APPLICATION FOR AMENDMENT TO LICENSE NO. SNM-1227: SUPERCRITICAL CO_2 EXTRACTION SYSTEM AREVA, RICHLAND FACILITY

1.0 **Executive Summary**

The proposed supercritical carbon dioxide (CO_2) extraction system implements scale-up to production capacity of a process previously tested at AREVA, Richland under small-scale laboratory and scale-up testing conditions. This production version is designed for commercially efficient extraction of uranium from waste material, such as incinerator ash, that contains a relatively low percentage of uranium.

The principal novel aspect of the proposed process is the use of supercritical CO_2, rather than dodecane, as the process solvent. Maintaining CO_2 in the supercritical state requires that the process be operated at high pressure: approximately 200 atmospheres (3,000 psig). The extremely low viscosity of supercritical CO_2 is the controlling property that increases efficiency of uranium recovery.

System design incorporates defense-in-depth principles to the extent practicable, including: 1) preference for the selection of engineered controls over administrative controls to increase overall system safety and reliability; and 2) features that enhance safety by reducing challenges to Items Relied on for Safety (IROFS).

Nuclear criticality in the bucket infeed system (duplex linear arrays) is ensured against by geometry control (container diameter and height; spacing between conveyors and conveyors and walls) as well as by enhanced administrative mass controls that maintain the total system SNM content below a safe batch on the entire set of conveyors.

Nuclear criticality safety in the process vessels is ensured primarily by favorable-geometry design and equipment spacing, a situation also improved by the low concentration of uranium in the process fluids. Air breaks are employed in various locations to preclude backflow of process fluid into unfavorable-geometry vessels.

Redundant controls are implemented in the design to ensure that high-consequence exposures of personnel to hazardous chemicals are at least highly unlikely, and intermediate-consequence exposures are at least unlikely. Process equipment is designed to preclude loss-of-containment incidents and consequent potential personnel exposure to high concentrations of CO_2 and aerosols of Uranyl Nitrate (UN), TBP, and HNO_3. Provisions to prevent these incidents include construction and inspection of process vessels in conformance with applicable pressure vessel codes and standards. Also included are passive-engineered features that ensure that the extraction vessels, which must be frequently opened for loading and unloading, are not subject to any single human error that could lead to catastrophic loss of containment.

2.0 **Amendment Request Associated with the Supercritical CO_2 Extraction System**

This document requests a license amendment to allow operation of the production version of a supercritical CO_2 extraction system. A license amendment is required under 10 CFR 70.72 because the proposed supercritical CO_2 extraction system employs a new process for which AREVA Richland does not have prior production experience. However, sufficient on-site laboratory-scale experience exists to warrant scale-up to a production system.

This testing has confirmed that the IROFS proposed for use will be adequate to protect against credible potential high and intermediate consequence loss of containment events. Operating experience with the laboratory and scale-up testing did result in some design changes that will enhance industrial safety. These changes include:

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- Use of infrared CO_2 detectors has been extensively tested in laboratory and scale up testing operations. The detectors have proven very reliable. Similar detectors will be used in the full-scale plant.
- Controlled CO_2 release tests were conducted in the pilot plant to validate the CO_2 the release rates used in calculations for the full-scale plant design..

AREVA's evaluation/documentation of the safety of the supercritical CO_2 extraction process is summarized below in Sections 8.0-11.0. In conjunction with that analysis effort, AREVA has further determined that:

- the process is adequately covered by the site's existing Fundamental Nuclear Material Control (FNMC) Plan;

- the process is adequately covered by the site's existing Emergency Plan (EP);

- no changes are required in the site's environmental program and Environmental Report and furthermore the change meets the categorical exclusion criteria of 10 CFR 51.22; and

- the site's current suite of management measures is adequate to assure the availability and reliability of the IROFS associated with the process.

The bases for these determinations are provided below.

FNMC Plan

The AREVA FNMC plan covers receipt and shipment of SNM as well as storage and processing of this material on site. Processing SNM in the supercritical CO_2 extraction process does not create any material control issues not already fully addressed under the site's existing FNMC Plan. No revisions or enhancements to the plan will be required. This process will reduce the onsite inventory of U-bearing ash materials. Any future commercial use of this process will have essentially no change on the plant inventory because recovered U will replace the amount of U that would have been obtained from other sources. In all cases, the SNM inventory will remain below the current license limits.

Emergency Plan

The AREVA Emergency Plan (EP) adequately covers the processes associated with nuclear fuel fabrication and uranium recovery operations. Off-normal scenarios potentially associated with the super critical CO_2 extraction process do not pose conditions beyond current emergency plan capabilities. The principle chemicals used in this process include [redacted] Each of these chemicals is currently used at the Richland site. The existing EP implementing procedures as well as the protocols and practices associated with emergency preparedness and responses to chemical, radiological, and nuclear events are adequate to cover the amounts of chemicals and SNM associated with this new process without any additional changes.

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The AREVA EP and associated procedures and protocols do not specifically address every potential hazardous chemical on site. Only the most significant hazardous chemicals are specifically mentioned. The protocols and procedures for those that are not specifically mentioned provide adequately conservative guidance for personnel protective equipment (PPE), evacuations, and notifications.

The current use of TBP is about 75-120 gallons per year and the amount stored on site is two to three 55-gallon drums at any given time. When the supercritical CO_2 extraction process is operational, the process will require about [redacted] and the onsite storage is not expected to increase by more than one 55-gallon drum

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Environmental Impact

Environmental safety aspects of the proposed supercritical CO_2 extraction system are discussed below in Section 8.4. Based on the well controlled effluents from the process, no revisions or enhancements are required to the site's existing environmental monitoring programs; environmental impacts as documented in the Richland site's Environmental Report currently on-file with the NRC remain valid. Equipment/waste volumes to be addressed at the time of plant decommissioning will not be significantly impacted.

While this amendment request is based on a change in process operations and equipment, the change meets the categorical exclusion criteria of 10 CFR 51.22(c)11)(i)-(iv) and thus does not require an environmental assessment or an environmental impact statement. Each criterion is addressed below

(i) there is no significant change in the types or significant increase in the amounts of any effluents that may be released offsite,

The supercritical CO_2 extraction process does not add any new chemicals to process streams. CO_2, uranium liquids and compounds, tri-butyl phosphate, and nitric acid are already used in uranium recovery and waste treatment processes. The amount of these chemicals in liquid and gaseous effluents, except for CO_2, will be comparable or in some cases decreased relative to using existing processes to recover uranium from ash materials. The amount of CO_2 used in the process is minimized via recycling into the process and CO_2 releases will be low relative to other current plant CO_2 usage / releases [redacted] The total CO_2 discharged from the AREVA Richland facility during calendar year 2007, was in excess of 19 tons.

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(ii) there is no significant increase in individual or cumulative occupational radiation exposure,

The direct dose radiation exposure will be essentially the same as using existing processing methods for U recovery from ash material. Internal exposure is expected to decrease due to better containment and equipment designs.. The amount of solid radioactive waste generated from this process will be slightly less than the alternate processing methods that AREVA could use. The inert material in the ash will remain unchanged but cartridge filters will not be part of the supercritical CO_2 process and the amount of solid filter-aid will be reduced.

(iii) there is no significant construction impact, and

This new process will be placed in an existing building that formerly housed one of the ADU lines and is currently being used for material storage. Increased truck traffic related to equipment delivery will be insignificant and spread over several months. Work will be accomplished by crafts personnel already working at the Richland site. Construction activities in this area will not increase the likelihood of high or intermediate consequence accidents as defined in

10CFR70.61. Appropriate IROFS are already in place to cover potential accidents from this construction activity.

(iv) there is no significant increase in the potential for or consequences from radiological accidents.

The risk of loss of containment events or accidental nuclear criticality have been shown in the ISA summary provided with this license amendment to be acceptable per the requirements of 10CFR 70.61.

Management measures program

The AREVA management measures program covers the processes associated with nuclear fuel fabrication and uranium recovery operations that are regulated by 10CFR70. The hardware, software, and administrative IROFS, and the associated management measures, including operator training and qualifications for the supercritical CO_2 extraction process, are similar to those used in currently licensed processes. The management measures program that is currently in place for AREVA's IROFS does not need to be modified to adequately support the supercritical CO_2 extraction process.

3.0 Background

The proposed supercritical CO_2 extraction system implements scale-up to production capability of a process that has previously undergone extensive small-scale testing at AREVA, Richland under laboratory and scale-up testing conditions. The proposed production version is designed for commercially efficient extraction of uranium from waste material, such as incinerator ash, that contains a relatively low percentage of uranium.

The principal novel aspect of the process is the use of supercritical CO_2, rather than dodecane, as the process solvent. Use of supercritical CO_2 requires that the process be operated at high pressure: approximately 200 atmospheres (3,000 psig). The extremely low viscosity of supercritical CO_2 is the principal contributing factor that increases efficiency of uranium recovery.

4.0 Facility Description and Design Criteria

The supercritical CO_2 extraction system will be installed and operated in the existing UO_2 Building, Room 131. This building was designed to meet International Building Code (IBC) standards applicable when it was constructed. Detailed facility information is available in the current ISA Summary (Integrated Safety analysis- ISA Summaries, E15-01-2.9A). Other applicable code information is also supplied in the current ISA Summary, as is information on process support systems, such as building HVAC and the deionized water (DIW) supply system.

The [redacted]

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[redacted]

[redacted] General [redacted]

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[redacted]

6.0 Details of the Process and Equipment

[redacted] *CO_2* [redacted]

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[redacted]

[redacted]

6.2 *Ash Handling*

[redacted]

[redacted]

[redacted]

[redacted]

6.3 *Extraction of Uranium from the Ash*

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

6.4 *Operation of the* [redacted]

[redacted]

[redacted]

[redacted]

These process solutions have been reviewed and do not adversely impact the existing ISA summary. These solutions remain bounded by the existing accident scenarios. The CO_2 gaseous outputs that are exhausted from the stack have also been reviewed and do not result in any high or intermediate consequences as defined in 10CFR 70.61.

Personnel exposure to aerosols from a catastrophic release of the working fluid is precluded by primary and secondary containment which have management measures to assure that they are available and reliable when needed. These management measures include periodically inspecting the process vessels in conformance with applicable pressure vessel codes and standards.

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[redacted]

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[redacted]

[redacted]

7.0 **Project Description**

This project includes fabrication, installation, and operation of the equipment described above in Sections 5.0 and 6.0, required for economically efficient extraction and recovery of uranium from incinerator ash and similar granular waste materials.

A piping and instrumentation diagram (P&ID, Drawing CSA-611,186 sheets 1-6) for the supercritical CO_2 extraction system is provided as Attachment 1.

Sheet [redacted]

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[redacted]

[redacted]

[redacted]

An equipment layout drawing (Drawing CSA-616,518 Sheets 1-4) is also provided as Attachment 2.

Process fluids will contain solutions of UN. Design of each of the process vessels maintains favorable geometry for both UN solution and credible concentrations of UO_x/H_2O mixtures. This illustrates the AREVA, Richland design commitment to rely primarily on engineered controls, as well as the defense-in-depth approach which, from inception, has characterized the equipment design. Table 1 provides a summary of vessel contents and diameters.

Table 1

Vessel Tag No	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

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[redacted]

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[redacted]

8.0 Safety Bases

8.1 *Nuclear Criticality Safety: Hazards and Controls*

The limits and controls on the Supercritical CO_2 Extraction System were established, in part by evaluating the results of computer modeling using the SCALE 4.4a system of codes and the 238 group cross section library to calculate k_{eff} values for the equipment arrangement under normal and credible abnormal conditions.

This system of codes has been extensively used and validated by the NCS community. The computer modeling used is consistent with the requirements listed in Chapter 4 of the AREVA License Application, SNM-1227.

A detailed summary of computer modeling and associated sensitivity studies, conclusions drawn from reference manuals and surface density calculations is included in the criticality safety analysis summary provided as part of this package.

Based on the computer modeling and handbook (ARH-600) information, the ISA Team judges that nuclear criticality in any of the process vessels is not credible, due to favorable geometry design throughout, combined with installed vessel separation distances. Additional protection is provided by the fact that the physical properties of the extraction system and the feedstock dictate that the process fluid will contain relatively low percentages of uranium. Backflow prevention of UN into unfavorable geometry supply tanks is ensured by incorporation of favorable geometry tanks, air breaks, and, where needed, active engineered controls as described in Section 6.0, above. Wherever practicable, design preference has been given to passive engineered controls over active engineered controls, and to engineered controls over administrative controls.

Accident sequences dealing with catastrophic fluid release were extensively analyzed and no associated nuclear criticality consequence was identified. A catastrophic release would tend to disperse any uranium contained in the system, rather than concentrate it into an unfavorable geometry. In a catastrophic release, most of the heavy materials would fall to the floor (covering a large area), and/or would spread evenly into exhaust duct or onto HEPA filters.

Various process upsets, such as excessively high flow of water into the scrub column V-9 which would strip uranium from the process fluid, could lead to the inclusion of excessive uranium in the raffinate stream. This could become a potential nuclear criticality concern related to a down stream system used to further process the raffinate. It is noted that a system currently used to process raffinate from another solvent extraction process will be also used to process the CO_2 extraction raffinate. The nuclear criticality controls for this existing system are not adversely impacted by processing the additional raffinate from the supercritical CO_2 process. The chemical characteristics of the raffinate have been reviewed and are such that they remain bounded by the accident sequences currently evaluated.

In [redacted]

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All identified accident sequences related to nuclear criticality are included in the attached ISA Summary.

8.2 *Chemical Safety: Hazards and Controls*

The principal hazards of the proposed supercritical CO_2 extraction system are related to sudden pressure release and subsequent personnel exposure to airborne hazardous chemicals, specifically CO_2 combined with aerosols of HNO_3, UN, and TBP.

Catastrophic release due to failure of pressure vessels and/or piping is prevented by design, construction, and periodic inspection in conformance with applicable pressure vessel codes and standards.

Potential catastrophic release due to human error or mechanical degradation related to frequent opening of the lids of the [redacted] extractor vessels became a primary design consideration. Catastrophic releases are prevented here by passive design features. For example, design ensures that the lids cannot be manually opened while under significant internal pressure. Also, large pressure relief vents that remain open until the lid is completely closed prevent buildup of high pressure in the vessel under unsafe lid positions.

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Catastrophic release due to overpressurization in the process system is prevented by: 1) pump design, which limits output pressure as a function of plant supply air pressure; and 2) equipping the process vessels with rupture disks or pressure relief valves. Flow from rupture disks or relief valves is designed to safely exhaust through the building exhaust system (K31), and environmental contamination is precluded by two stages of HEPA filtration.

Specific chemical hazards associated with the proposed supercritical CO_2 extraction system are discussed in individual detail below. In addition, all related accident sequences with potential 10 CFR 70 consequences of concern are included in the attached ISA Summary. A binary chemical interaction matrix is also included as Figure 2 in Section 11, below.

[redacted] Maximum [redacted]

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[redacted]

[redacted]

[redacted]

[redacted] Maximum [redacted]

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[redacted]

[redacted]

[redacted] Total [redacted]

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[redacted]

8.2.5 Potential Discharge of Contaminated Raffinate

One process upset was identified that could lead to contamination of the raffinate stream by TBP. This would require processing of the raffinate stream through the mop water dissolver in ELO/GSUR, similarly to processing high-U raffinate as discussed above. This upset was judged of no significant safety consequence.

8.2.6 Potential Discharge of Contaminated UN

One instrumentation failure was identified that could cause pumping of solution out the top of Scrub Column V-90 to the stripper column, so that the UN output would be contaminated with gadolinia, nitric acid, iron, calcium, etc. This situation was judged of no significant safety consequence.

8.2.7 Nitric Acid (HNO_3)

The principal process hazard related to nitric acid is potential inhalation of an aerosol from high-pressure release of the working fluid. All related accident sequences with potential 10 CFR 70 consequences of concern are included in the attached ISA Summary.

8.2.8 Tri-butyl Phosphate (TBP)

The principal process hazard related to TBP is potential inhalation of an aerosol from high-pressure release of the working fluid. All related accident sequences with potential 10 CFR 70 consequences of concern are included in the attached ISA Summary.

8.2.9 Uranyl Nitrate (UN)

The principal process hazard related to soluble uranium is potential inhalation of an aerosol from high-pressure release of the working fluid. All related accident sequences with potential 10 CFR 70 consequences of concern are included in the attached ISA Summary.

8.3 *Radiological Safety: Hazards and Controls*

Radiological safety of personnel involved in the operation and maintenance of the supercritical CO_2 extraction system is assured by AREVA's existing radiation protection program, which includes training, personal protective equipment (PPE), surveys, bioassay, etc. Solutions managed in the system are not high in uranium. [redacted] Under normal operating conditions solutions will be completely contained within the process vessels and associated piping.

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The area in which the process equipment is installed will remain subject to AREVA's routine radiation and radioactive contamination survey program. Routine protective clothing and PPE requirements will be as dictated by the results of those surveys. Routine activities will be covered in applicable standard operating procedures (SOPs) and radiation work procedures (RWPs). Non-routine activities not covered in SOPs and RWPs will be addressed as appropriate via radiation job permits (RJPs).

8.4 *Environmental Safety: Hazards and Controls*

All process vessels and associated pipes are constructed of materials (principally stainless steel) fully compatible with the pressure service requirements and with all components of the process fluids and solutions. Air emissions under normal processing conditions will contain no significant concentration of hazardous materials and will be exhausted through the building HVAC exhaust. Gaseous and/or aerosol release to the environment of significantly concentrated hazardous materials is prevented by a system of pressure relief valves designed to safely discharge through the building exhaust system. Such a release is therefore subject to two stages of HEPA filtration before it exits the building. Any liquid releases, such as UN and TBP, will remain contained within the UO_2 Building and manually recovered. Even though the CO_2 gaseous outputs that are exhausted from the stack occur after they have been separated from all significant levels of licensed materials, such releases do not result in any high or intermediate consequences as defined in 10CFR 70.61.

All significant amounts of hazardous materials released from the pressurized system in any identified, credible loss-of-containment incident will remain contained within the UO_2 Building.

The supercritical CO_2 extraction system will require no near-term changes to AREVA's current effluent and/or environmental monitoring programs. Sewered liquid effluent will remain subject to existing NRC and City of Richland radiological and chemical release limits.

The solid waste from this process will be similar in composition to the other solid waste that is generated from uranium recovery operations currently used at the AREVA Richland site. The overall volume of waste will be slightly reduced from the other recovery processes currently licensed at the Richland site due to increased efficiency and using fewer process filters that require disposal.

8.5 *Fire Safety*

As described above, the supercritical CO_2 extraction system is constructed primarily of stainless steel, which is non-combustible. The UO_2 building itself is of non-combustible construction, as described in the current ISA Summary, Section 9.2. The specific room in which the system is installed will remain subject to existing plant-wide monitoring programs, as required by IROFS 4502 and 4503, to maintain low combustible loading. These IROFS make it highly unlikely that a small fire, such as a trash-can fire, could grow into a large fire (fire involving a significant portion of a room). For additional fire protection, the UO_2 Building is fully equipped with fire extinguishers, alarm pull boxes, and heat detectors.

One of the process fluids is TBP, which is combustible. A fire involving TBP can be chemically hazardous, as phosphoric acid fumes may be produced. TBP is an OSHA Class III-B combustible fluid, which tends to be self-extinguishing when the source of ignition is removed. The conclusion drawn from this fact is that a small supply tank of liquid TBP will not contribute to the likelihood of a small fire growing into a large fire. [redacted] The potential for ignition of a TBP aerosol, as dispersed in its CO_2 vehicle by a catastrophic pressure release, was evaluated and determined to be not credible.

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The dodecane vehicle used in existing processes has been replaced, in the subject process, with supercritical CO_2, decreasing the fire hazard as opposed to existing processes.

Transparent portions of the process hoods and glove boxes are Lexan panels, which will not by themselves support combustion and will therefore not increase the likelihood of a small fire growing into a large fire.

In summary, fire risk will not be increased by the equipment installed under this license amendment request, by the operation of the equipment, or by any potential interactions with adjacent facilities and activities.

9.0 Baseline Design Criteria

10 CFR 70.64 requires that the following baseline design criteria be addressed in the design of new processes at existing facilities that require a license amendment under 10 CFR 70.72. Methods employed to address these criteria are discussed below.

ISA Team members participated in multiple design reviews from the inception of the design process. HAZOP methods were used to formulate accident sequences and evaluate potential consequences; ISA Team meeting results were used as feedback to the design process to ensure reduction of challenges to IROFS, application of defense-in-depth principles, and that preference be given to engineered controls.

9.1 *Quality Standards and Records*

AREVA's current quality assurance program as applied to IROFS is discussed in Section 8.8 of the current ISA Summary. No near-term changes to this plan are required to allow for installation and operation of the proposed supercritical CO_2 extraction system.

9.2 *Natural Phenomena Hazards*

10 CFR 70.64 requires that the design provide for adequate protection against natural phenomena with consideration of the most severe documented historical events for the site. The most severe documented historical events, as described in the current ISA Summary, are significantly less severe than the postulated design events, such as maximum wind loading and earthquake loading, used in design calculations. Therefore existing design practice and compliance with applicable building codes fulfill this requirement. Design basis natural phenomena such as flood, wind, fire, and earthquake are discussed in detail in the current ISA Summary, Section 7.1.1

Consistent with the guidelines provided by the NRC referring to the impact of natural phenomena on Category 1 and 3 uranium processing facilities, AREVA has used standard or uniform building codes, as applicable, to establish the threshold for highly unlikely initiating event frequency. That is to say, adverse natural phenomena discussed in this section that are of such magnitude as to exceed the building-code-based facility design basis are themselves considered highly unlikely.

9.3 *Fire Protection*

10 CFR 70.64 requires that the design provide for adequate protection against fires and explosions. As discussed in Section 8.5, above, the room in which the system is installed will remain subject to existing plant-wide monitoring programs, as required by IROFS 4502 and 4503, to maintain low combustible loading. These IROFS make it highly unlikely that a small fire, such as a trash-can fire (listed as an initiating event in many accident sequences) will grow into a large fire (fire involving a significant portion of a room). For additional fire protection, the UO_2 building is fully equipped with fire extinguishers, alarm pull boxes, and heat detectors. A key aspect of the site fire protection program is fire service provided by the City of Richland, with typical running times to the plant of less than 10 minutes. Also, a 65-member plant emergency response team is trained in first response (incipient) fire fighting techniques.

In summary, fire risk will not be increased by the equipment installed under this license amendment request, by the operation of the equipment, or by any potential interactions with adjacent facilities and activities.

9.4 *Environmental and Dynamic Effects*

10 CFR 70.64 requires that the design provide for adequate protection from environmental conditions and dynamic effects associated with normal operations, maintenance, testing, and postulated accidents that could lead to loss of safety functions.

All postulated environmental upset conditions are provided for as discussed in Section 9.2, Natural Phenomena Hazards, above, and in the current ISA Summary, Section 7.1.2, where external man-made hazards are discussed. Extensive discussions in ISA Team meetings, employed as an integral part of the design process, covered normal operations, maintenance, testing, and loss of safety functions. The HAZOP technique was employed in the principal portion of these meetings. A record of all postulated accident sequences having 10 CFR 70 consequences of concern, along with their associated defenses, is included in the ISA Summary for the subject system.

9.5 *Chemical Protection*

10 CFR 70.64 requires that the design provide for adequate protection against chemical risks produced from licensed material, facility conditions which affect the safety of licensed material, and hazardous chemicals produced from licensed material.

Extensive discussions in ISA Team meetings, employed as an integral part of the design process, covered all identified chemical risks associated with the supercritical CO_2 extraction process. The HAZOP technique was employed in the principal portion of these meetings. A record of all postulated accident sequences having 10 CFR 70 consequences of concern, along with their associated defenses, is included in the ISA Summary for the subject system. The only identified chemical consequences of concern were associated with significant accidental release from the high-pressure portions of the system. In conformance with standard Process Hazards Analysis (PHA) procedure, a binary chemical interaction matrix was prepared to aid in the identification of interaction hazards. The matrix is included in this document as Figure 2, Section 11.

The ability of chemicals not regulated by 10 CFR 70 to cause 10 CFR 70 consequences of concern in adjacent SNM processing facilities is already adequately addressed in "Inter-Building Accident Effects", Section 7.2.4 of the current ISA Summary. As discussed therein, potential impact to adjacent facilities/areas could result in the possibility of a mandatory evacuation of personnel from their workstations which, by plant shutdown design, will not lead to intermediate or high consequence events.

9.6 *Emergency Capability*

10 CFR 70.64 requires that the design provide for emergency capability to maintain control of: 1) licensed material and hazardous chemicals produced from licensed material; 2) evacuation of on-site personnel; and 3) on-site emergency facilities and services that facilitate the use of available off-site services.

Existing emergency capability, as discussed in the current ISA Summary, Sections 7.2.3.2, and as promulgated in the Emergency Plan, Document E08-01-1.0, is deemed sufficient to maintain control of the above-listed items. Installation and operation of the equipment installed under this license amendment request is judged to require no new provisions to the Emergency Plan.

9.7 *Utility Services*

10 CFR 70.64 requires that the design provide for continued operation of essential utility services.

Loss of each utility service was evaluated in the ISA Team meetings. No 10 CFR 70 consequences of concern were identified as proceeding from loss of any utility or combination of utilities. Additionally, all plant production systems are designed to be fail-safe upon emergency evacuation of all personnel.

9.8 *Inspection, Testing, and Maintenance*

10 CFR 70.64 requires that the design of IROFS provide for adequate inspection, testing, and maintenance, to ensure their availability and reliability to perform their function when needed.

Section 8 of the current ISA Summary contains a discussion of administrative and management measures as applied to all IROFS on site. This discussion applies in its entirety to the installation and operation of the equipment installed under this license amendment request. Details of the management measures as applied to individual IROFS are available for inspection at the Richland site.

9.9 ***Control of Nuclear Criticality***

10 CFR 70.64 requires that the design provide for nuclear criticality control including adherence to the double contingency principle.

Nuclear criticality in the bucket infeed system (duplex linear arrays) is ensured against by geometry control, as well as by enhanced administrative mass controls that maintain the total system SNM content below a safe batch.

The ISA Team judges that nuclear criticality in any of the process vessels is not credible, due to favorable geometry design throughout, combined with installed vessel separation distances. Design of the extractor basket transport system ensures that only one basket can be moved at a time and that a basket in transit cannot be moved axially adjacent to another basket. These facts illustrate the AREVA Richland design preference given to passive engineered controls and design features. Because of the high operating pressures in the subject equipment, catastrophic release sequences were extensively analyzed, but no associated nuclear criticality consequence was identified.

Nuclear criticality potentially resulting from high uranium in the waste liquid stream is ensured against by favorable geometry vessels and the existing mass/ geometry controls in the existing down steam processing systems.

In the spent ash handling system, spent ash is consolidated into 55-gal drums (unfavorable geometry without neutron absorbers). Nuclear criticality is ensured against by two independent uranium assays on each basket of spent ash, required before allowing transfer of the ash to a waste drum.

The attached ISA Summary information covering installation and operation of the equipment installed under this license amendment request demonstrates that potential nuclear criticality consequences of each listed accident sequence are controlled to at least "highly unlikely" and are also each subject to double contingency protection.

9.10 ***Instrumentation and Controls***

10 CFR 70.64 requires that the design provide for inclusion of instrumentation and control systems to monitor and control the behavior of IROFS.

Chapter 8 of the current ISA Summary discusses administrative and management measures as applied to all IROFS on site. This discussion applies in its entirety to the installation and operation of the equipment installed under this license amendment request. Details of the management measures as applied to individual IROFS are available for inspection at the Richland site.

Additionally, defects and unusual incidents are tracked through both the Preventive Maintenance/Instrument Repetitive Maintenance (PM/IRM) system and the Corrective Action

Program, again as described in Chapter 8 of the current ISA Summary. The Fuel America Corrective Action Program records are permanent company records. These records and those associated with the PM/IRM program are judged adequate to track the performance reliability of IROFS and ensure a feedback mechanism to the ISA process, should any adjustment be required.

10.0 Defense-in-Depth Practices

10 CFR 70.64 requires that facility and system design and facility layout must be based on defense-in-depth practices. The design must incorporate, to the extent practicable:
1) preference for the selection of engineered controls over administrative controls to increase overall system reliability; and 2) features that enhance safety by reducing challenges to IROFS.

Following are illustrative examples of AREVA Richland's defense-in-depth practices and preference for engineered controls used in the design of the equipment installed relative to this license amendment request.

The [redacted]

Comment [m28]: Trade secret / Proprietary

[redacted]

- In combination with the HVAC exhaust system, process enclosures are designed to contain releases of the high-pressure working fluid. Containment within enclosures is ensured by the normal capacity of the exhaust system which will maintain a negative pressure while handling the most likely postulated system breaches such as pump failures and single-sided pipe breaks. The excess capacity of the exhaust system will handle the largest postulated system breach by means of a pressure sensor installed in the ducting which will increase the exhaust fan speed to maintain negative within the hood. In addition, the amount of a potential release is limited to the contents of a single column or vessel by using shut-off valves interlocked to close and isolate individual columns or vessels if a sudden pressure is detected in the system or if excess CO_2 is detected inside the hood or in the room. The CO_2 monitors are also connected to alarms that will warn personnel of the need to shut down the system and evacuate if CO_2 is detected. As an additional measure to prevent personnel exposure to working fluid, a standard plant-wide requirement exists to evacuate the affected work area upon loss of the HVAC exhaust.

- The nitric acid supply system is equipped with an air break which precludes backflow into the unfavorable-geometry nitric acid supply tank. This illustrates the design commitment to installation of design features that render backflow accident sequences not credible. Further extending the principle of preference for passive engineered controls and design features, similar air breaks are likewise designed into the supply systems for deionized water and TBP.

- The extractor vessel closure system is designed to make catastrophic release of the high-pressure working fluid not credible. This design criterion was judged of prime importance due to the frequency at which these vessels are opened for emptying and recharging. The mechanical design precludes: 1) catastrophic release due to an accidental attempt to open a vessel when it is under pressure; 2) catastrophic release due to failure to close the lid completely prior to pressurization; 3) catastrophic release due to deterioration of the gasket or wear of the mechanical closure system.

- All process vessels subject to the high pressure working fluid are designed and periodically inspected in conformance with applicable pressure vessel codes and standards. All process pipes and fittings outside of containment hoods are of welded construction; threaded fittings are used only within hoods. Ductile materials, fully compatible with process fluids, are used throughout. The conclusion, therefore, is that any significant, sudden loss of containment will be preceded by a small leak. Any small leak will be detected and repair completed prior to a catastrophic failure. In addition, appropriate barriers are employed and process piping is routed to prevent impact by mobile equipment. Catastrophic vessel or pipe failure is therefore judged at least highly unlikely. Again, this fact illustrates the AREVA Richland design commitment to safety enhancement by reducing challenges to those IROFS that are designed to protect against personnel exposure to the working fluid after a release.

- IROFS 4502 and 4503 are employed to maintain low combustible loading throughout the Richland Facility at all times. These IROFS make it highly unlikely that a small fire, such as a trash-can fire, could grow into a large fire (fire involving a significant portion of a room). For additional fire protection, the UO_2 building is fully equipped with fire extinguishers, alarm pull boxes, and heat detectors.

11.0 Fig. 2: Hazardous Materials Interaction Matrix

		A	B	C	D	E	F
A	Carbon Dioxide (CO_2)						
B	Tri-butyl Phosphate (TBP)						
C	Nitric Acid (HNO_3)		1, 4				
D	Incinerator Ash			2			
E	Deionized Water (DIW)			3			
F	Sodium Hydroxide (NaOH)			5		1	

Notes:

1: An exothermic oxidizer/organic reaction that could initiate combustion of the organic material.

2: Nitrogen dioxide gas (NO_2) and other oxides of nitrogen (NO_x) will be given off in the reaction.

3: An exothermic reaction causes a temperature increase, which could cause materials to boil and spatter.

4: The reaction will produce di-butyl phosphate at approximately 12% from tri-butyl phosphate. Di-butyl phosphate is somewhat more corrosive.

5: An acid-base reaction. Acid (H+) and base (OH-) ions react to form a salt and water (H_2O). An exothermic reaction, the heat of which goes into the water which could boil and spatter.

12.0 Fig. 3: Flowsheet

[redacted]

Comment [c29]: Trade secret/ Proprietary

[redacted]

Super Critical CO_2 Extraction Process ISA Summary

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1.0 Title

1.1 *Introduction*

The following ISA Summary information will, after approval by the NRC, be added to the "Integrated Safety Analysis – ISA Summaries, E15-01-2.9A and will be included in the annual update of the ISA summary that will be submitted the January following approval of the License amendment application for the Super Critical CO_2 Extraction Process.

1.1.1 Purpose

This summary only provides the needed additions to describe the supercritical CO_2 extraction process. The ISA Summary of record for the portions of the UO_2 building associated with uranium recovery is contained in Document E15-01-2.9A and the reader is referred to this section of the ISA summary for additional information.

1.1.2 Scope

The processes in the UO2 Building that are evaluated in this portion of the ISA include the supercritical CO2 extraction process.:

1.2 *Building Information*

The reader is referred to section 9.2 of Part 2, Chapter 9A, of Document E15-01-2.9A for this information.

1.3 *Overview of Operations*

The Supercritical CO_2 Extraction System implements scale-up to production capability of a process that has previously undergone extensive small-scale testing under laboratory and pilot plant conditions. The production version is designed for commercially efficient extraction of uranium from material bearing relatively low concentrations, such as incinerator ash.

The [redacted]

Comment [m1]: Trade secret / Proprietary

1.4 ***Process Systems***

1.4.1 **Subcritical CO_2 Extraction (System 186)**

Comment [m2]: Trade secret / Proprietary

As [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

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[redacted]

1.4.1.1 Hazard Identification

Criticality

The Supercritical CO_2 Extraction (System 186) tanks have favorable geometry for the uranium compounds within the uranium density range of commercially available UO_2 oxide powders.

Nuclear criticality in the bucket infeed system (duplex linear arrays) is ensured against by geometry control (container diameter and height; spacing between conveyors and conveyors and walls) as well as by enhanced administrative mass controls that maintain the total system SNM content below half of a safe batch on each set of conveyors.

The ISA Team judges that nuclear criticality in any of the extraction process vessels is not credible, due to favorable geometry design throughout, combined with installed vessel separation distances. Appropriate protections are provided to prevent against backflow into all unfavorable geometry liquid supply tanks.

Design of the extractor basket transport system ensures that only one basket can be moved at a time and that a basket in transit cannot be moved axially adjacent to another basket. These facts illustrate the AREVA Richland design preference given to passive engineered controls and design features.

Because of the high operating pressures in the subject equipment, catastrophic release sequences were extensively analyzed, but no associated nuclear criticality consequence was identified.

Nuclear criticality potentially resulting from high uranium in the waste fluid stream (raffinate) is ensured by transferring the raffinate to existing favorable geometry storage tanks in Room 185, Tanks 52 and 53, and then obtaining a uranium analyses, before allowing the fluid to be transferred to raffinate storage tanks to await further processing. It is noted that tanks in Room 185 of the UO2 building are currently in service and storing Un solution or raffinate in these tanks will not have an adverse impact on NCS.

The raffinate will eventually be transferred from these tanks and will then be processed through an existing processing system and will use the criticality safety limits and controls currently employed.

In the spent ash handling system, spent ash is consolidated into 55-gal drums (unfavorable geometry without neutron absorbers). Nuclear criticality is ensured against by two independent uranium assays on each basket of spent ash, required before allowing transfer of the ash to a waste drum.

A listing of the high consequence nuclear criticality accident sequences is provided below. This listing provides a description of the accident sequences and the initiating events and provides a summary of the risk determination to ensure, by designation of appropriate IROFS and management measures, that the risks dealt with in these accident sequences are acceptable.

Chemical

The principal hazards of the proposed Supercritical CO_2 Extraction System are related to sudden pressure release and subsequent personnel exposure to airborne hazardous chemicals, specifically CO_2 combined with aerosols of HNO_3, UN, and TBP.

Catastrophic release due to failure of pressure vessels and/or piping is prevented by design, construction, and periodic inspection in conformance with applicable pressure vessel codes and standards.

Potential catastrophic release due to human error or mechanical degradation related to frequent opening of the lids of the six [redacted] became a primary design consideration. Catastrophic releases are prevented here by passive design features. For example, design ensures that the lids cannot be manually opened while under significant internal pressure. Also, large pressure relief vents that remain open until the lid is completely closed prevent buildup of high pressure in the vessel under unsafe lid positions.

Comment [m3]: Trade secret / Proprietary

Catastrophic release due to overpressurization in the process system is prevented by: 1) pump design, which limits output pressure as a function of plant supply air pressure; and 2) equipping the process vessels with pressure relief valves. Flow from relief valves is designed to safely exhaust through the building exhaust system (K31), and environmental contamination is precluded by two stages of HEPA filtration.

A listing of the high or intermediate chemical consequence accident sequences is provided below. This listing provides a description of the accident sequences and the initiating events and provides a summary of the risk determination to ensure, by designation of appropriate IROFS and management measures, that the risks dealt with in these accident sequences are acceptable.

Figure 2 Hazardous Materials Interaction Matrix

A	Carbon Dioxide (CO_2)	A	B	C	D	E	F
B	Tri-butyl Phosphate (TBP)						
C	Nitric Acid (HNO_3)		1, 4				
D	Incinerator Ash			2			
E	Deionized Water (DIW)			3			
F	Sodium Hydroxide (NaOH)			5		1	

Notes:

1. An exothermic oxidizer/organic reaction that could initiate combustion of the organic material.
2. Nitrogen dioxide gas (NO2) and other oxides of nitrogen (NOx) will be given off in the reaction.
3. An exothermic reaction causes a temperature increase, which could cause materials to boil and spatter.
4. The reaction will produce di-butyl phosphate at approximately 12% from tri-butyl phosphate. Di-butyl phosphate is somewhat more corrosive.

5. An acid-base reaction. Acid (H+) and base (OH-) ions react to form a salt and water (H2O). An exothermic reaction, the heat of which goes into the water which could boil and spatter.

Radiological

Radiological hazards and the controls to prevent or mitigate them are essentially universal throughout the plant site. As a result, the Radiological Safety program is applied plant-wide as discussed in Chapter 7 of Part 1 of the ISA Summary.

A listing of the high or intermediate radiological consequence accident sequences is provided below. This listing provides a description of the accident sequences and the initiating events and provides a summary of the risk determination to ensure, by designation of appropriate IROFS and management measures, that the risks dealt with in these accident sequences are acceptable.

1.4.1.2 Summary of High and Intermediate Accident Sequences

A listing of the high and intermediate consequence accident sequences is provided below. This listing provides a description of the accident sequences and the initiating events and provides a summary of the risk determination to ensure, by designation of appropriate IROFS and management measures, that the risks dealt with in these accident sequences are acceptable.

Accident [redacted]

Comment [m4]: Security-Related; Trade secret / Proprietary

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CRITICALITY SAFETY ANALYSIS SUMMARY

SUPERCRITICAL CARBON DIOXIDE (CO_2) EXTRACTION SYSTEM

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Table 1 - List of Acronyms

Acronym	Definition
CMF	Common Mode Failure
CO_2	Carbon Dioxide
FWR	Full Water Reflection
HNO3	Nitric Acid
HRR	Horn Rapids Road
ID	Inside Diameter
IROFS	Items Relied On For Safety
IROFS	Item Relied On For Safety
ISA	Integrated Safety Analysis
NCS	Nuclear Criticality Safety
NCSA	Nuclear Criticality Safety Analysis
OD	Outside Diameter
SBC	Safety Batch Container
SCALE	Standardized Computer Analysis for Licensing Evaluation
SNM	Special Nuclear Material
TBP	Tri-butyl Phosphate
UN	Uranyl Nitrate
DIW	Deionized Water
TBP	TriButyl Phosphate

1.0 EXECUTIVE SUMMARY

The proposed supercritical carbon dioxide (CO2) extraction system implements scale-up to production capacity of a process previously tested at AREVA, Richland under small-scale laboratory and scale-up conditions. This production version is designed for commercially efficient extraction of uranium from waste material, such as incinerator ash, that contains a relatively low percentage of uranium.

System design incorporates defense-in-depth principles to the most practicable extent, including: 1) preference for the selection of engineered controls over administrative controls to increase overall system safety and reliability; and 2) features that enhance safety by reducing challenges to Items Relied on for Safety (IROFS).

Nuclear criticality in the bucket infeed system (duplex linear arrays) is ensured against by geometry control, as well as by enhanced administrative mass controls that maintain the total system SNM content below a safe batch. This mass control extends through the ash preparation equipment.

The ISA Team judges that nuclear criticality in any of the process vessels is not credible, due to favorable geometry design throughout, combined with fixed vessel separation assembly. Additional protection is provided by the fact that the physical properties of the extraction system and the feedstock dictate that the process fluid will contain relatively low percentages of uranium.

Design of the extractor basket transport system ensures that only one basket can be moved at a time, and that a basket in transit cannot be moved axially adjacent to another basket. These facts illustrate the AREVA, Richland design preference given to passive engineered controls and design features. Due to the high operating pressures in the subject equipment, catastrophic release sequences were extensively analyzed, however no associated nuclear criticality consequence was identified.

Backflow prevention of UN into unfavorable geometry supply tanks is ensured by incorporation of favorable geometry tanks, air breaks, and, where needed, active engineered controls as described in Section 6.0 of the license application. Wherever practicable, design preference has been given to passive engineered controls over active engineered controls, and to engineered controls over administrative controls.

Accident sequences dealing with catastrophic fluid release were extensively analyzed and no associated nuclear criticality consequence was identified. A catastrophic release would tend to disperse any uranium contained in the system, rather than concentrate it into an unfavorable geometry. In a catastrophic release, most of the heavy materials would fall to the floor (covering a large area), and/or would spread evenly into the exhaust duct or onto the HEPA filters.

Various [redacted] could lead to the inclusion of excessive uranium in the raffinate stream. This becomes a potential nuclear criticality concern related to down stream processing of the raffinate. Nuclear criticality in these down-stream systems is prevented by use of favorable geometry vessels and procedures that ensure undesirable masses of U will not be transferred to the unfavorable geometry collection vessels (filter presses, 55-gallon drums, and IX columns) that exist further down-stream in the process. These existing processing control mechanisms ensure safe collection of solids that will be separated from the raffinate.

Comment [m1]: Trade secret / Proprietary

In the solid waste handling system, spent ash is dumped from the favorable geometry extractor baskets into 55-gallon waste drums (unfavorable geometry without neutron absorbers). Two independent uranium assays on each basket of spent ash, before the ash is transferred to a waste drum, ensures against nuclear criticality in this process.

Radiological safety is provided by equipment ventilation and enclosing SNM in containers before transporting them to storage areas of the HRR site and by assuring that long term storage of SNM is in appropriate closed containers. Radiological safety has been evaluated here and determined that any required response to a radiation exposure will not have an adverse effect on NCS.

With respect to process chemicals, this process uses nitric acid (HNO3), Tri-butyl Phosphate (TBP), and CO_2. For hazards, accidents, and protections related to the use of these chemicals refer to the ISA Summary. Chemical safety has been evaluated here and determined that any required response to a chemical exposure will not have an adverse effect on NCS.

Fire safety has likewise been evaluated and shown that neither a fire, nor the actions taken to mitigate a fire, will lead to a compromise in NCS for this process system.

2.0 INTRODUCTION

This NCSA provides a multi-disciplinary review and analysis of the supercritical CO_2 extraction process. It demonstrates NCS of the process equipment used in this processing system.

The following information provides a summary of the computer calculation results that support the supercritical CO_2 extraction process, process system 186.

Section 1.0 presents the executive summary. Section 2.0 discusses the purpose, scope of analysis, and summarizes the conclusions. Section 3.0 describes the system equipment and process. Section 4.0 details the methodologies used for NCS and accident sequence analysis. Equipment parametric studies are provided in section 5.0. Neutron and system interactions with other equipment and storage arrays are addressed in section 6.0. Section 7.0 details the accident analysis, including accident series and sequences, initiating events (IEs), and barriers/defenses. A discussion of the parameters affecting NCS and the IROFS that will be used to keep keff in acceptable ranges are provided in section 8.0. Appendix A contains a listing of data and calculations. Appendix B contains samples computer inputs.

2.1 *Purpose*

This summary provides a demonstration that the supercritical CO_2 extraction process will remain adequately subcritical at normal and credible abnormal conditions.

2.2 *Scope of Analysis*

This Summary covers the in-feed conveyor arrangement, the supercritical CO_2 extraction process equipment, the tanks that contain process fluids, and the solid waste material that will be disposed of in 55-gallon drums.

2.3 *Summary of Conclusions*

Criticality safety of the CO_2 extraction process is achieved through the use of either safe batch control or surface density control and by reducing the uranium content of the ash at the point of generation as much as practical. Geometry/volume and spacing of the containers and vessels is used for the containment of ash from various waste streams on which criticality safety is relied on. Mass requirements for ash containment are ensured by reliance on sampling of uranium content and verification of fissile material levels via waste handlers prior to placing into approved ash storage containers.

Radiological safety is provided by enclosing contaminated items in SBC's before transporting them to the super critical CO_2 extraction process. Additional radiological safety is implemented into the design by containing all of the process vessels and equipment inside of hoods.

Fire safety has been evaluated to show that neither a fire, nor the actions taken to mitigate a fire, will lead to a compromise in criticality safety. Since the super critical CO_2 extraction process takes no credit for moderation control, no restrictions on the use of water for fire fighting are necessary unless required by adjacent processes.

3.0 SYSTEM DESCRIPTION

The reader is referred to section 6.0 of the license amendment application for a detailed description of the process and process equipment.

4.0 ANALYSIS METHODOLOGY

4.1 *Nuclear Analysis Methodology*

4.1.1 Computer Codes and Databases Used

The calculations in this NCSA were performed using the KENO-V.a module in the Standardized Computer Analyses for Licensing Evaluation (SCALE), Version 4.4a-PC (Reference 2), to calculate the neutron multiplication factor, k_{eff}. The SCALE 4.4a/KENOV.a calculations in this NCSA were run on a Hewlett Packard Intel Core 2 Duo personal computer (PC).

4.1.2 Cross Section Preparation

The cross sections used were taken from the SCALE 4.4a 238-group based on the ENDF/B-V library. BONAMI and NITAWL-II were used for the resonance corrections.

4.1.3 Benchmarking

The SCALE 4.4a modular code system was developed for use by the USNRC and its licensees. The KENOV.a module in SCALE 4.4a, with BONAMI and NITAWL-II resonance corrected ENDF/B-V 238-group cross sections, has been extensively benchmarked against critical experiments. The HRR documentation of the validation effort for this system of codes is contained in Reference 2. This validation report demonstrates that, provided the KENO.Va calculated k_{eff} has a standard deviation less than or equal to 0.00100, then a 95/95 upper limit for k_{eff} is obtained by adding 0.0113 to calculations of well moderated homogenous systems. All peak cases in this NCSA occur in the well moderated range. Therefore, a total uncertainty of 0.0113 was added to the KENO-calculated k_{eff} values before comparing these values to the HRR SNM license application limits.

4.2 *Accident Analysis Methodology*

The reader is referred to Chapter 4 of the Integrated Safety Analysis, "E15-0 ISA Summaries Chapters 1-8 - Richland Facility ISA Program" for an explanation of the ISA accident analysis methodology.

4.2.1 Accident Scenario Development

A list of possible system upsets/pathways was compiled by Operations, Engineering, and NCS personnel familiar with the system. Drawings and system descriptions were gathered to provide a current up-to-date description of the system. The system was then analyzed to determine if any single or multiple common mode failure (CMF) points exist which could adversely affect NCS. All NCS control features and/or limits required to prevent, detect and mitigate these conditions were documented.

Those participating in a review of credible accident scenarios included:

- DM Carmichael ISA Team Leader
- SR Lockhaven, Industrial Safety
- CD Manning, NCS
- WL Doane, NCS
- SS Koegler, Responsible Engineer
- AB Allen, Engineer, Super Critical CO_2 Extraction expert

- MB Salisbury, Process Engineer
- RK Burklin, Health Physicist
- BE Lewis, I&C Engineer
- TL Knox, Process Operator

4.2.2 ISA Risk Indexing

The reader is referred to Chapter 4 of the Integrated Safety Analysis-, E15-01 ISA Summaries Chapters 1-8 - Richland Facility ISA Program for an explanation of the ISA Risk Indexing methodology.

5.0 EQUIPMENT PARAMETRIC STUDIES

As discussed in section 3.0, for safety analysis purposes, the supercritical carbon dioxide (CO_2) extraction system can be divided into the following components:

1. Infeed Conveyor System

[redacted] Ash [redacted]

[redacted]

Comment [m2]: Trade secret / Proprietary

5.1 *Infeed Conveyors*

This section includes the parametric studies for the infeed conveyors and the ash buckets used to store the staged infeed material.

NCS for the processing and storage of SNM in 5-gallon buckets on these conveyors is ensured by geometry, spacing, and material control.

5.1.1 Parameters

Table 2 Parameter Summary for Infeed Conveyor System

Parameter	Normal Condition	Abnormal Condition	Condition Used/Considered in Analysis
SNM Form Urania powders mixed with other oxides	Urania powders mixed with other oxides	Urania powders mixed with other oxides	UO_2
^{235}U Enrichment	≤ 5 wt%	≤ 5 wt%	5 wt%
Mass	<18 kg UO_2 equivalent combined on two sets of conveyors	<18 kg UO_2 equivalent on each set of conveyors	> 20 kg per 5-gallon container
Concentration UO_2	See Density	See Density	See Density
Density UO_2	Less than 25% of solids	More than 25% of solids	Optimally moderated UO_2 Saturated
Homogeneity	Uniform	Uniform	Uniform
Moderation	Optimal in Containers Low IM (< 1 vol%)	Optimal in Containers Low IM (< 1 vol%)	Optimal in Containers Optimal IM
Geometry (Shape)	All 5-gallon buckets ≤11.25" ID, ≤12.875" Inside Height	All 5-gallon buckets ≤11.25" ID, ≤13.375" Outside Height (Buckets sides sometimes dent but don't bulge. Occasionally the bottom bulges down.)	All 5-gallon buckets ≤11.25" OD, ≤13.5" Tall
Volume	≤ 20.972 liter	≤ 21.787 liter	≤ 21.990 liter
Interaction	Between Buckets on conveyors and between two conveyors of buckets	Between Buckets on conveyors and between two conveyors of buckets	Between Buckets on conveyors and between two conveyors of buckets
Reflection	Concrete floor and wall, Personnel	Concrete floor and wall, Personnel	Concrete floor and wall, FWR elsewhere
Neutron Absorption	Bucket wall (steel) other oxides in the ash	Bucket wall (steel) other oxides in the ash	No bucket wall No other oxides in the ash

5.1.2 Design Features and materials of construction

Ash containers are all standard metal 5-gallon buckets. Field measurements indicate nominal dimensions are 11.25" ID, 12.875" Inside Height, and the wall thickness is about 0.0159". The wall of the buckets tapers outward slightly at the top. The outside diameter at the bottom is about 10.375" and about 11.5" at the top under the double rolled rim. The outside height is about 13.375".

Table 3 shows the required design features for the equipment analyzed in this section.

Table 3 Required Design Features for Infeed Conveyors and associated containers

Description / Dimension	Requirement
Conveyor length	**A maximum of 100 inches or < 9 Buckets.**
Conveyor Height Above floor	**At least a minimum of 60 cm.**
Distance from Closest wall	**At least a minimum of 30 cm.**
Distance from adjacent conveyor	**At least a minimum of 30 cm.**

5.1.3 Computer Model Description

The computer model analyzes various mass loadings of water saturated UO_2 in each of the buckets on the conveyor system. The wall material of the containers is conservatively omitted. The buckets are modeled standing upright 60 cm above a 30 cm thick concrete floor, 30 cm between the Arrays, next to a 30 cm thick concrete wall. Then the entire geometry is modeled with 30 cm of FWR.

The arrangement of the buckets on the conveyor system model is illustrated below in **Figure 1**.

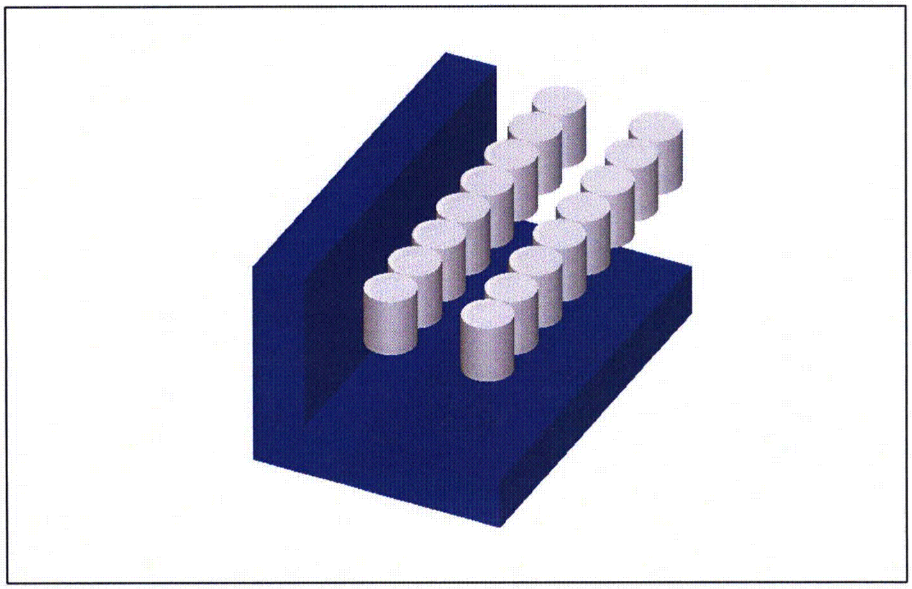

Figure 1 - Model of an 8x2 Array of 5-Gallon Buckets on the Conveyor System

5.1.4 Sensitivity Studies

The calculations in this section evaluate the impact of UO_2 density, mass loading, and moderator content in each bucket on the conveyor system for a range of various conditions.

The first sensitivity study considers UO_2 at various densities for several mass loadings in the 5-gallon buckets on the conveyor system. Water saturated UO_2 mass loadings of 5.1, 18, 20, 22, and 25 kg, were used for calculations of keff. Furthermore a distinct calculation was performed for completely filled buckets. The results for these calculations are illustrated graphically in **Figure 2** as well as shown numerically in Table 12.

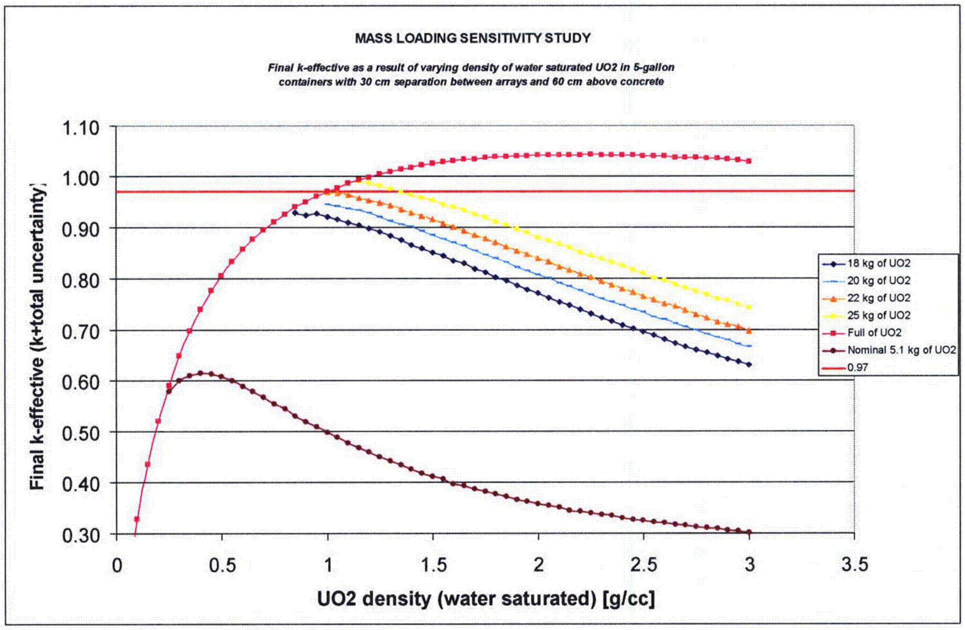

Figure 2 - Mass Loading Sensitivity Study

Figure 2 shows the full bucket loading, as expected will increase reactivity as UO_2 density increases with a slight drop off in keff after the peak for water saturated UO_2 density at 2.25 g/cc. However, for mass loadings of 5.1, 18, 20, 22, and 25 kg it is shown that from the minimum density required to fill a bucket, the result in keff slightly rises as does the trend for a full bucket and then decreases as the volume of material is limited by the increasing density for the given mass loadings.

The next sensitivity study is performed on the interspersed moderation for buckets with a mass loading of 18, and 20 kg of water saturated UO_2 at a density of 0.85 and 1.00 g/cc respectively. The results for these calculations are shown graphically in **Figure 3** and numerically in **Table 13.**

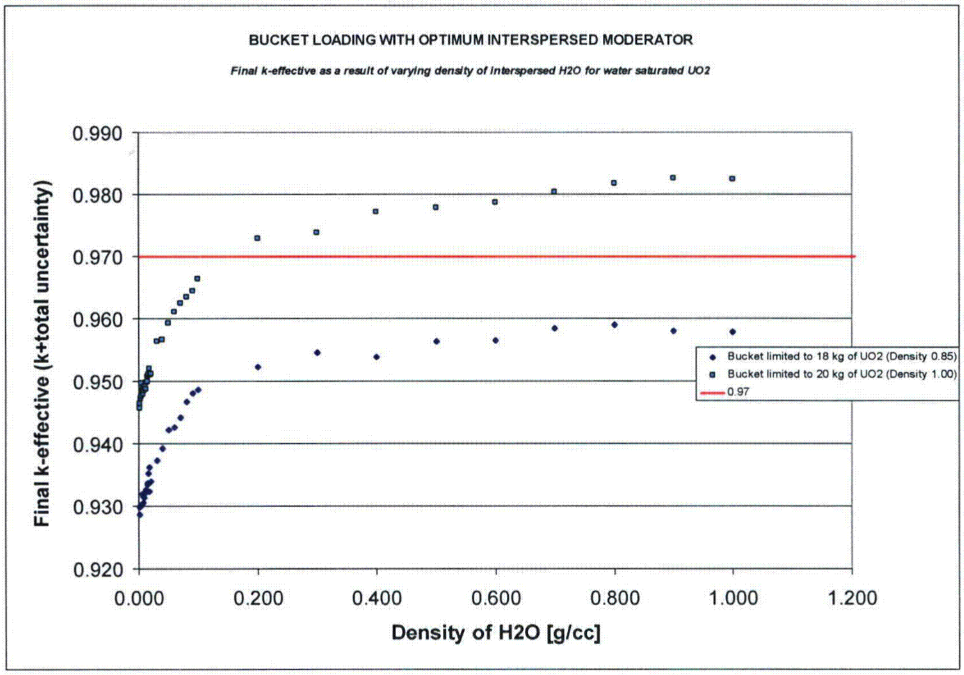

Figure 3 - Bucket Loading with Optimum Interspersed Moderator

Figure 3 demonstrates that if each 5-gallon bucket contains 18 kg of optimally moderated UO2 powder (0.80 g/cc saturated with water), k_{eff} remains less than 0.97 for all levels of interspersed moderator. If each bucket contains 20 kg of optimally moderated UO_2 powder (1.0 g/cc saturated with water) k_{eff} remains less than 0.97 for all credible amounts of interspersed moderator (< 10 volume %) including fire-fighting scenarios.

Another sensitivity study is done to analyze the loss of mass control. For this study the 8x2 arrangement of buckets on the conveyor system, there is a double batch bucket in each row. Five gallon containers of water saturated UO_2 with mass loadings of 5.1, 18, 20 and, 22 kg, were analyzed for k_{eff} effects when a single double batch or a single 100% full bucket (2.25 g/cc water saturated UO2) is also present in each row. The double batched / full container is located 4 buckets in on each row near the center of the array as illustrated in **Figure 4**. Note: Only one double batched bucket is included in this summary. The k_{eff} results are shown in Figure 5 and numerically in **Table 15**.

The density for the water saturated UO_2 powder in the double batched 5-gallon buckets is 1.65, 1.85, and 2.00 g/cc respectively. The results for these cases are graphically shown in **Figure 5** and numerically in **Table 14.**

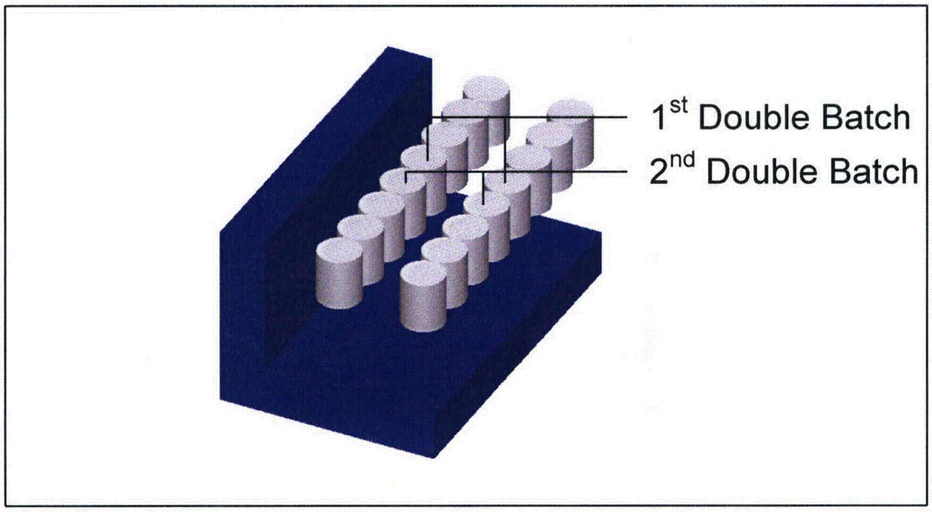

Figure 4 – Loss of Mass Control Locations

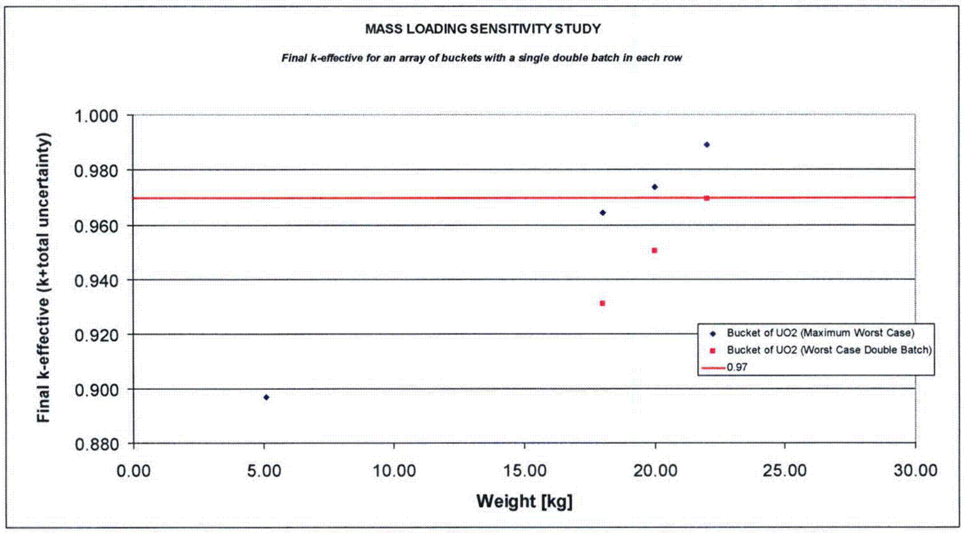

Figure 5 – Mass Loading Sensitivity Study

Figure 5 shows that a single 5-gallon bucket completely full of optimally moderated UO_2 powder at a density of 2.25 g/cc located 4 buckets inward within each row of the array of containers filled with a mass loading of 5.1 kg UO_2, optimally moderated has a k_{eff} less than 0.9 including biases and uncertainties. It also shows that in the same case but for a mass loading of 18 kg UO_2, optimally moderated, k_{eff} is less than 0.97 including biases and uncertainties.

Figure 5 further demonstrates for the second case that when each container on the conveyors is overbatched to 20, and 22 kg UO_2 and a single container on each conveyor is double batched over the 18 kg limit (resulting in 36 kg optimally moderated UO_2) k_{eff} remains less than 0.97 including biases and uncertainties.

5.1.5 Interactions

The sensitivity studies in the previous section include neutron interactions between the two infeed conveyors and associated containers.

[redacted] *Ash* [redacted]

Comment [m3]: Trade secret / Proprietary

[redacted]

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[redacted]	[redacted]	[redacted]	[redacted]

5.2.2 Design Features and materials of construction

The primary design features of this equipment include: containment, minimal hold-up during operation, spacing from other components, the ability to inspect for hold-up, and to remove any hold-up material from the equipment. The equipment dimensions are also required to be less than those modeled in this analysis.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

5.2.4 Sensitivity Studies

The calculations in this section evaluate the impact of UO_2 density, moderator content, and proximity of reflectors. The results are represented graphically in **Figure 7** through **Figure 10**.

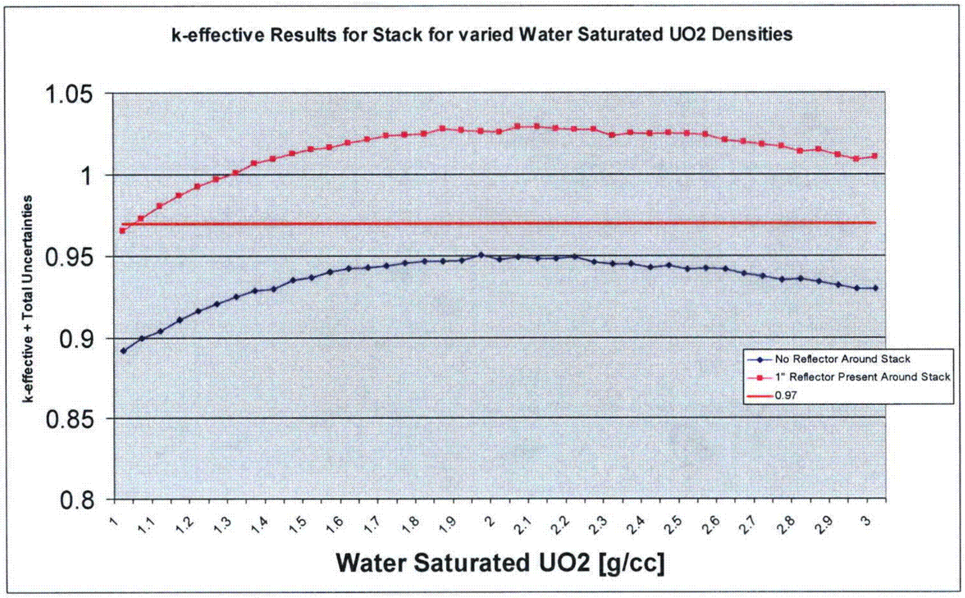

Figure 7 K-Effective Results for Stack for Varied Water Saturated UO_2 Densities

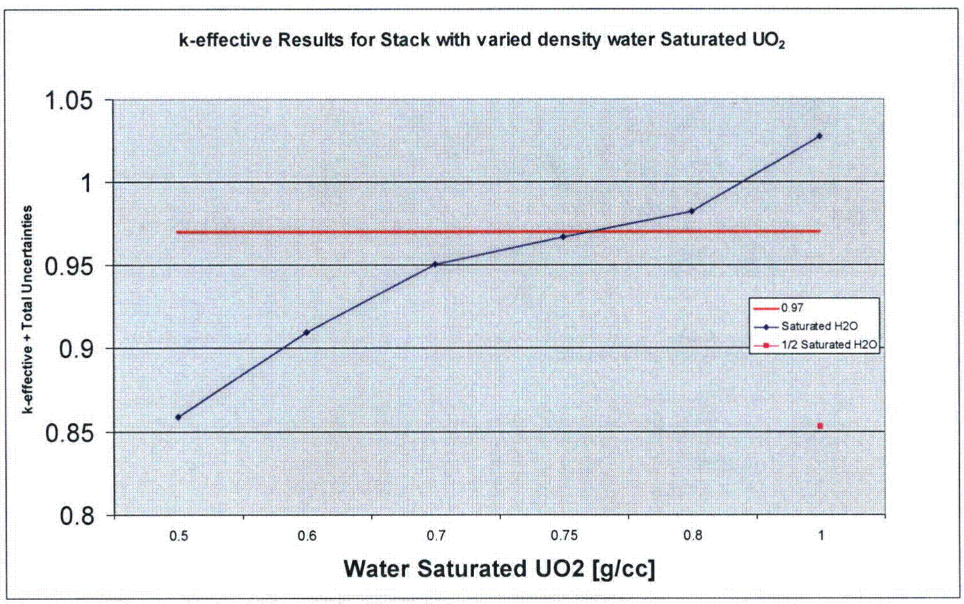

Figure 8 K-effective Results for Stack with Varied Density Water Saturated UO_2

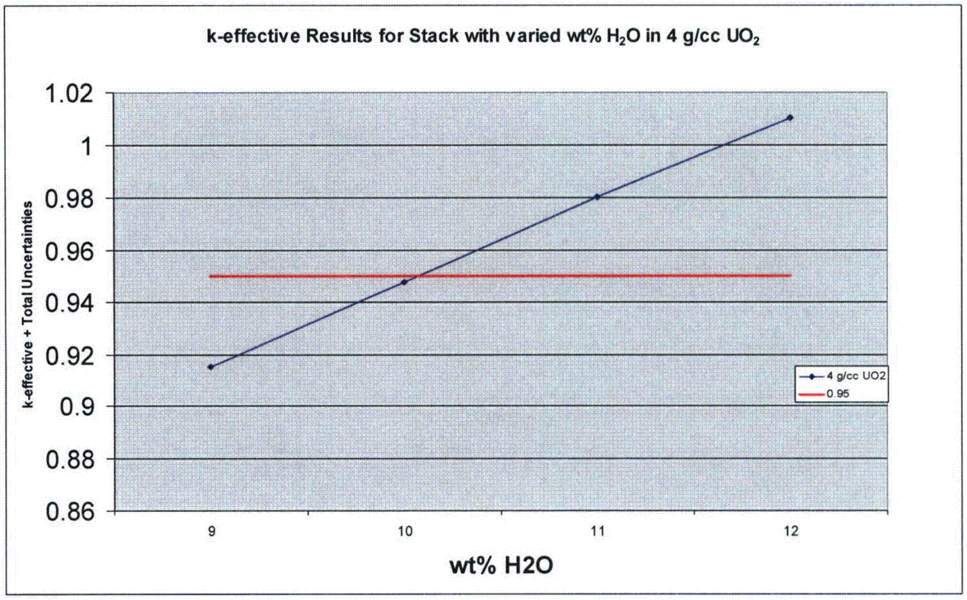

Figure 9 K-effective Results for Stack with Varied wt% H_2O in 4 g/cc UO_2

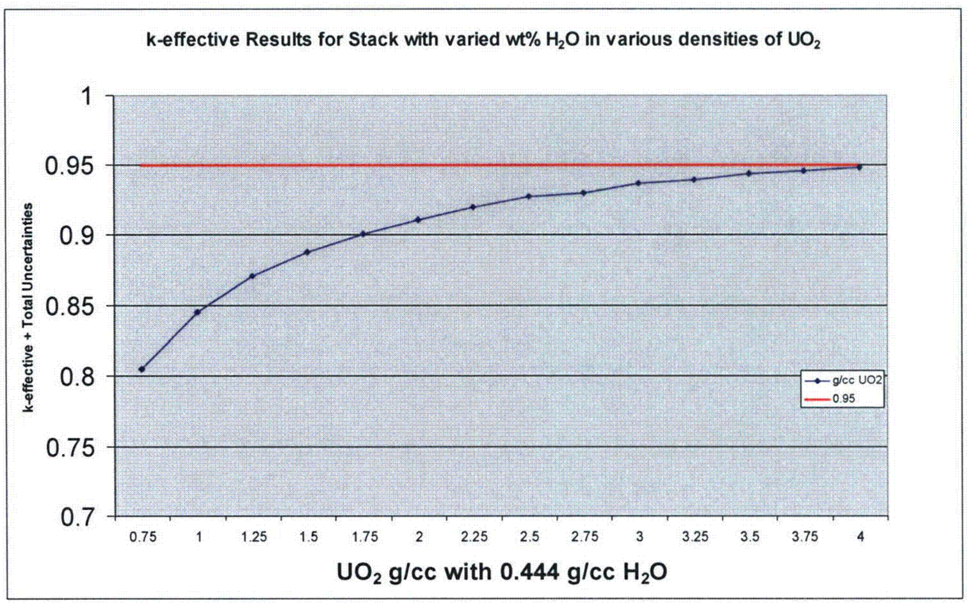

Figure 10 K-effective Results for Stack with Varied wt% H_2O in Various Densities of UO_2

5.2.5 Interactions

See section 6.0 for neutron interactions.

Comment [m4]: Trade secret / Proprietary

[redacted] ***Extractor*** [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

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[redacted] Design [redacted]

Comment [m5]: Trade secret / Proprietary

[redacted]

[redacted]	[redacted]
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[redacted]	[redacted]

5.3.3 Computer Model Description

The computer model for the extractor and associated baskets analyzes various vessel diameters, mass loadings of water saturated UO_2, interspersed moderator, and vessel edge-to-edge separation. [redacted]

Comment [m6]: Trade secret / Proprietary

[redacted]

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5.3.4 Sensitivity Studies

The first sensitivity study considers vessel diameter and is performed on a basket only cylindrical geometry of water saturated UO_2 at a density of 2.395 g/cc. Two models are analyzed. [redacted]

Comment [m7]: Trade secret / Proprietary

[redacted]

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Figure 14 – Optimum UO2-H2O Mixture Study (Normal Condition)

[redacted]

Figure 15 – Optimum UO2-H2O Mixture Study (Abnormal Condition)

[redacted]

Using [redacted]

Comment [m8]: Trade secret / Proprietary

[redacted]

Figure 16 – Optimum Interspersed Moderation Study (Normal Condition)

[redacted]

Figure 17 – Optimum Interspersed Moderation Study (Abnormal Condition)

Figure 16 [redacted]

[redacted]

[redacted]

Comment [c9]: Trade secret / Proprietary

[redacted]

Figure 18 – Vessel Separation Spacing Sensitivity Study (Abnormal Condition)

[redacted]

[redacted]

The [redacted]

Comment [m10]: Trade secret / Proprietary

[redacted] *Process* [redacted]

Comment [m11]: Trade secret / Proprietary

[redacted]

A listing of the credible nuclear criticality accident sequences is provided below. This listing provides a description of the accident sequence and the initiating event and provides a summary of the risk determination of ensure that these accident sequences are an acceptable risk by designating the appropriate IROFS and management measures.

Process fluids will normally contain only dilute solutions of UN. Design of each of the process vessels maintains favorable geometry for both UN solution and UO_x/H_2O mixtures. This illustrates the AREVA, Richland design commitment to rely primarily on engineered controls, as well as the defense-in-depth approach which, from inception, has characterized the equipment design.

[redacted] CO_2 [redacted]

Comment [m12]: Trade secret / Proprietary

[redacted]

The principal component of process offgas is CO_2; under normal operating conditions it will contain only trace amounts of TBP and UN. Offgas, under normal operating conditions as well as upon release from the various pressure relief valves, flows into the existing building exhaust system (K31). Calculations confirm that this exhaust system has ample capacity to handle an abnormal mixed-materials release, with about 10% TBP and some UN, such as might occur from a pipe leak. If a pressure relief valve is actuated, process fluids will be released to the TBP/CO_2 separator. Offgas from the separator, again flowing into the existing building exhaust, will also contain only trace amounts of TBP and HNO_3.

Comment [c13]: Trade secret / Proprietary

[redacted] Parameters

[redacted]

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[redacted] Design [redacted]

Comment [m14]: Trade secret / Proprietary

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[redacted] Computer [redacted]

Comment [m15]: Trade secret / Proprietary

[redacted]

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Figure 19 Process Vessels in an Array of [redacted]

[redacted] Sensitivity Studies

Comment [c16]: Trade secret / Proprietary

[redacted]

[redacted]

[redacted]

Comment [c17]: Trade secret / Proprietary

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[redacted]

[redacted]

The figures from ARH-600 indicate that all concentrations UN solution and UO_2-H_2O solutions up to 500 g U/l remain adequately subcritical in process vessels with a diameter less than 15 inches.

It is possible that trace amounts of UO_2-H_2O could enter the process vessel. However, as shown in **Figure 24** and **Figure 25** (III.B.4-6 and ARH-600 III.B.7-6) concentrations would have to exceed 500 g U/L and result in more than 15 kg/ft of length to approach critical. These conditions are at least highly unlikely in this process. The [redacted]

Comment [m18]: Trade secret / Proprietary

[redacted]

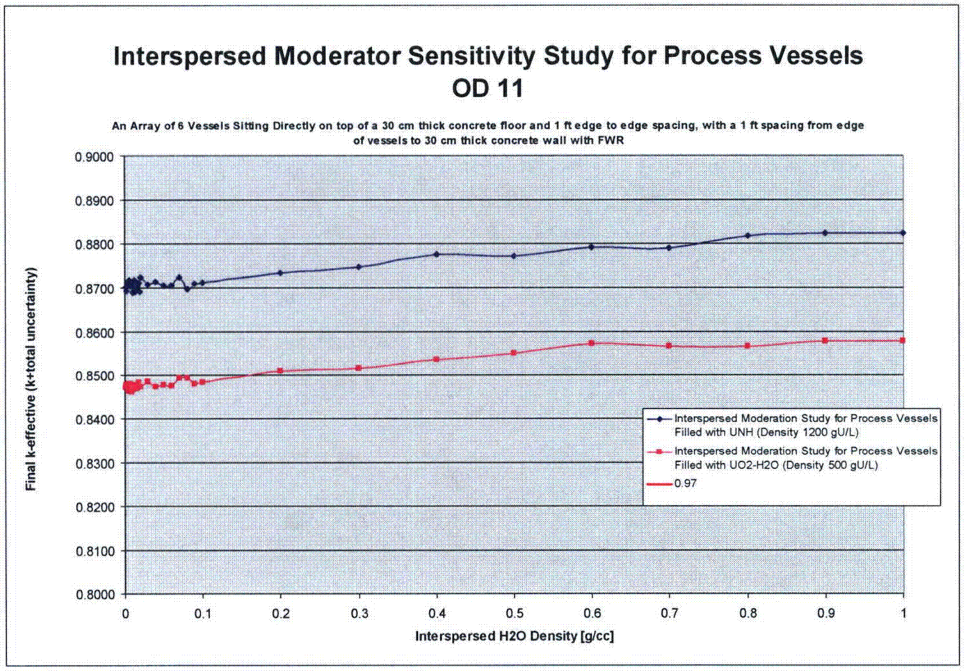

Figure 21 Interspersed Moderator Sensitivity Study for Process Vessels with OD 11.00"

Figure 21 shows the impact of interspersed moderator on k_{eff} for an array of process vessels filled with a solution of UNH with a U content of 1200 g U/l and a UO_2-H_2O solution with a U content of 500 g U/l. From the results, it is shown that at an optimum interspersed moderation of approximately 1 g/cc H_2O, k_{eff} is a great deal less than 0.90 for an array of process vessels.

The next sensitivity study carried out is on the edge to edge spacing between the process vessels containing both solutions. The results for both of these cases are graphically shown in **Figure 22** and numerically in **Table 26.**

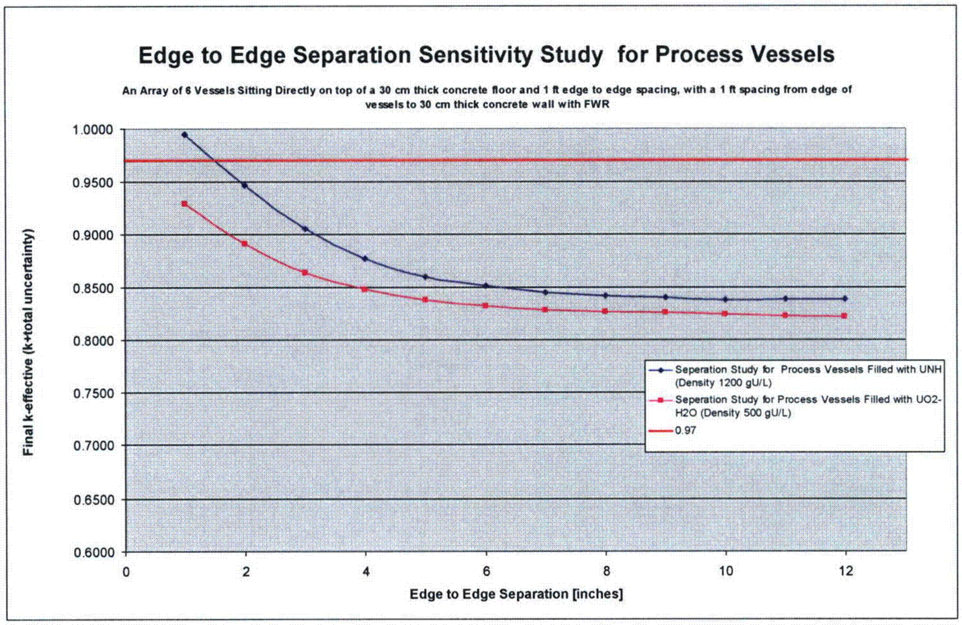

Figure 22 – Sensitivity Study for Edge-to-Edge Spacing of Process Vessels

Figure 22 illustrates how varying the edge to edge spacing between the vessels has a relatively consistent neutronic interaction from an edge to edge spacing of 6 inches to 12 inches, where k_{eff} is roughly 0.85 for a solution of UNH with a U content of 1200 g U/l and k_{eff} is less then 0.85 for a UO_2-H_2O solution with a U content of 500 g U/l. We see from the results that an array of six process vessels has a k_{eff} less than 0.95 for UNH filled vessels at a 2 inch separation and for UO_2-H_2O a 1 inch separation.

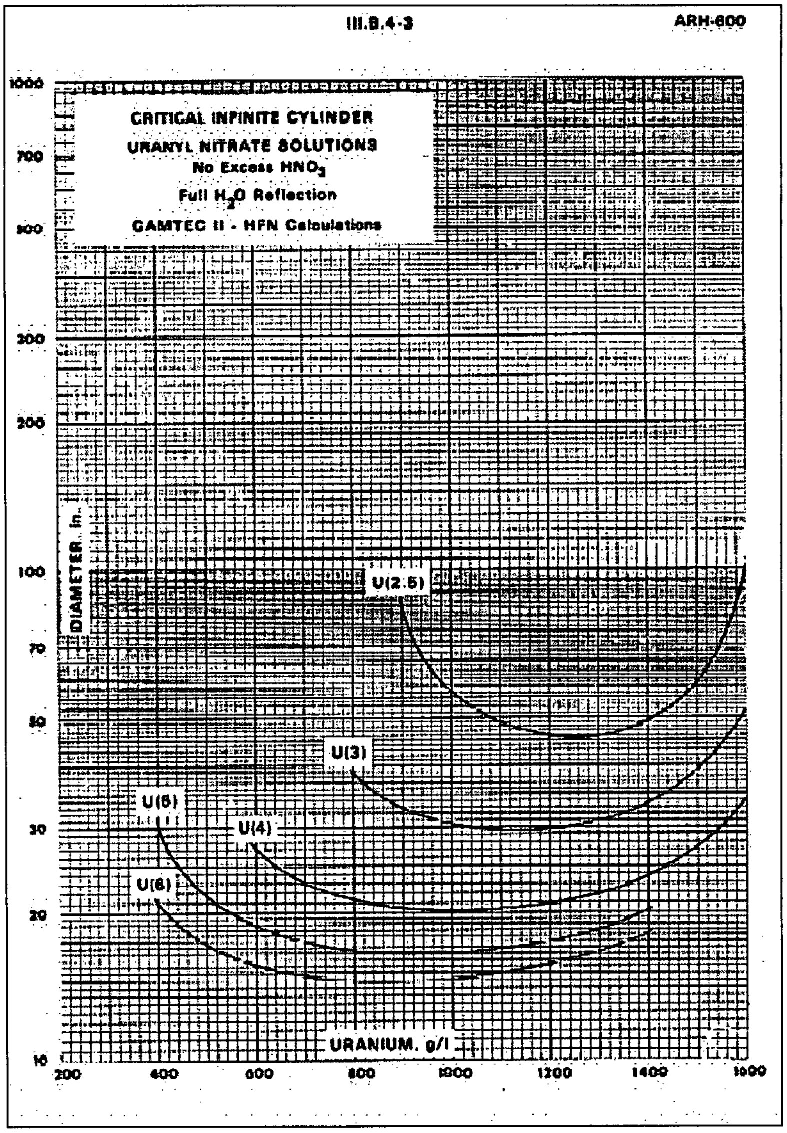

Figure 23 (ARH-600 III.B.4-3)

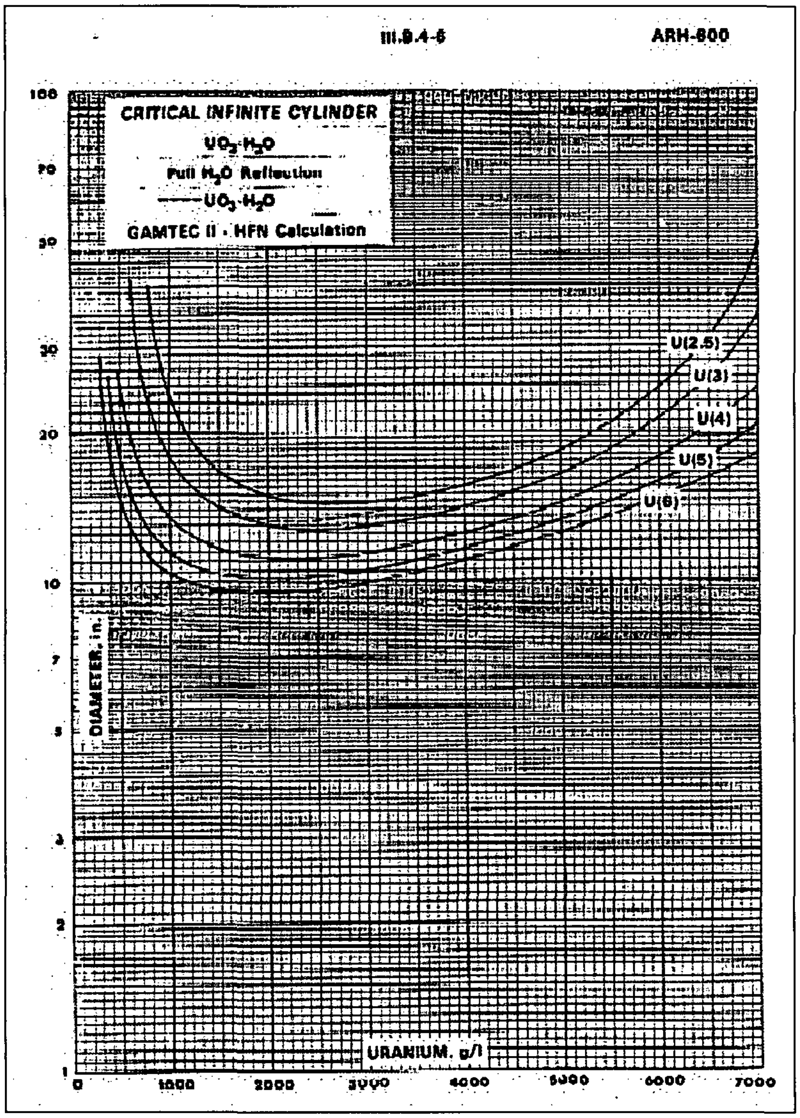

Figure 24 (ARH-600 III.B.4-6)

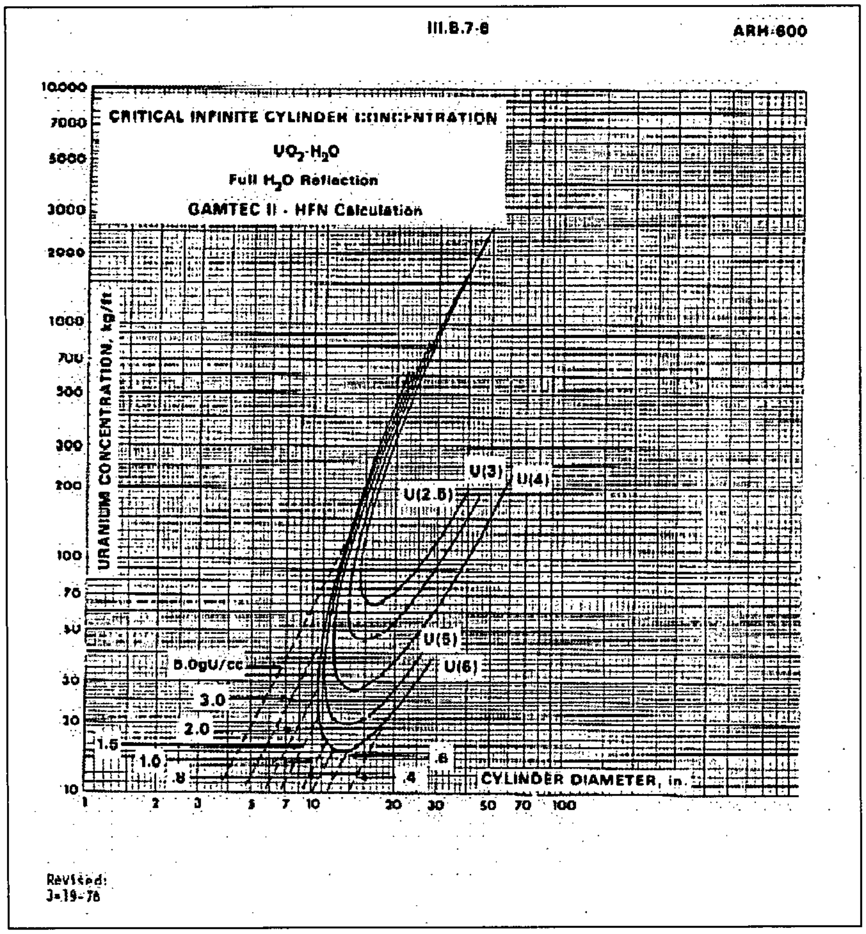

Figure 25 (ARH-600 III.B.7-6)

5.4.5 <u>Interactions</u>

The sensitivity studies in the previous section include neutron interactions between the process vessels.

5.5 *Waste Drums*

In the spent ash handling system, spent ash is consolidated into 55-gal drums (unfavorable geometry without neutron absorbers). Nuclear criticality is ensured against by two independent uranium assays on each basket of spent ash, required before allowing transfer of the ash to a waste drum.

5.5.1 Parameters

Table 9 Parameter Summary for Waste Drums

Parameter	Normal Condition	Abnormal Condition	Condition Used/Considered in Analysis
SNM Form Un solutions in vessels containing SNM	Uranium Oxides	Uranium Oxides	UO_2–H_2O
^{235}U Enrichment	≤ 5 wt%	≤ 5 wt%	5 wt%
Mass	<		—
Concentration U			
Density of U	See concentration	See concentration	See concentration
Homogeneity	Uniform	Uniform	Uniform
Moderation	Not applicable	Not applicable	Not applicable
Geometry (Shape)	See Table 11	See Table 11	See Table 11
Volume	See Table 11	See Table 11	See Table 11
Interaction	Between process vessels and Buckets on conveyors and between two conveyors of buckets	Between process vessels and Buckets on conveyors and between two conveyors of buckets	Between process vessels and Buckets on conveyors and between two conveyors of buckets
Reflection	Drum Walls of steel, Concrete floor, Personnel	Drum Walls of steel, Concrete floor, Personnel	Drum Walls of steel, Concrete floor, FWR elsewhere
Neutron Absorption	Drum walls (SS steel) other oxides in the spent ash	Drum walls (SS steel) other oxides in the spent ash	

5.5.2 Design Features and materials of construction

Table 10 Required Design Features for Basket Emptying and 55-Galloon Drum Filling

Description / Dimension	Requirement
Waste Drums	For OD See Table 11 0.125" Nominal 316L SS Wall Material

5.5.3 Computer Model Description

No computer modeling was performed for waste drums. This portion of the analysis is based on surface density.

5.5.4 Sensitivity Studies

Surface Density is defined as the average areal concentration (in terms of mass per unit area, typically in grams of uranium per cm^2) of an accumulation of uranium-bearing material and is described on page 77 of Ron Knief's Nuclear Criticality Safety - Theory and Practice (Reference 4). For example, a box occupying 100 cm^2 of floor area and containing 5000 g U per box would have a surface density of 50*N g U/cm^2 if stacked N units high.

The maximum allowed surface density is defined on page 77 of Reference 4 as

$$\sigma_{max} = 0.54\sigma_0(1 - 1.37f)$$

where σ_0 is the surface density (g/cm^2) of a critical water-reflected infinite slab and f is the "fraction critical", i.e., the ratio of the mass of a unit in the array (m) to the critical mass of an un-reflected sphere of the same material (m_0).

If each fissile unit is considered to be located at the center of a cube and the cubes stacked to form a regular array, the actual surface density is

$$\sigma_{act} = \frac{nm}{d^2}$$

where n is the number of units stacked perpendicularly to the bounding plane (typically the floor), m is the mass of a unit, and d is the center-to-center spacing between units (or, equivalently, the length of each side of the cubical cell). For non-cubical cells, the d^2 term may be replaced by the cell area projected to the plane; its square root serves as the characteristic dimension.

If the actual surface density is set equal to the maximum surface density, the two equations above may be combined and rearranged to determine the maximum stored mass per unit, i.e.,

$$m = \frac{0.54\sigma_0}{\frac{n}{d^2} + 0.7398\frac{\sigma_0}{m_0}}$$

To allow storage of all enrichments up to 5.0 wt.% ^{235}U, based on **Figure 28** (Figure III.B.8-6 of ARH-600) (Reference 3), the appropriate value for σ_0 is about 11.6 kg U/ft^2. This is equivalent to about 12.5 g U/cm^2. And based on **Figure 29** (Figure III.B.6-4 of ARH-600), the minimum critical mass for an un-reflected sphere of 5.0 wt.% ^{235}U is about 62.0 kgs U.

It must be noted, however, that the relationship between *m* and *n* in the above equation is not linear. If the full benefit of the surface density method is desired or required, the above equation gives nonconservative results for all values of *n* greater than one. That is, the surface density method provides for the possibility that the fissile material in a stacked array is compressed into a single layer at optimum moderation. Solving for the above equation for any $n > 1$ will give a value for *m(n)* that is greater than *m(n=1) / n*. If the material collapses, the total mass will be greater than that allowed for a single layer.

If, however, the maximum value for *m(n)* is set to *m(n=1) / n*, the units may be stacked with no concern given to such potential process upsets as a fire, a roof leak, or a collapsed roof leading to the stacked material sagging or being compressed into a single layer.

A similar calculation can be performed for waste drums using the same formula, except that d^2 must be replaced with $\frac{1}{4}\pi d^2$.

$$m = \frac{0.54(12.5)}{\frac{n}{\pi / 4 * d\wedge 2} + 0.7398 \frac{12.5}{62000}}$$

As mentioned before, the relationship between *m* and *n* is not linear. In addition, the footprint varies based on the diameter of the drum used. The following chart shows the relationship for values of *n* ranging from 1 to 3 for four values of *d*.

Table 11 - Waste Drum Loading & Stacking Data

Minimum Diameter	Stack Height	Allowable Mass per Drum		
		U (kgs)	^{235}U (g)	U Compounds (kgs)
17" (43.18 cm)	1	8.112	405.6	9.218
	2	4.056	202.8	4.609
	3	2.704	135.2	3.073
19" (48.26 cm)	1	9.700	485.0	11.023
	2	4.850	242.5	5.511
	3	3.233	161.7	3.674
21" (53.34 cm)	1	11.313	565.6	12.855
	2	5.656	282.8	6.428
	3	3.771	188.5	4.285
22.5" (57.15 cm)	1	12.523	626.2	14.231
	2	6.262	313.1	7.116
	3	4.174	208.7	4.744

5.5.5 Interactions

See section 6.0 for neutron interactions.

6.0 INTERACTION ANALYSIS

6.1 *Neutronic Interaction*

The purpose of this study is to demonstrate that the neutron interaction between equipment components will not cause keff to exceed the values obtained with tight fitted full water reflection surrounding the individual units.

6.1.1 Process Equipment in Room 131

The following equipment components are present in Room 131 and were included in the neutron interaction sensitivity study.

1. Infeed Conveyor System

[redacted] Ash [redacted]

Comment [m19]: Trade secret / Proprietary

5. 55 Gallon Waste Drum

6.1.2 Design Features and materials of construction

NA these items were discussed in previous sections.

[redacted] Computer [redacted]

Comment [m20]: Trade secret / Proprietary

The computer model analyzes the neutron interaction of all the equipment in the proposed supercritical carbon dioxide (CO_2) extraction system in room 131 [redacted]

The process vessels are filled with a UNH solution containing 1200 gU/l. The extractor vessels and baskets are filled with the most reactive water saturated UO2 density of 2.3 g/cc as analyzed and found earlier. [redacted] The 55 gallon drum is filled with a water saturated UO2 density of 0.10 g/cc. All of the model parameters are implemented very conservatively.

The proposed supercritical carbon dioxide (CO_2) extraction system model is illustrated below in **Figure 26.**

[redacted]

[redacted]

[redacted] Sensitivity [redacted]

Comment [m21]: Trade secret / Proprietary

[redacted]

The result for this case is graphically shown in **Figure 27** and numerically in

Table 27.

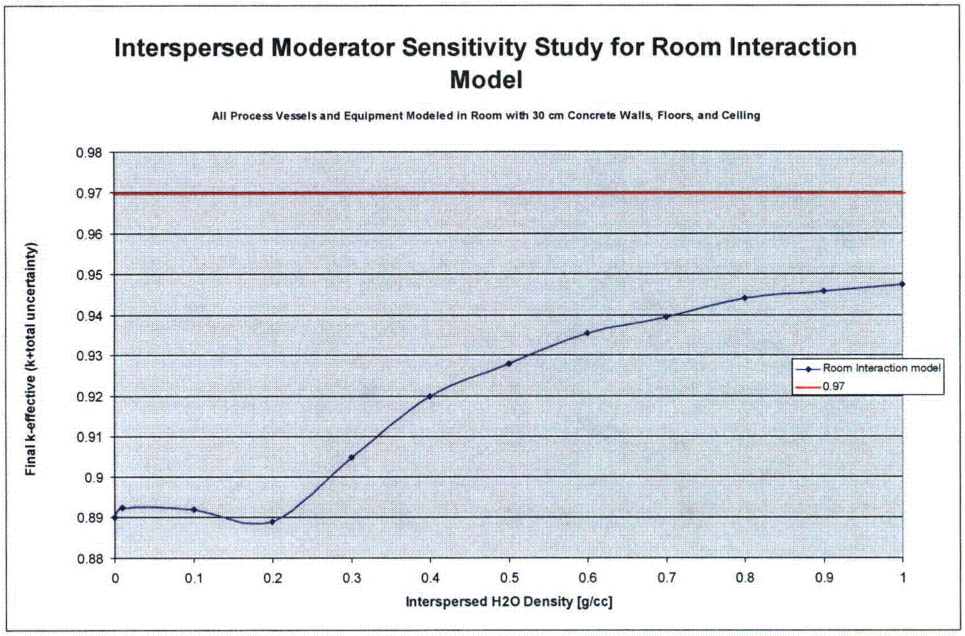

Figure 27 Interspersed Moderator Sensitivity Study for Room Interaction Model

Figure 27 shows the impact of interspersed moderator on k_{eff} for all of the equipment located in the room interaction model. From the results, it is shown that the equipment spacing is sufficient to ensure if the individual components have an acceptable k_{eff} at FWR, k_{eff} remains acceptable at all amounts of interspersed moderator.

[redacted] ***System*** [redacted]

Comment [m22]: Trade secret / Proprietary

[redacted]

See the ISA summary for sequences from other process systems that may impact the CO2 extraction process.

[redacted] ACCIDENT [redacted]

Comment [m23]: Security-Related; Trade secret / Proprietary

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9.0 LIST OF REFERENCES

1. EMF-2 Revision 52, Framatome ANP Richland, Inc. – Application for Renewal of Special Nuclear Material License No. SNM-1227, Framatome ANP, Inc., July 2004.
2. EMF-2670 Revision 2, PC-SCALE 4.4a Validation, Framatome ANP, Inc.
3. ARH-600, Criticality Handbook, Volume II, R. D. Carter, et al., Atlantic Richfield Hanford Company, May 23, 1969.
4. Ronald Allen Knief, Nuclear Criticality Safety - Theory and Practice, American Nuclear Society, 1985.
5. E15-01 ISA Summaries "Chapters 1-8 - Richland Facility ISA Program".

10.0 Appendix A

CALCULATED RESULTS

Table 12 Mass Loading Sensitivity Study Effects On K-Effective As A Result Of Varying Density For SBC's Filled With Water Saturated UO_2

File[redacted]

Comment [m24]: Trade secret / Proprietary

Description: Mass Loading Sensitivity Study effects on k-effective as a result of varying density for SBC's filled with water saturated UO2

Mass Loading	Filename	UO2-H2O Density of UO2 [g/cc]	UO2-H2O Density of H2O [g/cc]	k-effective	σ	Uncertainty	Final k-effective
5.1 kg	BS1-D-5_1kg_0.25_.in	0.25	0.977	0.5681	0.0005	0.0113	0.5794
	BS1-D-5_1kg_0.3_.in	0.30	0.973	0.5889	0.0005	0.0113	0.6002
	BS1-D-5_1kg_0.35_.in	0.35	0.968	0.5998	0.0006	0.0113	0.6111
	BS1-D-5_1kg_0.4_.in	0.40	0.964	0.6041	0.0006	0.0113	0.6154
	BS1-D-5_1kg_0.45_.in	0.45	0.959	0.6015	0.0006	0.0113	0.6128
	BS1-D-5_1kg_0.5_.in	0.50	0.954	0.5973	0.0005	0.0113	0.6086
	BS1-D-5_1kg_0.55_.in	0.55	0.950	0.5887	0.0005	0.0113	0.6000
	BS1-D-5_1kg_0.6_.in	0.60	0.945	0.5782	0.0006	0.0113	0.5895
	BS1-D-5_1kg_0.65_.in	0.65	0.941	0.5683	0.0006	0.0113	0.5796
	BS1-D-5_1kg_0.7_.in	0.70	0.936	0.5571	0.0005	0.0113	0.5684
	BS1-D-5_1kg_0.75_.in	0.75	0.932	0.5448	0.0006	0.0113	0.5561
	BS1-D-5_1kg_0.8_.in	0.80	0.927	0.5336	0.0006	0.0113	0.5449
	BS1-D-5_1kg_0.85_.in	0.85	0.922	0.5205	0.0006	0.0113	0.5318
	BS1-D-5_1kg_0.9_.in	0.90	0.918	0.5091	0.0006	0.0113	0.5204
	BS1-D-5_1kg_0.95_.in	0.95	0.913	0.4982	0.0006	0.0113	0.5095
	BS1-D-5_1kg_1_.in	1.00	0.909	0.4872	0.0006	0.0113	0.4985
	BS1-D-5_1kg_1.05_.in	1.05	0.904	0.4773	0.0006	0.0113	0.4886
	BS1-D-5_1kg_1.1_.in	1.10	0.900	0.4672	0.0007	0.0113	0.4785
	BS1-D-5_1kg_1.15_.in	1.15	0.895	0.4574	0.0006	0.0113	0.4687
	BS1-D-5_1kg_1.2_.in	1.20	0.891	0.4481	0.0006	0.0113	0.4594
	BS1-D-5_1kg_1.25_.in	1.25	0.886	0.4395	0.0006	0.0113	0.4508
	BS1-D-5_1kg_1.3_.in	1.30	0.881	0.4312	0.0006	0.0113	0.4425
	BS1-D-5_1kg_1.35_.in	1.35	0.877	0.4232	0.0006	0.0113	0.4345
	BS1-D-5_1kg_1.4_.in	1.40	0.872	0.4155	0.0006	0.0113	0.4268
	BS1-D-5_1kg_1.45_.in	1.45	0.868	0.4074	0.0005	0.0113	0.4187
	BS1-D-5_1kg_1.5_.in	1.50	0.863	0.4001	0.0006	0.0113	0.4114
	BS1-D-5_1kg_1.55_.in	1.55	0.859	0.3948	0.0006	0.0113	0.4061

	BS1-D-5_1kg_1.6_.in	1.60	0.854	0.3864	0.0006	0.0113	0.3977
	BS1-D-5_1kg_1.65_.in	1.65	0.849	0.3829	0.0006	0.0113	0.3942
	BS1-D-5_1kg_1.7_.in	1.70	0.845	0.3760	0.0006	0.0113	0.3873
	BS1-D-5_1kg_1.75_.in	1.75	0.840	0.3704	0.0006	0.0113	0.3817
	BS1-D-5_1kg_1.8_.in	1.80	0.836	0.3655	0.0006	0.0113	0.3768
	BS1-D-5_1kg_1.85_.in	1.85	0.831	0.3615	0.0006	0.0113	0.3728
	BS1-D-5_1kg_1.9_.in	1.90	0.827	0.3555	0.0005	0.0113	0.3668
	BS1-D-5_1kg_1.95_.in	1.95	0.822	0.3515	0.0006	0.0113	0.3628
	BS1-D-5_1kg_2_.in	2.00	0.818	0.3468	0.0006	0.0113	0.3581
	BS1-D-5_1kg_2.05_.in	2.05	0.813	0.3435	0.0006	0.0113	0.3548
	BS1-D-5_1kg_2.1_.in	2.10	0.808	0.3397	0.0005	0.0113	0.3510
	BS1-D-5_1kg_2.15_.in	2.15	0.804	0.3346	0.0005	0.0113	0.3459
	BS1-D-5_1kg_2.2_.in	2.20	0.799	0.3319	0.0005	0.0113	0.3432
	BS1-D-5_1kg_2.25_.in	2.25	0.795	0.3292	0.0005	0.0113	0.3405
	BS1-D-5_1kg_2.3_.in	2.30	0.790	0.3252	0.0005	0.0113	0.3365
	BS1-D-5_1kg_2.35_.in	2.35	0.786	0.3237	0.0005	0.0113	0.3350
	BS1-D-5_1kg_2.4_.in	2.40	0.781	0.3197	0.0005	0.0113	0.3310
	BS1-D-5_1kg_2.45_.in	2.45	0.776	0.3159	0.0005	0.0113	0.3272
	BS1-D-5_1kg_2.5_.in	2.50	0.772	0.3142	0.0005	0.0113	0.3255
	BS1-D-5_1kg_2.55_.in	2.55	0.767	0.3107	0.0006	0.0113	0.3220
	BS1-D-5_1kg_2.6_.in	2.60	0.763	0.3090	0.0005	0.0113	0.3203
	BS1-D-5_1kg_2.65_.in	2.65	0.758	0.3059	0.0005	0.0113	0.3172
	BS1-D-5_1kg_2.7_.in	2.70	0.754	0.3045	0.0005	0.0113	0.3158
	BS1-D-5_1kg_2.75_.in	2.75	0.749	0.3015	0.0005	0.0113	0.3128
	BS1-D-5_1kg_2.8_.in	2.80	0.745	0.3000	0.0005	0.0113	0.3113
	BS1-D-5_1kg_2.85_.in	2.85	0.740	0.2976	0.0005	0.0113	0.3089
	BS1-D-5_1kg_2.9_.in	2.90	0.735	0.2957	0.0005	0.0113	0.3070
	BS1-D-5_1kg_2.95_.in	2.95	0.731	0.2943	0.0005	0.0113	0.3056
	BS1-D-5_1kg_3_.in	3.00	0.726	0.2910	0.0005	0.0113	0.3023
	D-18kg_0.85_.in	0.85	0.922	0.9179	0.0008	0.0113	0.9292
	D-18kg_0.95_.in	0.90	0.918	0.9121	0.0007	0.0113	0.9234
	D-18kg_0.9_.in	0.95	0.913	0.9165	0.0006	0.0113	0.9278
	D-18kg_1_.in	1.00	0.909	0.9096	0.0008	0.0113	0.9209
	BS1-D-18kg_1.05_.in	1.05	0.904	0.9042	0.0008	0.0113	0.9155
	BS1-D-18kg_1.1_.in	1.10	0.900	0.8977	0.0007	0.0113	0.9090
18 kg	BS1-D-18kg_1.15_.in	1.15	0.895	0.8928	0.0007	0.0113	0.9041
	BS1-D-18kg_1.2_.in	1.20	0.891	0.8864	0.0007	0.0113	0.8977
	BS1-D-18kg_1.25_.in	1.25	0.886	0.8795	0.0007	0.0113	0.8908
	BS1-D-18kg_1.3_.in	1.30	0.881	0.8715	0.0007	0.0113	0.8828
	BS1-D-18kg_1.35_.in	1.35	0.877	0.8645	0.0008	0.0113	0.8758
	BS1-D-18kg_1.4_.in	1.40	0.872	0.8551	0.0008	0.0113	0.8664
	BS1-D-18kg_1.45_.in	1.45	0.868	0.8484	0.0008	0.0113	0.8597
	BS1-D-18kg_1.5_.in	1.50	0.863	0.8403	0.0007	0.0113	0.8516

	BS1-D-18kg_1.55_.in	1.55	0.859	0.8327	0.0007	0.0113	0.8440
	BS1-D-18kg_1.6_.in	1.60	0.854	0.8240	0.0007	0.0113	0.8353
	BS1-D-18kg_1.65_.in	1.65	0.849	0.8183	0.0007	0.0113	0.8296
	BS1-D-18kg_1.7_.in	1.70	0.845	0.8072	0.0008	0.0113	0.8185
	BS1-D-18kg_1.75_.in	1.75	0.840	0.8009	0.0008	0.0113	0.8122
	BS1-D-18kg_1.8_.in	1.80	0.836	0.7913	0.0009	0.0113	0.8026
	BS1-D-18kg_1.85_.in	1.85	0.831	0.7847	0.0009	0.0113	0.7960
	BS1-D-18kg_1.9_.in	1.90	0.827	0.7759	0.0007	0.0113	0.7872
	BS1-D-18kg_1.95_.in	1.95	0.822	0.7670	0.0008	0.0113	0.7783
	BS1-D-18kg_2_.in	2.00	0.818	0.7602	0.0008	0.0113	0.7715
	BS1-D-18kg_2.05_.in	2.05	0.813	0.7510	0.0007	0.0113	0.7623
	BS1-D-18kg_2.1_.in	2.10	0.808	0.7429	0.0008	0.0113	0.7542
	BS1-D-18kg_2.15_.in	2.15	0.804	0.7357	0.0007	0.0113	0.7470
	BS1-D-18kg_2.2_.in	2.20	0.799	0.7277	0.0007	0.0113	0.7390
	BS1-D-18kg_2.25_.in	2.25	0.795	0.7201	0.0008	0.0113	0.7314
	BS1-D-18kg_2.3_.in	2.30	0.790	0.7119	0.0007	0.0113	0.7232
	BS1-D-18kg_2.35_.in	2.35	0.786	0.7054	0.0007	0.0113	0.7167
	BS1-D-18kg_2.4_.in	2.40	0.781	0.6976	0.0007	0.0113	0.7089
	BS1-D-18kg_2.45_.in	2.45	0.776	0.6918	0.0008	0.0113	0.7031
	BS1-D-18kg_2.5_.in	2.50	0.772	0.6844	0.0007	0.0113	0.6957
	BS1-D-18kg_2.55_.in	2.55	0.767	0.6777	0.0007	0.0113	0.6890
	BS1-D-18kg_2.6_.in	2.60	0.763	0.6703	0.0007	0.0113	0.6816
	BS1-D-18kg_2.65_.in	2.65	0.758	0.6626	0.0008	0.0113	0.6739
	BS1-D-18kg_2.7_.in	2.70	0.754	0.6561	0.0007	0.0113	0.6674
	BS1-D-18kg_2.75_.in	2.75	0.749	0.6497	0.0008	0.0113	0.6610
	BS1-D-18kg_2.8_.in	2.80	0.745	0.6435	0.0008	0.0113	0.6548
	BS1-D-18kg_2.85_.in	2.85	0.740	0.6381	0.0007	0.0113	0.6494
	BS1-D-18kg_2.9_.in	2.90	0.735	0.6312	0.0007	0.0113	0.6425
	BS1-D-18kg_2.95_.in	2.95	0.731	0.6260	0.0007	0.0113	0.6373
	BS1-D-18kg_3_.in	3.00	0.726	0.6200	0.0007	0.0113	0.6313
20 kg	BS1-D-20kg_1_.in	1.00	0.909	0.9342	0.0009	0.0113	0.9455
	BS1-D-20kg_1.05_.in	1.05	0.904	0.9306	0.0008	0.0113	0.9419
	BS1-D-20kg_1.1_.in	1.10	0.900	0.9259	0.0009	0.0113	0.9372
	BS1-D-20kg_1.15_.in	1.15	0.895	0.9216	0.0008	0.0113	0.9329
	BS1-D-20kg_1.2_.in	1.20	0.891	0.9168	0.0007	0.0113	0.9281
	BS1-D-20kg_1.25_.in	1.25	0.886	0.9100	0.0007	0.0113	0.9213
	BS1-D-20kg_1.3_.in	1.30	0.881	0.9020	0.0008	0.0113	0.9133
	BS1-D-20kg_1.35_.in	1.35	0.877	0.8955	0.0007	0.0113	0.9068
	BS1-D-20kg_1.4_.in	1.40	0.872	0.8895	0.0007	0.0113	0.9008
	BS1-D-20kg_1.45_.in	1.45	0.868	0.8813	0.0007	0.0113	0.8926
	BS1-D-20kg_1.5_.in	1.50	0.863	0.8731	0.0008	0.0113	0.8844
	BS1-D-20kg_1.55_.in	1.55	0.859	0.8657	0.0007	0.0113	0.8770
	BS1-D-20kg_1.6_.in	1.60	0.854	0.8586	0.0007	0.0113	0.8699

	BS1-D-20kg_1.65_.in	1.65	0.849	0.8529	0.0008	0.0113	0.8642
	BS1-D-20kg_1.7_.in	1.70	0.845	0.8429	0.0008	0.0113	0.8542
	BS1-D-20kg_1.75_.in	1.75	0.840	0.8356	0.0008	0.0113	0.8469
	BS1-D-20kg_1.8_.in	1.80	0.836	0.8278	0.0007	0.0113	0.8391
	BS1-D-20kg_1.85_.in	1.85	0.831	0.8201	0.0008	0.0113	0.8314
	BS1-D-20kg_1.9_.in	1.90	0.827	0.8114	0.0008	0.0113	0.8227
	BS1-D-20kg_1.95_.in	1.95	0.822	0.8040	0.0008	0.0113	0.8153
	BS1-D-20kg_2_.in	2.00	0.818	0.7961	0.0007	0.0113	0.8074
	BS1-D-20kg_2.05_.in	2.05	0.813	0.7891	0.0007	0.0113	0.8004
	BS1-D-20kg_2.1_.in	2.10	0.808	0.7806	0.0008	0.0113	0.7919
	BS1-D-20kg_2.15_.in	2.15	0.804	0.7732	0.0008	0.0113	0.7845
	BS1-D-20kg_2.2_.in	2.20	0.799	0.7662	0.0007	0.0113	0.7775
	BS1-D-20kg_2.25_.in	2.25	0.795	0.7574	0.0008	0.0113	0.7687
	BS1-D-20kg_2.3_.in	2.30	0.790	0.7498	0.0008	0.0113	0.7611
	BS1-D-20kg_2.35_.in	2.35	0.786	0.7436	0.0007	0.0113	0.7549
	BS1-D-20kg_2.4_.in	2.40	0.781	0.7366	0.0007	0.0113	0.7479
	BS1-D-20kg_2.45_.in	2.45	0.776	0.7288	0.0007	0.0113	0.7401
	BS1-D-20kg_2.5_.in	2.50	0.772	0.7234	0.0007	0.0113	0.7347
	BS1-D-20kg_2.55_.in	2.55	0.767	0.7143	0.0007	0.0113	0.7256
	BS1-D-20kg_2.6_.in	2.60	0.763	0.7083	0.0007	0.0113	0.7196
	BS1-D-20kg_2.65_.in	2.65	0.758	0.7005	0.0008	0.0113	0.7118
	BS1-D-20kg_2.7_.in	2.70	0.754	0.6941	0.0007	0.0113	0.7054
	BS1-D-20kg_2.75_.in	2.75	0.749	0.6875	0.0008	0.0113	0.6988
	BS1-D-20kg_2.8_.in	2.80	0.745	0.6801	0.0008	0.0113	0.6914
	BS1-D-20kg_2.85_.in	2.85	0.740	0.6737	0.0007	0.0113	0.6850
	BS1-D-20kg_2.9_.in	2.90	0.735	0.6682	0.0007	0.0113	0.6795
	BS1-D-20kg_2.95_.in	2.95	0.731	0.6610	0.0007	0.0113	0.6723
	BS1-D-20kg_3_.in	3.00	0.726	0.6558	0.0008	0.0113	0.6671
22 kg	BS1-D-22kg_1_.in	1.00	0.909	0.9583	0.0006	0.0113	0.9696
22 kg	BS1-D-22kg_1.05_.in	1.05	0.904	0.9559	0.0007	0.0113	0.9672
22 kg	BS1-D-22kg_1.1_.in	1.10	0.900	0.9529	0.0008	0.0113	0.9642
22 kg	BS1-D-22kg_1.15_.in	1.15	0.895	0.9463	0.0007	0.0113	0.9576
22 kg	BS1-D-22kg_1.2_.in	1.20	0.891	0.9415	0.0007	0.0113	0.9528
22 kg	BS1-D-22kg_1.25_.in	1.25	0.886	0.9362	0.0008	0.0113	0.9475
22 kg	BS1-D-22kg_1.3_.in	1.30	0.881	0.9313	0.0008	0.0113	0.9426
22 kg	BS1-D-22kg_1.35_.in	1.35	0.877	0.9240	0.0008	0.0113	0.9353
22 kg	BS1-D-22kg_1.4_.in	1.40	0.872	0.9177	0.0007	0.0113	0.9290
22 kg	BS1-D-22kg_1.45_.in	1.45	0.868	0.9105	0.0008	0.0113	0.9218
22 kg	BS1-D-22kg_1.5_.in	1.50	0.863	0.9040	0.0008	0.0113	0.9153
22 kg	BS1-D-22kg_1.55_.in	1.55	0.859	0.8957	0.0008	0.0113	0.9070
22 kg	BS1-D-22kg_1.6_.in	1.60	0.854	0.8896	0.0009	0.0113	0.9009
22 kg	BS1-D-22kg_1.65_.in	1.65	0.849	0.8813	0.0008	0.0113	0.8926
22 kg	BS1-D-22kg_1.7_.in	1.70	0.845	0.8733	0.0009	0.0113	0.8846

	BS1-D-22kg_1.75_.in	1.75	0.840	0.8677	0.0009	0.0113	0.8790
	BS1-D-22kg_1.8_.in	1.80	0.836	0.8592	0.0008	0.0113	0.8705
	BS1-D-22kg_1.85_.in	1.85	0.831	0.8518	0.0008	0.0113	0.8631
	BS1-D-22kg_1.9_.in	1.90	0.827	0.8423	0.0008	0.0113	0.8536
	BS1-D-22kg_1.95_.in	1.95	0.822	0.8368	0.0008	0.0113	0.8481
	BS1-D-22kg_2_.in	2.00	0.818	0.8278	0.0008	0.0113	0.8391
	BS1-D-22kg_2.05_.in	2.05	0.813	0.8214	0.0009	0.0113	0.8327
	BS1-D-22kg_2.1_.in	2.10	0.808	0.8127	0.0008	0.0113	0.8240
	BS1-D-22kg_2.15_.in	2.15	0.804	0.8064	0.0008	0.0113	0.8177
	BS1-D-22kg_2.2_.in	2.20	0.799	0.7982	0.0008	0.0113	0.8095
	BS1-D-22kg_2.25_.in	2.25	0.795	0.7916	0.0007	0.0113	0.8029
	BS1-D-22kg_2.3_.in	2.30	0.790	0.7839	0.0008	0.0113	0.7952
	BS1-D-22kg_2.35_.in	2.35	0.786	0.7768	0.0007	0.0113	0.7881
	BS1-D-22kg_2.4_.in	2.40	0.781	0.7685	0.0008	0.0113	0.7798
	BS1-D-22kg_2.45_.in	2.45	0.776	0.7615	0.0008	0.0113	0.7728
	BS1-D-22kg_2.5_.in	2.50	0.772	0.7540	0.0008	0.0113	0.7653
	BS1-D-22kg_2.55_.in	2.55	0.767	0.7476	0.0008	0.0113	0.7589
	BS1-D-22kg_2.6_.in	2.60	0.763	0.7399	0.0009	0.0113	0.7512
	BS1-D-22kg_2.65_.in	2.65	0.758	0.7340	0.0009	0.0113	0.7453
	BS1-D-22kg_2.7_.in	2.70	0.754	0.7265	0.0007	0.0113	0.7378
	BS1-D-22kg_2.75_.in	2.75	0.749	0.7194	0.0007	0.0113	0.7307
	BS1-D-22kg_2.8_.in	2.80	0.745	0.7126	0.0007	0.0113	0.7239
	BS1-D-22kg_2.85_.in	2.85	0.740	0.7048	0.0007	0.0113	0.7161
	BS1-D-22kg_2.9_.in	2.90	0.735	0.6999	0.0007	0.0113	0.7112
	BS1-D-22kg_2.95_.in	2.95	0.731	0.6939	0.0008	0.0113	0.7052
	BS1-D-22kg_3_.in	3.00	0.726	0.6866	0.0007	0.0113	0.6979
25 kg	BS1-D-25kg_1.15_.in	1.15	0.895	0.9784	0.0009	0.0113	0.9897
	BS1-D-25kg_1.2_.in	1.20	0.891	0.9754	0.0007	0.0113	0.9867
	BS1-D-25kg_1.25_.in	1.25	0.886	0.9702	0.0008	0.0113	0.9815
	BS1-D-25kg_1.3_.in	1.30	0.881	0.9636	0.0008	0.0113	0.9749
	BS1-D-25kg_1.35_.in	1.35	0.877	0.9579	0.0007	0.0113	0.9692
	BS1-D-25kg_1.4_.in	1.40	0.872	0.9533	0.0008	0.0113	0.9646
	BS1-D-25kg_1.45_.in	1.45	0.868	0.9465	0.0009	0.0113	0.9578
	BS1-D-25kg_1.5_.in	1.50	0.863	0.9419	0.0008	0.0113	0.9532
	BS1-D-25kg_1.55_.in	1.55	0.859	0.9338	0.0007	0.0113	0.9451
	BS1-D-25kg_1.6_.in	1.60	0.854	0.9280	0.0008	0.0113	0.9393
	BS1-D-25kg_1.65_.in	1.65	0.849	0.9217	0.0007	0.0113	0.9330
	BS1-D-25kg_1.7_.in	1.70	0.845	0.9134	0.0008	0.0113	0.9247
	BS1-D-25kg_1.75_.in	1.75	0.840	0.9083	0.0008	0.0113	0.9196
	BS1-D-25kg_1.8_.in	1.80	0.836	0.9001	0.0008	0.0113	0.9114
	BS1-D-25kg_1.85_.in	1.85	0.831	0.8933	0.0009	0.0113	0.9046
	BS1-D-25kg_1.9_.in	1.90	0.827	0.8852	0.0009	0.0113	0.8965
	BS1-D-25kg_1.95_.in	1.95	0.822	0.8782	0.0009	0.0113	0.8895

	BS1-D-25kg_2_.in	2.00	0.818	0.8696	0.0008	0.0113	0.8809
	BS1-D-25kg_2.05_.in	2.05	0.813	0.8622	0.0008	0.0113	0.8735
	BS1-D-25kg_2.1_.in	2.10	0.808	0.8564	0.0007	0.0113	0.8677
	BS1-D-25kg_2.15_.in	2.15	0.804	0.8496	0.0008	0.0113	0.8609
	BS1-D-25kg_2.2_.in	2.20	0.799	0.8404	0.0007	0.0113	0.8517
	BS1-D-25kg_2.25_.in	2.25	0.795	0.8341	0.0009	0.0113	0.8454
	BS1-D-25kg_2.3_.in	2.30	0.790	0.8268	0.0009	0.0113	0.8381
	BS1-D-25kg_2.35_.in	2.35	0.786	0.8197	0.0008	0.0113	0.8310
	BS1-D-25kg_2.4_.in	2.40	0.781	0.8142	0.0007	0.0113	0.8255
	BS1-D-25kg_2.45_.in	2.45	0.776	0.8054	0.0007	0.0113	0.8167
	BS1-D-25kg_2.5_.in	2.50	0.772	0.8000	0.0009	0.0113	0.8113
	BS1-D-25kg_2.55_.in	2.55	0.767	0.7901	0.0007	0.0113	0.8014
	BS1-D-25kg_2.6_.in	2.60	0.763	0.7854	0.0008	0.0113	0.7967
	BS1-D-25kg_2.65_.in	2.65	0.758	0.7773	0.0008	0.0113	0.7886
	BS1-D-25kg_2.7_.in	2.70	0.754	0.7710	0.0008	0.0113	0.7823
	BS1-D-25kg_2.75_.in	2.75	0.749	0.7631	0.0007	0.0113	0.7744
	BS1-D-25kg_2.8_.in	2.80	0.745	0.7575	0.0007	0.0113	0.7688
	BS1-D-25kg_2.85_.in	2.85	0.740	0.7499	0.0008	0.0113	0.7612
	BS1-D-25kg_2.9_.in	2.90	0.735	0.7455	0.0007	0.0113	0.7568
	BS1-D-25kg_2.95_.in	2.95	0.731	0.7379	0.0008	0.0113	0.7492
	BS1-D-25kg_3_.in	3.00	0.726	0.7312	0.0008	0.0113	0.7425
Full of UO2	D-F_0.05_.in	0.05	0.995	0.1819	0.0002	0.0113	0.1932
	D-F_0.1_.in	0.10	0.991	0.3184	0.0002	0.0113	0.3297
	D-F_0.15_.in	0.15	0.986	0.4252	0.0003	0.0113	0.4365
	D-F_0.2_.in	0.20	0.982	0.5109	0.0004	0.0113	0.5222
	D-F_0.25_.in	0.25	0.977	0.5798	0.0004	0.0113	0.5911
	D-F_0.3_.in	0.30	0.973	0.6385	0.0005	0.0113	0.6498
	D-F_0.35_.in	0.35	0.968	0.6869	0.0005	0.0113	0.6982
	D-F_0.4_.in	0.40	0.964	0.7278	0.0005	0.0113	0.7391
	D-F_0.45_.in	0.45	0.959	0.7648	0.0006	0.0113	0.7761
	D-F_0.5_.in	0.50	0.954	0.7938	0.0005	0.0113	0.8051
	D-F_0.55_.in	0.55	0.950	0.8218	0.0006	0.0113	0.8331
	D-F_0.6_.in	0.60	0.945	0.8457	0.0006	0.0113	0.8570
	D-F_0.65_.in	0.65	0.941	0.8656	0.0006	0.0113	0.8769
	D-F_0.7_.in	0.70	0.936	0.8842	0.0008	0.0113	0.8955
	D-F_0.75_.in	0.75	0.932	0.8997	0.0008	0.0113	0.9110
	D-F_0.8_.in	0.80	0.927	0.9134	0.0007	0.0113	0.9247
	D-F_0.85_.in	0.85	0.922	0.9279	0.0006	0.0113	0.9392
	D-F_0.9_.in	0.90	0.918	0.9389	0.0007	0.0113	0.9502
	D-F_0.95_.in	0.95	0.913	0.9496	0.0008	0.0113	0.9609
	D-F_1_.in	1.00	0.909	0.9586	0.0008	0.0113	0.9699
	BS-D-F_1.05_.in	1.05	0.904	0.9666	0.0008	0.0113	0.9779
	BS-D-F_1.1_.in	1.10	0.900	0.9757	0.0008	0.0113	0.9870

	BS-D-F_1.15_.in	1.15	0.895	0.9818	0.0007	0.0113	0.9931
	BS-D-F_1.2_.in	1.20	0.891	0.9866	0.0008	0.0113	0.9979
	BS-D-F_1.25_.in	1.25	0.886	0.9939	0.0007	0.0113	1.0052
	BS-D-F_1.3_.in	1.30	0.881	0.9974	0.0007	0.0113	1.0087
	BS-D-F_1.35_.in	1.35	0.877	1.0029	0.0008	0.0113	1.0142
	BS-D-F_1.4_.in	1.40	0.872	1.0068	0.0008	0.0113	1.0181
	BS-D-F_1.45_.in	1.45	0.868	1.0112	0.0007	0.0113	1.0225
	BS-D-F_1.5_.in	1.50	0.863	1.0139	0.0007	0.0113	1.0252
	BS-D-F_1.55_.in	1.55	0.859	1.0176	0.0008	0.0113	1.0289
	BS-D-F_1.6_.in	1.60	0.854	1.0190	0.0008	0.0113	1.0303
	BS-D-F_1.65_.in	1.65	0.849	1.0218	0.0007	0.0113	1.0331
	BS-D-F_1.7_.in	1.70	0.845	1.0224	0.0007	0.0113	1.0337
	BS-D-F_1.75_.in	1.75	0.840	1.0251	0.0009	0.0113	1.0364
	BS-D-F_1.8_.in	1.80	0.836	1.0277	0.0008	0.0113	1.0390
	BS-D-F_1.85_.in	1.85	0.831	1.0274	0.0008	0.0113	1.0387
	BS-D-F_1.9_.in	1.90	0.827	1.0295	0.0008	0.0113	1.0408
	BS-D-F_1.95_.in	1.95	0.822	1.0295	0.0008	0.0113	1.0408
	BS-D-F_2_.in	2.00	0.818	1.0309	0.0008	0.0113	1.0422
	BS-D-F_2.05_.in	2.05	0.813	1.0302	0.0008	0.0113	1.0415
	BS-D-F_2.1_.in	2.10	0.808	1.0308	0.0008	0.0113	1.0421
	BS-D-F_2.15_.in	2.15	0.804	1.0313	0.0007	0.0113	1.0426
	BS-D-F_2.2_.in	2.20	0.799	1.0306	0.0009	0.0113	1.0419
	BS-D-F_2.25_.in	2.25	0.795	1.0316	0.0007	0.0113	1.0429
	BS-D-F_2.3_.in	2.30	0.790	1.0308	0.0008	0.0113	1.0421
	BS-D-F_2.35_.in	2.35	0.786	1.0304	0.0008	0.0113	1.0417
	BS-D-F_2.4_.in	2.40	0.781	1.0313	0.0008	0.0113	1.0426
	BS-D-F_2.45_.in	2.45	0.776	1.0305	0.0007	0.0113	1.0418
	BS-D-F_2.5_.in	2.50	0.772	1.0284	0.0008	0.0113	1.0397
	BS-D-F_2.55_.in	2.55	0.767	1.0283	0.0007	0.0113	1.0396
	BS-D-F_2.6_.in	2.60	0.763	1.0291	0.0008	0.0113	1.0404
	BS-D-F_2.65_.in	2.65	0.758	1.0264	0.0008	0.0113	1.0377
	BS-D-F_2.7_.in	2.70	0.754	1.0253	0.0008	0.0113	1.0366
	BS-D-F_2.75_.in	2.75	0.749	1.0254	0.0007	0.0113	1.0367
	BS-D-F_2.8_.in	2.80	0.745	1.0247	0.0008	0.0113	1.0360
	BS-D-F_2.85_.in	2.85	0.740	1.0236	0.0008	0.0113	1.0349
	BS-D-F_2.9_.in	2.90	0.735	1.0231	0.0007	0.0113	1.0344
	BS-D-F_2.95_.in	2.95	0.731	1.0216	0.0008	0.0113	1.0329
	BS-D-F_3_.in	3.00	0.726	1.0183	0.0009	0.0113	1.0296

Table 13 Bucket Loading With Optimum Interspersed Moderator Sensitivity Study For Buckets Filled With Water Saturated UO_2

File [redacted]

Comment [m25]: Trade secret / Proprietary

Description: Bucket Loading with Optimum Interspersed Moderator Sensitivity Study for Buckets filled with water saturated UO2-H2O

Mass Loading	Filename	Density of H2O [g/cc]		k-effective	σ	Uncertainty	Final k-effective
Bucket limited to 18 kg of UO2 (Density 0.85)	18kg-0.85_0.001_.in	0.001		0.9186	0.0008	0.0113	0.9299
	18kg-0.85_0.002_.in	0.002		0.9173	0.0008	0.0113	0.9286
	18kg-0.85_0.003_.in	0.003		0.9188	0.0007	0.0113	0.9301
	18kg-0.85_0.004_.in	0.004		0.9189	0.0007	0.0113	0.9302
	18kg-0.85_0.005_.in	0.005		0.9188	0.0007	0.0113	0.9301
	18kg-0.85_0.006_.in	0.006		0.9206	0.0007	0.0113	0.9319
	18kg-0.85_0.007_.in	0.007		0.9202	0.0008	0.0113	0.9315
	18kg-0.85_0.008_.in	0.008		0.9192	0.0007	0.0113	0.9305
	18kg-0.85_0.009_.in	0.009		0.9201	0.0006	0.0113	0.9314
	18kg-0.85_0.01_.in	0.010		0.9208	0.0007	0.0113	0.9321
	18kg-0.85_0.011_.in	0.011		0.9209	0.0007	0.0113	0.9322
	18kg-0.85_0.012_.in	0.012		0.9213	0.0007	0.0113	0.9326
	18kg-0.85_0.013_.in	0.013		0.9211	0.0007	0.0113	0.9324
	18kg-0.85_0.014_.in	0.014		0.9224	0.0007	0.0113	0.9337
	18kg-0.85_0.015_.in	0.015		0.9222	0.0008	0.0113	0.9335
	18kg-0.85_0.016_.in	0.016		0.9239	0.0006	0.0113	0.9352
	18kg-0.85_0.017_.in	0.017		0.9211	0.0007	0.0113	0.9324
	18kg-0.85_0.018_.in	0.018		0.9249	0.0007	0.0113	0.9362
	18kg-0.85_0.019_.in	0.019		0.9225	0.0007	0.0113	0.9338
	18kg-0.85_0.02_.in	0.02		0.9227	0.0007	0.0113	0.9340
	18kg-0.85_0.03_.in	0.03		0.9260	0.0008	0.0113	0.9373
	18kg-0.85_0.04_.in	0.04		0.9280	0.0008	0.0113	0.9393
	18kg-0.85_0.05_.in	0.05		0.9309	0.0007	0.0113	0.9422
	18kg-0.85_0.06_.in	0.06		0.9313	0.0007	0.0113	0.9426
	18kg-0.85_0.07_.in	0.07		0.9328	0.0006	0.0113	0.9441
	18kg-0.85_0.08_.in	0.08		0.9353	0.0007	0.0113	0.9466
	18kg-0.85_0.09_.in	0.09		0.9367	0.0006	0.0113	0.9480
	18kg-0.85_0.1_.in	0.10		0.9373	0.0008	0.0113	0.9486
	18kg-0.85_0.2_.in	0.20		0.9410	0.0007	0.0113	0.9523
	18kg-0.85_0.3_.in	0.30		0.9434	0.0007	0.0113	0.9547
	18kg-0.85_0.4_.in	0.40		0.9427	0.0008	0.0113	0.9540
	18kg-0.85_0.5_.in	0.50		0.9451	0.0007	0.0113	0.9564
	18kg-0.85_0.6_.in	0.60		0.9453	0.0008	0.0113	0.9566

	18kg-0.85_0.7_.in	0.70		0.9473	0.0007	0.0113	0.9586
	18kg-0.85_0.8_.in	0.80		0.9478	0.0008	0.0113	0.9591
	18kg-0.85_0.9_.in	0.90		0.9468	0.0006	0.0113	0.9581
	18kg-0.85_1_.in	1.00		0.9467	0.0007	0.0113	0.9580
Bucket limited to 20 kg of UO2 (Density 1.00)	20kg-1.00_0.001_.in	0.001		0.9344	0.0007	0.0113	0.9457
	20kg-1.00_0.002_.in	0.002		0.9351	0.0007	0.0113	0.9464
	20kg-1.00_0.003_.in	0.003		0.9358	0.0007	0.0113	0.9471
	20kg-1.00_0.004_.in	0.004		0.9363	0.0008	0.0113	0.9476
	20kg-1.00_0.005_.in	0.005		0.9384	0.0007	0.0113	0.9497
	20kg-1.00_0.006_.in	0.006		0.9371	0.0007	0.0113	0.9484
	20kg-1.00_0.007_.in	0.007		0.9375	0.0008	0.0113	0.9488
	20kg-1.00_0.008_.in	0.008		0.9366	0.0007	0.0113	0.9479
	20kg-1.00_0.009_.in	0.009		0.9371	0.0007	0.0113	0.9484
	20kg-1.00_0.01_.in	0.010		0.9380	0.0007	0.0113	0.9493
	20kg-1.00_0.011_.in	0.011		0.9374	0.0007	0.0113	0.9487
	20kg-1.00_0.012_.in	0.012		0.9385	0.0007	0.0113	0.9498
	20kg-1.00_0.013_.in	0.013		0.9385	0.0007	0.0113	0.9498
	20kg-1.00_0.014_.in	0.014		0.9387	0.0008	0.0113	0.9500
	20kg-1.00_0.015_.in	0.015		0.9395	0.0007	0.0113	0.9508
	20kg-1.00_0.016_.in	0.016		0.9397	0.0007	0.0113	0.9510
	20kg-1.00_0.017_.in	0.017		0.9405	0.0007	0.0113	0.9518
	20kg-1.00_0.018_.in	0.018		0.9407	0.0007	0.0113	0.9520
	20kg-1.00_0.019_.in	0.019		0.9398	0.0007	0.0113	0.9511
	20kg-1.00_0.02_.in	0.02		0.9399	0.0007	0.0113	0.9512
	20kg-1.00_0.03_.in	0.03		0.9451	0.0007	0.0113	0.9564
	20kg-1.00_0.04_.in	0.04		0.9455	0.0008	0.0113	0.9568
	20kg-1.00_0.05_.in	0.05		0.9480	0.0007	0.0113	0.9593
	20kg-1.00_0.06_.in	0.06		0.9499	0.0007	0.0113	0.9612
	20kg-1.00_0.07_.in	0.07		0.9512	0.0008	0.0113	0.9625
	20kg-1.00_0.08_.in	0.08		0.9522	0.0008	0.0113	0.9635
	20kg-1.00_0.09_.in	0.09		0.9532	0.0007	0.0113	0.9645
	20kg-1.00_0.1_.in	0.10		0.9551	0.0007	0.0113	0.9664
	20kg-1.00_0.2_.in	0.20		0.9617	0.0007	0.0113	0.9730
	20kg-1.00_0.3_.in	0.30		0.9626	0.0009	0.0113	0.9739
	20kg-1.00_0.4_.in	0.40		0.9660	0.0007	0.0113	0.9773
	20kg-1.00_0.5_.in	0.50		0.9666	0.0007	0.0113	0.9779
	20kg-1.00_0.6_.in	0.60		0.9675	0.0008	0.0113	0.9788
	20kg-1.00_0.7_.in	0.70		0.9691	0.0008	0.0113	0.9804
	20kg-1.00_0.8_.in	0.80		0.9705	0.0008	0.0113	0.9818
	20kg-1.00_0.9_.in	0.90		0.9713	0.0008	0.0113	0.9826
	20kg-1.00_1_.in	1.00		0.9712	0.0007	0.0113	0.9825

Table 14 Mass Loading Sensitivity Study Effects On K-Effective For SBC's Filled Almost Full With Optimum Water Saturated UO_2With A Single Double Batch In Each Row At Nearly Twice The Density

File[redacted]

Comment [m26]: Trade secret / Proprietary

Description: Mass Loading Sensitivity Study effects on k-effective for SBC's filled almost full with optimum water saturated UO2 with a single double batch in each row at nearly twice the density

Mass Loading	Filename	UO2-H2O Density of UO2 [g/cc] Main Bucket	UO2-H2O Density of UO2 [g/cc] Overbatch	k-effective	σ	Uncertainty	Final k-effective
18 kg	BS1-D-18kg_0.85_.in	0.85	1.650	0.9200	6E-04	0.0113	0.9313
20 kg	BS1-D-20kg_1_.in	1.00	1.850	0.9392	8E-04	0.0113	0.9505
22 kg	BS1-D-22kg_1_.in	1.00	2.000	0.9583	6E-04	0.0113	0.9696

Table 15 Mass Loading Sensitivity Study Effects On K-Effective For SBC's Filled Almost Full With Optimum Water Saturated UO2 With A Single Over Batch Completely Full With A Water Saturated UO_2Density Of 2.25 G/Cc In Each Row (Worst Case Scenario)

File[redacted]

Comment [m27]: Trade secret / Proprietary

Description: Mass Loading Sensitivity Study effects on k-effective for SBC's filled almost full with optimum water saturated UO2 with a single over batch completely full with a water saturated UO2 Density of 2.25 g/cc in each row (worst case scenario)

Mass Loading	Filename	UO2-H2O Density of UO2 [g/cc]	UO2-H2O Density of H2O [g/cc]	k-effective	σ	Uncertainty	Final k-effective
5.1 kg	BS1-D-5.1kg_0.4_.in	0.40	0.964	0.8855	9E-04	0.0113	0.8968
18 kg	BS1-D-18kg_0.85_.in	0.85	0.922	0.9531	9E-04	0.0113	0.9644
20 kg	BS1-D-20kg_1_.in	1.00	0.909	0.9625	9E-04	0.0113	0.9738
22 kg	BS1-D-22kg_1_.in	1.00	0.909	0.9777	7E-04	0.0113	0.9890

Table 16 Sensitivity Study Effects On K-Effective For Ash Preparation Equipment

File[redacted]

Comment [m28]: Trade secret / Proprietary

Description: Sensitivity Study effects on k-effective for Ash Preparation Equipment.

Vessel Description	Filename	Density of UO2 [g/cc]	Density of H2O [g/cc]	k-effective	σ	Uncertainty	Final k-effective
Ash Preparation Equipment	9	4.0	0.3956	0.9041	0.00085	0.0113	0.9154
	10	4.0	0.4444	0.9364	0.00078	0.0113	0.9477
	11	4.0	0.4944	0.9689	0.00093	0.0113	0.9802
	12	4.0	0.5455	0.9991	0.00071	0.0113	1.0104
	AP-05-sat	0.5	0.9544	0.8473	0.00057	0.0113	0.8586
	AP-06-sat	0.6	0.9453	0.8985	0.00064	0.0113	0.9098
	AP-07-sat	0.7	0.9361	0.9391	0.00073	0.0113	0.9504
	AP-075-sat	0.75	0.9316	0.9557	0.00067	0.0113	0.967
	AP-08-sat	0.8	0.9270	0.9709	0.00073	0.0113	0.9822
	AP-10-sat	1.0	0.90876	1.0163	0.00075	0.0113	1.0276
	AP-10-hfsat	1.0	0.4544	0.8408	0.00076	0.0113	0.8521
						0.0113	
	u-075-w444	0.75	0.4444	0.794	0.00087	0.0113	0.8053
	u-100-w444	1.0	0.4444	0.8338	0.00074	0.0113	0.8451
	u-125-w444	1.25	0.4444	0.86	0.0008	0.0113	0.8713
	u-150-w444	1.50	0.4444	0.8767	0.00084	0.0113	0.888
	u-175-w444	1.75	0.4444	0.8893	0.00078	0.0113	0.9006
	u-200-w444	2.0	0.4444	0.8993	0.0008	0.0113	0.9106
	u-225-w444	2.25	0.4444	0.9083	0.00082	0.0113	0.9196
	u-250-w444	2.5	0.4444	0.916	0.00097	0.0113	0.9273
	u-275-w444	2.75	0.4444	0.9183	0.00081	0.0113	0.9296
	u-300-w444	3.0	0.4444	0.9252	0.00084	0.0113	0.9365
	u-325-w444	3.25	0.4444	0.9279	0.00074	0.0113	0.9392
	u-350-w444	3.5	0.4444	0.9321	0.00082	0.0113	0.9434
	u-375-w444	3.75	0.4444	0.9337	0.00081	0.0113	0.945

Table 17 Vessel Diameter Sensitivity Study For A Single Basket Only And For An Array Of Baskets Only

File [redacted]

Comment [m29]: Trade secret / Proprietary

Description: Vessel Diameter Sensitivity Study for a single basket only and for an array of baskets only

Vessel Description	Filename	Diameter		k-effective	σ	Uncertainty	Final k-effective
Array of Baskets	B-OD_2395_8_.in	8.000		0.8995	0.0008	0.0113	0.9108
	B-OD_2395_8.125_.in	8.125		0.9070	0.0007	0.0113	0.9183
	B-OD_2395_8.25_.in	8.250		0.9151	0.0008	0.0113	0.9264
	B-OD_2395_8.5_.in	8.500		0.9330	0.0008	0.0113	0.9443
	B-OD_2395_8.75_.in	8.750		0.9502	0.0008	0.0113	0.9615
	B-OD_2395_9_.in	9.000		0.9649	0.0008	0.0113	0.9762
	B-OD_2395_9.25_.in	9.250		0.9791	0.0008	0.0113	0.9904
	B-OD_2395_9.5_.in	9.500		0.9929	0.0008	0.0113	1.0042
Single Basket	B-OD_2395_8_.in	8.000		0.8379	7E-04	0.0113	0.8492
	B-OD_2395_8.125_.in	8.125		0.8462	8E-04	0.0113	0.8575
	B-OD_2395_8.25_.in	8.250		0.8564	9E-04	0.0113	0.8677
	B-OD_2395_8.5_.in	8.500		0.8719	8E-04	0.0113	0.8832
	B-OD_2395_8.75_.in	8.750		0.8882	8E-04	0.0113	0.8995
	B-OD_2395_9_.in	9.000		0.9022	8E-04	0.0113	0.9135
	B-OD_2395_9.25_.in	9.250		0.9164	8E-04	0.0113	0.9277
	B-OD_2395_9.5_.in	9.500		0.9331	8E-04	0.0113	0.9444

Table 18 Optimum UO_2-H_2O Mixture Sensitivity Study Effects On K-Effective For The Extractors With Baskets And Baskets Only Filled With Water Saturated UO_2

File [redacted]

Comment [m30]: Trade secret / Proprietary

Description: Optimum UO2-H2O Mixture Sensitivity Study effects on k-effective for the extractors with baskets and baskets only filled with water saturated UO2

Vessel Description	Filename	UO2-H2O Density of UO2 [g/cc]	UO2-H2O Density of H2O [g/cc]	k-effective	σ	Uncertainty	Final k-effective
Basket Only	B_12_0.50.in	0.50	0.9544	0.6355	0.0005	0.0113	0.6468
	B_12_0.60.in	0.60	0.9453	0.6803	0.0007	0.0113	0.6916
	B_12_0.70.in	0.70	0.9361	0.7139	0.0006	0.0113	0.7252
	B_12_0.80.in	0.80	0.9270	0.7421	0.0007	0.0113	0.7534
	B_12_0.90.in	0.90	0.9179	0.7639	0.0006	0.0113	0.7752
	B_12_1.00.in	1.00	0.9088	0.7819	0.0007	0.0113	0.7932

	B_12_1.10.in	1.10	0.8996	0.7978	0.0008	0.0113	0.8091
	B_12_1.20.in	1.20	0.8905	0.8101	0.0006	0.0113	0.8214
	B_12_1.30.in	1.30	0.8814	0.8204	0.0007	0.0113	0.8317
	B_12_1.40.in	1.40	0.8723	0.8263	0.0007	0.0113	0.8376
	B_12_1.50.in	1.50	0.8631	0.8333	0.0007	0.0113	0.8446
	B_12_1.60.in	1.60	0.8540	0.8395	0.0008	0.0113	0.8508
	B_12_1.70.in	1.70	0.8449	0.8447	0.0007	0.0113	0.8560
	B_12_1.80.in	1.80	0.8358	0.8474	0.0008	0.0113	0.8587
	B_12_1.90.in	1.90	0.8266	0.8511	0.0007	0.0113	0.8624
	B_12_2.00.in	2.00	0.8175	0.8538	0.0009	0.0113	0.8651
	B_12_2.10.in	2.10	0.8084	0.8544	0.0007	0.0113	0.8657
	B_12_2.20.in	2.20	0.7993	0.8564	0.0007	0.0113	0.8677
	B_12_2.30.in	2.30	0.7901	0.8563	0.0009	0.0113	0.8676
	B_12_2.40.in	2.40	0.7810	0.8563	0.0008	0.0113	0.8676
	B_12_2.50.in	2.50	0.7719	0.8550	0.0008	0.0113	0.8663
	B_12_2.60.in	2.60	0.7628	0.8542	0.0008	0.0113	0.8655
	B_12_2.70.in	2.70	0.7536	0.8532	0.0008	0.0113	0.8645
	B_12_2.80.in	2.80	0.7445	0.8528	0.0007	0.0113	0.8641
	B_12_2.90.in	2.90	0.7354	0.8501	0.0007	0.0113	0.8614
	B_12_3.00.in	3.00	0.7263	0.8478	0.0007	0.0113	0.8591
	B_12_3.10.in	3.10	0.7172	0.8455	0.0008	0.0113	0.8568
	B_12_3.20.in	3.20	0.7080	0.8444	0.0008	0.0113	0.8557
	B_12_3.30.in	3.30	0.6989	0.8397	0.0007	0.0113	0.8510
	B_12_3.40.in	3.40	0.6898	0.8384	0.0007	0.0113	0.8497
	B_12_3.50.in	3.50	0.6807	0.8363	0.0008	0.0113	0.8476
	B_12_3.60.in	3.60	0.6715	0.8322	0.0007	0.0113	0.8435
	B_12_3.70.in	3.70	0.6624	0.8291	0.0008	0.0113	0.8404
	B_12_3.80.in	3.80	0.6533	0.8266	0.0007	0.0113	0.8379
	B_12_3.90.in	3.90	0.6442	0.8236	0.0008	0.0113	0.8349
	B_12_4.00.in	4.00	0.6350	0.8196	0.0008	0.0113	0.8309
Extractors	E_12_0.50.in	0.50	0.9544	0.6643	0.0005	0.0113	0.6756
	E_12_0.60.in	0.60	0.9453	0.7112	0.0006	0.0113	0.7225
	E_12_0.70.in	0.70	0.9361	0.7478	0.0007	0.0113	0.7591
	E_12_0.80.in	0.80	0.9270	0.7772	0.0006	0.0113	0.7885
	E_12_0.90.in	0.90	0.9179	0.8009	0.0006	0.0113	0.8122
	E_12_1.00.in	1.00	0.9088	0.8207	0.0007	0.0113	0.8320
	E_12_1.10.in	1.10	0.8996	0.8340	0.0007	0.0113	0.8453
	E_12_1.20.in	1.20	0.8905	0.8472	0.0007	0.0113	0.8585
	E_12_1.30.in	1.30	0.8814	0.8578	0.0007	0.0113	0.8691
	E_12_1.40.in	1.40	0.8723	0.8688	0.0008	0.0113	0.8801
	E_12_1.50.in	1.50	0.8631	0.8745	0.0007	0.0113	0.8858
	E_12_1.60.in	1.60	0.8540	0.8800	0.0008	0.0113	0.8913
	E_12_1.70.in	1.70	0.8449	0.8846	0.0008	0.0113	0.8959
	E_12_1.80.in	1.80	0.8358	0.8869	0.0008	0.0113	0.8982
	E_12_1.90.in	1.90	0.8266	0.8896	0.0007	0.0113	0.9009

	E_12_2.00.in	2.00	0.8175	0.8917	0.0010	0.0113	0.9030
	E_12_2.10.in	2.10	0.8084	0.8942	0.0008	0.0113	0.9055
	E_12_2.20.in	2.20	0.7993	0.8925	0.0008	0.0113	0.9038
	E_12_2.30.in	2.30	0.7901	0.8939	0.0007	0.0113	0.9052
	E_12_2.40.in	2.40	0.7810	0.8939	0.0008	0.0113	0.9052
	E_12_2.50.in	2.50	0.7719	0.8920	0.0008	0.0113	0.9033
	E_12_2.60.in	2.60	0.7628	0.8898	0.0007	0.0113	0.9011
	E_12_2.70.in	2.70	0.7536	0.8897	0.0007	0.0113	0.9010
	E_12_2.80.in	2.80	0.7445	0.8891	0.0007	0.0113	0.9004
	E_12_2.90.in	2.90	0.7354	0.8868	0.0007	0.0113	0.8981
	E_12_3.00.in	3.00	0.7263	0.8818	0.0008	0.0113	0.8931
	E_12_3.10.in	3.10	0.7172	0.8800	0.0008	0.0113	0.8913
	E_12_3.20.in	3.20	0.7080	0.8761	0.0008	0.0113	0.8874
	E_12_3.30.in	3.30	0.6989	0.8735	0.0008	0.0113	0.8848
	E_12_3.40.in	3.40	0.6898	0.8709	0.0008	0.0113	0.8822
	E_12_3.50.in	3.50	0.6807	0.8676	0.0008	0.0113	0.8789
	E_12_3.60.in	3.60	0.6715	0.8623	0.0007	0.0113	0.8736
	E_12_3.70.in	3.70	0.6624	0.8586	0.0008	0.0113	0.8699
	E_12_3.80.in	3.80	0.6533	0.8553	0.0008	0.0113	0.8666
	E_12_3.90.in	3.90	0.6442	0.8503	0.0008	0.0113	0.8616
	E_12_4.00.in	4.00	0.6350	0.8449	0.0008	0.0113	0.8562

Table 19 Optimum UO_2-H_2O Mixture Sensitivity Study Effects On K-Effective For The Extractors With Baskets And Baskets Only Filled With Water Saturated UO_2

File [redacted]

Comment [m31]: Trade secret / Proprietary

Description: Optimum UO2-H2O Mixture Sensitivity Study effects on k-effective for the extractors with baskets and baskets only filled with water saturated UO2

Vessel Description	Filename	UO2-H2O Density of UO2 [g/cc]	UO2-H2O Density of H2O [g/cc]	k-effective	σ	Uncertainty	Final k-effective
Basket Only	B_12_0.50.in	0.50	0.9544	0.6964	0.0005	0.0113	0.7077
	B_12_0.60.in	0.60	0.9453	0.7441	0.0006	0.0113	0.7554
	B_12_0.70.in	0.70	0.9361	0.7792	0.0006	0.0113	0.7905
	B_12_0.80.in	0.80	0.9270	0.8078	0.0006	0.0113	0.8191
	B_12_0.90.in	0.90	0.9179	0.8321	0.0007	0.0113	0.8434
	B_12_1.00.in	1.00	0.9088	0.8506	0.0008	0.0113	0.8619
	B_12_1.10.in	1.10	0.8996	0.8652	0.0007	0.0113	0.8765
	B_12_1.20.in	1.20	0.8905	0.8783	0.0007	0.0113	0.8896
	B_12_1.30.in	1.30	0.8814	0.8894	0.0007	0.0113	0.9007
	B_12_1.40.in	1.40	0.8723	0.8978	0.0007	0.0113	0.9091
	B_12_1.50.in	1.50	0.8631	0.9030	0.0007	0.0113	0.9143
	B_12_1.60.in	1.60	0.8540	0.9110	0.0007	0.0113	0.9223

	B_12_1.70.in	1.70	0.8449	0.9137	0.0008	0.0113	0.9250
	B_12_1.80.in	1.80	0.8358	0.9183	0.0007	0.0113	0.9296
	B_12_1.90.in	1.90	0.8266	0.9217	0.0008	0.0113	0.9330
	B_12_2.00.in	2.00	0.8175	0.9230	0.0008	0.0113	0.9343
	B_12_2.10.in	2.10	0.8084	0.9254	0.0008	0.0113	0.9367
	B_12_2.20.in	2.20	0.7993	0.9253	0.0008	0.0113	0.9366
	B_12_2.30.in	2.30	0.7901	0.9238	0.0009	0.0113	0.9351
	B_12_2.40.in	2.40	0.7810	0.9259	0.0009	0.0113	0.9372
	B_12_2.50.in	2.50	0.7719	0.9257	0.0008	0.0113	0.9370
	B_12_2.60.in	2.60	0.7628	0.9230	0.0007	0.0113	0.9343
	B_12_2.70.in	2.70	0.7536	0.9244	0.0008	0.0113	0.9357
	B_12_2.80.in	2.80	0.7445	0.9205	0.0009	0.0113	0.9318
	B_12_2.90.in	2.90	0.7354	0.9206	0.0008	0.0113	0.9319
	B_12_3.00.in	3.00	0.7263	0.9189	0.0008	0.0113	0.9302
	B_12_3.10.in	3.10	0.7172	0.9173	0.0008	0.0113	0.9286
	B_12_3.20.in	3.20	0.7080	0.9139	0.0007	0.0113	0.9252
	B_12_3.30.in	3.30	0.6989	0.9106	0.0007	0.0113	0.9219
	B_12_3.40.in	3.40	0.6898	0.9108	0.0008	0.0113	0.9221
	B_12_3.50.in	3.50	0.6807	0.9063	0.0009	0.0113	0.9176
	B_12_3.60.in	3.60	0.6715	0.9031	0.0008	0.0113	0.9144
	B_12_3.70.in	3.70	0.6624	0.9010	0.0007	0.0113	0.9123
	B_12_3.80.in	3.80	0.6533	0.8981	0.0007	0.0113	0.9094
	B_12_3.90.in	3.90	0.6442	0.8963	0.0008	0.0113	0.9076
	B_12_4.00.in	4.00	0.6350	0.8918	0.0008	0.0113	0.9031
	E_12_0.50.in	0.50	0.9544	0.6763	0.0005	0.0113	0.6876
	E_12_0.60.in	0.60	0.9453	0.7242	0.0005	0.0113	0.7355
	E_12_0.70.in	0.70	0.9361	0.7612	0.0005	0.0113	0.7725
	E_12_0.80.in	0.80	0.9270	0.7916	0.0007	0.0113	0.8029
	E_12_0.90.in	0.90	0.9179	0.8161	0.0006	0.0113	0.8274
	E_12_1.00.in	1.00	0.9088	0.8372	0.0006	0.0113	0.8485
	E_12_1.10.in	1.10	0.8996	0.8532	0.0008	0.0113	0.8645
	E_12_1.20.in	1.20	0.8905	0.8667	0.0006	0.0113	0.8780
	E_12_1.30.in	1.30	0.8814	0.8782	0.0007	0.0113	0.8895
	E_12_1.40.in	1.40	0.8723	0.8883	0.0008	0.0113	0.8996
Extractors	E_12_1.50.in	1.50	0.8631	0.8957	0.0007	0.0113	0.9070
	E_12_1.60.in	1.60	0.8540	0.9018	0.0007	0.0113	0.9131
	E_12_1.70.in	1.70	0.8449	0.9071	0.0007	0.0113	0.9184
	E_12_1.80.in	1.80	0.8358	0.9117	0.0008	0.0113	0.9230
	E_12_1.90.in	1.90	0.8266	0.9149	0.0008	0.0113	0.9262
	E_12_2.00.in	2.00	0.8175	0.9163	0.0008	0.0113	0.9276
	E_12_2.10.in	2.10	0.8084	0.9173	0.0008	0.0113	0.9286
	E_12_2.20.in	2.20	0.7993	0.9177	0.0007	0.0113	0.9290
	E_12_2.30.in	2.30	0.7901	0.9182	0.0007	0.0113	0.9295
	E_12_2.40.in	2.40	0.7810	0.9190	0.0007	0.0113	0.9303
	E_12_2.50.in	2.50	0.7719	0.9182	0.0008	0.0113	0.9295

	E_12_2.60.in	2.60	0.7628	0.9178	0.0007	0.0113	0.9291
	E_12_2.70.in	2.70	0.7536	0.9147	0.0008	0.0113	0.9260
	E_12_2.80.in	2.80	0.7445	0.9156	0.0007	0.0113	0.9269
	E_12_2.90.in	2.90	0.7354	0.9113	0.0008	0.0113	0.9226
	E_12_3.00.in	3.00	0.7263	0.9105	0.0007	0.0113	0.9218
	E_12_3.10.in	3.10	0.7172	0.9084	0.0009	0.0113	0.9197
	E_12_3.20.in	3.20	0.7080	0.9049	0.0008	0.0113	0.9162
	E_12_3.30.in	3.30	0.6989	0.9034	0.0007	0.0113	0.9147
	E_12_3.40.in	3.40	0.6898	0.8986	0.0008	0.0113	0.9099
	E_12_3.50.in	3.50	0.6807	0.8952	0.0007	0.0113	0.9065
	E_12_3.60.in	3.60	0.6715	0.8927	0.0007	0.0113	0.9040
	E_12_3.70.in	3.70	0.6624	0.8881	0.0008	0.0113	0.8994
	E_12_3.80.in	3.80	0.6533	0.8829	0.0007	0.0113	0.8942
	E_12_3.90.in	3.90	0.6442	0.8797	0.0007	0.0113	0.8910
	E_12_4.00.in	4.00	0.6350	0.8759	0.0007	0.0113	0.8872

Table 20 Optimum Interspersed Moderation Sensitivity Study Effects on K-Effective for Extractors and Baskets Filled With Water Saturated UO_2 At A Density Of 2.3 [G/Cc]

File [redacted]

Comment [m32]: Trade secret / Proprietary

[redacted]

Description: Optimum Interspersed Moderation Sensitivity Study effects on k-effective for extractors and baskets filled with water saturated UO2 at a density of 2.3 [g/cc]

Vessel Description	Filename	Density of H2O [g/cc]		k-effective	σ	Uncertainty	Final k-effective
Basket Only	B_12_0.0001.in	0.0001		0.8179	0.0008	0.0113	0.8292
	B_12_0.0002.in	0.0002		0.8174	0.0008	0.0113	0.8287
	B_12_0.0003.in	0.0003		0.8177	0.0008	0.0113	0.8290
	B_12_0.0004.in	0.0004		0.8180	0.0008	0.0113	0.8293
	B_12_0.0005.in	0.0005		0.8175	0.0007	0.0113	0.8288
	B_12_0.0006.in	0.0006		0.8186	0.0007	0.0113	0.8299
	B_12_0.0007.in	0.0007		0.8180	0.0008	0.0113	0.8293
	B_12_0.0008.in	0.0008		0.8176	0.0007	0.0113	0.8289
	B_12_0.0009.in	0.0009		0.8177	0.0008	0.0113	0.8290
	B_12_0.0010.in	0.001		0.8192	0.0008	0.0113	0.8305
	B_12_0.0020.in	0.002		0.8194	0.0008	0.0113	0.8307
	B_12_0.0030.in	0.003		0.8159	0.0008	0.0113	0.8272
	B_12_0.0040.in	0.004		0.8185	0.0007	0.0113	0.8298
	B_12_0.0050.in	0.005		0.8174	0.0007	0.0113	0.8287
	B_12_0.0060.in	0.006		0.8178	0.0008	0.0113	0.8291
	B_12_0.0070.in	0.007		0.8160	0.0008	0.0113	0.8273
	B_12_0.0080.in	0.008		0.8171	0.0009	0.0113	0.8284
	B_12_0.0090.in	0.009		0.8157	0.0008	0.0113	0.8270
	B_12_0.0100.in	0.01		0.8161	0.0008	0.0113	0.8274

	B_12_0.0200.in	0.02		0.8152	0.0007	0.0113	0.8265
	B_12_0.0300.in	0.03		0.8136	0.0008	0.0113	0.8249
	B_12_0.0400.in	0.04		0.8114	0.0008	0.0113	0.8227
	B_12_0.0500.in	0.05		0.8114	0.0007	0.0113	0.8227
	B_12_0.0600.in	0.06		0.8099	0.0008	0.0113	0.8212
	B_12_0.0700.in	0.07		0.8081	0.0008	0.0113	0.8194
	B_12_0.0800.in	0.08		0.8062	0.0008	0.0113	0.8175
	B_12_0.0900.in	0.09		0.8072	0.0007	0.0113	0.8185
	B_12_0.1000.in	0.1		0.8061	0.0008	0.0113	0.8174
	B_12_0.2000.in	0.2		0.8028	0.0007	0.0113	0.8141
	B_12_0.3000.in	0.3		0.8040	0.0009	0.0113	0.8153
	B_12_0.4000.in	0.4		0.8108	0.0007	0.0113	0.8221
	B_12_0.5000.in	0.5		0.8164	0.0008	0.0113	0.8277
	B_12_0.6000.in	0.6		0.8203	0.0007	0.0113	0.8316
	B_12_0.7000.in	0.7		0.8247	0.0007	0.0113	0.8360
	B_12_0.8000.in	0.8		0.8300	0.0007	0.0113	0.8413
	B_12_0.9000.in	0.9		0.8335	0.0008	0.0113	0.8448
	B_12_1.0000.in	1		0.8359	0.0008	0.0113	0.8472
Extractors	E_12_0.0001.in	0.0001		0.8939	0.0007	0.0113	0.9052
	E_12_0.0002.in	0.0002		0.8930	0.0008	0.0113	0.9043
	E_12_0.0003.in	0.0003		0.8929	0.0008	0.0113	0.9042
	E_12_0.0004.in	0.0004		0.8938	0.0007	0.0113	0.9051
	E_12_0.0005.in	0.0005		0.8948	0.0007	0.0113	0.9061
	E_12_0.0006.in	0.0006		0.8939	0.0008	0.0113	0.9052
	E_12_0.0007.in	0.0007		0.8940	0.0007	0.0113	0.9053
	E_12_0.0008.in	0.0008		0.8926	0.0008	0.0113	0.9039
	E_12_0.0009.in	0.0009		0.8937	0.0008	0.0113	0.9050
	E_12_0.0010.in	0.001		0.8931	0.0008	0.0113	0.9044
	E_12_0.0020.in	0.002		0.8936	0.0008	0.0113	0.9049
	E_12_0.0030.in	0.003		0.8925	0.0008	0.0113	0.9038
	E_12_0.0040.in	0.004		0.8921	0.0007	0.0113	0.9034
	E_12_0.0050.in	0.005		0.8930	0.0007	0.0113	0.9043
	E_12_0.0060.in	0.006		0.8917	0.0007	0.0113	0.9030
	E_12_0.0070.in	0.007		0.8915	0.0007	0.0113	0.9028
	E_12_0.0080.in	0.008		0.8921	0.0008	0.0113	0.9034
	E_12_0.0090.in	0.009		0.8941	0.0007	0.0113	0.9054
	E_12_0.0100.in	0.01		0.8945	0.0008	0.0113	0.9058
	E_12_0.0200.in	0.02		0.8900	0.0007	0.0113	0.9013
	E_12_0.0300.in	0.03		0.8905	0.0008	0.0113	0.9018
	E_12_0.0400.in	0.04		0.8877	0.0009	0.0113	0.8990
	E_12_0.0500.in	0.05		0.8884	0.0008	0.0113	0.8997
	E_12_0.0600.in	0.06		0.8878	0.0007	0.0113	0.8991
	E_12_0.0700.in	0.07		0.8865	0.0007	0.0113	0.8978
	E_12_0.0800.in	0.08		0.8847	0.0008	0.0113	0.8960

	E_12_0.0900.in	0.09		0.8859	0.0007	0.0113	0.8972
	E_12_0.1000.in	0.1		0.8838	0.0008	0.0113	0.8951
	E_12_0.2000.in	0.2		0.8820	0.0008	0.0113	0.8933
	E_12_0.3000.in	0.3		0.8802	0.0007	0.0113	0.8915
	E_12_0.4000.in	0.4		0.8807	0.0007	0.0113	0.8920
	E_12_0.5000.in	0.5		0.8815	0.0009	0.0113	0.8928
	E_12_0.6000.in	0.6		0.8810	0.0008	0.0113	0.8923
	E_12_0.7000.in	0.7		0.8811	0.0008	0.0113	0.8924
	E_12_0.8000.in	0.8		0.8810	0.0007	0.0113	0.8923
	E_12_0.9000.in	0.9		0.8814	0.0007	0.0113	0.8927
	E_12_1.0000.in	1		0.8811	0.0008	0.0113	0.8924

Table 21 Optimum Interspersed Moderation Sensitivity Study Effects on K-Effective for Extractors and Baskets Filled With Water Saturated UO_2At A Density Of 2.3 [G/Cc]

File [redacted]

Comment [m33]: Trade secret / Proprietary

Description: Optimum Interspersed Moderation Sensitivity Study effects on k-effective for extractors and baskets filled with water saturated UO2 at a density of 2.3 [g/cc]

Vessel Description	Filename	Density of H2O [g/cc]		k-effective	σ	Uncertainty	Final k-effective
Basket Only	B_12_0.0001.in	0.0001		0.9238	0.0009	0.0113	0.9351
	B_12_0.0002.in	0.0002		0.9250	0.0008	0.0113	0.9363
	B_12_0.0003.in	0.0003		0.9241	0.0007	0.0113	0.9354
	B_12_0.0004.in	0.0004		0.9265	0.0007	0.0113	0.9378
	B_12_0.0005.in	0.0005		0.9245	0.0008	0.0113	0.9358
	B_12_0.0006.in	0.0006		0.9243	0.0008	0.0113	0.9356
	B_12_0.0007.in	0.0007		0.9251	0.0008	0.0113	0.9364
	B_12_0.0008.in	0.0008		0.9252	0.0008	0.0113	0.9365
	B_12_0.0009.in	0.0009		0.9250	0.0007	0.0113	0.9363
	B_12_0.0010.in	0.001		0.9256	0.0007	0.0113	0.9369
	B_12_0.0020.in	0.002		0.9252	0.0008	0.0113	0.9365
	B_12_0.0030.in	0.003		0.9259	0.0007	0.0113	0.9372
	B_12_0.0040.in	0.004		0.9257	0.0007	0.0113	0.9370
	B_12_0.0050.in	0.005		0.9244	0.0007	0.0113	0.9357
	B_12_0.0060.in	0.006		0.9254	0.0007	0.0113	0.9367
	B_12_0.0070.in	0.007		0.9250	0.0008	0.0113	0.9363
	B_12_0.0080.in	0.008		0.9248	0.0008	0.0113	0.9361
	B_12_0.0090.in	0.009		0.9253	0.0008	0.0113	0.9366
	B_12_0.0100.in	0.01		0.9243	0.0008	0.0113	0.9356
	B_12_0.0200.in	0.02		0.9210	0.0008	0.0113	0.9323
	B_12_0.0300.in	0.03		0.9190	0.0008	0.0113	0.9303

	B_12_0.0400.in	0.04		0.9192	0.0008	0.0113	0.9305
	B_12_0.0500.in	0.05		0.9164	0.0008	0.0113	0.9277
	B_12_0.0600.in	0.06		0.9153	0.0008	0.0113	0.9266
	B_12_0.0700.in	0.07		0.9137	0.0009	0.0113	0.9250
	B_12_0.0800.in	0.08		0.9130	0.0008	0.0113	0.9243
	B_12_0.0900.in	0.09		0.9130	0.0008	0.0113	0.9243
	B_12_0.1000.in	0.1		0.9100	0.0008	0.0113	0.9213
	B_12_0.2000.in	0.2		0.8983	0.0008	0.0113	0.9096
	B_12_0.3000.in	0.3		0.8952	0.0008	0.0113	0.9065
	B_12_0.4000.in	0.4		0.8946	0.0008	0.0113	0.9059
	B_12_0.5000.in	0.5		0.8978	0.0007	0.0113	0.9091
	B_12_0.6000.in	0.6		0.8978	0.0008	0.0113	0.9091
	B_12_0.7000.in	0.7		0.9012	0.0008	0.0113	0.9125
	B_12_0.8000.in	0.8		0.9032	0.0007	0.0113	0.9145
	B_12_0.9000.in	0.9		0.9083	0.0008	0.0113	0.9196
	B_12_1.0000.in	1		0.9096	0.0007	0.0113	0.9209
Extractors	E_12_0.0001.in	0.0001		0.9177	0.0008	0.0113	0.9290
	E_12_0.0002.in	0.0002		0.9180	0.0007	0.0113	0.9293
	E_12_0.0003.in	0.0003		0.9198	0.0007	0.0113	0.9311
	E_12_0.0004.in	0.0004		0.9187	0.0008	0.0113	0.9300
	E_12_0.0005.in	0.0005		0.9180	0.0008	0.0113	0.9293
	E_12_0.0006.in	0.0006		0.9182	0.0009	0.0113	0.9295
	E_12_0.0007.in	0.0007		0.9172	0.0007	0.0113	0.9285
	E_12_0.0008.in	0.0008		0.9184	0.0008	0.0113	0.9297
	E_12_0.0009.in	0.0009		0.9188	0.0008	0.0113	0.9301
	E_12_0.0010.in	0.001		0.9178	0.0007	0.0113	0.9291
	E_12_0.0020.in	0.002		0.9177	0.0008	0.0113	0.9290
	E_12_0.0030.in	0.003		0.9172	0.0008	0.0113	0.9285
	E_12_0.0040.in	0.004		0.9199	0.0008	0.0113	0.9312
	E_12_0.0050.in	0.005		0.9182	0.0008	0.0113	0.9295
	E_12_0.0060.in	0.006		0.9177	0.0007	0.0113	0.9290
	E_12_0.0070.in	0.007		0.9192	0.0007	0.0113	0.9305
	E_12_0.0080.in	0.008		0.9178	0.0008	0.0113	0.9291
	E_12_0.0090.in	0.009		0.9186	0.0007	0.0113	0.9299
	E_12_0.0100.in	0.01		0.9179	0.0007	0.0113	0.9292
	E_12_0.0200.in	0.02		0.9166	0.0009	0.0113	0.9279
	E_12_0.0300.in	0.03		0.9144	0.0007	0.0113	0.9257
	E_12_0.0400.in	0.04		0.9145	0.0007	0.0113	0.9258
	E_12_0.0500.in	0.05		0.9133	0.0008	0.0113	0.9246
	E_12_0.0600.in	0.06		0.9125	0.0007	0.0113	0.9238
	E_12_0.0700.in	0.07		0.9117	0.0008	0.0113	0.9230
	E_12_0.0800.in	0.08		0.9127	0.0008	0.0113	0.9240
	E_12_0.0900.in	0.09		0.9112	0.0008	0.0113	0.9225
	E_12_0.1000.in	0.1		0.9091	0.0007	0.0113	0.9204

	E_12_0.2000.in	0.2		0.9067	0.0008	0.0113	0.9180
	E_12_0.3000.in	0.3		0.9046	0.0008	0.0113	0.9159
	E_12_0.4000.in	0.4		0.9047	0.0008	0.0113	0.9160
	E_12_0.5000.in	0.5		0.9050	0.0007	0.0113	0.9163
	E_12_0.6000.in	0.6		0.9053	0.0008	0.0113	0.9166
	E_12_0.7000.in	0.7		0.9055	0.0007	0.0113	0.9168
	E_12_0.8000.in	0.8		0.9050	0.0007	0.0113	0.9163
	E_12_0.9000.in	0.9		0.9060	0.0008	0.0113	0.9173
	E_12_1.0000.in	1		0.9048	0.0008	0.0113	0.9161

Table 22 Vessel Separation Spacing Sensitivity Study Effects on K-Effective for Extractors and Baskets Filled With Water Saturated UO_2At A Density of 2.3 [G/Cc]

File [redacted]

Comment [m34]: Trade secret / Proprietary

Description: Vessel Separation Spacing Sensitivity Study effects on k-effective for extractors and baskets filled with water saturated UO2 at a density of 2.3 [g/cc]

Vessel Description	Filename	Edge to Edge Separation [cm]	Edge to Edge Separation [inches]	k-effective	σ	Uncertainty	Final k-effective
Basket Only	B_2.30_1.in	1.27	1.0000	0.9596	0.0009	0.0113	0.9709
	B_2.30_2.in	2.54	2.0000	0.9431	0.0008	0.0113	0.9544
	B_2.30_3.in	3.81	3.0000	0.9268	0.0008	0.0113	0.9381
	B_2.30_4.in	5.08	4.0000	0.9155	0.0009	0.0113	0.9268
	B_2.30_5.in	6.35	5.0000	0.9043	0.0007	0.0113	0.9156
	B_2.30_6.in	7.62	6.0000	0.8960	0.0008	0.0113	0.9073
	B_2.30_7.in	8.89	7.0000	0.8865	0.0008	0.0113	0.8978
	B_2.30_8.in	10.16	8.0000	0.8796	0.0009	0.0113	0.8909
	B_2.30_9.in	11.43	9.0000	0.8740	0.0007	0.0113	0.8853
	B_2.30_10.in	12.7	10.0000	0.8674	0.0007	0.0113	0.8787
	B_2.30_11.in	13.97	11.0000	0.8608	0.0008	0.0113	0.8721
	B_2.30_12.in	15.24	12.0000	0.8563	0.0009	0.0113	0.8676
Extractors	E_2.30_1.in	1.27	1.0000	0.9187	0.0008	0.0113	0.9300
	E_2.30_2.in	2.54	2.0000	0.9152	0.0008	0.0113	0.9265
	E_2.30_3.in	3.81	3.0000	0.9100	0.0008	0.0113	0.9213
	E_2.30_4.in	5.08	4.0000	0.9072	0.0006	0.0113	0.9185
	E_2.30_5.in	6.35	5.0000	0.9040	0.0008	0.0113	0.9153
	E_2.30_6.in	7.62	6.0000	0.9016	0.0008	0.0113	0.9129
	E_2.30_7.in	8.89	7.0000	0.9014	0.0007	0.0113	0.9127
	E_2.30_8.in	10.16	8.0000	0.8996	0.0007	0.0113	0.9109
	E_2.30_9.in	11.43	9.0000	0.8974	0.0007	0.0113	0.9087
	E_2.30_10.in	12.7	10.0000	0.8965	0.0007	0.0113	0.9078
	E_2.30_11.in	13.97	11.0000	0.8946	0.0008	0.0113	0.9059
	E_2.30_12.in	15.24	12.0000	0.8939	0.0007	0.0113	0.9052

Table 23 Vessel Separation Spacing Sensitivity Study Effects on K-Effective for Extractors and Baskets Filled With Water Saturated UO_2 At A Density of 2.3 [G/Cc]

File [redacted]

Comment [m35]: Trade secret / Proprietary

Description: Vessel Separation Spacing Sensitivity Study effects on k-effective for extractors and baskets filled with water saturated UO2 at a density of 2.3 [g/cc]

Vessel Description	Filename	Edge to Edge Separation [cm]	Edge to Edge Separation [inches]	k-effective	σ	Uncertainty	Final k-effective
Basket Only	B_1_2.30.in	1.27	1.0000	1.0558	0.0007	0.0113	1.0671
	B_2_2.30.in	2.54	2.0000	1.0358	0.0008	0.0113	1.0471
	B_3_2.30.in	3.81	3.0000	1.0184	0.0009	0.0113	1.0297
	B_4_2.30.in	5.08	4.0000	1.0023	0.0007	0.0113	1.0136
	B_5_2.30.in	6.35	5.0000	0.9903	0.0009	0.0113	1.0016
	B_6_2.30.in	7.62	6.0000	0.9771	0.0008	0.0113	0.9884
	B_7_2.30.in	8.89	7.0000	0.9687	0.0008	0.0113	0.9800
	B_8_2.30.in	10.16	8.0000	0.9553	0.0009	0.0113	0.9666
	B_9_2.30.in	11.43	9.0000	0.9472	0.0008	0.0113	0.9585
	B_10_2.30.in	12.7	10.0000	0.9399	0.0007	0.0113	0.9512
	B_11_2.30.in	13.97	11.0000	0.9314	0.0007	0.0113	0.9427
	B_12_2.30.in	15.24	12.0000	0.9238	0.0009	0.0113	0.9351
Extractors	E_2.30_1.in	1.27	1.0000	0.9457	0.0007	0.0113	0.9570
	E_2.30_2.in	2.54	2.0000	0.9411	0.0008	0.0113	0.9524
	E_2.30_3.in	3.81	3.0000	0.9377	0.0009	0.0113	0.9490
	E_2.30_4.in	5.08	4.0000	0.9329	0.0009	0.0113	0.9442
	E_2.30_5.in	6.35	5.0000	0.9299	0.0007	0.0113	0.9412
	E_2.30_6.in	7.62	6.0000	0.9285	0.0008	0.0113	0.9398
	E_2.30_7.in	8.89	7.0000	0.9244	0.0007	0.0113	0.9357
	E_2.30_8.in	10.16	8.0000	0.9240	0.0008	0.0113	0.9353
	E_2.30_9.in	11.43	9.0000	0.9239	0.0007	0.0113	0.9352
	E_2.30_10.in	12.7	10.0000	0.9219	0.0008	0.0113	0.9332
	E_2.30_11.in	13.97	11.0000	0.9212	0.0007	0.0113	0.9325
	E_2.30_12.in	15.24	12.0000	0.9177	0.0008	0.0113	0.9290

Table 24 Vessel Diameter Sensitivity Study For Process Vessels Filled With For Process Vessels Filled With A Solution Of UNH With A U Content Of 1200 G U/L And A UO_2-H_2O Solution With A U Content Of 500 G U/L

File[redacted]

Comment [m36]: Trade secret / Proprietary

Description: Vessel Diameter Sensitivity Study for process vessels filled with for Process Vessels filled with a solution of UNH with a U content of 1200 g U/l and a UO2-H2O solution with a U content of 500 g U/l

Vessel Description	Filename	Diameter		k-effective	σ	Uncertainty	Final k-effective
UNH with a U content of 1200 g U/l	1200_8_.in	8.000		0.6726	0.0007	0.0113	0.6839
	1200_8.125_.in	8.125		0.6795	0.0007	0.0113	0.6908
	1200_8.25_.in	8.250		0.6864	0.0006	0.0113	0.6977
	1200_8.375_.in	8.375		0.6930	0.0007	0.0113	0.7043
	1200_8.5_.in	8.500		0.7021	0.0006	0.0113	0.7134
	1200_8.625_.in	8.625		0.7081	0.0007	0.0113	0.7194
	1200_8.75_.in	8.750		0.7159	0.0007	0.0113	0.7272
	1200_8.875_.in	8.875		0.7226	0.0008	0.0113	0.7339
	1200_9_.in	9.000		0.7286	0.0007	0.0113	0.7399
	1200_9.125_.in	9.125		0.7360	0.0008	0.0113	0.7473
	1200_9.25_.in	9.250		0.7426	0.0007	0.0113	0.7539
	1200_9.375_.in	9.375		0.7499	0.0006	0.0113	0.7612
	1200_9.5_.in	9.500		0.7562	0.0006	0.0113	0.7675
	1200_9.625_.in	9.625		0.7643	0.0007	0.0113	0.7756
	1200_9.75_.in	9.750		0.7694	0.0006	0.0113	0.7807
	1200_9.875_.in	9.875		0.7749	0.0007	0.0113	0.7862
	1200_10_.in	10.000		0.7811	0.0007	0.0113	0.7924
	1200_10.125_.in	10.125		0.7869	0.0008	0.0113	0.7982
	1200_10.25_.in	10.250		0.7917	0.0007	0.0113	0.8030
	1200_10.375_.in	10.375		0.7995	0.0007	0.0113	0.8108
	1200_10.5_.in	10.500		0.8045	0.0007	0.0113	0.8158
	1200_10.625_.in	10.625		0.8116	0.0007	0.0113	0.8229
	1200_10.75_.in	10.750		0.8157	0.0007	0.0113	0.8270
	1200_10.875_.in	10.875		0.8200	0.0007	0.0113	0.8313
	1200_11_.in	11.000		0.8269	0.0007	0.0113	0.8382
	1200_11.125_.in	11.125		0.8324	0.0007	0.0113	0.8437
	1200_11.25_.in	11.250		0.8374	0.0007	0.0113	0.8487
	1200_11.375_.in	11.375		0.8440	0.0007	0.0113	0.8553
	1200_11.5_.in	11.500		0.8484	0.0008	0.0113	0.8597
	1200_11.625_.in	11.625		0.8536	0.0007	0.0113	0.8649
	1200_11.75_.in	11.750		0.8579	0.0007	0.0113	0.8692
	1200_11.875_.in	11.875		0.8639	0.0007	0.0113	0.8752

	1200_12_.in	12.000		0.8689	0.0007	0.0113	0.8802
UO2-H2O solution with a U content of 500 g U/l	500_8_.in	8.000		0.6623	0.0005	0.0113	0.6736
	500_8.125_.in	8.125		0.6705	0.0006	0.0113	0.6818
	500_8.25_.in	8.250		0.6772	0.0006	0.0113	0.6885
	500_8.375_.in	8.375		0.6850	0.0006	0.0113	0.6963
	500_8.5_.in	8.500		0.6911	0.0006	0.0113	0.7024
	500_8.625_.in	8.625		0.6983	0.0006	0.0113	0.7096
	500_8.75_.in	8.750		0.7060	0.0006	0.0113	0.7173
	500_8.875_.in	8.875		0.7128	0.0006	0.0113	0.7241
	500_9_.in	9.000		0.7189	0.0006	0.0113	0.7302
	500_9.125_.in	9.125		0.7258	0.0006	0.0113	0.7371
	500_9.25_.in	9.250		0.7307	0.0006	0.0113	0.7420
	500_9.375_.in	9.375		0.7404	0.0006	0.0113	0.7517
	500_9.5_.in	9.500		0.7451	0.0006	0.0113	0.7564
	500_9.625_.in	9.625		0.7503	0.0006	0.0113	0.7616
	500_9.75_.in	9.750		0.7570	0.0006	0.0113	0.7683
	500_9.875_.in	9.875		0.7627	0.0006	0.0113	0.7740
	500_10_.in	10.000		0.7691	0.0007	0.0113	0.7804
	500_10.125_.in	10.125		0.7741	0.0007	0.0113	0.7854
	500_10.25_.in	10.250		0.7798	0.0006	0.0113	0.7911
	500_10.375_.in	10.375		0.7867	0.0006	0.0113	0.7980
	500_10.5_.in	10.500		0.7920	0.0006	0.0113	0.8033
	500_10.625_.in	10.625		0.7967	0.0006	0.0113	0.8080
	500_10.75_.in	10.750		0.8019	0.0006	0.0113	0.8132
	500_10.875_.in	10.875		0.8076	0.0007	0.0113	0.8189
	500_11_.in	11.000		0.8115	0.0006	0.0113	0.8228
	500_11.125_.in	11.125		0.8184	0.0006	0.0113	0.8297
	500_11.25_.in	11.250		0.8228	0.0006	0.0113	0.8341
	500_11.375_.in	11.375		0.8284	0.0006	0.0113	0.8397
	500_11.5_.in	11.500		0.8326	0.0006	0.0113	0.8439
	500_11.625_.in	11.625		0.8362	0.0007	0.0113	0.8475
	500_11.75_.in	11.750		0.8419	0.0006	0.0113	0.8532
	500_11.875_.in	11.875		0.8463	0.0007	0.0113	0.8576
	500_12_.in	12.000		0.8503	0.0006	0.0113	0.8616

Table 25 Optimum Interspersed Moderation Sensitivity Study Effects On K-Effective For Process Vessels Filled With A Solution Of UNH With A U Content Of 1200 G U/L And A UO_2-H_2O Solution With A U Content Of 500 G U/L

File [redacted]

Comment [m37]: Trade secret / Proprietary

Description: Optimum Interspersed Moderation Sensitivity Study effects on k-effective for Process Vessels filled with a solution of UNH with a U content of 1200 g U/l and a UO2-H2O solution with a U content of 500 g U/l

Vessel Description	Filename	Density of H2O [g/cc]		k-effective	σ	Uncertainty	Final k-effective
UNH with a U content of 1200 g U/l	11_1200_0.001_.in	0.001		0.8588	0.0007	0.0113	0.8701
	11_1200_0.002_.in	0.002		0.8580	0.0007	0.0113	0.8693
	11_1200_0.003_.in	0.003		0.8591	0.0007	0.0113	0.8704
	11_1200_0.004_.in	0.004		0.8600	0.0007	0.0113	0.8713
	11_1200_0.005_.in	0.005		0.8596	0.0007	0.0113	0.8709
	11_1200_0.006_.in	0.006		0.8605	0.0008	0.0113	0.8718
	11_1200_0.007_.in	0.007		0.8591	0.0007	0.0113	0.8704
	11_1200_0.008_.in	0.008		0.8595	0.0007	0.0113	0.8708
	11_1200_0.009_.in	0.009		0.8592	0.0007	0.0113	0.8705
	11_1200_0.011_.in	0.01		0.8577	0.0007	0.0113	0.8690
	11_1200_0.012_.in	0.011		0.8580	0.0007	0.0113	0.8693
	11_1200_0.013_.in	0.012		0.8600	0.0006	0.0113	0.8713
	11_1200_0.014_.in	0.013		0.8604	0.0007	0.0113	0.8717
	11_1200_0.015_.in	0.014		0.8579	0.0007	0.0113	0.8692
	11_1200_0.016_.in	0.015		0.8600	0.0007	0.0113	0.8713
	11_1200_0.017_.in	0.016		0.8585	0.0007	0.0113	0.8698
	11_1200_0.018_.in	0.017		0.8595	0.0007	0.0113	0.8708
	11_1200_0.019_.in	0.018		0.8599	0.0006	0.0113	0.8712
	11_1200_0.01_.in	0.019		0.8578	0.0007	0.0113	0.8691
	11_1200_0.02_.in	0.02		0.8610	0.0007	0.0113	0.8723
	11_1200_0.03_.in	0.03		0.8595	0.0007	0.0113	0.8708
	11_1200_0.04_.in	0.04		0.8600	0.0007	0.0113	0.8713
	11_1200_0.05_.in	0.05		0.8592	0.0007	0.0113	0.8705
	11_1200_0.06_.in	0.06		0.8592	0.0007	0.0113	0.8705
	11_1200_0.07_.in	0.07		0.8610	0.0007	0.0113	0.8723
	11_1200_0.08_.in	0.08		0.8584	0.0007	0.0113	0.8697
	11_1200_0.09_.in	0.09		0.8596	0.0008	0.0113	0.8709
	11_1200_0.1_.in	0.1		0.8599	0.0007	0.0113	0.8712
	11_1200_0.2_.in	0.2		0.8621	0.0008	0.0113	0.8734
	11_1200_0.3_.in	0.3		0.8635	0.0007	0.0113	0.8748
	11_1200_0.4_.in	0.4		0.8663	0.0008	0.0113	0.8776
	11_1200_0.5_.in	0.5		0.8658	0.0007	0.0113	0.8771
	11_1200_0.6_.in	0.6		0.8679	0.0007	0.0113	0.8792

	11_1200_0.7_.in	0.7		0.8676	0.0007	0.0113	0.8789
	11_1200_0.8_.in	0.8		0.8704	0.0007	0.0113	0.8817
	11_1200_0.9_.in	0.9		0.8711	0.0007	0.0113	0.8824
	11_1200_1_.in	1		0.8711	0.0007	0.0113	0.8824
UO2-H2O solution with a U content of 500 g U/l	11_500_0.001_.in	0.001		0.8360	0.0006	0.0113	0.8473
	11_500_0.002_.in	0.002		0.8366	0.0006	0.0113	0.8479
	11_500_0.003_.in	0.003		0.8359	0.0005	0.0113	0.8472
	11_500_0.004_.in	0.004		0.8352	0.0006	0.0113	0.8465
	11_500_0.005_.in	0.005		0.8368	0.0007	0.0113	0.8481
	11_500_0.006_.in	0.006		0.8361	0.0006	0.0113	0.8474
	11_500_0.007_.in	0.007		0.8361	0.0006	0.0113	0.8474
	11_500_0.008_.in	0.008		0.8368	0.0006	0.0113	0.8481
	11_500_0.009_.in	0.009		0.8349	0.0006	0.0113	0.8462
	11_500_0.011_.in	0.01		0.8360	0.0006	0.0113	0.8473
	11_500_0.012_.in	0.011		0.8355	0.0007	0.0113	0.8468
	11_500_0.013_.in	0.012		0.8359	0.0007	0.0113	0.8472
	11_500_0.014_.in	0.013		0.8366	0.0006	0.0113	0.8479
	11_500_0.015_.in	0.014		0.8366	0.0006	0.0113	0.8479
	11_500_0.016_.in	0.015		0.8365	0.0007	0.0113	0.8478
	11_500_0.017_.in	0.016		0.8357	0.0007	0.0113	0.8470
	11_500_0.018_.in	0.017		0.8360	0.0006	0.0113	0.8473
	11_500_0.019_.in	0.018		0.8372	0.0006	0.0113	0.8485
	11_500_0.01_.in	0.019		0.8361	0.0006	0.0113	0.8474
	11_500_0.02_.in	0.02		0.8362	0.0006	0.0113	0.8475
	11_500_0.03_.in	0.03		0.8373	0.0006	0.0113	0.8486
	11_500_0.04_.in	0.04		0.8362	0.0006	0.0113	0.8475
	11_500_0.05_.in	0.05		0.8366	0.0006	0.0113	0.8479
	11_500_0.06_.in	0.06		0.8364	0.0006	0.0113	0.8477
	11_500_0.07_.in	0.07		0.8382	0.0006	0.0113	0.8495
	11_500_0.08_.in	0.08		0.8382	0.0007	0.0113	0.8495
	11_500_0.09_.in	0.09		0.8367	0.0006	0.0113	0.8480
	11_500_0.1_.in	0.1		0.8372	0.0007	0.0113	0.8485
	11_500_0.2_.in	0.2		0.8398	0.0007	0.0113	0.8511
	11_500_0.3_.in	0.3		0.8404	0.0007	0.0113	0.8517
	11_500_0.4_.in	0.4		0.8425	0.0006	0.0113	0.8538
	11_500_0.5_.in	0.5		0.8439	0.0006	0.0113	0.8552
	11_500_0.6_.in	0.6		0.8461	0.0006	0.0113	0.8574
	11_500_0.7_.in	0.7		0.8454	0.0007	0.0113	0.8567
	11_500_0.8_.in	0.8		0.8454	0.0006	0.0113	0.8567
	11_500_0.9_.in	0.9		0.8467	0.0006	0.0113	0.8580
	11_500_1_.in	1		0.8466	0.0006	0.0113	0.8579

Table 26 Vessel Separation Spacing Sensitivity Study Effects On K-Effective For Process Vessels Filled With A Solution Of UNH With A U Content Of 1200 G U/L And A UO_2-H_2O Solution With A U Content Of 500 G U/L

File [redacted]

Comment [m38]: Trade secret / Proprietary

Description: Vessel Separation Spacing Sensitivity Study effects on k-effective for Process Vessels filled with a solution of UNH with a U content of 1200 g U/l and a UO2-H2O solution with a U content of 500 g U/l

Vessel Description	Filename	Edge to Edge Separation [cm]	Edge to Edge Separation [inches]	k-effective	σ	Uncertainty	Final k-effective
UNH with a U content of 1200 g U/l	1200_OD_11_1.27_.in	1.27	1.0000	0.9833	0.0006	0.0113	0.9946
	1200_OD_11_2.54_.in	2.54	2.0000	0.9351	0.0007	0.0113	0.9464
	1200_OD_11_3.81_.in	3.81	3.0000	0.8939	0.0007	0.0113	0.9052
	1200_OD_11_5.08_.in	5.08	4.0000	0.8655	0.0006	0.0113	0.8768
	1200_OD_11_6.35_.in	6.35	5.0000	0.8488	0.0007	0.0113	0.8601
	1200_OD_11_7.62_.in	7.62	6.0000	0.8402	0.0007	0.0113	0.8515
	1200_OD_11_8.89_.in	8.89	7.0000	0.8334	0.0007	0.0113	0.8447
	1200_OD_11_10.16_.in	10.16	8.0000	0.8306	0.0007	0.0113	0.8419
	1200_OD_11_11.43_.in	11.43	9.0000	0.8290	0.0008	0.0113	0.8403
	1200_OD_11_12.7_.in	12.7	10.0000	0.8262	0.0007	0.0113	0.8375
	1200_OD_11_13.97_.in	13.97	11.0000	0.8269	0.0007	0.0113	0.8382
	1200_OD_11_15.24_.in	15.24	12.0000	0.8274	0.0009	0.0113	0.8387
UO2-H2O solution with a U content of 500 g U/l	500_OD_11_1.27_.in	1.27	1.0000	0.9178	0.0006	0.0113	0.9291
	500_OD_11_2.54_.in	2.54	2.0000	0.8800	0.0006	0.0113	0.8913
	500_OD_11_3.81_.in	3.81	3.0000	0.8524	0.0006	0.0113	0.8637
	500_OD_11_5.08_.in	5.08	4.0000	0.8369	0.0006	0.0113	0.8482
	500_OD_11_6.35_.in	6.35	5.0000	0.8268	0.0006	0.0113	0.8381
	500_OD_11_7.62_.in	7.62	6.0000	0.8210	0.0007	0.0113	0.8323
	500_OD_11_8.89_.in	8.89	7.0000	0.8174	0.0006	0.0113	0.8287
	500_OD_11_10.16_.in	10.16	8.0000	0.8154	0.0006	0.0113	0.8267
	500_OD_11_11.43_.in	11.43	9.0000	0.8143	0.0006	0.0113	0.8256
	500_OD_11_12.7_.in	12.7	10.0000	0.8132	0.0006	0.0113	0.8245
	500_OD_11_13.97_.in	13.97	11.0000	0.8115	0.0006	0.0113	0.8228
	500_OD_11_15.24_.in	15.24	12.0000	0.8105	0.0006	0.0113	0.8218

Table 27 Optimum Interspersed Moderation Sensitivity Study Effects on K-Effective for Room Interaction Model

File Location: \Results\Full Room Interaction\Input Files\

Description: Optimum Interspersed Moderation Sensitivity Study effects on k-effective for Room Interaction Model

Vessel Description	Filename	Density of H2O [g/cc]		k-effective	σ	Uncertainty	Final k-effective
Room Interaction Model	room_A00	0		0.8789		0.0113	
	room_A01	0.01		0.8811		0.0113	
	room_A10	0.1		0.8806		0.0113	
	room_A20	0.2		0.8777		0.0113	
	room_A30	0.3		0.8935		0.0113	
	room_A40	0.4		0.9086		0.0113	
	room_A50	0.5		0.9168		0.0113	
	room_A60	0.6		0.9242		0.0113	
	room_A70	0.7		0.9282		0.0113	
	room_A80	0.8		0.9329		0.0113	
	room_A90	0.9		0.9346		0.0113	
	room_A100	1		0.9363		0.0113	
						0.0113	
						0.0113	
						0.0113	

APPENDIX [redacted]

Comment [m39]: Trade secret / Proprietary

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APPENDIX C – COPIES OF REFERENCES

This appendix includes copies references, e.g. tables, unissued drawings, sketches, graphs, miscellaneous calculations, etc.

SPECIAL NUCLEAR MATERIAL LICENSE NO. SNM-1227, NRC DOCKET NO. 70-1257

PART II - SAFETY DEMONSTRATION — REV. 40

TABLE II-14.2
HOMOGENEOUS AND HETEROGENEOUS MINIMUM CRITICAL AND SAFE MASSES
ASSUMED CONDITIONS: SPECIAL GEOMETRY, FULL WATER REFLECTION, OPTIMUM MODERATION

Enrichment, Wt.% U^{235}	Minimum Critical Mass, kg UO_2 UO_2 Powder	Maximum Allowed Batch Size, kg UO_2	Minimum Critical Mass, kg UO_2 UO_2 Pellets	Maximum Allowed Batch Size, kg UO_2
Depleted	∞	∞	∞	∞
Natural	∞	∞	∞	∞
1.0	∞	∞	2723	1225
1.25	3970	1786	1009	454
1.5	941	423	521	234
1.75	453	204	322	145
2.0	283	127	226	102
2.25	204	92	169	76
2.5	156	70	135	61
2.75	124	56	111	50
3.0	102	46	93	42
3.25	85	38	81	36
3.5	72	32	69	31
3.75	64	29	61	27
4.0	56	25	55	25
4.25	51	23	50	22.5
4.5	46	20.7	45	20.3
4.75	43	19.3	43	19.3
5.0	40	18.0	40	18.0
5.25	37	16.7	37	16.7
5.5	35	15.8	35	15.8

AMENDMENT APPLICATION DATE: January 28, 1998 — PAGE NO.: 14-9

Table II-14.2 of Special Nuclear Material License No.-1227, NRC Docket No. 70-1257

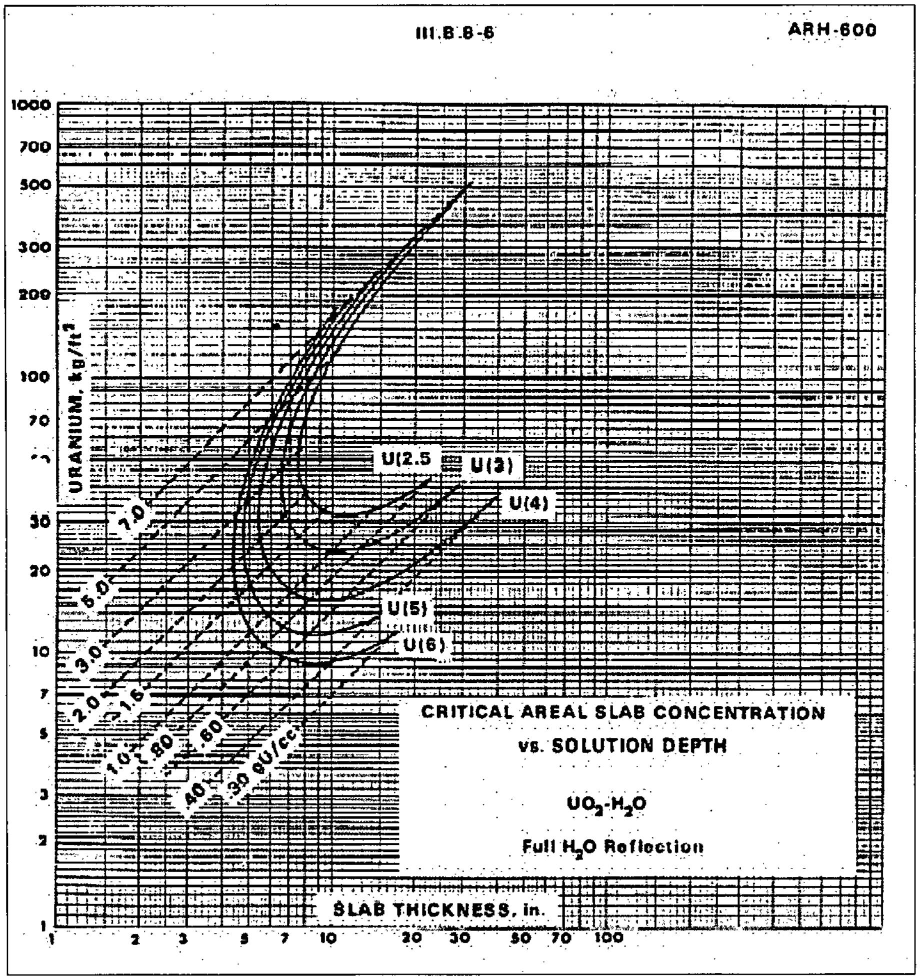

Figure 28 (ARH-600 III.B.8-6)

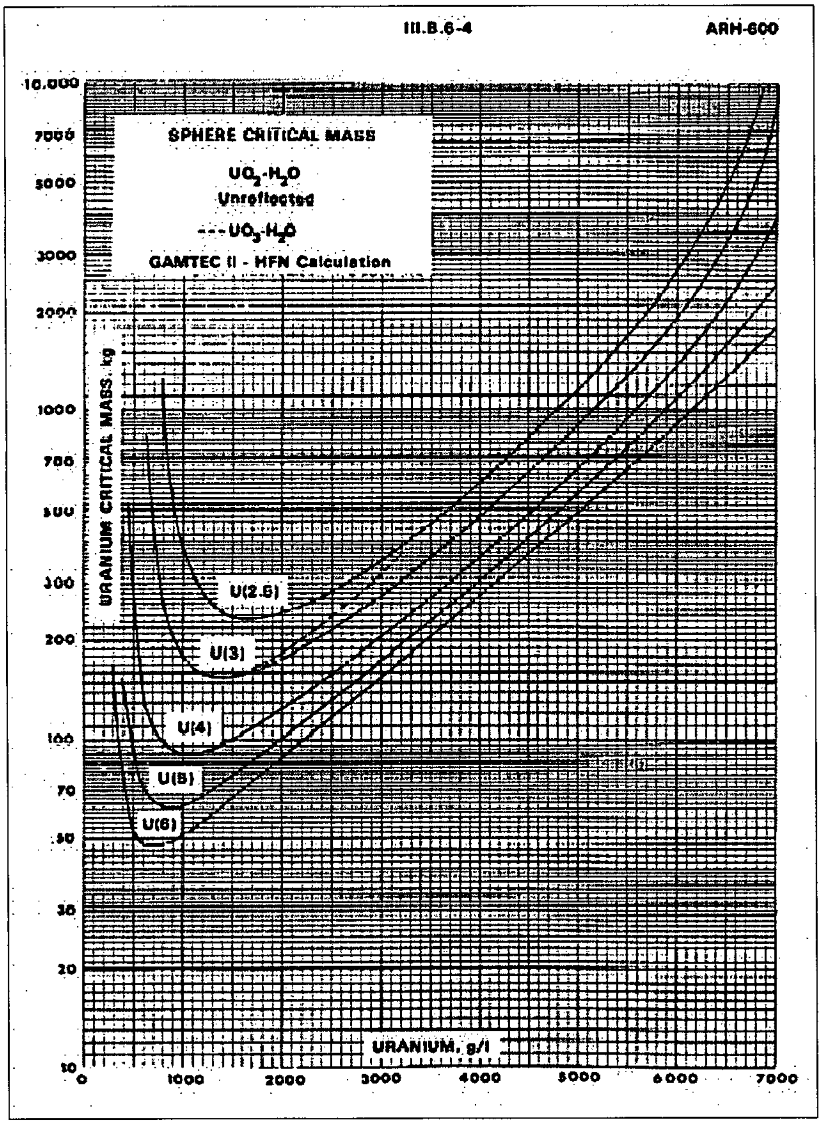

Figure 29 **(ARH-600 III.B.6-4)**

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