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A CONCEPT OF A NONFISSILE URANIUM HEXAFLUORIDE OVERPACK FOR STORAGE, TRANSPORT, AND PROCESSING OF CORRODED CYLINDERS

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DISCLAIMER

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ABSTRACT

There is a need to develop a means of safely transporting breached 48-in. cylinders containing depleted uranium hexafluoride (UF_6) from current storage locations to locations where the contents can be safely removed. There is also a need to provide a method of safely and easily transporting degraded cylinders that no longer meet the U.S. Department of Transportation (DOT) and American National Standards Institute, Inc., (ANSI) requirements for shipments of depleted UF_6.

A study has shown that an overpack can be designed and fabricated to satisfy these needs. The envisioned overpack will handle cylinder models 48G, 48X, and 48Y and will also comply with the ANSI N14.1 and the American Society of Mechanical Engineers (ASME) Sect. 8 requirements.

I. INTRODUCTION AND BACKGROUND

Cylinders used to contain and store depleted uranium hexafluoride (UF_6) are made of formed and welded American Society for Testing and Materials (ASTM) A516 or A285 carbon-steel plates. Nominal thickness is 312 mils; the minimum allowable thickness for safe transportation is 250 mils according to U.S. Department of Transportation (DOT) 49 CFR § 173.420. Cylinders used for transporting depleted UF_6 and shipping under "exclusive use" conditions are currently required to qualify as "strong tight containers" in accordance with 49 CFR § 173.425(b) and the additional requirements of 49 CFR § 173.420, "Uranium Hexafluoride (fissile, fissile excepted, and non-fissile)," and also to conform to the ANSI N 14.1-1990 "Uranium Hexafluoride Packaging for Transport."

The inventory of depleted UF_6, which is currently in long-term storage is located at the Oak Ridge, Tennessee, K-25 Site and the Paducah, Kentucky, and the Portsmouth, Ohio, gaseous diffusion plant sites.

During the FY 1992 baseline inspection of the K-25 cylinder storage yards, holes were discovered in the cylinder wall of four 48-in.-diam cylinders. The damage was attributed to improper handling and poor outdoor storage conditions. Because the K-25 Site has been permanently shut down, there is currently no suitable method for emptying the cylinders or performing transfer operations at that site.

All four cylinders with holes have been patched with a gasketed patch that was designed and tested at the K-25 Site. The patches are held in place by metal bands surrounding the cylinder. Each patch consists of an inner and outer patch that conforms to the shape of the cylinder. These cylinders do not meet the approved

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packaging requirements for shipping UF_6 in accordance with ANSI N14.1 and 49 CFR. Subsequently, steps have been taken to obtain permission in the form of a DOT exemption for transporting these four patched cylinders to the United States Enrichment Corporation (USEC) at the Paducah Gaseous Diffusion Plant, where the capabilities exist for safe handling and removal of the UF_6. However, other steps may be required before transportation is possible. These steps may include placing the damaged cylinders in a pressure-retaining overpack.

II. DEFENSE NUCLEAR FACILITY SAFETY BOARD FINDINGS

The Defense Nuclear Facilities Safety Board (DNFSB) has assigned dedicated staff to investigate and monitor the U.S. Department of Energy's (DOE's) depleted uranium activities as they pertain to the large inventory of UF_6 currently stored in cylinders at Portsmouth, Paducah, and the K-25 Site. At present, this inventory totals over 50,000 cylinders. This oversight activity has resulted in DNFSB Recommendation 95-1, dated May 5, 1995, which addresses the immediate stabilization and long-term disposition of the cylinders. While this recommendation does not specifically address the disposition of the breached cylinders, the technical report in support of the recommendation does negatively comment on K-25 Site's limited capability to safely manage the risks associated with the chemical hazards presented by this condition. The DNFSB staff members are cognizant of the condition of the cylinders, having inspected them visually in the field, and also are aware of the length of time the cylinders have been awaiting transfer.

The DNFSB staff have also noted in its technical report accompanying Recommendation 95-1 that it can be expected that more than 1000 cylinders have the potential to breach by the year 2020 if no remedial actions are taken to stop or decelerate the corrosion rates of the cylinder bodies. Even with remedial actions, the potential exists for additional cylinders to breach in the future.

III. IMPACTS OF FUTURE CHANGES IN TRANSPORTATION REGULATIONS

Internationally, it is expected that the 1996 edition of the International Atomic Energy Agency (IAEA) *Safety Series No. 6* transportation regulations will provide added requirements including thermal testing of cylinders containing more than 100 g of UF_6 regardless of enrichment level. The regulations are expected to cite the International Organization for Standardization 7195 Standard (the international equivalent of ANSI N14.1) and will also require a pressure test and a drop test. The thermal test may be avoided if the cylinder design is multilaterally approved (i.e., approved by the competent authority of the country of origin of the design and of each country through or into which the loaded cylinder is to be transported).

These changes in the regulatory requirements are being imposed primarily because of the concern to address the chemical, not the radiological, hazard of the material. This is significant when addressing the concerns of the breached and degraded thin-walled cylinders because of the concern for the chemotoxic nature of the UF_6, which hypothetically could be released from bare cylinders containing depleted UF_6 in the event of a severe transportation accident.

Ultimately, the changes being promulgated in the international regulations are expected to be imposed domestically in the United States. Thus, any requirements for an overpack for depleted UF_6 cylinders should consider these projected changes.

IV. IMPACTS OF FACILITY OPERATOR REQUIREMENTS

The enrichment facilities located at Paducah and Portsmouth are now leased to the USEC, which is a separate entity from DOE. To facilitate that arrangement, Lockheed Martin Utility Services was created to perform the management and operation of these facilities. The breached or questionable cylinders at K-25 may ultimately need to be shipped to the USEC facilities and will therefore need to be accepted by USEC. Thus, any solution to shipping these cylinders must also address facility requirements imposed by the receiving site.

V. OVERPACK DESIGN REQUIREMENTS

An overpack could provide a method for reducing the vulnerability of storage of breached or questionable cylinders at the K-25 Site by facilitating transport of these cylinders safely to the Paducah plant, which is located approximately 300 miles northwest of Oak Ridge in Paducah, Kentucky. The overpack will need to satisfy the original cylinder design requirements approved for shipment. When this project is

completed, future vulnerability will be reduced because a suitable overpack then will be available for use should transport of the four breached cylinders be required and also if additional breached depleted UF_6 cylinders are identified for which similar action is needed.

Three fundamentally different configurations of the proposed protective UF_6 cylinder overpack system were investigated in a preliminary study. The primary design requirement imposed on all three of these configurations was that the overpack vessel, when loaded with a damaged, deteriorated, or breached UF_6 cylinder, could safely be subjected to the same handling, storage, transportation, pressure, temperature, and operational requirements as new, pristine condition 48G, 48X, and 48Y UF_6 cylinders. Furthermore, it was required that the overpack be designed to accommodate each of these three UF_6 cylinder models.

Additional design requirements established for the study are:

1. The overpack design shall permit the removal of UF_6 from standard cylinders contained within the overpack using a 72-in.-internal-diameter autoclave. In addition, a separate connection or valve shall also permit the removal of any gaseous material contained within the annulus between the overpack and a leaking or breached cylinder contained within.

2. The overpack shall be a pressure vessel designed in accordance with ANSI N14.1 design criteria for cylinders. Design, fabrication, and testing shall be in accordance with ASME Boiler and Pressure Vessel Code, Sect. VIII, Division 1.

3. The vessel shall be "U" stamped and capable of containing an internal pressure of 400 pounds per square inch (psi). Preliminary analysis indicates that a vessel wall thickness of 0.750 in. will be conservatively acceptable. A reduction of this wall thickness is expected to occur during detail design.

4. The overpack shall be provided with both a pressure-relief valve and a pressure and vacuum gauge. A rupture disk that is designed to break at 110% of allowable pressure shall be installed upstream of the pressure-relief valve.

5. All construction materials, including seals, shall be acceptable for long-term storage in contact with UF_6.

6. Transportation and movement of cylinders shall be in the horizontal position at all time.

7. Any special cradles or support structure of the UF_6 cylinder shall be an integral part of the overpack.

8. The total weight of the overpack, containing a filled cylinder, shall not exceed DOT unrestricted transportation limits.

VI. OVERPACK DESIGN CONCEPTS

Three different design options were evaluated, and the advantages and disadvantages of each were identified as follows:

A. Vertically Loaded UF_6 Cylinder with Single Removable Overpack Head

This concept would require up-ending the cylinder, enclosed in a constraining, dedicated custom sling, followed by the vertical lowering of this assembly into an open-ended, upright pressure vessel. It would require a bolted sealing flange on one end of the pressure vessel overpack to effect closure.

Advantages:

a. Short seal length
b. Low sealing flange stresses and deflections
c. Low stresses and deflections of the overpack walls
d. Few sealing flange fasteners
e. No loading ramp is required for insertion
f. No internal tracks or rollers in the overpack vessel are required

Disadvantages:

a. Cylinder does not remain in horizontal position
b. Unacceptable impact loads on ends of cylinders resulting from the potential shifting of UF_6 within the cylinders during loading and unloading

This concept was not recommended.

B. Horizontally Loaded UF_6 Cylinder with Single Removable Overpack Head

This concept requires the horizontal insertion of the cradle-mounted cylinder into a cylindrical pressure vessel using a loading ramp and rollers. The cylinder

cradle includes runners or track. The companion rollers are part of the loading ramp and integral to the overpack. This arrangement permits the cradled cylinder to stand alone on its runners and also protects the rollers. This concept also requires a bolted sealing flange on one end of the overpack to effect closure.

Advantages:

a. Short seal length
b. Low sealing flange stresses and deflections
c. Low stresses and deflections of the overpack walls
d. Few sealing flange fasteners
e. Cylinder remains in horizontal position

Disadvantages:

a. Added design and fabrication costs for cradle
b. Added design and fabrication costs for loading ramp
c. Added design and fabrication costs for rollers
d. Added design and fabrication costs for mechanism to insert and remove cradled cylinders
e. Multiple handling operations
f. Loading ramp is required for horizontal insertion

Although not unacceptable, this concept was also not recommended because of the listed disadvantages.

C. Horizontally Loaded UF_6 Cylinder with Clamshell Overpack

This concept consists of a horizontal, clamshell pressure vessel into which a level cylinder, supported by dedicated slings, is lowered by a crane. Closure of the overpack cylinder would be achieved by bolting the two halves together at the midpoint sealing flange.

Advantages:

a. No special handling or support equipment needed
b. Lower fabrication and design costs
c. Cylinder moved only once during loading operations
d. Cylinder remains in horizontal position

Disadvantage:

a. Stresses and deflections in the flange area

This concept was recommended. It was determined that the single identified disadvantage could be resolved during design.

VII. PRELIMINARY DESIGN ANALYSES FOR THE HORIZONTALLY LOADED UF_6 CYLINDER WITH CLAMSHELL OVERPACK

Figure 1 depicts, in three-dimensions, the general concept considered, while Fig. 2 provides a cross-sectional view of the cylinder loaded into the overpack. As conceived, this overpack can also be used for storage, transport, and processing of damaged, breached, or questionable 48X, 48Y, and 48G depleted UF_6 cylinders.

Since there is a known structural problem for a horizontally split pressure vessel, this concept was evaluated using finite element analysis methods. The results of this analysis show a maximum-direction deflection in the Y-direction (vertical) of the flange of the overpack to be about 0.007 in. when the vessel is subjected to an internal pressure of 400 psi. The maximum displacement during normal operations will be less than half that value. The analysis also showed that flange rotation is a maximum of about 0.003 in. between the clamping bolts. These deflections and the rotation is much less than what is required to maintain a good seal.

The maximum Z-direction (lateral) deflection of the flange was calculated to be approximately 0.075 in. when subjected to the required internal pressure of 400 psi. This magnitude of displacement is of little consequence because the flanges on both halves of the clamshell will move together in the lateral Z-direction. Displacement between the two flanges will be negligible during normal operations.

Finally, it was determined that the Von Mises stresses in the flange areas are acceptable because they do not exceed yield of the steel at 400-psi internal test pressure. Normal operational pressure will be less than half that value.

VIII. CONCLUSION

A need exists to provide a structurally sound, operationally feasible overpack for the storage, transport, and processing of damaged, breached or questionable 48X, 48Y, and 48G depleted UF_6 cylinders. Requirements for the overpack have been developed.

A preferred concept has been defined, the basis for this definition has been documented, and a preliminary structural analysis for the preferred overpack has been performed.

This effort serves as the starting point for future design efforts on an overpack to reduce the vulnerability of storage of breached or questionable cylinders at the K-25, Paducah, or Portsmouth sites. For the K-25 Site, this vulnerability will be reduced by transporting these cylinders safely to an operating plant for processing.

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Fig. 1. Three-dimensional view of the horizontally loaded UF_6 cylinder clamshell overpack.

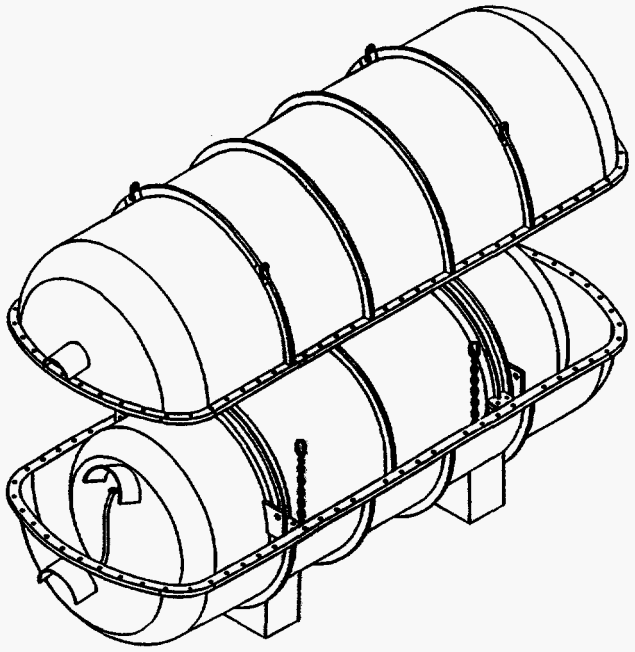

Fig. 2 Cross-sectional view of the cylinder loaded into the horizontally loaded UF_6 cylinder clamshell overpack.