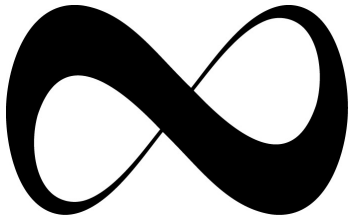
Design Overview of the MSR-1

Brazos Fitch

TRTR Conference

October 1st, 2024



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OAK RIDGE National Laboratory

NEXT

1954-1969
MSR HISTORY

- (Nov 1954) Aircraft Reactor Experiment (ARE) at Oak Ridge National Laboratory (ORNL) is the first reactor to demonstrate the feasibility of molten-salt fuel.
- (1964) Molten Salt Reactor Experiment (MSRE) is constructed at ORNL.
- (June 1965) MSRE goes critical utilizing uranium-235.
- (Oct. 1968) MSRE goes critical utilizing uranium-233.

2016 - 2019
EARLY ENGAGEMENT

- (2016) Nuclear Energy eXperimental Testing (NEXT) Lab established at Abilene Christian University (ACU).
- (2017) **Douglass Robison** commits **$3.2M** gift to the NEXT Lab to support molten salt research.
- (Dec. 2018) **Secretary of Energy, Rick Perry,** sends representatives from the **Department of Energy (DOE) Office of Nuclear Energy (NE)** to visit NEXT Lab at ACU.
- (Jan. 2019) Robison and ACU representatives visit the DOE in **Washington D.C.**
- (Nov. 2019) **DOE** encourages the development of a **Molten Salt Research Reactor (MSRR)** at ACU and provides **Programmatic Letter of Support.**

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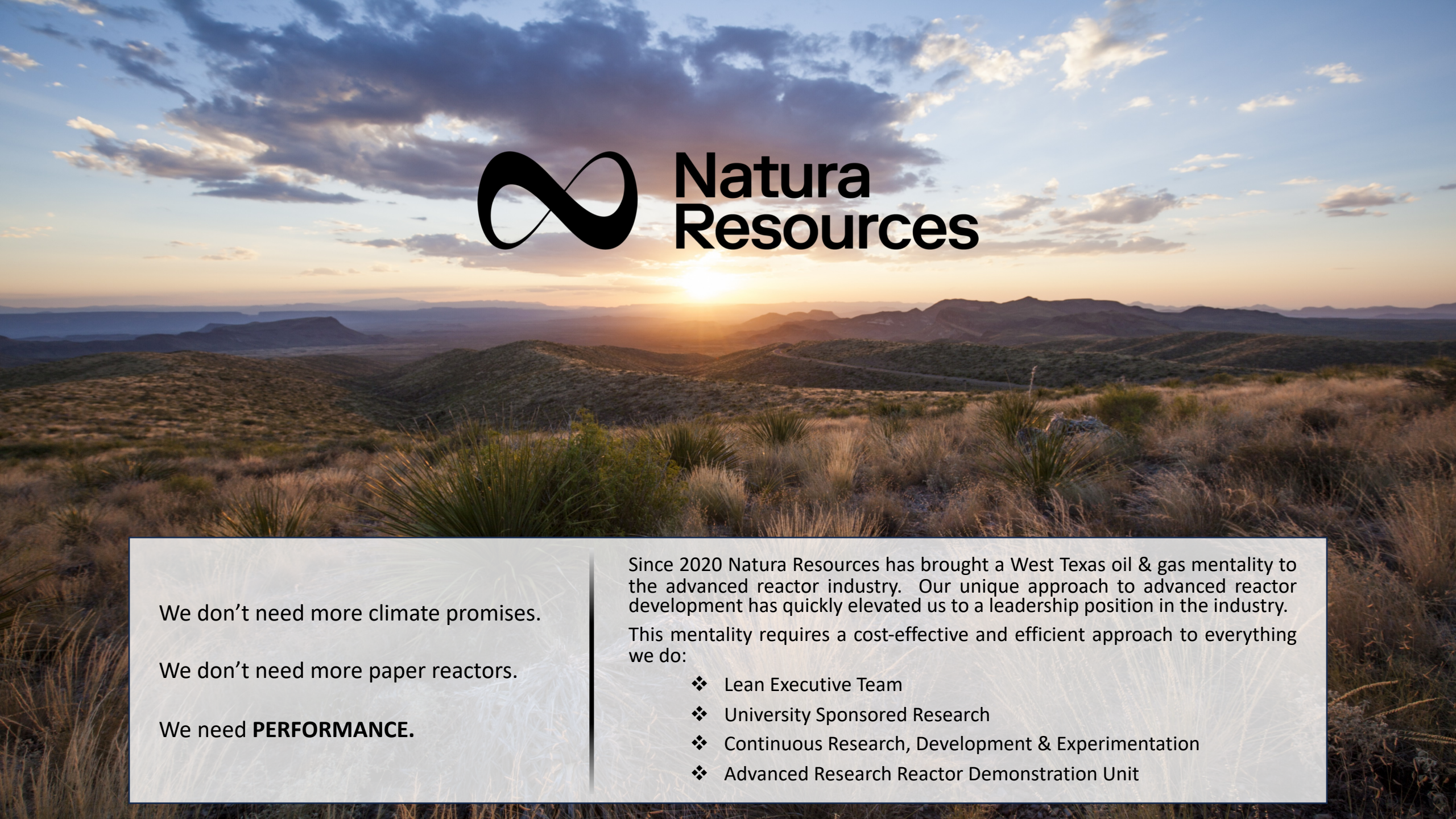

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We don’t need more climate promises.

We don’t need more paper reactors.

We need **PERFORMANCE.**

Since 2020 Natura Resources has brought a West Texas oil & gas mentality to the advanced reactor industry. Our unique approach to advanced reactor development has quickly elevated us to a leadership position in the industry.

This mentality requires a cost-effective and efficient approach to everything we do:

- Lean Executive Team
- University Sponsored Research
- Continuous Research, Development & Experimentation
- Advanced Research Reactor Demonstration Unit

Natura Resources Research Alliance

Demonstration Reactor Facility

Science & Engineering Research Center (SERC)

The MSRR will be deployed in a multi-use research facility on the campus of Abilene Christian University (ACU). Groundbreaking took place in March 2022 and the facility was completed in August 2023.

The **SERC**, completed in August 2023, is the only current advanced reactor demonstration facility in the U.S.

March 2022

August 2022

September 2022

August 2023

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ABILENE CHRISTIAN UNIVERSITY

Natura Resources MSR-1 at ACU Receives Historic NRC Construction Permit

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LF-MSR Technology

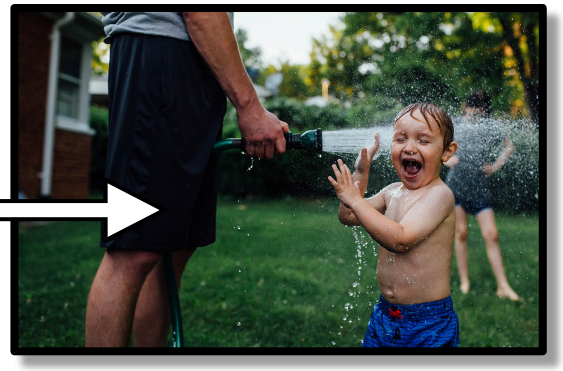
Natura Resources LF-MSRs have two specific characteristics that **raise efficiency, increase safety,** enable various **commercial applications** and provide **access to a wide range of radioisotopes**, while at the same time **decrease waste**.

MOLTEN SALT COOLANT

Molten Salt Reactor (MSR)

High Temperature – Low Pressure

- Salt Thermal Properties
  - Melting Point: ~450°C
  - Operating Temp: ~650°C
  - Boiling Point: ~1430°C
- Operating Pressure: 15-20 psi



By comparison…

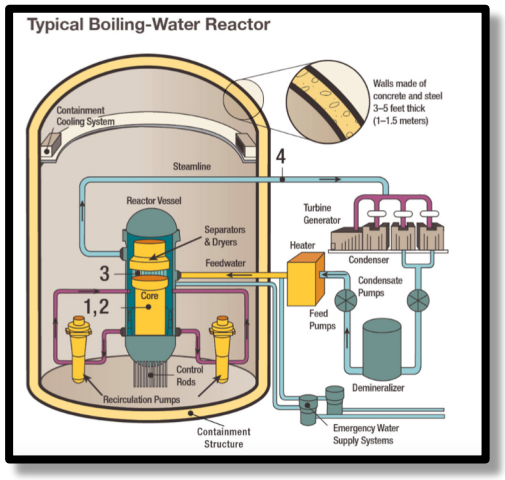
- *Light Water Reactor (LWR)*
  - *300°C water @ 2,250 psi*

High Temperature

- Convert thermal energy to electricity with almost **40% increased efficiency**
- Meet the thermal energy needs of industries requiring **high process heat** (refining, chemical production, etc.)

Low Pressure

- **Increased safety** → no risk of radioactive vapor release
- **Decreased cost** → reduced quantities of concrete and steel for high-pressure containment.

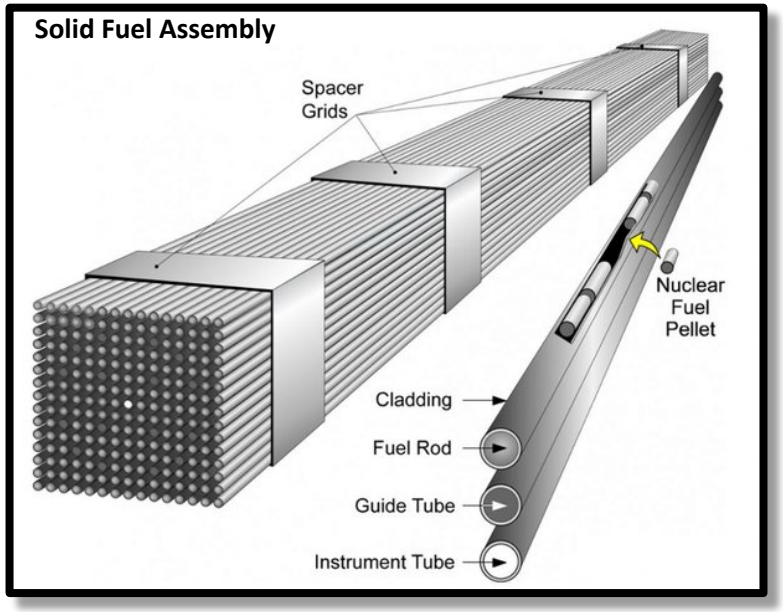


LIQUID FUEL

UF4 fuel dissolved in the molten salt coolant provides two primary benefits:

1) Enhanced Fuel Utilization

- Greater burnup of fuel means there is significantly **reduced nuclear waste**



2) Radioisotope Access

- Isotopes produced in the fission process have applications ranging from **medical treatments to nuclear batteries** and can be extracted and utilized.

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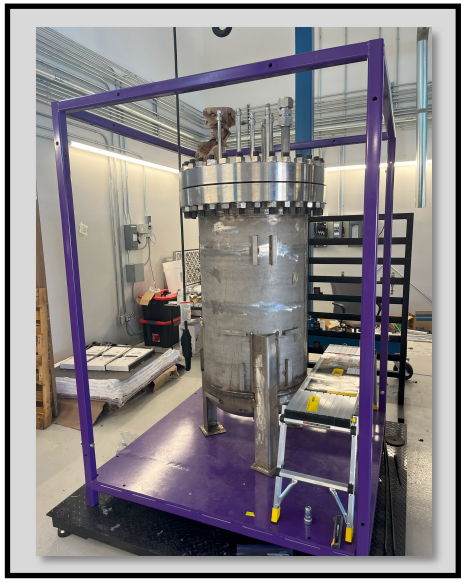
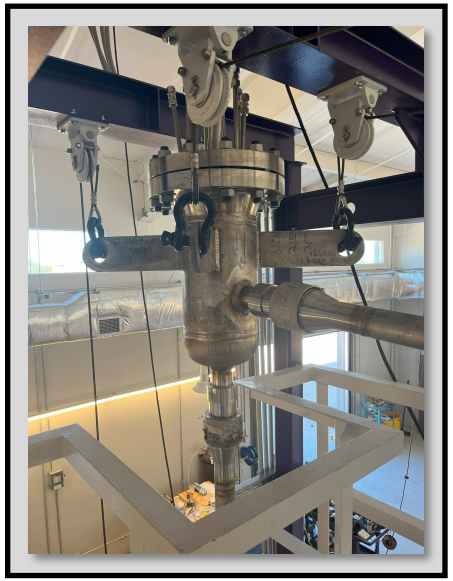
Natura Resources R&D: Molten Salt Test System (MSTS)

PUMP



PURIFICATION SYSTEM



EXPERIMENTAL TANK

DRAIN TANK

• 50 Gallons	• Salt Purification System	• Experimental Tank
• FLiNak Salt	• Drain tank, configuration, and gas system similar to MSRR to further validate operations	• Operational demonstration of patented technologies
• 700°C		

Demonstration Reactor (2026)

Molten Salt Research Reactor (MSRR)

Design	Thermal Output:	1 MW_{th}
	Electric Output:	n/a
	Fuel:	HALEU (enriched to 19.5%) as UF4 dissolved in LiF-BeF_2-UF_4 (FLiBe)
	Moderator:	Graphite
	Coolant Salt:	FLiBe
	Const. Material:	Type 316H SS
	Deployment:	2026
	Features:	• Passive shut down & cooling • Off-site, modular construction
	Commercial Benefits:	• Demonstrates licensure with NRC • Produces data to verify models & codes
License	• August 2022 – CP Submitted • November 2022 – CP Docketed for Review • Sept 2024 – CP Approval • Q3 2025 – Expected OL Submission • Q3 2026 – Expected OL Approval	
Site	Science and Engineering Research Center (SERC) at Abilene Christian University (ACU) • March 2022 – Groundbreaking • August 2023 – Completed (17 months)	
Engineering & Design	• October 2022 – Conceptual Design Complete • Q2 2025 – Expected Detailed Engineering & Design Completion	

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Demonstration Reactor Facility

Science & Engineering Research Center (SERC)

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Demonstration Reactor Facility

Research Bay

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MSR-1: Fuel Handling System

- When the fuel salt is received, it is inserted into the FHS. The fuel salt will be sparged with HF, H2 and He gases to remove impurities.
- Once the salt is confirmed to be the desired composition and purity, it is transferred into the reactor system. The salt travels through heated transfer lines to the drain tank.
- The FHS is capable of handling used salts.
- The Fuel salt purification vessel will be constructed from UNS N02201 (NI-201, low carbon nickel).
- FHS is contained within an enclosure to mitigate the release of radionuclides.

NOT the Fuel Handling System!
This is the Salt Purification System for the Molten Salt Test System

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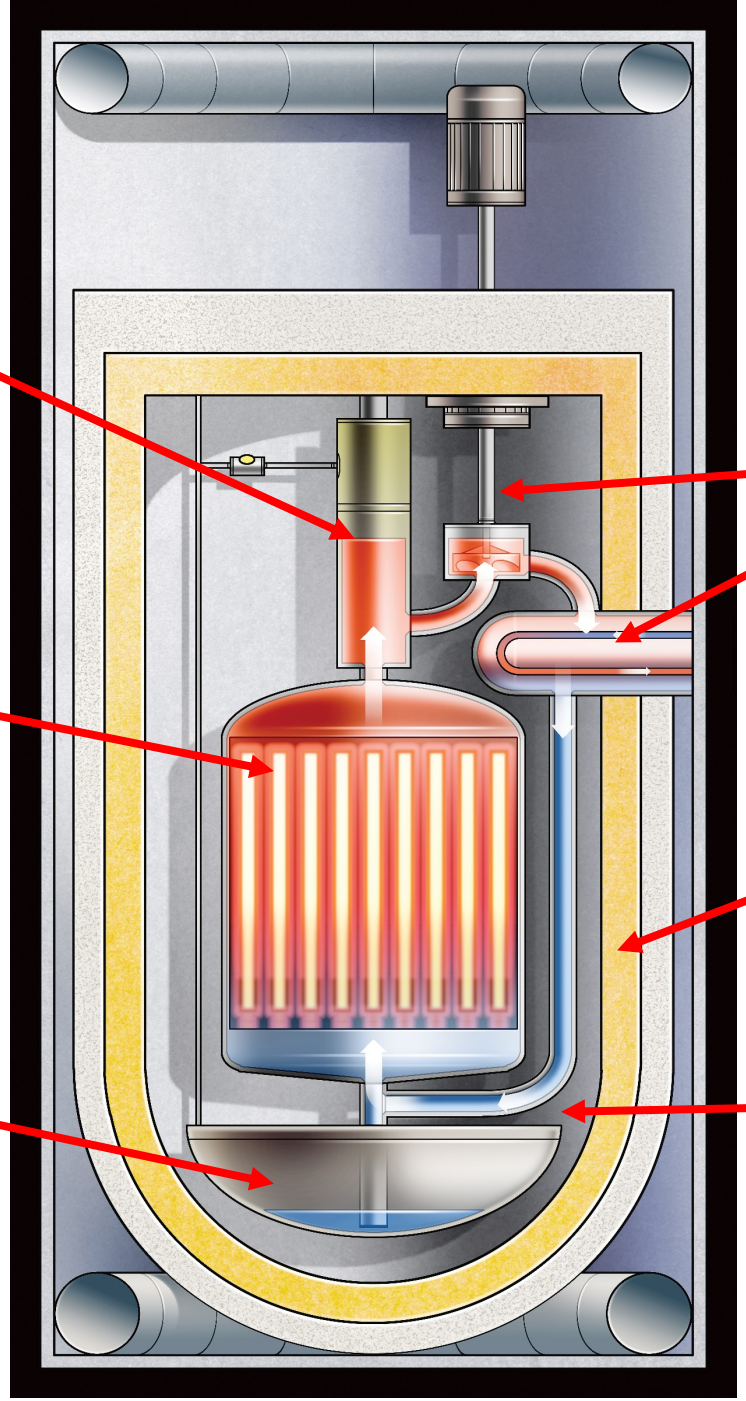
MSR-1: Reactor Loop



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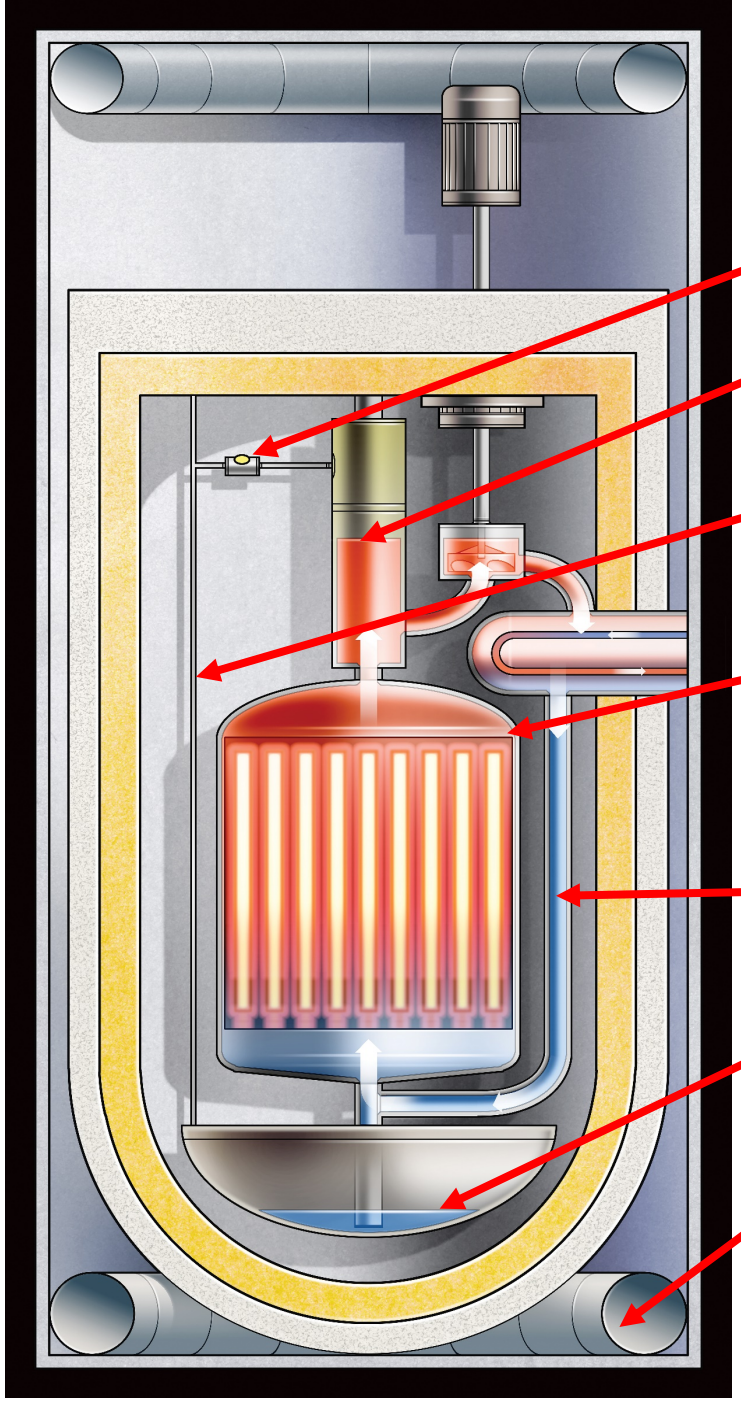
MSR-1: Reactor System

Drain Tank

- The drain tank can hold all of the fuel salt from the reactor system when not in operation.
- The MSRR fuel salt has a short and unobstructed path from the reactor vessel to the drain tank, allowing the fuel salt to be completely drained passively in approximately one minute.
- Draining of the reactor system is controlled by equalizing the pressure within the RAV and the drain tank.
- Safety analyses are based on achieving reactor shutdown by draining the fuel salt from the reactor vessel to the drain tank.
- Decay heat can be removed passively from the drain tank indefinitely without exceeding the safety limit temperature for the stainless steel material.



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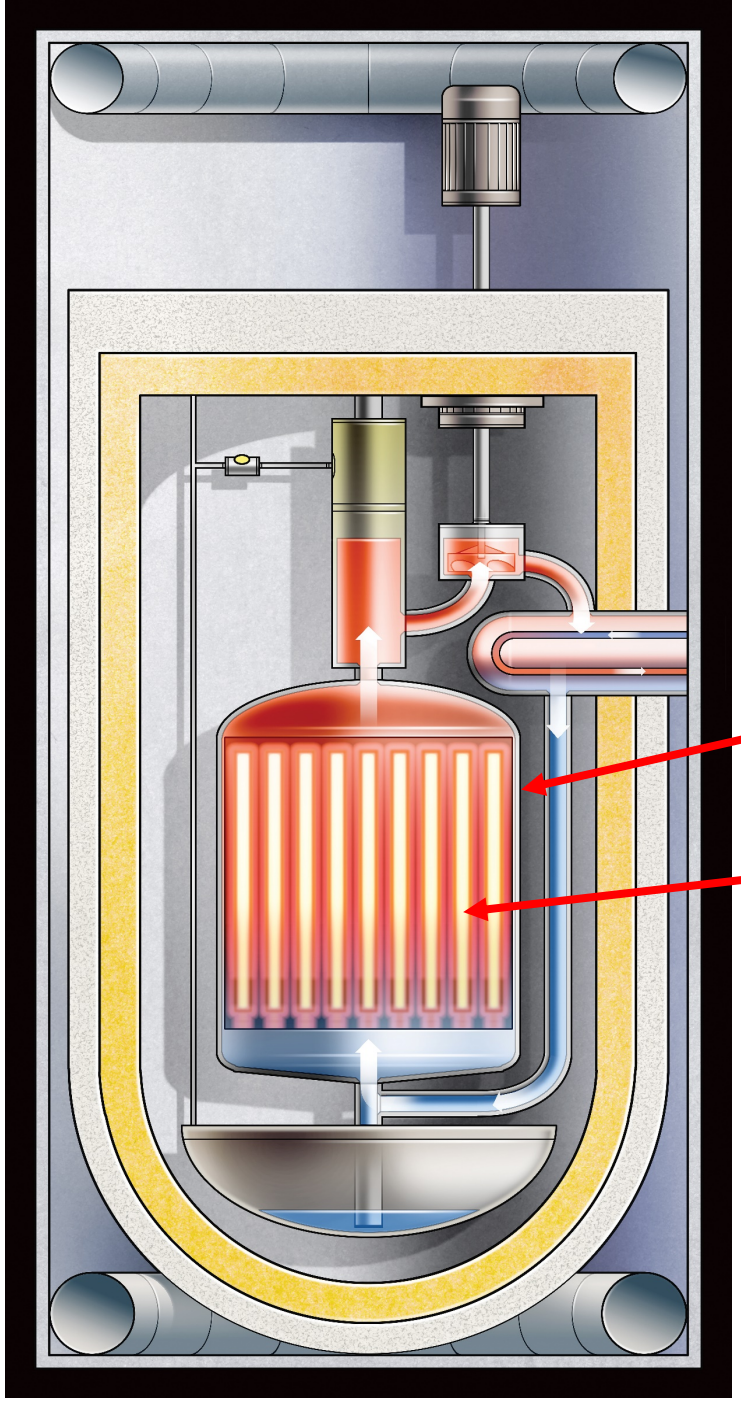
MSR-1: Reactor System

Reactor Vessel

- The reactor vessel is approximately 52 inches in diameter and 70 inches tall.
- Constructed out of Type 316H to the requirements of ASME BPVC Section 3 Division 5.
- The reactor vessel is the only location where criticality can be reached and sustained in the MSRR.
- The reactor vessel surrounds and supports the cylindrical graphite core.
- Control rods provide reactivity control during normal operations.
- Safety analyses are based on achieving reactor shutdown by draining the fuel salt from the reactor vessel to the drain tank.



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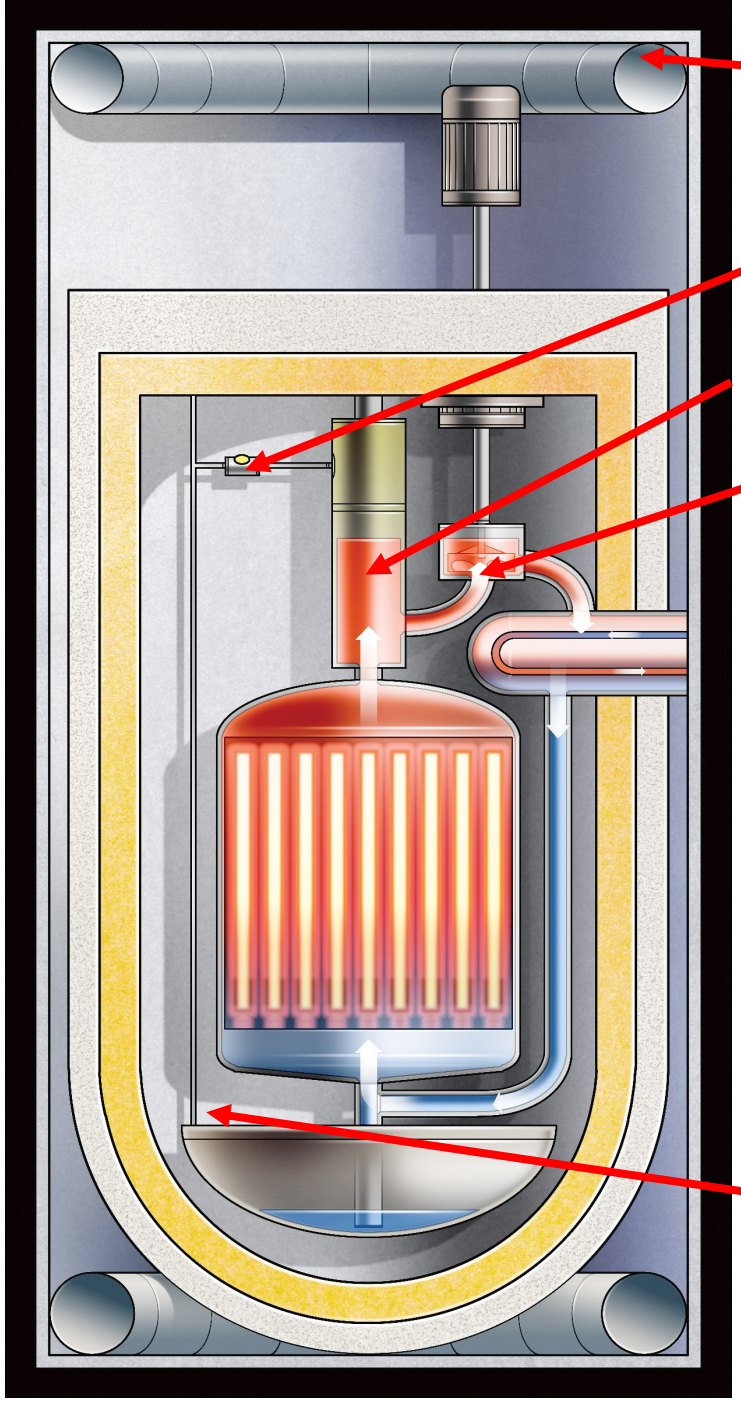
MSR-1: Reactor System

Reactor Access Vessel

- The RAV is situated directly above the core to accommodate expansion or contraction within the loop.
- The MSRR is refueled by adding additional UF4 directly to the fuel salt through the RAV.
- Coupons will be located in the bypass line from the pump discharge to the RAV.
- Redox potential may be measured directly with probes mounted from the top of the RAV.
- Helium can be actively bubbled into the fuel salt through the RAV to remove xenon and krypton as an experiment.
- Fuel salt and the gas headspace will be sampled for analysis from the RAV.



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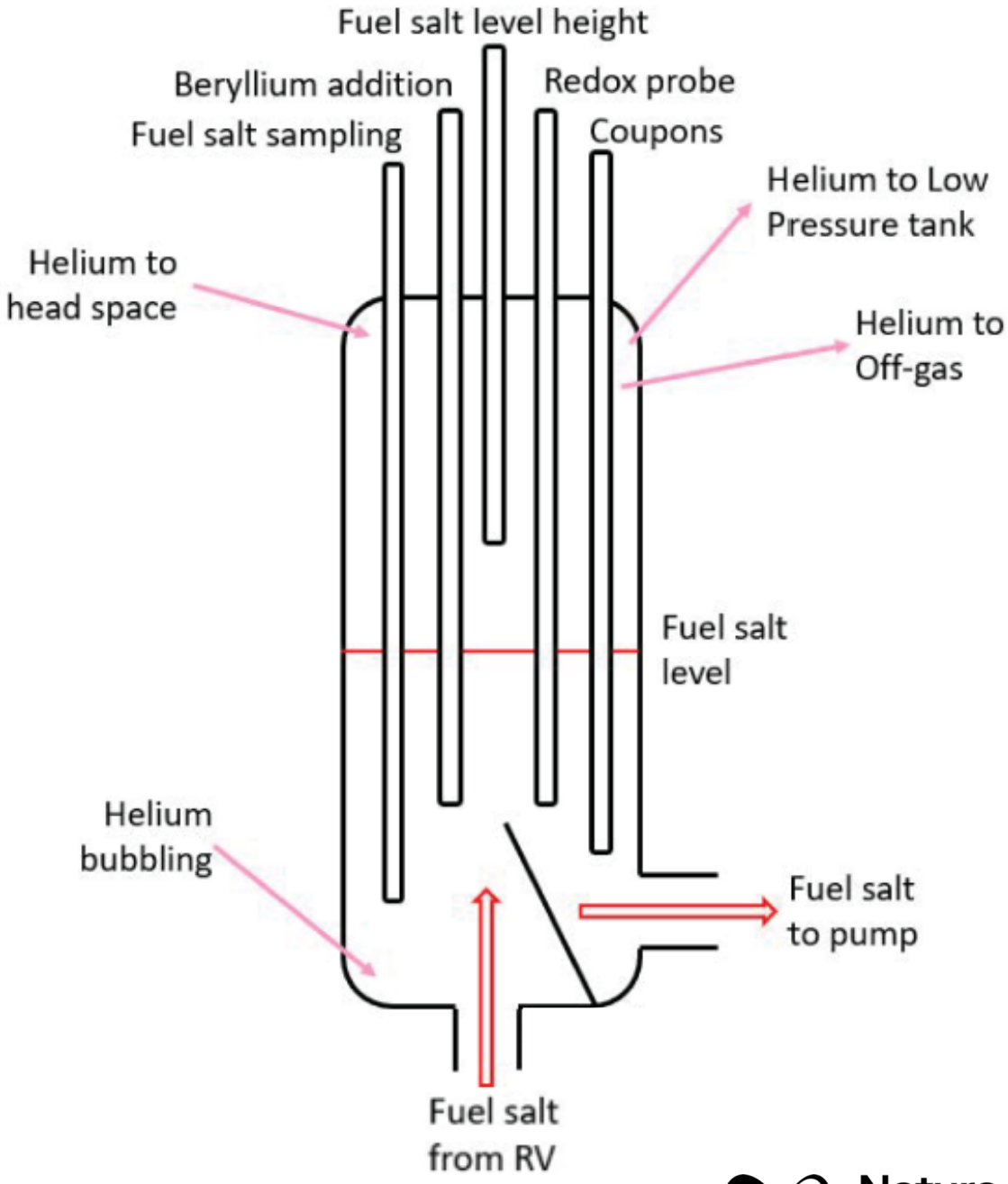

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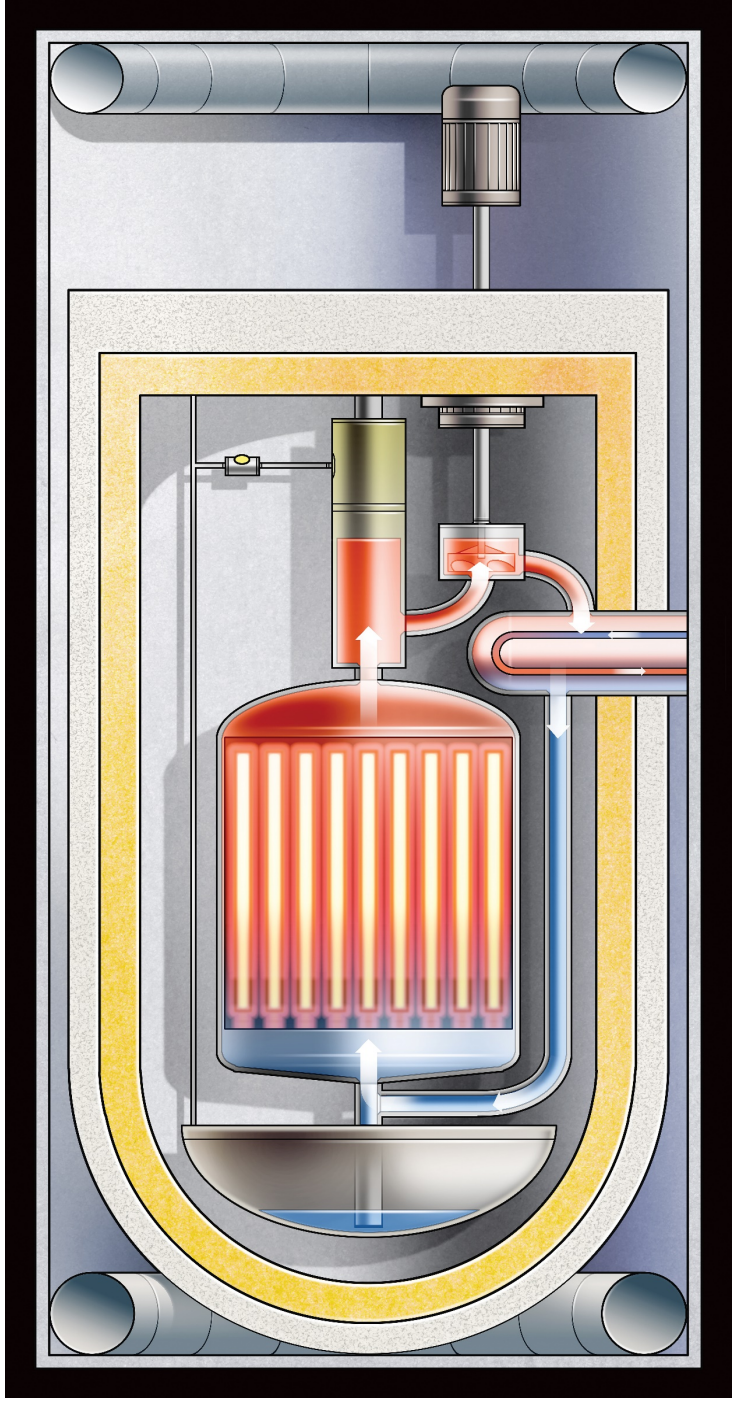
MSR-1: Off-Gas Cleanup

- The MSRR is equipped with an off-gas system that can relocate fission gases from the reactor headspaces through stainless steel circuit components for sequestration and decay.
- The off-gas system cleans helium contaminated with fission gases for reuse or release.
- Without an off-gas system in operation, gaseous fission products and their daughters build up in the reactor headspace.
- The off-gas system cleans the radioactive gases from the reactor GMS using a holdup container and two charcoal beds. Two air-cooled charcoal beds hold up the fission gasses until they either decay away or decay into solids, which remain in the charcoal.
- Off-gas content and performance is monitored by samples taken at designated locations
- The off-gas system will be fully enclosed within the off-gas cleanup enclosure, which is safety related.



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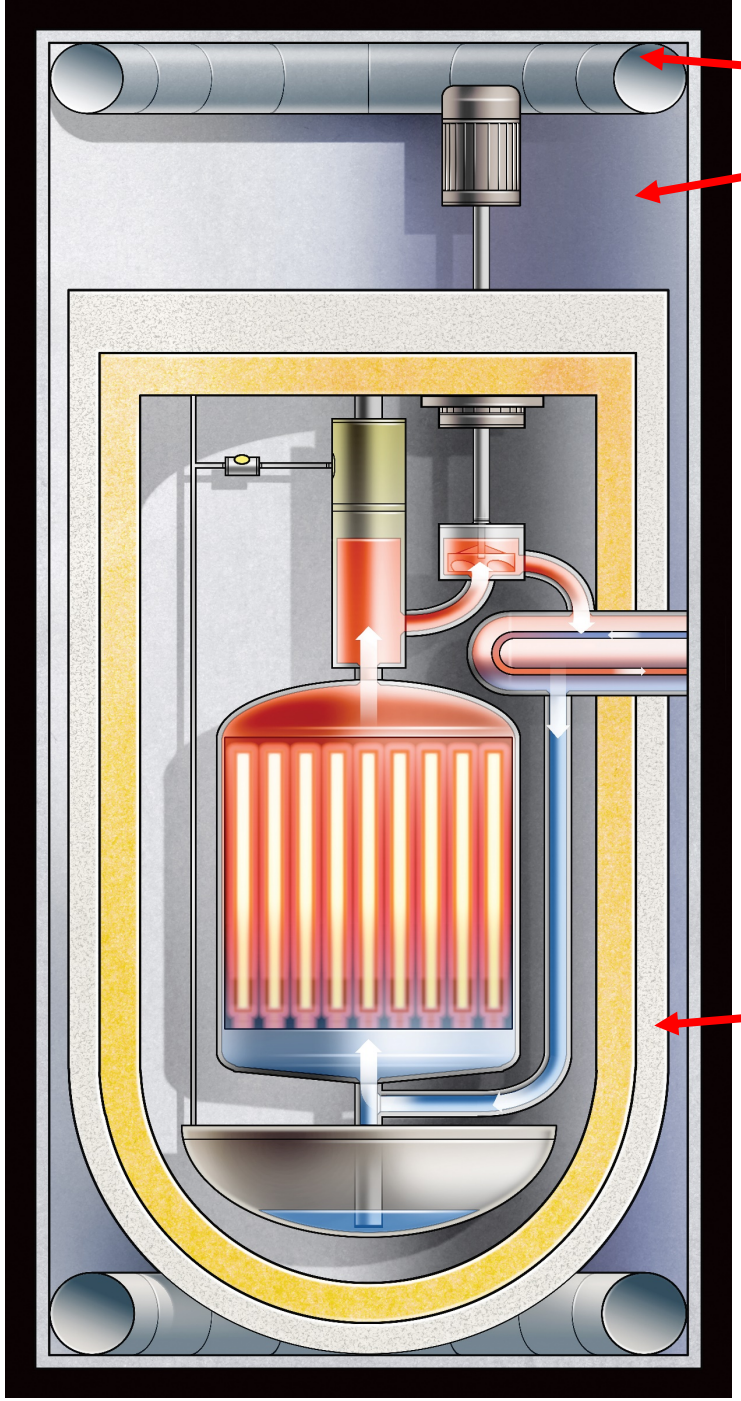
MSR-1: Reactor System

Reactor Enclosure

- The entire reactor system is mechanically supported inside a 316H steel reactor enclosure designed to isolate all potential radiological releases from the reactor loop.
- The reactor enclosure is a leak-tight fission product barrier that operates under slightly negative pressure under normal and accident conditions.
- Reactor enclosure gas will be monitored for radionuclides and periodically sampled.
- The exterior surface of the reactor enclosure is cooled during operation.
- The reactor enclosure lid has additional hatches for equipment and personnel that are sealed during operation but can be opened for maintenance.



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Historic NRC Construction Permit Approval

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