U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Sodium Fast Reactor Safety and Licensing Research Plan

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Project Overview
Sodium Fast Reactor (SFR) Research Plan

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Project Overview

Planning

Initial Gap Identification and Rankings (~3 years)

Final Evaluation (~1 year)

What topical areas are vital to SFR Licensing?

Ranking Process

Regulatory Concern

High (H)

- The phenomenon of interest can directly lead to a material failure
- The regulatory body will require a high degree of confidence in the experimental database, materials knowledge or modeling techniques.

Medium (M)

- The phenomenon is of secondary importance to understanding overall material performance and failure.
- The regulatory body will desire information about the phenomenon.

Low (L)

- Understanding the phenomenon of interest is not instrumental to predicting material performance

State of Knowledge

High (H)

- A physics- or correlation-based model that adequately represents the phenomenon over the parameter space of interest is available.
- A database exists adequate to validate relevant models or to make an assessment.

Medium (M)

- A candidate model or correlation is available that addresses most of the phenomenon over a considerable portion of the parameter space.
- Data are available but are not necessarily complete or of high fidelity, allowing only moderately reliable assessments.

Low (L)

- No model exists, or model applicability is uncertain or speculative.
- No database exists; assessments cannot be made reliably.

Gap Evaluation Process

Gap Categorization

All gaps identified by the reports were:

- Summarized
- Grouped into topical areas

The degree of detailed information varied between expert panels

Table 5. List of Research Gaps Associated with High Level Gap Topical Areas for Sodium Technology (Cont.).

Gap	Experimental Database	Ability to Model	Details
Sodium-Fluid Interactions (ST02)			
High pressure fluid jet leak into sodium in heat exchanger	L	L	This general phenomenon is considered important but knowledge is good for sodium-water interactions and is lacking for sodium-CO_2 interactions.
Sodium Surface Pool Fire on an Inert Substrate (ST03)			
Radiation net heat flux	L	H	Models are good but parameters are poor with low accuracy (surface and aerosol optical properties; optical properties are linked with sprays).
Mass Burning Rate	L	H	When at high temperature burning, the models are good. For smoldering fires (burning through the crust) the models are poor. Most experiments were conducted using non-representative insulated surfaces.
Oxide crust behavior on pool substrate	L	L	Difficult to measure experimentally because of the low residence time of oxide to hydroxides.
Near-surface aerosol size/distribution	L	L	No good model is available.
Surface aerosol production	L	L	Interfacial effect at the crust is not well known.
Aerosol Dynamics (ST04)			
Sodium aerosol source term	L	L	The gap panel did not have the expertise to list specific research areas, but sodium aerosol source term was agreed to be an area where significant R&D is needed.
Hydrolysis of peroxides	M	L	Hydrolysis may not be lacking data, but aerosol behavior is the key concern.
Cavity Liner (ST05)			
Liner failure pressure or thermal response	M	M	Likely no composite model exists for liner failure (because of the complexity involved in the modeling process and the necessary constraints). Also, there are little data for combined effects.
Reaction Product Swelling Behavior	L	L	There is very little modeling known between steel and sodium mixed with sodium oxides, peroxides, and hydroxides at elevated temperatures
Corrosion of Liner	M	M	The Japanese conducted some steel immersed into sodium tests (Aoto et al., 1998; 2001).

Gap Evaluation Process (2)

Gaps were identified in a variety of subject areas

Importance to safety was either extracted from the underlying reports or from additional expert judgment.

Fuels and Materials Gap Topical Areas Summary

Gap ID	Name of Gap Topical Areas	Importance to Safety Within Category	State of Knowledge
FM01	High Burnup Fuel Characterization	H	M
FM02	Fission Product Carryover Fuel Characterization	H	L
FM03	MA Carryover Fuel Characterization	H	L
FM04	Advanced Cladding and Duct Fabrication, HT-9, 9Cr-1Mo, ODS	H	M
FM05	Advanced Cladding and Duct Material Properties	H	M
FM06	Duct/Bundle Performance Experience	H	L
FM07	Structural Material Issues, Rotating Plug, IHX, EM Pump	M	L
FM08	Brayton (S/CO_2) Materials Issues	H	L
FM09	SFR Fuels and Materials Knowledge Base Preservation	H	L
FM10	Fuel Performance Code Documentation and Training Issues	H	L

Gap Evaluation Process (3)

Table 10. Fuels and Materials Gap Closure Estimates.

Gap ID	Estimated Cost Range	DOE Funding Programs Other than ARC?	International Funding Programs?	Time Sensitivity (years)	Time Required to Fill Gap (years)	Precursors	US Facilities	International Facilities	Event Category (O, AOO, DBE, BDBE, SA)	Importance	Optional Design Feature
FM01	+100M*	AFC	Not for Metal Fuel	15 +	5 – 10*	Access to a fast flux irradiation facility	-	CEFR / BN60	O	M/M	Yes
FM02	1M-10M	AFC	Not for Metal Fuel	5 – 10*	5 – 10*	Access to a fast flux irradiation facility, Irradiated FP fuel	-	CEFR / BN60	O	H/M	Yes
FM03	1M-10M	AFC	Not for Metal Fuel	5 – 10*	5 – 10*	Access to a fast flux irradiation facility, Irradiated MA fuel	-	CEFR / BN60	O	H/M	Yes
FM04	1M-10M	AFC	Not for Metal Fuel	5 – 10*	5 – 10*	-	-	-	O	H/L	Yes
FM05	1M-10M	AFC	Not for Metal Fuel	5 – 10*	5 – 10*	Access to a fast flux irradiation facility	-	CEFR / BN60	O	H/L	Yes
FM06	1M-10M*	AFC	Not for Metal Fuel	5 – 10*	5 – 10*	Senior personnel	-	-	O, AOO, DBE, BDBE, SA	H/L	No
FM07	10M-100M*	AFC	Not for Metal Fuel	5 – 10*	5 – 10	Large sodium test loop	ANL**	-	O , AOO , DBE , BDBE , SA	H/M	No
FM08	1M-10M	Solar & Fossil Energy***	Not for Metal Fuel	5 – 10*	5 – 10	Coupled Na/S-CO_2 test loop	-	-	DBE	H/M	Yes
FM09	100K-1M	AFC	Not for Metal Fuel	< 5	< 5	Senior personnel	-	-	O, AOO, DBE, BDBE, SA	H/M	No
FM10	100K-1M	AFC	Not for Metal Fuel	< 5	5 – 10*	Senior personnel	-	-	O, AOO, DBE, BDBE, SA	H/L	No

* The experts did not reach a consensus regarding these ranges. In each case, the highest range was placed in the table. In no case did the range vary more than one classification (i.e., Author A chose 5-10 years and Author B chose < 5 years. At no point did Author A chose 10-15 years and Author B chose < 5 years.)

** When the exact facility name is unknown, the laboratory designation is used.

*** If Solar and Fossil Energy can be convinced to uses sodium as their thermal storage medium for solar concentration and then decided to couple as S-CO_2 power conversion loop

External Feedback

In early April, a draft of the report was distributed to a limited audience of stakeholders including:

- Academics,
- Industrial Partners
- Laboratory Personnel

For minor comments, in-text changes were incorporated into the final report.

When author consensus could not be reached, the comments were summarized and placed in a feedback section at the end of the report. Brief author responses were included.

- 3 Laboratory Comments
- 4 Industrial Partner Comments

Summary of SFR Research Plan Recommendations

Coordinated Knowledge Management and Preservation Effort ($400K-$4M)

- Documentation of safety related codes and experiments risk being lost
- Piecemeal and underfunded efforts will lead to lost information which will have to be reproduced in the future

Improvements to U.S. safety related codes ($1.3M-$23M)

- Adequate stewardship and documentation of U.S. safety related codes required for licensing (e.g., LIFE-Metal)
- Modernization of U.S. Codes to satisfy current licensing needs
- Code (e.g., SAS4A) improvements related to seismic response of the entire SFR system will be required post-Fukushima
- Probabilistic safety analysis of containment response capabilities need to be developed for SFRs within the U.S. (i.e., incorporation of sodium phenomena into MELCOR)

Continued U.S. experimental facility utilization, even if on a small scale ($6M-$60M)

- Ensures that future testing capabilities are not lost in budget conscious environments
- Identify testing to address phenomenological uncertainties which could be performed to maintain facilities

Treatment of the Applied Technology (AT) designation must be streamlined

- The current process makes removing AT designations on documents which no longer need to be protected extremely difficult.
- The U.S. NRC is not set up to handle AT documents.