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Advanced Sodium Fast Reactor Source Terms: Research Needs

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Albuquerque, NM

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Define Accident Source Term

- **Objective**
  - Define research needed to mechanistically model an accident source term for advanced sodium-cooled fast reactor suitable to meet the requirements of 10 CFR 100.11
    - Appreciable radionuclide release to the reactor containment or confinement not exceeded by any accident deemed credible
- **Constraints**
  - Design not fixed
    - Pool versus loop
    - Oxide versus metal fuel
  - Accident scenarios leading to radionuclide release not specified

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Approach

- **Expert Opinion Elicitation**
  - **Substantial sodium reactor source term expertise resides outside the USA**
- **Assembly of Background Literature**
  - **Much preliminary work done for CRBR, FFTF, as well as Japanese and European fast reactors**
  - **Panel member from Japan was able to augment the background information base with more recent work**
- **“Strawman” starting point for candidate topics and information status**

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Panel Members

- **D.A. Powers** (chairman): Sandia
- **Bernard Clément**: Institut de Radioprotection et Sûreté Nucléaire, France
- **Richard S. Denning**: professor, Ohio State University
- **Shuji Ohno**: Computational Fast Reactor Engineering Group, Advanced Nuclear System Directorate, JAEA
- **Roland Zeyen**: Institute for Energy, Petten, The Netherlands

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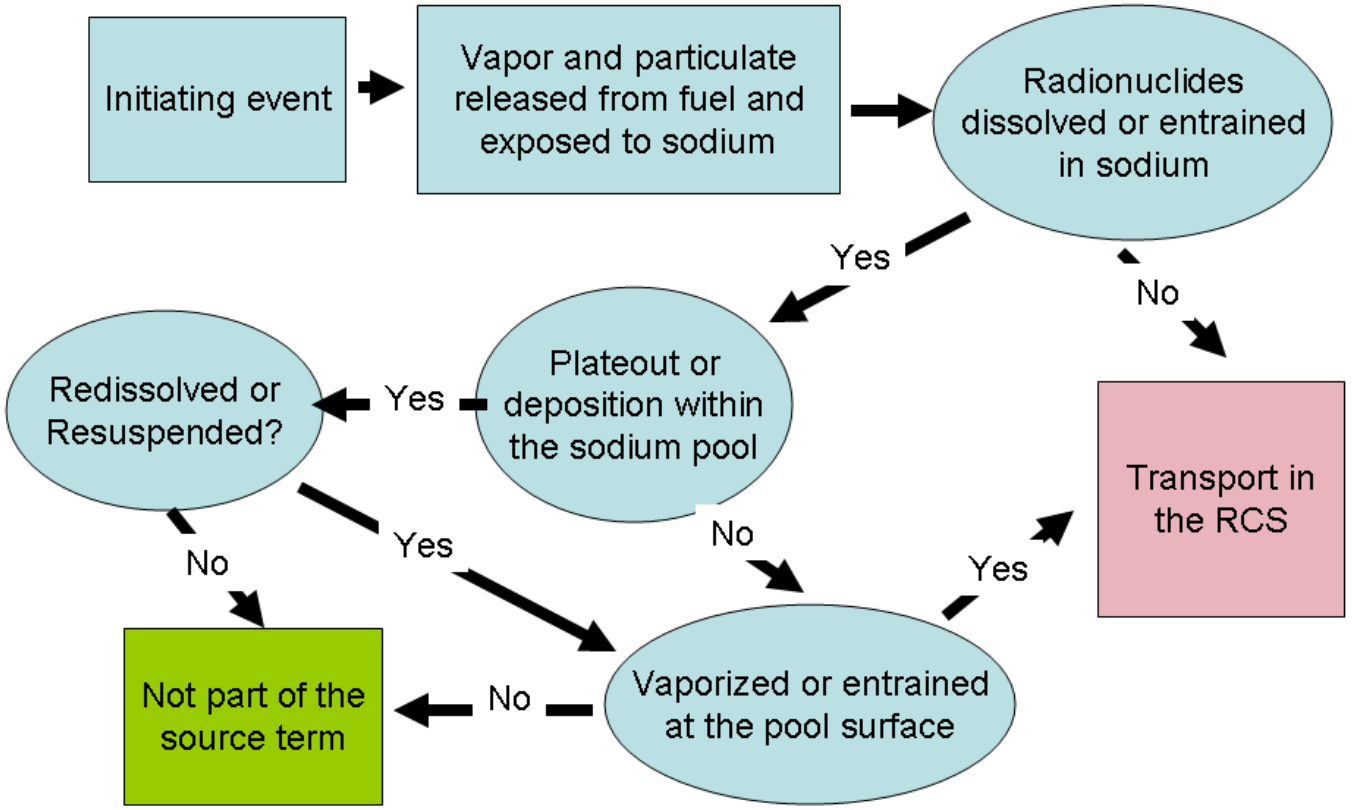
Generic Accident Sequence

- **Accident initiation event** (intended to handle any accidents eventually defined for the reactor)
- **Energetic core damage**
- **Slow core damage (“transition” phase)**
- **Quiescent sodium pool leaching radionuclides from damaged fuel that may or may not be coolable**
- **Radionuclide transport in the reactor coolant system**
- **Radionuclide behavior in the containment**
- **Sodium fires (spray and pool) and sodium interactions with concrete**



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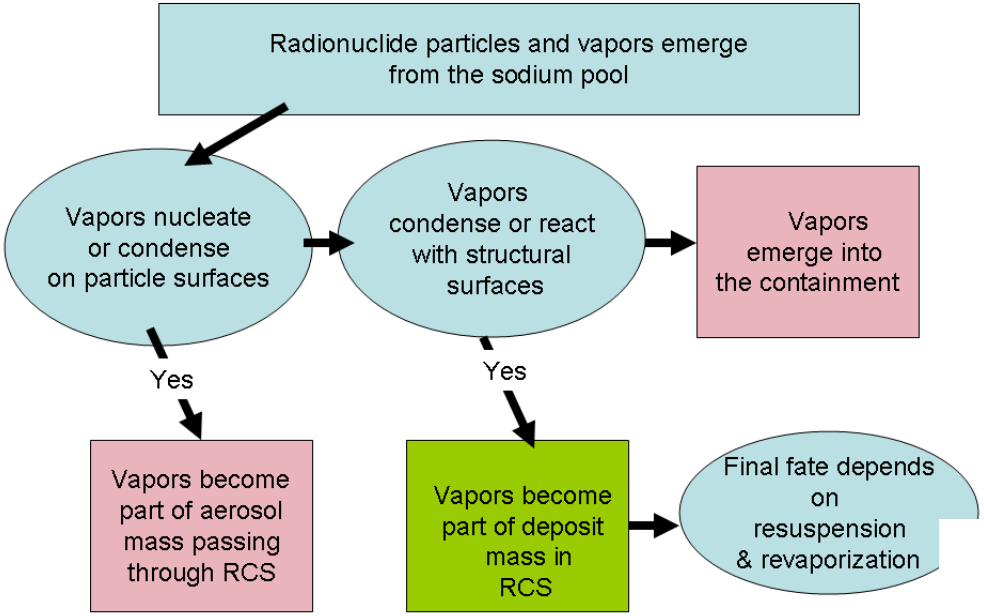

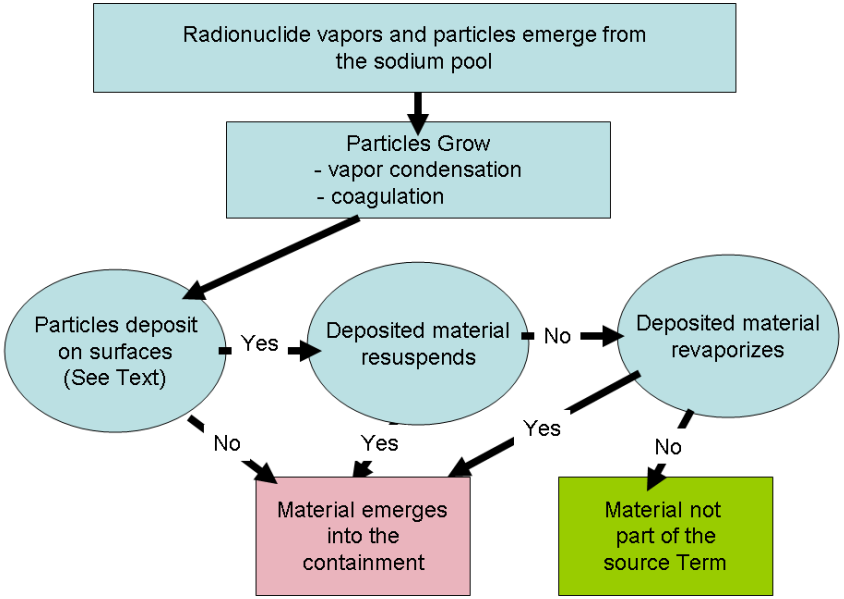

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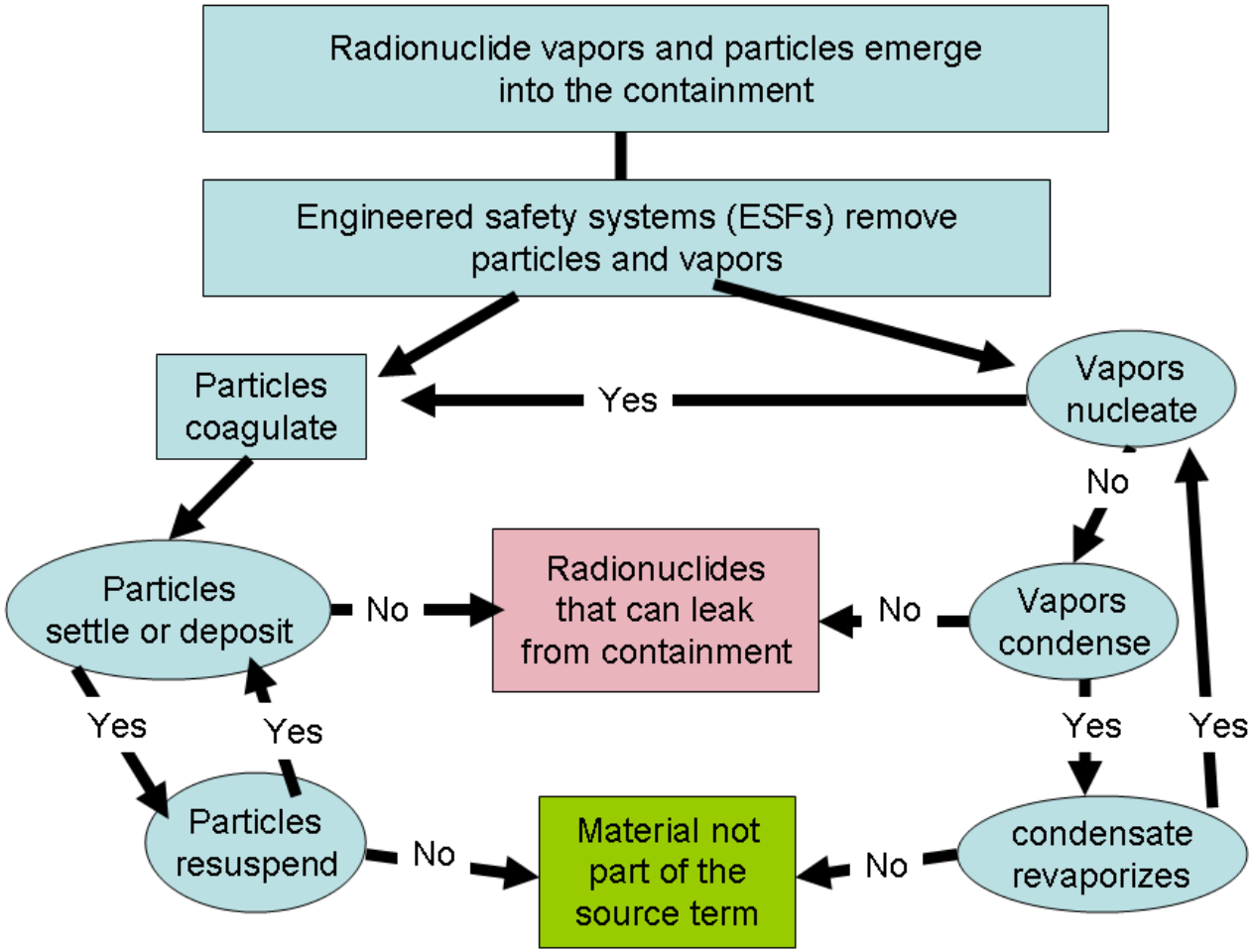

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Note

- **Panelists did not explicitly explore releases from sodium fires or sodium interactions with concrete**
  - **Consensus opinion that if there was sufficient technical knowledge to handle radionuclide behavior from the fuel, through the reactor coolant system and into containment, then radionuclide behavior in fires and sodium/ concrete interactions could be handled.**

Expert Opinion Elicitation

- **Importance of 71 technical issues identified by panelists**
  - **High: essential to consider in the development of a mechanistic source term model**
  - **Medium: should be considered in a mechanistic source term model**
  - **Low: can be considered to improve accuracy and defensibility of a mechanistic source term model, but will not greatly change predicted results**
- **Need for additional research on issue**
  - **High: insufficient data or understanding to formulate confidently even an approximate model**
  - **Medium: further research would greatly improve the quantitative accuracy of a mechanistic model**
  - **Low: further research could be used to refine a mechanistic model**
- **Consensus derived from individual rankings**
  - **Concurrence after review by panelists**

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Issues of High Importance and High Merit for Additional Research

- **Radionuclide release from reactor fuel during energetic event.**
- **Radionuclide behavior during energetic interactions of molten fuel with sodium.**
- **Entrainment of radionuclide contaminated 'sodium bond' of metal fuel during fuel rod depressurization.**
- **Radionuclide leaching from cooled, but damaged, reactor fuel.**
- **Enrichment of sodium pool surfaces by dissolved or suspended radionuclides.**
- **Thermal decomposition of sodium iodide to form gaseous iodine.**
- **Formation of organic iodides in containment.**

Issues of High Importance and a Medium Need for Additional Research

- Sodium vapor bubble growth and radionuclide scrubbing from bubble
- Mass transport within rising sodium bubbles
- Accumulation of radionuclides in sodium bond on metal fuel
- Chemical form of radionuclides in fuel and fuel/cladding gap
- Chemical activities of radionuclides in the fuel
- Solubilities of radionuclides in sodium contaminated with various levels of oxygen
- Chemical activities of radionuclides in sodium contaminated with oxygen
- Nucleation and growth of radionuclide particles in liquid sodium
- Multicomponent gas phase diffusion of radionuclides across gas-liquid interface
- Entrainment of contaminated sodium by bubbles bursting at the surface
- Revaporization of radionuclide deposits in the reactor coolant system

Notable

- Neither high nor medium needs for additional aerosol research
- No important needs for research on engineered safety systems used to mitigate radionuclide inventory suspended in containment
- Many research issues disappear for reactors immune to energetic initiating events
- Some interfacial issues with thermal hydraulics
  - Convective mass transport in sodium pool and fuel debris bed
  - Flow over the sodium coolant