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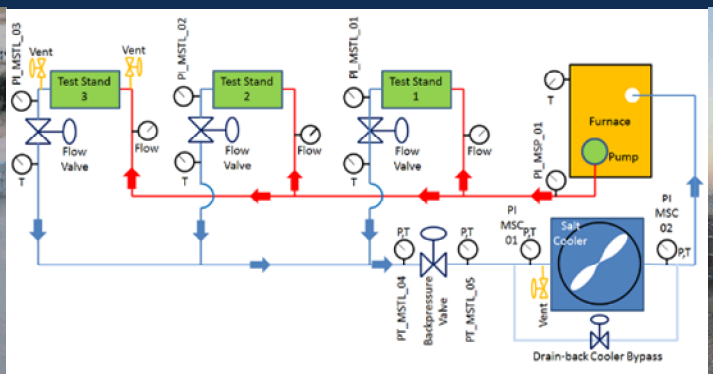
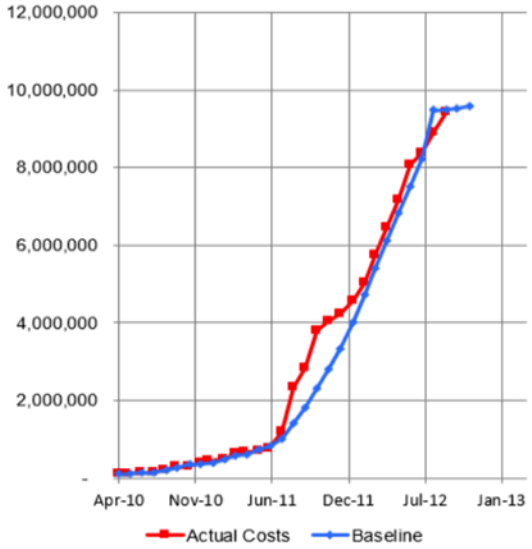


Molten Salt Test Loop

Options to Support the DOE NE MSR Program

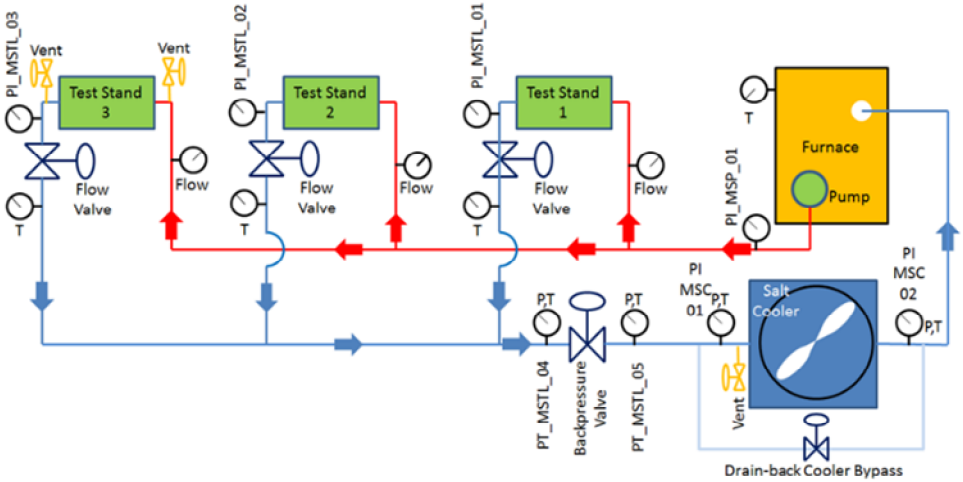
Molten Salt Test Loop

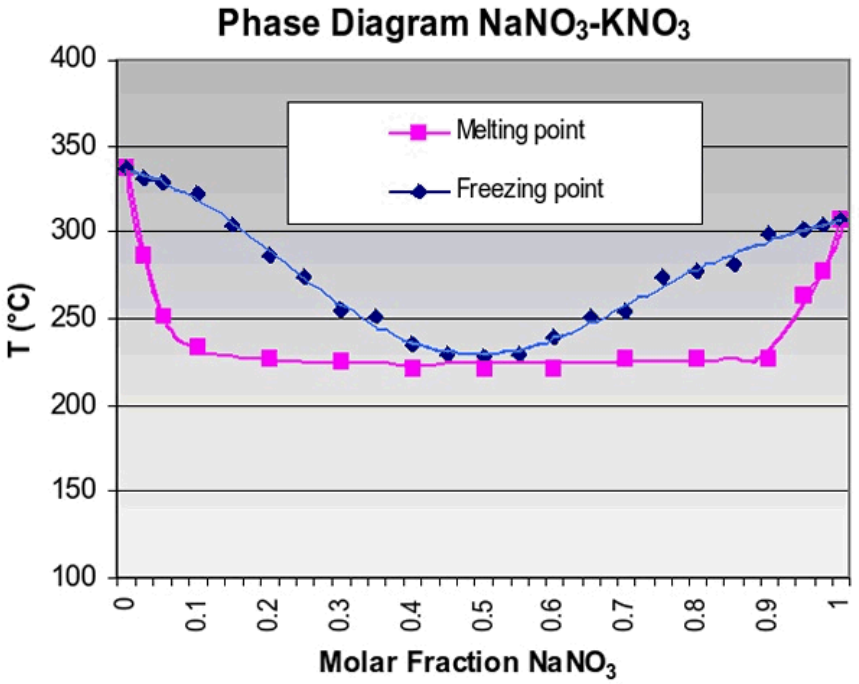
Parameter	Specification	Unit
Heating Capacity	240	kW
Cooling Capacity	1400	kW
Pump Pressure	580	psi
Flow Rate	44-55	Kg/s
Max Temp	650	°C
Operating Range	300-585	°C
Ramp Rate	10	°C/hr
Cooling Rate	60	°C/hr



Molten Salt Test Loop Salt Characteristics

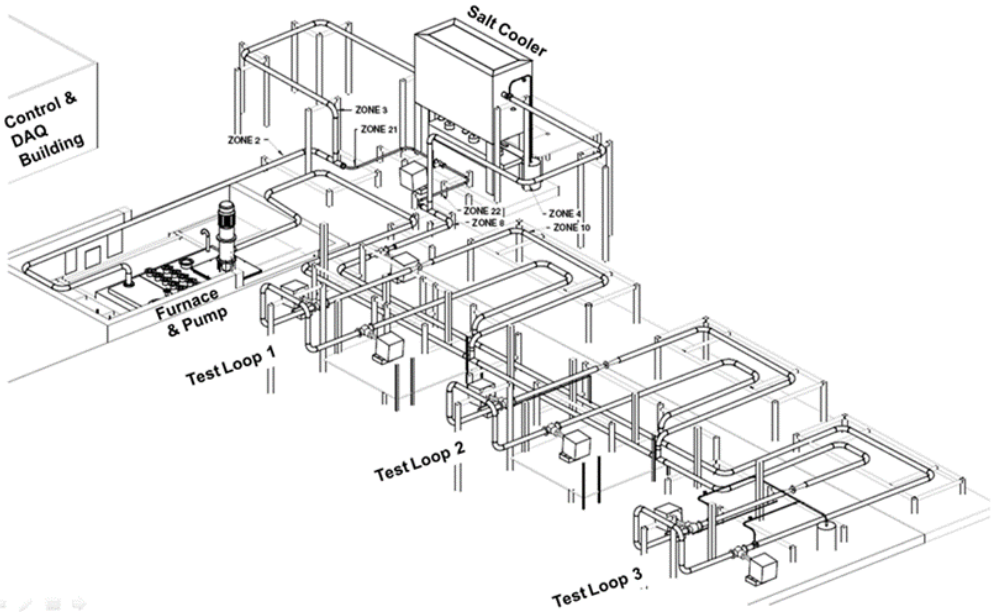
Parameter	Specification	Unit
Melting Point	220	°C
Salt Chemistry	60% NaNO3	%wt
	40% KNO3	%wt
Melt Expansion	+4.6	%-Vol
Heat Capacity	1.52	J/g-K
Density	1.7	kg/L





Molten Salt Test Loop Site Characteristics

Parameter	Specification	Unit
Available Site Power	280	kW
Site Voltage (60hz)	480/270	Vac
Site Current	380	A
Experiment Power	45	kW
Voltage (60hz)	220/110	Vac
Current	100	A
CDA Pressure	132	Psi
CDA Flow	38.6	CFM



MSTL Lessons Learned

- Regular, daily inspection or automated notification is required to prevent inadvertent freeze-up.
- Drain-back is critical, while large piping is considered with sloping, there are small places to trap salt, which when frozen becomes an issue.
- Valves were incorrectly mounted with stem points downward—they should point upward so that the bellows drain effectively.
- Flanges don't work well with salt—always leak when thermally cycled. Pipe joints need to be welded.
- Other lessons learned on prior tests (pump and valve test, Solar 2 integrated test).

MSTL Startup – ROM

- Restoration and Refurbishment with existing nitrate salt ($500k to $1M).
  - Requires re-melting the existing salt
  - Some sub-components will need repair or replacement (fittings, flow control valves, pumps)
  - Requires weekly maintenance to keep the loop operating
  - Environment, Safety, and Health requirements are all in place
- Should consider optional investments to reduce costs and enhance capabilities
- Timeframe (with necessary funding and support):
  - Basic restoration (melt and test): 6-9 weeks
  - Valve refurbishment: 8-12 weeks
- The original investment in the loop was $10 million.

MSTL Configuration Options

Option	Description	ROM Cost Estimates
A1) Use existing nitrate salts for component testing. A2) Reconfigure for O&M cost reduction	Test components, instrumentation, flow, pressure on nitrate salts up to 585 ºC.	$500 to $1M for startup
B) Add cover gas and convert to Fl salts.	Test components and instrumentation using fluoride salts up to 550 ºC.	$1-1.5 M for the conversion
C) Add cover gas and convert to Cl salts.	Test components and instrumentation using chloride salts up to 550 ºC.	$1-1.5 M for the conversion

*** Potential first step would be to complete a detailed restart plan in FY18**

MSTL Support for MSR Technology Development & Demonstration

- Bulk molten salt properties
  - Impurities
  - Physical properties – density, viscosity, heat capacity, thermal conductivity
- Instrumentation & Controls
  - Measuring physical properties at production scale & volume
  - Reliability & Accuracy
- Operational Conditions
  - Heat transfer & energy conversion
  - Flow properties
  - Corrosion / Erosion
  - Freeze Plug Testing?

Experimental Capability Matrix Supporting MSR Technology Needs

			Sandia Facilities					
			MSTL	ACRR	IBL	GIF	THF	NESL
MSR Support Area	Plant Design	Component Testing	x	x				x
		Design Qualification	x	x				x
		Operational Studies	x					x
		Reliability Studies	x	x				x
		Energy Conversion	x					x
	Safety and Security	Fuel Accountancy	x					
		Fuel Reprocessing	x				x	
		Diversion	x					
		Subversion	x					x
	Materials Development and Testing	Aging Effects	x	x	x	x	x	x
		Material Characterization			x		x	x
		Material Corrosion Testing	x	x	x	x	x	
		Material Mechanical Testing		x	x	x		x
		Radiation Effects Testing		x	x	x		
		Model Development	x	x	x	x	x	x
	Coolant Behavior	Aging Effects	x	x	x	x	x	
		Radiation Effects		x	x	x		
		FP Retention	x	x				

- Molten Salt Test Loop
- Annular Core Research Reactor
- Ion Beam Laboratory
- Gamma Irradiation Facility
- Tritium Handling Facility
- Nuclear Energy Sys. Laboratory

ACRR, IBL & GIF are DOE/NE NSUF Program Facilities

Additional SNL Capabilities

DOE MSR PROGRAM PRIORITIES

DOE MSR FY18 Priorities

(from MSR Workshop in October)

- Materials and salt combinations and their interactions
  - MSTL and CSP program for lessons learned (pull from past work)
- Salt chemistry data, database, and chemistry models
  - Data framing activity and lessons learned report (pull from past work)
- Enabling technology
  - SCO_2 & Energy Conversion (future activity)
- Concept evaluation
- Modeling and simulation
  - CFD, PRA, and SSPM
- Licensing and safeguards
  - Examine challenges early to avoid costly retrofits later (Safeguards by Design)
- Salt processing, reuse, and waste forms
  - What infrastructure is required for processing at the reactor versus centralized processing facilities (tie to transportation and storage of waste)?

Licensing and Safeguards

- Three main types of MSR designs, all will have unique licensing challenges:
  - Liquid fueled, drop-in design, with centralized salt processing

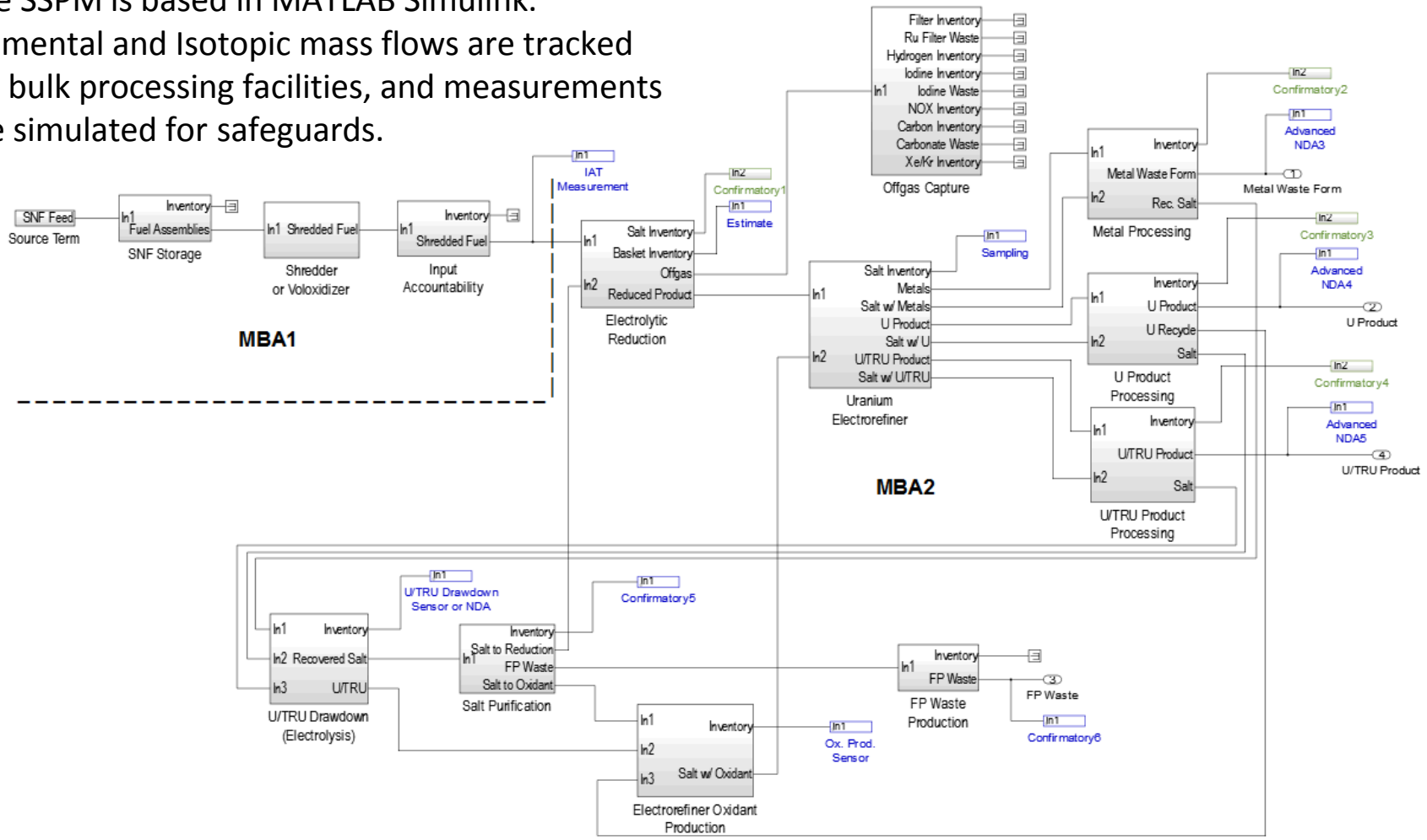
    Materials accountancy could require sampling, but the loop is simplified and self-contained. Centralized salt processing requires the full accountancy system of a reprocessing plant.
  - Liquid fueled design with on-site salt processing

    Materials accountancy more complex on-site, but eliminates the need for a reprocessing plant. Past work on pyroprocessing safeguards is directly applicable.
  - Solid TRISO fuel elements (either pebble bed in MS or fixed assemblies)

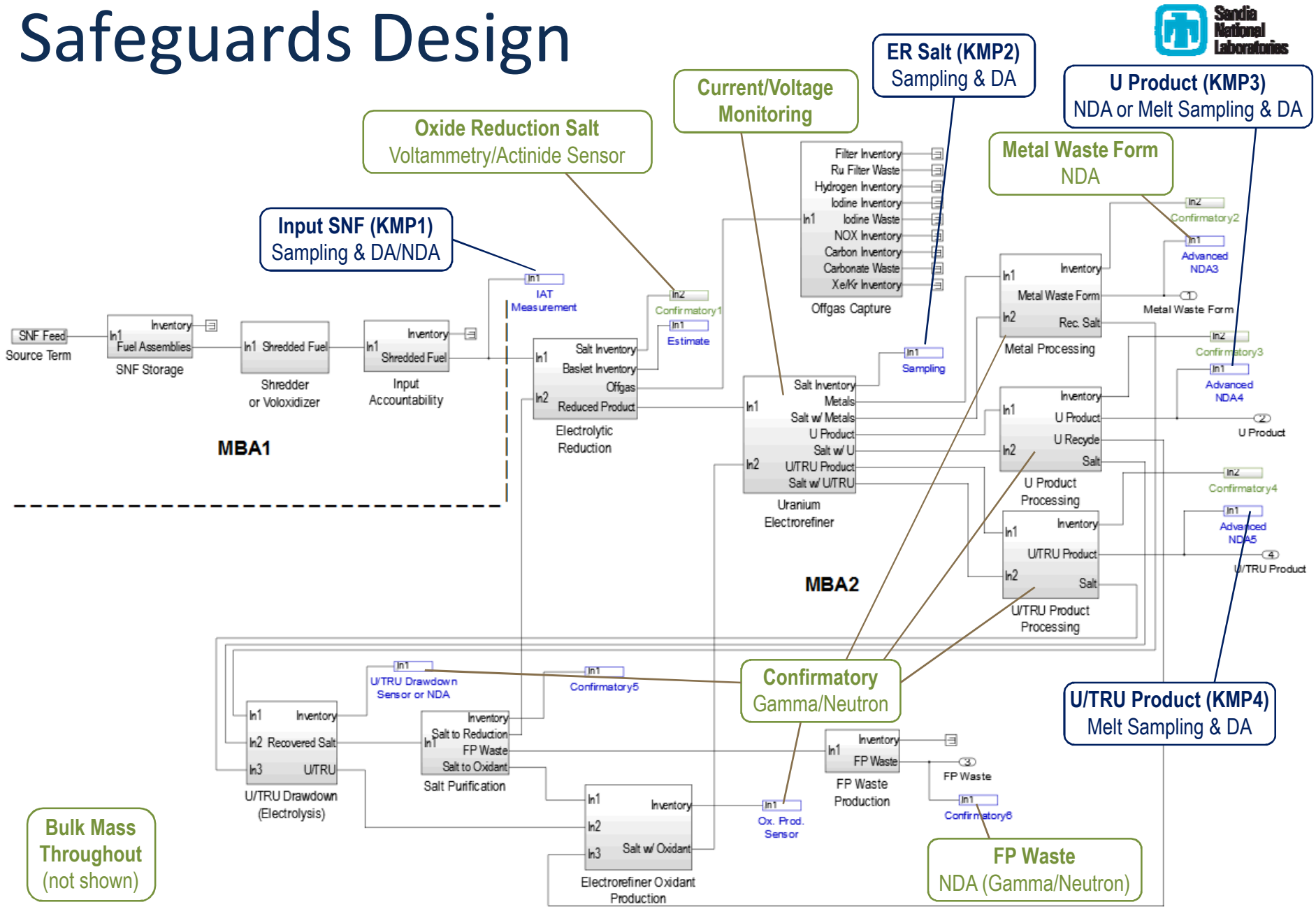
    Pebble beds have the challenge of accounting for pebbles, but fixed assemblies have no greater accountancy challenges than a LWR.

Separation and Safeguards Performance Model (SSPM)

The SSPM is based in MATLAB Simulink.
Elemental and Isotopic mass flows are tracked for bulk processing facilities, and measurements are simulated for safeguards.



Safeguards Design



Salt Processing, Reuse, & Waste Forms

- For the various MSR designs, do we have the infrastructure to support the entire system?
  - Liquid fueled, drop-in design, with centralized salt processing

    Reprocessing is a very hard sell in the U.S., and internationally there is a lot of interest in moving away from enrichment and reprocessing due to safeguards and proliferation concerns. From a very high level, Safeguards by Design can affect the choice of systems.
  - Liquid fueled design with on-site salt processing

    Salt processing on-site may be easier to sell since the processed amount is smaller, no removal of actinides, much less transportation. Transportation logistics need to be considered.
  - Solid TRISO fuel elements (either pebble bed in MS or fixed assemblies)

    TRISO fuel in general requires much larger throughputs of fuel, which means more waste by volume. Is fuel fabrication more complex?

Salt Processing, Reuse, & Waste Forms

- SNL has a significant background in systems analysis.
- The integration of safeguards, safety, security, and operations plays a strong role in concept evaluation.
- Extensive expertise on the back end of the fuel cycle, including storage and transportation can be leveraged to support systems analysis.
- SNL also has expertise in off-gas capture and fission product interactions as they apply to waste forms.

Summary

- While the MSR program is not planning to down-select, there are a number of implications of the various reactors designs that need to be examined.
- Safeguards, safety, security, and operational concerns should be examined now to avoid costly errors later.
- Systems analysis, particularly how a MSR design can be built and operated in the U.S., will need to address a number of challenges in moving toward an advanced fuel cycle.

Backup Slides

MSTL COMPONENTS

Molten Salt Test Loop
Primary Pump

Sandia National Laboratories

Flowserve / Baldor

- High Temperature
- Vertical Turbine
- 250 HP
- 1800 RPM

Molten Salt Test Loop
Forced Air Cooler

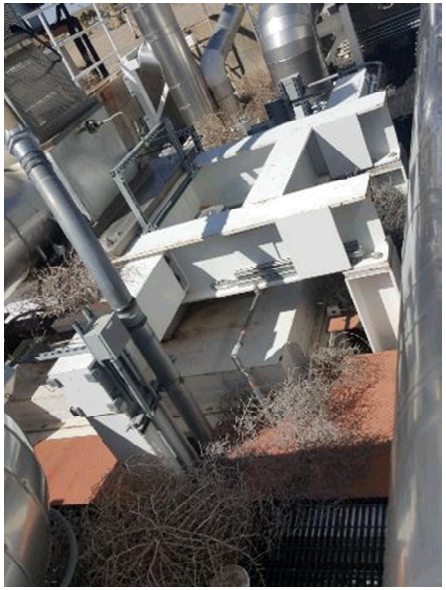
Hoffman Process

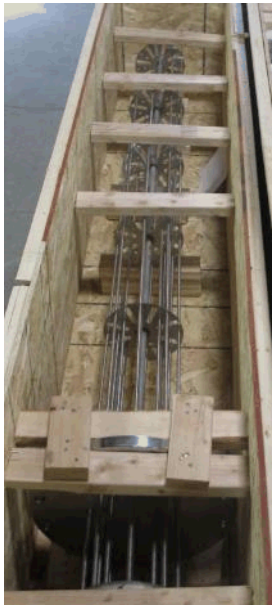
- 1.4 MW Capacity
- Louvered Control
- SA312 SS Throughout

Molten Salt Test Loop Heater/Storage Tank

Heat Exchange and Transfer, INC

- 112 KW immersion heater (12x20KW)
- 12000 gallons





Molten Salt Test Loop Valves

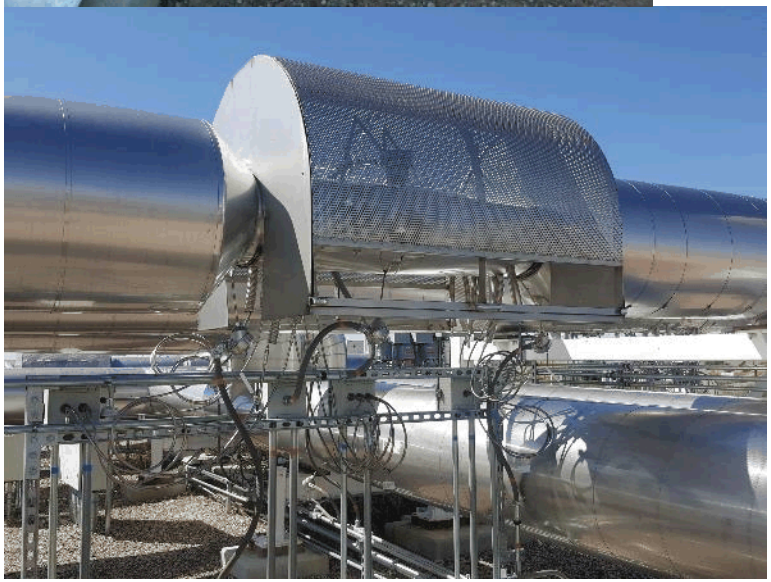
Flowserve

- High Temperature
- Air Cooled Stem
- Globe Valve
- Variable Control
- Manual Backup

Molten Salt Loop
Piping and Insulation

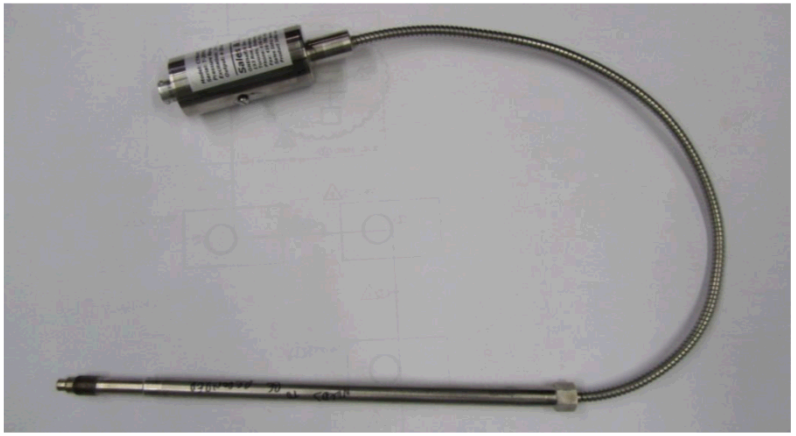
- 347 Stainless Steel
- 18” of Insulation
  - Preformed Perlite block
  - Preformed “Fibermat” blanket
  - Preformed “Duramat” blanket
  - 316 Stainless

Molten Salt Test Loop Heat Trace



- Fully Wrapped
- ~1KW / m
- 120 kW total

Molten Salt Test Loop Sensors and Control



Molten Salt Test Loop
Issues During Construction

Insulation
- Tight Bends
- Wire Hangers

Molten Salt Test Loop
Issues During Construction

Heat Trace
- Wrapping Valve Trees
- Forced Heated Air
- Not Enough

Molten Salt Test Loop
Issues During Construction

Structure:

- Warping at interfaces
- Thermal expansion

Molten Salt Test Loop Lessons Learned

Sandia National Laboratories

Valve Orientation Matters:

- Source of Leaks
- Frozen Valves

Molten Salt Test Loop Lessons Learned

Sensor Feedthroughs:

- Cold Spots
- Pressure Transducers
- Insulated Boxes