Structural and Salt Facing Material Needs Molten Chloride Fast Reactor (MCFR)

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Purpose of Materials Testing

Purpose	Intended Output	Test Characteristics	Key Stakeholders
Design Analysis	Best estimate materials performance data with tight uncertainty.	• Near prototypical • Good statistics • Consistent data	Design Engineers, Safety
Qualification	Conservative and/or bounding materials performance data with highest quality control.	• ASME and ASTM standards • External audits or surveillance • Heavy documentation	Quality Assurance, Safety, and Licensing
Risk Mitigation	Qualitative trend data to gain better understanding of previously unknown material behavior or mechanism.	• Novel and complex test methods • Surrogate or non-standard materials • Often require subject matter expertise to correctly interpret data	Design Engineers, and Project Management

No single test can cover all the needs. Industry will often prioritize testing based on maturation of technology, material and program risk profile.

MCFR program is focusing on materials tests that support design analysis and hopefully leverage the same data set for eventual NRC licensing and qualification.

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Materials of Interest (Qualitative Analysis)

Material	Cost and Product Form Availability	High Temperature Strength	Corrosion Resistance (Molten Chlorides)	Irradiation Resistance (~20 dpa)	Weldability and Manufacturability	NRC Endorsement (i.e. ASME Section III Div 5 Qualified)
A625 Gr 2	Expensive and available	182 MPa @ 800°C[1]	Okay – some data	Okay – some data	Weld specifications commercially available	No data in Section III
A617	Expensive and available	159 MPa @ 800°C[1]	Average – some data	Okay – some data	Weld specifications commercially available	Data in Section III but not NRC endorsed
SS316H	Cheap and available	81 MPa @ 800°C[1]	Average – most data	Okay – most data	Weld specifications commercially available	Data in Section III with NRC endorsement
Refractory Alloys (Mo, TMZ, etc)	Expensive and barely available	Varies depending on alloy	Good – lack of data	Okay – little data	Difficult to weld, weld specifications to be developed.	No data in ASME
Ceramics (SiC, etc)	Varies depending on product form	~250MPa [2]	Unknown – lack of data	Okay – some data	Un-weldable	No data in ASME

1. Yield strength taken from ASME Section II
2. Tensile strength taken from vendor studies, ceramics are brittle and have very little plastic deformation.

Inconels are currently the preferred structural material for MCFRs due to their known high temperature and corrosion performance, commercial availability, weldability, and ASME code case.

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Engineering Properties of Interest

- Creep (550 – 800°C)
  - Time to 1% strain
  - Time to creep rupture
- Fatigue (550 – 800°C)
  - Cycles to fatigue failure
- Creep - Fatigue (550 – 800°C)
  - Cycles and time to failure
- Corrosion and Erosion (550 – 800°C, 0 – 3 m/s)
  - Weight loss/gain vs time
- Irradiation Mechanical (550 – 800°C, 0 – 100 dpa fast spectrum)
  - Swelling/creep vs dose (strain vs dpa)
  - Embrittlement vs dose (Δfracture toughness vs dpa)
- Irradiation Chemical (550 – 800°C, 0 – 100 dpa fast spectrum)
  - Weight loss/gain vs dpa

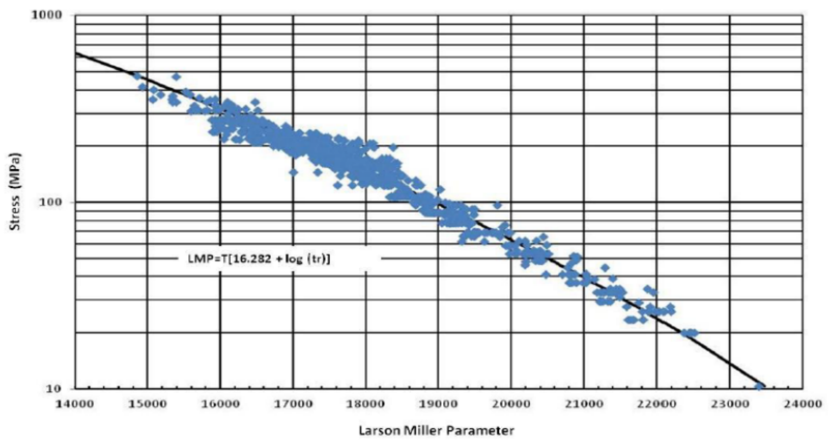
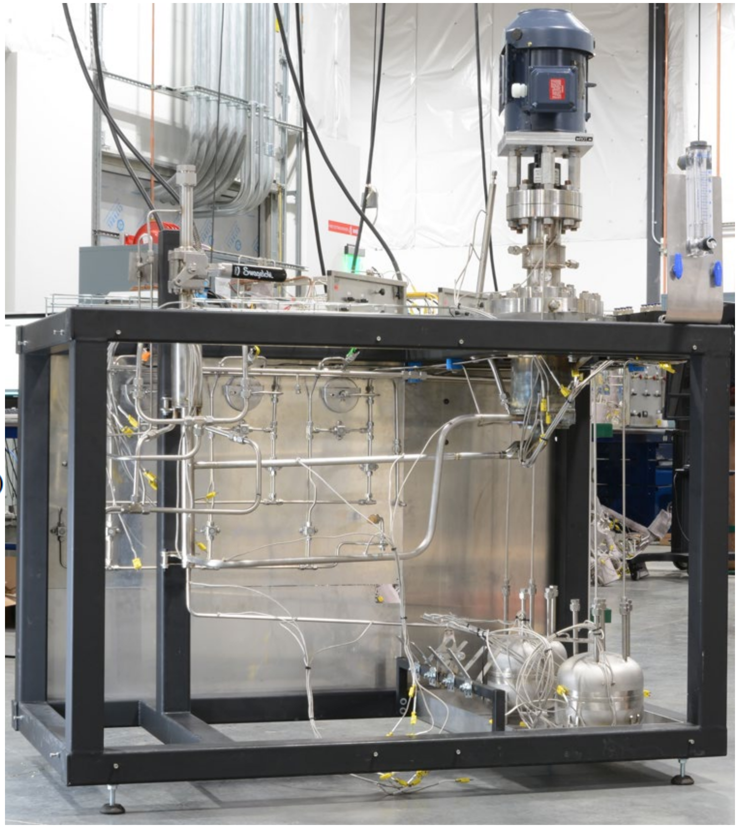


Figure 3.1.1-5 Time-to-Rupture Regression for Type 316H Stainless Steel (Reference 1)



Small Isothermal Molten-chloride Pumped Loop (SIMPL) for corrosion erosion testing - TerraPower EVL

1. Impact of Tertiary Creep on Time Dependent Allowable Stresses for Type 304H and 316H Stainless Steels, MPR 0300-0003-RPT-001 Rev 1, 2021

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Key Questions to be Answered

- What is the Inconel molten chloride corrosion mechanism and how will it accelerate or decelerate in the presence of fast neutron irradiation?
- How does the presence of fission products impact the corrosion, mechanical, and irradiation behavior of Inconels.
- How can we predict and verify Inconel corrosion behavior in contact with high temperature molten chloride without exhaustive destructive testing?
- Will NRC ever endorse advanced manufacturing techniques (e.g. 3D printing, coating, etc) for the fabrication of safety class SSCs to support commercial reactors planned to be built in 2035?
- How can we leverage historical or existing scientific data not performed under an NQA-1 program to be qualified for use as design input for commercial nuclear reactor design?

These questions have no easy answers, but the industry can not tackle them all alone. Help from the scientific community can significantly reduce unknown risk on molten chloride salt facing material to support commercial advanced reactor programs planned for the next decade.

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