SAND2018-7875PE

DLR Arcjet Simulations

PRESENTED BY

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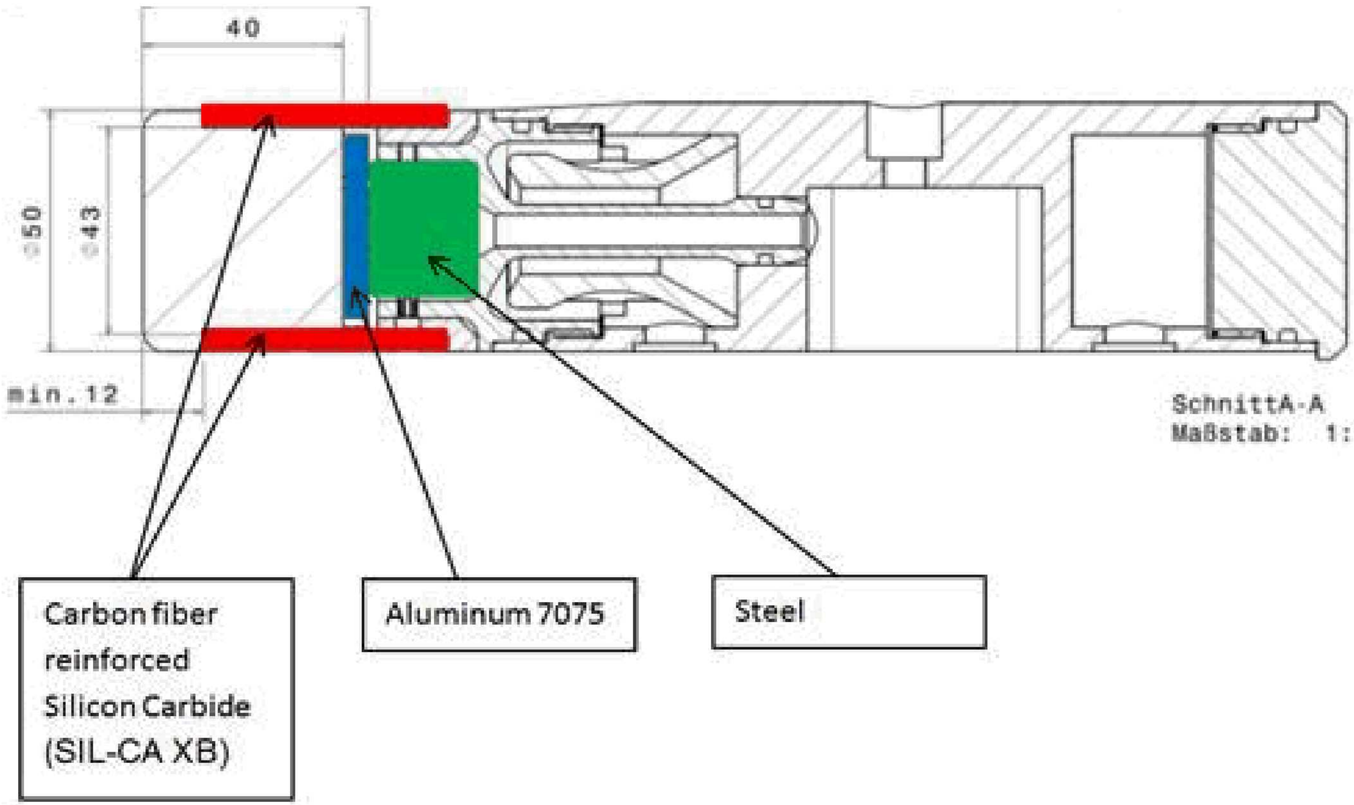
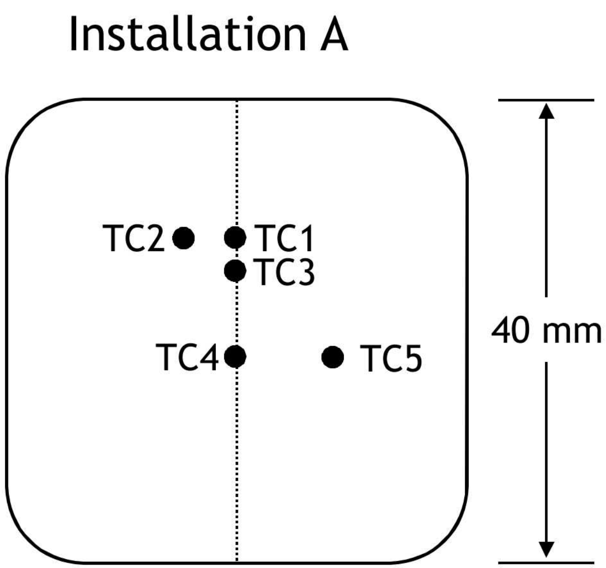
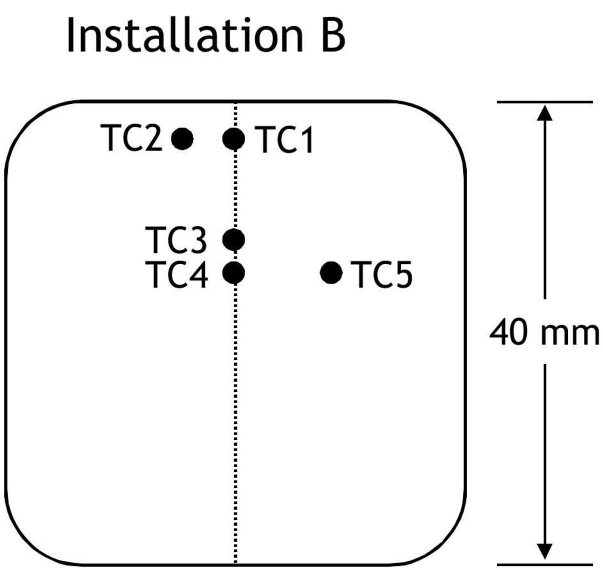
Test Setup

- Test schematic illustrating sample, SIL-CA, and aluminum and steel backing
- 1-D and 2-D thermal meshes created based on dimensions below



Thermocouple Installations





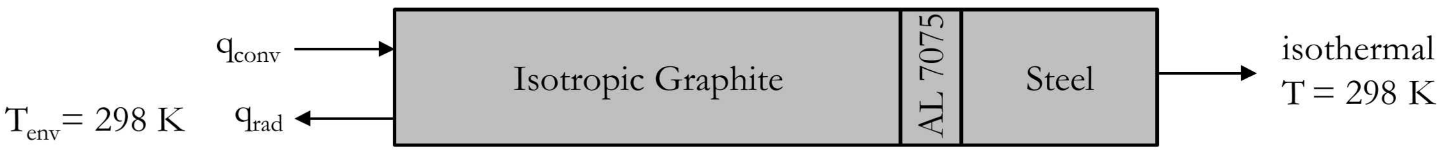
Installation A			
On axis	Offaxis: 4mm	Offaxis: 10mm	
TC (Type)	TC (Type)	TC (Type)	Depth (mm)
TC1 (K)	TC2 (S)		12
TC3 (K)			15
TC4 (K)		TC5 (K)	26

Installation B			
On axis	Offaxis: 4mm	Offaxis: 10mm	
TC (Type)	TC (Type)	TC (Type)	Depth (mm)
TC1 (K)	TC2 (S)		3
TC3 (K)			12
TC4 (K)		TC5 (K)	15

Note: TC1 = DLR TC1, TC2 = DLR TC0, TC3 = DLR TC2, TC4 = DLR TC3, TC5 = DLR TC4

1-D Problem Setup

- Only considering tests using air atmosphere
- Tests covering 3 heating rates have been chosen: Tests 1, 18, 19



DSTL 2017: Test matrix

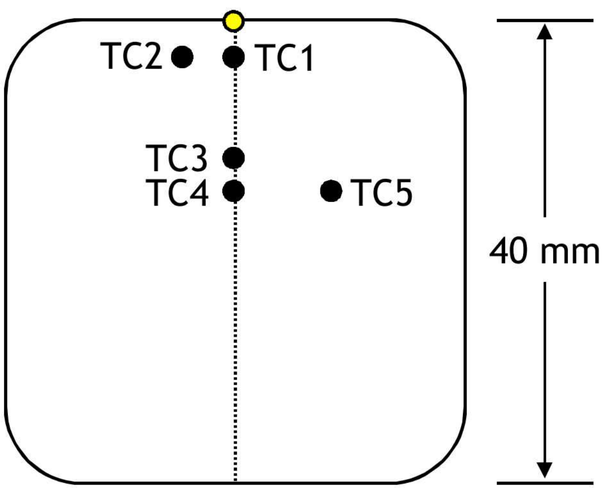
Test	Run #	DSTL Test #	Sample	Facility	Atmosphere	Heat flux rate [MW/m^2]	Test duration [s]
01	110917_02	8	PSG00042899C	L2K	air	0.89	80.3
02	110917_03	7	PSG00042899F	L2K	nitrogen	0.88	80.8
03	120917_01	1	PSG00042899E	L2K	argon	0.88	80.2
04a	120917_02	6	PSG00042899B	L2K	argon	0.88	23.8
04	130917_02	6	PSG00042899B	L2K	argon	0.88	160.3
05	130917_03	2	PSG00042899E	L2K	argon	0.88	160.7
06	140917_01	4	PSG00042963A	L2K	argon	0.88	160.6
07	140917_02	3	PSG00042899E	L2K	argon	0.88	161.1
08	140917_03	5	PSG00042963C	L2K	argon	0.88	160.3
09	017175L	20	PSG00042899A	L3K	Nitrogen	10	21.9
10	018175L	14	PSG00042963A	L3K	Nitrogen	10	20.5
11	019175L	13	PSG00042963C	L3K	Nitrogen	10	20.4
12	020175L	9	PSG00042899E	L3K	Nitrogen	5	40.5
13	021175L	12	PSG00042899B	L3K	Nitrogen	5	40.9
14	022175L	10	PSG00042899F	L3K	Nitrogen	5	41.0
15	023175L	11	PSG00042899C	L3K	Nitrogen	5	40.6
16	024175L	15	PSG00042899E	L3K	Air	5	39.9
17	025175L	16	PSG00042899F	L3K	Air	5	40.2
18	026175L	17	PSG00042899C	L3K	Air	5	60.6
19	027175L	19	PSG00042899B	L3K	Air	10	20.9
20	028175L	22	PSG00042963A	L3K	Air	10	20.5
21	029175L	18	PSG00042963C	L3K	Air	10	21.0
22	030175L	21	PSG00042963B	L3K	Air	10	29.9

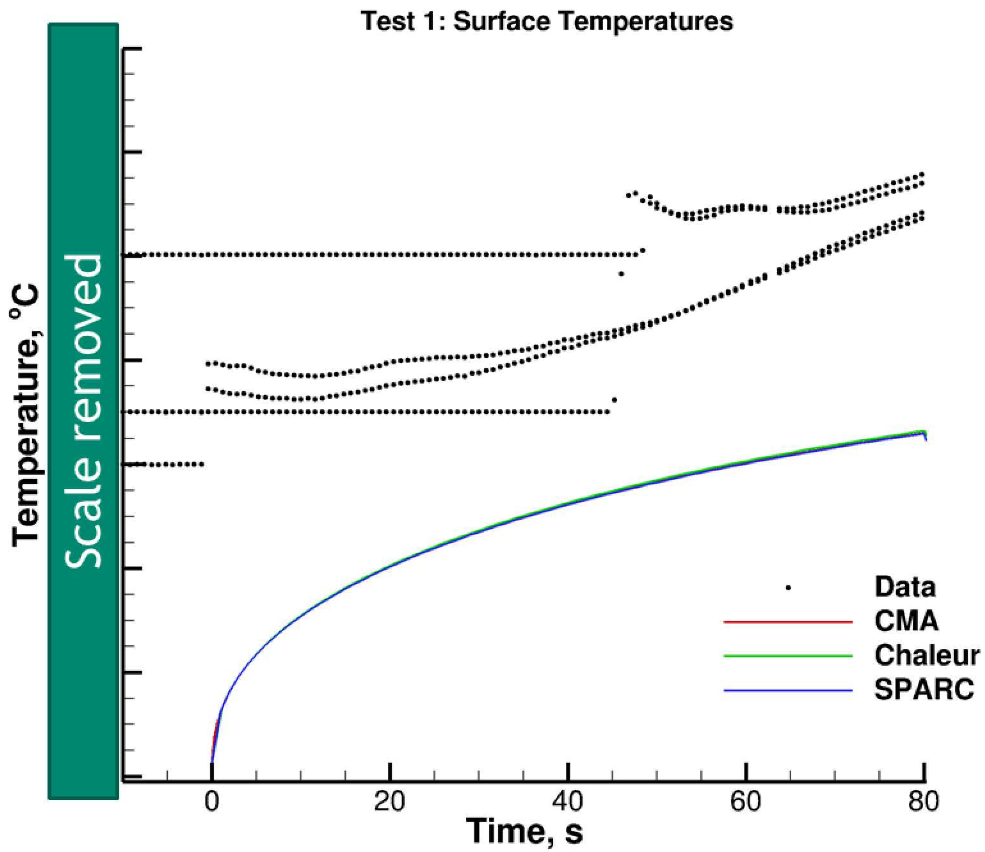
Test	Run #	DSTL Test #	Sample	Facility	Atmosphere	Heat flux rate [MW/m^2]	Test duration [s]
01	110917_02	8	PSG00042899C	L2K	air	0.89	80.3
18	026175L	17	PSG00042899C	L3K	Air	5	60.6
19	027175L	19	PSG00042899B	L3K	Air	10	20.9

Test 01: Surface Temperatures

- Loading conditions
  - q_w=0.86 MW/m^2
  - h=8.4 MJ/kg
  - P=0.05 atm
  - Duration = 80.3 s

Installation B

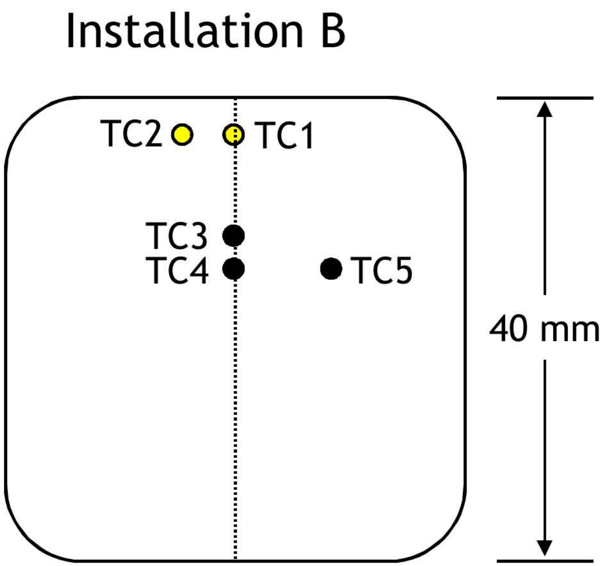


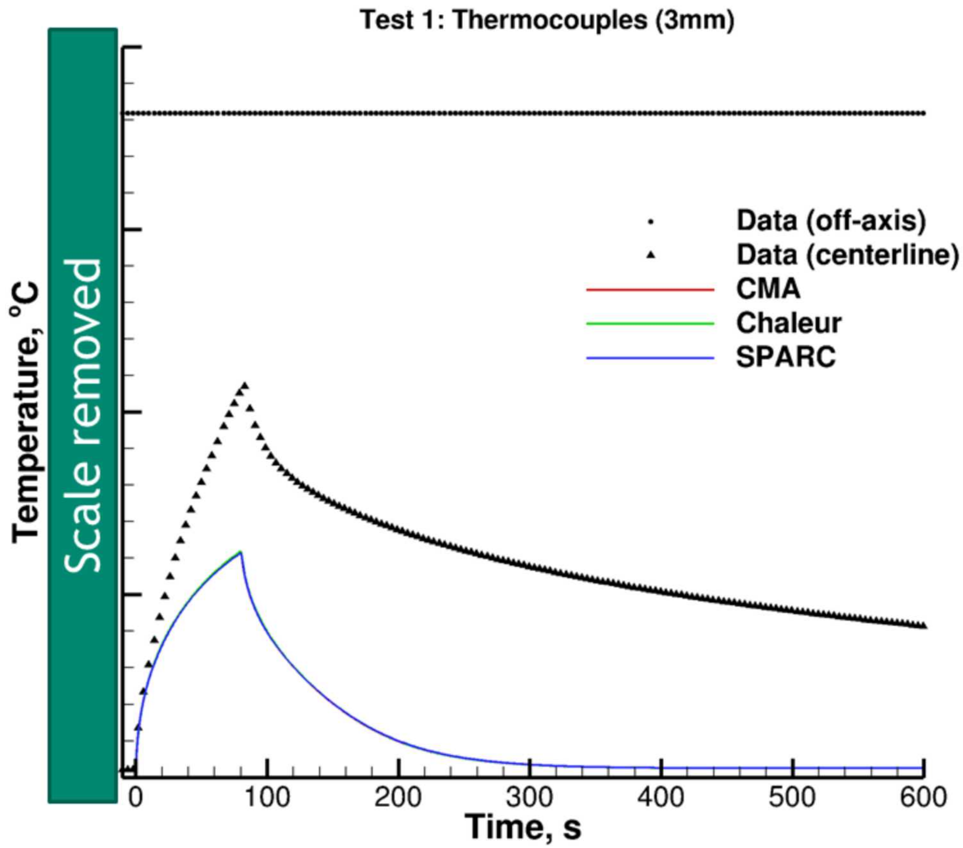


*For visual clarity, not all experimental data points shown

Test 01: 3 mm in-depth TC

- Simulations start under-predicting rise in temperature after approximately 20 s
- Results in under-prediction of peak heating and cooldown process

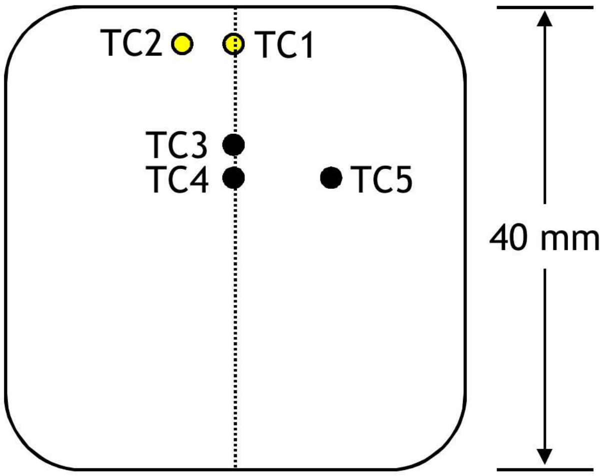


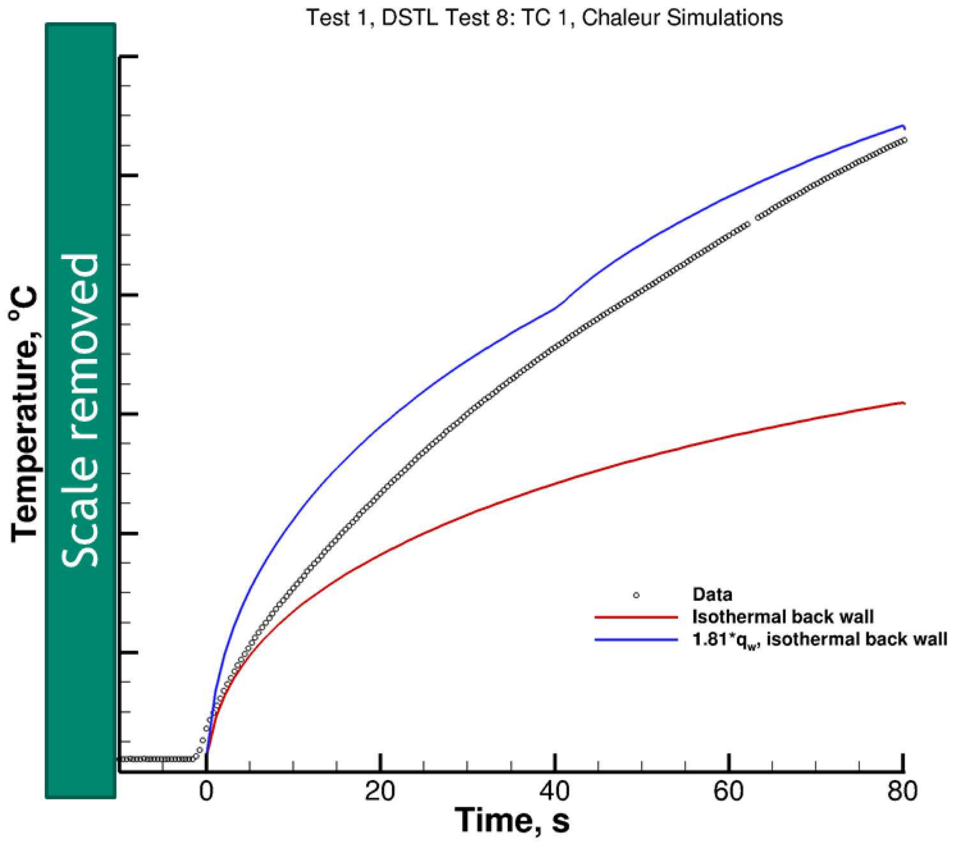


Test 01: 3 mm in-depth TC

- How much heating would be required to approximate peak TC 1 temperature?
  - Approximately $1.8q_w$
- Numerical results below generated using Chaleur

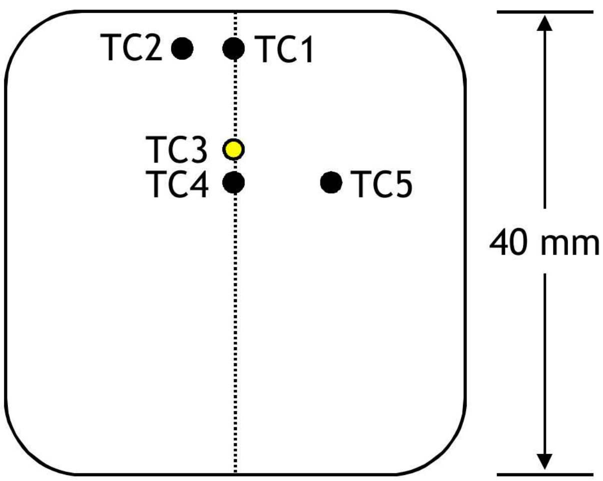
Installation B

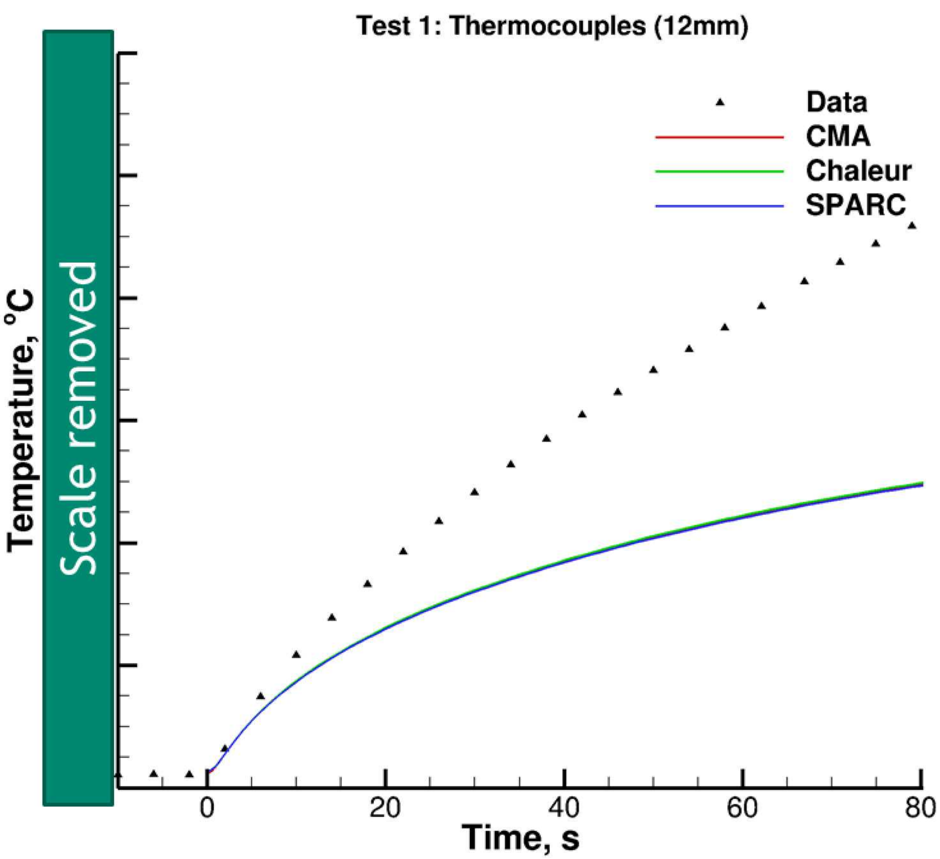




Test 01: 12 mm in-depth TC

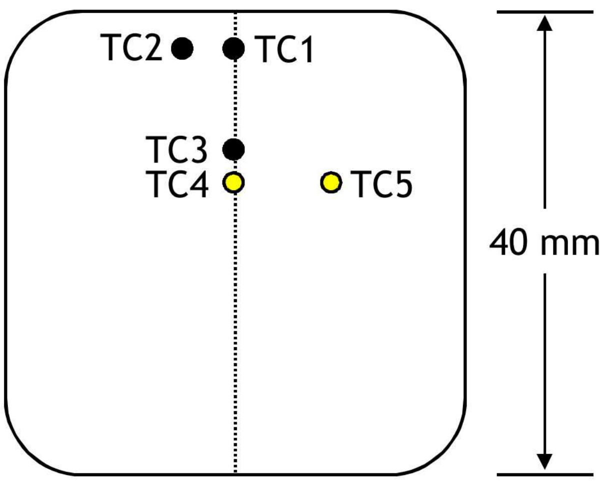
Installation B

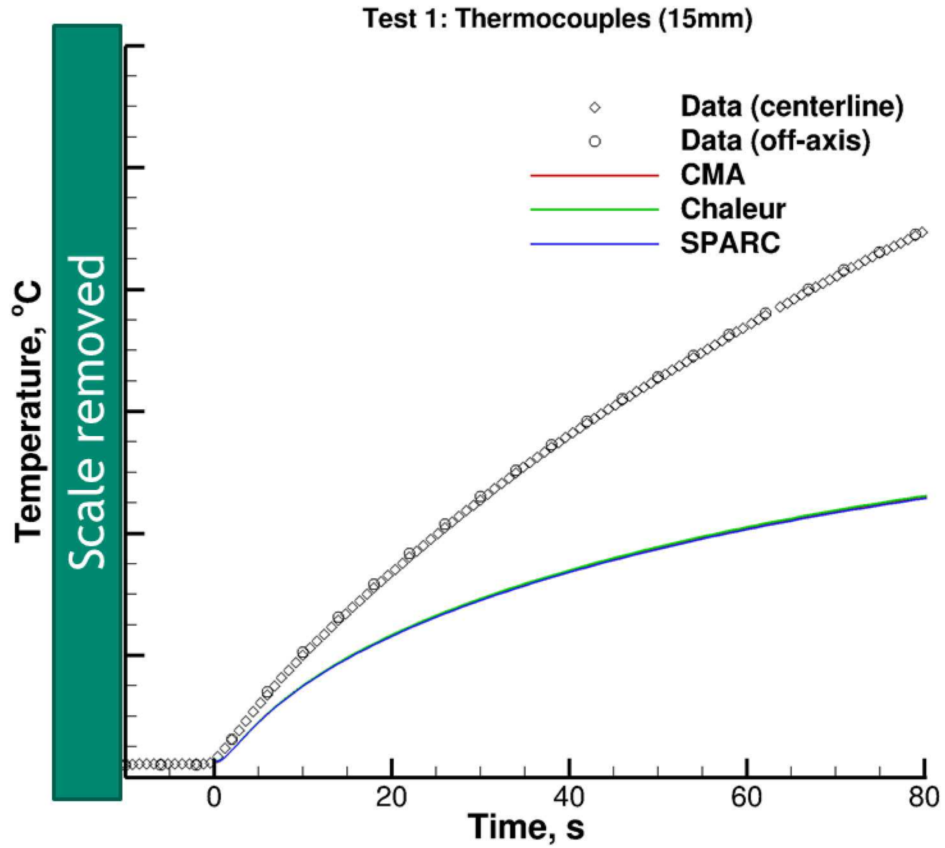




Test 01: 15 mm in-depth TC

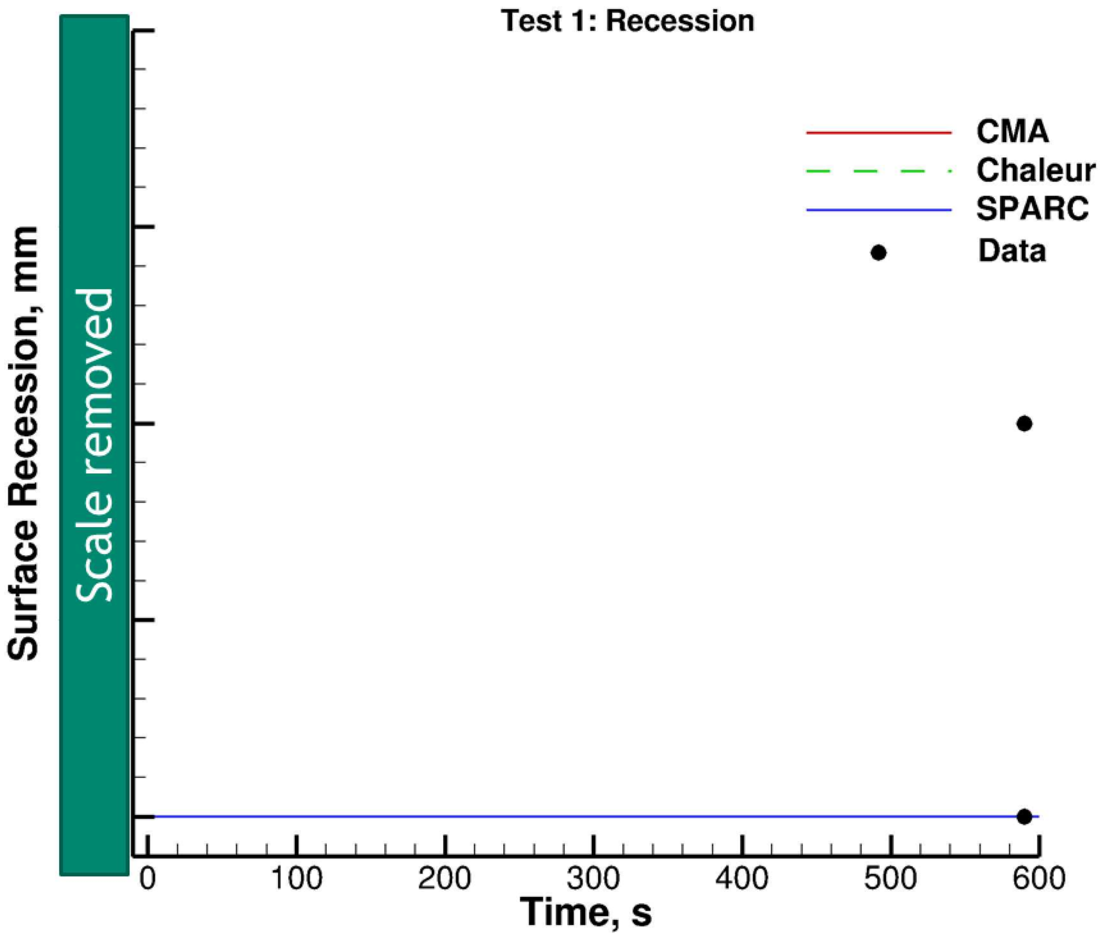
Installation B





Test 01 (DSTL Test 08): Surface Recession

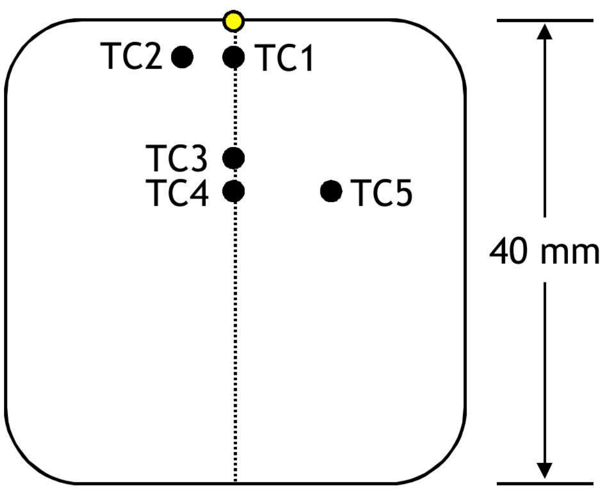
- All 3 simulations predicting zero recession

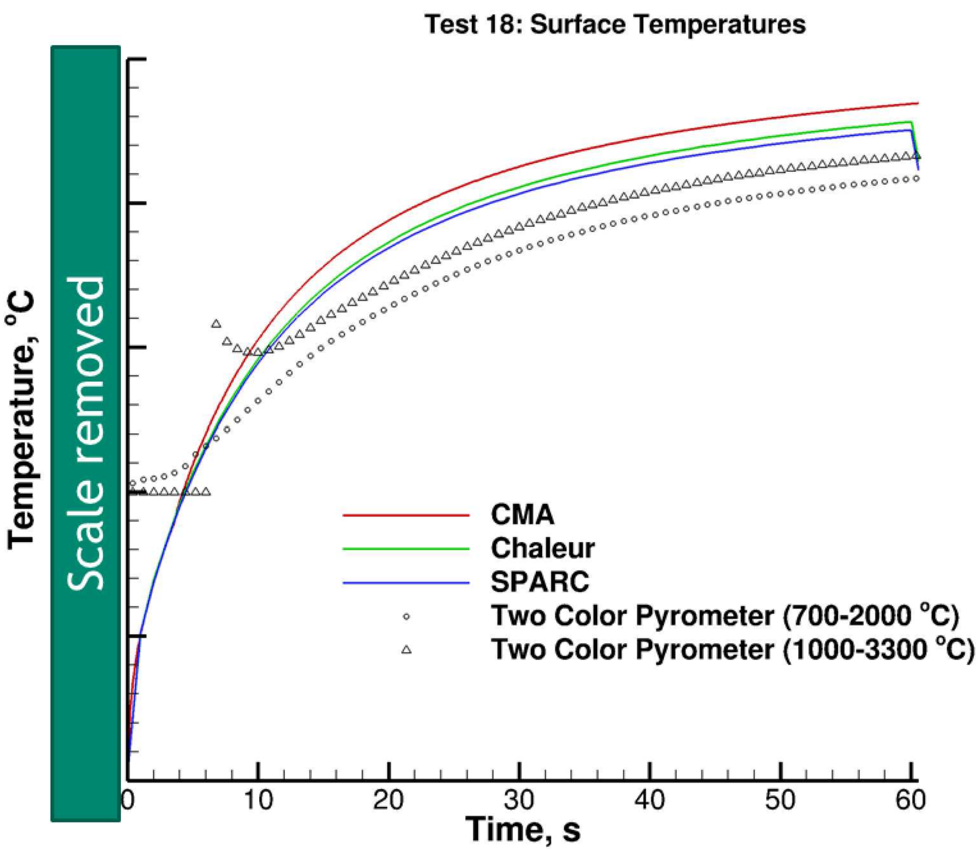


Test 18: Surface Temperatures

- Loading Conditions
  - $q_w = 5\ MW/m^2$
  - h = 16 MJ/kg
  - P = 0.21 atm
  - Duration = 60.6 s

Installation B

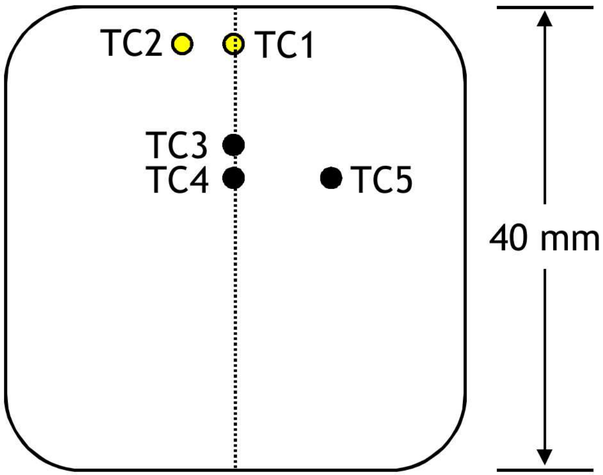


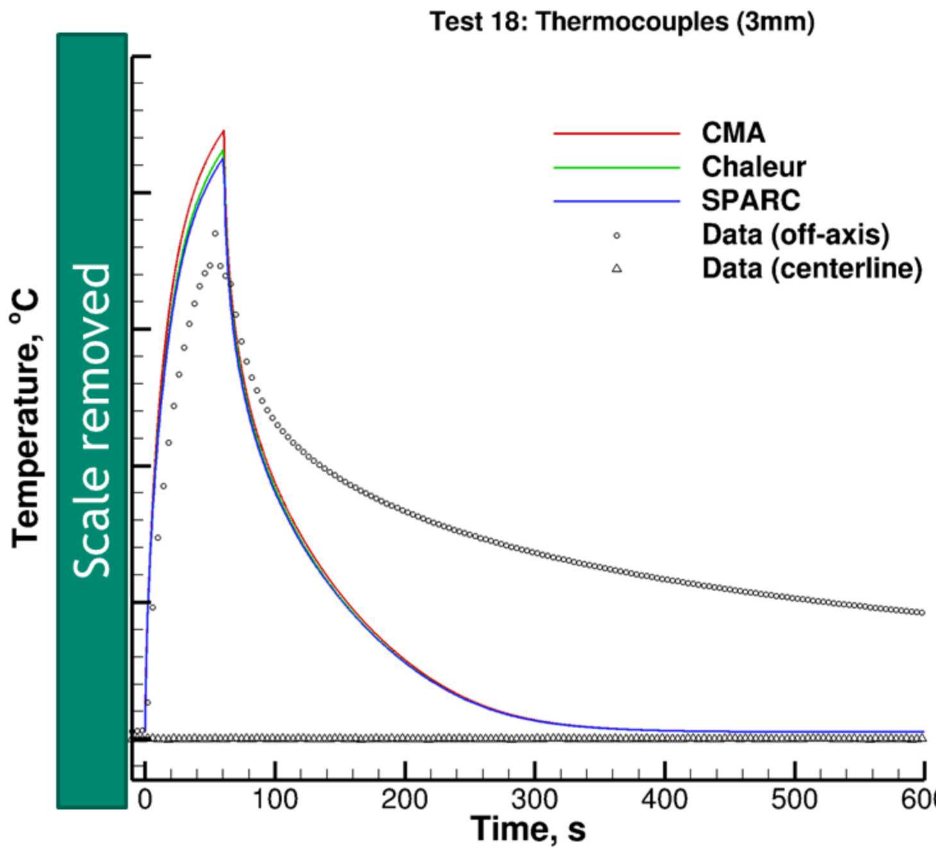


Test 18: 3 mm in-depth TC

- Temperature on surface and at 3mm rises too quickly compared to data
- Results in under-prediction of cooldown process

Installation B

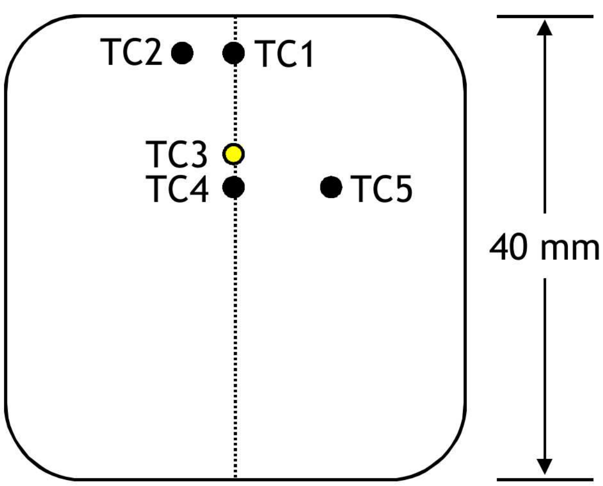


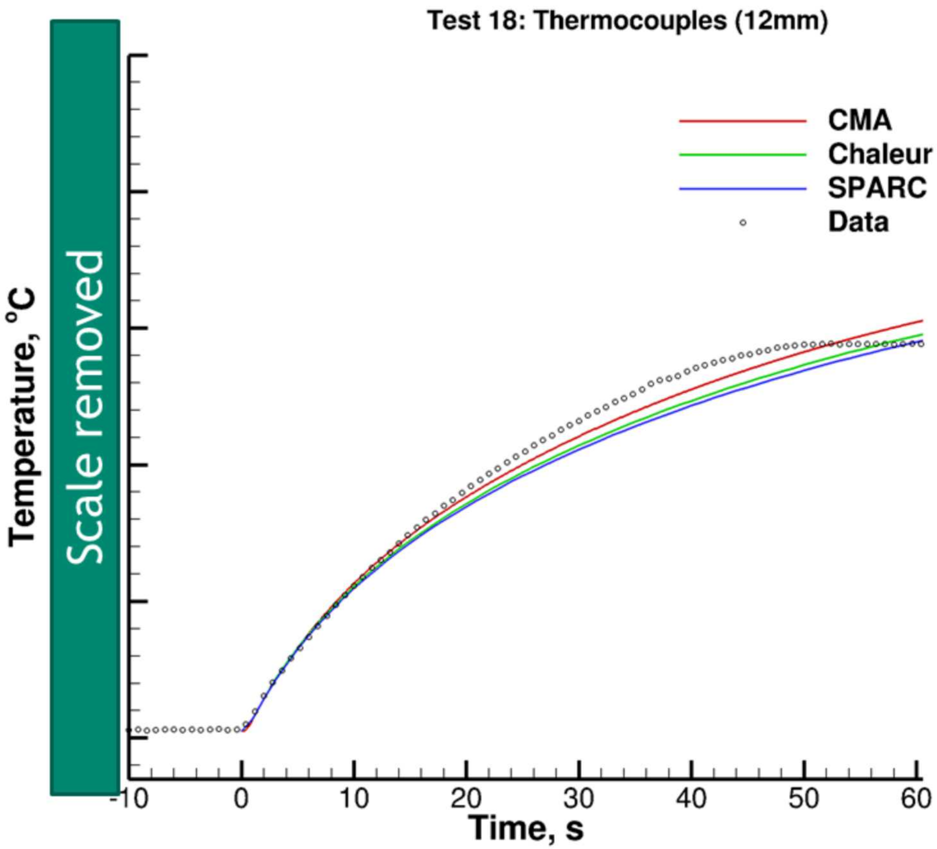


Test 18: 12 mm in-depth TC

- Temperature rise follows data more closely deeper within sample

Installation B

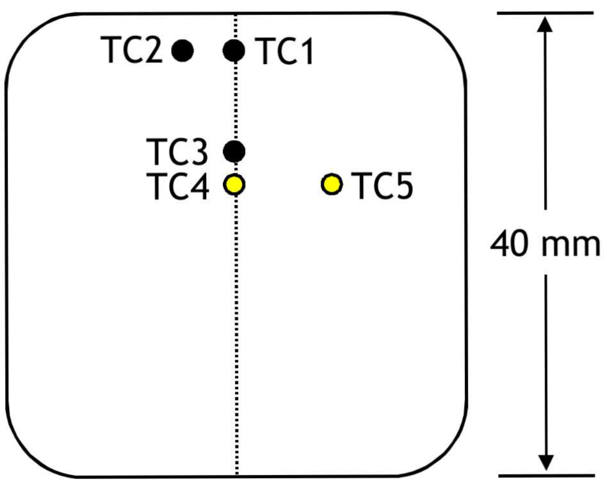


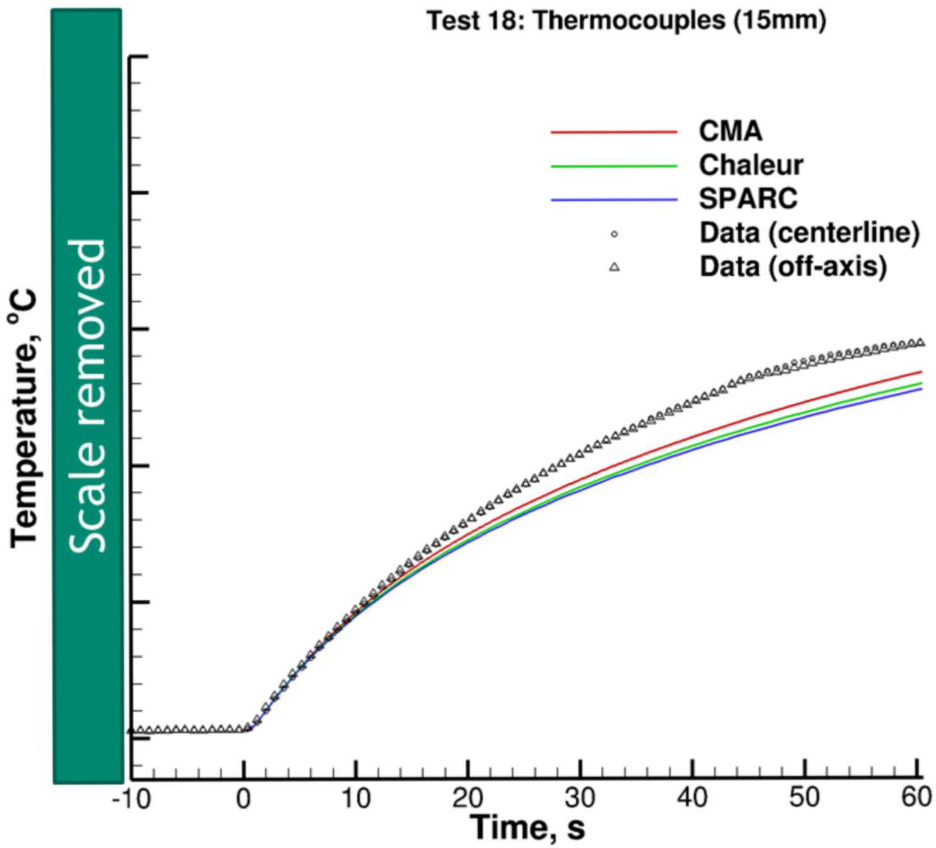


Test 18: 15 mm in-depth TC

- With further depth, the numerical results start to under-predict

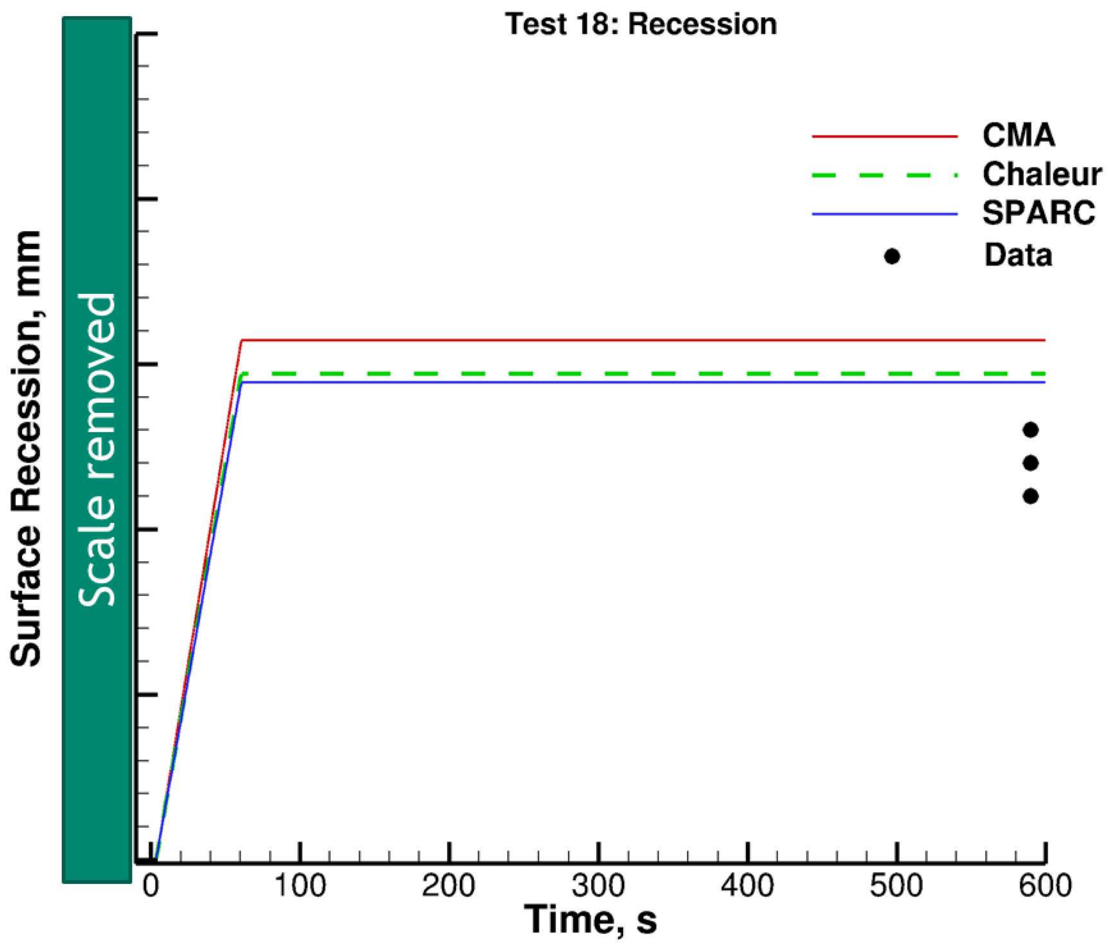
Installation B





Test 18: Surface Recession

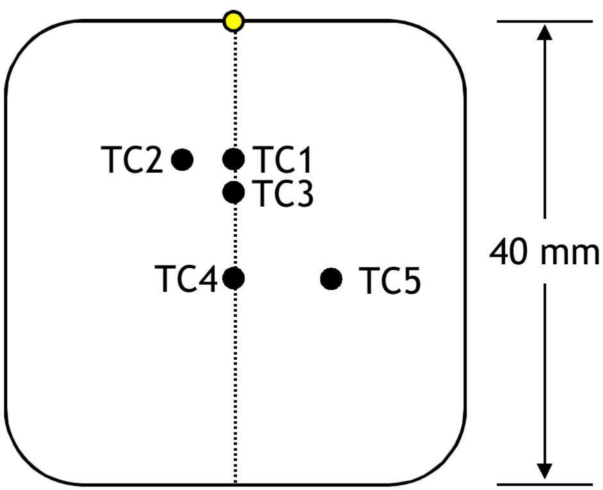
- Recession values within 11.5% - 43% of data

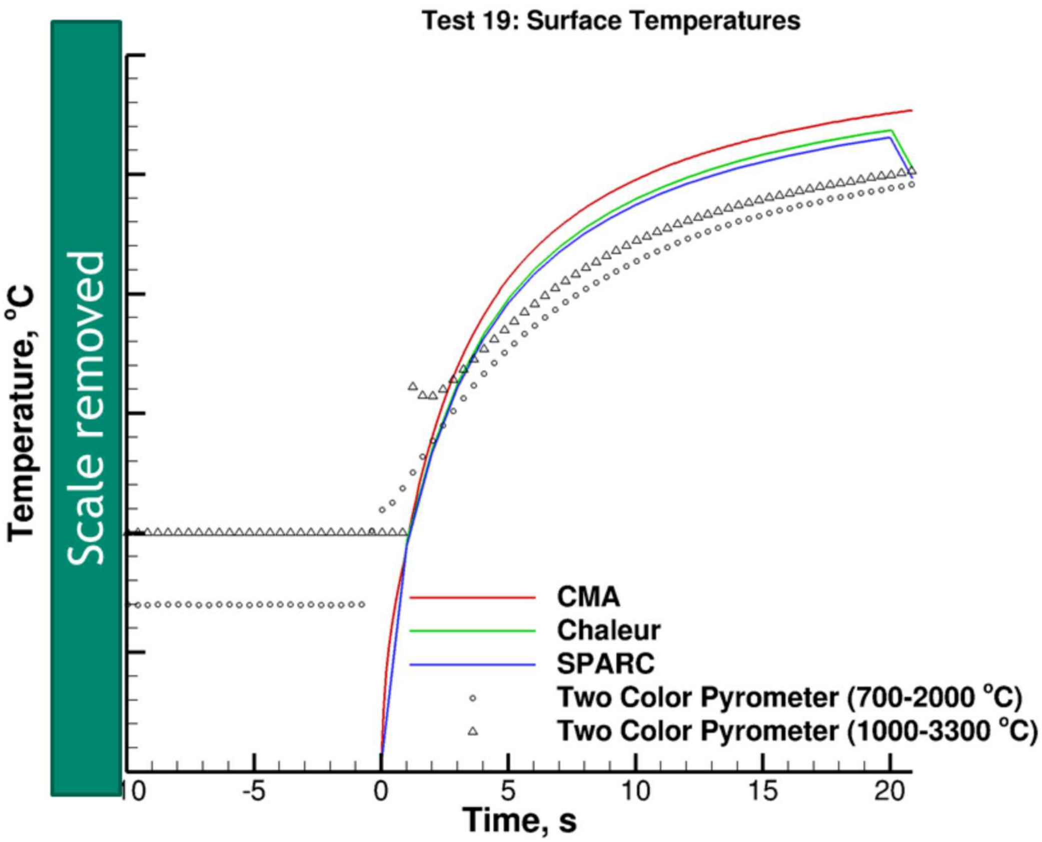


Test 19: Surface Temperatures

- Loading conditions
  - q_w =10 MW/m^2
  - h = 16 MJ/kg
  - P = 0.6 atm
  - Duration = 20.9 s

Installation A

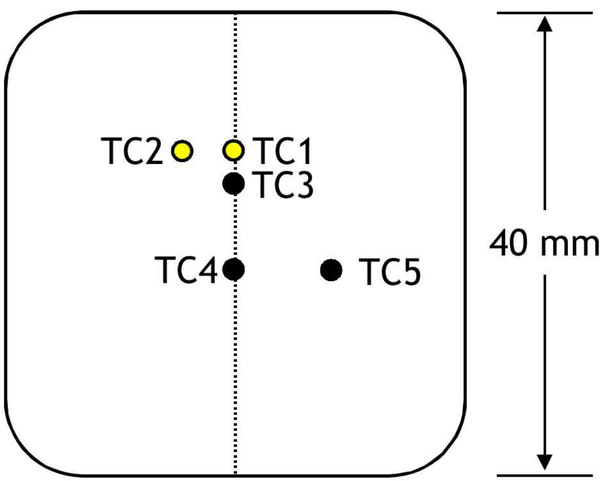


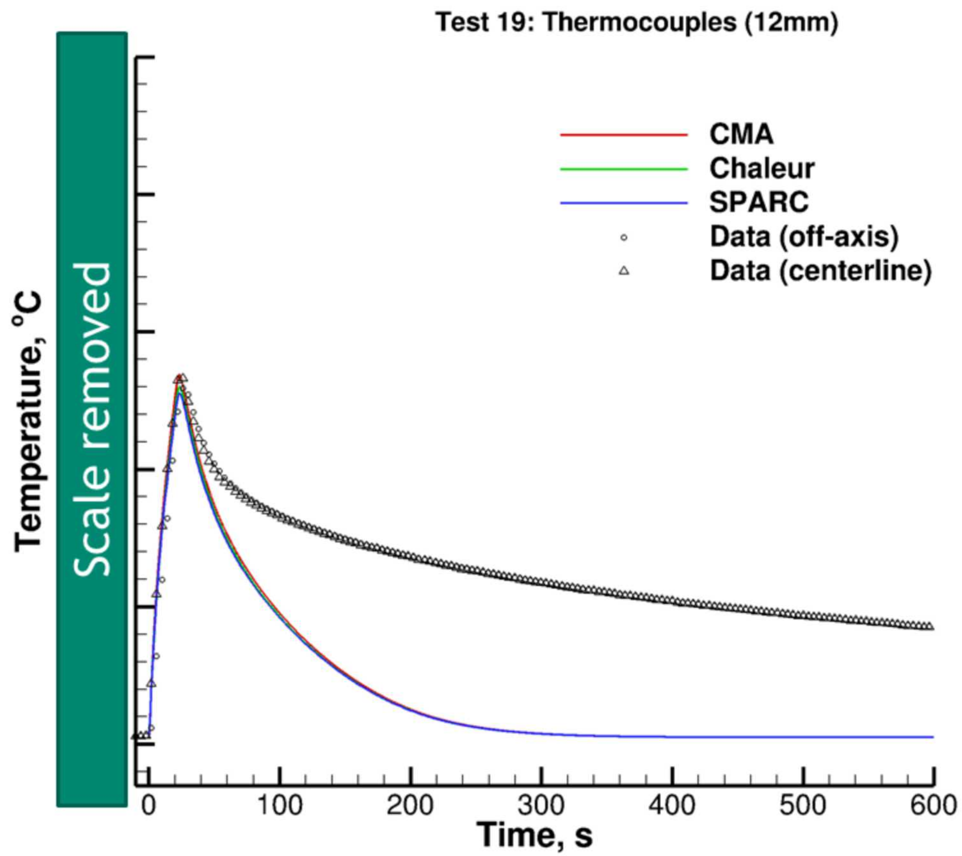


Test 19: 12 mm in-depth TC

- Simulation temperature rise passes through data points through peak temperature
- Similar rapid cooldown to previous two cases

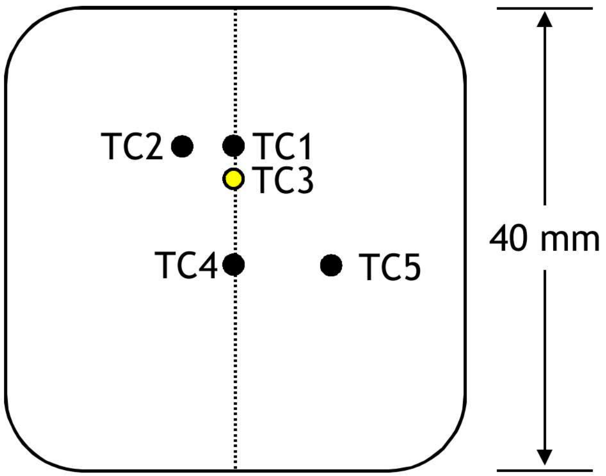
Installation A

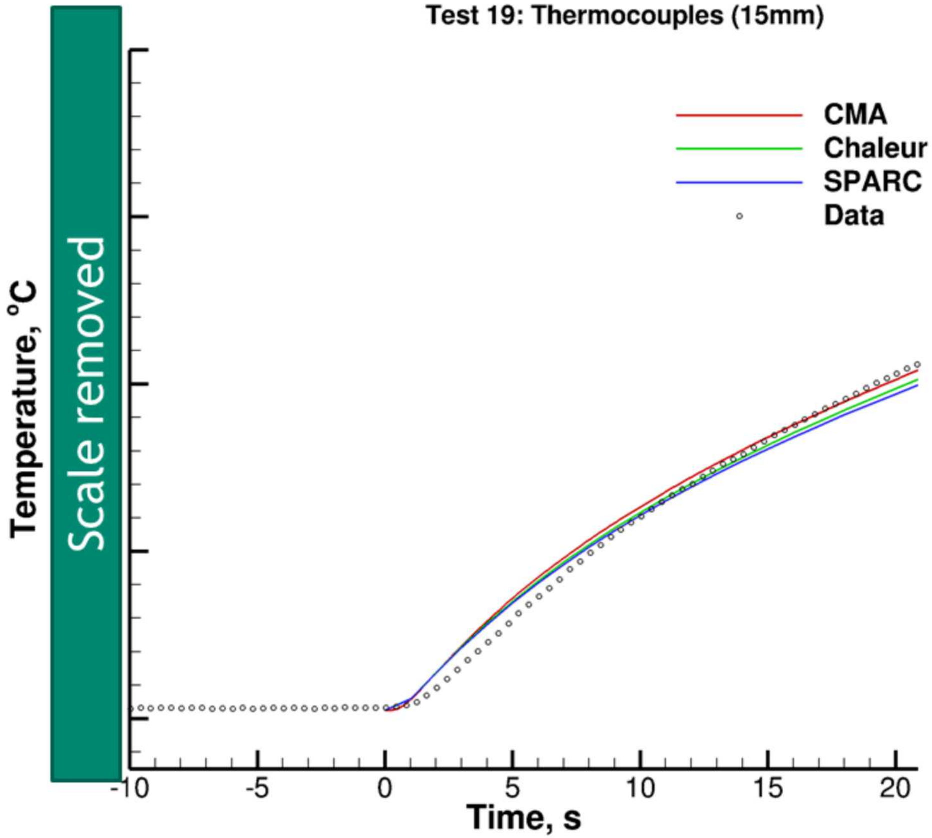




Test 19: 15 mm in-depth TC

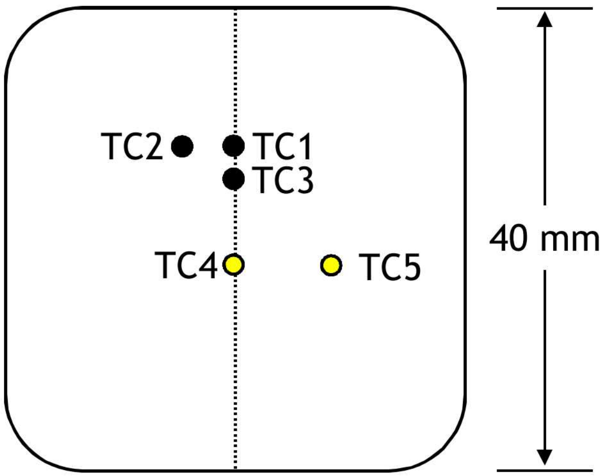
Installation A

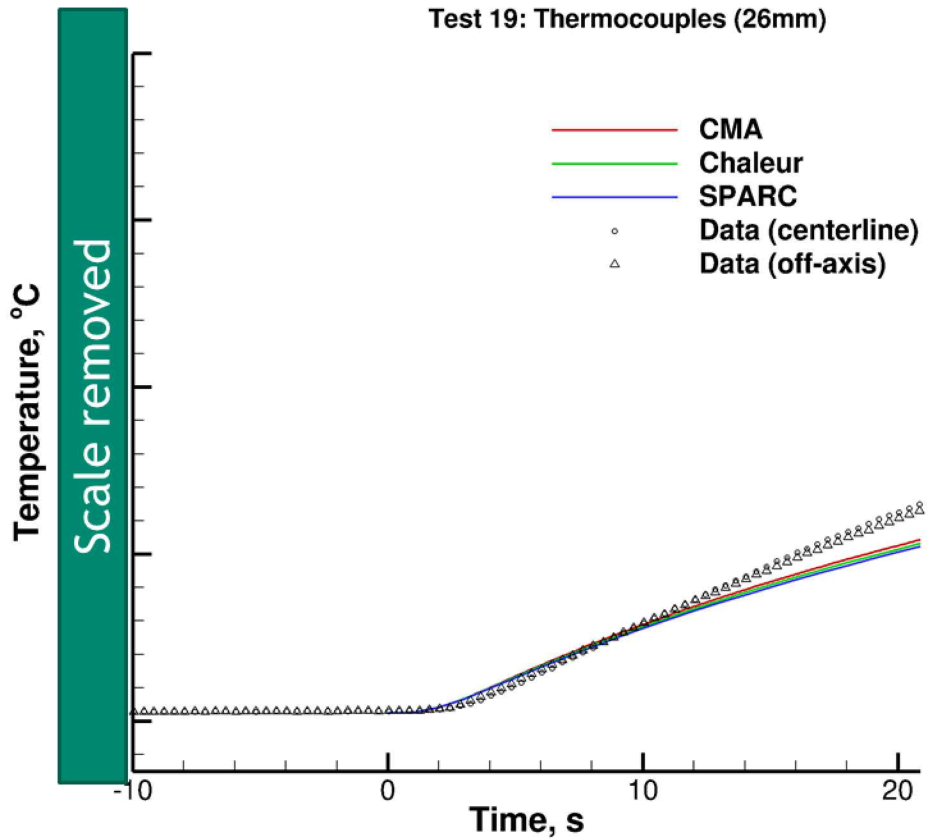




Test 19: 26 mm in-depth TC

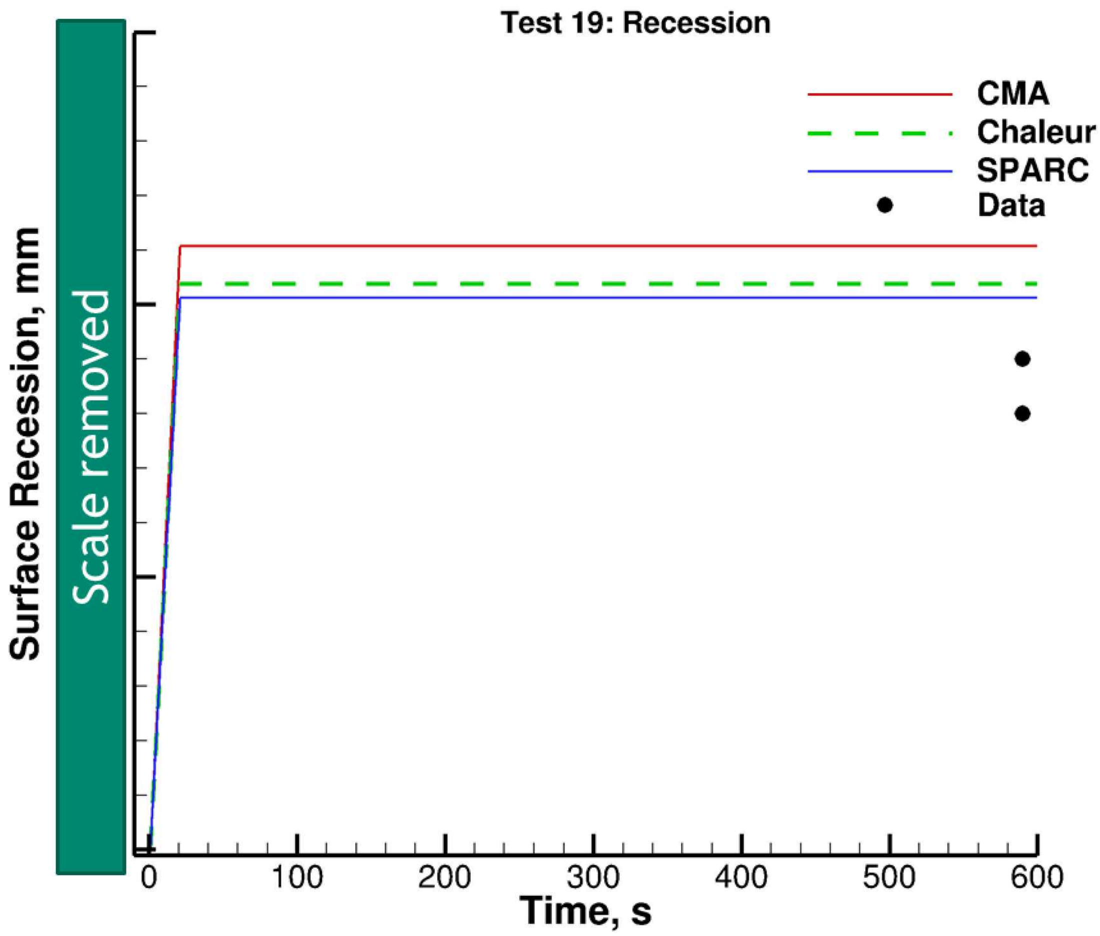
Installation A





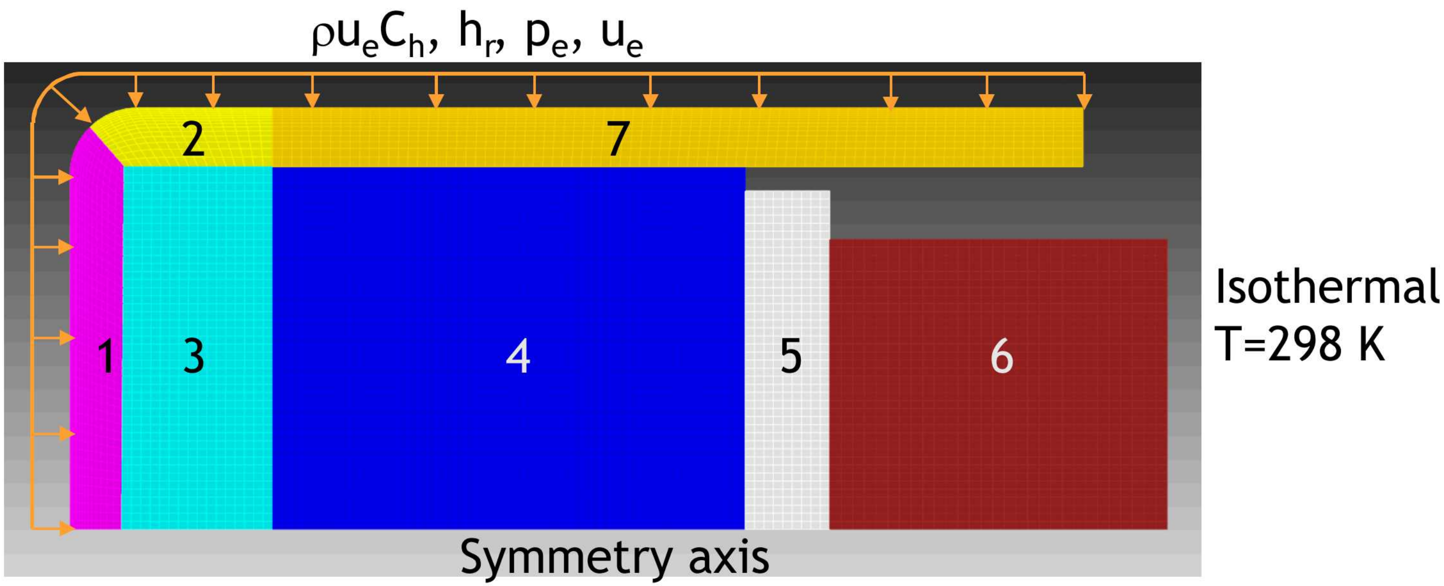
Test 19: Surface Recession

- Recession values within 11% - 37.5% of data



2-D Thermal Problem Setup

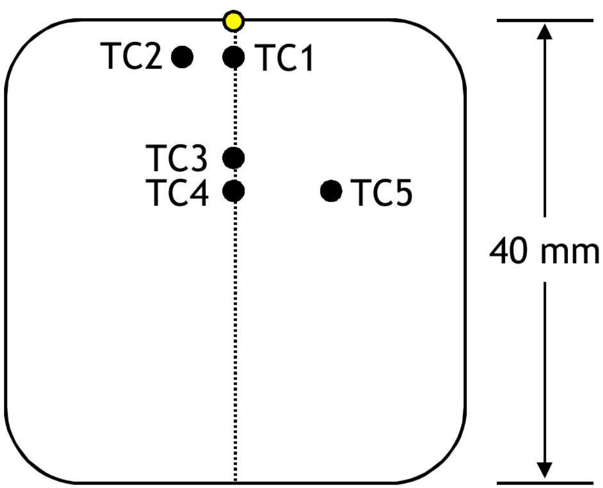
- Constant thermal loading to test thermal-only SPARC simulation for present model
- Graphite Sample: Blocks 1,2,3,4
- Aluminum: Block 5
- Steel: Block 6
- SIL-CA: Block 7

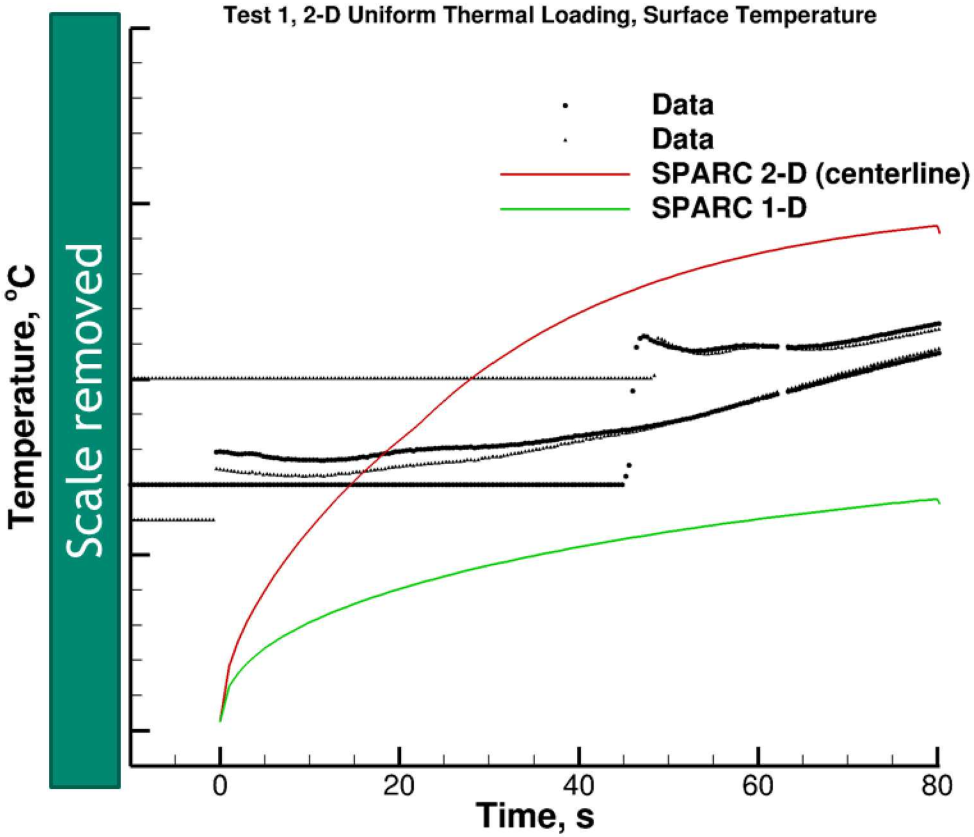


Test 01 2-D: Surface Temperatures

- Loading conditions
  - q_w=0.86 MW/m^2
  - h=8.4 MJ/kg
  - P=0.05 atm
  - Duration = 80.3 s

Installation B



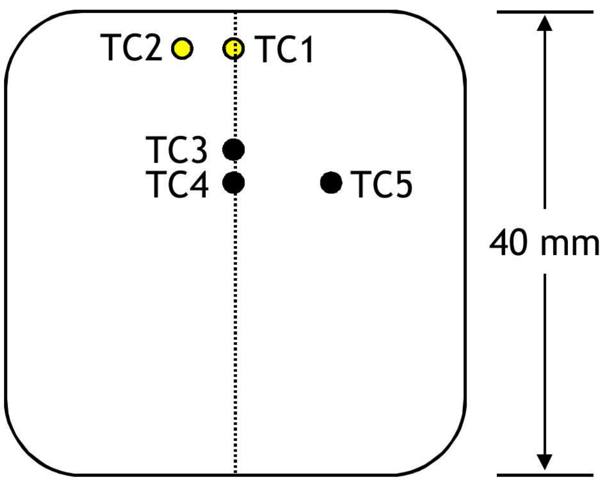


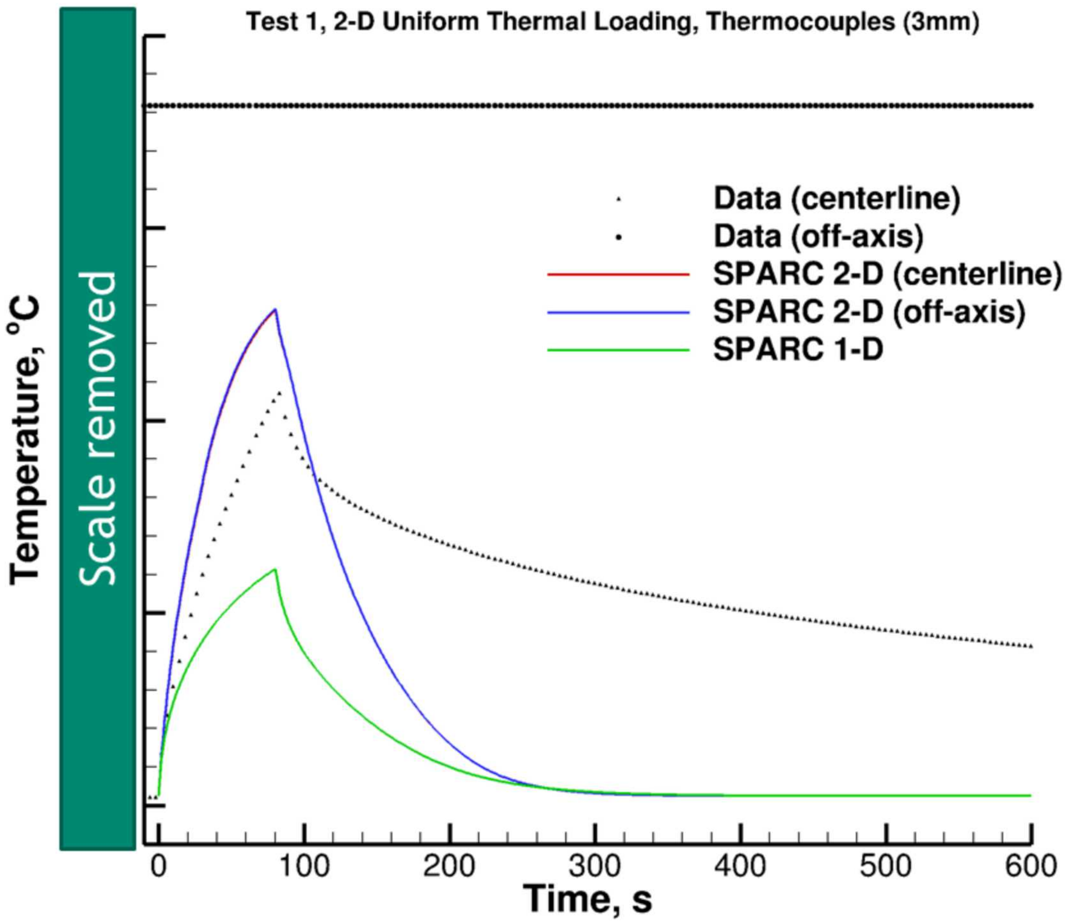
- Note: Centerline taken slightly off centerline (0.01mm)

Test 01 2-D: 3 mm in-depth TC

- In general, peak temperatures higher than 1-D simulations
- Likely due to increased thermal loading along entire sample surface
- Similar cooldown to 1-D

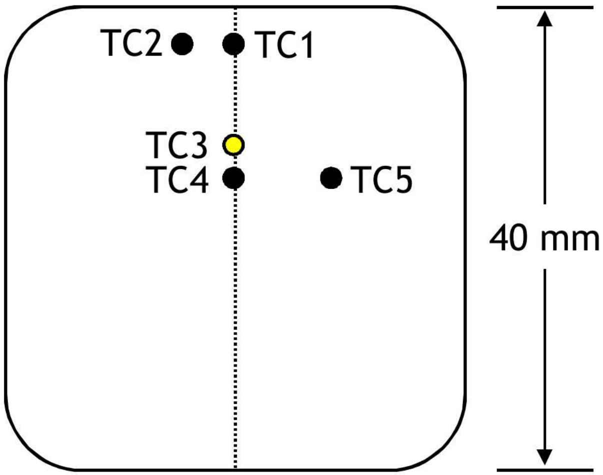
Installation B

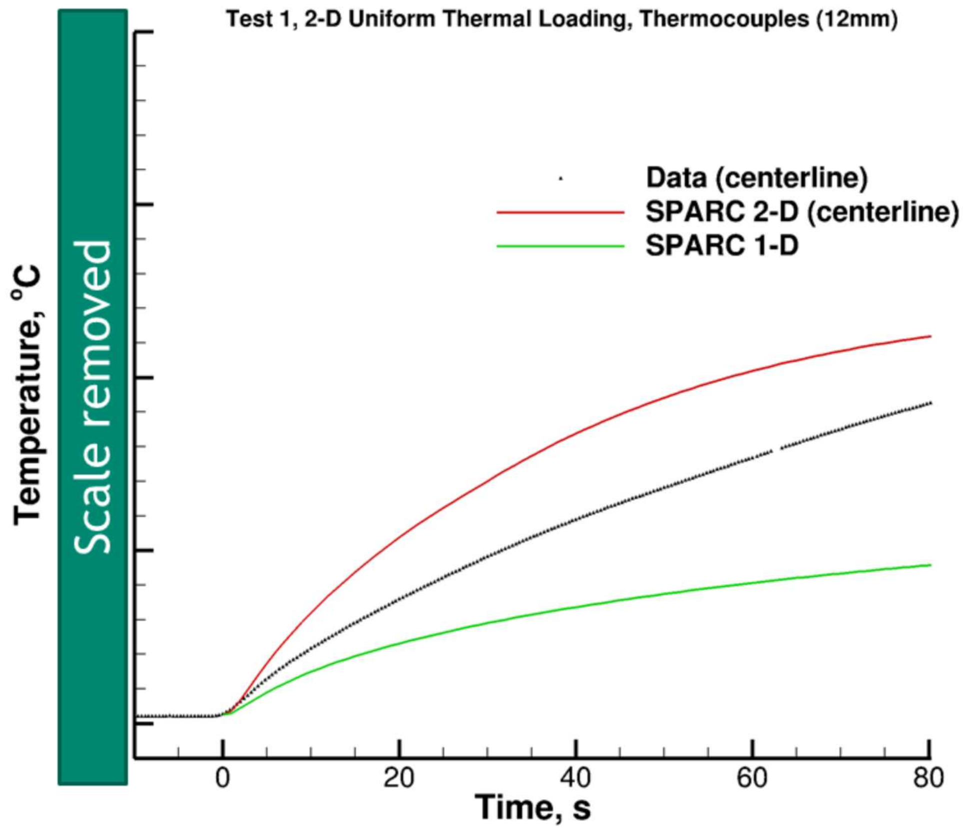




Test 01 2-D: 12 mm in-depth TC

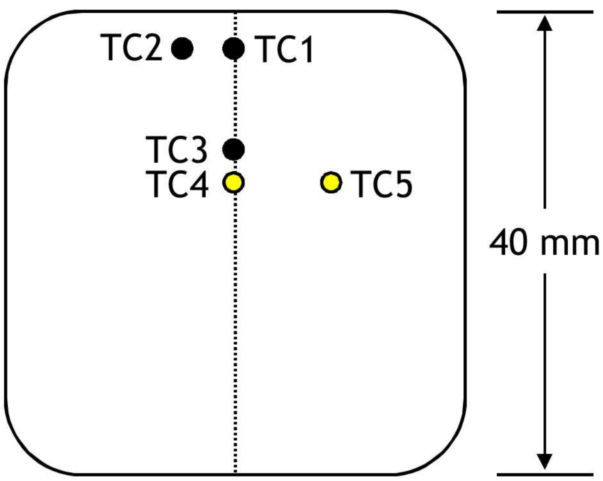
Installation B

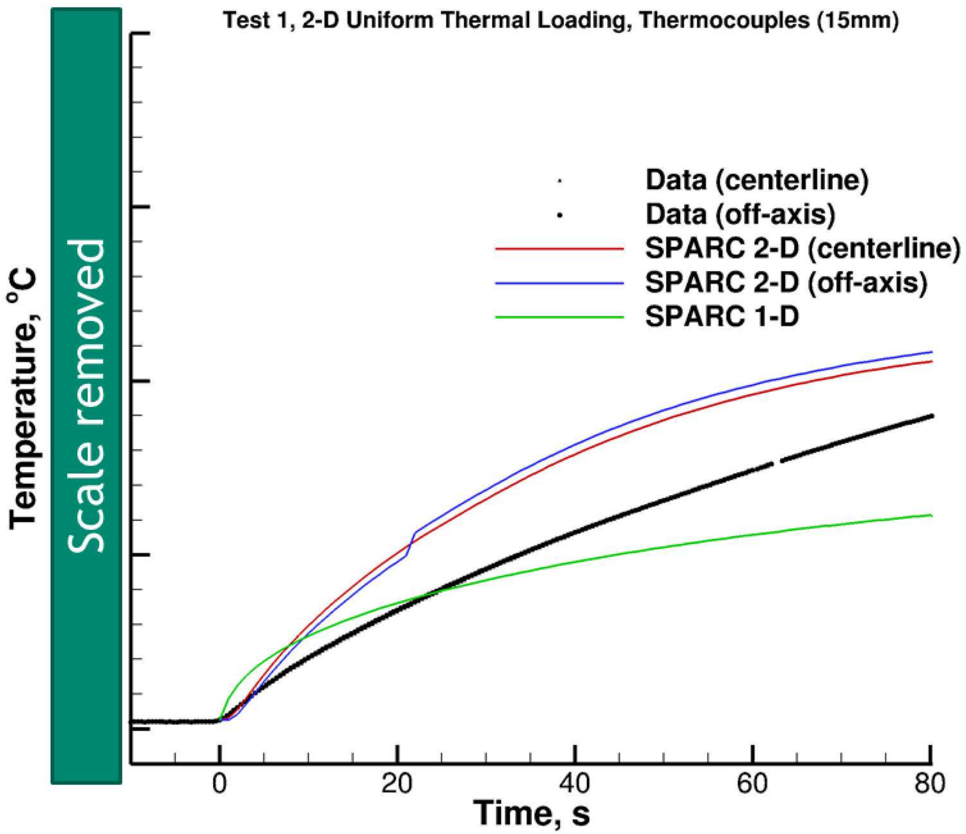




Test 01 2-D: 15 mm in-depth TC

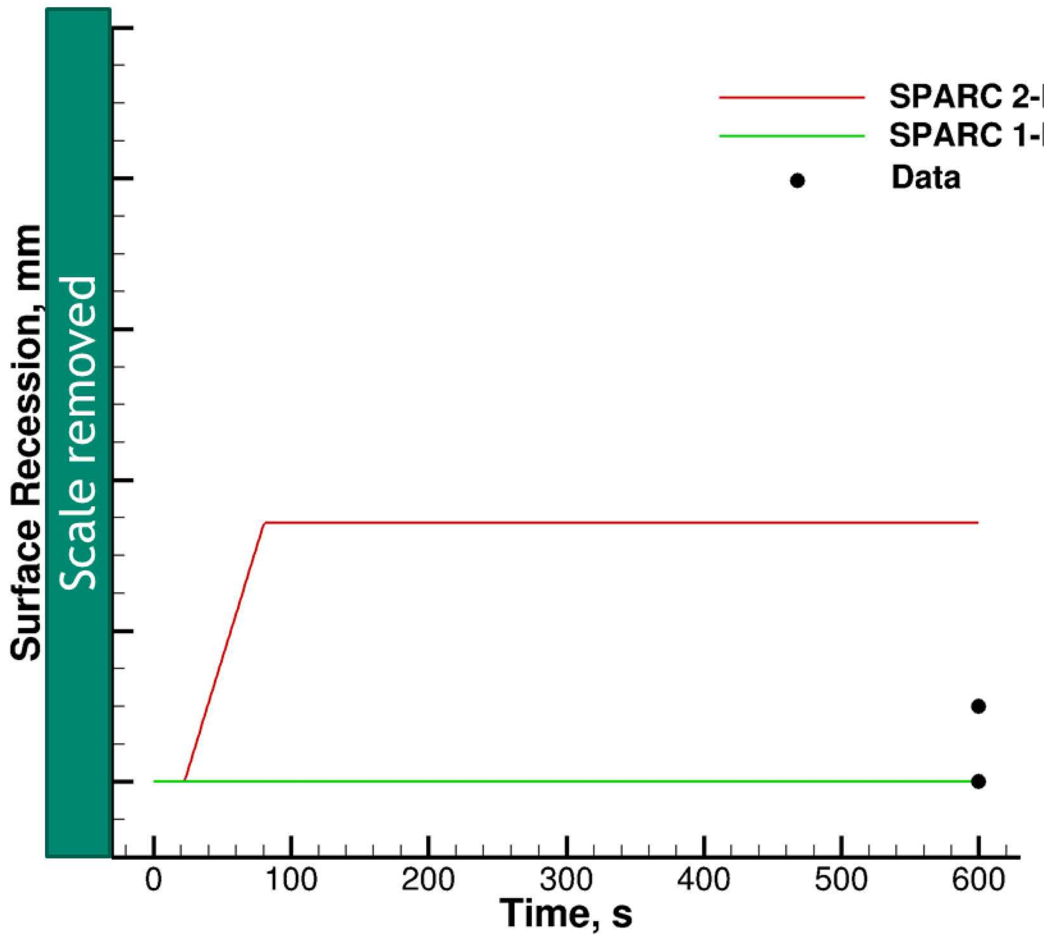
Installation B





Test 01 2-D: Surface Recession

- Expected recession to be near zero



Summary

- 1-D Thermal Analysis
  - Simulations for the test case 1 (low heating), under-predict much of the temperature profile, though still capture the near-zero surface recession
  - Simulations for test cases 18 and 19 (higher heating), demonstrate closer agreement during the heating phase, and in general, under-predict the temperature in cooldown.
- 2-D Thermal Analysis
  - Similar trends as compared to 1-D
  - In general, higher temperatures are present due to constant heating along entire surface