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Uranium Hexafluoride (UF_6) Cylinders Periodic Inspections and Tests

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1. Introduction

Approximately 200 tons of Uranium Hexafluoride (UF_6) remaining after Low-Enriched Uranium (LEU) production for Pressurized Water Reactor (PWR) fuel were imported, and some of it was used for research purposes. Currently, remaining UF_6 185 tons are being stored and managed in annex to the Cold Neutron Science Facility at Korea Atomic Energy Research Institute (KAERI).

The stored UF_6 is highly chemically reactive and reacts with moisture in the air to produce UO_2F_2 and HF. Therefore, UF_6 is stored in standardized cylinders of a certain specification, and continuous management is required, such as periodic painting to prevent external corrosion of the carbon steel container material.

Although there is no legal requirement for evaluating the integrity of cylinders, we performed an assessment to ensure the safe storage performance of the UF_6 cylinders.

2. Methods of periodic inspections and tests

The UF_6 cylinders currently in use at KAERI were unable to undergo the 5-year periodic inspections required by ANSI N14.1 due to constraints such as the inability to empty their contents. Considering the current constraints, we selectively performed feasible items among those specified in the code to evaluate the integrity assessment of the operational suitability, residual life evaluation of the UF_6 cylinders according to API 579-1 FFS/ASME FFS-1. [1]

The UF_6 cylinders were produced in 1983 (1 cylinder) and 1986 (15 cylinders), and no periodic inspections specified in ANSI N14.1 were carried out after their installation, indicating a lack of basic data. Therefore, all the data collected in this assessment can be used as basic data for periodic evaluations in the future. Specification of the UF_6 cylinders is shown as Table I.

- Target: UF_6 cylinders
- Type: ANSI N14.1 48Y cylinders
- Quantity: 16 cylinders (KEPC 01~15 & 17)

2.1 Constraints

These cylinders are subject to the following constraints, as they cannot be moved in their UF_6 storage state or emptied of their contents.

- Data collection was based on ASME MDR (Manufacturer's Data Record) information due to lack of foundational data
- Constraints on measurement locations
- Errors in the prediction of actual thickness due to the calculation method used in the absence of initial thickness measurement data

Table I: UF_6 Cylinder Specification [2]

Model Number	48Y
Nominal Diameter (in)	48
Material of Construction	Steel
Approximate Tare Weight (Without Valve Protector) (lb)	5,200
Maximum Enrichment Wt% ^{235}U	4.5
Maximum Fill Limit (lb UF_6)	27,560

2.2 STEP 1: Collection of Design Basic Data

The minimum design data, including the year of manufacture, is indicated on the nameplate of products manufactured according to ASME BPVC (Boiler and Pressure Vessel Code). [3] Based on this, it is possible to obtain the MDR registered with The National Board of Boiler and Pressure Vessel Inspectors. MDR contains the following information:

- Buyer information
- Installation location
- Product shape/type/manufacturer's unique number/registration number/year of manufacture
- Manufacturing code
- Material used, dimensions, and other details
- Design data
  (design, operating pressure and temperature, etc.)
- Material testing conditions
- Pressure test and leak test conditions
- Material, welding, and non-destructive testing methods for each part of the product
- Details of flanges, fittings, material used, dimensions, etc. attached to the product

We conducted a reverse engineering method to recreate the drawings report, and the results are shown as Fig. 1.

2.3 STEP 2: Physical Integrity Assessment

All containers may differ from the originally designed conditions depending on usage conditions such as operating pressure, temperature, and environment. Therefore, periodic inspections can be conducted to assess the integrity of the container based on the product's design and manufactured codes.

According to section 5.4.2.2 of ANSI N14.1, the integrity assessment of cylinders requires a 5-year periodic inspection, and the following inspection items are required:

- Visual inspection of the cylinder by an ASME certified inspector (internal and external)
- Hydrostatic testing according to the cylinder fabrication code
- Tightness test for all connections (including fine tightness test)
- Visual inspection of lifting lug welds and magnetic particle inspection (MT) if necessary

Considering that the storage containers are currently in use and filled with UF_6, and there are various constraints such as the prohibition of container movement, we selectively applied applicable inspection items as follows:

- Visual inspection of the cylinder by an ASME certified inspector (external only)
- Visual inspection of lifting lug welds and magnetic particle inspection (MT) if necessary
- Measurement of container thickness, including cladding thickness
- Volumetric examination (ultrasonic examination) of complete penetration welds: longitudinal and transverse welds

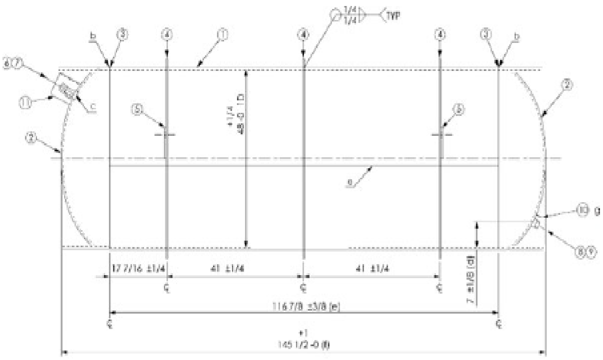

Fig. 1. UF_6 Cylinder Drawings

2.4 STEP 3: Assessment for Fitness-For-Service (FFS) & Life-Time-Evaluation (LTE)

FFS evaluation is a quantitative engineering assessment technique performed to evaluate the structural integrity of operating equipment. It helps determine whether components of equipment can continue to operate safely for a certain period. FFS evaluation can be used to make decisions regarding operation, maintenance, or replacement of the equipment.

API 579-1 FFS provides three levels of assessment for evaluating the FFS of equipment components such as pressure vessels. Level 1 is the most conservative, and the procedures included provide conservative screening criteria that can be used with minimal inspection or data on the components. Furthermore, the data obtained from this evaluation can be used to predict the remaining life of the equipment, known as LTE.

Since there is no accumulated data available for the UF_6 storage container owned by KAERI, a Level 1 evaluation was performed based on the data collected in STEP 2.

2.4.1. Level 1 Evaluation Method

Two different techniques can be used for the Level 1 FFS evaluation, based on the Coefficient of Variation (COV), which is calculated during the initial screening process.

Point Thickness Reading (PTR) uses thickness measurement data based on randomly or pre-selected measurement locations. Critical Thickness Profile (CTP) measures the minimum thickness by continuously measuring the entire cylinder using grid pattern data.

3. Conclusions

Through API 579-1 FFS/ASME FFS Level 1 evaluation of the 16 UF_6 cylinders at KAERI, it was determined that all 16 cylinders satisfied the operational integrity and there were no safety issues with their use. Additionally, the remaining life evaluation results were also derived accordingly.

However, these results were based on data collected from the manufacturer's data registered with the National Board and data collected during this assessment, without any accumulated data since installation in 1986. As a result, in order to ensure continuous integrity evaluation and data collection, a 5-year inspection cycle was set in accordance with ANSI N14.1.

REFERENCES

[1] American Petroleum Institute & The American Society of Mechanical Engineers, Fitness-for-Service, API 579-1/ASME FFS-1, 2021.

[2] American National Standards Institute, Packaging of Uranium Hexafluoride for Transport, ANSI N14.1, 2001.

[3] The American Society of Mechanical Engineers, BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1, 2021.