfied or bounded. In addition, the analysis demonstrated that the new canisters are fully compliant with performance requirements for the transport of UNL materials.

Description of the Package Configuration

The UNL containers (Figure 1) are designed and analyzed to be capable of transporting UNL materials within the NAC-LWT transportation cask (Figure 2). The NAC-LWT cask assembly includes the cylindrical cask body, and closure (including bolts). The top and bottom of the cask are protected from impact by aluminum honeycomb removable impact limiters. The cask's cavity, which is lined with stainless steel, can accommodate a variety of removable baskets or containers for various contents and loading configurations. The cavity shell is surrounded by a lead shield. Outside the lead is a stainless steel shell. The steel and lead gamma shield and structure is surrounded by a neutron shield tank having an external stainless steel shell and containing a mixture of water and ethylene glycol, which is the neutron shield. The top, bottom and lid of the cask are stainless steel forgings. The cask lid is held in place by twelve bolts. Metallic and Teflon O-ring seals are used between the lid and the cask body. Basic information on the NAC-LWT Cask is provided in Figure 2 and Table 1.

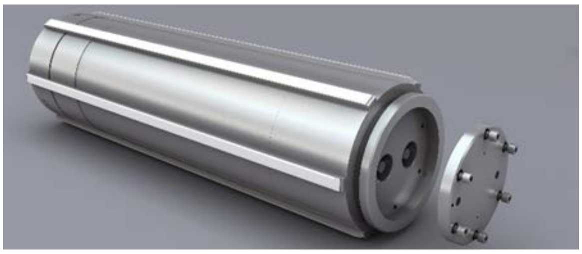

Figure 1 Rendering of UNL Containers

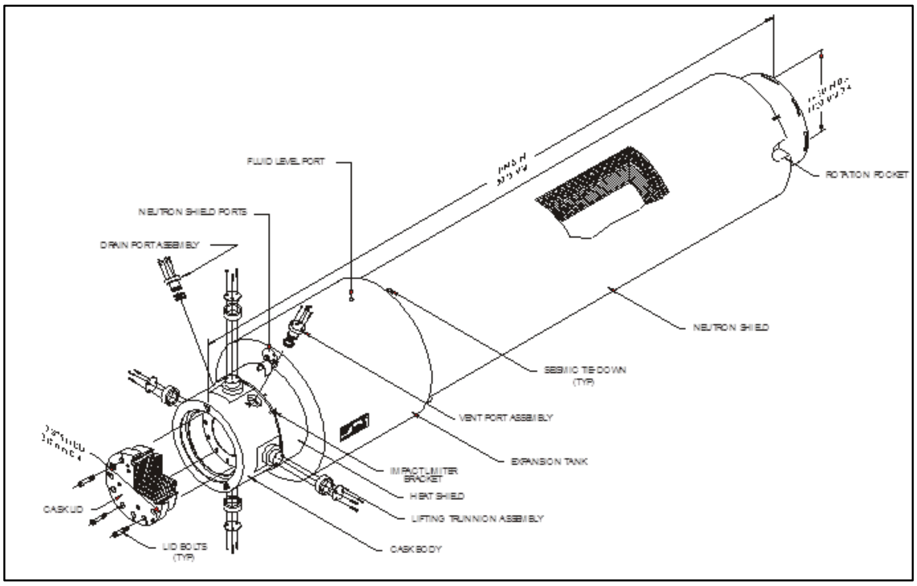

Figure 2 NAC-LWT Cask (U.S. NRC CoC 71-9225)

Table 1 NAC-LWT Cask Specifications and Parameters

Specification	Parameter	NAC-LWT Transport Cask
Capacity	UNL Canisters	4
Weight (kg)	Empty	21,772
	Loaded	23,223
Thermal	Design Heat Rejection (kW)	2.5
	Maximum Fuel Clad Temp. (°F)	653
	Operating Temp. (°F)	228 (cask radial surface; max.)
	Maximum Burnup (GWD/MTU)	35
Dimensions (mm)	Overall Length w/o Impact Limiters	5,074.9
	Overall Length w/Impact Limiters	5,887.7
	Overall Cross Section w/o Impact Limiters	1,122.7
	Overall Cross Section w/ Impact Limiters	1,658.6
	Cavity Length	4,518.7
	Cavity Cross Section	339.72
Materials of Construction	Cask Body	Stainless Steel/Lead
	Canisters	Stainless Steel
	Neutron Shielding	Borated Water/Ethylene Glycol
Cavity Atmosphere		He
Maximum Leak Rate (atm-cm^3/sec)		1.0 x 10-7

Overall Requirements

Handling Requirements

The UNL container is designed for various loading configurations for filling and draining in either the horizontal or vertical orientation. This allows the container to be adaptable to facilities with limited access or handling capabilities. Loading is accomplished by use of a transfer cask system that handles each container and is capable of draining and filling in either horizontal or vertical orientation. Each container is lifted/handled using a dry transfer system type grapple relying on a three-point outboard lift point design that meet the lifting requirements under ANSI 14.6 or alternative safe lift requirements.

Design Specifications

The UNL containers are constructed of Stainless Steel. Each UNL container shall accommodate the maximum volume of 15 gallons of material, which is the maximum amount to meet safety analysis conditions. Other key design requirements are:

a.) The UNL container can be used with the key system within the NAC-LWT to maintain orientation and prevent rotation of the container during transport, cask handling, and loading/unloading operations.

b.) The UNL container was designed to contain the contents during postulated accident transportation temperature conditions and fire accident (including freezing or boiling).

c.) Design and analysis criteria for the UNL container (as part of the NAC-LWT cask and in conjunction with the cask) shall comply with 71.41 through 71.51 of 10 CFR 71, 49 CFR 173, and International Atomic Energy Agency (IAEA) Safety Series No. SSR-6, Regulatory Guide 7.11, NUREG/CR-3854 and NAC-LWT Design Specification 315-S-14.

Content Conditions

The content conditions were established as part of the safety evaluation:

a.) Total Transport Inventory – The UNL container design was optimized for a single cask shipping capacity of 60 gallons.

b.) Design and safety analysis addresses material characteristics with respect to chemical composition, radioactive source terms, and heat generation.

c.) The maximum NAC-LWT cask contents including loaded UNL canisters is less than 4,000 pounds, consistent with the NAC-LWT SAR and CoC.

Structural Analysis Requirements

Limiting requirements were established so that the design content conditions meet the requirements in the NAC-LWT Design Specification. Some of the key requirements were:

a.) Allowable stress limits for the UNL container were as defined in ASME Code, Section III, Subsection NB, found to be bounding of the stress limits for pressure vessels used in the NAC-LWT SAR and/or allowable stress limits for internal components.

b.) Normal conditions of transport correspond to Level A Service Limits, and hypothetical accident conditions correspond to Level D Service Limits of the ASME Code.

c.) The structural analysis demonstrated that all normal operating and hypothetical accident structural loads imparted by the UNL container structure to the NAC-LWT containment vessel were bounded by previously approved SAR analyses.

d.) The structural analysis also demonstrated that the UNL container meets the stress criteria under normal conditions of transport and hypothetical accident conditions as currently specified in the NAC-LWT SAR.

Figure 3 Rendering of NAC-LWT Transport Cask Accommodating Four UNL Containers

Thermal Analysis Requirements

The bounding heat content of the UNL material (1.16 Watts per container) poses no challenges with respect to the thermal performance of the NAC-LWT cask and its components. In addition, the accident analysis considered any design basis conditions that postulated boiling, and also evaluated freezing conditions of the UNL material, demonstrating regulatory compliance and robustness of design.

Shielding Analysis Requirements

For a maximum source term of gamma emitters is 9.0 Ci/liter, the shielding analysis demonstrated that the package meets the applicable requirements of 10 CFR 71.47. Following the hypothetical accident conditions of 10 CFR 71.73, no external dose rate is found to exceed 1 Rem/h at 1 m from the external surface of the package in accordance with 10 CFR 71.51(a)(2).

Criticality Analysis Requirements

The fissile material content of the UNL material is less than 7.4 grams U235 per liter. Criticality analysis was performed to demonstrate the cask with UNL contents meets the applicable requirements of 10 CFR 71.55 and 10 CFR 71.59. The analysis was also performed meeting the applicable requirements of NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transport Packages," April 1997; in addition to applicable requirements of ANSI/ANS-8.1-1998; R2007, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors." Furthermore, the analysis relied on NRC-accepted criticality methods and modeling techniques appropriate to the UNL-type content conditions.

Containment Analysis Requirements

NAC's UNL containers were designed to provide additional containment, although not credited as such, beyond the NAC-LWT containment boundary. Their specific containment analysis easily demonstrated that that the UNL containers, as contents of the NAC-LWT cask assembly, met the applicable requirements of 10 CFR 71.51. In addition, the containment analysis of the UNL container was performed according to the requirements of NUREG/CR-6487, “Containment Analysis for Type B Packages Used to Transport Various Contents,” November 1996. The leak tight Containment Analysis presented in the NAC-LWT SAR was not affected by the UNL contents.

Materials Evaluation Requirements

The materials evaluation demonstrated that there are no reactions between any materials used in the fabrication of any component included in the NAC-LWT SAR amendment for UNL content that are not accounted for in the existing NRC Bulletin 96-04 response. The corrosion and effects of the UNL content in the containers were considered to impose inspection, testing and maintenance requirements on the utilization of the UNL containers.

Operating Procedures

The NAC-LWT operating procedures for the safe filling/loading and unloading/draining of the UNL container were developed providing appropriate controls for the monitoring and measurement of fissile materials during loading and unloading of the UNL containers. Up to four filled UNL containers are to be loaded into the NAC-LWT. Using empty (unfilled) containers as axial spacers is also permitted. Loading of containers and the cask may be performed in either the horizontal or vertical orientation, depending on facility capabilities and/or site requirements, with the appropriate configuration of the container and loading system. Each container is independently filled with UNL material and positioned within the NAC-LWT cask. Each container will have two ports, one vent and one drain/fill. Each port is connected to a material delivery system via dripless quick disconnects. After each container is filled, a cover-plate will be installed and leak tested prior to the container being loaded in the cask. As illustrated in Figure 4, a specially designed loading system permits loading of the containers in the horizontal orientation. The loading can also be performed vertically using the NAC standard dry transfer equipment. After completion of the container loadings, the NAC-LWT closure lid will then be installed. The closure lid and vent and drain port covers are leak tested in accordance with SAR requirements. The cask will be prepared for transport in a closed ISO shipping container in accordance with NAC-LWT CoC and U.S. DOT requirements.

At the receiving facility, unloading of containers may be performed in either the horizontal or vertical orientation, depending on facility capabilities and/or site requirements, with the appropriate configuration of the container and unloading system. The operations permit the removal, drainage and inspection of the containers. The containers may be reusable according to established maintenance and inspection procedures up to 18 months of total container filled time to account for the corrosive effects of the UNL material.

Figure 4 UNL Canister Horizontal Loading

Conclusions

The need for small transport packages capable of shipping UNL materials has been identified as a necessity to handle the waste streams from Mo-99 used in the production of medical isotopes. Traditionally, these waste streams have been stored and maintained at the isotope production reactor facilities, due to the limited options for packaging, transportation and disposition.

The NAC-LWT UNL container offers a modern transportation package such that this material can be shipped to a suitable disposal or processing facility. The system and components described in this paper provide a viable Type B package solution that can be used to ship these materials in sufficient quantities to justify the cost of an off-site disposition strategy. Furthermore, this offers a new opportunity to minimize proliferation risks, as it obviates the need for most facilities that generate irradiated UNL materials to expand on-site storage tanks or containers, resulting in the significant accumulation of UNL inventories worldwide. This paper has provided an overview of the general design requirements for the sealed irradiated UNL transport containers that now permits safe transportation of these materials in the NAC-LWT cask.