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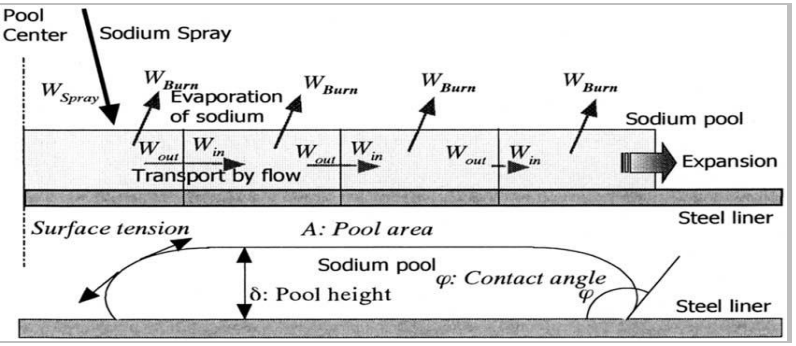


# CONTAIN-LMR Sodium Fire Benchmarking

## JAEA Pool Fire Experiments F7-1 and F7-2

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Civil Nuclear Energy Research and Development Working Group

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# Objectives

- Review JAEA Pool Fire Experiments
- Discuss modeling results for F7-1 experiment
- Discuss modeling results for F7-2 experiment

# Test Matrix

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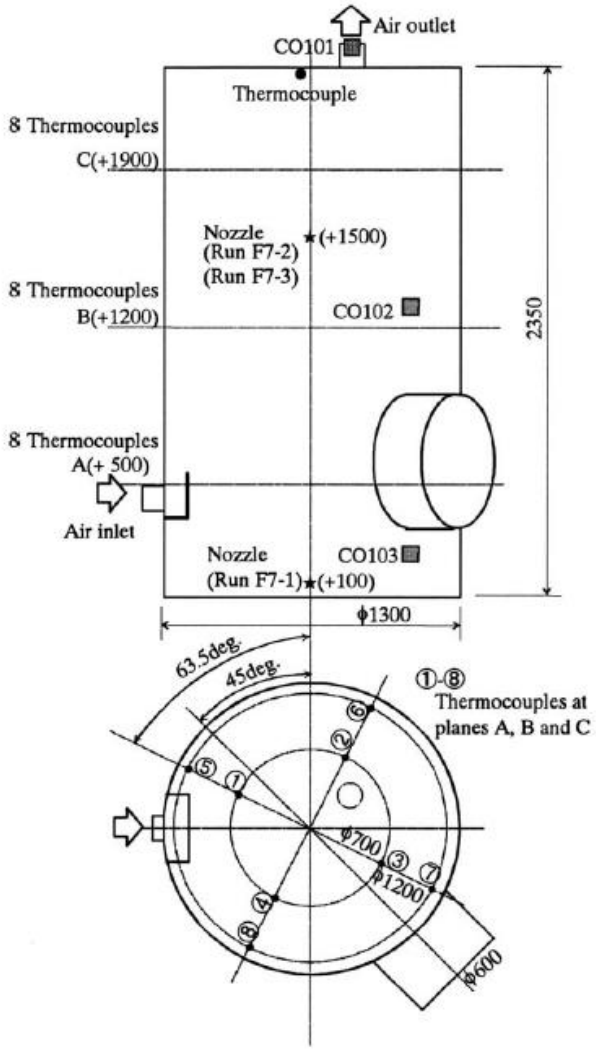
| Test ID | Test Originator | Open or Closed to the Environment | Pool/Spray | Amount of Sodium (kg) | Thickness Ratio (liquid sodium/ stainless steel) | Average Peak Temperature at bottom of pan (°C) |
|---|---|---|---|---|---|---|
| P1 | SNL | Open | Pool | 2.6 | 0.7 | 320 |
| P2 | SNL | Open | Pool | 2.6 | 0.7 | 320 |
| P3 | SNL | Open | Pool | 4.4 | 11.5 | 800 |
| P4 | SNL | Open | Pool | 1.0 | 5.9 | 780 |
| P5 | SNL | Open | Pool | - | - | - |
| P6 | SNL | Open | Pool | 4.8 | 1.3 | 480 |
| P7 | SNL | Open | Pool | 7.8 | 2.0 | 600 |
| P8 | SNL | Open | Pool | 1.6 | 0.4 | 220 |
| P9 | SNL | Open | Pool | 6.0 | 1.6 | 490 |
| P10 | SNL | Open | Pool | 11.6 | 3.0 | 746 |
| P11 | SNL | Open | Pool | 9.6 | 2.5 | 648 |
| T3 | SNL | Closed | Spray | 20 | - | 259 (atmosphere) |
| T4 | SNL | Closed | Spray | 20 | - | 1205 (atmosphere) |
| F7-1 | JAEA | Closed | Pool | 4.94 | ? | 616 |
| F7-2 | JAEA | Closed | Pool | 4.94 | ? | 675 |

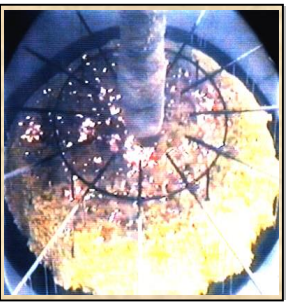
# JAEA Sodium Pool Fire Experiments

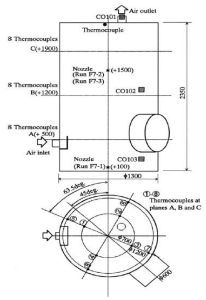
- F7-1:
  - Nozzle elevation: 0.1 m
  - Leakage Rate: 11.8 kg/hr
  - Leakage Mass: 4.94 kg
  - Initial Sodium Temperature: 507°C
- F7-2:
  - Nozzle elevation: 1.5 m → Spray fire?
  - Leakage Rate: 11.9 kg/hr
  - Leakage Mass: 4.94 kg
  - Initial Sodium Temperature: 507°C

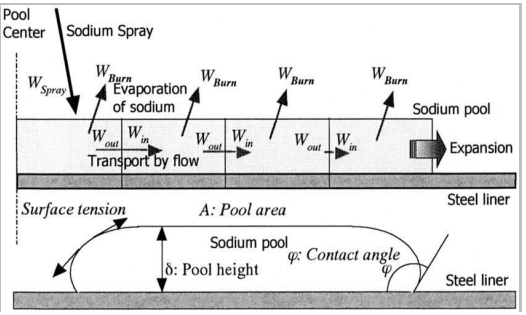


# Questions about Experiment

- Area or diameter of outlet duct?
  - Clarify vessel volume: 2.65 $m^3$ or 3.0 $m^3$?
- Steel liner thickness?
  - Thickness of vessel?
  - Is the vessel insulated?
- Does elevated F7-2 nozzle height cause any spray fire phenomena?
  - What is the expected droplet diameter coming out of the nozzle?
- Is their a catch pan in vessel for sodium?
  - Are thermocouples on top or bottom of liner?






# JAEA F7-1 Experiment

Contain-LMR

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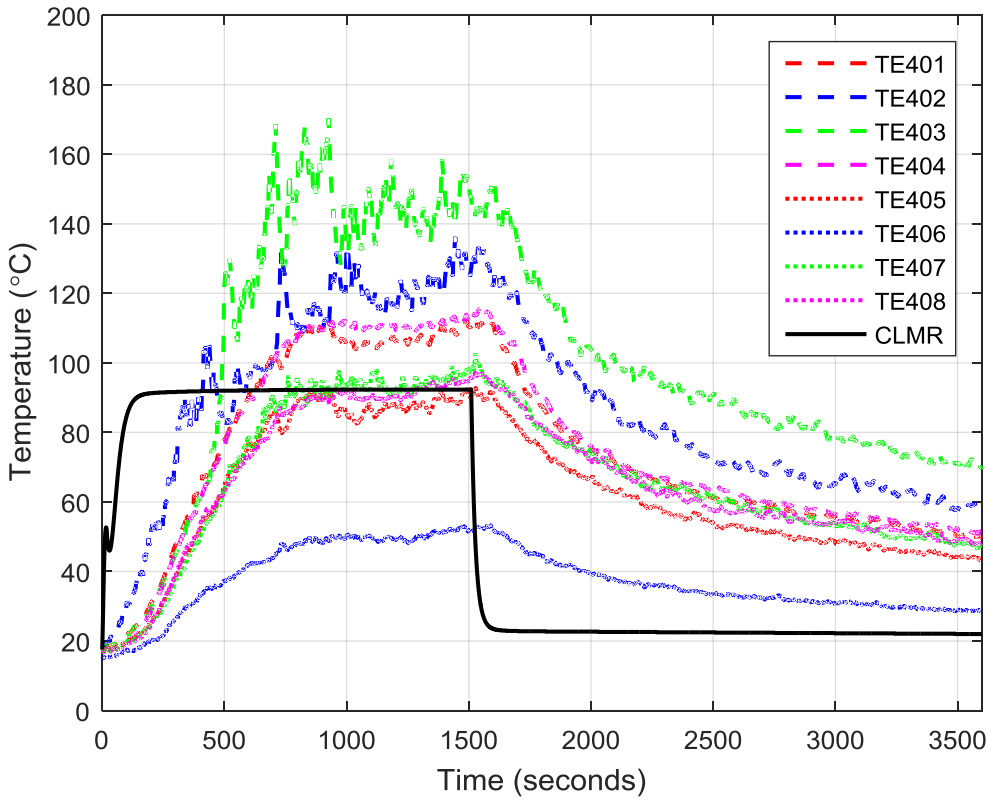
# F7-1 Preliminary Results

| Terms | CONTAIN-LMR |
|---|---|
| Vessel free volume | 2.65m$^3$ |
| Vessel thickness | 0.05m(5.0cm) |
| Vessel wall emissivity | 0.9 [-] |
| Droplet height | 0.1m |
| Leak Rate | 3.3g/s |
| Initial Sodium temperature | 505ºC |
| Sodium pool fire | Activated |
| Pool fire ratios (*f1, f2, f3, f4, f5*) | 0.5, 0.7, 0.9, 0.9, 1510 |
| Atmospheric chemistry | Deactivated |
| Initial gas temperature | 17.5℃ |
| Initial gas pressure | 101.3kPa A |
| Oxygen concentration (molar fraction) | 0.21 [-] |

- Pool fire ratio *f5* signals when the pool fire model should be turned off [seconds].

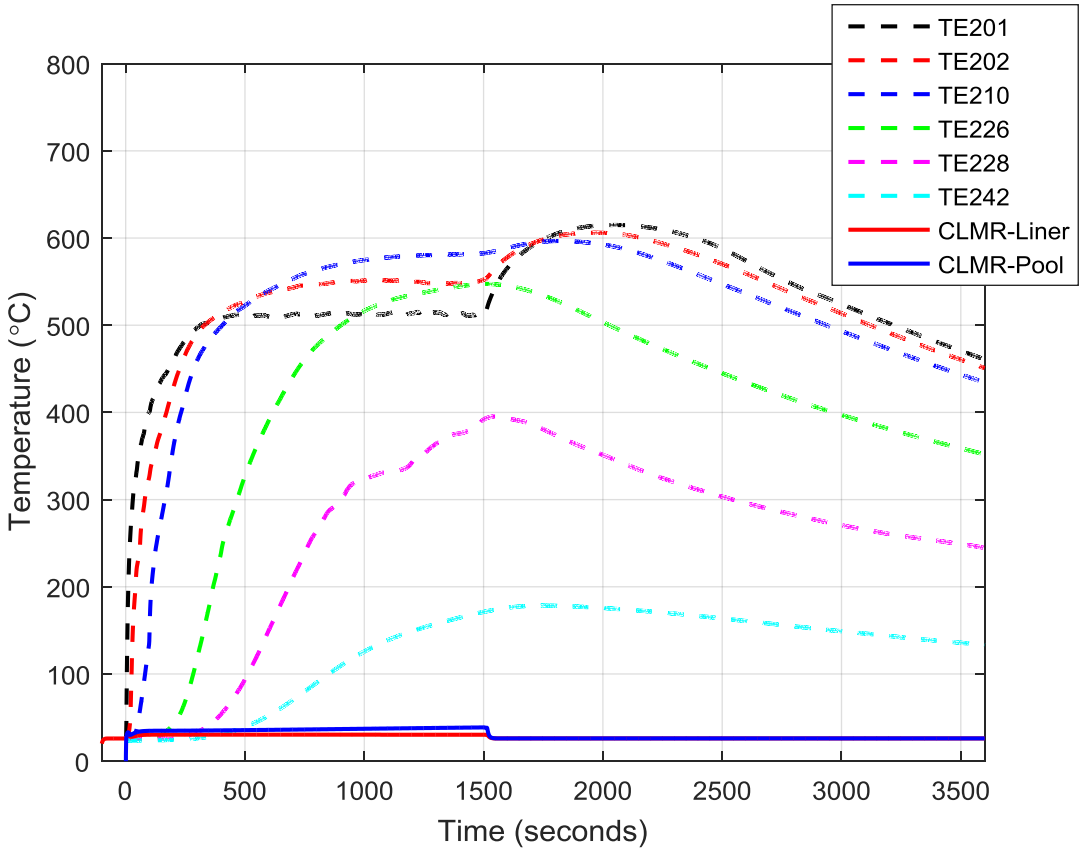
# Vessel Temperature

- Vessel temperature poorly predicted.
  - Specifically, poor prediction of steady vessel heat up as seen in data.



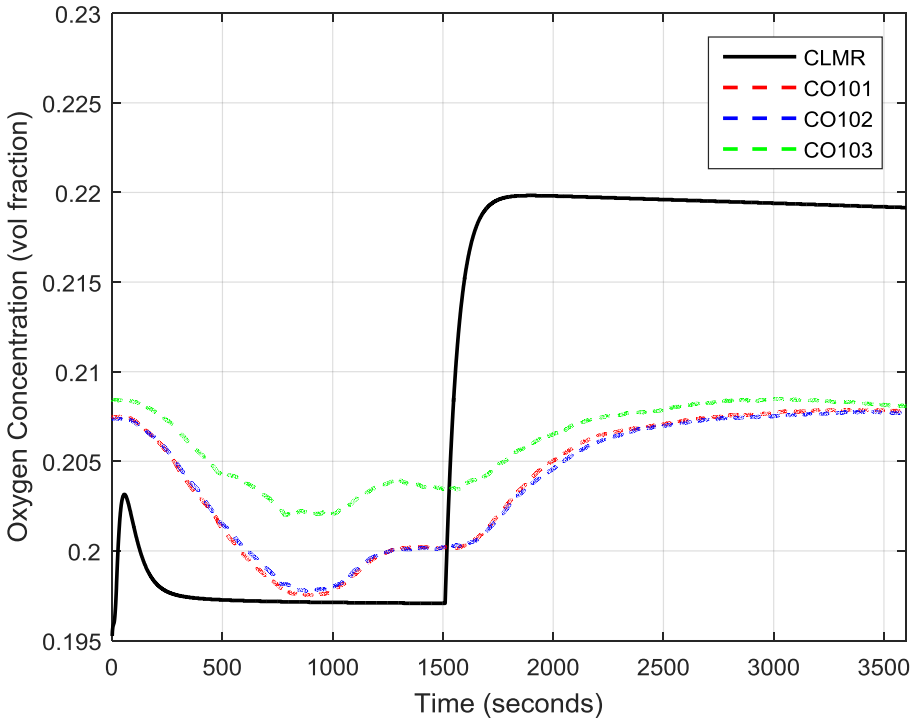
# Catch Pan Temperature

- Poor estimation of catch pan and sodium pool temperature.
  - Investigate the heat conduction parameters from pool to catch pan.
- CLMR does not model pool spreading and thus, cannot model catch pan temperatures at different positions.



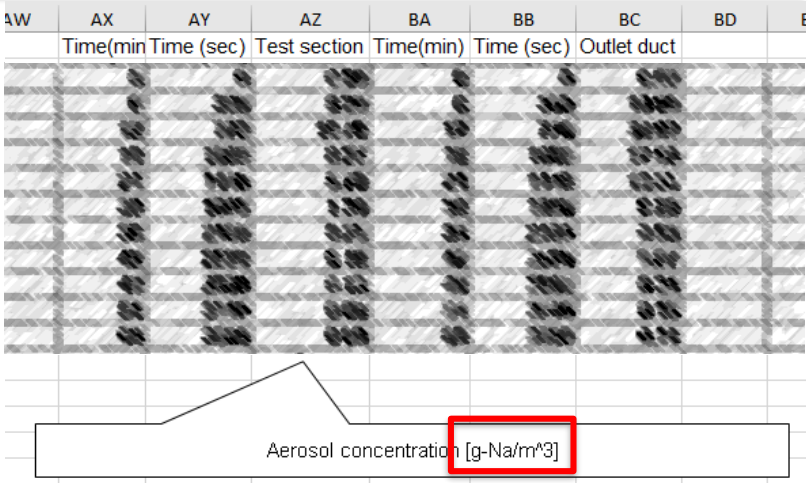
# Oxygen Concentration

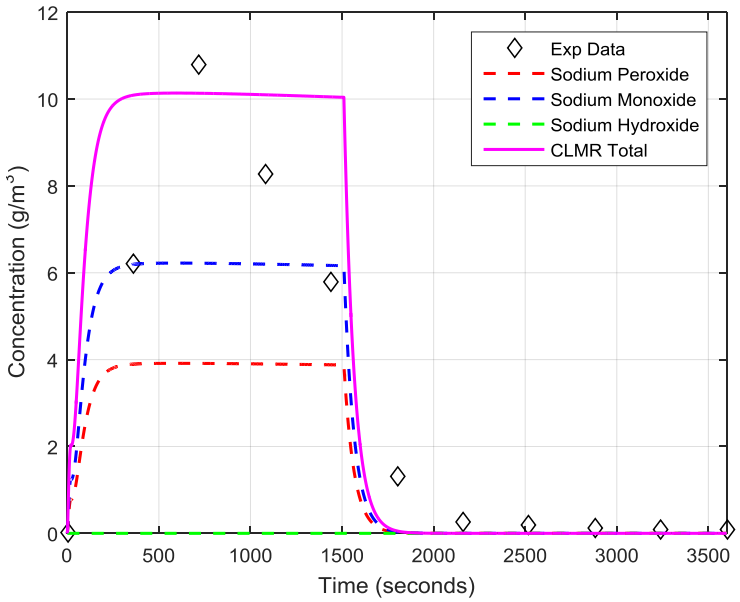
- Initial spike is most likely due to the air flowrate through vessel.
  - For CLMR, we will consider letting vessel equalize for some time before initiating pool fire.
- New input for turning off pool fire → set to 1505 s.
  - Large increase due to termination of pool burning;
  - No more oxygen being consumed.



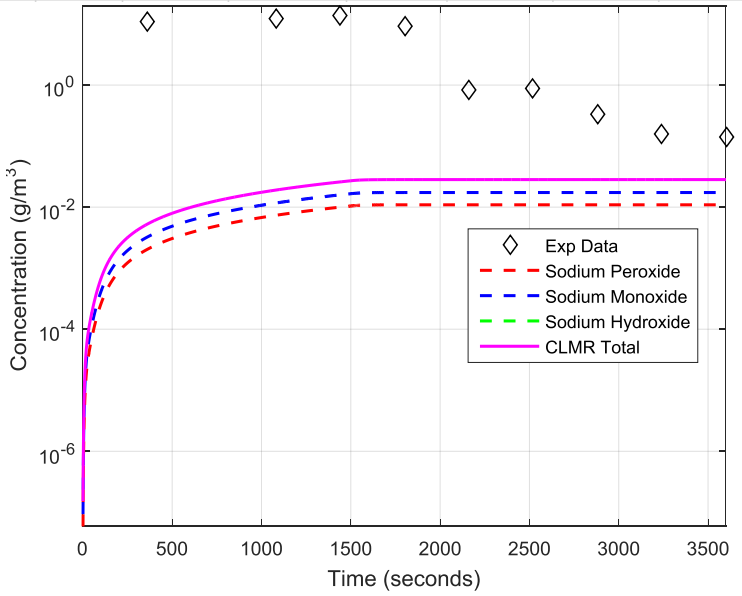
# Aerosol Concentration

- Aerosol concentrations for Test Section do not follow trend, but approximately match the peak concentration.
- Aerosol concentration for Outlet Duct are off by several orders of magnitude. Most likely due to aerosol deposition inside vessel.




Test Section



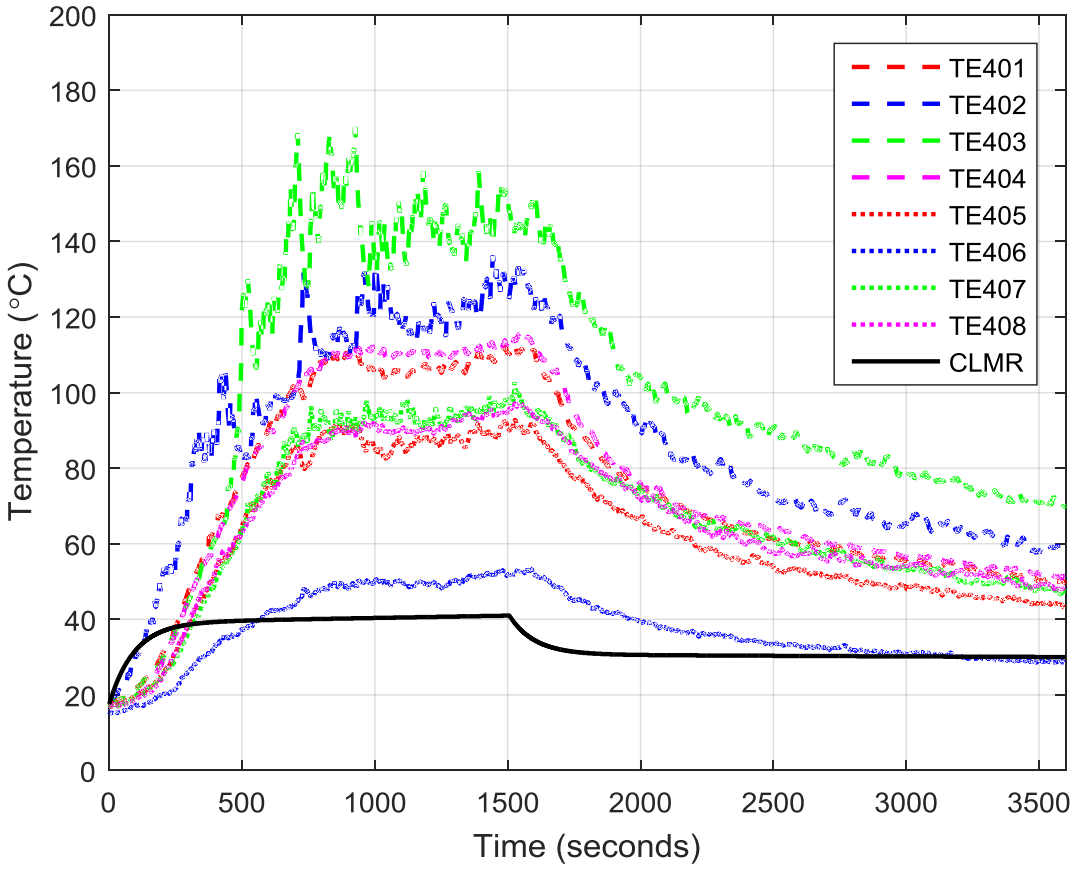

Outlet Duct

# Questions about F7-1 and F7-2

- Data is labeled as “[g-Na/m^3]”, but aerosols will consist of all Na byproducts?
- For “Test Section”, is this data for airborne concentration or deposited?
  - Similarly for “Outlet Duct”.
- Area/diameter of outlet nozzle?

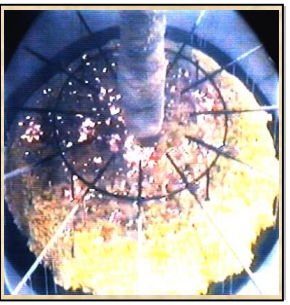
# F7-1 Sensitivity – Vessel Volume

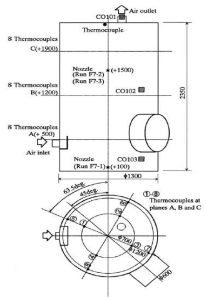
- Vessel heat up is more relaxed; i.e., no initial spike in temperature.

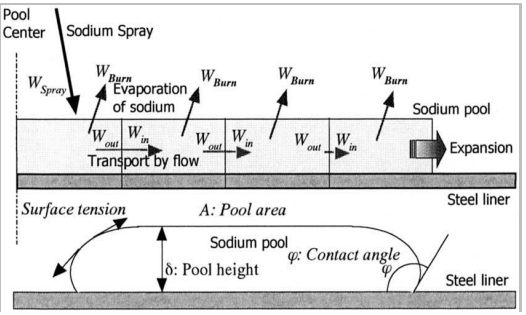


# Future F7-1 Sensitivities

- Pool fire ratios
  - f1 → investigate effect oxygen concentration.
  - f2 → investigate effect on vessel temperature and catch pan temperature.
  - f3 and f4 → investigate effect on aerosol concentrations.
- Atmospheric chemistry
  - Investigate effect on all data.






# JAEA F7-2 Experiment

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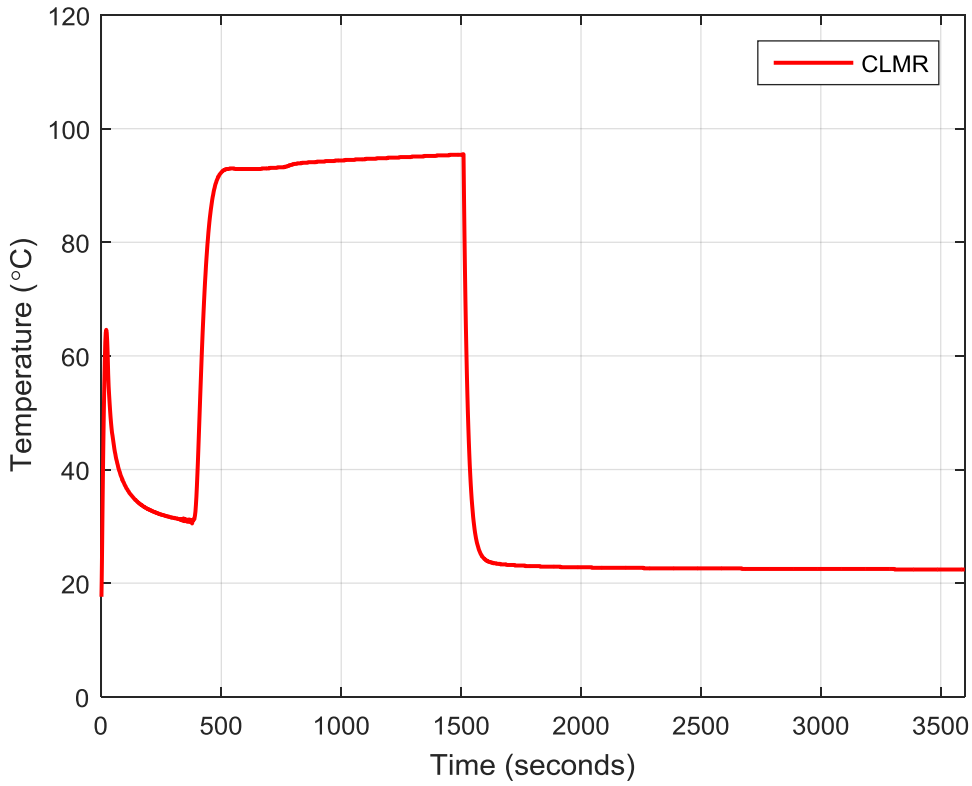
# F7-2 Preliminary Results

| Terms | CONTAIN-LMR |
|---|---|
| Vessel free volume | 2.65m$^3$ |
| Vessel thickness | 0.05m(5.0cm) |
| Vessel wall emissivity | 0.9 [-] |
| Spray height | 1.5m |
| Leakage Rate | 3.3g/s |
| Initial Sodium temperature | 505ºC |
| Mean droplet diameter (volumetric mean) | 10mm |
| Sodium pool fire | Activated |
| Pool fire ratios (*f1, f2, f3, f4, f5*) | 0.5, 0.7, 0.9, 0.9, 1510 |
| Atmospheric chemistry | Deactivated |
| Initial gas temperature | 17.5℃ |
| Initial gas pressure | 101.3kPa A |
| Oxygen concentration (molar fraction) | 0.21 [-] |

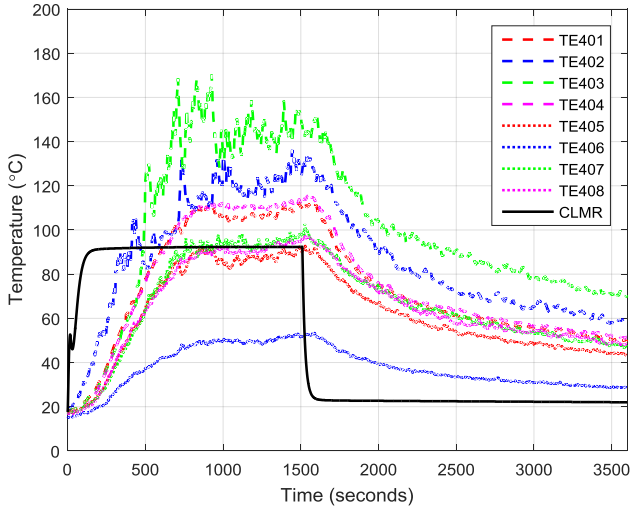
- Implement sodium source as a sodium spray fire.

# F7-2 Preliminary Results

- Behavior during first 400 seconds is different. That is, following the initial depressurization, it takes longer for vessel to heat up.




F7-2




F7-1

# Future F7-2 Sensitivities

- Spray fire parameters
- Pool fire ratios
  - f1 → investigate effect oxygen concentration.
  - f2 → investigate effect on vessel temperature and catch pan temperature.
  - f3 and f4 → investigate effect on aerosol concentrations.
- Atmospheric chemistry
  - Investigate effect on all data.

# Conclusions

- Predictions for both experiments are inaccurate.
  - All results follow the same general trend; i.e., rapid increase, followed by result plateau, and rapid decrease to zero.
- Volume sensitivity possibly points to unrealistic sodium pool influence.
  - Attempt to delay sodium pool source to see how vessel responds without initial sodium source.
- Aerosol concentrations in outlet duct off by several orders of magnitude.
  - Possible that significant deposition is occurring inside the vessel.
- Pool spreading not modeled.

# Future Work for F7-1 and F7-2

- Run models using CONTAIN2-LMR.
- Perform thorough sensitivity analysis and deliver results in letter report (end of February).
- Use SNL Surtsey Outdoor pool fire test for further sodium pool fire investigations.
- Compare CONTAIN-LMR and SPHINCS models with burning rate equations developed by Tara Olivier[1].
- Setup CONTAIN-LMR with DAKOTA[2].

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

[2]Adams, B.M., Bauman, L.E., Bohnhoff, W.J., Dalbey, K.R., Ebeida, M.S., Eddy, J.P., Eldred, M.S., Hough, P.D., Hu, K.T., Jakeman, J.D., Stephens, J.A., Swiler, L.P., Vigil, D.M., and Wildey, T.M., "Dakota, A Multilevel Parallel Object-Oriented Framework for Design Optimization, Parameter Estimation, Uncertainty Quantification, and Sensitivity Analysis: Version 6.0 User's Manual," Sandia Technical Report SAND2014-4633, July 2014. Updated November 2016 (Version 6.5).