71-6553

USEC
A Global Energy Company

February 29, 2000
GDP 00-0032

Mr. William F. Kane
Director, Office of Nuclear Material Safety and Safeguards
Attention: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Paducah Gaseous Diffusion Plant (PGDP)
Docket No. 71-6553
Proposed Changes to the Paducah Tiger Overpack Safety Analysis Report

Dear Mr. Kane:

The United States Enrichment Corporation (USEC) herein submits for NRC review and approval a change to KY-665, Revision 1, "Safety Analysis Report on the 'Paducah Tiger' Protective Overpack for 10-Ton Cylinders of Uranium Hexafluoride". This report is incorporated by reference in Certificate of Compliance No. 6553 for the Paducah Tiger Overpack (PTO). As a result, USEC requests that the NRC issue a revision to Certificate of Compliance No. 6553. To help the NRC schedule its review resources, USEC informed the NRC of its intent to submit this request in the Reference.

The proposed change to the PTO Safety Analysis Report (SAR) is associated with the Paducah Production Flexibility Project. This project will provide USEC options to maintain a reliable and economical source of enrichment services in the United States, which is a high priority for USEC. Enclosure 1 to this letter provides a detailed description of the change. The actual revised PTO SAR pages are provided in Enclosure 2 with the Removal/Insertion Instructions. The technical basis that supports the change is summarized in Enclosure 3.

USEC met with the NRC staff on December 20, 1999 and January 28, 2000 to discuss this change and the supporting technical basis. Consistent with the project schedule presented at the most recent meeting, USEC requests NRC approval by August 31, 2000. Any questions regarding this matter should be directed to Dr. Elizabeth Darrough at (301) 564-3422. There are no new commitments contained in this submittal.

Sincerely,

M.D. Smith

Steven A. Toelle for
Nuclear Regulatory Assurance and Policy Manager

USEC Inc.
6903 Rockledge Drive, Bethesda, MD 20817-1818
Telephone 301-564-3200 Fax 301-564-3201 http://www.usec.com

NMSS01Public

Enclosures:

1. United States Enrichment Corporation (USEC), Detailed Description of the Changes to KY-665, "Safety Analysis Report on the "Paducah Tiger" Protective Overpack for 10-Ton Cylinders of Uranium Hexafluoride," Revision 1.

2. United States Enrichment Corporation (USEC) Certificate Amendment Request, Paducah Gaseous Diffusion Plant, Letter GDP 00-0032, Removal/Insertion Instructions.

3. Technical Basis Supporting Changes to KY-665, Revision 1, "Safety Analysis Report on the "Paducah Tiger" Protective Overpack for 10-Ton Cylinders of Uranium Hexafluoride."

Reference: Letter from Steven A. Toelle (USEC) to E. William Brach (NRC), "Intent to Request Revision to Certificate of Compliance No. 6553", Docket 70-7001, GDP 00-0024, dated February 4, 2000

cc: E. Brach, NRC HQ
C. Chappell, NRC HQ
P. Hiland, NRC Region III Office
K. O' Brien, NRC Resident Inspector - PGDP
D. Hartland, NRC Resident Inspector - PORTS

United States Enrichment Corporation (USEC)
Detailed Description of the Changes to
KY-665, "Safety Analysis Report on the 'Paducah Tiger' Protective Overpack for 10-Ton Cylinders of Uranium Hexafluoride," Revision 1

Description of Change

To support the Higher Assay Upgrade portion of the Paducah Production Flexibility Project, USEC has determined that an increase in the current limit of residual UF_6 in the Paducah Tiger Overpack (PTO) Safety Analysis Report (SAR) is needed. Specifically, changes are proposed to PTO Safety Analysis Report Revision 1 Section 3.5.1 "Thermal Model", Section 3.5.6 "Evaluation of Package Performance for Hypothetical Accident Thermal Conditions", Section 4.2.2 "Pressurization of Containment Vessel" and Section 7.1.2, "Loading the Overpack." The proposed change increases the lower cylinder fill limit of residual UF_6 that can be shipped in the 48X cylinder from 350 pounds to 1500 pounds. The bases for the change and for the analytical model are also provided.

Reason for Change

As a result of the Higher Assay Upgrade Project, USEC will introduce up to 4.5 wt % UF_6 into 48X 10-ton cylinders at Paducah. These cylinders will then be transported in PTOs to Portsmouth for transfer into fuel fabricators' 2.5 ton cylinders by draining liquid UF_6 from the 48X cylinder into 30B cylinders. Although the operation involves rolling and tilting the cylinder, some liquid UF_6 will remain below the valve and cannot be transferred. To remove the remaining UF_6 would require a vapor transfer into an evacuation source (such as an operating cascade or cold trap). Since this vapor transfer is time consuming and requires the use of an autoclave, it is advantageous to simply ship the cylinders back to Paducah without further processing. This is not currently an issue because the 48X cylinder is evacuated below 350 pounds using the autoclaves with the Portsmouth cascade serving as an evacuation source.

Sections 3.5.6 and 7.1.2 of the PTO SAR currently limit the amount of residual UF_6 in the 48X cylinder to 350 pounds. In order to provide increased flexibility in the operation of USEC's two enrichment facilities, USEC proposes to increase the maximum limit of residual UF_6 that could be in the 48X cylinder from 350 pounds to 1500 pounds. The new higher limit was analytically determined to be acceptable by conservatively demonstrating that this amount of UF_6 could not result in the cylinder reaching its design pressure limit when a thermal transient as described in Chapter 2 of the PTO Safety Analysis Report is assumed.

Justification of the Change

The technical justification for the change is included as Enclosure 3.

United States Enrichment Corporation (USEC) Certificate Amendment Request Paducah Gaseous Diffusion Plant Letter GDP 00-0032 Removal/Insertion Instructions	
Remove Page	**Insert Page**
PTO SAR	
3.5-1, 3.5-4, 4.2-2, 7.1-1	3.5-1, 3.5-4, 4.2-2, 7.1-1

United States Enrichment Corporation
Paducah Gaseous Diffusion Plant

KY-665, Safety Analysis Report On The "Paducah Tiger" Protective Overpack for 10-Ton Cylinders of Uranium Hexaflouride

REVISION LOG

Date	Description
7/15/99	Initial Issue. Complete Revision of all pages
2/29/00	Submittal issued to increase the amount of residual UF_6 allowed for shipment in the overpack. Sections revised include 3.5.1.1, 3.5.1.2, 4.2.2 and 7.1.2

3.5 Hypothetical Accident Thermal Evaluation

The Hypothetical Accident Condition (HAC) specifies that the container be subjected to a 30-minute fire at a temperature of 1475°F (800°C) using a flame emissivity of 0.9. A surface absorptivity coefficient of no less than 0.8 must be used for the container surfaces. After the fire, the container is allowed to cool by radiation and convection to the ambient conditions at a temperature of 100°F.

3.5.1 Thermal Model

3.5.1.1 Analytical Model

An analytical model was developed and used to evaluate the thermal performance of the Paducah Tiger overpack containing a partially full 48X cylinder. The model bounded the physical damage from the finite element analysis detailed in Section 2.7. The results of this analysis are only utilized for validating the maximum lower fill limit for shipment delineated in Section 3.5.6.

3.5.1.2 Test Model

A damaged package, consisting of a prototype Paducah Tiger overpack and a 48X cylinder filled with more than 20,000 pounds of steel shot and $BaSO_4$ to simulate an actual fully loaded cylinder, was subjected to a 1475°F fire test conducted by Protective Packaging, Inc., of Tacoma, Washington in November 1971. [9] This test is included as Appendix A. Before undergoing the fire test, this single test package was subjected to two different series of drop tests. Each series of drop tests involved a 30-foot free drop test followed by a 40-inch pin puncture test. In addition, each series of drop tests was performed on opposite edges of the overpack, one on the lid and the other on the body. [10] Therefore, the prototype incurred twice as much physical damage as required by the 10 CFR 71.73 hypothetical accident conditions.

The second series of drop tests, where mild carbon steel breakaway plates were used on the bottom of the overpack body, caused the greatest damage to the package. The 6-inch diameter bar penetrated the outer skin, breakaway plates, foam, and 3/16-inch carbon steel inner liner of the overpack, thus exposing the foam insulation and the 48X cylinder to the external environment. Due to design changes since the development of the prototype which was actually tested, this level of damage would not occur to a production overpack. The carbon steel breakaway plates which were punctured on the prototype were not used in the production

The fire test resulted in temperatures that exceed the cylinder design temperature (250°F). However, the physical testing exposed the overpack to temperatures well in excess of the testing requirements (1820°F vs 1475°F), portions of the overpack were exposed to elevated temperatures for almost an hour, and no credit is taken for the high heat of fusion of UF_6. Even if the entire cylinder and contents reached a temperature of 275°F, the resulting pressure (approximately 135 psia) is well within the design pressure of the cylinder of 200 psig. Cylinders partially loaded with UF_6 were also evaluated, and it was determined that 48X cylinders must contain a "minimum fill" level of 12,000 pounds (approximately 60% of the UF_6 in a nominally filled cylinder) of UF_6. An equivalent amount of energy is required to heat 12,000 pounds of UF_6 to 275°F as is required to heat the 20,000 pounds of barium sulfate/steel mixture that was used in the actual fire testing to 275°F.

The analytical model discussed in Section 3.5.1.1 provided results that demonstrate any 48X cylinder containing between 100 and 1500 lbs UF6 would not exceed the cylinder design pressure of 200 psig. Likewise, the vapor density of UF6 at 1475°F and 200 psig (the 48X cylinder design pressure) being 3.35 lb/ft3, is such that 100 lbs of UF6 or less does not exceed the 48X cylinder design pressure. 100 lbs of UF6 under these conditions occupies less than 33 ft3, which is far below the minimum certified 48X cylinder volume of 108.9 ft3. Because the density remains constant in this calculation, smaller amounts of UF6 would occupy an even smaller volume. Additionally, the maximum resulting shell temperature (322°F) does not challenge the integrity of the 48X cylinder because the components required for containment (e.g. valve seats, Teflon gaskets, and tin applied to threads) can all withstand a temperature of at least 361°F. Therefore, given the analytical model results, and the fact that 100 pounds of UF6 will not fill the 48X cylinder at 1475°F and 200 psig, 48X cylinders containing 1500 pounds of UF6 or less may be shipped. Likewise, 48X cylinders containing at least 12,000 pounds of UF6 may be shipped because they will provide the necessary heat load during the thermal event to ensure the design pressure is not exceeded. However, 48X cylinders containing more than 1500 pounds of UF6 but less than 12,000 pounds of UF6 have not been analyzed and therefore, must not be shipped.

4.2.2 Pressurization of Containment Vessel

During filling with liquid UF_6, the maximum temperature inside the 48X cylinder is 180°F. This temperature corresponds to an internal UF_6 gas pressure of 40 psia. As the UF_6 cools and solidifies, the pressure in the cylinder drops below atmospheric prior to shipment.

At the maximum normal temperature for UF_6, 135.4 °F, the vapor pressure is considerably less than 22 psia (Section 3.4.4). At the maximum temperature for a fire accident, 322 F, the vapor pressure is 177 psig (Section 3.5.4). These values are below the ANSI N14.1 design pressure of 200 psig.

4.2.3 Containment Criterion

The 48X cylinder is air pressure tested to 100 psig. A soap bubble test is used to test for air leaks.

The 1-inch cylinder valve is pressure tested to 400 psig. The pressure test is applied to both the valve seat and to valve stem packing by partly opening the valve with the valve outlet port capped. A bubble test, using either a soap bubble test method or immersion in water, is used to demonstrate a leak-tightness of the valve seat and valve stem packing.

Since the cylinder contains less than the A_2 value of the mixture, no leak rate calculation is required. These tests demonstrate that the cylinder and valve adequately contain the UF_6 and heel contents.

7.1 LOADING THE PADUCAH TIGER

The Paducah Tiger is intended for the shipment of a 48X 10-ton cylinder. The cylinder may be full or contain a heel. Cylinders containing UF_6 must be inspected in accordance with ANSI N14.1. Cylinders which are empty (i.e., net weight less than 50 pounds) need not be handled in accordance with this procedure.

Prior to loading the cylinder into the overpack, the lower half (body) of the overpack must be secured to the floor or bed of the conveyance. The conveyance may be a dedicated rail car or a truck trailer. The overpack is only attached and detached from the conveyance when empty.

7.1.1 Inspection of the Overpack and 48X Cylinder

Inspection of the overpack and the 48X cylinder is required to verify that both are acceptable for use. Defects identified in the inspection must be corrected before use.

1. Inspect the overpack in accordance with Table 8.2-1.
2. Inspect the 48X cylinder in accordance with the requirements of ANSI N14.1.
3. Visually inspect the cylinder lifting lugs prior to attachment of the lifting slings.
4. Perform a surface contamination survey and a radiation survey, and record the survey results.

7.1.2 Loading the Overpack

Loading of the overpack requires a suitable lifting device. The body of the overpack must be secured to the bed or floor of the conveyance prior to loading the cylinder into the overpack. Prior to loading the 48X cylinder into the overpack, verify that the UF_6 weight is either less than or equal to 1450 pounds (analyzed limit less 50 pounds measurement uncertainty margin), or between 12,000 and 21,030 pounds; and that the pressure within the cylinder is less than 0 psig.

1. Using a suitable lifting device, place the cylinder into the overpack body with the valve end of the cylinder facing the lid guide in the body.
   CAUTION: The opposite (nonvalve) end of the cylinder is tapered. The tapered end of the cylinder must rest in the matching tapered shape of the body of the overpack. The body of the overpack may be damaged if the cylinder is not correctly oriented.

Technical Basis
Supporting Changes to KY-665, Revision 1
"Safety Analysis Report on the Paducah Tiger Protective Overpack for 10-Ton Cylinders of Uranium Hexafluoride"

Introduction

USEC is requesting an increase in the lower cylinder fill limit of residual UF_6 for shipment of 48X cylinders in the Paducah Tiger Overpack. The current lower cylinder fill limit in the Paducah Tiger Overpack SAR (KY-665, Rev. 1) is 350 pounds. This limit was derived by determining the amount of UF_6 which would reach the design pressure of the 48X cylinder (200 psig) at hypothetical accident conditions (1475°F). Due to the extensive conservatism of this calculation resulting from the assumption that the bulk UF_6 is at the accident temperature, USEC evaluated the effects of increasing this limit to 1500 pounds. In order to account for inaccuracies involved in the transfer operation (e.g., scale inaccuracy) the operational limit (in Section 7 of KY-665, Rev. 1) is set at 1450 pounds. This limit is justified by the facts that the 1) scale accuracy is on the order of +/- 7 pounds and 2) that the parent (48X) cylinder is weighed before the transfer operation and each daughter (30B) cylinder is weighed during each transfer. Each parent cylinder can be transferred into approximately 4 daughter cylinders, thus introducing up to 40 pounds of error into the estimated weight of the parent cylinder. Therefore, the limit of 1500 pounds is conservatively reduced by 50 pounds.

To justify the increase to 1500 pounds, a finite element analysis was performed in 2 phases. (Ref. 1 & 2) The first phase was a thermal transient which conservatively predicted the 48X cylinder shell temperature as a function of time and location on the cylinder during the hypothetical accident condition specified in 10 CFR 71.73. The second phase consisted of a fluid flow analysis which determined the resulting UF_6 temperature and pressure. Each analysis phase is discussed in more detail below.

Phase I – Thermal Transient Analysis

The thermal transient analysis was performed on an overpack which exhibited damage that bounded what is described in Chapter 2 of KY-665, Rev. 1. The damage described in Chapter 2 of KY-665 was incurred on a package that weighed 40,000 pounds, the maximum allowed by the Paducah Tiger Certificate of Compliance. Actual package weight incorporating the requested lower fill limit (1500 pounds) increase is less than 19,000 pounds. Since substantially less damage would have been incurred on this lighter package, assuming damage that bounds that described in Section 2 of KY-665 is a conservative assumption. For example, had the model been developed to predict the damage caused by the drop test and puncture test for a 19,000 pound package and had that damage been used in the thermal analysis, substantially more foam could have been credited for providing thermal insulation to the 48X cylinder during the hypothetical fire.

Prior to initiation of the thermal transient, the insolation requirements of 10 CFR Part 71 were applied to the Paducah Tiger. This insolation resulted in an initial cylinder shell temperature of 156°F, which is above the triple point of UF_6. Therefore, at the onset of the thermal transient UF_6 would exist in a liquid/vapor equilibrium. In order to bound the heat input to the system, all UF_6 is modeled as a solid throughout this phase. Since solid UF_6 exhibits a higher thermal conductivity than either liquid or vapor, this approach is conservative. As discussed below, Phase II assumed all of the UF_6 to be vapor, thus eliminating heat consumption through the latent heats of fusion or vaporization and introducing additional conservatism into the calculation.

The thermal transient was allowed to continue until sufficient evidence was obtained to prove the full effects of the thermal event (Ref. 10 CFR 71.73(c)(4)) had been considered, i.e., the analysis was allowed to continue until the model showed that the 48X cylinder began transferring heat to the overpack. This analysis resulted in a maximum cylinder skin temperature of 322°F. This temperature is conservative with respect to the UF_6 temperature reported after physical testing of the Paducah Tiger of 275°F (Ref. KY-665, Rev. 1) which was originally used to determine the "minimum fill" limit of 12,000 pounds UF_6. The cylinder skin temperature (322°F) as a function of time and location on the cylinder was then used as an input to a subsequent analysis which determined the resulting UF_6 temperature (as discussed in "Fluid Flow Analysis", below). Therefore, the method for determining the lower fill limit discussed in this Technical Justification is highly similar to the previous method used to determine the minimum fill limits. Additionally, even this temperature (322°F), which was purposely modeled to provide conservative results with respect to predicted pressure, would not challenge the integrity of the cylinder materials. Nonmetallics in the cylinder are limited to the teflon gasket in the cylinder valve which can withstand operating temperatures of up to 500°F. The tin applied to the valve and plug threads exhibits a solidus temperature of 361°F (Ref. ASTM B32, Alloy Sn50). Note that due to reaction kinetics, superheat would be required in order to melt the tin contained on the plug or valve threads. Therefore, the point at which the solder would begin to melt under accident conditions is higher.

Other cylinder components (e.g., shell, valve, and plug) are able to withstand the resulting temperatures because they are metals with much higher solidus temperatures.

Phase II- Fluid Flow Analysis

Given the results of the thermal transient, a fluid flow analysis was performed. This analysis applied the 48X cylinder shell temperature distribution as a function of both location on the cylinder and time. Throughout this analysis the UF_6 contained in the 48X cylinder was assumed to be 100% vapor. No credit was taken for heat removed from the system as a result of the latent heat of fusion or the latent heat of vaporization.

Furthermore, additional solid UF_6 was included in the cylinder (which was not allowed to absorb any heat) in order to ensure the amount of heat which could be transferred to the UF_6 vapor was adequately bounded. Solid UF_6 was chosen because it has a higher thermal conductivity than liquid UF_6. The fluid flow analysis illustrated that the maximum UF_6 pressure was 177 psig, which is less than 90% of the 48X design pressure (Ref. ANSI N14.1-1990).

Conclusion

It is concluded that this thermal analysis of the Paducah Tiger overpack demonstrates the overpack's ability to provide adequate protection for 48X cylinders containing 1500 pounds UF_6 or less when exposed to the hypothetical accident conditions of 10 CFR Part 71.73, thus ensuring that the structural integrity of the cylinder is not compromised. Therefore, USEC requests an increase to the lower cylinder fill limit from 350 pounds UF_6 to 1500 pounds UF_6. This increase is justified by a finite element analysis which is consistent with physical testing and shows that the cylinder pressure remains below 90% of the design pressure during the thermal event even with conservatisms in the model which included the following:

1) Limited amount of foam available for thermal insulation due to the model considering damage incurred by a package weighing 40,000 pounds corresponding to a package containing a full cylinder.
2) No credit taken for heat absorbed by the latent heat of fusion or the latent heat of vaporization.
3) Additional solid UF_6 included in the model in order to adequately bound the amount of heat being transferred to the cylinder contents.

References:

1) NAC International "Fire Transient Thermal Analysis of the Paducah Tiger Overpack and 48X Cylinder", Calculation No. 12408-300-01, Rev. 0, dated December 20, 1999.

2) NAC International "The Two Dimensional Fluid Flow Analysis of the UF_6 for the Fire Accident Conditions", Calculation No. 12408-300-02, Rev. 0, dated January 24, 2000.