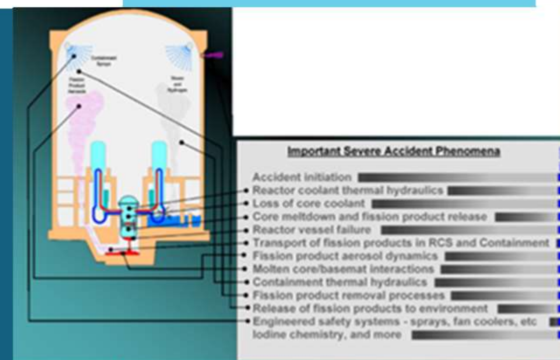
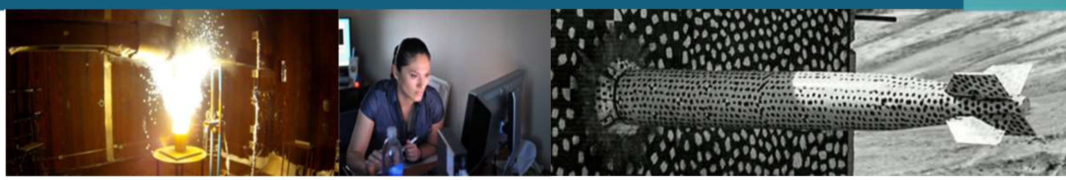
SAND2021-6930C

Sandia National Laboratories

US-Japan BLC-CNWG

Study of Sodium Pool Fire Model Improvement in MELCOR for SFR





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June 14-16, 2021

June 16, 2021

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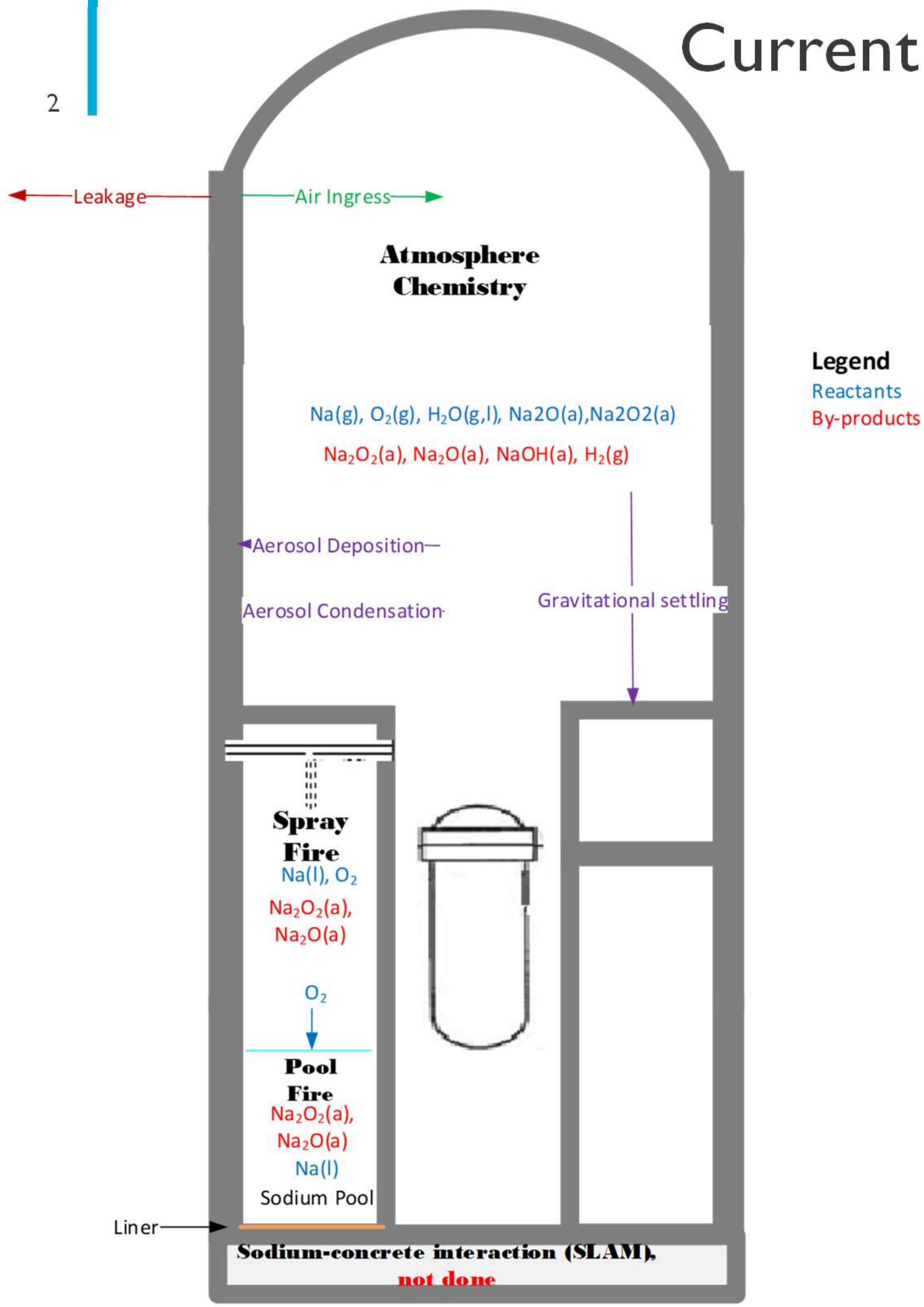
Current Sodium Fire Models in MELCOR



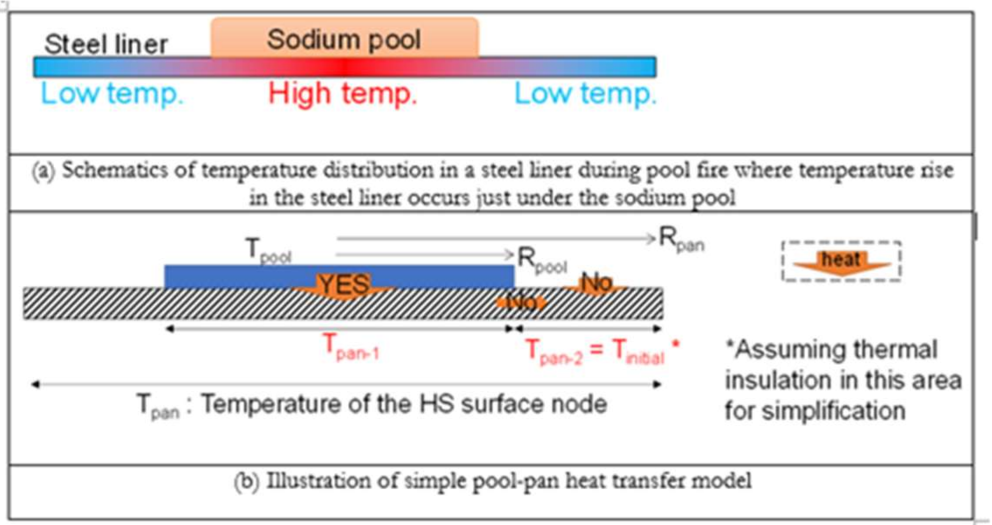
Na_chemistry_Diagram_vCa.vsdx

- Under U.S. DOE ART-FRP program, most sodium fire models from CONTAIN-LMR had been implemented:
  - Most input parameters for the models are constant
  - Original spray fire model has been added upward spray sub-model
  - Atmospheric chemistry model assumes the water vapor as an ideal gas
  - CF input approach improves the model flexibility and allows sensitivity studies
    - Added CF capability to input key fire model parameters.
- Previous validation works include benchmarks using ABCOVE AB5 and AB1 tests and comparison to CONTAIN-LMR results

Model improvements under CNWG Efforts

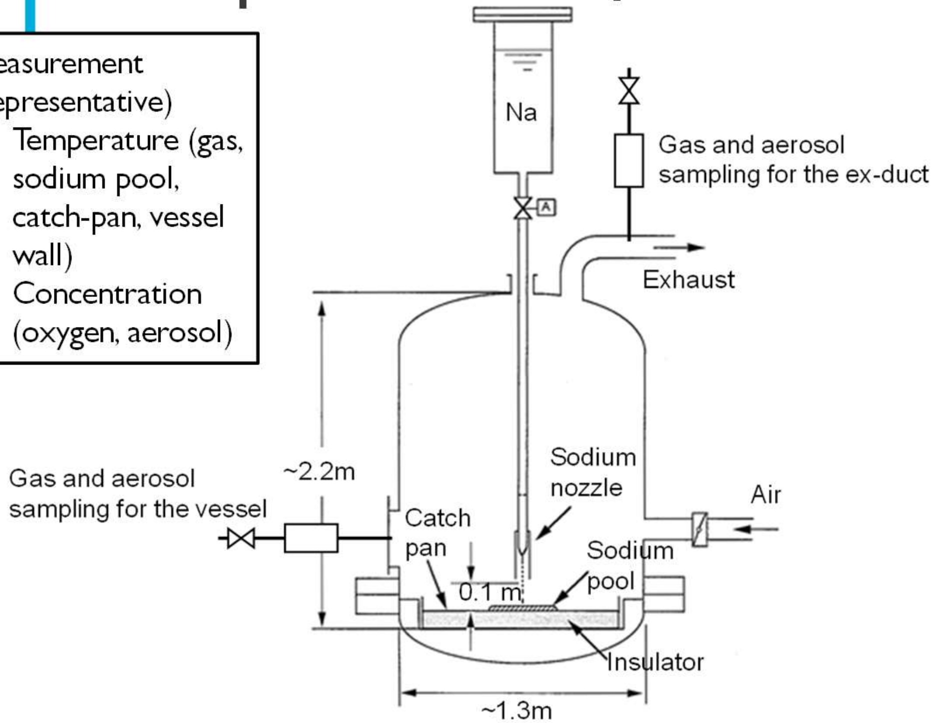
A joined research was identified to improve the MELCOR pool fire model using F series pool fire tests from JAEA

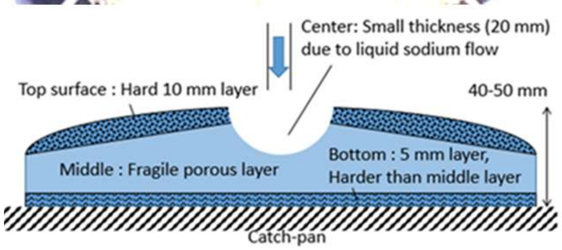
- Using the Control Function input capability to enhance models with code modification for the proposed models:
  - Pool heat transfer model
    - Pool-Pan heat transfer – enhanced with pool radius functionality
    - Quasi-2D HT model – partitioning of combustion heat transfer between pool and atmosphere
  - Oxide layer model
    - Correlated diffusion coefficient as function of the oxide layer thickness
    - Consideration of sodium by-products in the pool
  - Pool spreading model
    - Viscosity dependent spreading

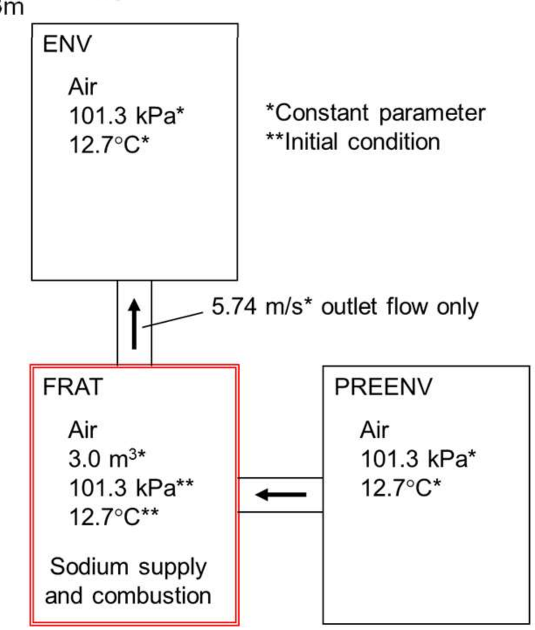


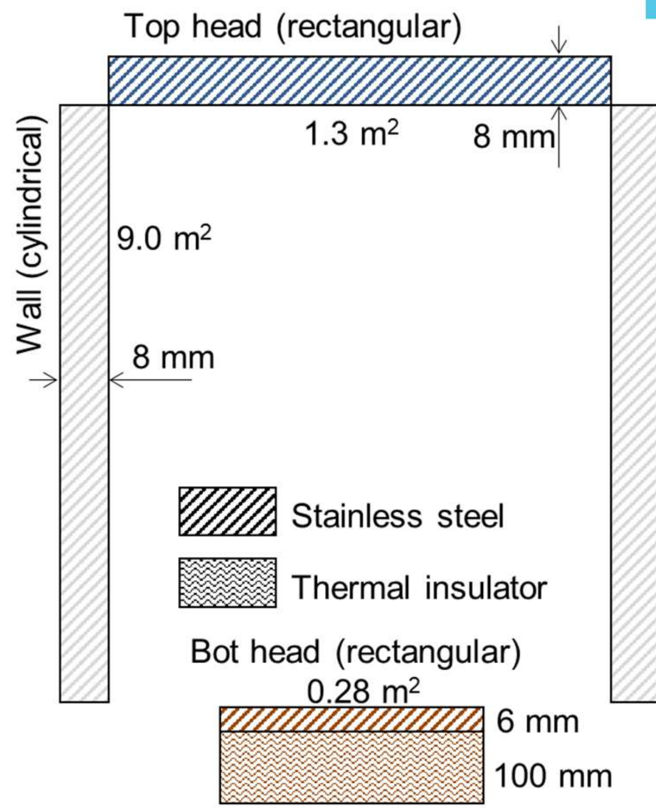
F7-1 pool fire experiment/MELCOR Model

Measurement (representative)
- Temperature (gas, sodium pool, catch-pan, vessel wall)
- Concentration (oxygen, aerosol)









FRAT cell heat structures

Sodium Fire Models used
- Spray fire
- Pool fire

Pool oxide layer model

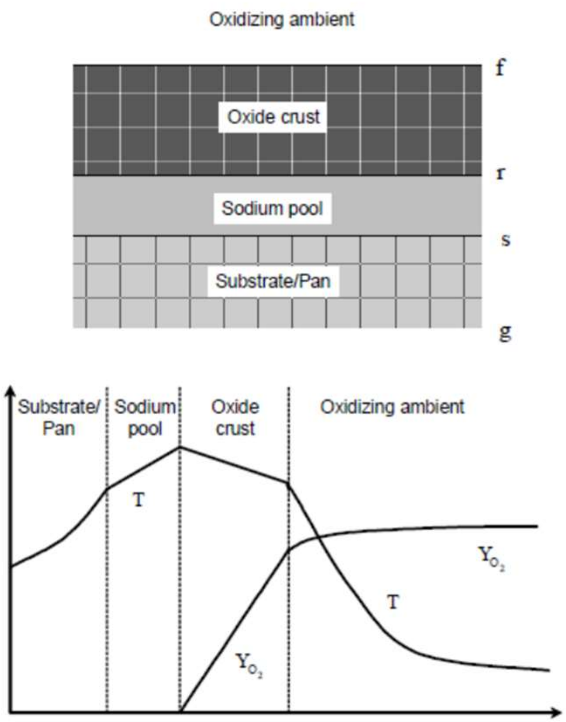
- Oxidation is limited by diffusion through the oxide layer
  - Normal pool combustion

$$\dot{m}_{O2} = A_s H \rho_g Y_{O2} \qquad H = 0.14 D_{diff}\left(g S_c \frac{\beta}{\nu^2}\left|T_{surf} - T_g\right|\right)^{1/3} \qquad D_{diff} = \frac{6.4312\times10^{-5}}{P_g}\left[\frac{\left(T_{surf} + T_g\right)}{2}\right]^{1.823}$$

=DAB: default

  - Oxygen diffusion through the oxide layer [Oliver 2010]

$$\dot{m}_{O2} = A_s\left[\left(\frac{Sh}{L}\right)\frac{D}{1+\delta/\Delta_1}\right]\rho_g Y_{O2,\infty} \qquad H^* = \left(\frac{Sh}{L}\right)\frac{D}{1+\delta/\Delta_1} \qquad D_{diff} = \frac{\left(\frac{Sh}{L}\right)\frac{D}{1+\delta/\Delta_1}}{0.14\left(g S_c \frac{\beta}{\nu^2}\left|T_{surf} - T_g\right|\right)^{1/3}}$$



Schematic of the pool layers, temperature Profile (T), and Oxygen Fraction (YO2) [Olivier 2010]

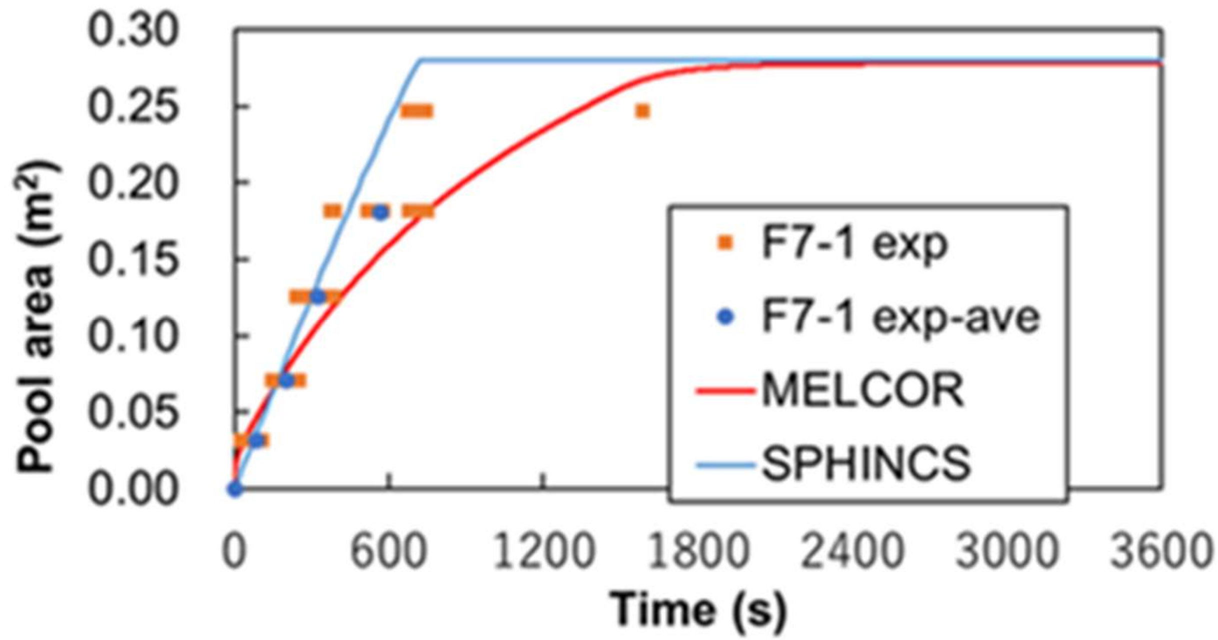
The oxide layer thickness δ is given by the amount of oxide formed in the pool with an assumed porosity function.

[Olivier 2010] Olivier, T.J., et al., Metal Fires and Their Implications for Advanced Reactors Part 3: Experimental and Modeling Results, SAND2010-7113, Sandia National Laboratories, Albuquerque, NM, October 2010.

Pool spreading model

Comparison with the F7-1 data

- The current pool spreading uses an assumed linear rate from experiment data.
- The spreading rate was improved using a viscosity dependent model adapted from the ex-vessel corium spreading model in MELCOR



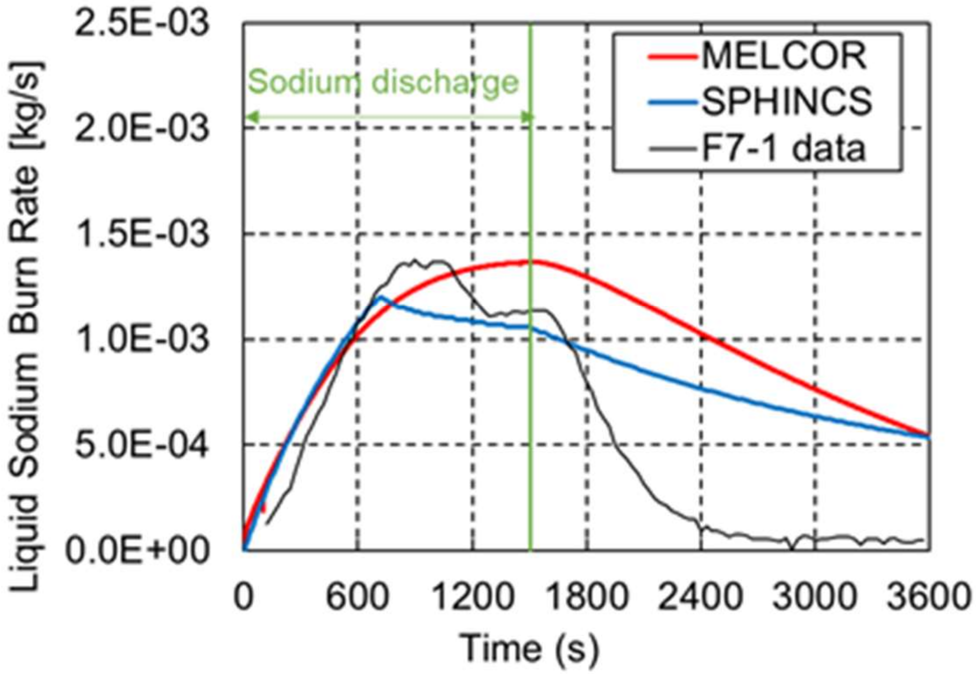
Adapted corium spreading model:

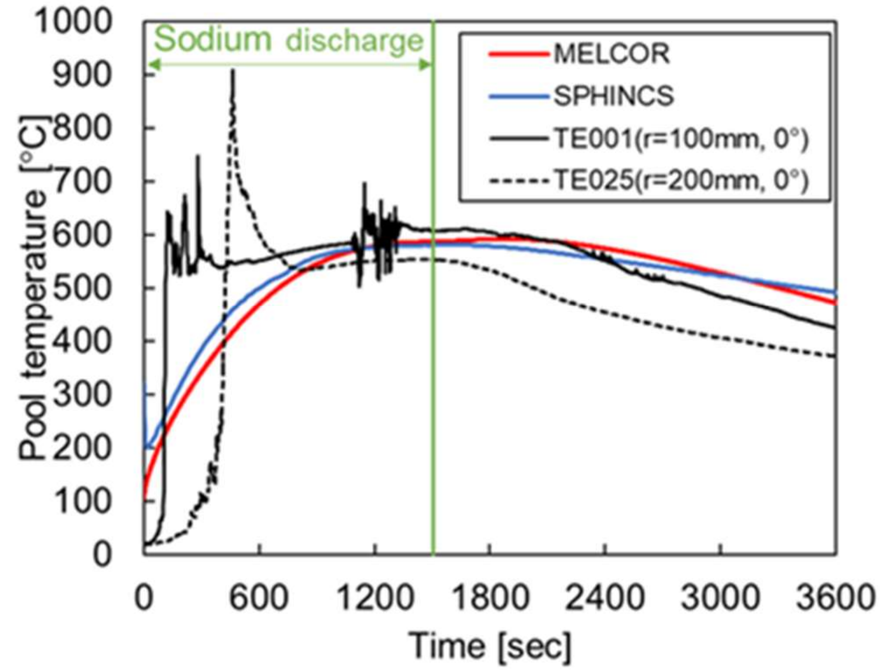
$$\mu \frac{u}{H^2 R} \propto \rho g H \qquad \frac{dR}{dt} = C1 \frac{\rho g}{\mu \, \pi^3} \frac{V^3}{R^7}$$

$$R(t+\Delta t) = \sqrt[8]{R(t)^8 + C1 \cdot \frac{g}{\mu \, \pi^3 \rho^2} m^3 \Delta t}$$

Ramacciotti correlation: $\mu = \mu_0 \cdot \exp(2.5 \cdot C \cdot \varepsilon)$

MELCOR Results



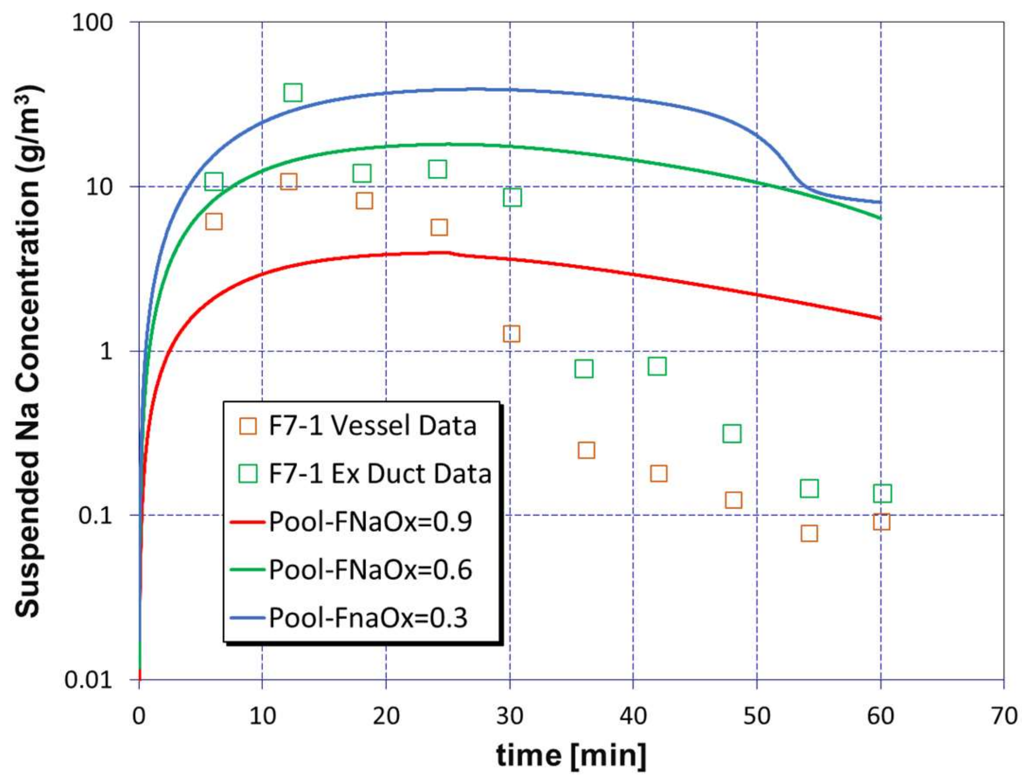


- Model updates show a significant improvement in comparison to key parameters
- Future tasks include:
  - Optimization of additional model parameters
  - Remaining model development
    - 2-D heat structure model when it becomes available
    - Net Enclosure Radiation model
    - Heat capacity of aerosols

Future SNL-JAEA Collaborative Work

- Complete thermodynamic enhancements to pool fire model and assess benchmark using F7-1 and F7-2 test data
  - Incorporate Network Enclosure Radiation Model
  - Examine the impact of the aerosol heat capacity on the thermal-hydraulic response

- Aerosol data benchmark



THANK YOU