OAK RIDGE National Laboratory

# Fuel Salt Qualification Method Overview

Advanced Reactor Stakeholder Meeting (On-line)

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April 22, 2020

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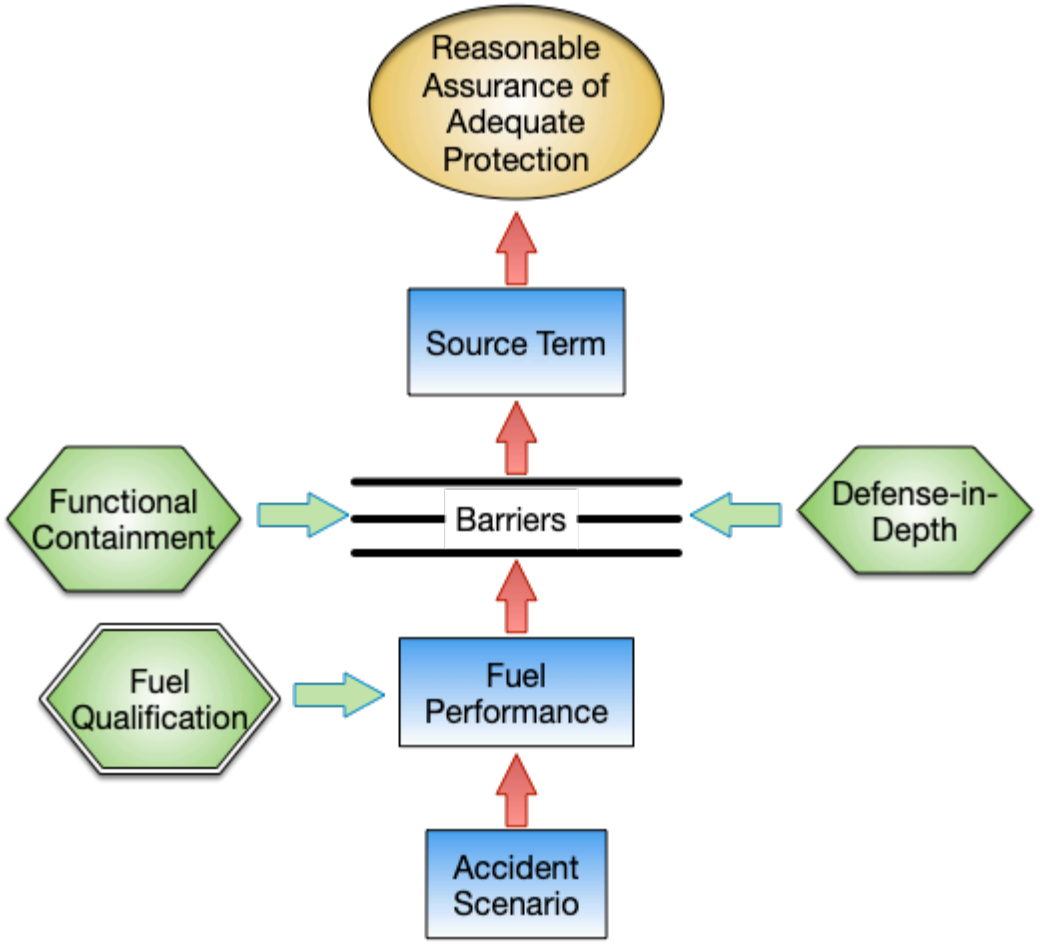
U.S. DEPARTMENT OF ENERGY

# Fuel Qualification is an Element in Achieving Sufficient Understanding of Fuel Behavior




Fuel qualification is a process which provides high confidence that physical and chemical behavior of fuel is sufficiently understood so that it can be adequately modeled for both normal and accident conditions, reflecting the role of the fuel design in the overall safety of the facility. Uncertainties are defined so that calculated fission product releases include the appropriate margins to ensure conservative calculation of radiological dose consequences. - ML17220A315

# No Qualification Method Appropriate for Liquid Salt Fuel Currently Exists

- Existing fuel qualification methodology is based upon the characteristics and safety functions of solid fuels
- Role of liquid fuel salt in plant safety is significantly different from solid fuels
  - Physical and chemical behaviors are significantly different
- Stakeholders have indicated that significant confusion and delay would result from attempting to apply a solid fuel-based methodology to liquid salt fuel

| Safety Functions | |
|---|---|
| **Solid Fuel** | **Liquid Salt Fuel** |
| Retain radionuclides | Retain some radionuclides |
| Maintain coolable geometry | Provide decay heat removal |
| Provide net negative prompt reactivity feedback | Provide net negative reactivity feedback |

# Key Issue is "What Constitutes Fuel Salt?"

- Fuel salt does not come in discrete elements (rods or assemblies) and moves independently of its container during normal operations
  - Cladding and fuel assembly structures are qualified as part of solid fuel
- Fuel salt includes all of the material containing fissionable elements or radionuclides that remain in hydraulic communication, but not the surrounding systems, structures, or components
  - Salt vapors and aerosols remain part of the fuel salt system until they become trapped adequately
  - Container corrosion products become part of the fuel salt
  - Fresh and used fuel salt in on-site storage are within scope

# Qualification is Based Upon Understanding the Chemical and Physical Properties of Representative Fuel Samples

- Liquid state significantly changes the physical behavior of fuel
  - Liquids do not accumulate internal stresses
    - No history dependent properties
  - Flow homogenizes fluid properties
    - No position dependent properties
    - No size dependent properties
- Chemical and physical properties are set by elemental composition and temperature
  - Independent of isotopic content

**Small non-radioactive liquid fuel salt samples provide representative physical and chemical properties**

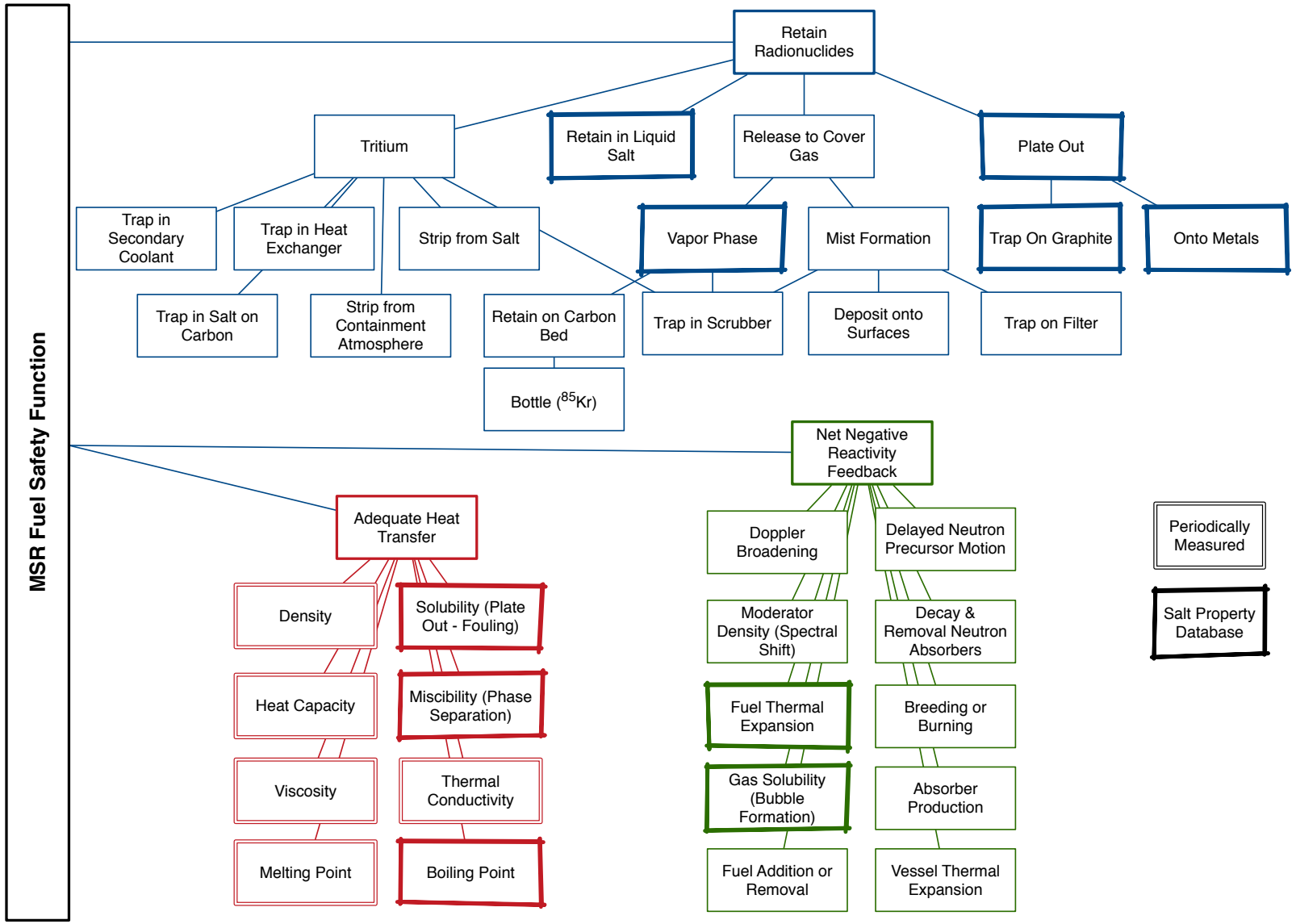
# Liquid Fuel Salt Qualification Establishes Acceptable Salt Composition Range That Maintains Safety Functions

- Liquid fuel salt is a Newtonian fluid
  - Heat transfer and fluid flow behave in well known manners
  - Continuous variance in physical properties with composition
- Reasonable assurance of adequate protection derives from a combination of measured salt composition and knowledge of consequent chemical and physical properties
- A liquid fuel salt property database would capture the relationship between fuel salt composition and properties

# Liquid Salt Property Database Relates Composition to Physical and Chemical Properties

- Database development underway under DOE-MSR campaign
  - Salt property measurement program in progress
    - Not currently including minor constituent transuranic elements (Am, Cu)
  - Requires appropriate quality assurance for both new and existing data
- Database initially sparsely populated
  - Safety evaluations / accident models performed with bounding values to establish acceptable performance range
- Additional data added to database over time
- Goal is to eventually only require salt composition measurement at operating plants and look up properties from database

# Database and Measured Properties Combine To Support Safety Function Demonstration



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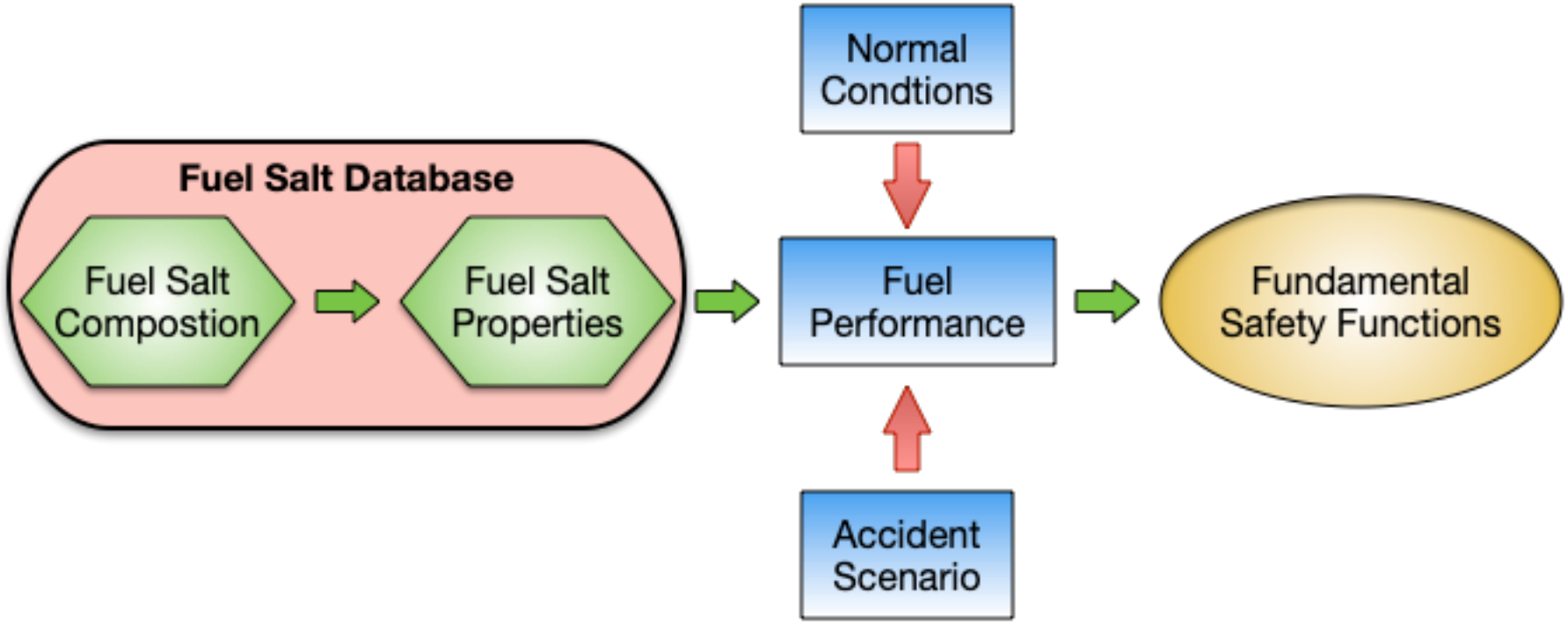
# Fuel Salt Properties Support Modeling Reactor Performance Under Normal and Accident Conditions

- Heat transfer in Newtonian fluids is determined primarily by density, viscosity, and heat capacity
  - Thermal conductivity and radiative heat transfer parameters can become important in specialized situations



# Periodic Fuel Salt Property Assessment Will Be an Element of Reactor Operations

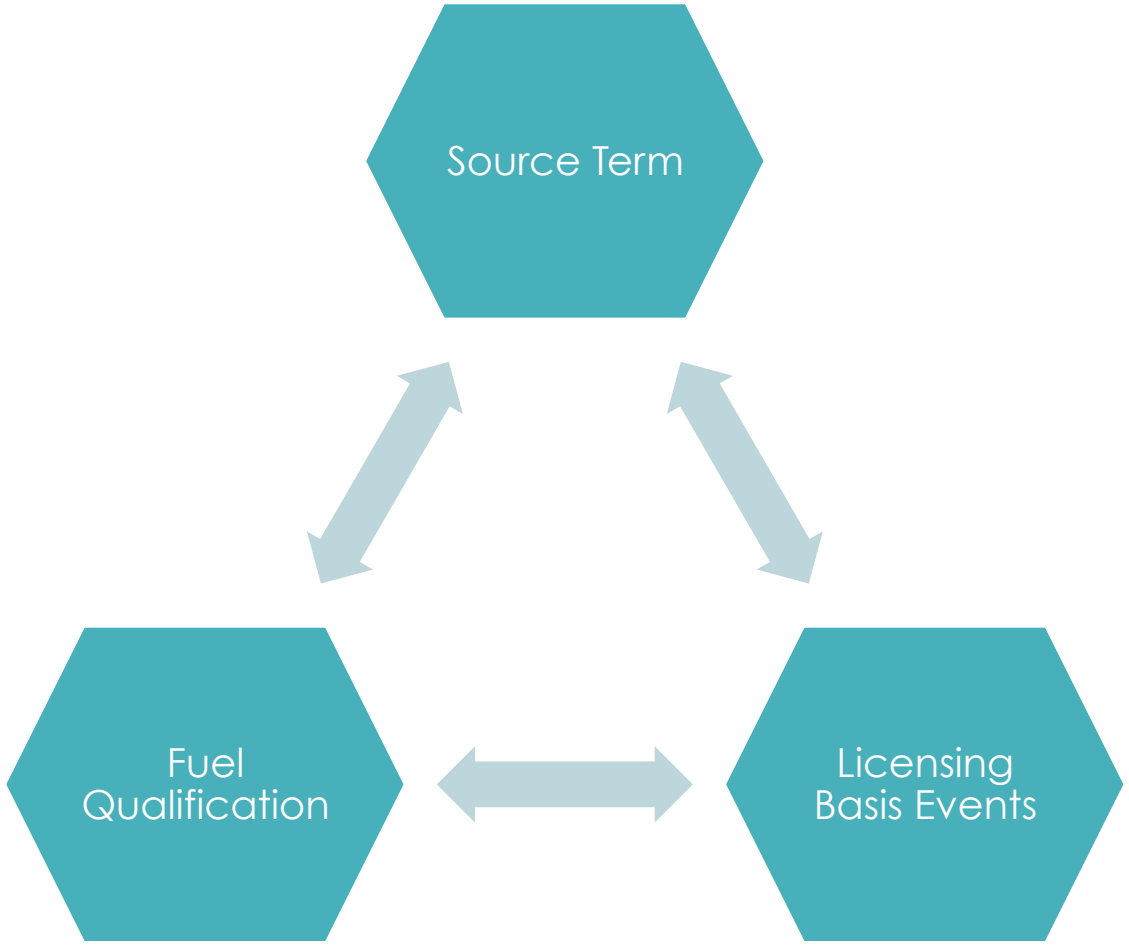
- Analogous to material surveillance coupons
  - Compare measurement to prediction
- Frequency of property measurement depends on potential rate of change and how close salt composition is to allowable limits
  - Chromium composition was measured weekly at MSRE
  - Uranium content was inferred from reactivity impact
  - MSRE did not accumulate sufficient fission products to require reassessing most properties: density, viscosity, etc.

# Fuel Salt Properties are a Significant Part of Establishing a Mechanistic Source Term

- SECY-92-092 (ML040210725) establishes requirements for advanced reactors to employ MST

1) The performance of the reactor and fuel under normal and off normal conditions is **sufficiently well understood** to permit a mechanistic analysis.
2) The transport of fission products can be **adequately modeled** for all barriers and pathways to the environs, including specific consideration of containment design.
3) The events considered in the analyses to develop the set of source terms for each design are selected to **bound severe accidents and design-dependent uncertainties**.

# Fuel Salt Qualification is an Element of MSR Safety Evaluation




- DG-1353 or maximum hypothetical accident approach can be used to identify licensing basis events[1]
  - Accident progression models and tools
  - Barrier performance
- Advanced reactor siting criteria based upon radiological consequences from design-specific characteristics[2]
  - Bounding simplifications may be possible[3]

[1] Non-Light Water Review Strategy Staff White Paper Draft, ML19275F299,
[2] NRC Staff White Paper, Population-Related Siting Considerations for Advanced Reactors, ML19163A168
[3] ACRS Review of Draft SECY Paper, Population-Related Siting Considerations for Advanced Reactors, ML19277H031