

**Criticality Safety Aspects of  
K-25 Building Uranium Deposit Removal**

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Paper for Presentation

at the

1995 American Nuclear Society Annual Meeting

June 25-29, 1995  
Philadelphia, Pennsylvania

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# Criticality Safety Aspects of K-25 Building Uranium Deposit Removal<sup>1</sup>

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## INTRODUCTION

The K-25 Building of the Oak Ridge Gaseous Diffusion Plant (now the K-25 Site) went into operation during World War II as the first large scale production plant to separate <sup>235</sup>U from uranium by the gaseous diffusion process. It operated successfully until 1964, when it was placed in a stand-by mode. The Department of Energy has initiated a decontamination and decommissioning program.

The primary objective of the Deposit Removal (DR) Project is to improve the nuclear criticality safety of the K-25 Building by removing enriched uranium deposits from unfavorable-geometry process equipment to below minimum critical mass.

Although the likelihood of a nuclear criticality accident is considered remote, the

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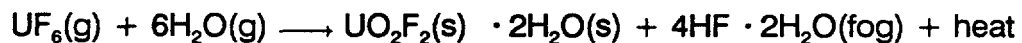
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existence of large enriched uranium deposits in unfavorable-geometry process equipment is inherently unsafe. Thus, deposit removal activities are being conducted in the K-25 Building to enhance safety. Department of Energy orders require that the calculated probability of a nuclear criticality event be less than one in a million ( $10^{-6}$ ) per year (Reference 1).

### GRADED APPROACH

Original nuclear criticality safety evaluations of diffusion plant equipment were based on maintaining uranium in the gas phase of  $UF_6$ . In the event of a freeze-out, i.e., deposit formation, a nuclear criticality accident was not likely because levels of moderation available in an operating diffusion plant are low. In general, uranium deposits are formed when gaseous  $UF_6$  reacts with moisture in air (from air leakage into process equipment) to form  $UO_2F_2$  and various other chemical compounds. The typical reaction of gaseous  $UF_6$  with water vapor at room temperature is



A graded approach will be used in removing deposits. Deposits will be removed from the simpler equipment first (e.g., tubing, piping) before attempting to remove them from equipment with complex geometry. Also, prototype removals will be conducted for each type of equipment before removing deposits of greater than the subcritical  $^{235}\text{U}$  mass limit of 760 g. These practice sessions with equipment containing low amounts of enriched uranium will be used to test methods and procedures to ensure safe operations.

The Phase I schedule for equipment removal calls for compressor blowout preventer tube removal in FY 1994; large (12 in. diam) pipe removal in FY 1995; large (12 in.) valves, cold traps, chemical traps, and surge tanks in FY 1996; compressors and large pumps in FY 1997; and converters in FY 1998.

## FACILITIES

A special facility (Reference 2) has been constructed for deposit physical, i.e., mechanical, removal. The Deposit Removal (DR) Room is a 60x20x10-ft room within the K-25 building and was originally used as a maintenance area. The room contains work tables, temporary storage areas, a nondestructive assay measurement area, a 10x4x6-ft glove box, and a 1-t capacity overhead monorail system for lifting heavy objects. The intent is to remove deposits from equipment within the glove box.

Efforts are underway to examine techniques for removing deposits other than using physical and mechanical methods. For example, a fluorination ( $\text{ClF}_3$ ) process is being investigated as a means of converting solid deposits on equipment surfaces, in situ, to volatile fluoride compounds that can be pumped away to gas treatment systems.

## METHODS USED IN CRITICALITY SAFETY ASSESSMENTS

National standards, Department of Energy orders, Martin Marietta Energy Systems, Inc. policies and procedures, K-25 Site guidelines, and detailed computer calculations are used in planning and conducting the deposit removals. Wherever possible, detailed calculations are avoided by relating fissile material mass, conditions, and configurations to the ANSI/ANS 8.1 Standard (Reference 3), the K-25 criticality safety guide (Reference 4), and an ORNL report on estimated critical conditions for  $\text{UO}_2\text{F}_2\text{-H}_2\text{O}$  systems (Reference 5). Where detailed calculations are required, e.g., the design of a critically safe vacuum cleaner, they are performed with the SCALE/CSAS25 (KENO V.a) code (Reference 6) and the ENDF-B/IV 27 group cross section library (Reference 7).

A nuclear criticality safety engineer has been assigned to the project. The removal of highly enriched uranium involves many small process steps, and a nuclear criticality safety assessment is performed for each step. A three-site (K-25, Oak Ridge National Laboratory, and Y-12) team of nuclear criticality safety engineers conduct technical peer reviews for each nuclear criticality safety assessment.

#### METHODS OF NUCLEAR CRITICALITY CONTROL DURING DEPOSIT REMOVAL

Safe geometry is used as a control wherever possible during the deposit removal process. Many deposits exist in process equipment of unfavorable geometry for non-gas-phase materials. Demonstrated double-contingency control is reestablished by removing the deposit into safe-geometry containers. Safe geometry is used as the primary control in support equipment (e.g., deposit collection bottles, HF traps). The next most desirable control is mass. Since by definition the objective of the project is to remove relatively large masses, limiting  $^{235}\text{U}$  mass handled to less than a minimum critical mass is not always possible. The single most important control for deposits in unfavorable-geometry equipment is the control of bulk moderators such as water, oil, etc. Interaction and reflection are examples of secondary controls.

Immediately prior to its removal, equipment is tested for any free-standing liquid by drilling holes at the lowest points. During equipment removal from the cascade, the fire protection sprinkler system is disabled. Equipment openings are sealed closed during transport to the DR Room and while outside the DR Room glove box. Physical, dry methods (i.e., wire brushes, scraping) are used to remove deposits. Only a small amount (less than 4 L) of liquid is permitted for wiping and cleaning.

The double-contingency principle is applied wherever possible. The principle states that "at least two unlikely, independent, and concurrent changes in process conditions (i.e., controls) must occur before a criticality accident is possible." The deposits, as they presently exist, are the result on ongoing, abnormal conditions of operation and do not meet the double-contingency principle. A change in moderation and/or geometry, for example, could result in criticality in their present condition. Administrative controls are present to prevent changes in moderation and geometry (i.e., such as masses of uranium coming together to form a larger volume) to maintain an acceptable level of nuclear safety.

In summary, the object of the Deposit Removal Program is to remove and place uranium deposits into a safe geometry to meet the double-contingency principle. There are portions of the deposit removal process where the double-contingency principle cannot be met since it is not originally present. Each step of the removal process takes us to safer conditions where multiple controls will be present. Upon completion of the project, nuclear criticality safety concerns will be greatly reduced.

## REFERENCES

1. DOE Order 6430.1A, Section 1300-5.
2. Ladd, L. D., L. C. Hensley, M. J. Haire, M. R. Jugan, "Uranium Deposit Removal from the K-25 Gaseous Diffusion Plant," 1994 Decontamination and Decommissioning International Symposium, April 24-29, 1994, Knoxville, Tennessee.
3. American National Standard Institute/American Nuclear Society (ANSI/ANS) Standard 8.1, 1983.
4. Henry, H. F., A. J. Mallett, C. E. Newlon, and W. A. Pryor, "Criticality Data and Nuclear Safety Guide Applicable to the Oak Ridge Gaseous Diffusion Plant," K-1019, Fifth Revision, May 22, 1959.
5. Jordan, W. C., J. C. Turner, "Estimated Critical Conditions for  $UO_2F_2$ - $H_2O$  Systems in Fully Water Reflected Spherical Geometry," ORNL/TM-12292, December 1992.
6. Oak Ridge National Laboratory, "SCALE: A Modular Code Systems for Performing Standardized Computer Analyses for Licensing Evaluation" {computer program}, Volumes 1-3, NUREG/CR-0200, U.S. Nuclear Regulatory Commission (originally issued July 1980, reissued January 1982, Revision 1 issued July 1982, Revision 2 issued June 1983, and Revision 3 issued December 1984).
7. "SCALE Cross-Section Libraries," W. C. Jordan, NUREG/CR-0200, Vol. 3, Section M4, or ORNL/NUREG/CSD-2/V3/R3, November 1993.