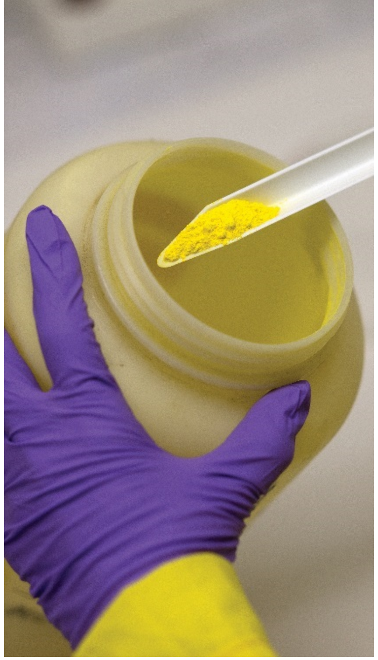

CNS consolidated nuclear security, llc
PANTEX PLANT | Y-12 NATIONAL SECURITY COMPLEX

Crediting a Soluble Neutron Absorber at Y-12 under ANSI/ANS-8.14-2004

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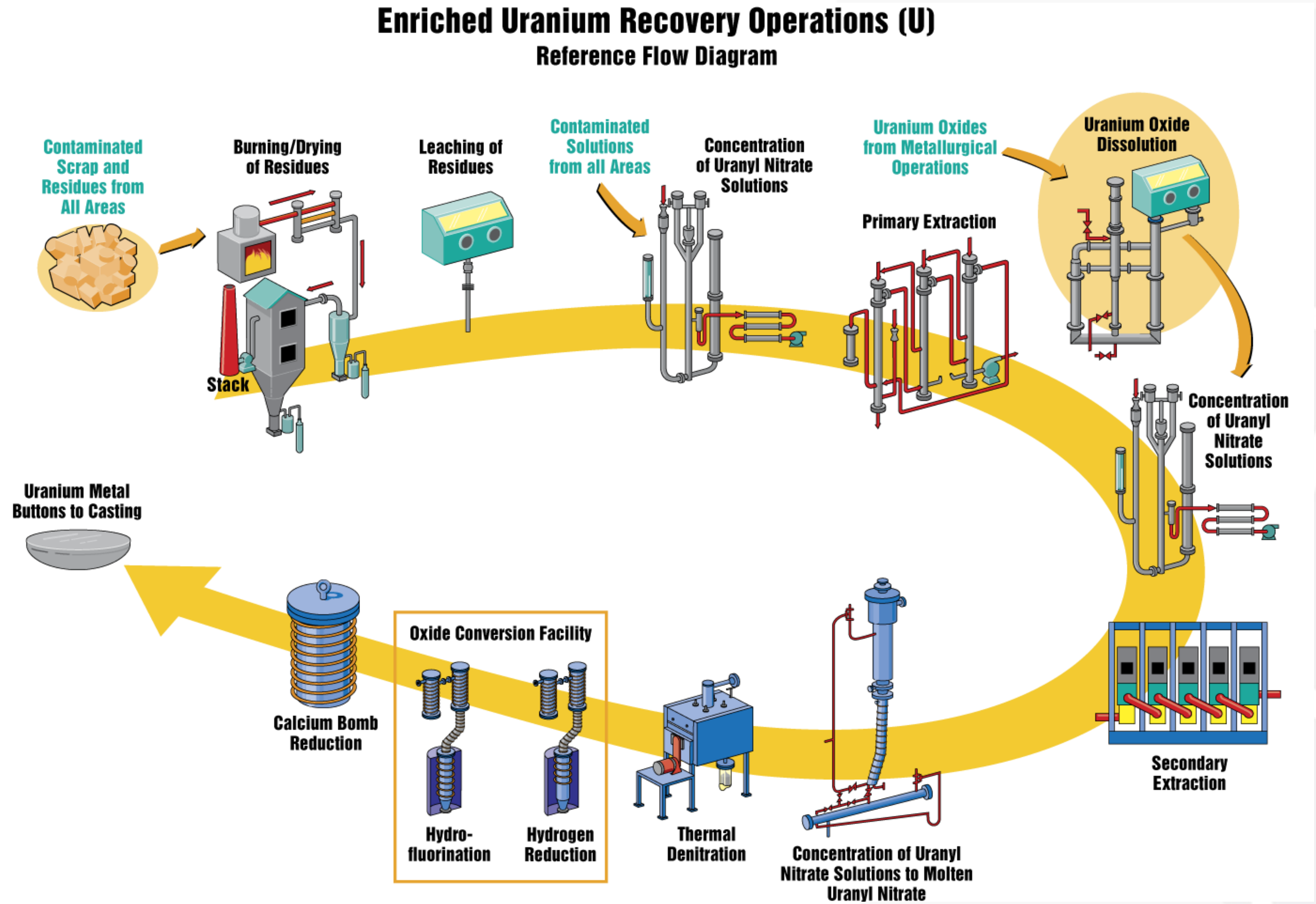
Outline

- Current uranium reprocessing technology at Y-12
- Electrorefining at Y-12
- ANS/ANSI-8.14 brief overview & main requirements
- Conclusions
- Questions

Current Reprocessing Technology



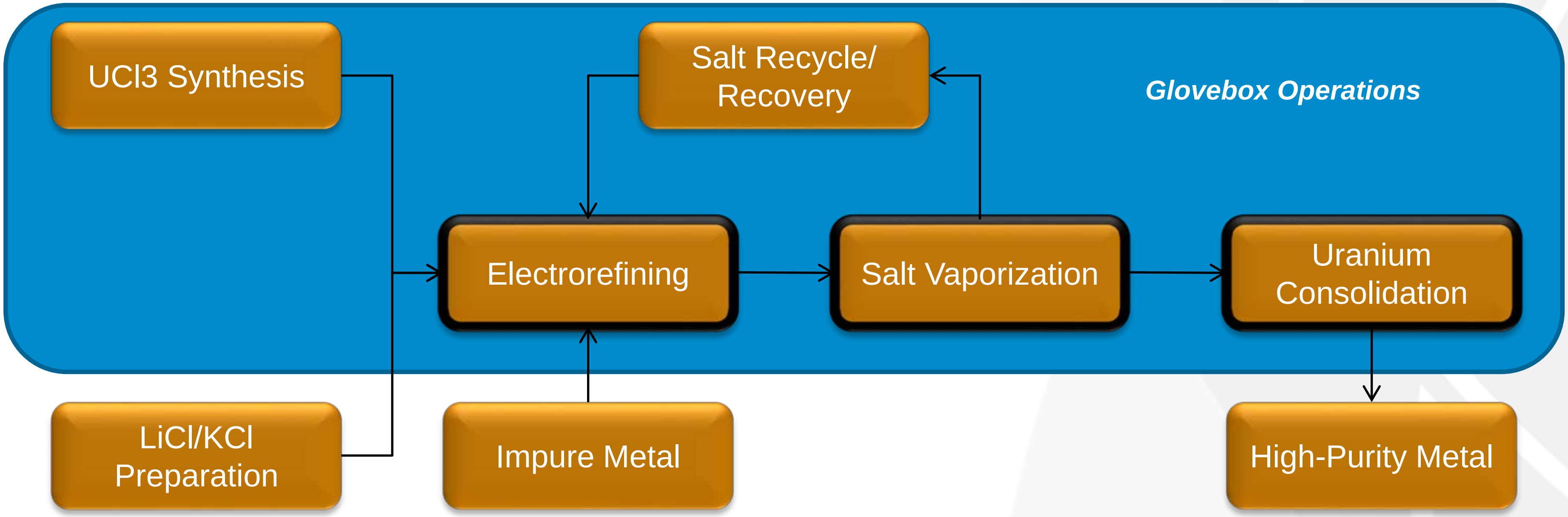
Introduction

Electrorefining (ER) is a major development effort of the Y-12 National Security Complex to revolutionize the reprocessing and purification of enriched uranium (EU).

- **Potentially eliminates most wet chemistry systems and associated hazards**
- **Smaller footprint (4 to 1)**
- **Accelerates/improves technology transition and Building 9212 Shutdown**
- **Reduces operating requirements**
  - ~25 fewer surveillance, 150 fewer procedures, 500 fewer calibrations
- **Estimated reduction in operating costs by ~75% for reprocessing and purification**

Y-12 ER System Overview

- **Electrorefining:** Purifies uranium by dissolving metal in molten salt and electrodeposition
- **Salt Vaporization:** Removes electrolyte from ‘raw’ ER product
- **Uranium Consolidation:** Melt/cast purified U crystals into usable form (buttons)



Uranium Electrorefining

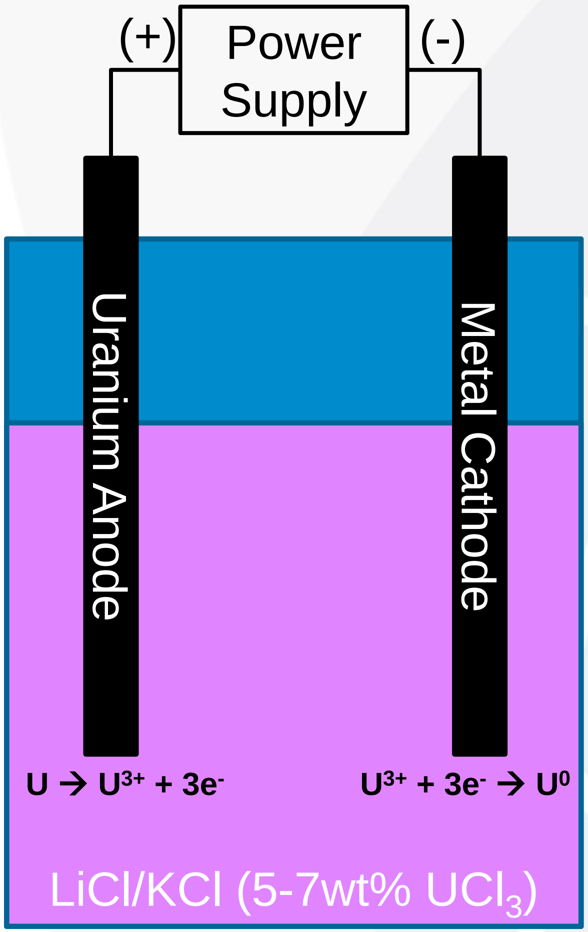
- **Electrolyte:** Molten LiCl/KCl Eutectic with UCl_3 dissolved at 5-7 wt% - establishes equilibrium

$$U^0 \leftrightharpoons U^{3+}$$

- **Electrorefiner:** Electrolytic Cell
  - Anode: Basket containing impure Uranium Metal
  - Cathode: Inert metal
  - Potential applied to cell
    - Uranium in anode dissolves into salt – impurities are left in basket $$U^0 \rightarrow U^{3+}$$
    - Uranium deposits onto cathode – forms crystals

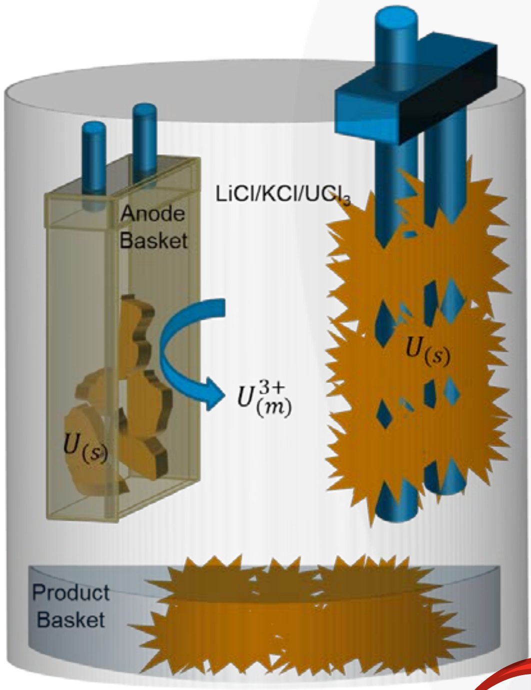
$$U^{3+} \rightarrow U^0$$

    - Uranium is selectively purified



Uranium Electrorefining: Purifying Metal

- Broken metal placed into anode basket and lowered into molten salt
- Potential applied between anode and cathode
  - Anode $U_{(s)} \rightarrow U^{3+}_{(m)}$
  - Cathode $U^{3+}_{(m)} \rightarrow U_{(s)}$
- Product crystals build up
- Crystals scraped into basket below cathodes
- Product collection basket pulled out of molten salt
- Molten salt adheres to surface of metal crystals when removed



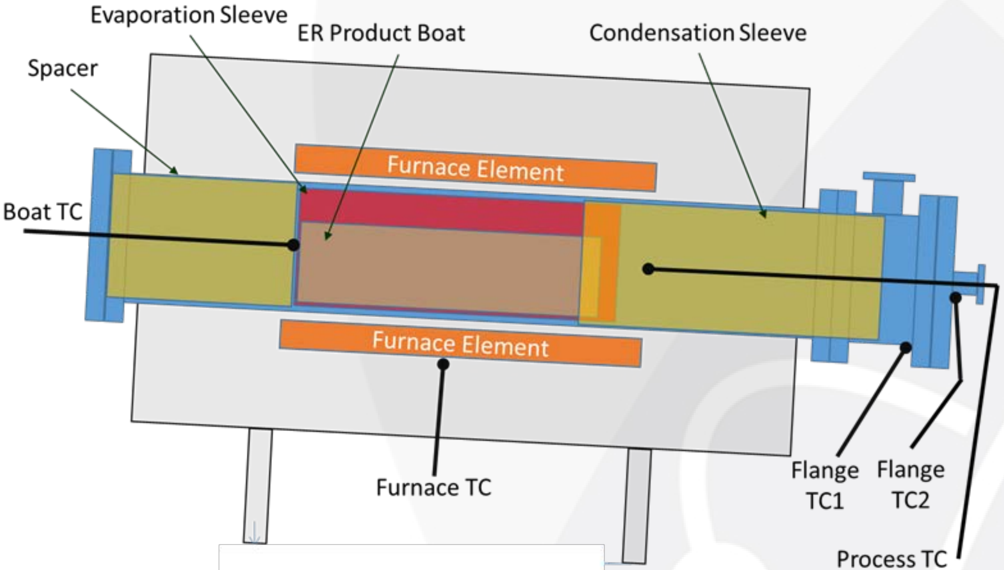
Crystals formed on Cathode

Impure Metal

Pure metal crystal bundles with salt

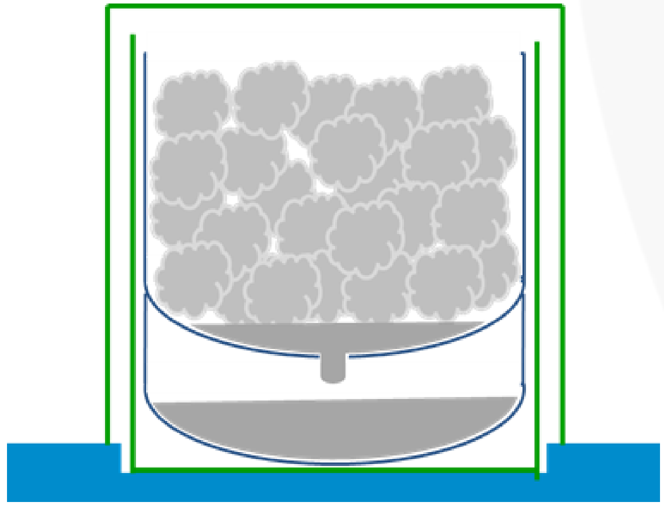
Salt Vaporization Furnace

- Product is placed in a furnace to evaporate and separate adhered salt
- Result is pure uranium metal crystals
- Separated salt is collected and returned to the ER cell



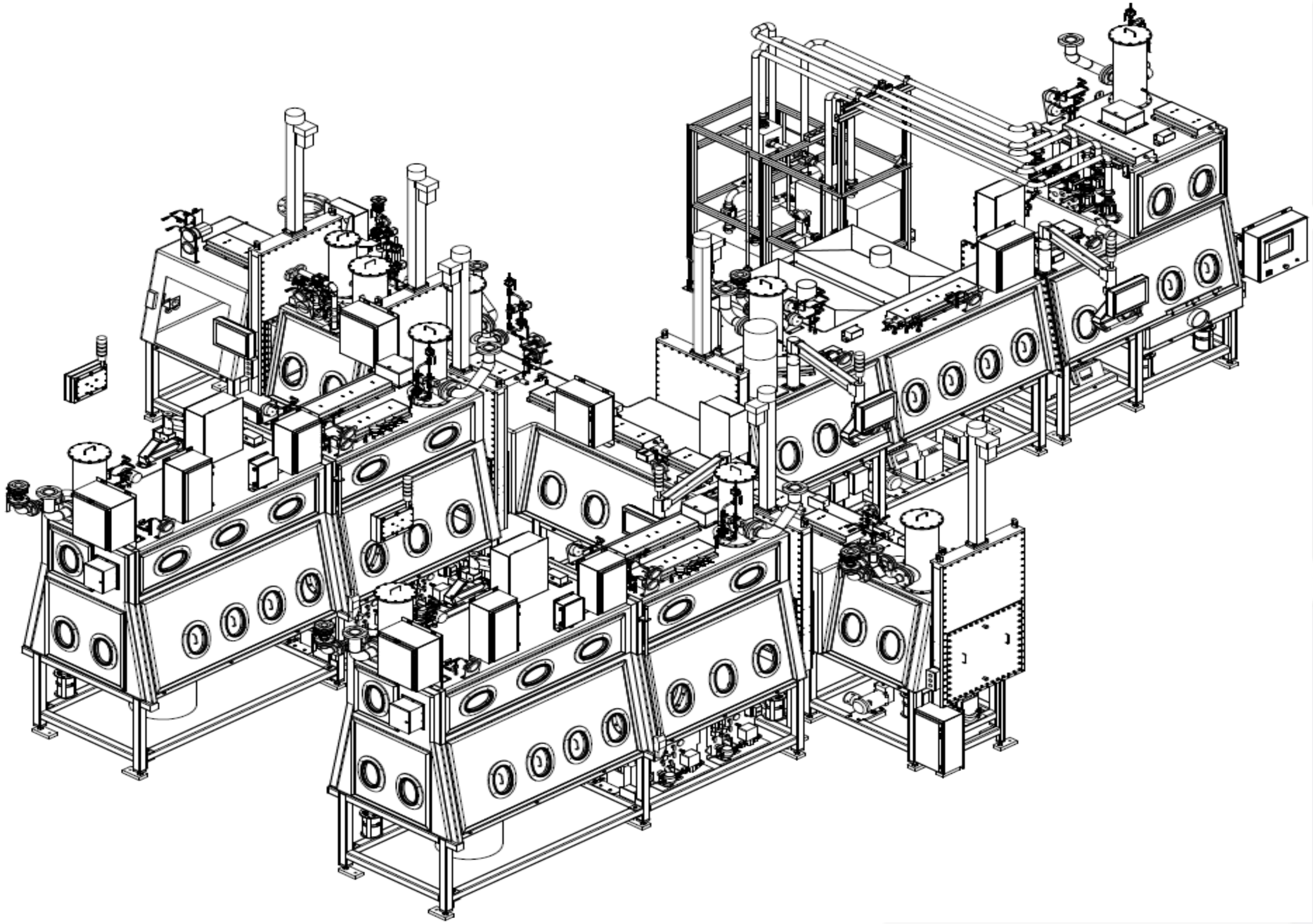
Uranium Consolidation Furnace

- Cleaned vaporization furnace product is loaded into a drip-cast stack



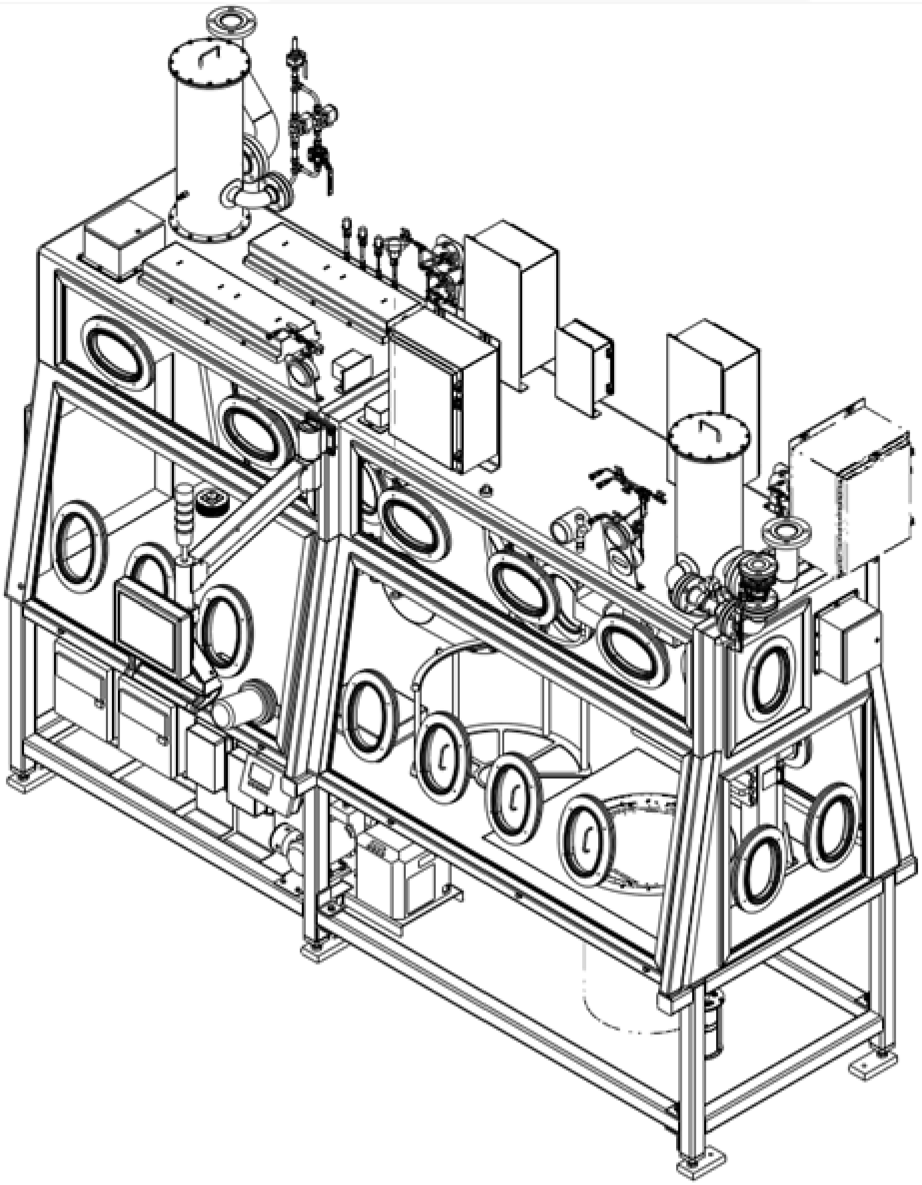
Glovebox Operations

- Outside of the ER Cell, fairly standard operations and control strategies (mass limits, spacing, etc.)



ER Cell Safety Concerns

- Large geometry cell
- Eutectic salts are hygroscopic and water soluble
- Cannot limit to < 700 g^{235}U because of required throughput
- Credit the ^{6}Li as a soluble neutron absorber



ANSI/ANS 8.14 – Use of Soluble Neutron Absorbers in Facilities Outside Reactors

- Provides guidance for the use of soluble neutron absorbers for process and handling operations in which solutions of neutron absorbers are used for criticality control.
  - Absorber Selection
  - System Design and Modifications
  - Criticality Safety Evaluations
  - Quality Control Program
  - Facility Operation with Soluble Absorbers
- Not currently implemented anywhere at Y-12
- Report has been prepared that outlines how Y-12 will meet each standard requirement

ANSI/ANS 8.14 Main Requirements

- Absorber Selection
  - Chemical compatibility
  - Radiation effects
  - Operational Aspects

- Criticality Safety Evaluations
  - Minimum mass of absorber required
  - Uncertainty allowances required
  - Criticality Safety Process Study

ANSI/ANS 8.14 – Absorber Selection

- Chemical compatibility
  - LiCl already present in the eutectic mixture
  - Y-12 has a reliable supply of enriched Li
  - Nothing about the process chemistry is altered

- Radiation effects
  - ^{6}Li depletion from n + $^{6}Li \rightarrow \alpha + {}^{3}H$
  - Neutron flux in the subcritical ER cell is essentially zero
  - Neutron sources – spontaneous fission of uranium, $^{7}Li(\alpha,n)^{10}B$ reactions, and $^{37}Cl(\alpha,n)^{40}K$ reactions, cosmic neutrons
  - Depletion of ^{6}Li found to be insignificant
  - Tritium production study (i.e. ^{6}Li depletion)

- Operational Aspects
  - Adhered eutectic containing ^{6}Li is removed during normal operations
  - Salt level is maintained for efficient processing
  - Salt recycling operations
  - Mass tracking of ^{6}Li throughout the process

ANSI/ANS 8.14 – Criticality Safety Evaluations

- Criticality Safety Process Study has been issued
- Minimum ^{6}Li mass required for safe operation
- Safety factors to account for uncertainties in the ^{6}Li mass and its distribution

ANSI/ANS 8.14 – Criticality Safety Evaluations

- MCNP and KENO V.a calculations
  - Minimum critical masses of $^{235}UO_2Cl_2$ (uranyl chloride) and LiCl (lithium chloride) in aqueous solution
  - Reflector characteristics of the ER salts around ^{235}U metal
- Novel corollary between ^{10}B and ^{6}Li
  - The thermal neutron absorption cross section of ^{10}B is about four times that of ^{6}Li
  - Verified by calculations
- Additional criticality benchmarks
  - The most common experimental data is in a fluoride or nitrate complex

ANSI/ANS 8.14 – Crediting ^{6}Li

- Contingency - ER Cell operated with less than the required mass of ^{6}Li
  - Subcritical based on dry metal mass limits (20.1 kg for fully reflected metal)
  - Material in the ER cell is at a reduced density based on its form → increased subcritical mass limit
- Contingency - Water Ingress into ER Cell
  - Sources:
    1. Water is spilled into the cell
    2. Hygroscopic absorption of the salt mixture
       - Salt mixture is highly hygroscopic
       - Salt mixture could be exposed to humid air
  - Minimum mass of ^{6}Li keeps the ER cell safe
  - Addition of water thermalizes neutrons and increases ^{6}Li neutron absorber effectiveness

Conclusions

- Electrorefining un-irradiated enriched uranium metal on a production scale is something new
- Y-12 will credit ^{6}Li for criticality safety in accordance with ANSI/ANS-8.14
- CSPS has evaluated the minimum ^{6}Li mass required for safe operation
- Questions

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