

ENCLOSURE 2

SHINE MEDICAL TECHNOLOGIES, INC.

**MEETING SLIDES FOR THE JANUARY 29 AND 30, 2019 MEETING
BETWEEN SHINE MEDICAL TECHNOLOGIES, INC. AND THE NRC**

**SHINE TECHNOLOGY OVERVIEW
PUBLIC VERSION**



SHINE Technology Overview

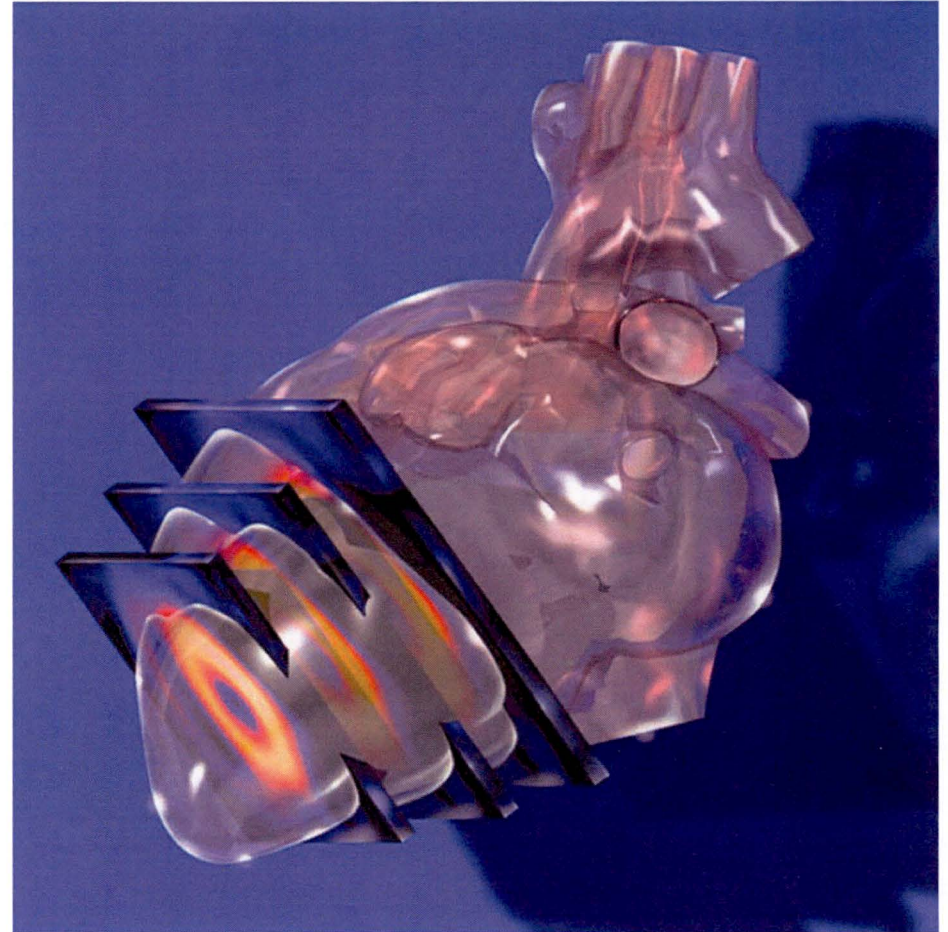
Eric Van Abel, Chief Technical Officer

Health. Illuminated.™



Mission

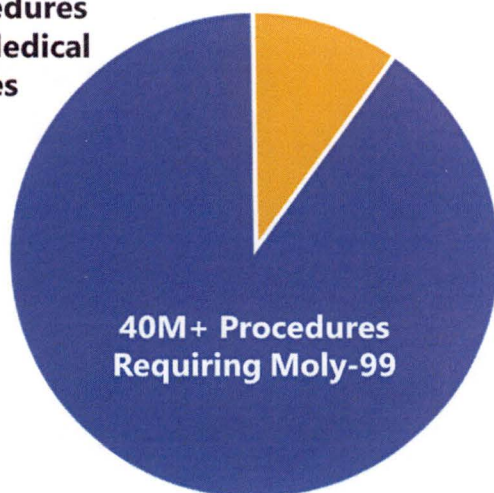
Dedicated to being the world leader in the safe, clean, affordable production of medical tracers and cancer treatment elements.



Medical isotopes enable doctors to diagnose and treat illnesses, such as heart disease and cancer



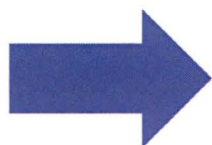
50M+ Procedures
Requiring Medical
Isotopes



40M+ Procedures
Requiring Moly-99

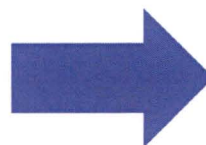
Radioactive
Decay

Moly-99

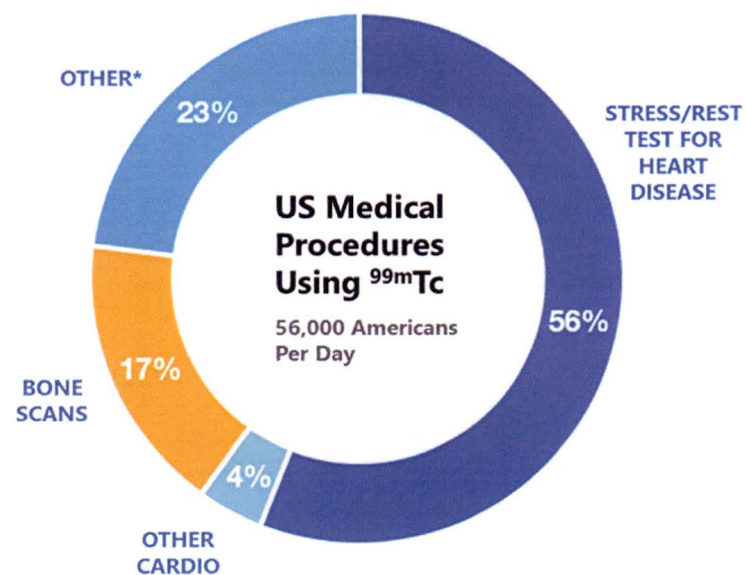


Tc-99m

Medical
Procedure



Patient Dose



* Other includes liver, respiratory, thyroid / parathyroid, renal, inflammation, tumor imaging, etc.



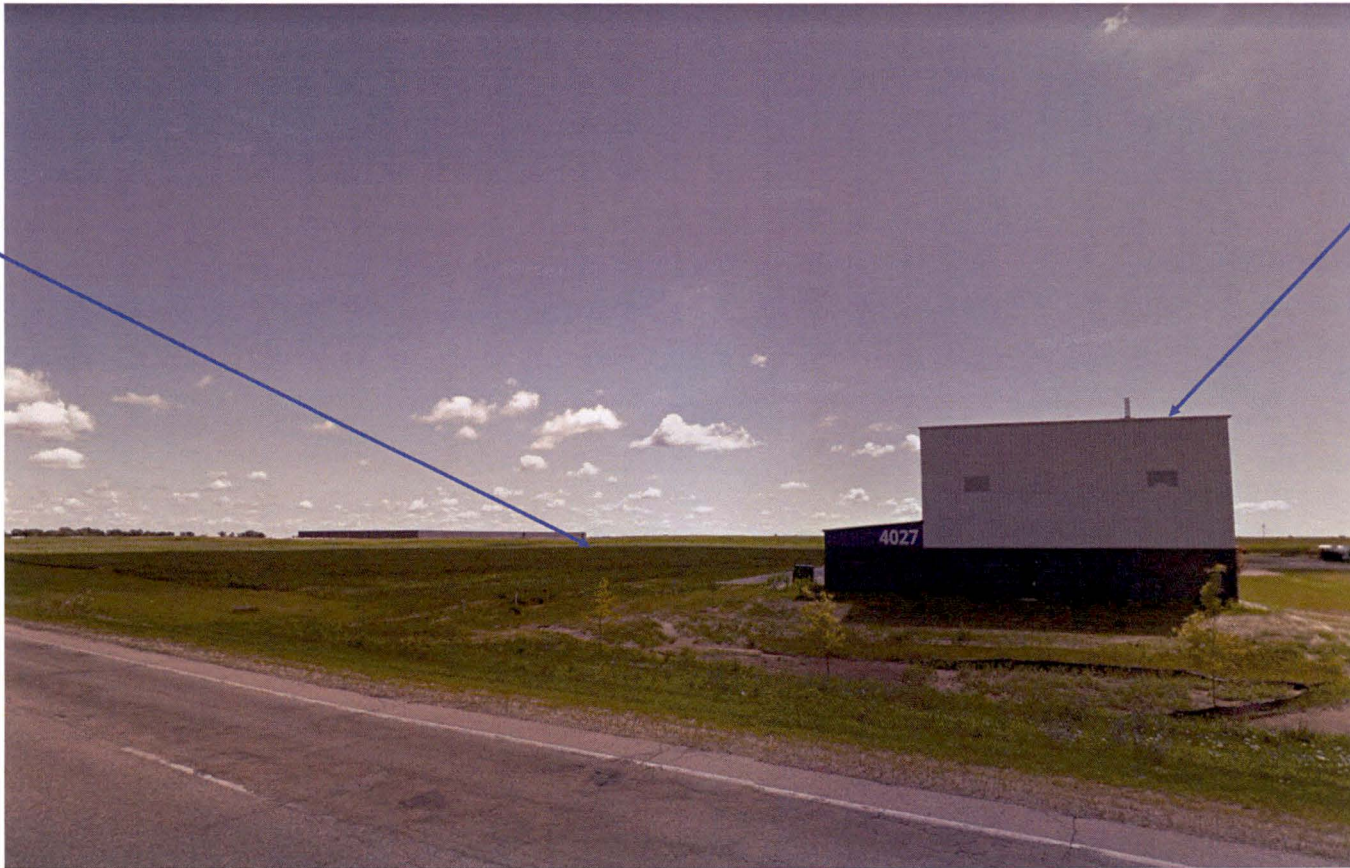
Located in Janesville, Wisconsin





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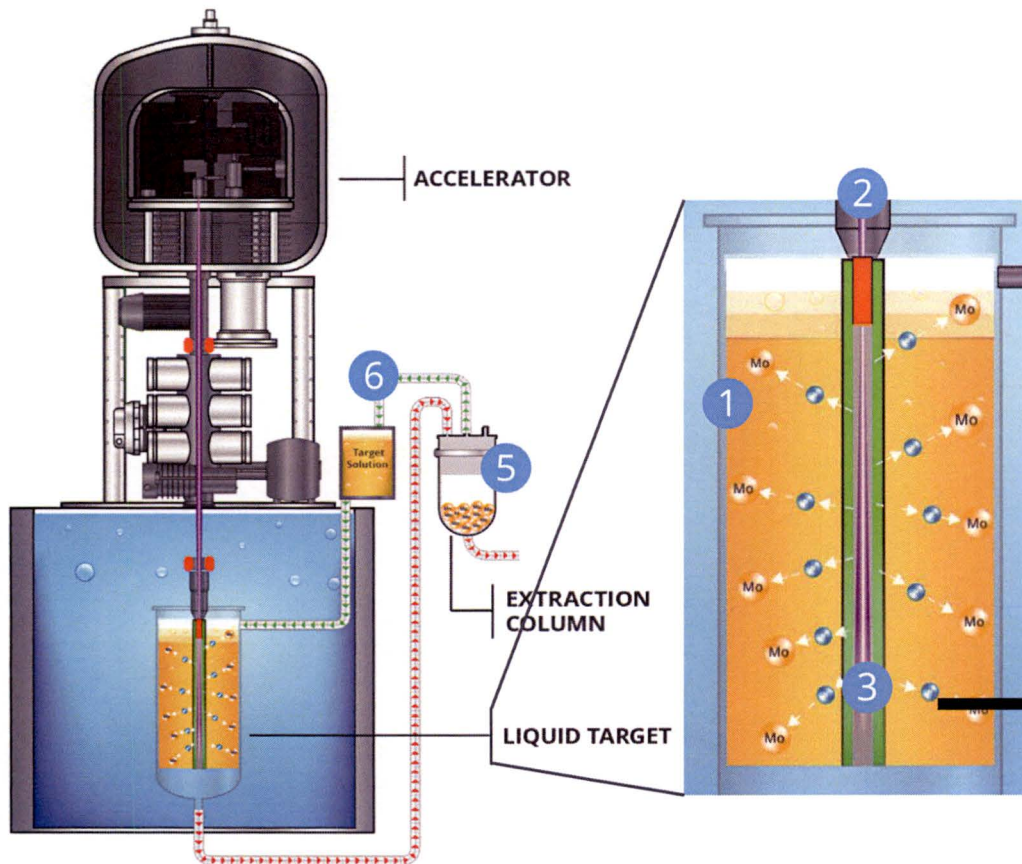
Future SHINE
Production
Facility



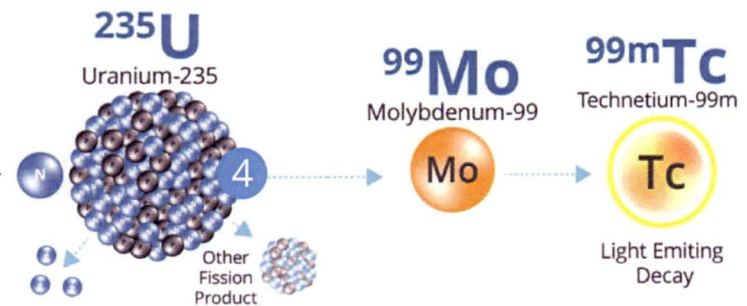
SHINE
Building One



SHINE High Level Overview



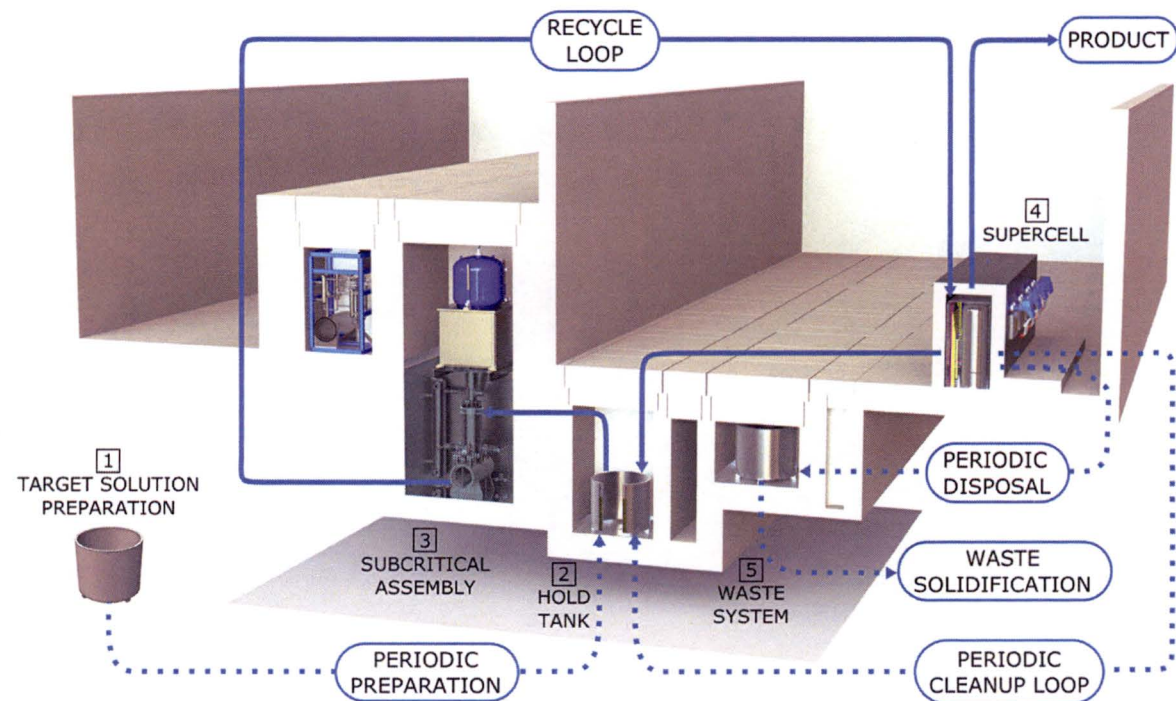
- 1 LEU is dissolved to form the liquid target
- 2 Accelerator fires ion beam into tritium gas target chamber
- 3 Ions from accelerator beam undergo fusion with gas target, freeing neutrons into target solution tank
- 4 Uranium undergoes fission in target solution tank, producing Mo-99 and other isotopes
- 5 Mo-99 is captured from the solution via an extraction column
- 6 The LEU solution is returned to the target solution tank





Process Overview

1. Periodic solution preparation from LEU
2. Solution chemistry check and staging
3. Irradiation for 5.5 days
4. Extraction, purification, QC & packaging
5. Periodic cleanup and solution disposal





Building One

- Construction complete Q1 2018
- Full size accelerator demo currently in-progress
 - Radioactive material license by State of Wisconsin
- Future mockups and prototypes planned
- Future use for employee training and technology development





Top Long-Lead Process Equipment Items

- Supercell
- Neutron Flux Detectors
- Safety I&C System (TRPS/ESFAS)
- Neutron Drivers (Accelerators)
- Thermal Cycle Absorption Process (TCAP) Equipment
- Radioactive Liquid Waste Immobilization System



Technological Approach

- Small systems: Hundreds of times less power than isotope production reactors being used
 - Low source term—helps ensure safety of public and workforce
 - Decay heat per system < 1 kW within 5 hours
 - Minimizes waste nuclide generation compared to reactors
- Low enriched uranium (LEU) reusable target
 - Reduces waste
 - Product compatible with current supply chain
 - Eliminates need for HEU
- Driven by low-energy electrostatic accelerator
 - Eliminates need for HEU
- Multiple units and trains provide operational scalability and flexibility





Safety Philosophy

- Low decay heat, low pressure, low temperature system
 - Minimal stored energy
- Independent units limit common cause failures
- Operator actions are not required for safe response to an accident
- In the event of an upset condition:
 - TSV reactivity protection system (TRPS) initiates trip of system
 - Two completely independent safety-related TSV dump valves open
 - Target solution gravity drains to the TSV dump tank (criticality safe at all uranium concentrations)
 - Hydrogen concentration is maintained below LFL by off-gas system blowers
- Following UPS battery run time, entire plant is passively safe
 - 90 days without cooling: Pool temperature rise is less than approximately 12°F
 - Nitrogen purge system for hydrogen control



Facility Layout – General Arrangement

Security-Related Information



Facility Layout – General Arrangement

Security-Related Information

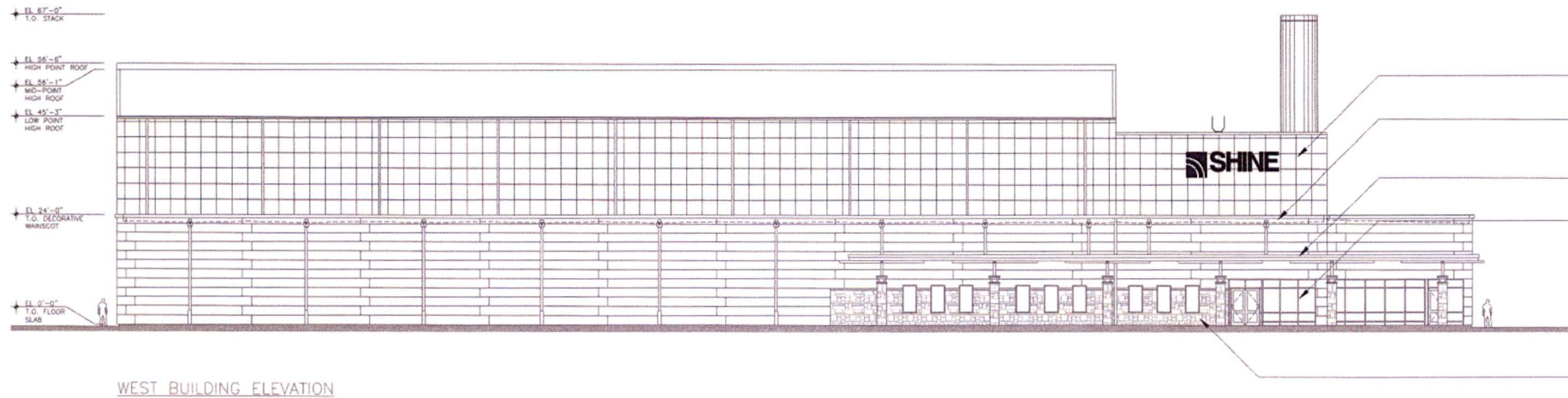


Facility Layout – General Arrangement – Mezzanine

Security-Related Information



Facility Layout – Elevation and Section Views





Facility Layout – Elevation and Section Views

Security-Related Information



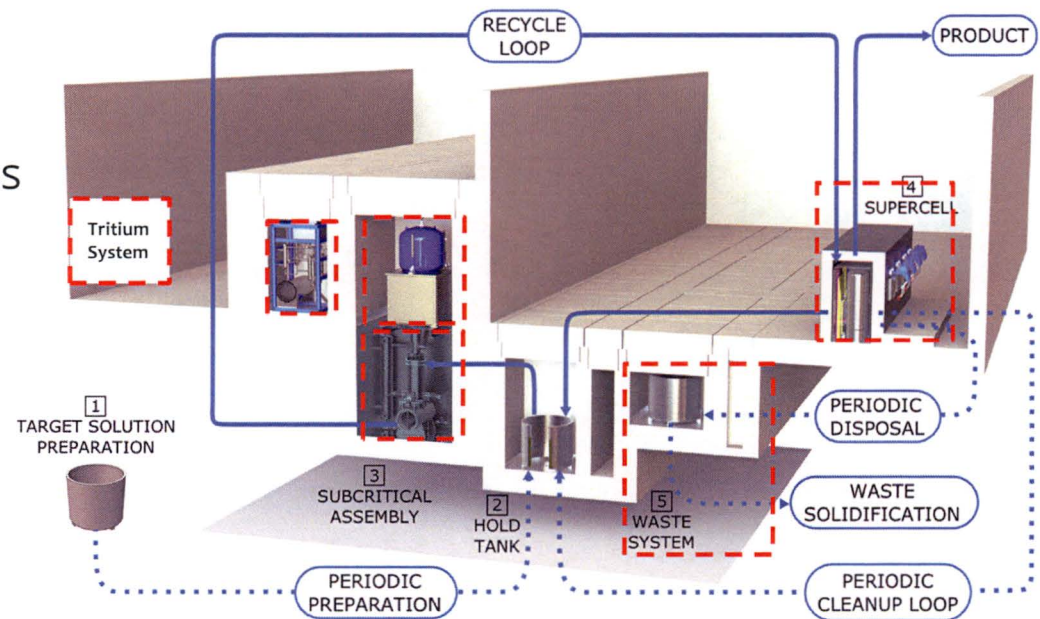
Facility Layout – Elevation and Section Views

Security-Related Information



Major Process Equipment

- Subcritical Assembly and TSV Off-Gas System
- Neutron Driver
- Tritium Purification System
- Extraction and Purification Process
- Supercell
- Radioactive Waste Handling





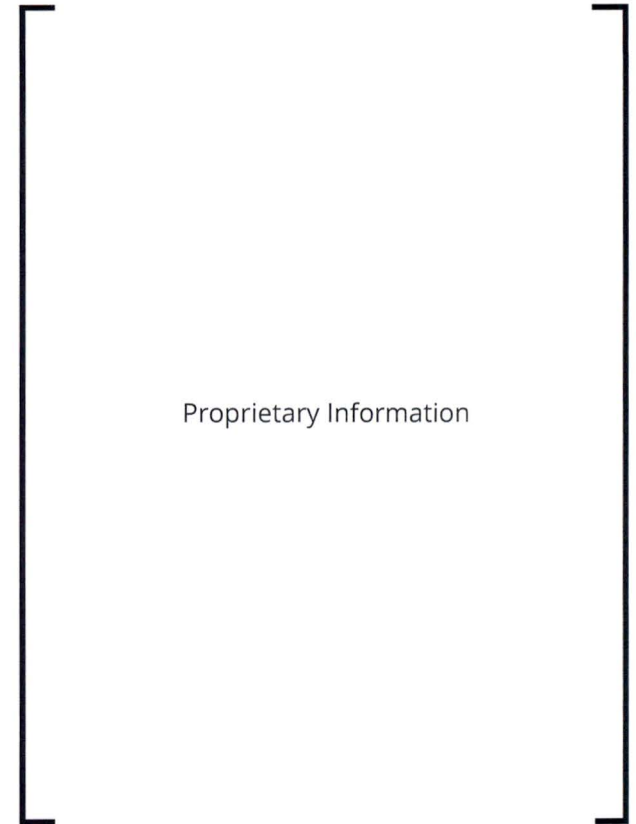
Subcritical Assembly Overview

■ Hybrid fusion-fission device

- Accelerator generates fusion neutrons from D-T reaction
- Subcritical assembly takes fusion neutrons, slows them down, and multiplies them through fission reactions

■ Process

- Fast neutrons created in center of assembly (neutron spark plug)
- Neutrons pass through [Proprietary Information] multiplier
- Multiplied neutrons pass into uranium solution in TSV, where they are absorbed by uranium and cause fission
- Transfer solution to the processing facility for isotope removal



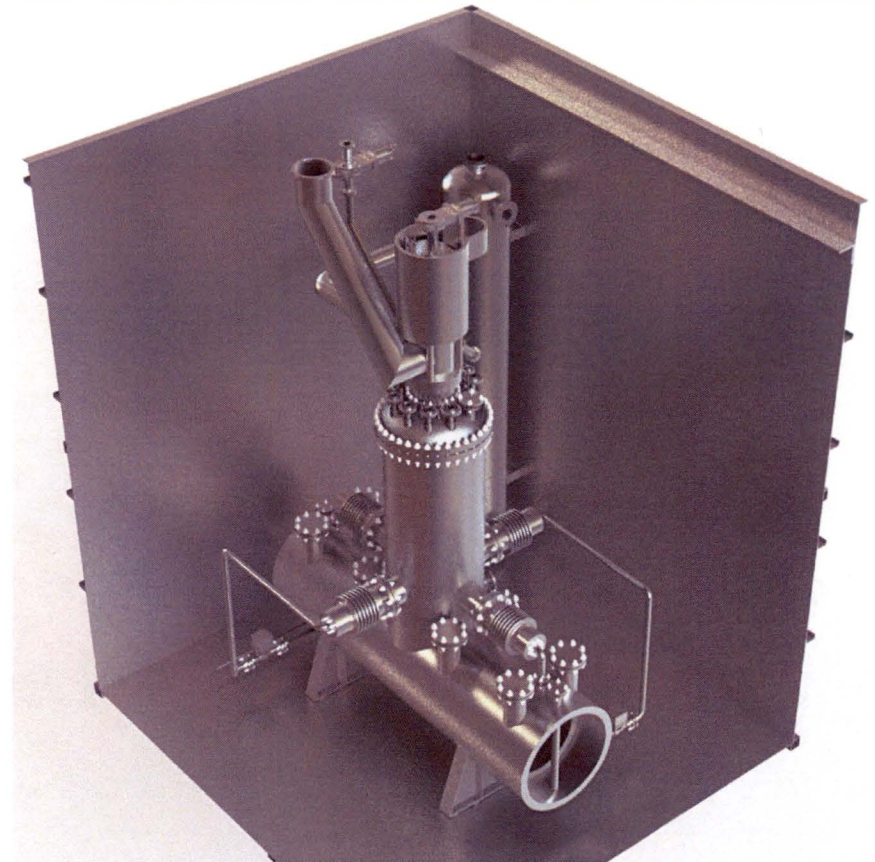
Subcritical Assembly with Accelerator Target Assembly



Low energy, inherently-safe system

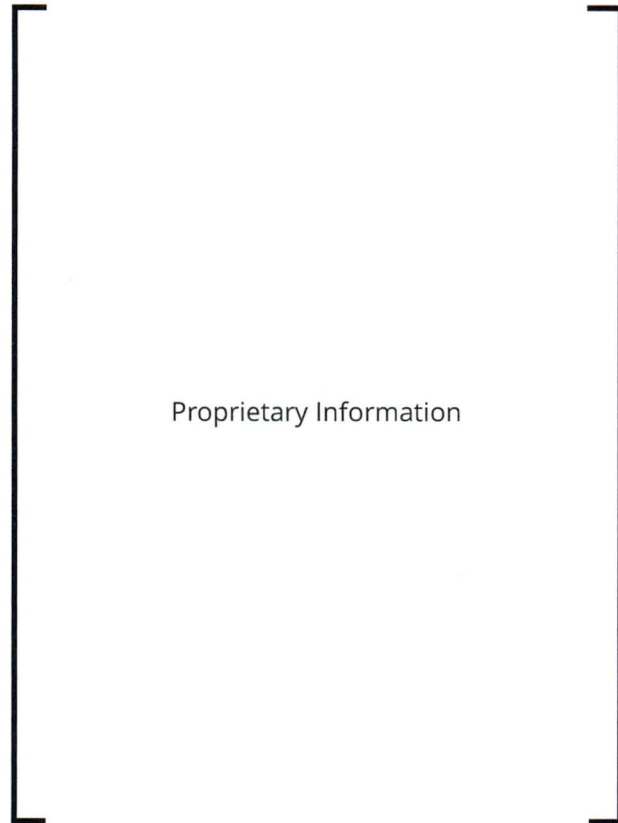
■ Key parameters:

- Pressure: Below atmospheric
- Target solution: Uranyl sulfate
- Low temperature: $< 212^{\circ}\text{F}$
- Low fluid flow rates: Natural circulation of target solution
- Reactivity: Subcritical





Subcritical Assembly – Design Summary



Subcritical Assembly with Accelerator Target Assembly

- Skid-fabricated components
- Safety-related to retain target solution in proper geometry
- Target solution pressure boundary principally constructed of Type 347 stainless steel
- Designed for 100 psig



TSV Offgas System (TOGS)

- The TOGS sweeps gas through the TSV headspace
- Operates during irradiation to remove and recombine hydrogen and oxygen
- Sweep gas passed over catalytic recombiner beds to form water vapor
- Water vapor generated by the TSV and the recombiner beds is condensed and returned to the TSV

Proprietary Information



TSV Offgas System (TOGS)

- TOGS general parameters
 - Sweep gas flowrate: [Proprietary Information]
 - Design nominal hydrogen concentration: [Proprietary Information]
 - Liquid return rate: [Proprietary Information]
 - Recombiner materials: [Proprietary Information]
- Safety-related functions to ensure hydrogen concentrations remain acceptable
- Operates on UPSS power for minutes following loss of offsite power to recombine decay hydrogen

Proprietary Information

TOGS Skid



Neutron Driver

- Neutron driver is hydrogen particle accelerator
- Supplied by Phoenix
- 300 kV constant voltage (static)
 - Accelerates hydrogen isotopes to a gas target chamber
- Deuterium-deuterium reaction produces ~1% output
- Deuterium-tritium reaction produces ~100% output
- Neutron source to drive the subcritical chain reactions
- Operation is not safety function
- Turning off accelerator is a safety function
 - Safety-related breakers isolate power feed to accelerator high voltage power supply

Proprietary Information



Tritium Purification System (TPS) Overview

- Function: Continuously supply purified tritium (target gas) and deuterium (source gas) to neutron drivers
- Uses Thermal Cycling Absorption Process (TCAP) technology
 - IP Licensed from Savannah River National Laboratory
- Key features
 - Semi-continuous operational mode (batched gas chromatography)
 - 1 TPS serves up to 8 drivers
 - Tritium maintained sub-atmospheric outside of glovebox

Security-Related Information



Major TPS Equipment and Functions

- TPS process equipment and main glovebox
 - Remove impurities
 - Separate tritium and deuterium
 - Confine tritium
 - Process equipment normally contains tritium
 - Glovebox confines in the event of a release
- ATIS skids and gloveboxes
 - Distribute gases via headers
 - Interface with neutron drivers and regulate flow to a neutron driver
 - Confine tritium
- Stripper system & air hood
 - Remove residual tritium that enters glovebox atmosphere

Proprietary Information



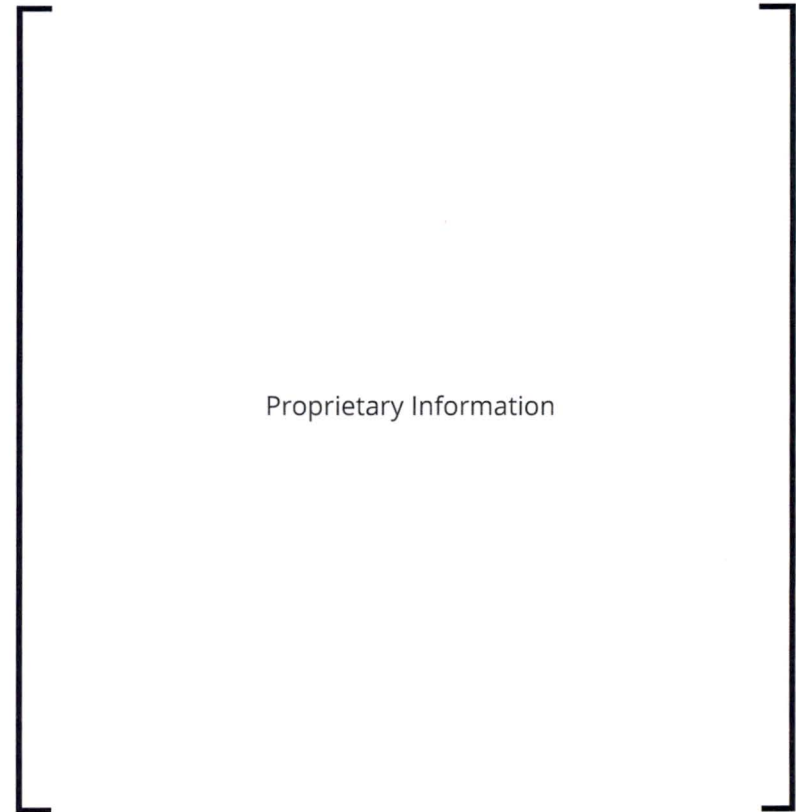
TPS Flow Diagram (Production Facility)

Proprietary Information
Security-Related Information



Overview of Mo-99 Separation Process

- Target solution transferred from IU cell to hot cells via vacuum lift system
- Mo-99 separated from target solution by extraction column
- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- Mo-99 solution evaporated and transferred to purification process



Mo-99 Extraction Equipment



Overview of Mo-99 Purification Process

- Purification via the Low Enriched Uranium (LEU) Modified Cintichem Process
 - Developed by Argonne National Laboratory for the Department of Energy
- Cintichem is a long-established process
 - Used at the Cintichem facility in Tuxedo, NY until 1989
- Process performed by manipulators in hot cell
 - Precipitation and filtration of contaminants
 - Complexation of molybdenum
 - Adsorption and filtration of contaminants on charcoal columns





Supercell

Proprietary Information

Proprietary Information

- Redundancy is included to handle the 8 irradiation cells and provide flexibility in operations



Supercell Design

- Safety function to confine radioisotopes upon release
 - Confinement limits release to stack and to Radioisotope Production Facility (RPF) area
- Provides biological shielding for workers
- Criticality safety controls incorporated

Proprietary Information



Waste Treatment

■ Waste Stream Overview

- Three types of radioactive waste:
 - As generated solid radioactive waste, including spent adsorption columns
 - Solidified radioactive waste
 - Gaseous wastes
- Liquid waste is collected in tanks with and without critically-safe geometry, depending on liquid waste stream
 - Size and configuration of liquid waste tanks provide for operational flexibility and reduction in waste source term
 - Liquid waste streams are analyzed and blended to allow for solidification in cement and acceptance at a licensed burial facility
 - Waste streams are solidified in a sealed solidification skid maintained at a slight negative pressure compared to the surrounding Radioisotope Production Facility



Solid Wastes Exported to Storage Drums

Proprietary Information



Radioactive Liquid Waste Storage System

Security-Related Information



Radioactive Liquid Waste Immobilization System

- Receives liquid wastes from the plant and solidifies them in a cement-based mixture
- Drums are cured and transported to on-site staging building, prior to offsite shipment
- Waste system is skid-mounted and assembled

Proprietary Information



Gaseous Waste Treatment

Proprietary Information