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Sensitivity study of CVTR containment pressure behavior

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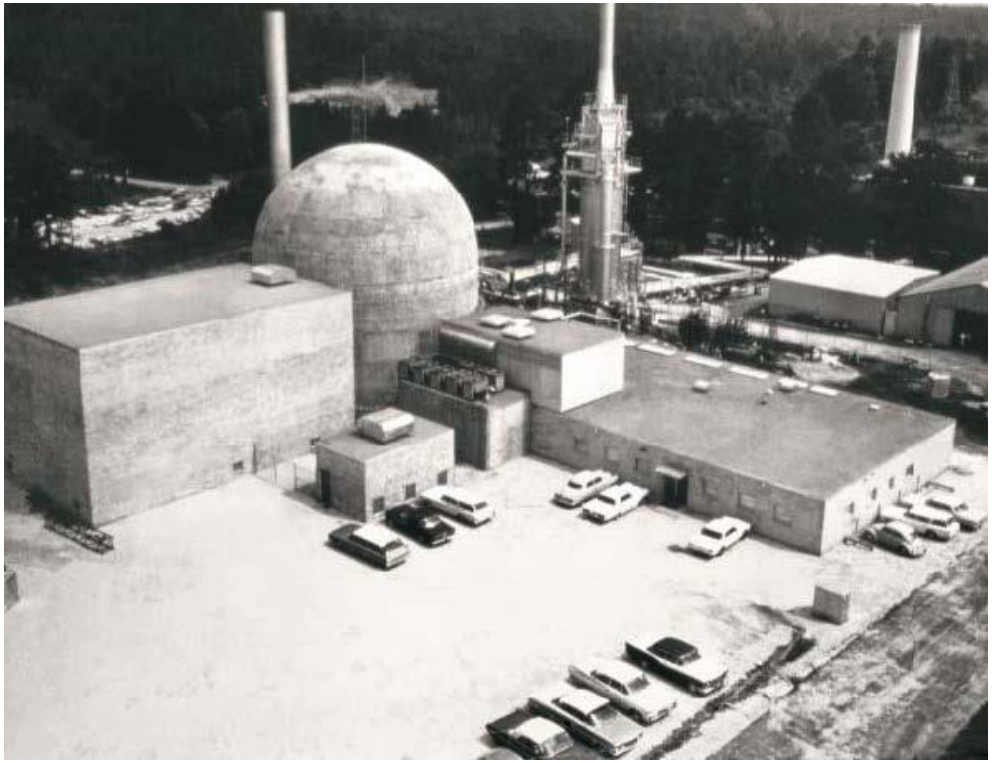
Agenda

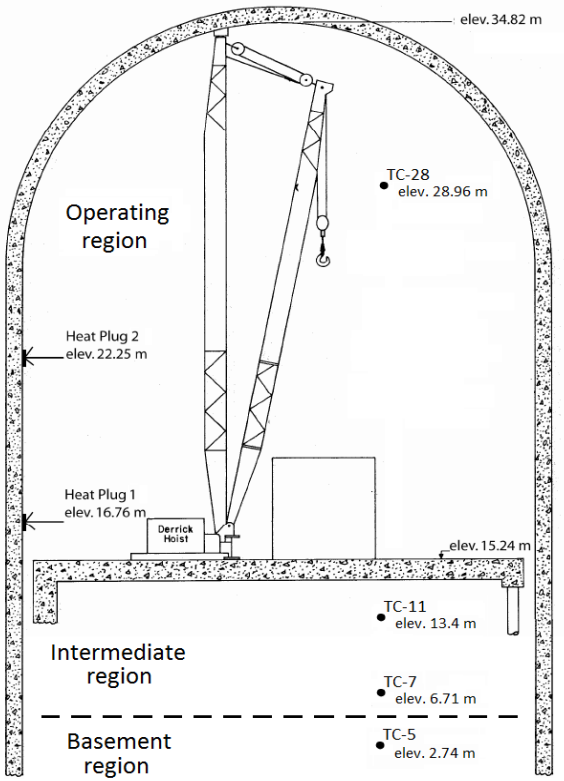
- Experimental facility & tests description
- Input deck & settings
- Calculation results
- Conclusion

CVTR facility

- Carolinas Virginia Tube Reactor (CVTR) containment
- Conducting large scale tests of the containment structures response to accidents
- Reinforced concrete + steel lining
- Installed for the tests:
  - steam source,
  - spray system,
  - instrumentation
    - temperatures
    - pressure
    - heat transfer

CVTR facility

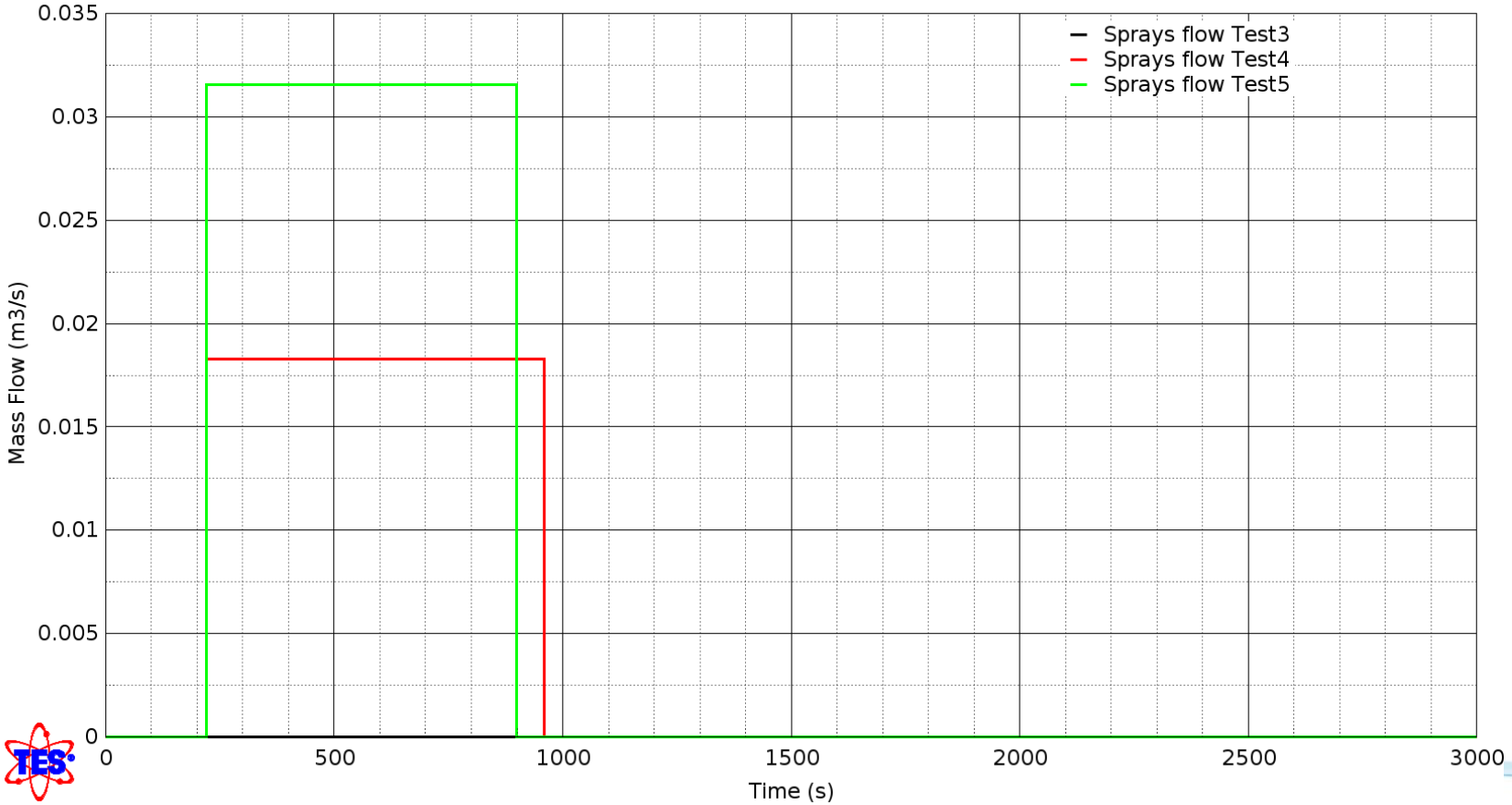




Tests analyzed

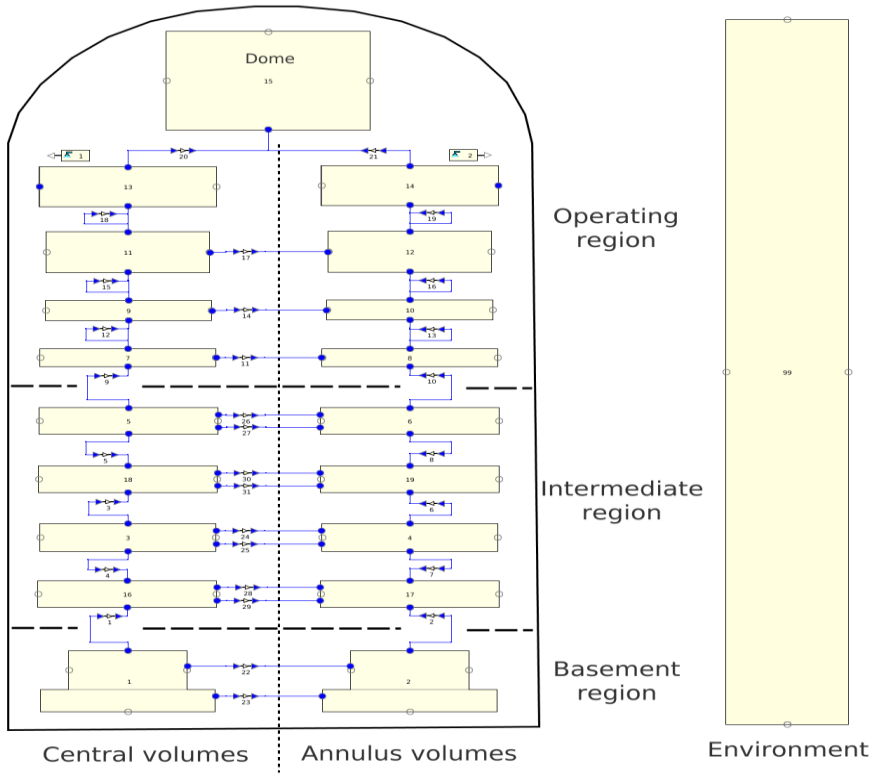
- Test 3: Natural containment depressurization
  - steam injection of 45 kg/s for 170s
  - only heat transfer between atmosphere and containment structures
- Test 4: Containment spray system activated
  - spray mass flowrate 0.0183 m3/s
- Test 5: Containment spray system activated
  - spray mass flowrate 0.03155 m3/s

Sprays operation



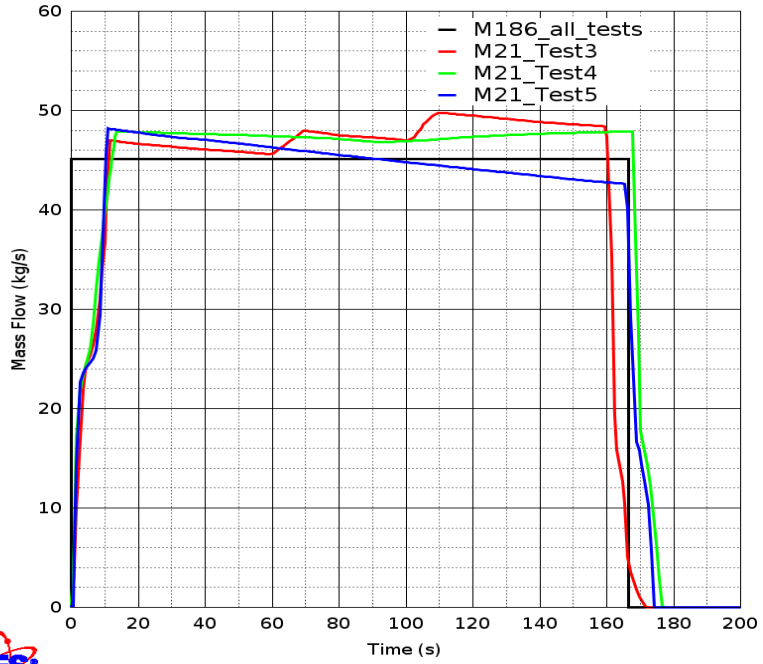
Input deck

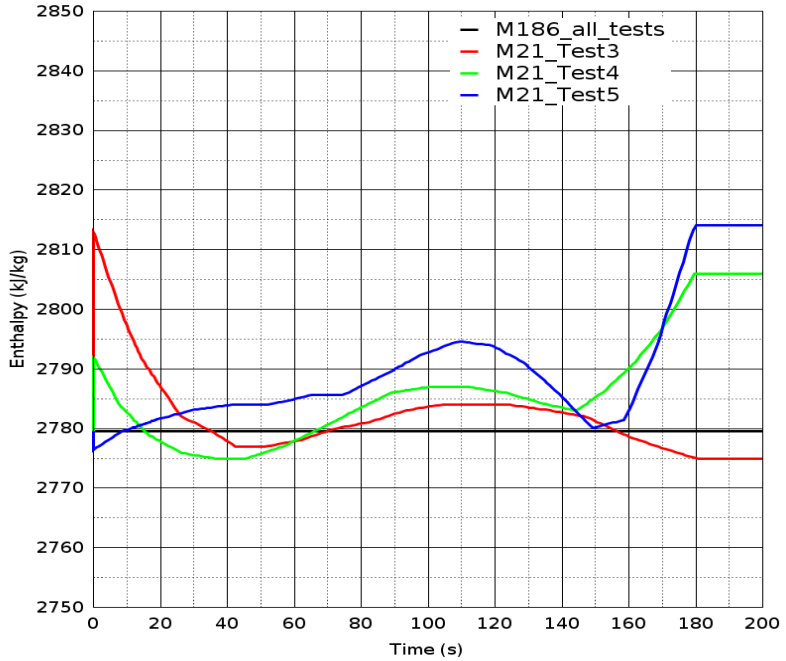
- Originally taken over from assessment of M1.8.6
  - 2 channels configuration
  - divided into 3 regions
  - environment added



Input deck

- Modifications of BC
  - mass flow and enthalpy
  - material properties





What we analyzed and why

- The original goal was to find the proper settings for realistic calculation of containment parameters for DEC A and DEC B analyses
  - CVTR tests 3,4,5 were chosen as a source of reference experimental data
  - first calculations using default settings confirmed the conservative values of CTMT pressure peak
  - two sensitivity studies were performed in MELCOR 2.1 and MELCOR 2.2

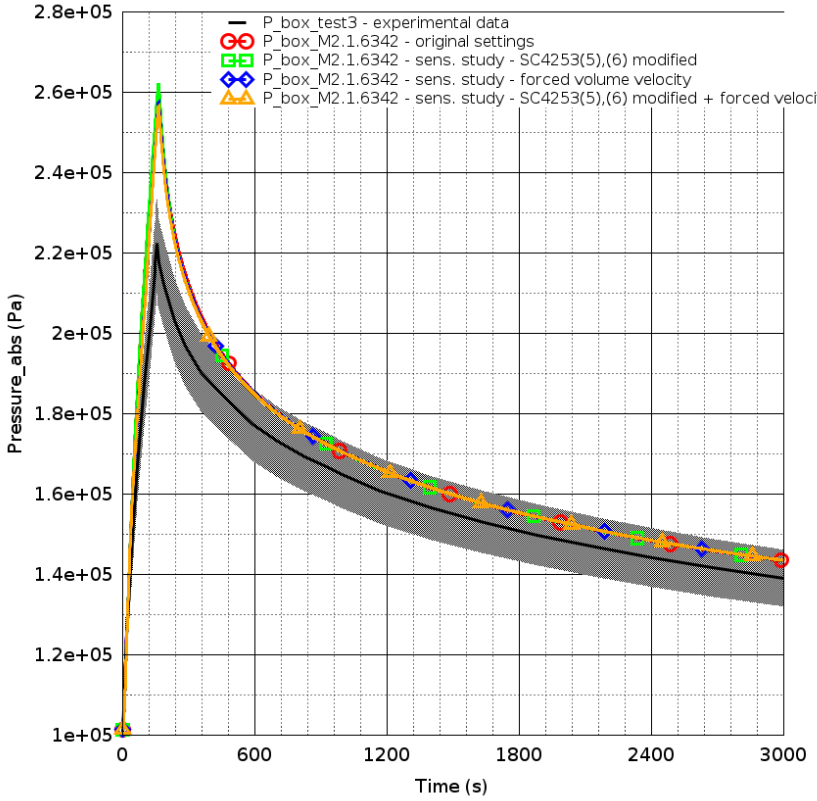
M2.1.6342 calculations

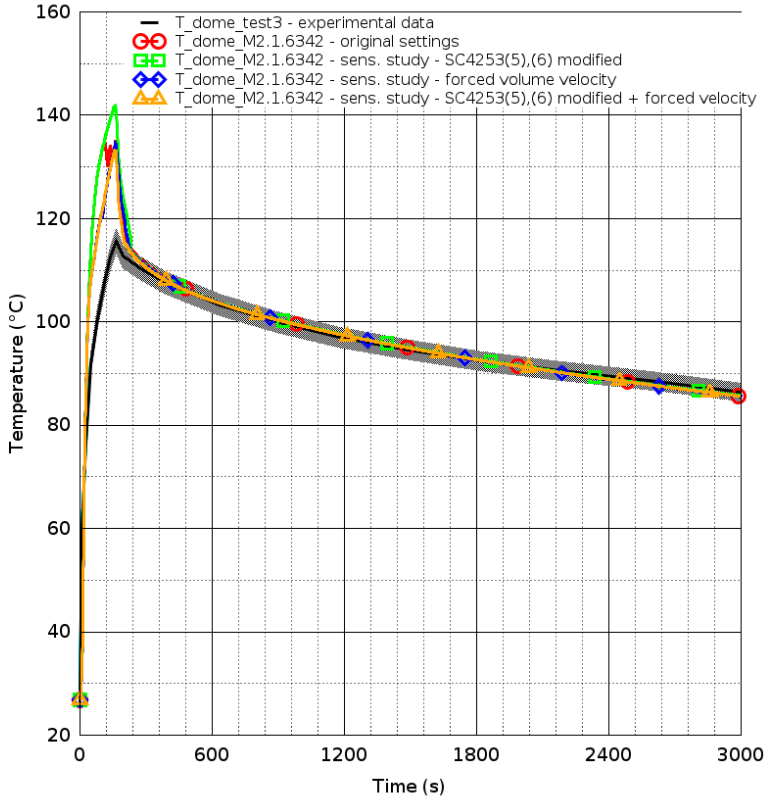
- Sensitivity coefficients modified
  - Film Tracking Model Correlation Parameters [Ref1]
    - SC 4253(5) = 30.0 (default 1000.0)
    - SC 4253(6) = 1800.0 (default 3000.0)
- Forced volume atmosphere velocity
  - based on comparison of measured and calculated heat transfer coefficient [Ref2]
  - forced flow in volumes 8 (break) and adjacent 10,12 was increased from original 1-2 m/s to 6-14 m/s

[Ref1] Tuomo Sevón; MELCOR Simulations of Steam Condensation in a Condenser Tube; VTT-R-01503-10; February 2010

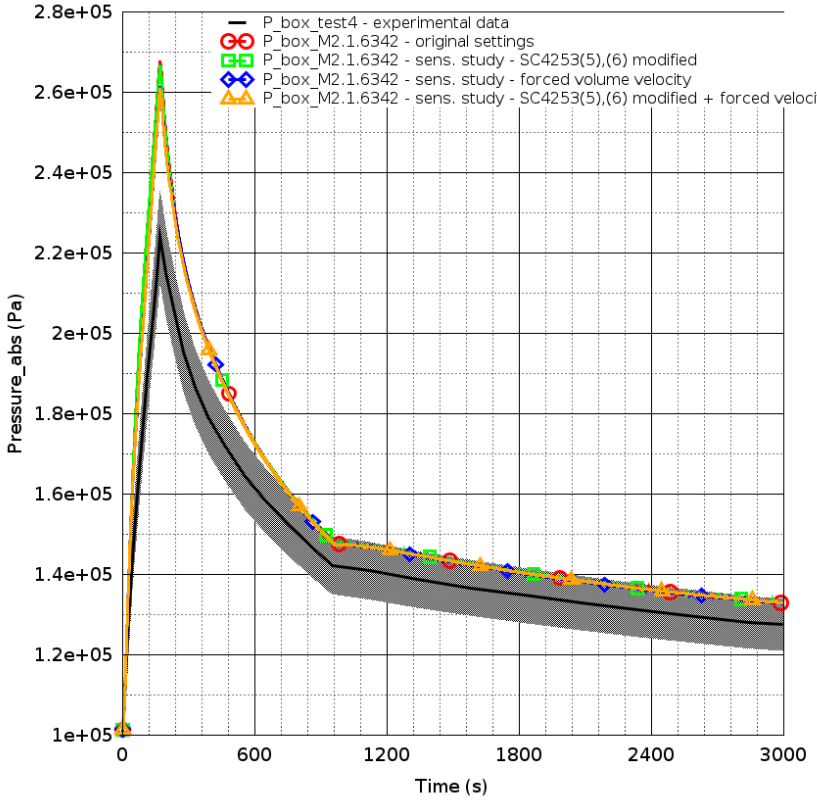
[Ref2] J.Tills, A. Notafrancesco, P. Longmire; An Assessment of MELCOR 1.8.6: Design Basis Accident Tests of the Carolinas Virginia Tube Reactor (CVTR) Containment; SAND2008-1224; February 2008

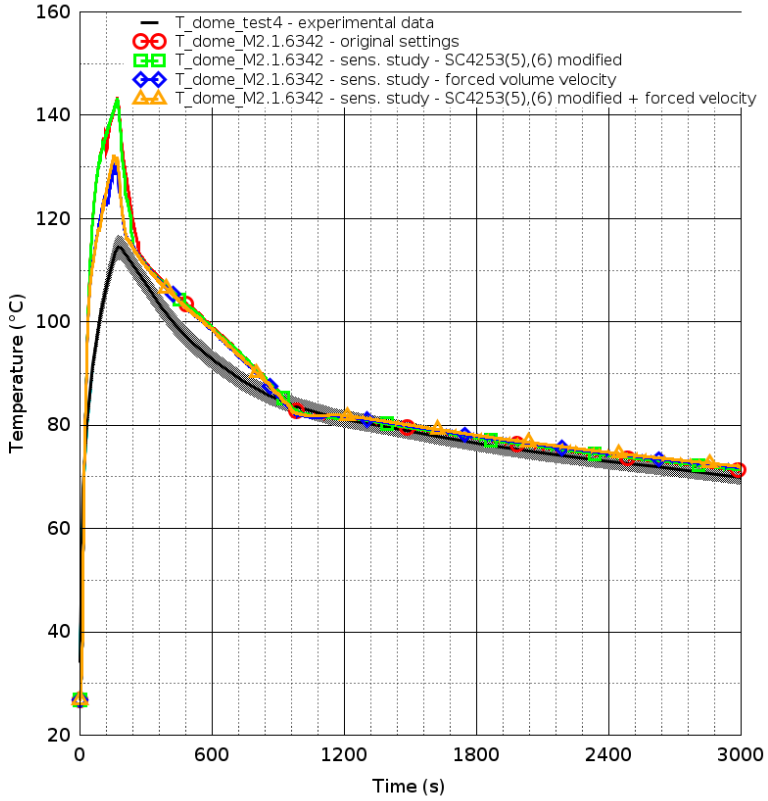
Test 3 – M2.1.6342



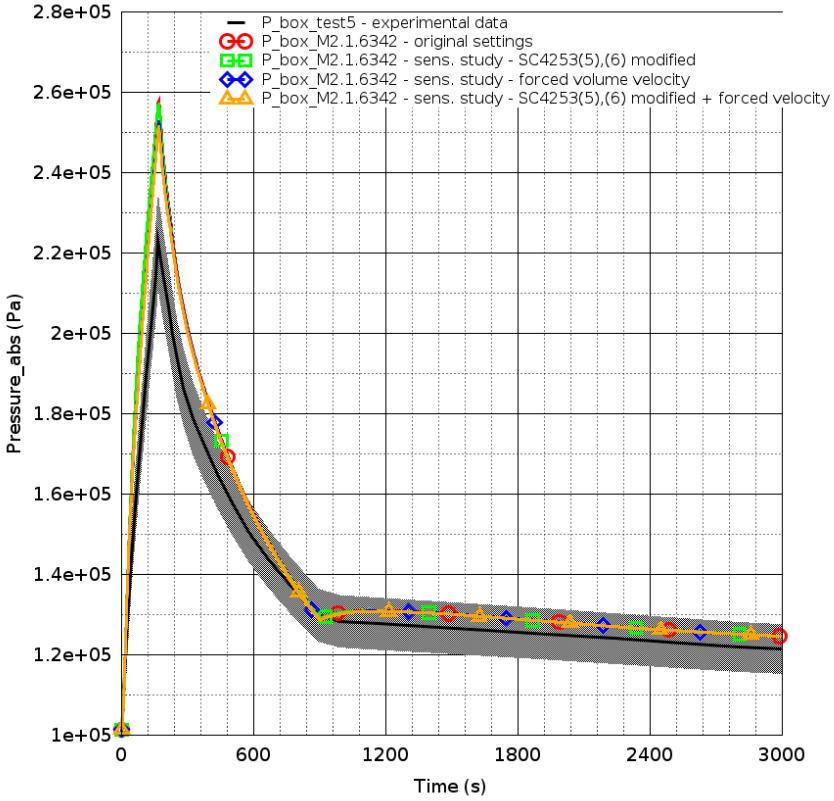


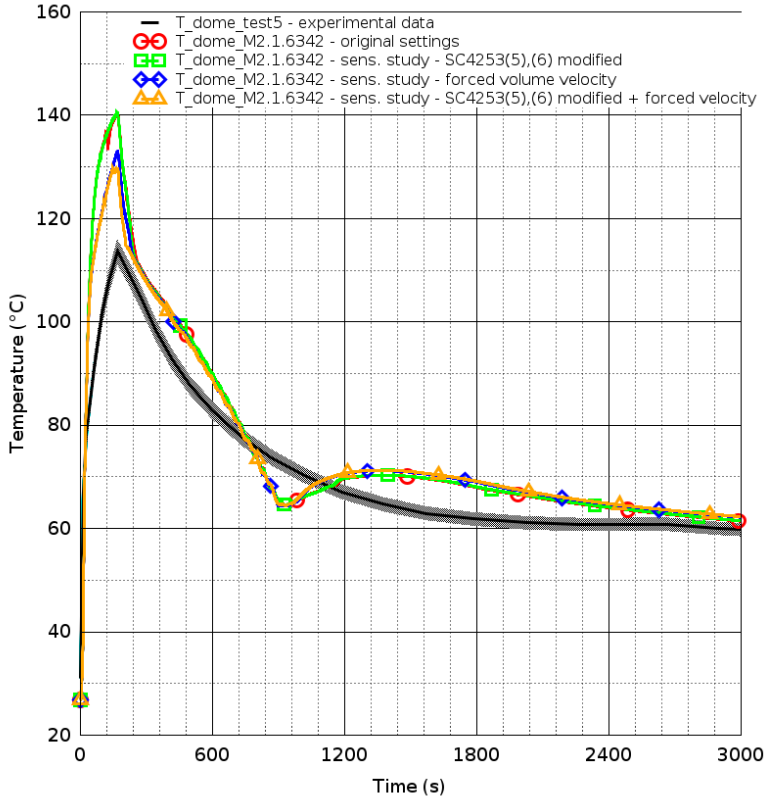
Test 4 – M2.1.6342





Test 5 – M2.1.6342





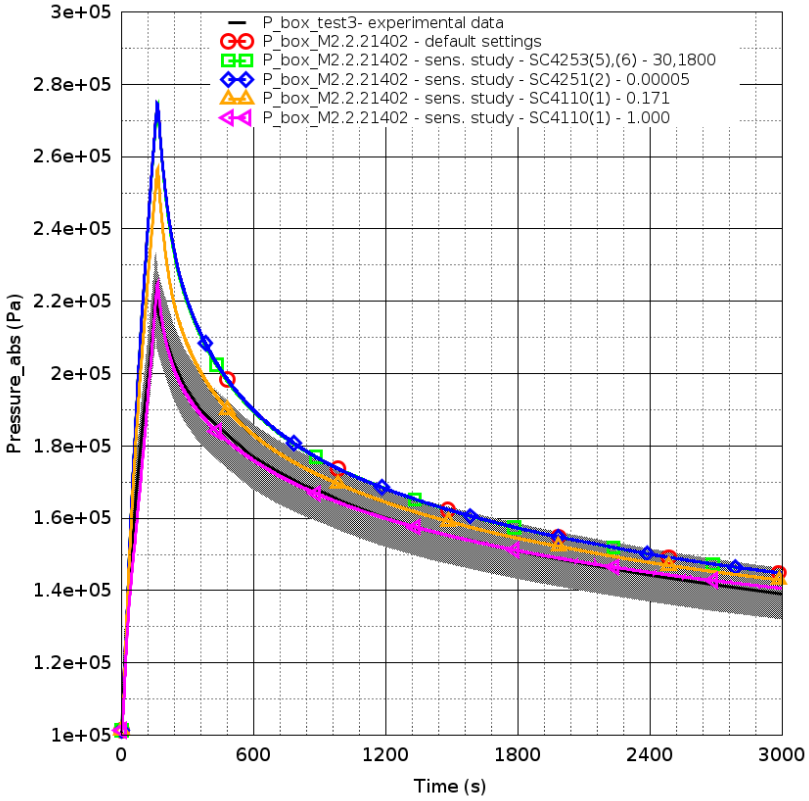
M2.2.21402 calculations

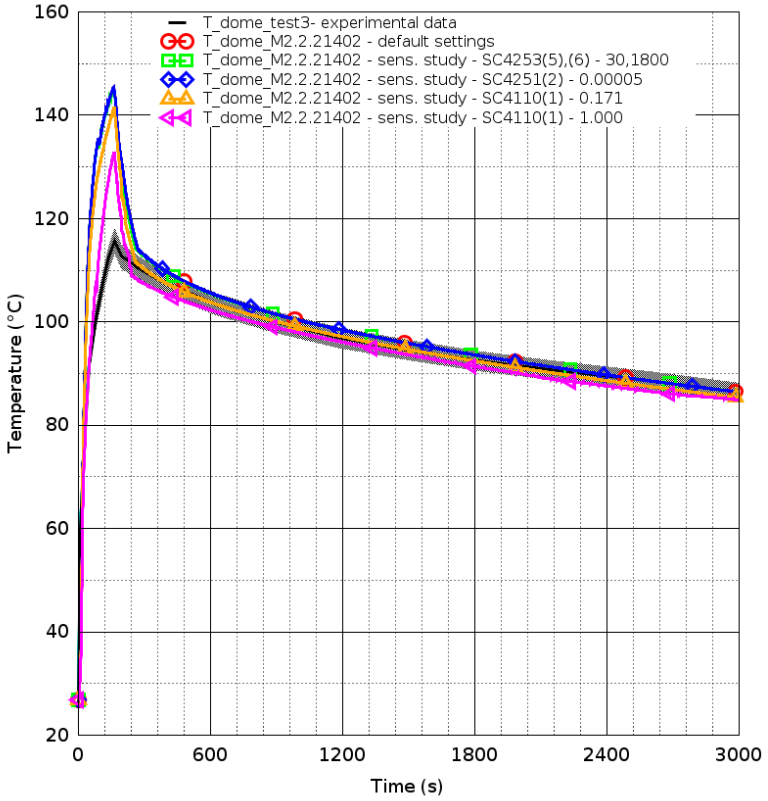
- Sensitivity coefficients modified
  - Film Tracking Model Correlation Parameters [Ref1]
    - SC 4253(5) = 30.0 (default 1000.0)
    - SC 4253(6) = 1800.0 (default 3000.0)
  - Atmosphere Natural Convection [Ref3]
    - SC 4110(1)=0.171 (default 0.10)
  - Maximum Liquid Film Thickness [Ref4]
    - SC 4251(2)=5.0E-5 (default 5.0E-4)

[Ref3] J.M. Yoo, J.H. Kang, B.J. Yun, S.W. Hong, J.J. Jeong, Modification of the Condensation Heat Transfer Model of the MELCOR code under the Thermal-Hydraulic Conditions of a PWR Containment, Transactions of the Korean Nuclear Society Spring Meeting Jeju, Korea, May 17-19, 2017

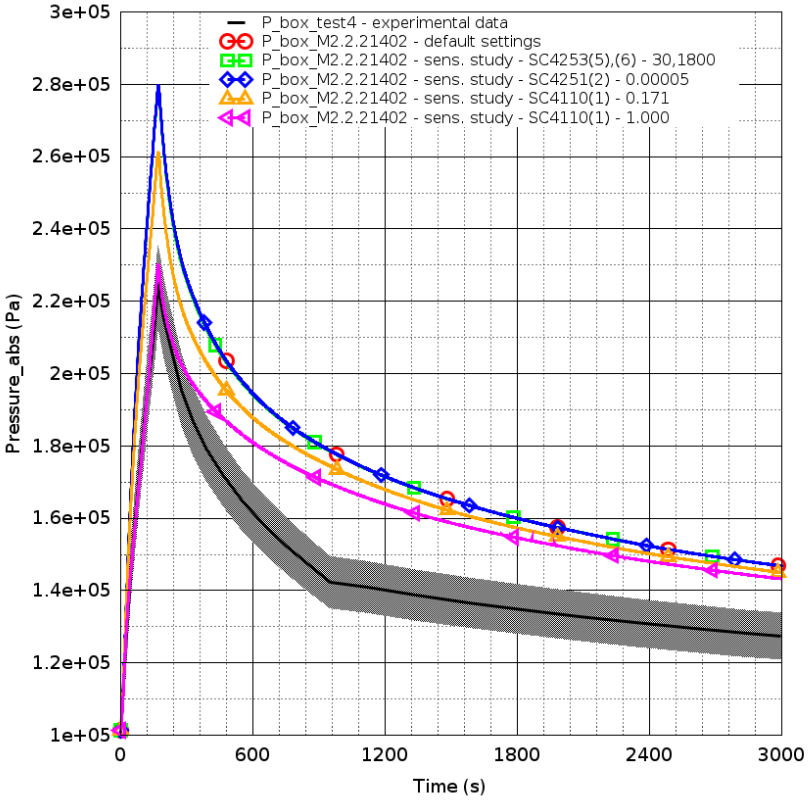
[Ref4] R. C. Schmitt, G. E. Bingham, J. A. Norberg; Simulated Design Basis Accident Tests of the Carolinas Virginia Tube Reactor Containment – Final Report; IN-1403; December 1970

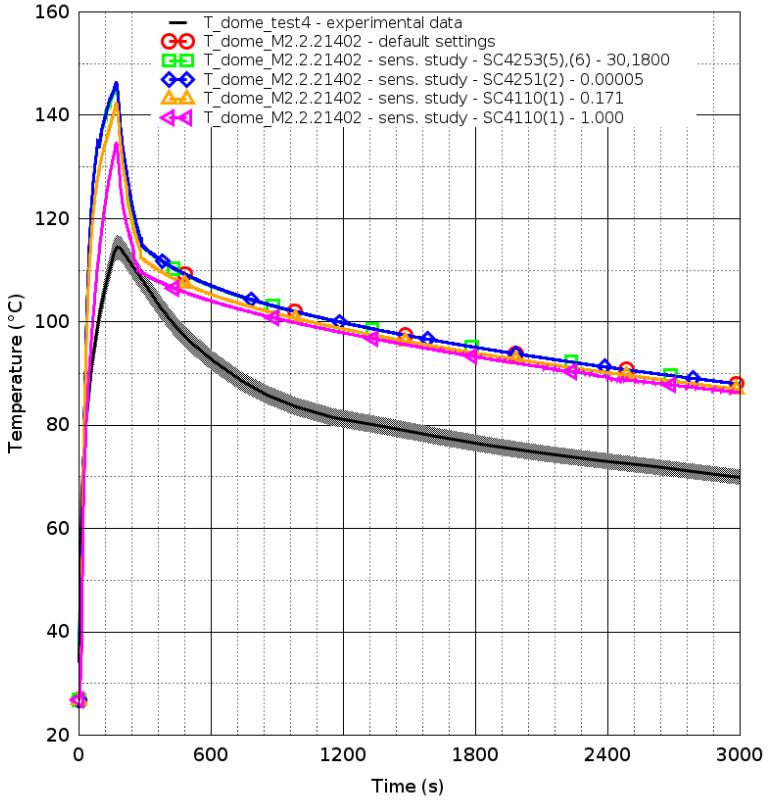
Test 3 – M2.2.21402



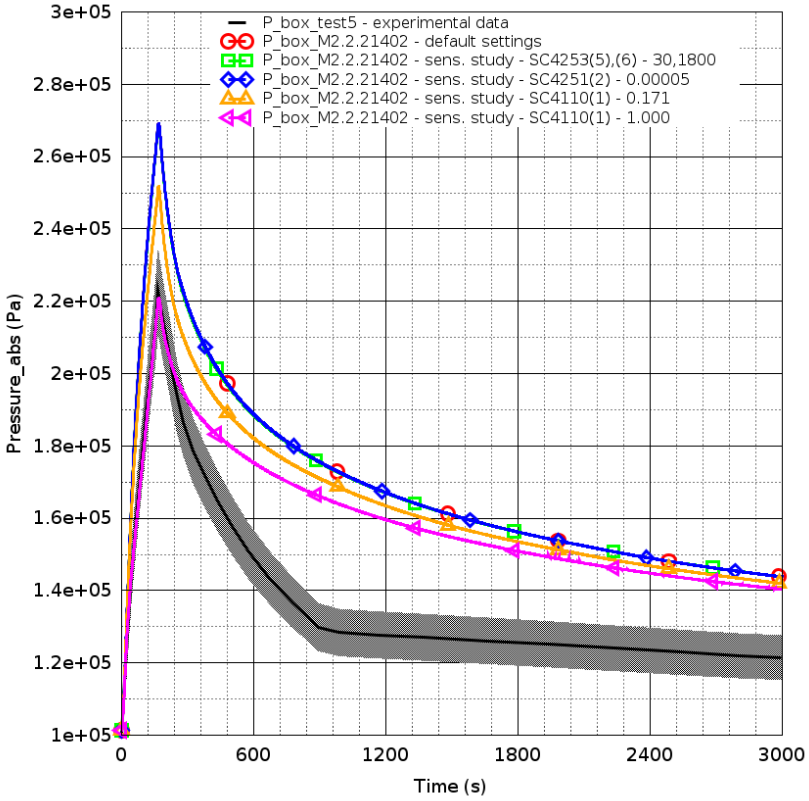


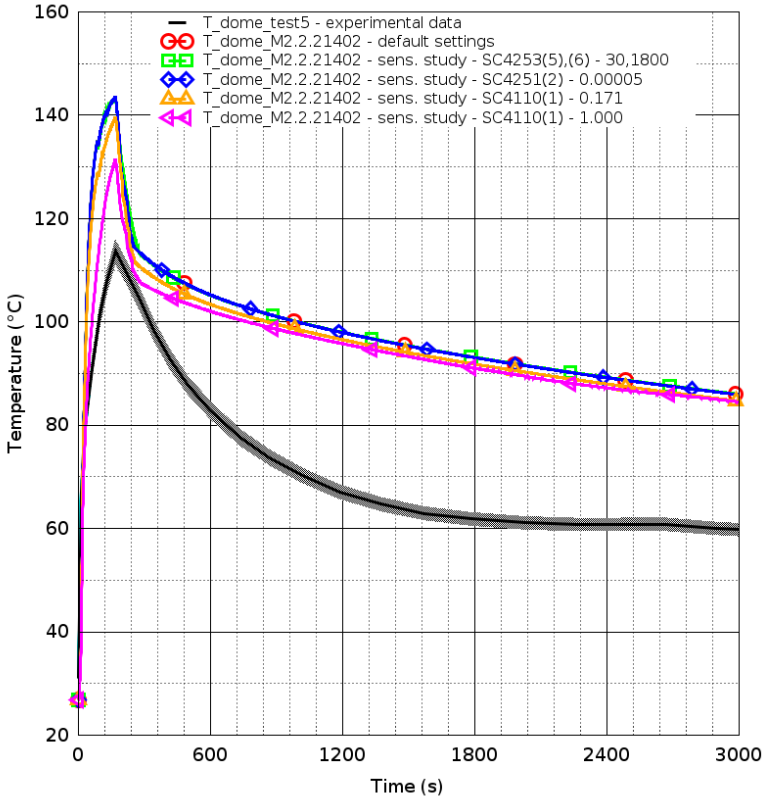
Test 4 – M2.2.21402





Test 5 – M2.2.21402

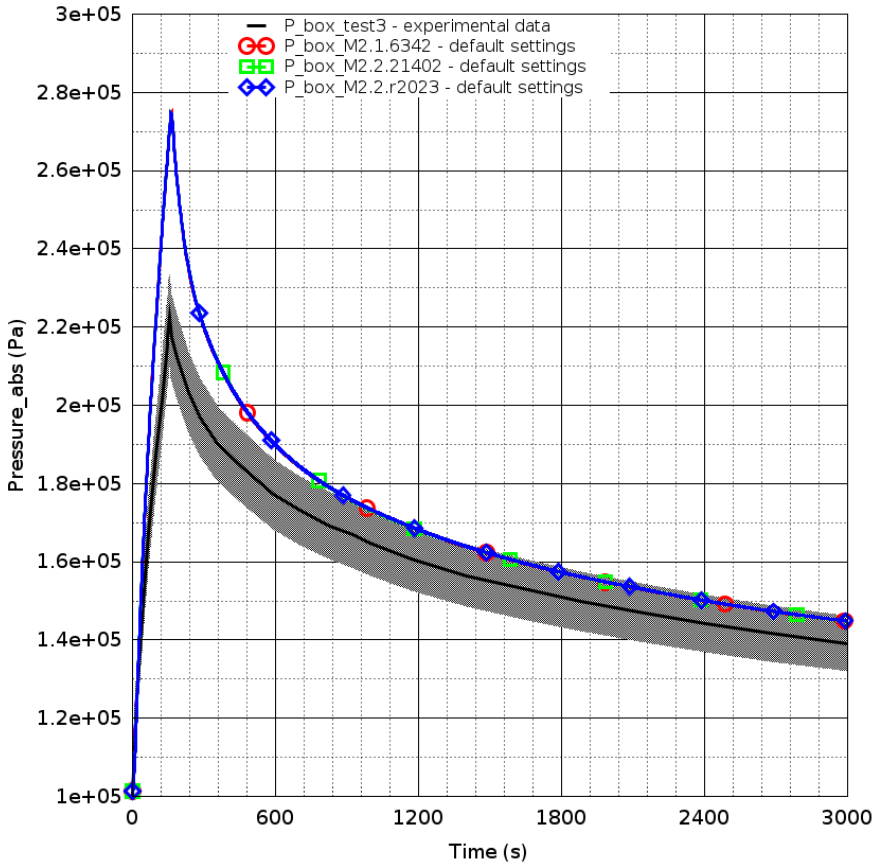


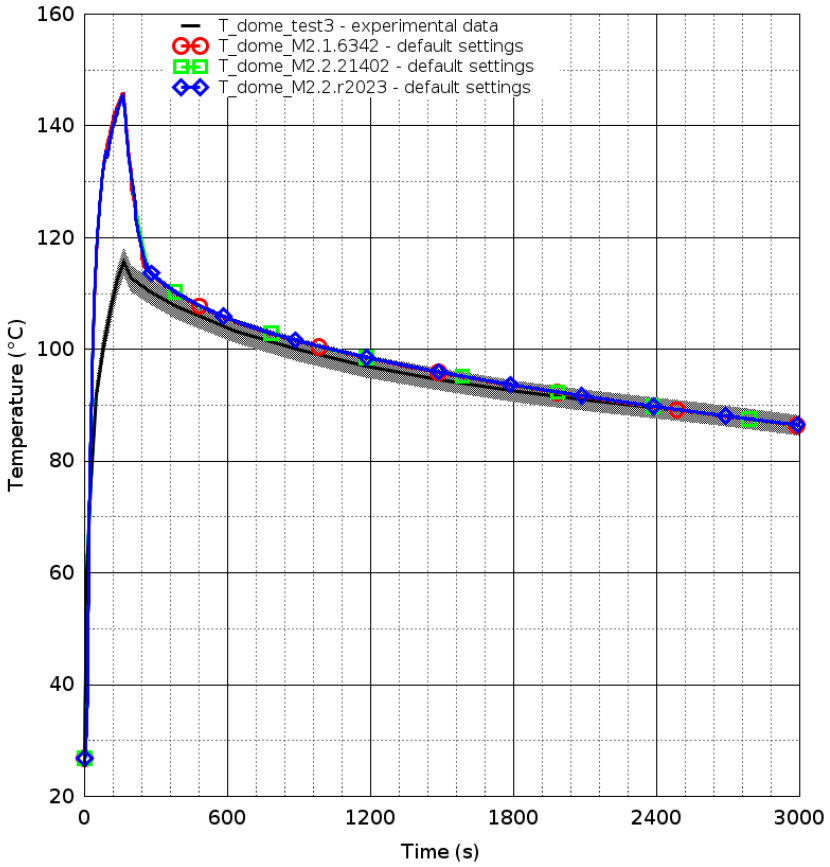


Comparison of versions

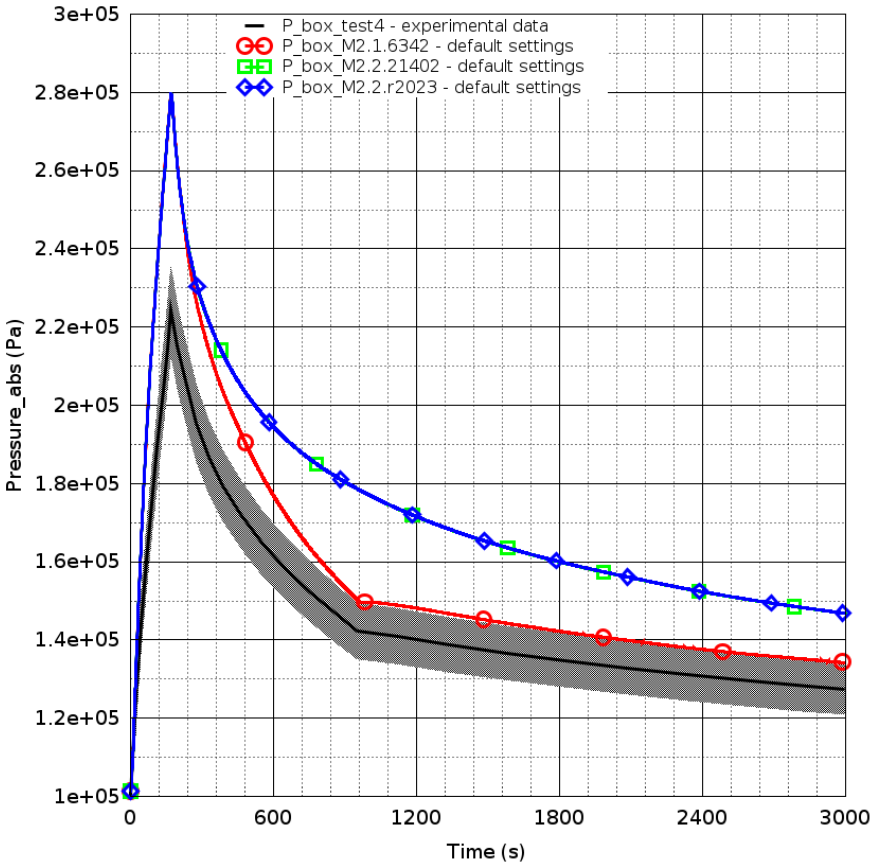
- MELCOR 2.1.6342
- MELCOR 2.2.21402
- MELCOR 2.2.r2023

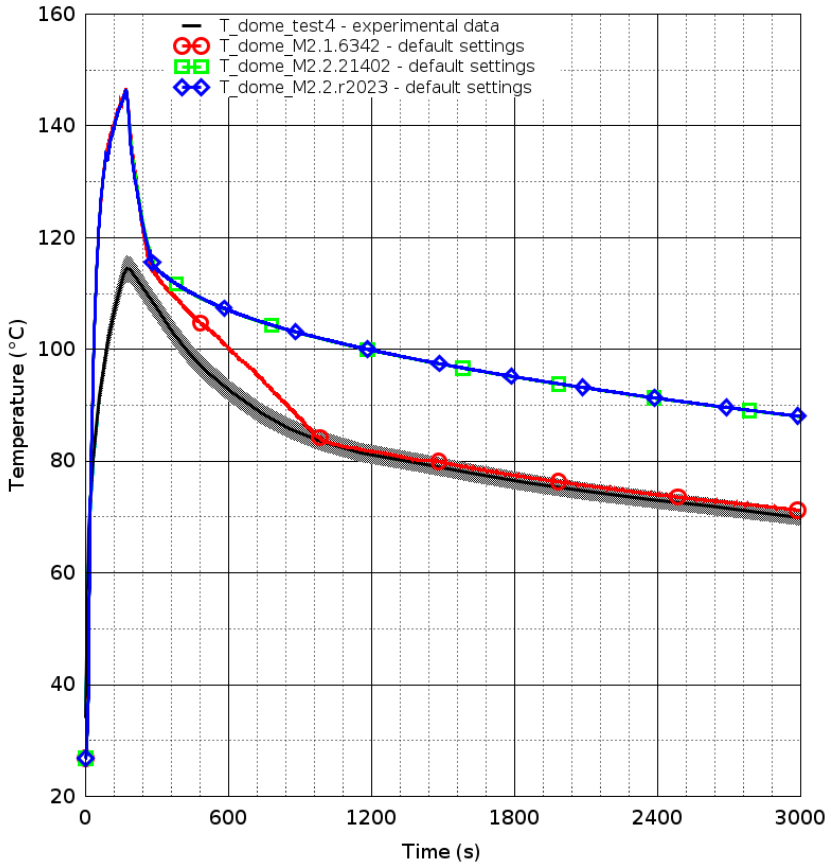
Test 3


P_box_test3 - experimental data
P_box_M2.1.6342 - default settings
P_box_M2.2.21402 - default settings
P_box_M2.2.r2023 - default settings
Pressure_abs (Pa)
3e+05
2.8e+05
2.6e+05
2.4e+05
2.2e+05
2e+05
1.8e+05
1.6e+05
1.4e+05
1.2e+05
1e+05
0
600
1200
1800
2400
3000
Time (s)

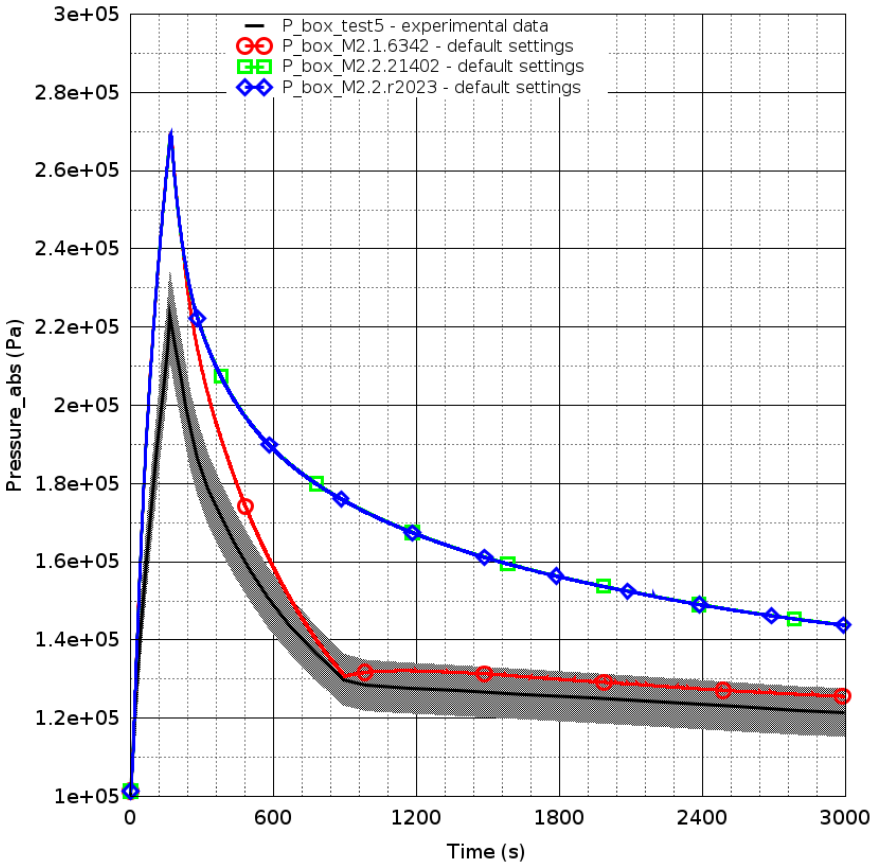

T_dome_test3 - experimental data
T_dome_M2.1.6342 - default settings
T_dome_M2.2.21402 - default settings
T_dome_M2.2.r2023 - default settings
Temperature (°C)
160
140
120
100
80
60
40
20
0
600
1200
1800
2400
3000
Time (s)

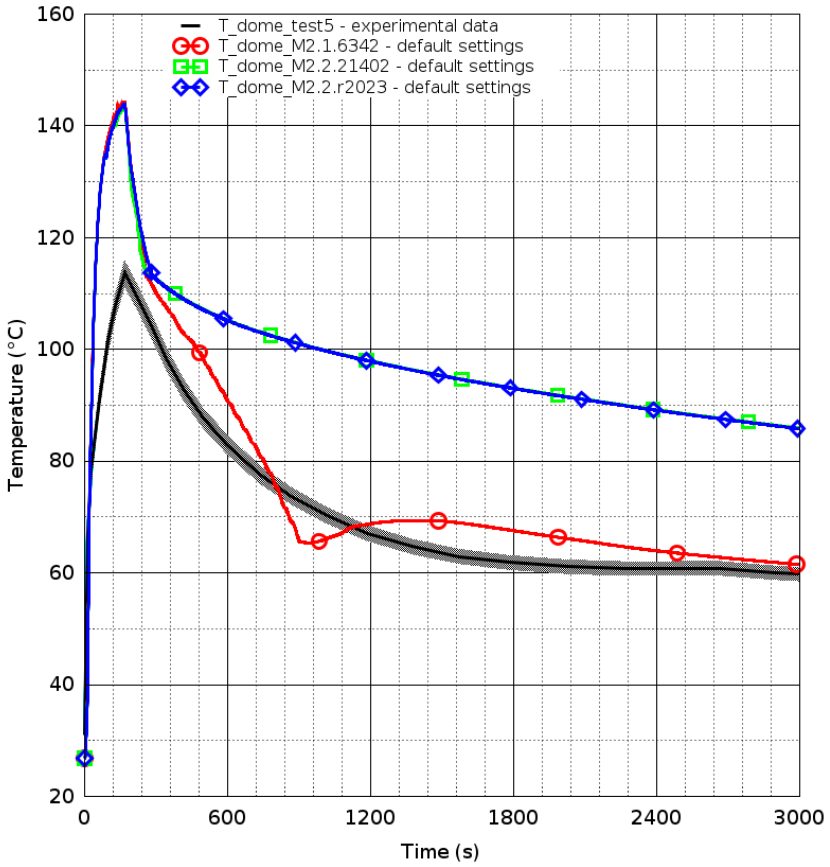
Test 4


P_box_test4 - experimental data
P_box_M2.1.6342 - default settings
P_box_M2.2.21402 - default settings
P_box_M2.2.r2023 - default settings
Pressure_abs (Pa)
3e+05
2.8e+05
2.6e+05
2.4e+05
2.2e+05
2e+05
1.8e+05
1.6e+05
1.4e+05
1.2e+05
1e+05
0
600
1200
1800
2400
3000
Time (s)


T_dome_test4 - experimental data
T_dome_M2.1.6342 - default settings
T_dome_M2.2.21402 - default settings
T_dome_M2.2.r2023 - default settings
Temperature (°C)
160
140
120
100
80
60
40
20
0
600
1200
1800
2400
3000
Time (s)

Test 5


P_box_test5 - experimental data
P_box_M2.1.6342 - default settings
P_box_M2.2.21402 - default settings
P_box_M2.2.r2023 - default settings
Pressure_abs (Pa)
3e+05
2.8e+05
2.6e+05
2.4e+05
2.2e+05
2e+05
1.8e+05
1.6e+05
1.4e+05
1.2e+05
1e+05
0
600
1200
1800
2400
3000
Time (s)


T_dome_test5 - experimental data
T_dome_M2.1.6342 - default settings
T_dome_M2.2.21402 - default settings
T_dome_M2.2.r2023 - default settings
Temperature (°C)
160
140
120
100
80
60
40
20
0
600
1200
1800
2400
3000
Time (s)

Conclusion

- The calculations confirmed the conservative values of CTMT pressure peak
- The proper settings for realistic calculation of CTMT parameters analyzed based on CVTR data
  - limited impact of investigated sensitivity coefficients
- The substantial differences were identified between MELCOR 2.1 and MELCOR 2.2 within CVTR Test 4 and Test 5 with CTMT spray operation
  - seems like there is no condensation effect of CTMT sprays in M2.2 (SPR-HTTRAN=0 in M2.2)
  - no such problem found in VVER-1000 model (??)

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Thanks for your attention

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