

ORNL/TM-1999/287
Revision 0

**System Requirement Document
for the Molten Salt Reactor
Experiment ^{233}U Conversion
System**

R. D. Aigner

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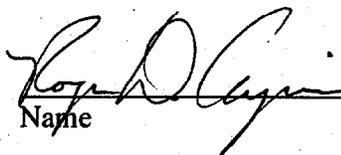
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**SYSTEM REQUIREMENTS DOCUMENT
FOR THE MOLTEN SALT REACTOR EXPERIMENT**

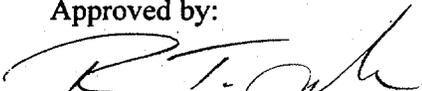
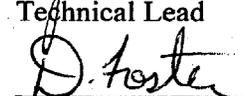
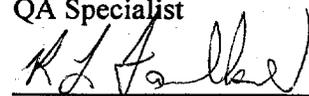
²³³U CONVERSION SYSTEM

January 10, 2000

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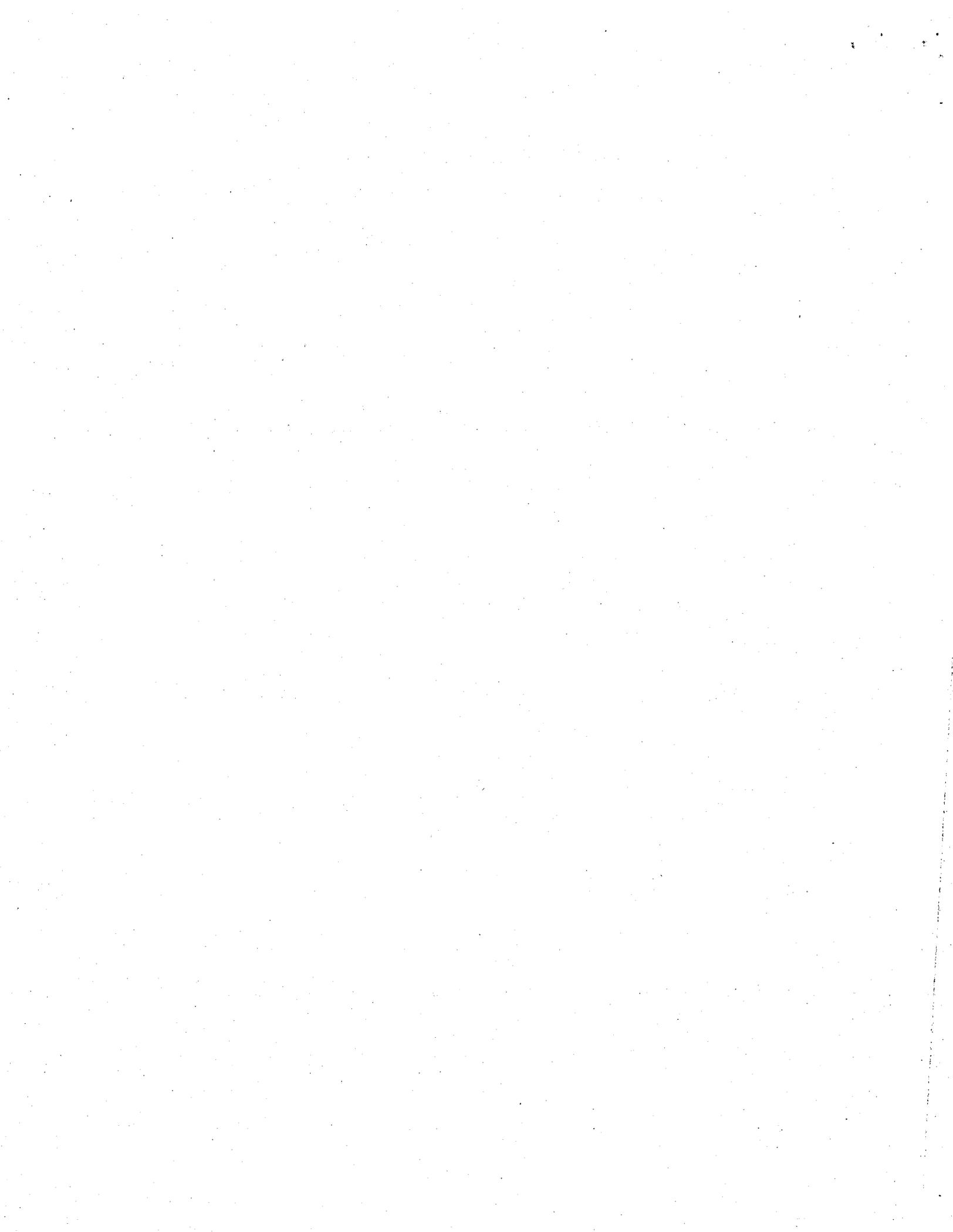
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ACRONYMS, ABBREVIATIONS, AND INITIALISMS

| | |
|-------|--|
| ACB | Auxiliary Charcoal Bed |
| ALARA | As Low As Reasonably Achievable |
| ASME | American Society of Mechanical Engineers |
| CFR | Code of Federal Regulations |
| CPS | conversion piping system |
| DOT | Department of Transportation |
| FMCL | fissionable material control limit |
| FTIR | Fourier transform infrared |
| HEPA | high efficiency particulate air |
| hr | hour |
| mR | milli-REM |
| MSRE | Molten Salt Reactor Experiment |
| ORNL | Oak Ridge National Laboratory |
| ppm | parts per million |
| psig | pounds per square inch gauge |

1. MISSION STATEMENT

The purpose of the conversion process is to convert the ^{233}U /fluoride compounds that are being extracted from the Molten Salt Reactor Experiment (MSRE) equipment and convert the material to a stable oxide for long-term storage at Building 3019.

2. INTRODUCTION

The fissile material reclamation activities for the MSRE remediation project include the removal and recovery of uranium from the off-gas system, from the stored fuel salt, and finally, from the uranium-laden charcoal in the Auxiliary Charcoal Bed (ACB). Each of these operations produces an uranium/fluoride compound that is not suitable for long-term storage. The uranium-fluoride compounds can be stored for a limited period of time in pressure vessels. The interim-storage vessels are designed to handle the internal pressure buildup from gases formed by radiolysis of the uranium-fluoride compounds. The conversion process will take the pressurized vessels from interim storage and process the materials in a hot cell located at Building 4501. The gas in the vessels will be vented through chemical traps and then the traps will be processed to convert the various uranium-fluoride compounds to a stable uranium oxide form. This will be done one trap at a time.

The chemical form of uranium being extracted from the off-gas system and from fuel salt fluorination process is uranium hexafluoride UF_6 . During the operations at MSRE, the UF_6 is chemisorbed onto sodium fluoride (NaF) traps where it forms the complex, $2\text{NaF}\cdot\text{UF}_6$. The conversion process that will be installed in the Building 4501 Hot Cell D will recover the UF_6 from the NaF traps by decomposition of the binary complex at elevated temperatures ($>300^\circ\text{C}$). After the uranium is extracted from the NaF traps, it is collected in the conversion process reaction vessel. The reaction vessel is then hydrolyzed and heated through several step operations up to 900°C in order to convert the material to a stable uranium oxide.

The ACB at MSRE contains uranium-laden charcoal with unstable C_xF compounds. After extraction at MSRE, this material will be delivered to Building 4501 Hot Cell D for processing to a stable oxide. The charcoal conversion process is still under development, with mockup and full scale testing of the proposed flow sheet funded in FY 99 and FY 00. The uranium-laden charcoal has been pre-treated with ammonia to prevent the deflagration of the C_xF if localized heating ($>\sim 150^\circ\text{C}$) occurs during the charcoal removal process. Prior to removal, the treatment will be performed a second time to denature the 1 to 5% reformation of C_xF that has occurred due to radiolysis of NH_4F . The uranium-laden charcoal will be physically extracted and stored in several pressure vessels at MSRE until the conversion process is designed and installed in Hot Cell A in Building 4501.

3. SYSTEM DESCRIPTION

3.1 PROJECT SCOPE

Because the chemical stability of the $2\text{NaF}\cdot\text{UF}_6$ complex and the uranium-laden charcoal are not suitable for long term storage, these materials must be converted into a more stable chemical

form such as the oxide, U_3O_8 . Because of the hazard associated with the high energy (2.6 MeV) gamma radiation emitted from ^{208}Tl , a daughter of ^{232}U , the conversion process must be performed in a hot cell. Equipment shall be designed, fabricated and installed in accordance with this document. Inspection and testing of the system shall be accomplished through the use of test plans and procedures. Operation of the system will not commence until fabrication packages, engineering as-built drawing packages, test plans and procedural walk-downs have been completed and approved.

Due to space limitations in the hot cells, there will be one processing system designed and installed in Hot Cell D in Building 4501 for converting the $2NaF \cdot UF_6$ complex to an oxide and one processing system designed and installed in Hot Cell A in Building 4501 for converting uranium-laden charcoal to an oxide. The scope of this document will be limited to only the $2NaF \cdot UF_6$ conversion process until the development work for the charcoal material has been completed.

3.2 PROJECT OBJECTIVES

The main objective of the conversion process is to transform the reactive and volatile UF_6 to a stable uranium oxide by replacing fluorine with oxygen. The main criteria used for the process selection are the following:

- Minimize uranium losses
- Minimize secondary wastes and contamination
- Simplicity and adaptability to small scale hot-cell operation
- No stirring, mixing, or transfers between vessels
- No need for purity (except as required for long-term storage)
- Suitable to treat all of the materials ($2NaF \cdot UF_6$ complex, uranium-laden charcoal, fluoride salt, and miscellaneous ^{233}U -containing materials)

3.3 PROJECT COMPLETION

The project shall be deemed complete when (1) all of the $2NaF \cdot UF_6$ complex materials and the uranium-laden charcoal received from the MSRE has been processed into stable oxide forms and transported to Bldg. 3019 for storage; (2) waste generated as a result of the process of conversion has been identified and appropriately disposed of; (3) the process equipment has been removed from the cells and disposed of; and (4) the cells have been cleaned to their initial condition.

3.4 PROJECT DISCUSSION

The process consist of two uranium reclamation schemes interconnected with the oxide conversion unit. Most of the equipment is common to three steps.

3.4.1 NaF Conversion

The first part of the process relates to the recovery of the uranium contained in the NaF traps and is shown in Fig. 1. As mentioned, the UF_6 from the off-gas system is being chemisorbed onto sodium fluoride (NaF) traps where the UF_6 forms a complex ($2NaF \cdot UF_6$) which decomposes at

higher temperatures ($>300^{\circ}\text{C}$). UF_6 is desorbed from the heated NaF trap ($300\text{-}450^{\circ}\text{C}$) in a closed-loop (below hot-cell pressure) and condensed in a cooled vessel. A small volume of fluorine gas is continuously circulated at a pressure below the external hot-cell pressure using a double-sealed metal bellows pump.

The purpose of the fluorine is two fold: first as a gas carrier and second as a fluorination agent to recover any oxyfluorides or lower fluorides that could be present in the trap. Two in-line infrared (IR) gas cells located before and after the UF_6 conversion vessel are used to monitor the completeness of the recovery. Any UF_6 that could escape condensation in the cooled conversion vessel will be re-circulated and trapped afterward. Most of the fluorine, except the volume of the piping loop, will be recycled and reused. All lines will be evacuated and filled-up with an inert gas helium (He) prior to trap removal. A soda-lime trap is located before the vacuum pump to ensure that not even traces of fluorine or uranium could leave the system. Alternatively, the UF_6 can be recovered by (a) diffusion from the heated NaF trap into the cooled conversion vessel in a static mode or (b) a combination of static diffusion followed by fluorine circulation.

The conversion of the frozen UF_6 into U_3O_8 will be conducted in the same conversion vessel used in the previous steps as shown in Fig. 3. Initially, a slight excess of water vapor will be condensed as ice on top of the frozen UF_6 . The vessel will be allowed to warm-up resulting in the formation of solid $\text{UO}_2\text{F}_2 \cdot x\text{H}_2\text{O}$ and HF. A freezing-thawing cycle is repeated two or three times to ensure complete hydrolysis of the UF_6 and to promote cracking of the solid cake that will facilitate the further steam treatment. The resulting solid cake will be step-heated and sequentially contacted with pressurized steam. The steam will penetrate into the cake, gradually reacting with the oxyfluoride-oxide mixture forming HF. The HF and steam will be transported to an HF trap in each step until completion. Wet air will be injected at the end of the process when the system reaches a temperature of $600\text{-}650^{\circ}\text{C}$ to complete the reaction. The vessel will then be heated up to about 850°C under wet air to produce U_3O_8 . At the end, the vessel will be allowed to cool-down. The lines will be evacuated and filled with an inert gas. The vessel will then be disconnected, capped, placed in an overpack, and removed from the cell to be transported to Bldg. 3019 for storage. Alternatively, the oxide product can be removed, characterized and transferred to a final storage container before transportation to the Bldg. 3019 storage wells.

3.4.2 Charcoal Conversion

The second sub-unit, shown in Fig. 2, is for the recovery and condensation of UF_6 from the passivated activated charcoal. The charcoal trap will be connected to the Fourier transform infrared (FTIR) gas cells and the conversion vessel. An intermediate trap (an empty vessel with a liquid-nitrogen cooled cold finger in the center) will be present during the initial heating of the charcoal to condense the ammonium fluoride (NH_4F). Once the charcoal reaches approximately 600 , it will be burned to carbon tetrafluoride (CF_4) using F_2 . Above 500°C charcoal burns completely with F_2 producing gaseous CF_4 and a small fraction of C_2F_6 and higher fluorocarbons. No intermediate fluorinated charcoal is formed at these high temperatures. The uranium is retained by the charcoal until almost all of the charcoal is transformed into gaseous fluorocarbons. When the charcoal is converted to CF_4 , the uranium is fully fluorinated to the volatile UF_6 . The recovered UF_6 will be condensed in the conversion vessel. The heavier fluorocarbons that are formed as minor byproducts and that will also condense, do not interfere with the further processing of the UF_6 into uranium oxide.

The F_2 flow will be stopped once the CF_4 is no longer detected by the FTIR gas cells, indicating that all the charcoal has been removed as CF_4 . As before, the soda-lime trap located in front of

the vacuum pump will trap any fugitive fluorine or uranium. The CF_4 will leave the system through a long coil of tubing to allow for the safe decay of the radioactive uranium daughters. Alternatively, the F_2 burning will be performed in a closed-loop mode starting from an evacuated system and continuing until system pressure is slightly below atmospheric pressure. At this point, the CF_4 will be released prior to starting another close-loop burning cycle.

3.4.3 Other Methods

Another method presently under testing consists of burning the charcoal with oxygen at a lower temperature ($\sim 400^\circ\text{C}$) in a closed system. The CO_2 formed will be collected as a frozen solid. The charcoal burning will be followed by a waiting period to allow for the decay of radon daughters before releasing the CO_2 . As envisioned, uranium will remain in the original charcoal container as uranium fluoride or oxyfluoride. These fluorides or oxyfluorides will then be converted to UF_6 using the F_2 closed-loop treatment shown in Fig. 1.

4. SYSTEM REQUIREMENTS AND SPECIAL ISSUES(NaF CONVERSION)

4.1 GENERAL REQUIREMENTS

4.1.1 Piping Systems Design

The Conversion Process System (CPS) primary piping shall be designed and fabricated in accordance with ANSI Standard B31.3 for all process piping and components with the exception of vessel design.

4.1.2 Operating Environment

The CPS primary piping shall be compatible with a gas stream containing the following:

- a) UF_6 @ 0-400 mm Hg
- b) F_2 @ 0-1000 mm Hg
- c) MoF_6 @ 0-50 mm Hg
- d) CF_4 @ 0-400 mm Hg
- e) HF
 - 1) @ 0-1000 mm Hg during circulation
 - 2) @ $\sim 50\%$ concentration from Thermal Cryostat to HF Condenser
- f) NF_3 (trace)
- g) N_2F_4 (trace)
- h) ClF_3 @ 0-200 mm Hg
- i) PuF_6 (trace)

Helium is expected to make up the balance of the gas stream.

4.1.3 Design Pressure/Temperature

The CPS primary piping shall be designed to maintain confinement between 300 psig maximum @ 200°C temperature, and vacuum @ 200°C temperature.

4.1.4 Gas Stream Clean Up

The CPS shall be capable of removing the following constituents from the CPS piping gas stream prior to disconnecting conversion vessels/traps:

- a) UF_6
- b) F_2
- c) ClF_3
- d) HF
- e) PuF_6

4.1.5 Operating Philosophy

The CPS shall be designed for intermittent operating cycles as a batch process. The remainder of the time, the system will be in a standby condition.

4.1.6 Materials of Construction

All piping components, including vessels, expected to be in direct contact with the gas stream during normal operations shall be fabricated from Monel Alloy 400 and/or of proven service within operating environments similar to that defined in 4.1.2. The line from the Thermal Cryostat to the HF Condensor shall be fabricated from Haynes 230 Alloy.

4.1.7 System Evacuation/Purge

The CPS shall be configured such that piping components can be evacuated and purged by inert gas as necessary.

4.1.8 Pre-operational Cleaning

All piping components, including vessels, expected to be in direct contact with the process gas stream during normal operation shall be thoroughly cleaned and conditioned following fabrication but prior to system operation. Cleaning shall be in accordance with procedures contained in ANSI N14.1-1990, American National Standard for Nuclear Materials - Uranium Hexafluoride - Packaging for Transport.

4.1.9 Transportation System

The transportation system (cask, overpack, and procedures) shall comply with the guidelines contained in ORNL/M-808, Lockheed Martin Energy Research, Inc., Oak Ridge National Laboratory "On-Site Transportation Operations Manual for Transporting Hazardous Materials and Hazardous Wastes", and ORNL Radiological Protection Procedure RPP-420, "Release and Transport of Radioactive Materials". The transportation system shall be described in a Transportation Plan, which shall be reviewed and approved by the ORNL Transportation Safety & Compliance Manager and the Transportation Operations Site Manager prior to intra-plant transport of a processed conversion vessel.

4.1.10 System/Component Designations

All system and component designators (valve numbers, line numbers, equipment identifications) on engineering drawings and specifications shall be consistent with the existing Building 4501 Cell D labeling system.

4.1.11 Radiation Exposure Limits

The CPS (equipment and procedures) design shall be such that the radiation exposure limits comply with the ORNL Office of Radiation Protection Procedures RPP-128, "Radiological Design Considerations", RPP-210, "Administrative Control Levels and Dose Limits", and RPP-310, "Planning Radiological Work". Additionally, ALARA principles shall be incorporated into system design.

4.1.12 Radiological Design Guidelines

ORNL Office of Radiation Protection Procedure RPP-128, "Radiological Design Considerations" and its Appendix A shall be used in determining the adequacy of the CPS design features for radiological considerations.

4.1.13 Nuclear Criticality Safety

System (equipment and procedures) design shall be such that compliance with the requirements of ORNL-NS-PO2, "Nuclear Criticality Safety Program" is maintained.

4.1.14 Natural Phenomena Mitigation Considerations

- a) Analysis shall be performed to evaluate the integrity of the structure of the building 4501 facility that houses Hot Cell D, where the CPS is to be installed and shall meet the requirements of DOE-STD-1021-93¹.
- b) Modifications and/or additions to the Building 4501 facility Hot Cell D structures, systems and components, shall be designed and analyzed for Natural Phenomena Hazards Mitigation to meet the requirements of DOE Order 420.1, "Facility Safety".

4.1.15 Secondary Confinement

Vessels and components which may be expected to convey and/or accumulate more than trace quantities of uranium upstream of the final trap vessel during operation of the CPS shall be secondarily confined in a hot cell. The CPS will be installed inside a hot cell to protect workers from gaseous release, radiation and contamination associated trap constituents. The hot-cell pressure will be maintained negative relative to the pressure in the adjacent operating area.

4.1.16 Accountability

Operations within the Building 4501 facility shall meet the minimum requirements and procedures for the control and accountability of nuclear materials as prescribed in DOE Order 5633-3B, "Control and Accountability of Nuclear Materials".

¹ Derived from DOE ORDER 420.1, "Facility Safety".

4.1.17 Gas Flow Initiation and Termination

Venting of the CPS off-gas piping shall be controlled. Termination of the venting operation shall be performed by operation of redundant solenoid-operated valves.

4.1.18 Radon Decay

The system shall be configured such that a minimum hold-up time of not less than 10 minutes is provided for the "cleaned" effluent gas in order for adequate radon decay to occur.

4.1.19 Safeguards and Security

There shall be no more than 2 kg of uranium accessible within hot cells A & D at any time.

4.1.20 Service Life

CPS components shall be designed for a service life of not less than 10 years except for portions of the system that are specifically identified for replacement due to high concentrations of corrosive gas.

4.2 SPECIAL DESIGN CONDITIONS

4.2.1 Cell Ventilation

Ventilation of the cell will draw air from the operating area through the cell and then send it on to the 3039 stack.

4.2.2 Remote Operations

Operations in the hot cell will require the use of manipulators or remote-control of processes (e.g., remotely air operated valves). Process design and layout shall accommodate remote operations and shall minimize cell entry for hands-on operation.

4.2.3 Confinement Requirements

Both the environment and operational areas must be protected from the ^{233}U . Confinement shall be governed by the following requirements:

- a) The process equipment (i.e., the piping, valves, and vessels) shall serve as the primary confinement.
- b) Additionally, all processing of UF_6 shall be performed sub-atmospheric.
- c) The hot cell provides secondary confinement. The hot cell pressure is maintained negative with respect to the adjacent operating areas to ensure that air flow is into the cell.
- d) Normal air intake into the cell shall be HEPA filtered. Air exhaust from the cell and from the hot cell off gas system shall be HEPA filtered prior to release through the 3039 stack.

- e) Process instrumentation (e.g., pressure transducers) shall be available to provide indications of a breach of primary confinement. Process piping shall be segmented by closure of valves to isolate such a breach.

4.2.4 Shielding Requirements

Shielding for protection of operating personnel is provided by the hot-cell walls, viewing windows, and cell access doors. Localized shielding of sources shall be provided to protect equipment, eliminate potential streaming pathways, and allow for operator entry, if necessary. Shielding shall be designed and implemented following guidelines defined by 4.1.11 and 4.1.12 of this document. Shielding for operations shall include the following:

- a) During transportation operations, shielding shall be provided by a shielded carrier.
- b) Inside the cell, the trap load-in station and the desorption station shall be shielded. See Section 5.10 and 5.11 of this document.

4.2.5 Decontamination Requirements

The equipment/system shall be designed to facilitate decontamination to the maximum extent practicable.

5.0 SYSTEM REQUIREMENTS FOR SPECIAL SUPPORT EQUIPMENT

5.1 REACTION/STORAGE VESSEL DESIGN REQUIREMENTS

5.1.1 Primary Containment & Design Life

The conversion/storage vessel shall provide the primary containment for ^{233}U and/or HF and/or F_2 contained in oxide form for a storage life of not less than 50 years. Trap vessel penetrations shall be sealed with threaded end caps or similar fittings when not connected to the CPS process piping.

5.1.2 Storage Location

The conversion/storage vessel and overpack shall be designed for storage within existing storage wells in Building 3019. Size limitations shall be less than 4 inches in diameter, and 21.25 inches tall.

5.1.3 Vessel Design Standards

The conversion vessel shall be designed in accordance with ASME Boiler and Pressure Vessel Code Section VIII, Division I.

5.1.4 Vessel Fabrication Standards

To ensure fabrication in accordance with NQA-1, the trap vessel shall be fabricated in accordance with the ORNL Quality Assurance Procedures as outlined in the ORNL Standard Practice Procedures.

5.1.5 Normal Operating Conditions

The vessel shall be designed to meet the following conditions:

- a) One (1) atmosphere (15 psig) external pressure at a maximum temperature of approximately 450 degrees C (842 degrees F) for a continuous operating period not to exceed 24 hours. Calculations for this operating condition shall be made using best engineering practices and methods. This calculation reflects the requirement of the vessel to safely withstand normal operating conditions when UF_6 is being frozen inside the vessel using liquid nitrogen and the vessel is at internal sub-atmospheric pressure. Gas flows will be controlled during this operation.
- b) 300 psig internal working pressure at a maximum temperature of 650 degrees C (1202 degrees F) for a continuous operating period not to exceed 8 hours. Calculations for this operating condition shall be made using the ASME Boiler & Pressure Vessel Code (B&PVC) Section VIII, Division I. This calculation reflects the requirement of the vessel to safely withstand normal operating conditions when injecting steam into the vessel.
- c) 200 psig internal working pressure at a maximum temperature of 885 degrees C (1625 degrees F) for a continuous operating period not to exceed 8 hours. Calculations for this operating condition shall be made using the ASME Boiler & Pressure Vessel Code (B&PVC) Section VIII, Division I. This calculation reflects the requirement of the vessel to safely withstand normal operating conditions while subjecting the vessel to final heating operations using wet air.
- d) One (1) atmosphere (15 psig) external pressure at a maximum temperature of 250 degrees C (482 degrees F) for a continuous period not to exceed 1 hour. Calculations for this operating condition shall be made using the ASME Boiler and Pressure Vessel Code (B&PVC) Section VIII Division I. This calculation shall meet the requirements for transportation as specified in DOE Order 440.1.

5.1.6 Materials of Construction

Fabrication of the conversion vessel shall be done using Haynes 230 Ni alloy. Fittings external to the primary confinement envelope may be 300 series stainless steel.

5.2 STEAM GENERATOR VESSEL DESIGN REQUIREMENTS

Preliminary concept of steam generator provides for an external Watlow electric heating furnace. The amount and rate of steam generated will depend upon the operational phase where the steam will be used. (controller criteria? an on-off controller with too much power could overheat the UF_6) During the initial "icing" phase, a predetermined amount of water will be slowly heated to boiling at sub-atmospheric pressure. This saturated steam provides water vapor which will be used to cover the desorbed UF_6 with water ice. Later, up to a dozen steam pressurization and

release cycles at 200 psig nominally, will be used to hydrate and defluorinate the UO_2F_2 at temperatures up to 600°C .

Placement of the steam generator in the hot cell should allow 2nd closest proximity to the reaction vessel, at an elevation to promote drainage of condensate \leftrightarrow to the reaction vessel, but toward the rear or side of the cell to allow visual and tactile access to other components.

Instrumentation in the preliminary concept consists only of an electrically sensed Bourdon pressure transducer, but level indication may be desirable. A precise water metering device inside the cell and after the back flow preventers might be necessary for controlling the amount of water needed for the initial hydration reaction.

5.2.1 Primary Containment & Design Life

The steam generator vessel shall provide the primary containment for $^{233}\text{UF}_6$ and/or HF and/or F_2 for a service life of not less than 10 years. Trap vessel penetrations shall be sealed with VCR type or similar fittings when not connected to the CPS process piping.

5.2.2 Vessel Design Standards

The steam generator vessel shall be designed in accordance with ASME Boiler and Pressure Vessel Code Section VIII, Division I.

5.2.3 Vessel Fabrication Standards

To ensure fabrication in accordance with NQA-1, the steam generator vessel shall be fabricated in accordance with the ORNL Quality Assurance Procedures as outlined in the ORNL Standard Practice Procedures.

5.2.4 Materials of Construction

Fabrication of the steam generator shall be done using any commercially available 400 series stainless steel.

5.2.5 Normal Operating Conditions

The vessel shall be designed to meet the following conditions:

| | |
|------------------------|---|
| Design Pressure: | 300 psig |
| Operating Pressure: | 200 psig |
| Design Temperature: | 417 + controller margin °F |
| Operating Temperature: | 381 + controller margin °F |
| Diameter: | 4" max. |
| Volume: | 1 liter liquid, 2 liters vapor space |
| Ports: | 1 pressure tap, 1 liquid inlet, 1 steam outlet, 1 relief valve outlet |

(Ports may be combined, if required.)

- a) 300 psig maximum internal working pressure at a maximum temperature of 232 degrees C (450 degrees F) for a continuous operating period not to exceed 8 hours. Calculations for this operating condition shall be made in accordance with the ASME Boiler and Pressure Vessel Code (B&PVC) Section VIII Division I.
- b) 15 psig internal working pressure at a maximum temperature of 885 degrees C (1625 degrees F) for a continuous operating period not to exceed 8 hours. Calculations for this operating condition shall be made using standard engineering calculations based on ANSI B31.3 requirements. This calculation reflects the requirement of the vessel to safely withstand normal operating conditions when not injecting wet oxygen into the vessel and the vessel is at sub-atmospheric pressure.
- c) One (1) atmosphere (15 psig) external pressure at a maximum temperature of 250 degrees C (482 degrees F) for a continuous period not to exceed 8 hours. Calculations for this operating condition shall be made using the ASME Boiler and Pressure Vessel Code (B&PVC) Section VIII Division I.

5.3 HF TRAP VESSEL DESIGN REQUIREMENTS

(TBD in later revision)

5.4 PROCESS FLUORINE TANK VESSEL DESIGN REQUIREMENTS

(TBD in later revision)

5.5 CONDENSER VESSEL DESIGN REQUIREMENTS

(TBD in later revision)

5.6 NAF SCRUBBER VESSEL DESIGN REQUIREMENTS

(TBD in later revision)

5.7 EVAPORATOR VESSEL DESIGN REQUIREMENTS

(TBD in later revision)

5.8 ALUMINA SCRUBBER VESSEL DESIGN REQUIREMENTS

(TBD in later revision)

5.9 MSRE NAF TRAP VESSEL DESIGN REQUIREMENTS

(TBD in later revision)

5.10 SHIELDED LOAD IN STATION DESIGN REQUIREMENTS

(TBD in later revision)

5.11 SHIELDED OVEN ASSEMBLY DESIGN REQUIREMENTS

(TBD in later revision)

5.12 THERMAL CRYOSTAT DESIGN REQUIREMENTS

(TBD in later revision)

5.13 FTIR ANALYTICAL CELL DESIGN REQUIREMENTS

(TBD in later revision)

6.0 SYSTEM REQUIREMENTS AND SPECIAL ISSUES(CHARCOAL CONVERSION)

(TBD in later revision)

6.1 GENERAL REQUIREMENTS

(TBD in later revision)

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