Molten Salt Reactor Development

2017 Molten Salt Reactor Workshop
Oak Ridge Tennessee

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Why Nuclear?

- ***Energy density***
- Low-carbon electricity
- National energy security
- Diverse energy portfolio

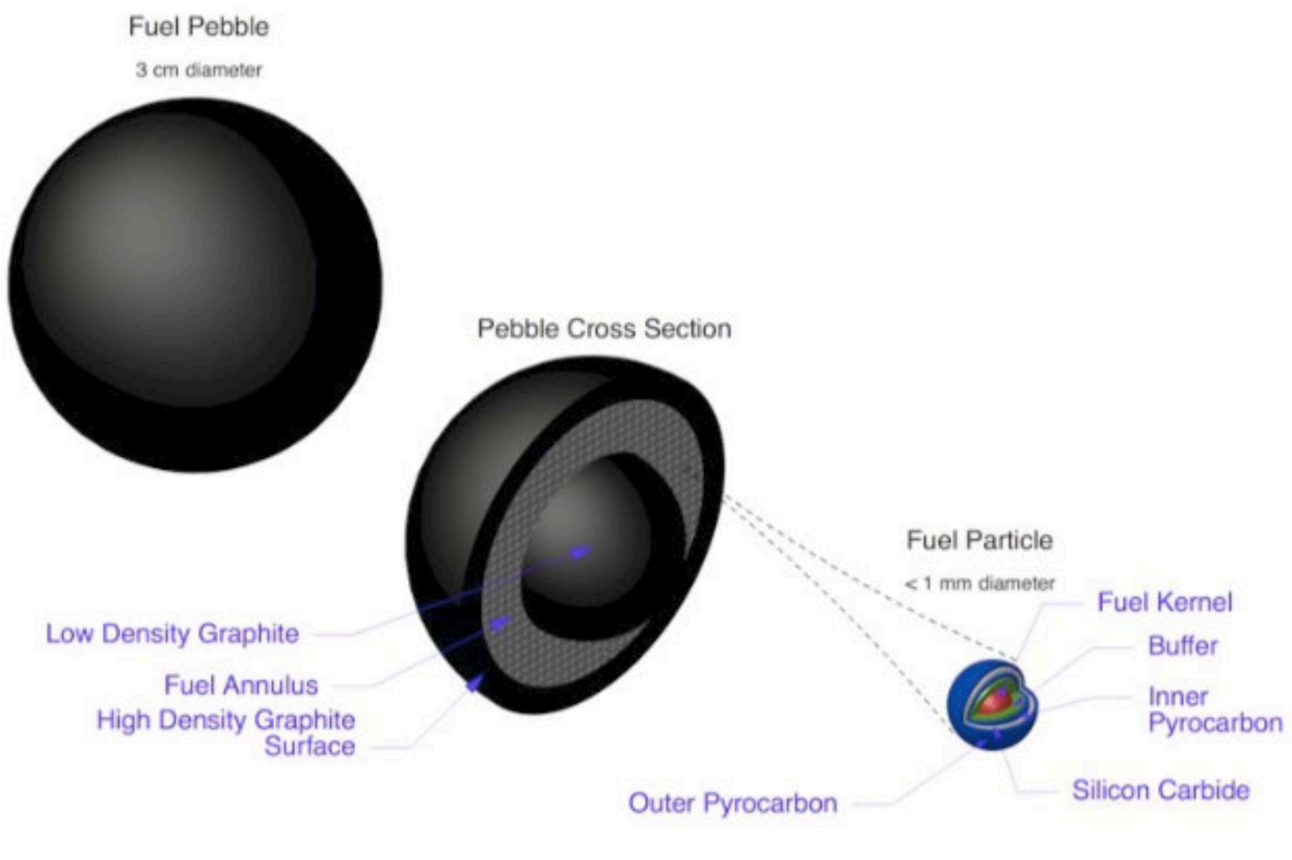


Figure 2-1. A PB-FHR pebble fuel element (Credit: D. Holcomb, ORNL).

- PB-FHR fuel pebbles
  - **Four** 3.0-cm diameter **pebbles** can provide electricity **for a year for an average U.S. household**
  - **8.1 tons** of anthracite coal, or **17 tons** of lignite coal are needed to produce the same amount of electricity using a coal power plant.

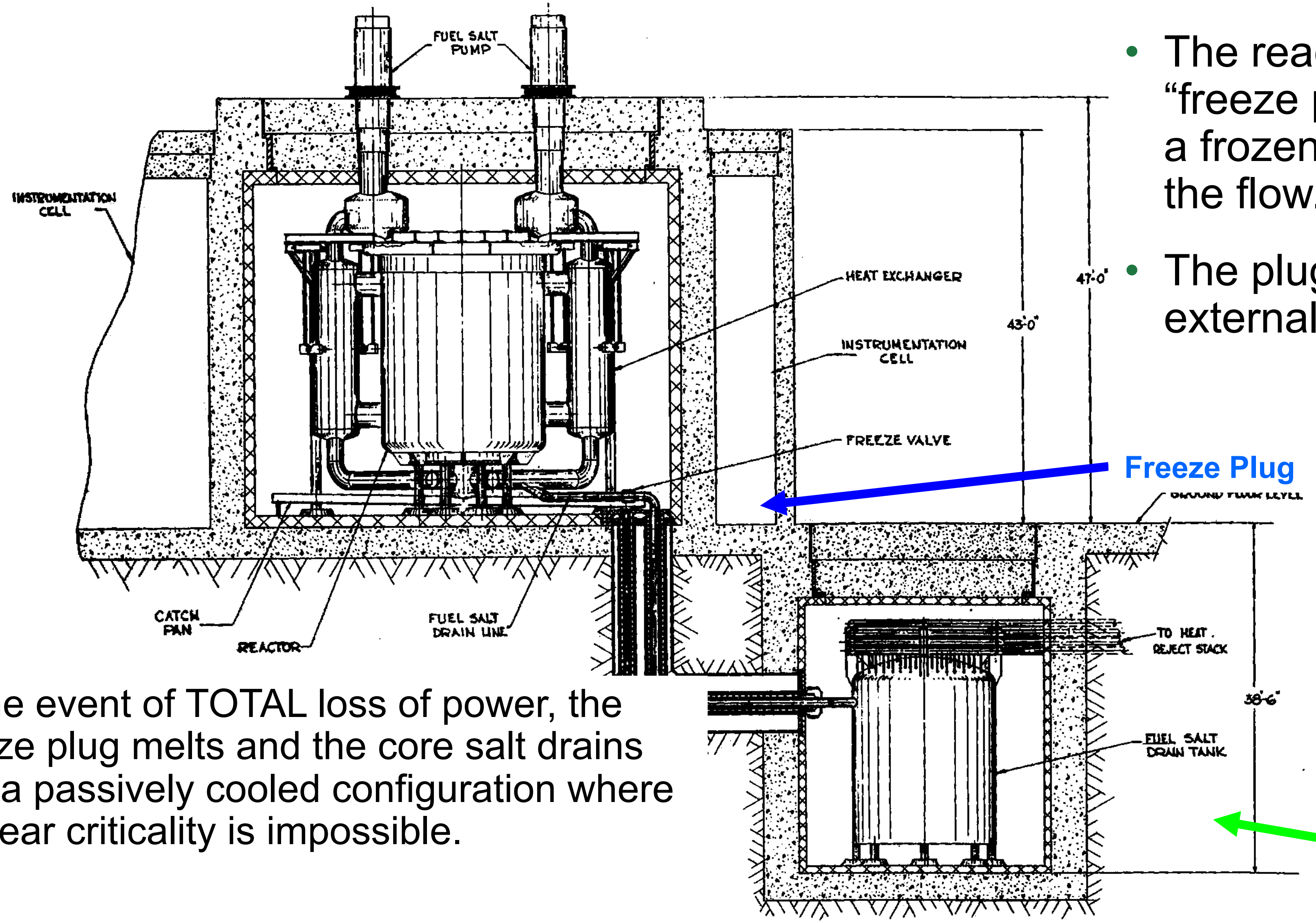
Why Advanced Reactors?

– Better safety posture
– Lower costs
– Reduced accident consequences
– Expanded siting options
– Better resource utilization
– Ability to close the fuel cycle
– Reduced waste products

Why MSRs?

- ***High-temperature***, ***low-pressure*** systems with chemically ***inert fluids***
  - Lower-cost components
  - Dry heat rejection capability
- Large ***temperature margins to boiling***
  - Passive safety response
  - Fewer safety critical systems
- Large ***baseload*** or ***small modular*** deployment
- ***Continual salt and fission product*** processing possible
  - Reduced emergency planning zone (?)
  - Ability to use UNF
  - Ability to help close the fuel cycle and reduce waste to repositories

MSR Passive Safety: The Freeze Plug

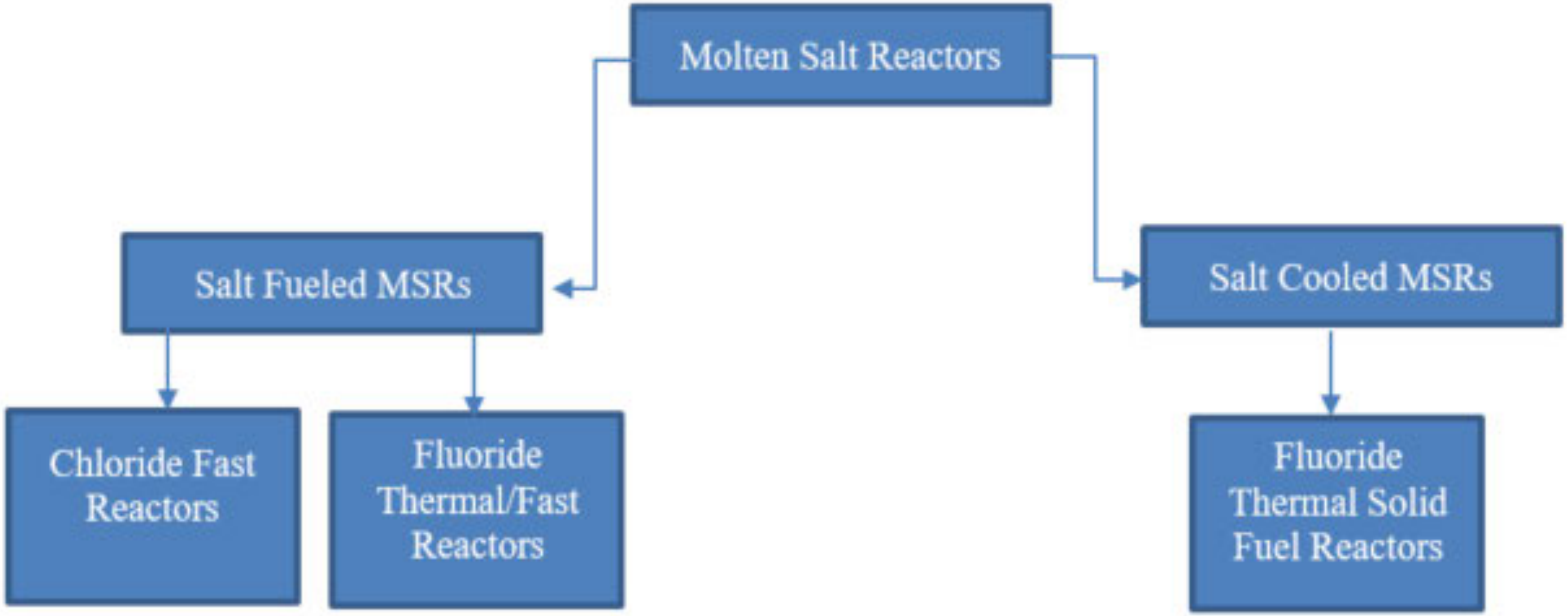


- The reactor is equipped with a “freeze plug”—an open line where a frozen plug of salt is blocking the flow.
- The plug is kept frozen by an external cooling fan.

- In the event of TOTAL loss of power, the freeze plug melts and the core salt drains into a passively cooled configuration where nuclear criticality is impossible.

MSRs are a broad class of advanced reactors

- MSRs are ***revolutionary*** for the implementation of nuclear power
- MSRs can ***revitalize*** the U.S. nuclear energy sector
- MSRs are ***near-term*** innovations



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How do you get into a market?
Sell a product or provide a service

- Either
  - Produce ***cost-competitive electricity*** or ***industrial heat***
    - Lower capital cost
    - Lower O&M costs
- Or
  - Play a positive role in ***closing the fuel cycle***
- Or
  - Uniquely meet the needs of a ***niche market***
    - ***High quality heat***
    - ***"expensive" power for special applications***

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What do we need to get MSRs to market?

- **Materials**, salts, and an understanding of their behavior
- Enabling **technology**
- Design **rules** and standards
- Reactor **designs** and **mod-sim methods** to effectively evaluate their performance
- A convincing story of reactor **safety** and **source term management**
- Understanding and agreements about ultimate **waste** forms
- A **business** case for the concept
- A well-defined path for **licensing** of the first reactors
- A follow-on path for licensing **commercial** reactors
- Interested **investors** and a **supportive government**
- **Supply chains** and supporting **infrastructure**
- Initial **fuel** core loadings

New Chemistry and Reactor Modeling Challenges

- ***Understand reactor performance and behavior***
  - *Develop and integrate **dynamic salt chemistry models** with neutronic and thermal hydraulic analyses for reactor performance evaluation all the way through severe accident transients*

- ***Understand source term behavior***
  - *Develop **constituent lifecycle data** and models to account for **source term behavior***

DOE MSR FY18 Priorities

- Materials and salt combinations and their interactions
- Salt chemistry data, database, and chemistry models
- Enabling technology
- Concept evaluation
- Modeling and simulation
- Licensing and safeguards
- Salt processing, reuse, and waste forms

Which Molten Salt Reactors are we interested in?

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- All of them
  - “if you’re interested in it, we’re interested in it”
- The market needs diversity

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- Our job is to facilitate an environment in which new reactors can be developed

- We are <u>not</u> designing a DOE reactor or picking winning designs

Each concept requires acceptable materials and salts

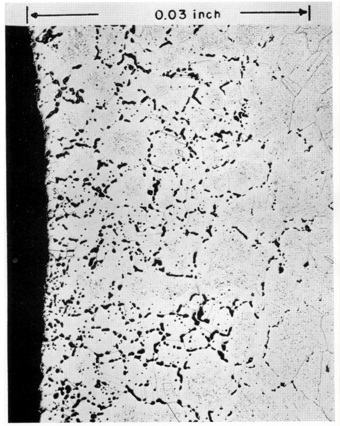
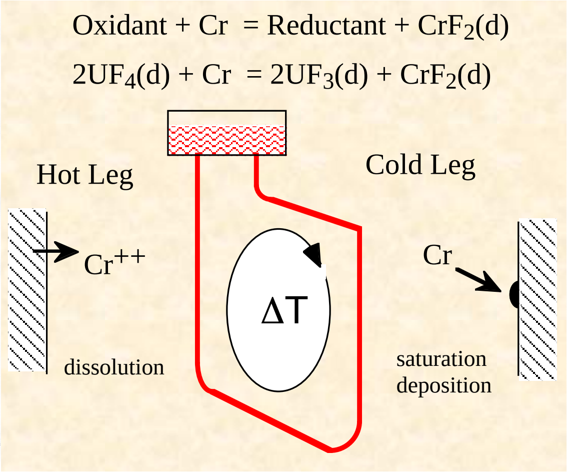


Fig. 6. Attack found in Inconel loop after circulating NaF–KF–LiF–UF_4. (11·2–41·0–45·3–2·5 mole %) for 630 hr at a maximum fluoride mixture temperature of 815°C and Reynolds number of 10,000.



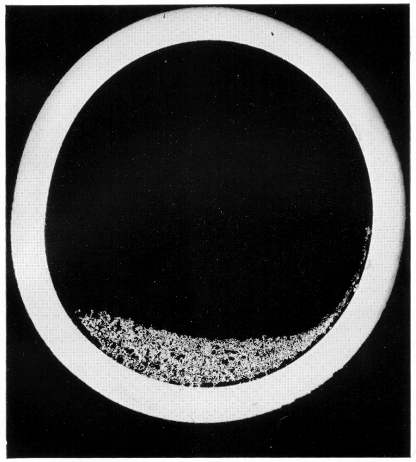
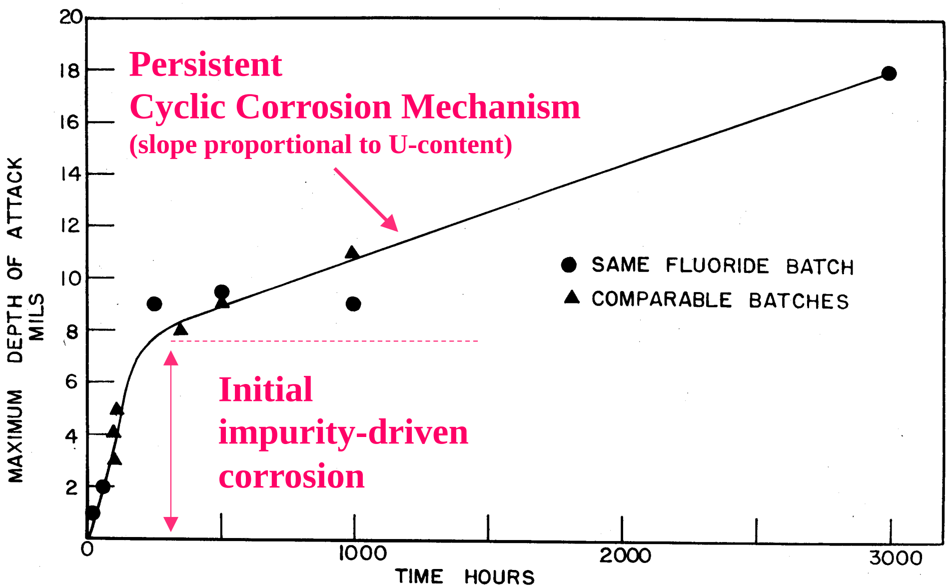
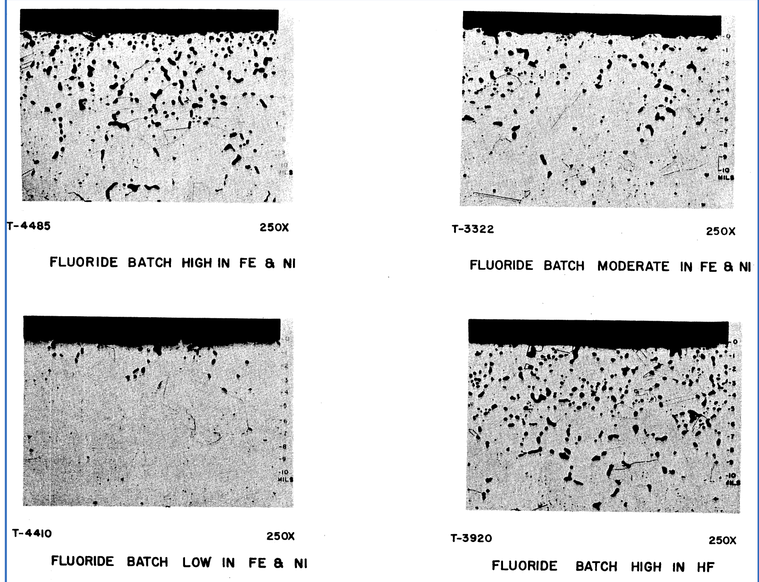


Fig. 7. Chromium deposits found in cold leg of Inconel loop discussed in Fig. 5.



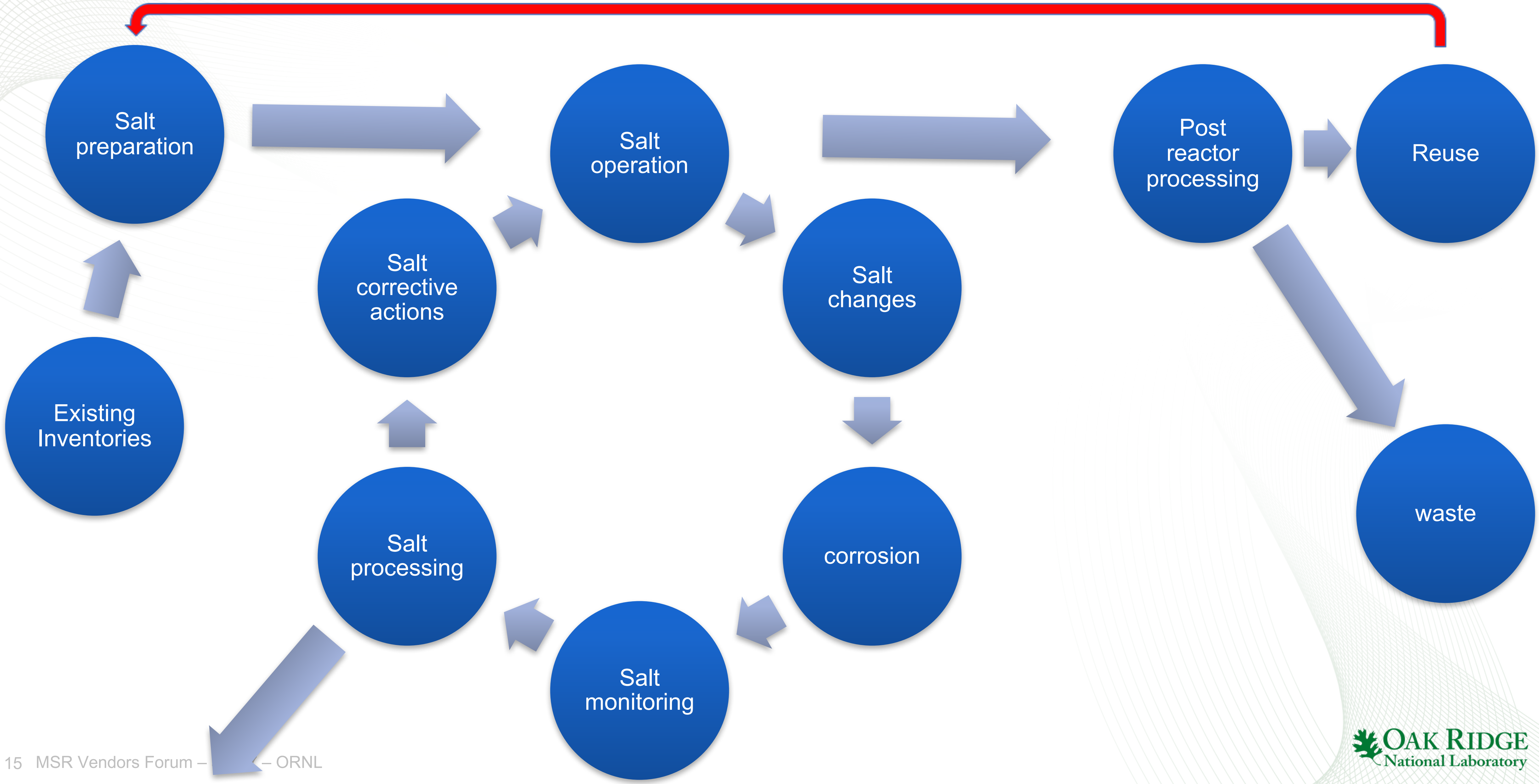
ig. 6 (T-3844) EFFECT OF TIME ON CORROSION DEPTH FLUORIDE IN INCONEL



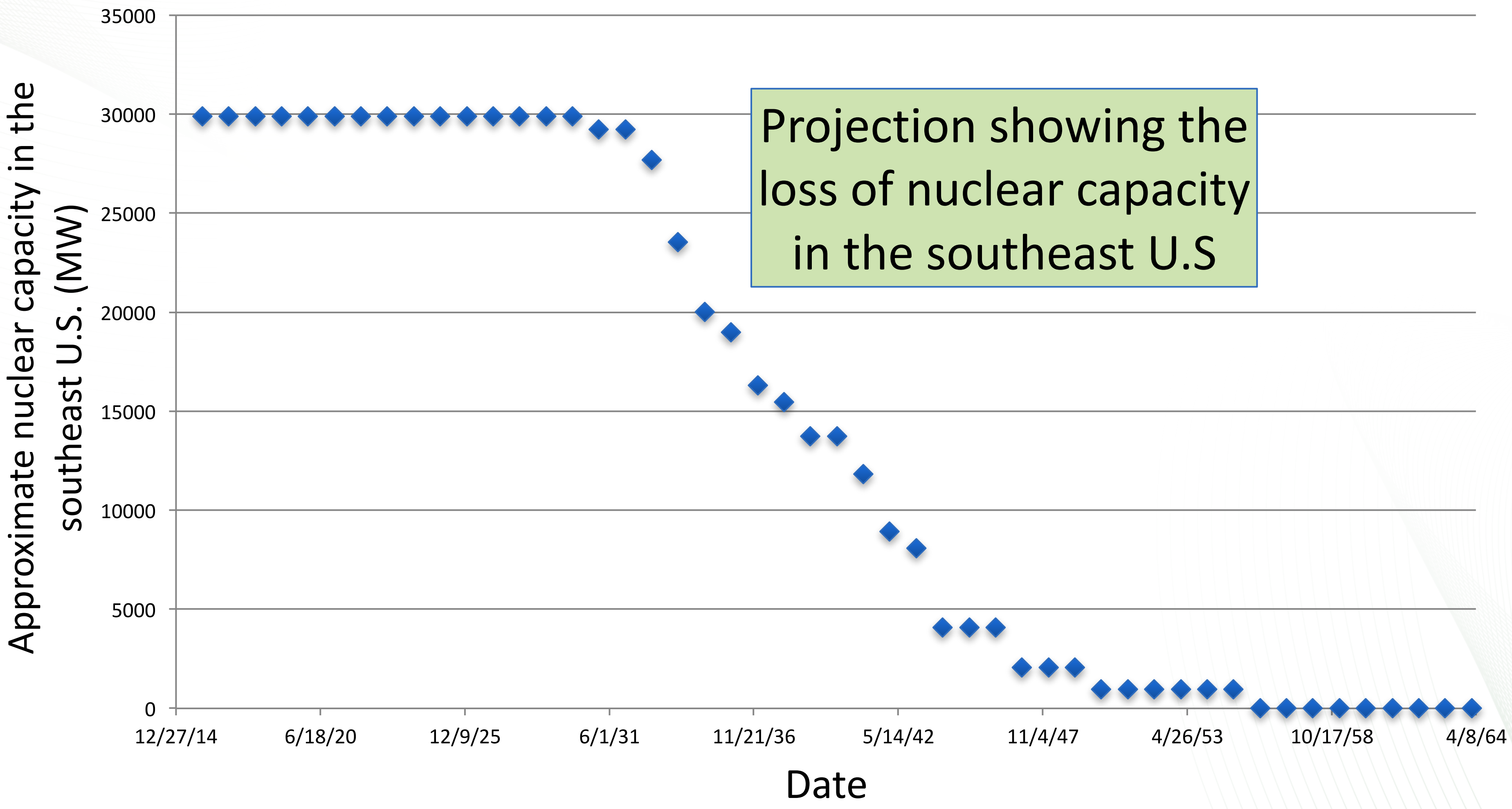
INCONEL THERMAL CONVECTION LOOPS - 500 HRS. AT 1500°F

(T-4544) EFFECT OF FLUORIDE BATCH PURITY

Each concept needs a “Cradle-to-Grave” plan



We've got to do something soon
(M. Herald and M. Adkisson)



DOE is taking a focused, near-term development approach to reactor development and deployment

- Science
  - Technology
    - Development
      - Demonstration

- Salts, materials and their interactions
- Components, processes, systems
- Reactor concepts
- Engineering scale testing

~10 years

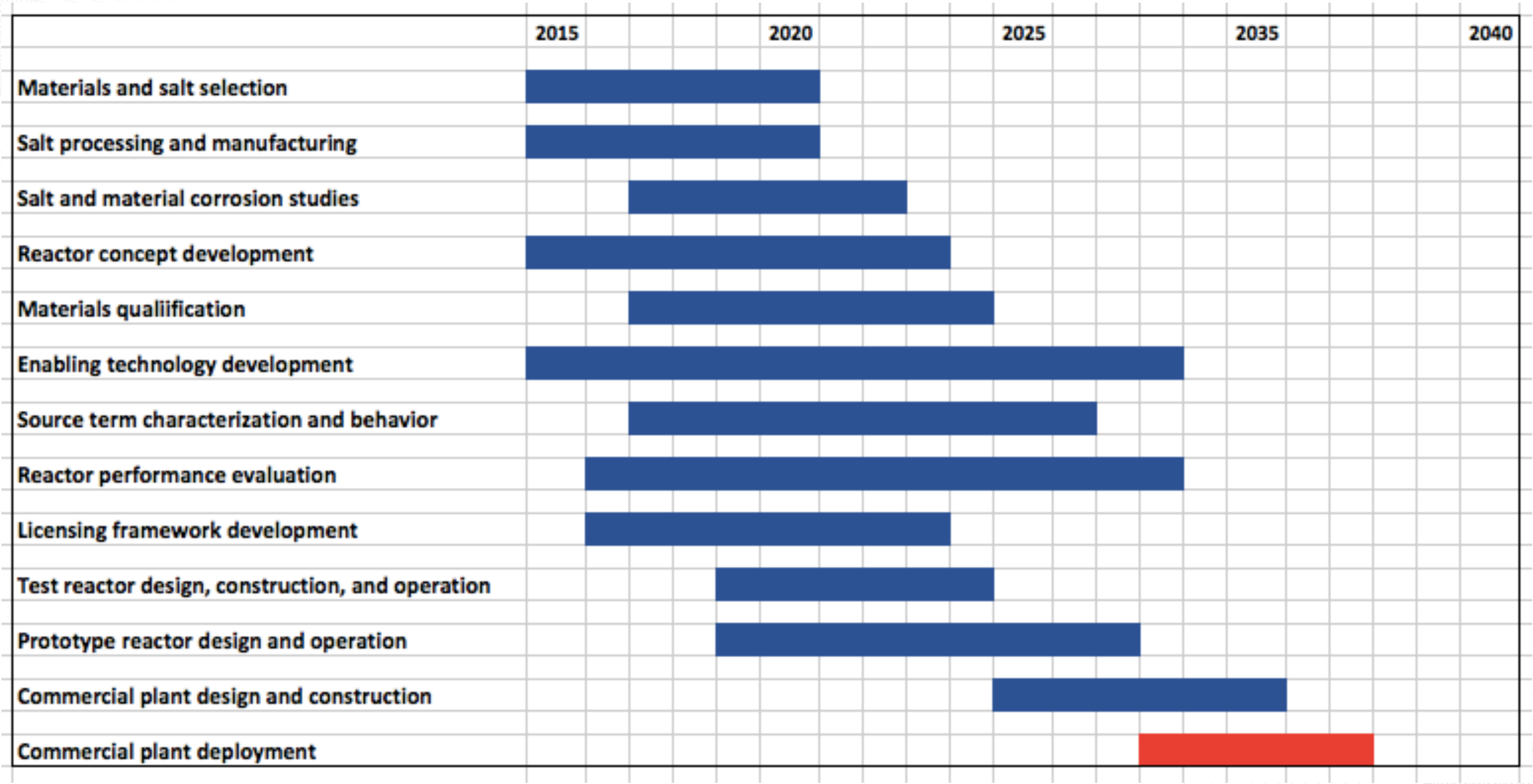
- First reactors

Licensing and Safeguards

~15 - 20 years

- Next reactors

Notional Timeline to MSR Deployment



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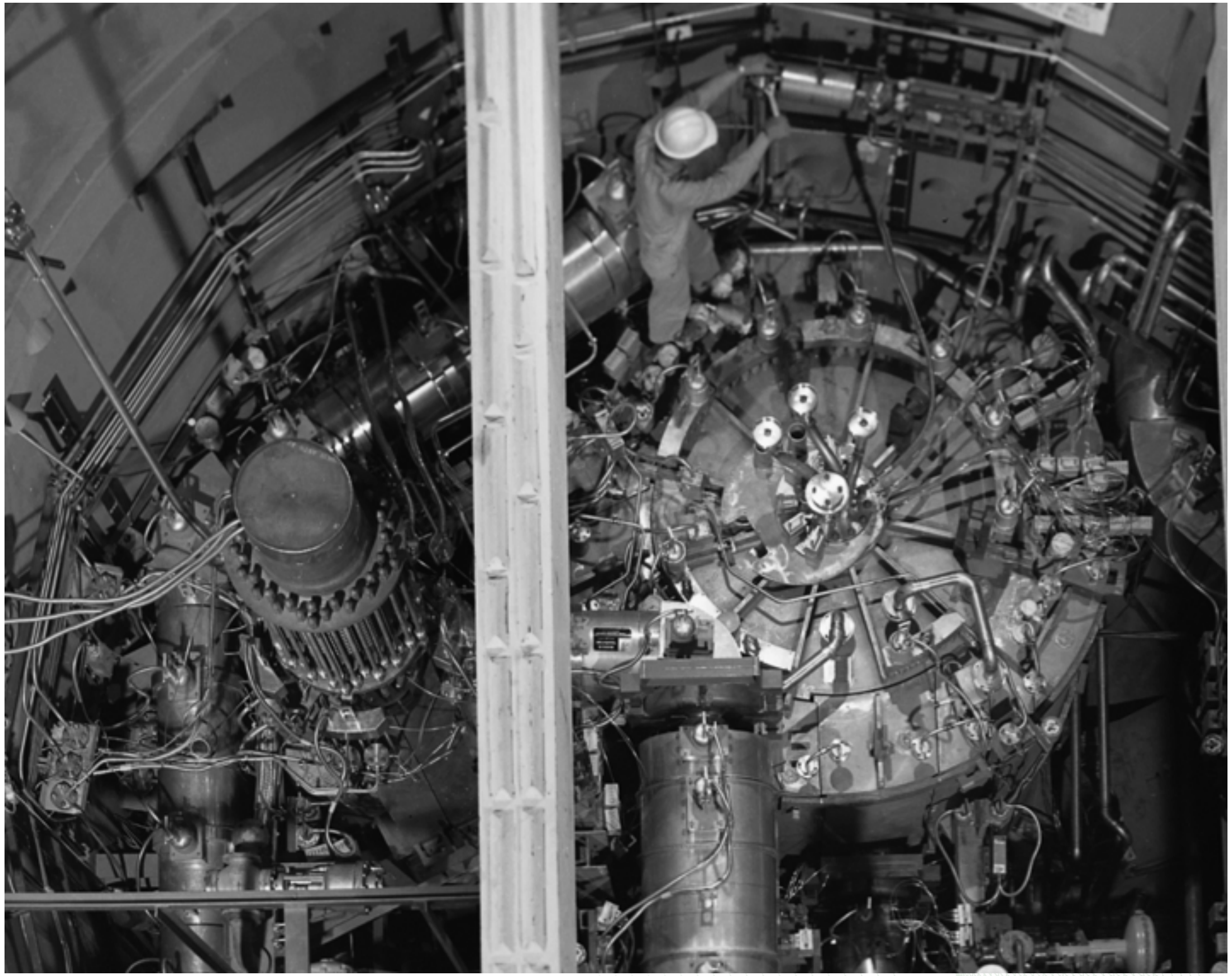
Molten Salt Reactor Experiment

- **Timeline**
  - Salt loaded into tanks - **Oct. 24, 1964**
  - Salt first circulated through core - Jan. 12, 1965
  - **First criticality (U^{235}) - June 1, 1965**
  - **First operation in megawatt range - Jan. 24, 1966**
  - **Full power reached - May 23, 1966**
  - Nuclear operation with U^{235} concluded
  - **Strip uranium from fuel salt - Aug. 23-29, 1968**
  - **First criticality with U^{233} Oct. 2, 1968**
  - **Full power reached with U^{233} Jan. 28, 1969**
  - Nuclear operation concluded - **Dec. 2, 1969**



Questions?

Thank you