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Molten Salt Reactor Safety Evaluation - A US Perspective

Summary / Objectives:

Reactor safety is evaluated to demonstrate that a plant's operation does not present significant additional risk to the life and health of the public. Reactor safety evaluation historically focused on maintaining adequate containment of radionuclides during the maximum credible accident. However, as progressively larger light water-cooled reactors (LWRs) were developed in the 1960s, the increased potential for catastrophic accidents necessitated expanding the safety adequacy from the containment of radionuclides under all conditions to the prevention of accidents and the mitigation of their consequences. **Either a deterministic or probabilistic pathway could be taken to demonstrate the safety adequacy for US molten salt reactors (MSRs).** The deterministic pathway relies on adapting accepted minimum design criteria for LWRs to MSRs, whereas the probabilistic pathway relies on adequately modeling the risks of MSR accidents to discern what can occur, how likely it is to occur, and the consequences of its occurrence. MSR designs as envisioned have a readily apparent high degree of passive safety. **Their combination of low pressure, low stored energy within containment, negative reactivity feedback, and effective passive decay heat removal substantially reduces the potential** for cascading and escalating events. This MSR resiliency opens a third demonstration pathway that refocuses safety adequacy on containment of credible accidents, precluding the need for complete probability information. This approach would be especially useful for early prototype plants which lack sufficient performance data to take advantage of higher fidelity, data-driven risk modeling. This webinar will describe the current status and comparative advantages of the three alternative MSR safety adequacy demonstration pathways.

Meet the Presenter:

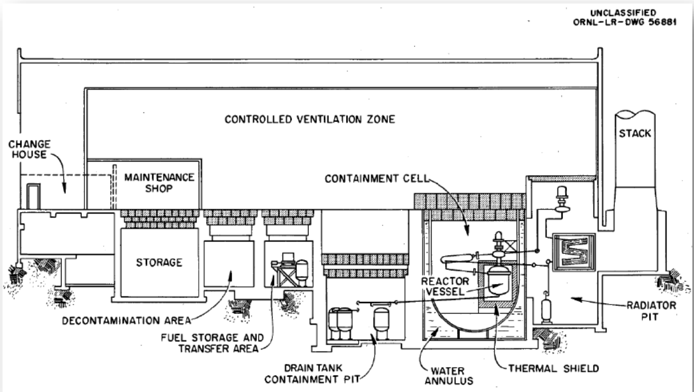
Dr. David E. Holcomb is a distinguished member of the technical staff and distinguished inventor **at Oak Ridge National Laboratory (ORNL).** Dr. Holcomb currently represents the U.S. and serves as a vice chair of the provisional system steering committee for the Generation IV International Forum on MSRs, chairs the American Nuclear Society's working group developing a design safety standard for liquid fueled MSRs (ANS 20.2), and provides technical oversight of DOE's university projects on MSRs.

1. Functional Containment Provides Performance-Based Evaluation of Radionuclide Retention

Example of **containment system** employed at Molten Salt Reactor Experiment (MSRE) are explained.

Functional Containment Provides Performance-Based Evaluation of Radionuclide Retention

- Multiple barriers - some of which are not normally stressed
  - Barrier performance requirements depend on their safety function
- Segmented containment
  - Limits accident scope
- Independent barriers
  - Failure of single barrier does not substantially stress other barriers
  - Minimizes potential for cascading or escalating failures



Multi-Layer, Segmented Containment at Molten Salt Reactor Experiment (MSRE)

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2. MSRs Present Different Safety Analysis Challenges Than Other Reactor Classes

Specific safety features due to radionuclides distributed system and less operating experience are summarized.

MSRs Present Different Safety Analysis Challenges Than Other Reactor Classes

- Radionuclides distributed across plant
  - Solid fuel concentrates radionuclides in core and used fuel pool
  - Gaseous fission products inherently separate from fuel salt
  - Integrated fuel salt processing possible
  - Salt wetted components have limited lifetimes resulting in unconventional high-activity waste stream
- Less (and dated) operating experience
  - Only one prior reactor operating for significant period
    - MSRE ~7.34 MWth operated from 1965-69
  - No large-scale reactor or component demonstrations
  - No fast spectrum systems demonstrated
  - Minimal prior accident performance demonstrations

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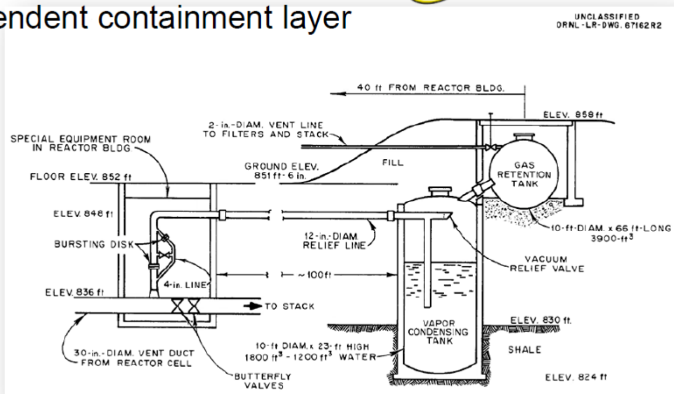
3. MSRE Employed MCA for Siting Evaluation

Safety adequacy of MSRE was evaluated by **a combination of hazard assessment and containment of the maximum credible accident(MCA)**

MSRE Employed MCA for Siting Evaluation

- MCA was based upon a dual, independent containment layer failures
  - Water spill to pressurize containment sufficiently to induce significant leakage in second containment layer
    - Pressure relief and radionuclide capture using rupture disk isolated vent line to suppression pool and gas retention tank
    - Potential for manual final venting



  - MSRE had two quasi leak-tight containment layers plus low leakage reactor building / confinement
    - Dose following MCA was due to residual postulated leaks (1%/day) in exterior containment due to pressurizing to 2.7 atmospheres (39.9 psi)
    - Required continuing to actively vent reactor building to disperse radionuclides

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4. MSRs Retain the Potential of Containing All Credible Accidents At Any Scale

Perspective of safety assurance of MSR as well as challenging points are explained

MSRs Retain the Potential of Containing All Credible Accidents At Any Scale

- Avoiding potentially cascading accidents (especially accident sequences that pressurize containment) key consideration
  - MSRE type suppression pool – capture tank system would be quite large for commercial-scale plants
- System immaturity necessitates additional conservatism (design requirements) to ensure containment survival
  - High degree of passive safety minimizes additional cost
  - Reliable quantitative performance data and models would decrease required conservatism
- Additional requirements intended to prevent single event from damaging all containment layers – e.g. core catcher or guard vessel employed to maintain decay heat removal capability following vessel rupture

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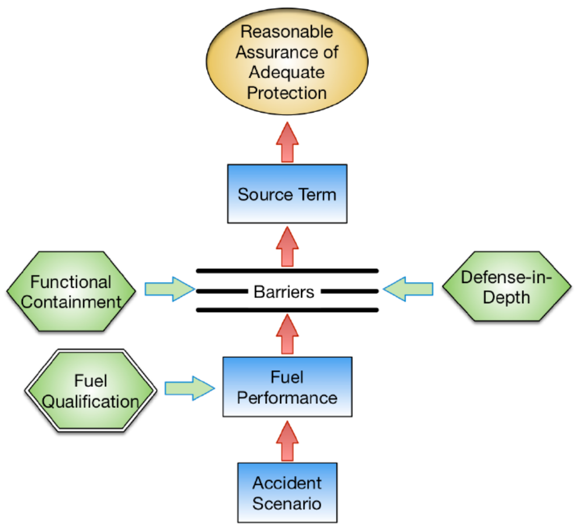
5. Qualified Fuel Salt is Key to Reliably Modeling MSR Performance

It is important to understand the chemical and physical behavior of the fuel salt adequately to model its performance in both normal and accident conditions

Qualified Fuel Salt is Key to Reliably Modeling MSR Performance

- Need to understand the chemical and physical behavior of the fuel salt adequately to model its performance in both normal and accident conditions
- Currently key focus of US national MSR activities is to develop adequate data to qualify fuel salt
- NRC is currently supporting activities to define acceptable liquid fuel salt qualification methods



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MSR Safety Adequacy Evaluation Capabilities Are Advancing on Many Fronts

The present status of capability with some challenging points are summarized.

MSR Safety Adequacy Evaluation Capabilities Are Advancing on Many Fronts

- Don't yet have a complete and mature set of capabilities
- Preferred method for MSR safety adequacy demonstration will evolve as experience is gained with the technology
- Need to continue to advance fuel salt property understanding, modeling tool capabilities, as well as safety evaluation methodologies
- Distributed radionuclide configuration during normal operations necessitates a new material accountancy tool
- Most significant experimental hole is lack of data to model decay heat removal following fuel salt boundary rupture

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