Validation of the Sodium Fire Models in the CONTAIN-LMR/1B-Mod.1 Code Against the ABCOVE Experiments

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Purpose and Ultimate Goal

Purposes : To validate the sodium fire models in the CONATIN-LMR/1B code against the ABCOVE experiments, and

To compare the results with the MELCOR results without using the sodium fire models.

Ultimate Goal : Demonstration of the CONTAIN-LMR/1B code's capability to estimate transient P and T inside the containment during postulated accident conditions, as a design tool for the SFR(Sodium-cooled Fast Reactor) containment

Sodium Spray Fire Model

Phenomenological model used in NACOM code :

- **Spray burning rate**

$$\dot{m}_s(t) = \int_{D_i}\int_{t'} \dot{m}_f\left(D(D_i,t',t), V_f(D_i,t',t)\right) d^2N$$

- **Calculation begins by partitioning the injected sodium spray source among 11 discrete droplet-size classes**

$$\frac{dR_V}{dD} = \left(\frac{3.915}{\bar{D}}\right)^6 \frac{D^5}{120}\exp\left(-\frac{3.915}{\bar{D}}\right)$$

- **Now, d^2N can be derived from the sodium leak rate and drop size distribution**

$$d^2N = \frac{6m_l(t')}{\pi D_i^3 \rho_{Na}} \frac{dR_V}{dD_i} dt' dD_i$$

- **Important user input parameters**
  - Mass mean droplet diameter
  - Fall height and terminal velocity
  - Relative proportions of Na_2O and Na_2O_2 in the reaction products

$\dot{m}_f$ = sodium droplet burning rate
D = droplet diameter
V_f = droplet velocity
d^2N = number of droplets in $D \sim D+dD$ & $z \sim z+dz$
R_V = volume fraction of spray with droplets of smaller diameters than D
$\bar{D}$ = volume mean diameter

Sodium Pool Fire Model

Chemical reaction model used in SOFIRE II code :

- **Sodium burning rate is proportional to oxygen concentration at the sodium pool surface, to which oxygen in the atmosphere diffuse.**
- **Diffusion coefficient for oxygen-nitrogen mixtures**

$$D_{O_2-N_2} = 6.4315\times10^{-5}\frac{T^{1.823}}{P}$$

- **Sodium burning rate**

$$\left(\frac{dm}{dt}\cdot\frac{1}{A_S}\right) = H_G C \rho_G S$$

- **Gas transport coefficient, H_G, by heat-mass transfer analogy**

$$H_G = 0.14 D_{O_2-N_2}\left[g S_C \frac{\beta}{\nu^2}(T_{SS}-T_G)\right]^{1/3}$$

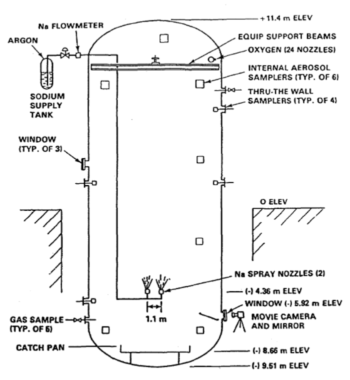
- **Default Assumptions in the CONTAIN-LMR/1B:**
  - All the produced peroxide(Na_2O_2) is aerosolized.
  - All the produced monoxide(Na_2O) enter the pool.

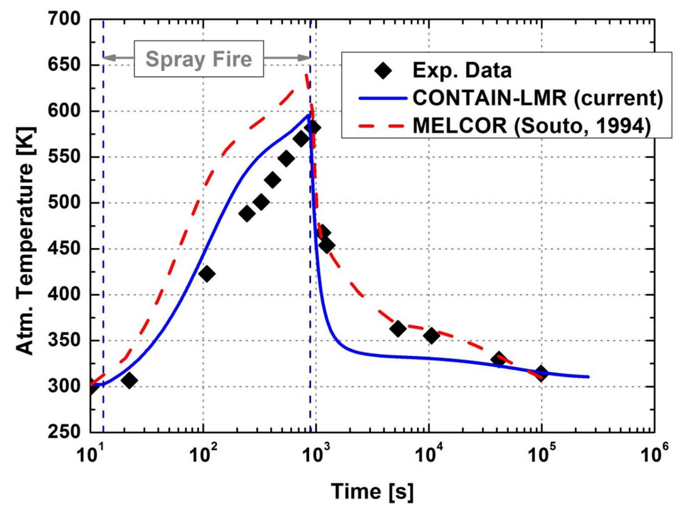
T = gas (film) temperature [K]
P = pressure [atm]
m = mass of sodium burned
t = burning time
A_S = sodium pool surface area
C = mass fraction of oxygen
ρ_G = gas density
S = stoichiometric combustion ratio
g = gravity
β = gas expansion coefficient
ν = kinematic viscosity,
T_{SS} = sodium surface temp.
T_G = gas temperature
Sc = Schmidt number

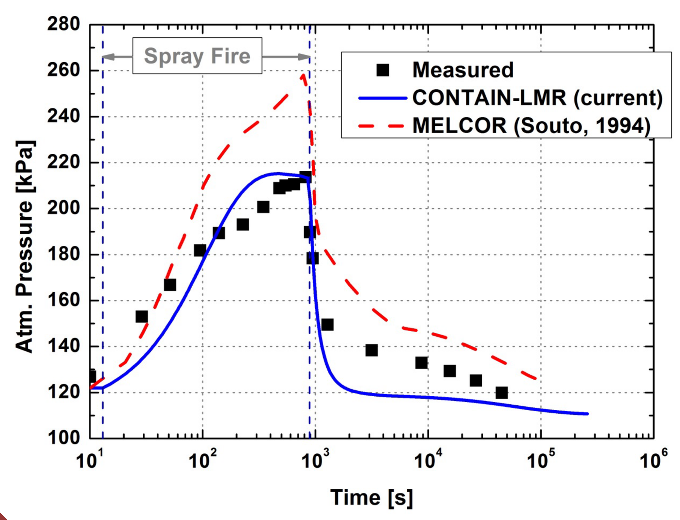
Validation against ABCOVE AB5

Single-species aerosol test by spraying sodium into air

- Containment System Test Facility(CSTF): 852 m³ carbon steel vessel
- Sodium spray starts from 13s to 885s.





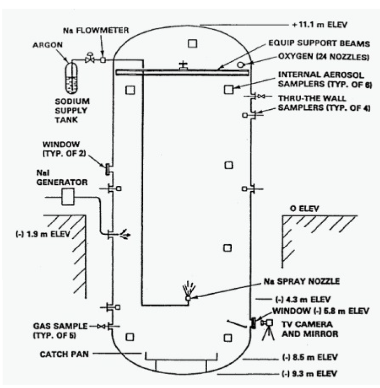


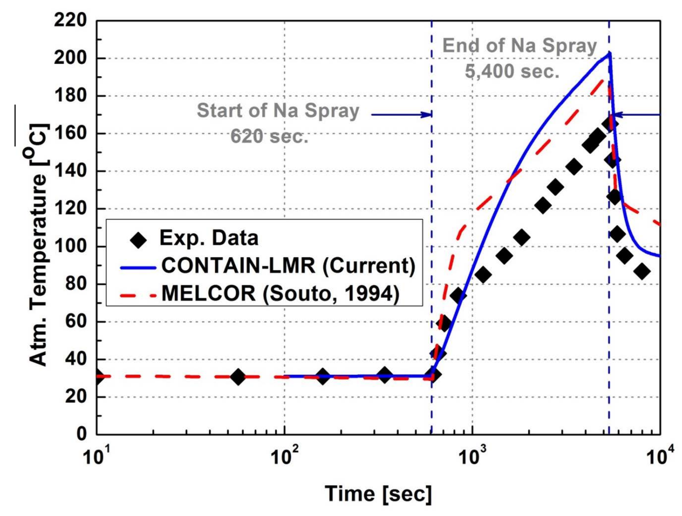
Good agreement ! However, the CONTAIN-LMR/1B slightly under-estimates the atmospheric pressure and temperature after the sodium spray fire period !

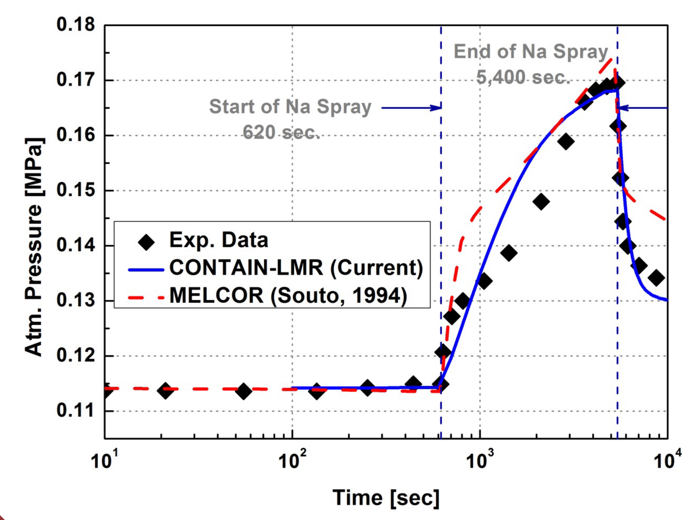
Validation against ABCOVE AB6

NaI aerosol release test in the presence of a sodium spray fire

- Spraying 205kg of sodium into the CSTF over a period of 4780s (from 620s to 5,400s).
- Oxygen conc. was maintained relatively constant.





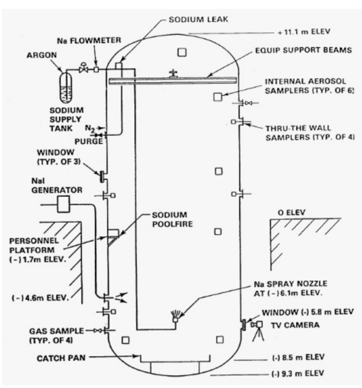


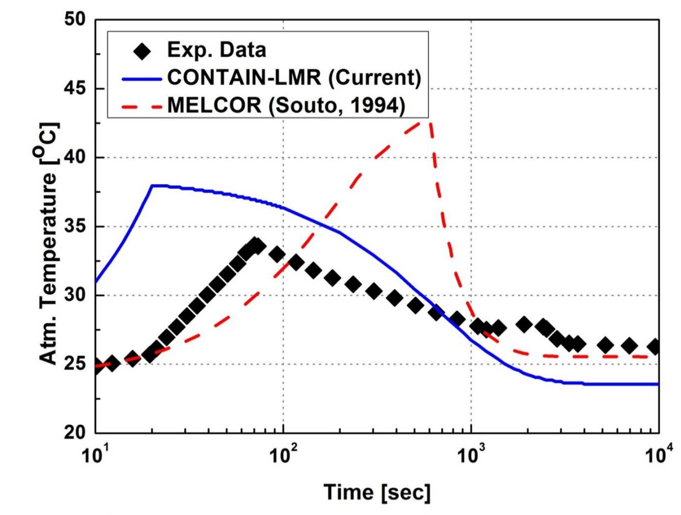
CONTAIN-LMR/1B predictions give more realistic (still conservative) atmospheric P and T values during the spray fire period than the MELCOR code !

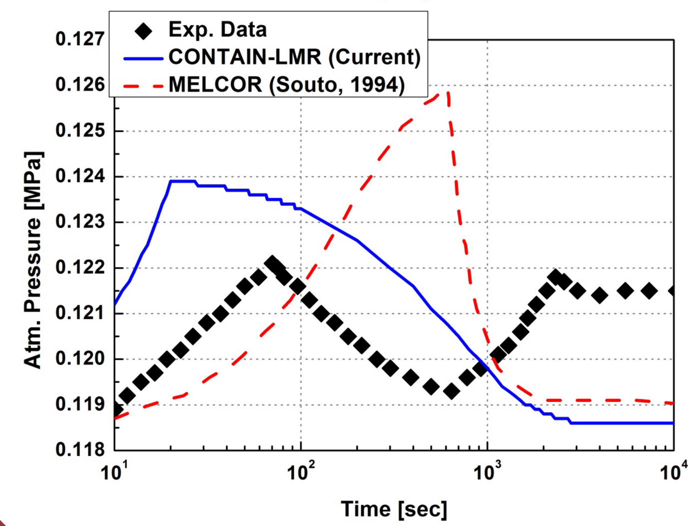
Validation against ABCOVE AB7

A small sodium pool fire following sodium leakage from a line at 10-m elevation.

- Leakage from a sodium spray line was stopped 20s after.
- Leaked sodium formed a pool and burned as a pool fire.







CONTAIN-LMR/1B simulation with sodium fire models gives the better matched trends of the CSTF atmospheric P and T, than the MELCOR simulation without sodium fire model !

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