September 30, 2005

Mr. Richard W. Boyle
Radioactive Materials Branch
Office of Hazardous Materials
Technology
U.S. Department of Transportation
400 Seventh Street, S.W.
Washington, DC 20590

SUBJECT: EVALUATION OF 48-INCH URANIUM HEXAFLUORIDE CYLINDERS IN A FIRE

Dear Mr. Boyle:

As requested by your letter dated April 1, 2005, we have reviewed the report entitled "Investigation of 48-inch Diameter UF_6 Cylinders in the TS-R-1 Regulatory Thermal Environment," dated November 2004, by Shin H. Park. We also reviewed technical papers referenced in the report. The report presented a thermal analysis and evaluation of the ability of the cylinder to withstand the regulatory fire test conditions. We have included detailed technical comments in the enclosure to this letter.

Based on our review, the staff cannot conclude, with reasonable assurance, that the bare cylinder could withstand the regulatory fire test. For example,

- The extrapolation of the test data and simplifying modeling assumptions used in the thermal analysis in some cases may not be representative or conservative, and, therefore, the uncertainties in the analysis are largely undefined. Additional data would be useful in evaluating these uncertainties.

- The overall margin with respect to the time of cylinder failure in the analysis is not large enough to conclude that the analytical uncertainties are unimportant in predicting actual cylinder behavior in the regulatory fire.

- The analysis is largely based on physical testing done on modified cylinders heated within a furnace. These physical tests have characteristics that should be resolved with respect to cylinder wall temperature, test conditions, and prototype scaling. It is not clear that the test was an adequate representation of the regulatory fire test, or that the overall results would adequately represent cylinder behavior in a fire.

If you have any questions concerning this matter, please contact me or Nancy Osgood of my staff at 301-415-8500.

Sincerely,

/RA/

Robert J. Lewis, Chief
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

Docket No.: 71-3077
TAC No.: L23834

Enclosure: Technical Review Comments

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Enclosure: Technical Review Comments **ML052780503**

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TECHNICAL REVIEW COMMENTS
for Report Entitled
"Investigation of 48-inch Diameter UF_6 Cylinders
in the TS-R-1 Regulatory Thermal Environment"
by Shin H. Park
dated November 2004

Summary

By letter dated April 1, 2005, the U.S. Department of Transportation requested our review of the report entitled "Investigation of 48-inch Diameter UF_6 Cylinders in the TS-R-1 Regulatory Thermal Environment," dated November 2004, by Shin H. Park. The Park report documents results of an evaluation of the behavior of a 48-inch diameter cylinder containing uranium hexafluoride in fire test conditions.

Uranium hexafluoride that is not enriched, i.e., non-fissile, natural uranium hexafluoride, may be shipped in 48-inch diameter cylinders conforming to the designs in ANSI N14.1, "Uranium Hexafluoride–Packaging for Transport." Historically, these cylinders have been shipped "bare," that is, without thermal protection. There have been a number of evaluations performed to assess the ability of a bare cylinder containing uranium hexafluoride to withstand the regulatory fire test without rupture. One important evaluation included a series of physical tests using modified cylinders containing various quantities of uranium hexafluoride, which were heated within a furnace. This evaluation is named the Tenerife Program, and provides the primary test data that is used to support analytical evaluations.

Using the Tenerife data, the Park report uses analytical techniques to predict the cylinder temperatures in the regulatory fire and to predict the time of rupture of the cylinder due to internal pressure caused by heating of the uranium hexafluoride. In addition, various other studies regarding the behavior of filled cylinders were described. The staff's review included the Park report, as well as the referenced documents. The staff did not perform confirmatory calculations.

Based on the technical review, the staff cannot conclude, with reasonable assurance, that the bare cylinder could withstand the regulatory fire test. For example,

- The extrapolation of the test data and simplifying modeling assumptions used in the thermal analysis in some cases may not be representative or conservative, and, therefore, the uncertainties in the analysis are largely undefined. Additional data would be useful in evaluating these uncertainties.

- The overall margin with respect to the time of cylinder failure in the analysis is not large enough to conclude that the analytical uncertainties are unimportant in predicting actual cylinder behavior in the regulatory fire.

- The analysis is largely based on physical testing done on modified cylinders heated within a furnace. These physical tests have characteristics that should be resolved with respect to cylinder wall temperature, test conditions, and prototype scaling. It is not clear that the test was an adequate representation of the regulatory fire test, or that the overall results would adequately represent cylinder behavior in a fire.

Technical Review Comments

The staff reviewed the Park report and the associated reference documents. The following review comments were noted. These comments provide the basis for the staff's conclusion, as stated above.

1. According to reference 1 of the Park report, the function of the electric oven was to heat the outside walls of the test container by radiation. The container-oven assembly was thus placed in an enclosure under a vacuum, called the enclosure tank. Figure 2 of the Park report shows wall cylinder temperature in the upper section. The temperature increase on this part of the cylinder seems to be unusually slow when compared to results from other thermal tests or computer simulation for the fire test conditions. Typically, the temperature of the outer wall increases very rapidly (in a mater of 4 to 5 minutes) to values which are closer to 800°C. One reason for this slow increase could be that radiation is the only heat transfer mechanism from the ambient (oven) to the container walls.

2. The Park report states that “Since the Tenerife test was conducted with a 1/3 length 48Y uranium hexafluoride cylinder in full capacity (62 percent of solid volume in the test cylinder), a simulated numerical model constructed based on the Tenerife data would be credible.” This justification seems vague and is not convincing. There should be a complete technical justification regarding the validity of reducing the specimen to 1/3 the length of a typical 48-inch diameter cylinder.

3. The Park report states that with the variations of the temperatures in the cylinder wall and the uranium hexafluoride, the pressure measurement seems to be the most reliable data. This may be a valid point since, according to the thermal test, the cylinder may rupture because of high pressure developed in the cylinder. However, when considering the extrapolation as shown on Figure 3 of the report, the calculated results appear to be falling on the non-conservative side, even though the model does an excellent job of predicting pressure until the point when heat was shut down.

4. The developed model includes many modeling simplifications and the analysis states the reasons behind those simplifications and the inability to correctly include them in the model. However, the report does not indicate how these factors may play different roles at different stages of the fire event. Keeping the number of assumptions and simplifications to a minimum could have resulted in a better prediction.

5. A major simplification of the model includes the use of a convective heat transfer coefficient of 0.1 Btu/min.ft^2°F, which is used as an effective coefficient that best fits the data. This coefficient includes the effect of the evaporation and condensation of uranium hexafluoride. The use of the above convective heat transfer coefficient value may have resulted in a good comparison of the model to the limited measured data, however, it is not clear that use of this value is valid for accurately predicting the behavior in the regulatory fire test.

6. According to Figure 6, assuming that scaling of the 1/3 to a full-length cylinder is acceptable, the model predicts a safety factor of 12 minutes before the cylinder fails. No uncertainties are discussed or factored into the analysis.

7. The report states that

> "The simplified model, which was validated with Ten4 data, calculates the temperatures and pressure beyond the Ten4 data range of 19.5 minutes. Given the short time, i.e., 4-5 minutes, that the cylinder temperatures and pressure are calculated beyond the Ten4 data range, the extrapolation is justified. It is also reasonable to assume that there is no internal/external factor that would cause drastic changes in the uranium hexafluoride evolution process during the short period beyond the end of 19.5 minute timeframe."

The justification for the extrapolation does not appear to be technically convincing. This is a very dynamic event, especially at the time where the pressure starts to increase more rapidly. Extrapolation could be missing the most important dynamic part of the fire event.