Small Modular Reactors
Source Terms

October 28, 2014

Review of Activities

- SECY-10-0034
  - SMR iPWR source terms based upon
    - Information from current generation LWRs
    - Understanding of accident phenomena, including fission product transport and release
- NRC memo dated 12/29/2011
  - Plans to address methods to determine mechanistic source term
  - Contributes to staff's evaluation of siting, EP and other areas
  - Anticipates industry proposing a detailed calculation methodology

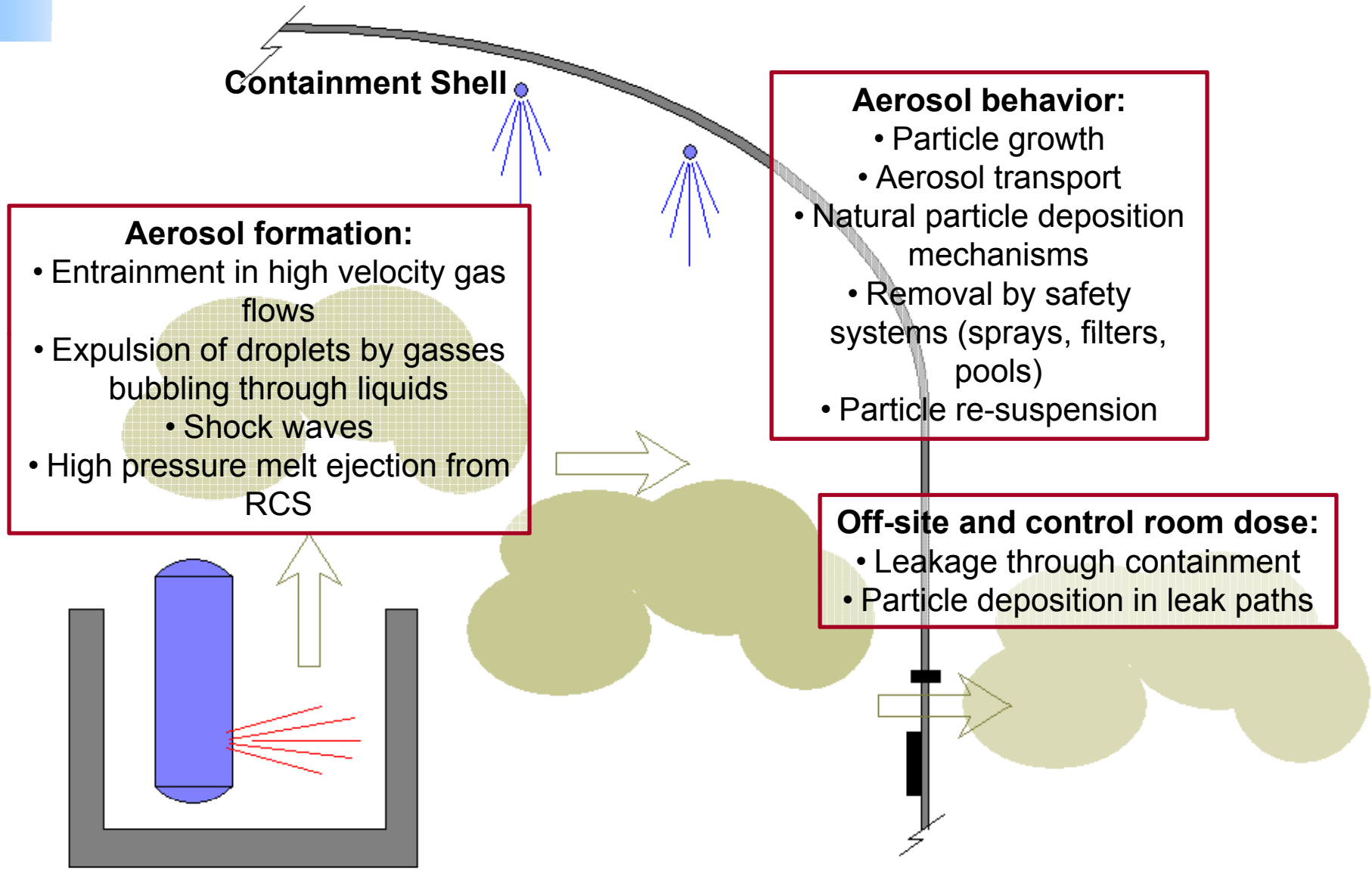
Review of Activities (cont'd)

- NEI position paper dated 12/27/2012
  - Areas where the methodology used for LLWRs will be used (Category 1)
  - Areas where the methodology will differ from LLWRs (Category 2)
  - Identifies unique SMR source term issues and path forward to address them
  - Identifies those issues that require additional information

Current Path to Addressing SMR Source Term

- Industry to provide additional information
  - Areas where further generic study is needed
  - Design specific papers
- Containment Aerosol Deposition
  - Identified as highest priority issue for generic resolution in the NEI position paper
  - DOE and EPRI joint study initiated in 2013 and recently completed Phase 1
  - Discuss with NRC and determine what additional information is needed

General Containment Aerosol Phenomena



The Need for More Information on Aerosols

- **Impact**
  - The behavior of aerosols in containment is an important component in the evaluation of on-site and off-site **doses**.
- **Why new testing?**
  - SMR containment designs contain **features that are different** from conventional, large light water reactors (LWRs).

Development of an approach for evaluating the **deposition of aerosols** in current light-water-based Small Modular Reactors (SMRs).

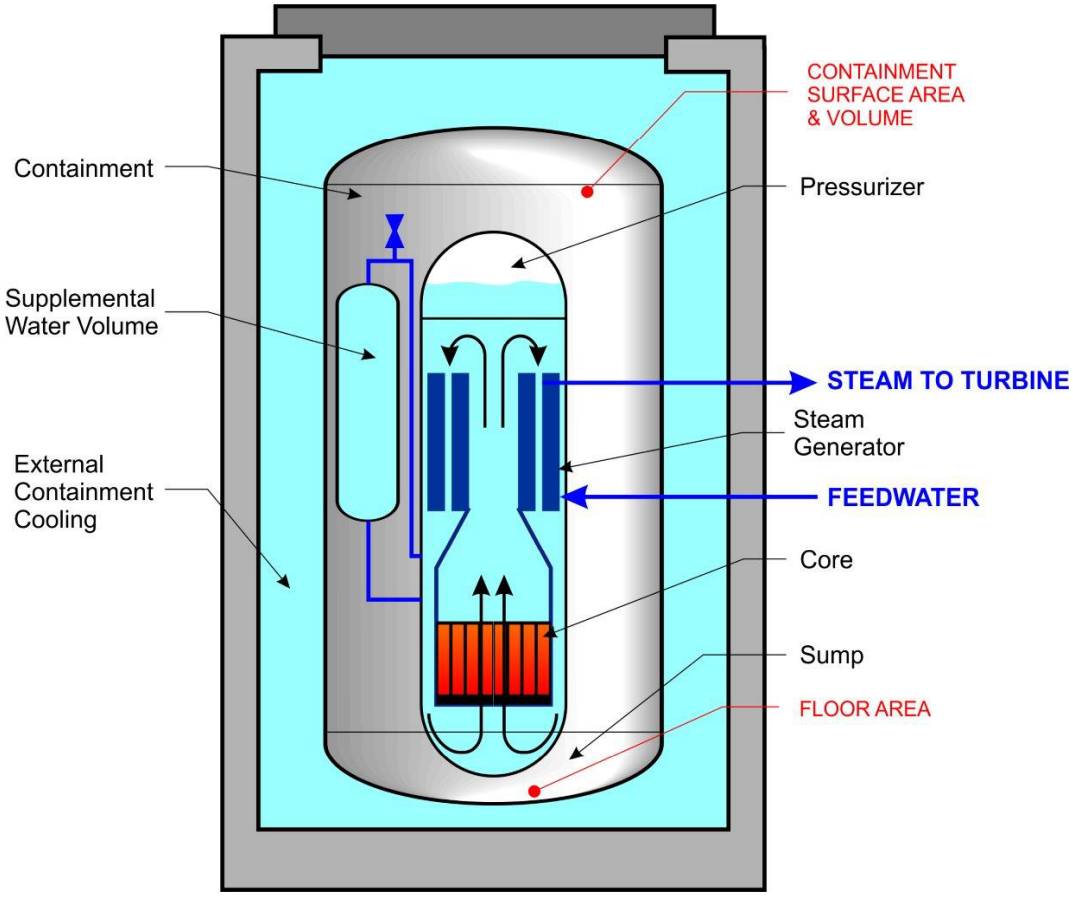
EPRI/DOE Project Background

- Funded in October 2013 for 6 months via contract to Lucius Pitkin and Sandia National Laboratory
- Investigation Phase Tasks:
  - **Task 1 – Generic Containment Model for Aerosol Deposition in SMRs** for Westinghouse, mPower, NuScale and Holtec designs.
  - **Task 2 –** Review of U.S. and international post-1993 **aerosol deposition test data** for applicability to SMR containment post-accident conditions and geometries.
  - **Task 3 – Complete review of correlations** for coagulation, condensation, phoretic, and diffusive deposition mechanisms and evaluate applicability to SMR containment design and expected post-accident conditions.
  - **Task 4 –** Evaluation of need for **additional SMR containment aerosol tests** and revisions to aerosol deposition correlations for SMRs.

Evaluated Containment Aerosol Deposition Processes and their Key Parameters

- Gravitational Settling
  - Particle size
  - Particle density
- Thermophoresis
  - Temperature and thermal gradient
  - Particle and gas thermal properties
- Diffusiophoresis
  - Steam quality
  - Steam and particle temperature and pressure
  - Steam thermophysical and diffusive mass properties

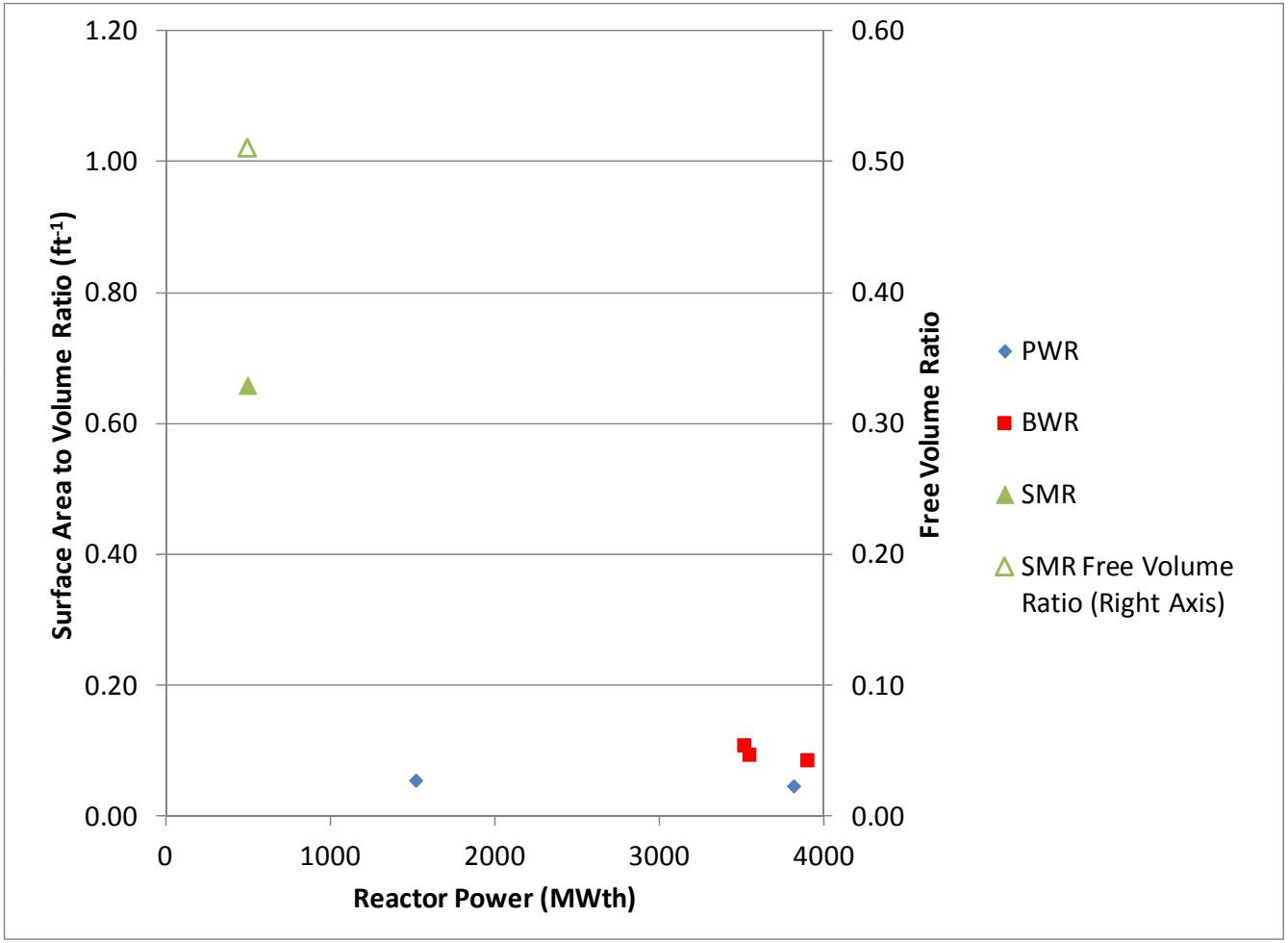
Generic SMR Containment Model



Generic SMR containment[1]

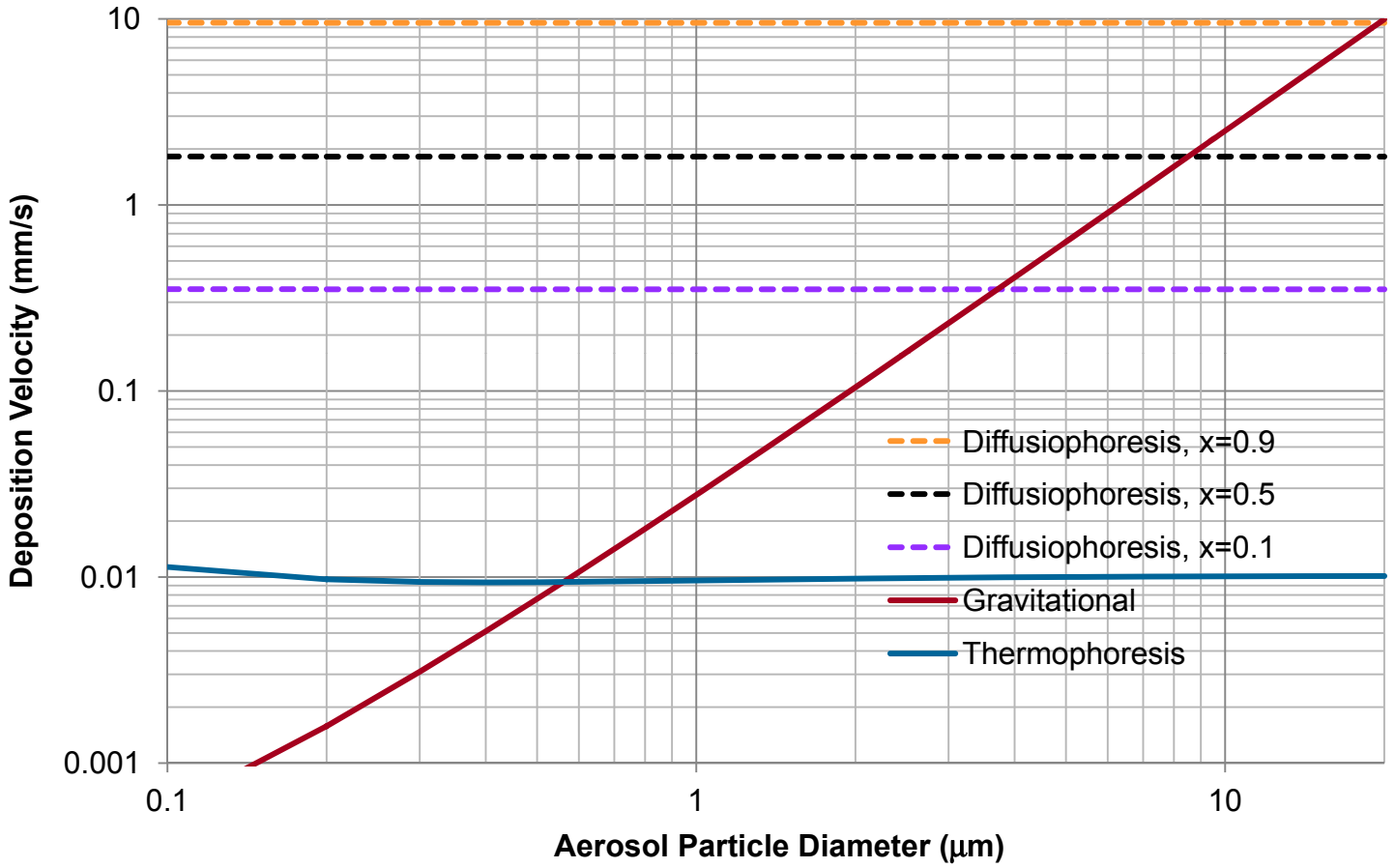
[1]Conglomeration of design data provided by Holtec, mPower, NuScale Power, and Westinghouse for their SMR designs

Generic SMR Containment Model



Containment Surface Area to Volume Ratio

Key Result – Impact of Diffusiophoresis



Comparison of Respirable (≤20 micron) Aerosol Particle Deposition Velocities for Diffusiophoresis, Gravitational, and Thermophoresis Processes
(x is the steam mole fraction)

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Diffusiophoresis is Important to SMR Containment Aerosol Deposition

- Steam condensation on particles causes increased deposition
- Small SMR containments have higher steam content than large LWRs
- Small SMR containments offer increased exposure time and surface area for aerosols to interact with steam
- Diffusiophoresis respirable particle deposition
  - is constant for the respirable range of aerosol particle diameters
  - is 30 to 1,000 times greater than thermophoresis
  - Exceeds gravitational deposition (depending on steam quality)

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Diffusiophoresis Decontamination Factor (DF)

- SMR containments have much larger surface area to volume ratios (SAVR) than large LWRs
- Containment Diffusiophoresis DF is a function of
  - Surface area to volume ratio
  - Magnitude of steam quality
  - Steam residence time
- For generic SMR containment SAVR (0.66 ft^{-1}), 30 minute containment steam residence time DF is:
  - DF= 4 for a quality of 0.1
  - DF> 100 for a quality of 0.5
  - DF>> 100 for a quality of 0.9

Potential Testing to Validate Results

- Objective: Provide data to validate Phase 1 conclusions and to improve aerosol behavior modeling in severe accident codes
- Diffusiophoresis is the phenomena with the largest effect
- Multi-phase test plan identified in report
  - Comprehensive, but results may not be available for SMR design applications
- Industry is considering alternative test plans
  - Limited in scope and focused on the more important phenomena
  - Provide adequate and timely information for SMR design applications

Relevance of EPRI/DOE Conclusions

- Substantiates the enhanced safety of SMR design features
- Effective in reducing the source term and limiting off-site releases from accidents
  - Diffusiophoresis and gravitational settling are large contributors to the decontamination factor
  - Other natural deposition processes that are enhanced by the SMR design can further reduce the source term
- Can be incorporated into regulatory framework for SMRs
  - Safety evaluations (Design basis, and beyond design basis, accidents)
  - Severe accident management
  - Emergency planning
  - Security

Discussion Topics

- Containment aerosol deposition
  - Reasonableness of the conclusions and methodology in the EPRI/DOE report
  - Define an adequate scope of testing that meets the needs of SMR applicants and NRC reviewers
  - Potential submittal to NRC for review and endorsement
- Other areas that need additional information
  - Reactor building fission product dilution and deposition
- Provide clarity to applicants and NRC reviewers on SMR source term development
  - Based upon NEI position paper, design specific papers, and additional generic information
  - Potentially through NRC interim staff guide or industry template