CRITICALITY SAFETY FOR DEACTIVATION OF THE ROVER DRY HEADEND PROCESS

Deborah J. Henrikson
INEL/Lockheed Martin Idaho Technologies
P.O. Box 1625
Idaho Falls ID 83415-3458
208/526-9698 debby@barbie.inel.gov

ABSTRACT

The Rover dry headend process combusted Rover graphite fuels in preparation for dissolution and solvent extraction for the recovery of ^{235}U. At the end of the Rover processing campaign, significant quantities of ^{235}U were left in the dry system. The Rover Dry Headend Process Deactivation Project goal is to remove the remaining uranium bearing material (UBM) from the dry system and then decontaminate the cells. Criticality safety issues associated with the Rover Deactivation Project have been influenced by project design refinement and schedule acceleration initiatives. The uranium ash composition used for calculations must envelope a wide range of material compositions, and yet result in cost effective final packaging and storage. Innovative thinking must be used to provide a timely safety authorization basis while the project design continues to be refined.

I. INTRODUCTION

From April 1983 to August 1984, the Rover Fuels Processing Facility at the Idaho Chemical Processing Plant (ICPP) recovered nearly 3000 kg ^{235}U from Rover fuels.[1] Rover fuel is a general term for highly enriched uranium-graphite matrix fuels with similar physical, chemical, and radiological characteristics. The Rover fuels processed included a combination of irradiated and unirradiated powders and intact and broken fuel rods, packaged in cardboard tubes.[2]

The Rover dry headend process used two stages of combustion to lower the fuel carbon content from 75 wt.% to 2 wt.%, and allow for dissolution and uranium extraction. After completion of the processing campaign, the dry process cells were abandoned in place with an estimated 100 kg ^{235}U remaining in equipment. The process area was operated with a strict hydrogenous moderator limit and is not safe for uncontrolled moderator intrusion. The largest motivator for the Rover Dry Headend Process Deactivation Project is the elimination of criticality risk.

II. BACKGROUND INFORMATION

When Rover fuels processing was complete, the wet system for ash dissolution was isolated from the dry system and flushed. The dry system cleanout was more difficult due to a liquid moderator operating limit of 0.5 L and a plugged vessel. Different strategies were proposed for uranium removal, but none were acted upon until recently.

The Rover dry headend process includes eight vessels in two process areas, the Mechanical Handling Cave (MHC) and Cells 3 and 4. These are shown in Figures 1 and 2. The combustion vessels (burners) are located in Cells 3 and 4. Both utilized a fluidized alumina bed and jet grinders during fuel processing.

The combustion process began in the MHC by placing a cardboard tube of Rover fuel in the charge chute of the primary burner, VES-100. In VES-100 the carbon content was reduced from 75 wt.% to 25 wt.%. The ash was elutriated to the primary collection pot, VES-102, and then to the secondary burner ash weigh pot, VES-103. The ash was charged in batches to the secondary burner, VES-104. In VES-104 the ash carbon content was further reduced to 2 wt.% and elutriated to the secondary burner ash collection pot, VES-105. Then, ash was transferred to the dissolver weigh pot, VES-106, where it accumulated in preparation for dissolution.

Two other vessels were located in the MHC: the bed storage vessel, VES-101; and the secondary burner makeup pot, VES-120. Both were used for alumina bed addition to the burners. Neither contained uranium during the process.

Some difficulties occurred in the Rover dry headend process during fuel processing. Many were a result of unexpected materials being charged to the primary burner, including nylon ropes, sand particles, and incombustible structural materials. By the end of processing, elutriation lines from VES-100 to VES-102 and VES-102 to VES-103 had repeatedly plugged. Attempts to clear these plugs resulted in ash spread over the general cell areas. VES-102 became completely plugged up and had to be bypassed. Attempts to unplug the vessel at the end of the processing campaign were unsuccessful.

The primary activity of the Rover Deactivation

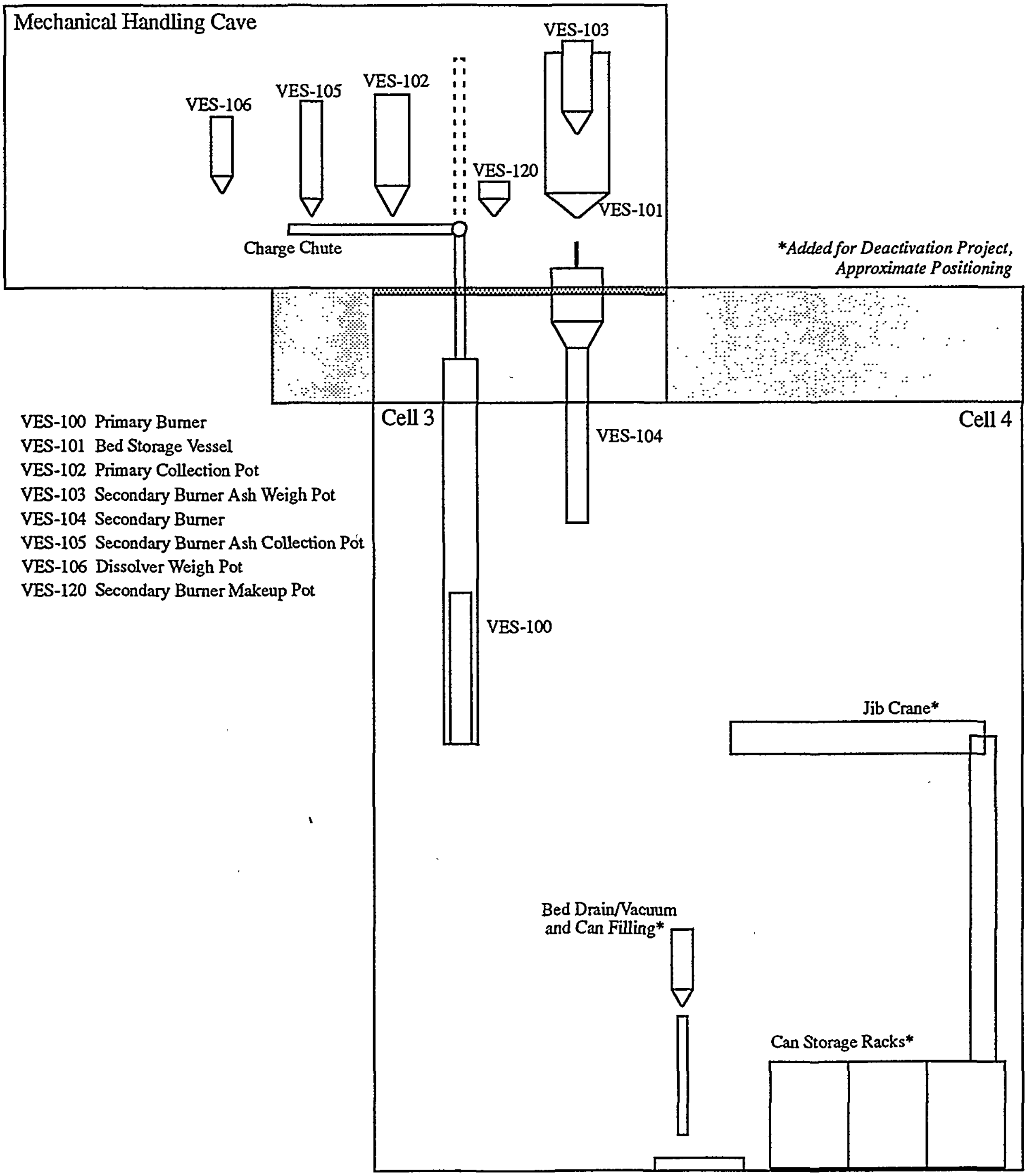

Fig. 1. Elevation View of the Rover Fuels Processing Facility MHC and Cells 3 and 4

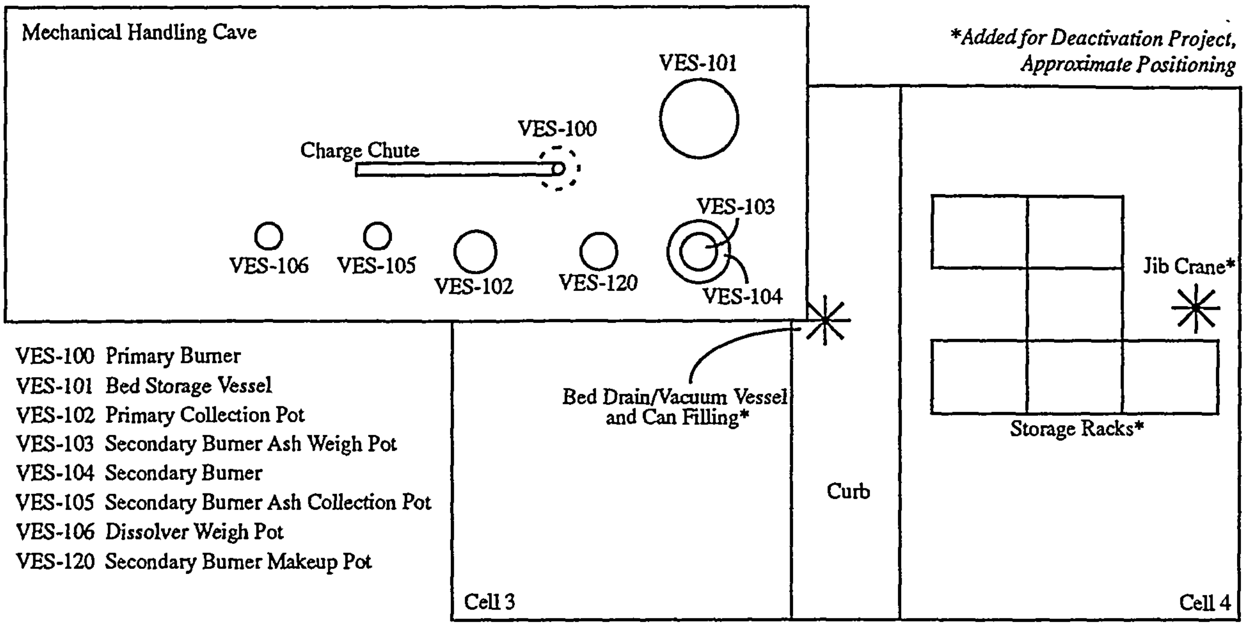

Fig. 2. Plan View of the Rover Fuels Processing Facility MHC and Cells 3 and 4

Project is UBM collection and canning. The term "uranium bearing material" was decided upon due to the unusual form and heterogeneous nature of the uranium. It is mixed with alumina bed and other non-combusted material in the burners. The uranium remaining in VES-102 is of uncertain quantity and is not well characterized. Uranium ash also collected on off-gas HEPA filters and coats the cells walls and equipment.

Vessels VES-105 and VES-106 were inspected remotely by borescope and verified empty of UBM in December of 1995. VES-106 has been relocated to Cells 3 and 4, where it will collect drained bed material and serve as a central vacuum system. UBM will be canned from VES-106. Items such as filter media and clinkers which cannot be vacuumed will also be placed in cans. All UBM cans will be stored temporarily in a rack in Cell 4. After UBM collection is complete, the cans will be transferred to another ICPP facility for final storage.

III. DISCUSSION

The Rover dry system in its current configuration has been identified as a high priority Environmental, Safety, and Health issue at the ICPP. The risk of criticality will be eliminated by the Rover Deactivation Project. Criticality safety issues associated with the project include: large uncertainties in the amount of uranium present in the Rover process; the heterogeneous nature of the ash; the final disposition of the uranium ash; and the level of safety analysis required for a unique and short-term operation. Resolution of these issues has been affected by continued efforts to refine the project design and accelerate the schedule.

The operating limits for hydrogenous moderator in the Rover dry process cells are 2.0 kg for solids and 0.5 L for liquids. No liquids are allowed in the dry process vessels, pipes, or instrument lines. New criticality calculations have confirmed that the moderator limits will not change substatially for UBM removal. However, new pathways for moderator to mix with UBM will be formed by the Deactivation activities. The process cells are protected from moderator intrusion by removable roof hatches that will be removed as needed during Deactivation. Vessels and pipes will be cut open for inspection and UBM removal. The new operations also introduce different UBM spill scenarios.

A. Uranium Inventory

An accurate assessment of the ^{235}U inventory prior to Deactivation Project activities would require destructive sampling of some process equipment. Several samples were obtained from the primary and secondary burners after processing was complete and provide a reliable estimate of ^{235}U in these two vessels. Although one sample was obtained from VES-102 after processing was complete, quantifying the UBM remaining in VES-102 would require extensive sampling throughout the vessel.

It is possible that solid material plugged the vessel output lines, then ash continued to enter VES-102 until it was full. Therefore it cannot be assumed that the single clinker sample obtained from VES-102 is representative of the entire vessel.

Several filters are located throughout the Rover dry headend process. Although an old filter has been analyzed, the current filters would also need to be destructively sampled for the UBM collected on them to be quantified. It is assumed that piping, particularly that which connects to VES-102, also contains UBM. This would be quantified by cutting open the pipes and sampling the UBM inside. Completing all this additional sampling would require personnel entries into the highly contaminated cells.

No uncertainties in uranium quantities were provided when the Rover fuels were received at ICPP, so the uncertainty for the book inventory ^{235}U value is based only on fuel processing. Based on chemical sampling and process knowledge, the ^{235}U mass in the dry headend process is estimated at 100 kg. However, the most conservative accountability projection incorporates a 5% uncertainty in the shipper values for ^{235}U, which would give an upper estimate of 319 kg of ^{235}U. A more realistic uncertainty for the shipper values is 1%, whether the shipper value was based on non-destructive assay or manufacturing specifications. This gives an upper value of 191 kg of ^{235}U for the Rover dry system.

Chemical sampling will be performed during UBM canning and should provide more realistic ^{235}U estimates for storage records.

B. Ash Composition

The ash is heterogeneous in nature, both within a particular vessel and throughout the vessels and piping in the process. Chemical sampling and frequent process plugging during operation indicate the presence of many impurities, including soil, rocks, and structural materials. Defining a conservative mixture for calculational purposes, which is not excessively conservative or prohibitive to the Deactivation Project, is complex.

The dry system combustion product ash was known to include U_3O_8, Nb_2O_5, Nb_3UO_{10}, Al_2O_3, and carbon. The proportions of these compounds differed throughout the stages of combustion and also during the fuel processing campaign. Fuel type, feed rate, combustion efficiency, and process plugs all affected the final ash compositions in each vessel.

Two sources exist for determining ash composition: experiments using simulated and pilot plant ash, and Rover dry system chemical sampling. Experiments determined the bulk ash density would not exceed 4.0 g/cm^3 and the minimum void fraction to be 0.3.[3] Further analysis[4] showed that the combined U_3O_8 and carbon densities would not exceed 2.5 g/cm^3. Scoping criticality calculations omitted the niobium poison compounds (Nb_2O_5 and Nb_3UO_{10}), setting the experimental data composition at 2.44 g/cm^3 U_3O_8, 0.06 g/cm^3 carbon, and 1.5 g/cm^3 Al_2O_3.[5] Water adsorption by the ash in a water saturated environment was measured at 0.67 mg H_2O per g of ash. Most H_2O was lost under ambient conditions, for a final value of 60 µg H_2O per g of ash.[6]

Chemical sampling after the completion of fuel processing was performed for five different sources throughout the dry system. Multiple samples were obtained for both the primary and secondary burners through normal sampling ports in the vessels. These exhibit some uniformity for each vessel and are representative of the materials present. One sample was obtained from VES-102 by routing a clinker out of the bottom of the vessel, but the vessel remained plugged. Since the vessel is also plugged at the top, it is assumed that VES-102 does not have a uniform material distribution and this single sample is not representative. UBM samples from the floor of Cells 3 and 4 and a roughing filter in the MHC were also analyzed.

A comparison of the chemical sampling results and the composition determined by experimentation indicates that, for criticality safety purposes, the experimental composition envelopes the sample results. Since UBM will probably not remain segregated according to source when canned, the experimental data composition was used for criticality calculations. The maximum water uptake was added to the composition at a density of 2.7 mg/cm^3. The chemical sampling during Deactivation Project UBM canning may result in different composition assumptions for later analyses.

C. UBM Disposition

Disposition of the recovered uranium ash is limited by the conservative assumptions required by the unknown quantity and heterogeneous nature of the ash. The UBM cans were designed so that a single can is critically safe by geometry for all water moderator and reflector conditions. The cans are stainless steel type 304, with an outer diameter of 11.43 cm.

Chemical sampling of UBM will not occur until the Deactivation Project canning is in progress, so the enveloping composition based on experimental data was used for the storage rack calculations. All cans were conservatively assumed full of UBM. The temporary storage rack in Cell 4 will be under strict hydrogenous moderator limits, to prevent intrusion into the UBM cans. The storage array reactivity rises dramatically when the UBM cans have internal moderation.

Criticality calculations for final storage may incorporate sample data if it is available in a timely manner. Two destinations are being considered, a dry storage facility and underground storage wells. The dry storage facility is preferred. It is a moderator exclusion area, with no source of hydrogenous liquids permitted. It would allow the most efficient storage of UBM cans. The underground storage wells do not exclude moderator, require evaluation of water intrusion into the storage package, and will result in more restrictive storage requirements.

D. Safety Authorization Basis

To support schedule acceleration and cost effectiveness, Deactivation Project activities are being performed within the existing safety authorization basis whenever possible. The original authorization basis was written in 1983 and includes a Safety Analysis Report and Technical Standards. Since the Rover process operated only during 1983 and 1984, the safety analysis has not been revised recently. A brief Shutdown Status Addendum was added in 1993, but it did not consider the Rover Deactivation Project activities. Bringing all Rover facility safety documentation up to current standards for a one-time operation would be timely and costly, with little added value.

The adequacy of the safety envelope is being addressed in two ways. First, all operating procedures relating to UBM handling require review and approval by criticality and safety analysts to ensure all Deactivation activities are within the existing safety authorization basis. Second, safety documentation and criticality safety analyses are being prepared to cover anticipated operations and equipment that will not fall within the scope of the current safety analysis.

Special operating procedures address short-term and one-time operations such as inspection of a vessel. Criticality and safety analysts review all special and technical procedures that relate to UBM removal and disposition. All procedures are screened against the safety authorization basis for an Unreviewed Safety Question (USQ). A positive screening leads to an evaluation, and a positive evaluation requires additional safety analysis. USQs are resolved by either a revision to the existing safety analysis or a safety assessment to reestablish adherence to the authorization basis.

One activity not covered by the existing safety authorization basis is personnel entry into the MHC and Cells 3 and 4 during UBM handling. The Criticality Alarm System (CAS) used during Rover fuel processing was a gamma CAS, and provided coverage for a shielded criticality. To provide coverage for an unshielded criticality with personnel in the Rover process cells, a neutron CAS with a shorter response time and new detector locations was added.

It is apparent that a number of other planned Deactivation Project activities will not fall under the existing authorization basis. Two major activities not included are the storage of UBM cans in Cell 4, and the placement of UBM-loaded filter media in UBM cans for storage. The new VES-106 vacuum and bed drain system with its associated filters is also not included. The existing Shutdown Status Addendum is being revised to incorporate these and other anticipated systems and equipment.

Technical Standards implement administrative controls and surveillance requirements for criticality safety. The existingTechnical Standards are being reviewed against new demands by the Deactivation Project and are being revised to allow for new uses of equipment. If necessary, new Technical Standards will be written to cover new activities.

The authorization basis update is complicated by the magnitude of the Deactivation Project, and the speed with which it is proceeding. The design for UBM canning equipment has progressed in parallel with the Safety Analysis Report revision, and has required constant communications between safety, operations, and design personnel to resolve criticality safety issues. Similarly, operations and procedures for UBM removal are continuing to evolve, and close communication is necessary to detect difficulties before they occur.

IV. CONCLUSIONS

The maximum Rover dry system ^{235}U estimate for criticality safety calculations is nearly twice that expected from sampling and operating experience estimates. The high estimate of 191 kg is required due to an inability to completely characterize the Rover UBM, and a lack of uncertainty data for ^{235}U from the shipper.

The UBM composition chosen is quite conservative for similar reasons. As a result of the two-step combustion process and plugging in the system, the UBM is not homogeneous throughout the system. Statistically significant samples are not available for all UBM sources in the Rover dry headend process.

The final UBM cans storage location has not been settled conclusively. The current destination is the dry storage facility, but it is still a possibility that the UBM cans will be sent to the underground storage wells. Criticality calculations must be sufficiently generic to encompass both possibilities.

Changing Deactivation Project design and operations while maintaining adherence to the current safety authorization basis has required close communication between criticality analysis, safety analysis, design, and operations personnel. Installation of a new CAS was required to better protect personnel during new operating circumstances. Acceleration of the schedule has required versatility to anticipate alternate paths and incorporate new concepts into the safety documentation.

ACKNOWLEDGMENTS

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