5K or not?
&
TTF module thermal modeling update

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Loads on the 5 K shield

Temperature Level	2K	
RF load		7,46
Supports	0,60	-
Input coupler	0,55	0,16
HOM coupler (cables)	0,01	0,18
HOM absorber	0,14	0,01
Beam tube bellows		0,36
Current leads	0,28	0,28
HOM to structure		1,20
Coax cable (4)	0,05	
Instrumentation taps	0,07	
Scales as Gfac		**7,83**
Scales as Pfac		**0,16**
Independent of G,Tf	**1,70**	**1,68**
Static, dynamic sum	**1,70**	**9,66**
2K Sum [W]	**11,4**	

	5K	
Radiation	1,41	
Supports	2,40	
Input coupler	1,48	1,32
HOM coupler (cables)	0,29	1,82
HOM absorber	3,13	0,76
Current leads	0,47	0,47
Diagnostic cable	1,39	-
Scales as Pfac		**1,32**
Independent of G,Tf	**10,56**	**3,04**
Static, dynamic sum	**10,56**	**4,37**
5K Sum [W]	**14,9**	

lead to increase on static
not the same **MLI!**

From Webex SCRF meeting
on 5 K shield removal

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TTF module thermal modeling

provide thermal intercepts on the many penetrations!

- couplers x 8 (9)
- leads
- cables

Shield surface provides surface for thermal strapping with small braids

5 K shield removal: what happens @ 2K?

- From Tom Cryo spreadsheet (Feb07)
  - 2K: 11.4 (1.7 s + 9.7 d) @ 700 W/W
  - 5K: 15.0 (10.6 s + 4.4 d) @ 200 W/W
  - 40K: 153.5 (59.2 s + 94.3 d) @ 16 W/W
  - Sum 14.4 kW plug power for each module (no overcapacity)
- If all 5K load goes into 2K "as is"
  - Plug power increased by 56%
    - Need to provide same efficient radiation shield for the 2K mass, with at least 10 layers MLI protecting the 2K cold mass
- If only radiation flow into 2K (consider factor 2 increase for worse MLI protection) and all conduction intercepted
  - Plug power increased by 15%
  - 5K thermalization for 3 posts, 8-9 couplers, HOM, leads, cables

From Webex SCRF meeting on 5 K shield removal

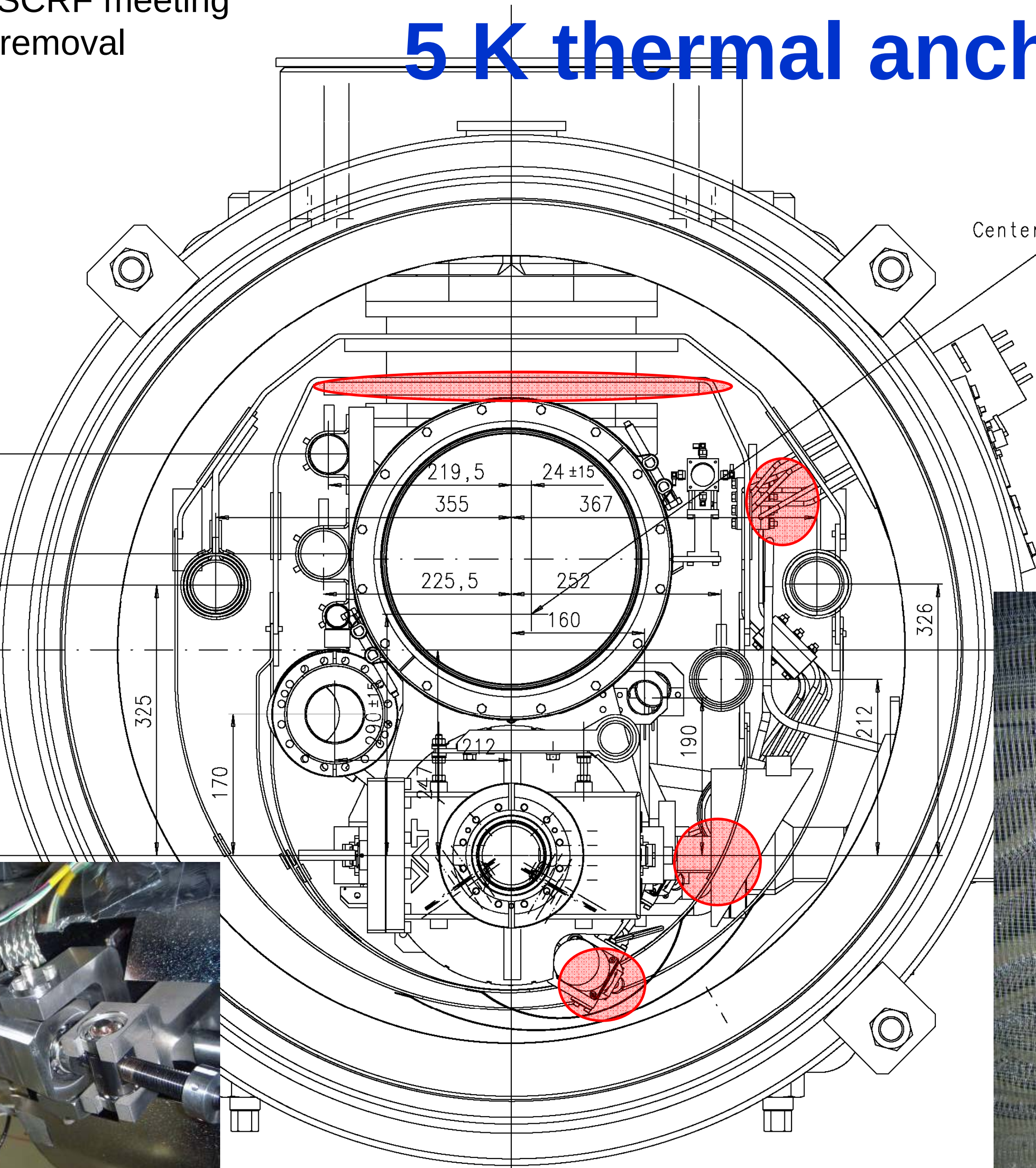
Operation vs Capital

- Range of effect on plug power (operation cost) is 15% to 55% **without redesigning cross section**
  - optimistic conditions given the many penetrations that the module has to the 2 K environment, and **located at different positions along the transverse section (support at top, couplers to the side)**
    - Bulky braids?
    - We need anyway a 5K cryo circuit for 90% of the conduction heat removal

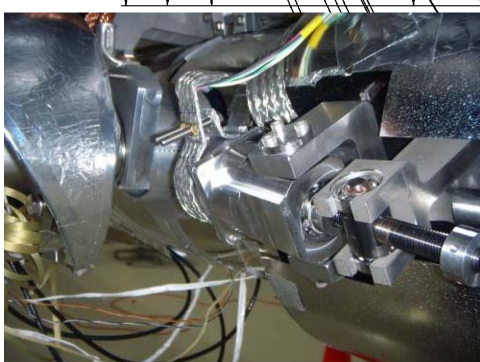
From Webex SCRF meeting on 5 K shield removal

From Webex SCRF meeting on 5 K shield removal

5 K thermal anchors in TTF



- 5 K shield surface provides convenient thermalization using small braids

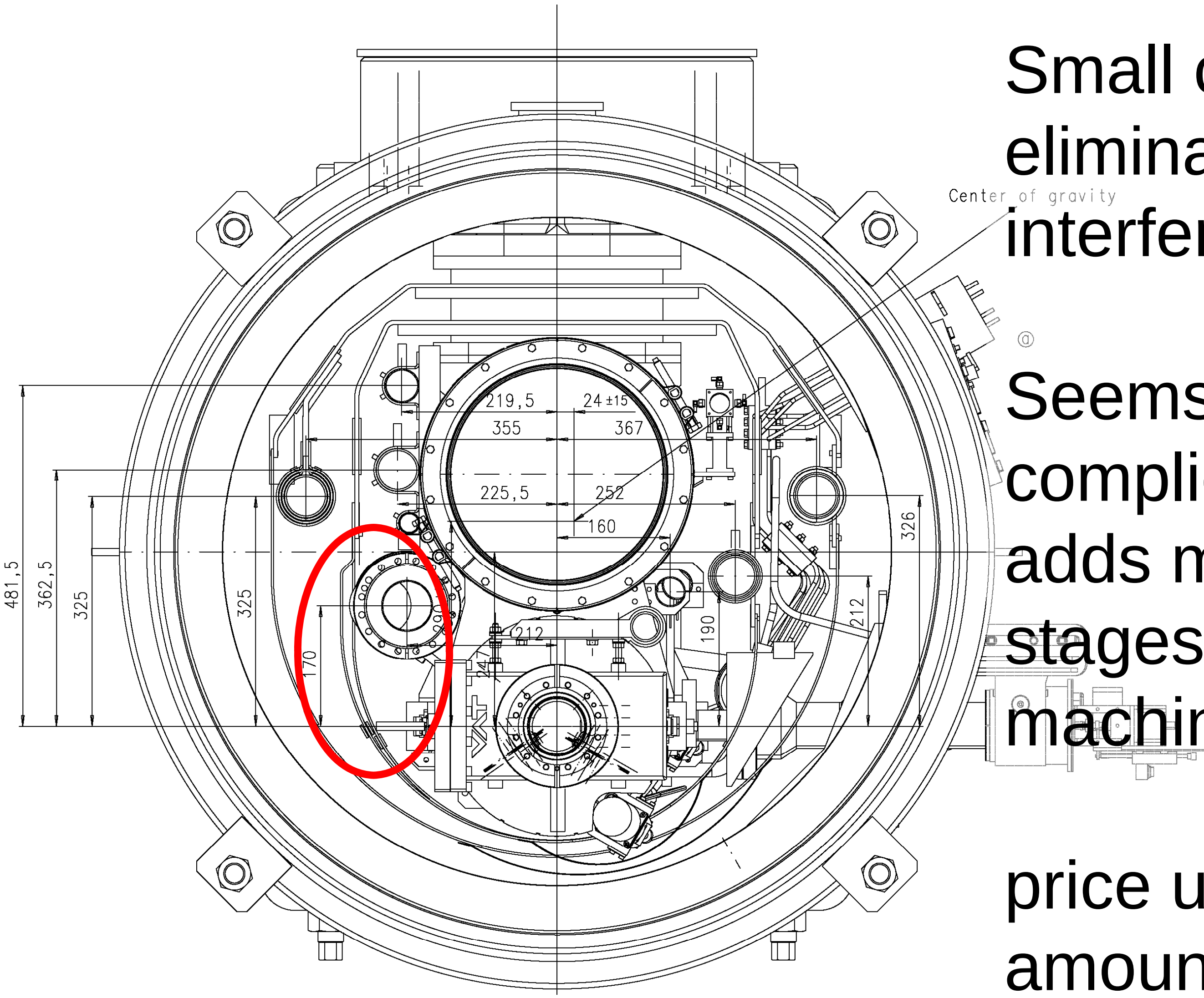


Type I--III

- “Historical” note: One of the most effective cost reduction stategies from generation I to generation II was the elimination of the many braids to perform the shield thermalization

- Sometimes changes that seem minor have heavy implications later in terms of complexity or cost
  - e.g. discussions yesterday/today of modules plug compatibility between regions
  - changes in the shield geometry from TypeII+ to XFEL proto

Example: Type III+ modification



Small change to eliminate interferences

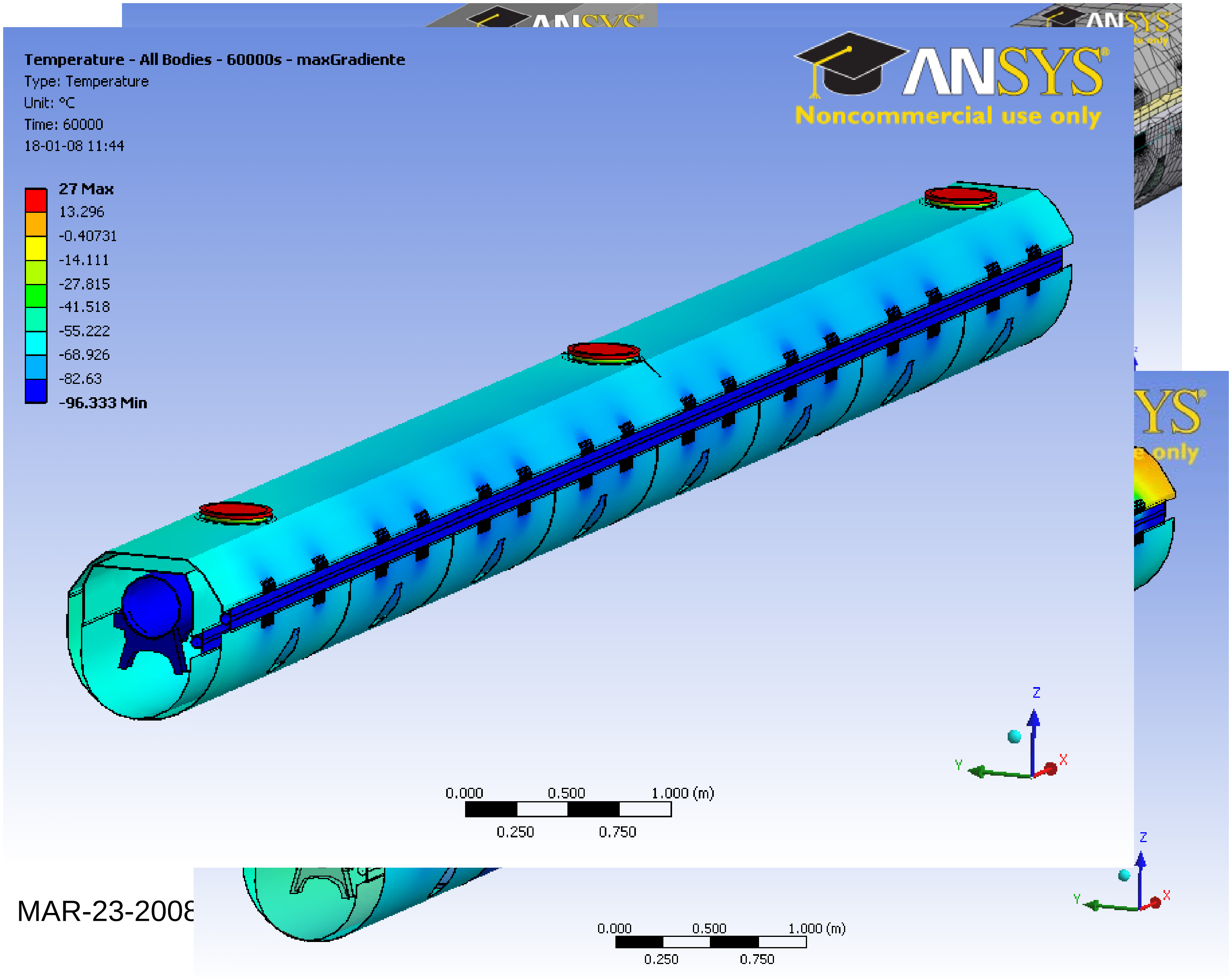
Seems minor, but it complicates life and adds manifacturing stages (in/out rolling machine)

price up, estimate amounts to 5-7%

TTF Thermal analysis with ANSYS

- We did transient thermal analysis 12 years ago on shields only
- Serena developed an ANSYS model for static and transient thermal behavior aimed at
  - static and transient heat loads,
  - thermal gradients on the internals during transient, …
  - comparison of different cooling procedures
- Opportunity to benchmark with **present M3* testing at CMTB**
  - The input data (cool down times, flow rates, …)
    - from CMTB cryogenic system
  - Several cooldowns available
  - A new set of thermal sensor has been included in CMTB

Model overview



Thermal conditions

- In the simulation (both static and transient) we have implemented the following thermal conditions:
  - Cooling provided by convection at the finned Aluminum tubes integrated in both the 5 K and 70 K shields
  - Conduction through penetration and supports (posts, couplers)
  - Thermal radiation load
  - 300 K thermal boundary at top of posts

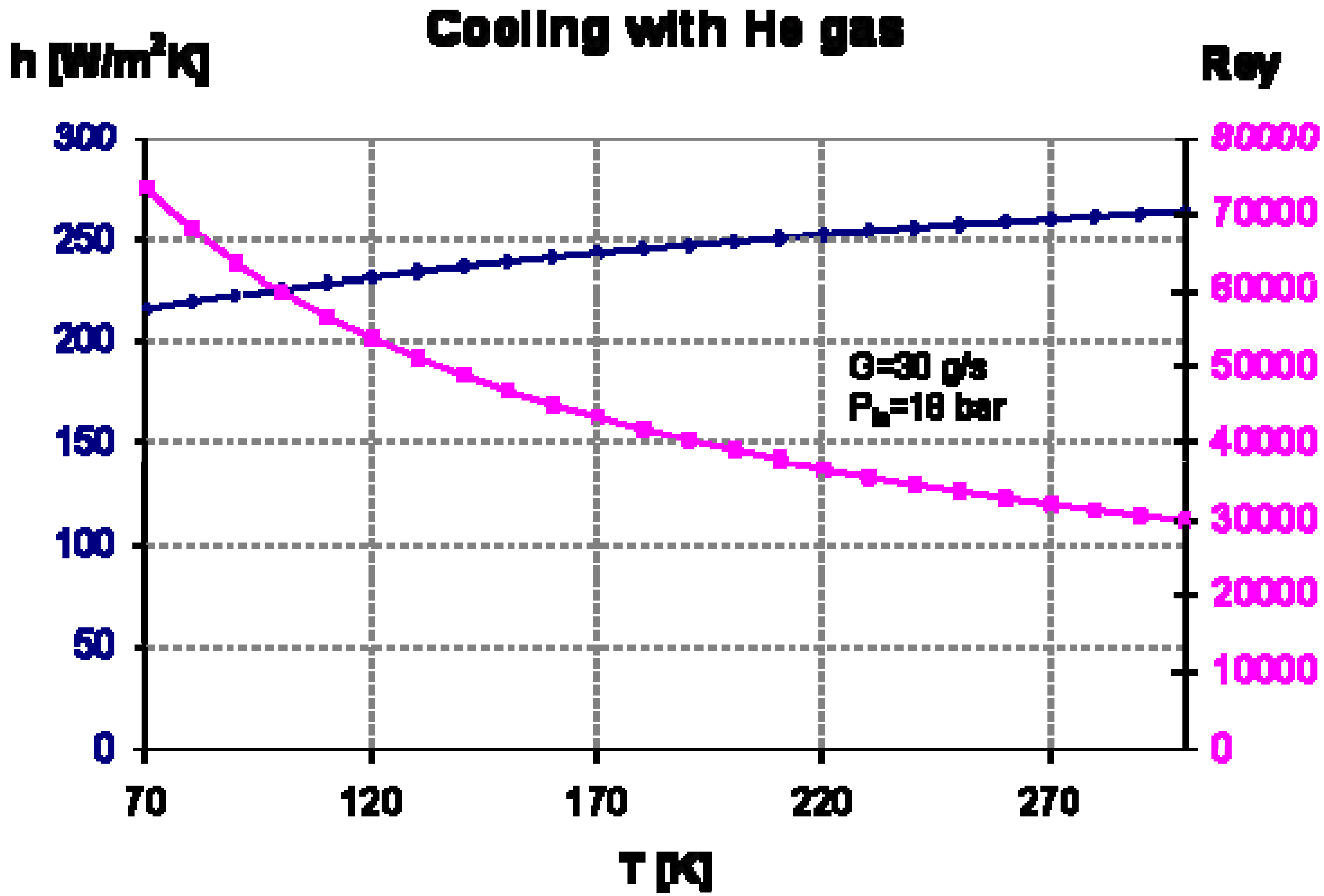
- Under development: still working on or planning
  - Model so far has double shield and no radiation load at 2 K
  - No single shield model
  - Details of cavity tanks are still missing
    - Imposed temperature at the GRP and connections to tanks

Heat conditions in the transient analysis

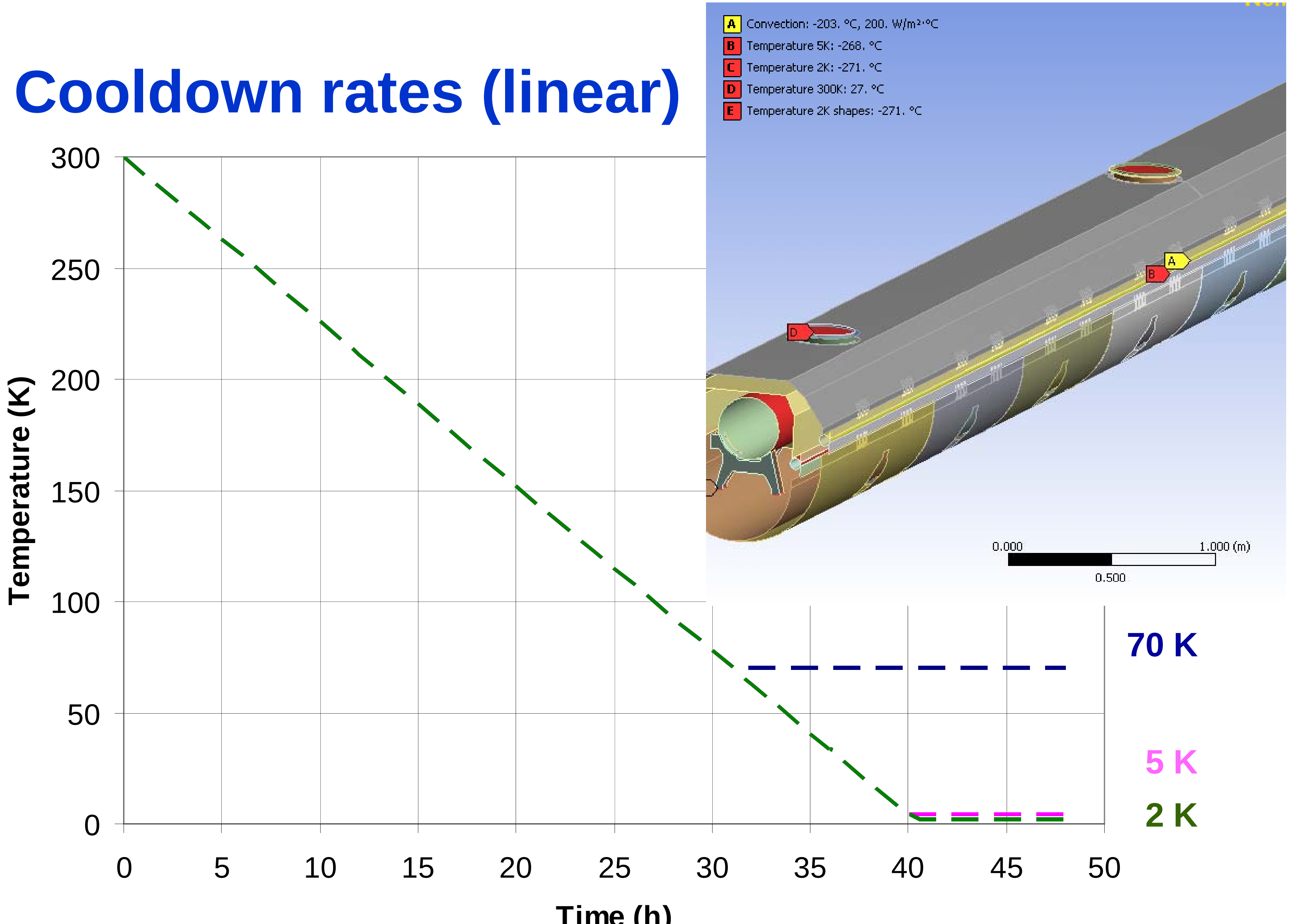
- Time dependent convection cooling at the 5 K and 70 K finned tubes and HeGRP
  - Linear T decrease
  - Evaluation of h_f from fluid
  - Imposed linear temperature decrease at the 2 K cavity boundary, with no limit to heat exchange
- Time dependent heat loads:
  - Radiation heat flux acting on the shields surfaces
  - Conduction effects from couplers being implemented at 70 K, 5 K and 2K
    - not modeling real coupler geometry, though
    - heat load at the thermal anchors positions on the shields

Convective heat exchange on 70 K pipe

Derived from fluid properties (T, P, …) and mass flows



Cooldown rates (linear)



Simplified model presented at Sendai, simple linear loads

Radiation load through MLI

- CERN data used so far
  - From r.t. to neglibible temperatures using 30 layers MLI
    - 1 W/m^2
  - From 80 K to neglibible temperatures using 10 layers MLI
    - 0.05 W/m^2
- Scale behavior during cooldown from these data using experimental plots reported in J. Weisend text

From J.Weisend

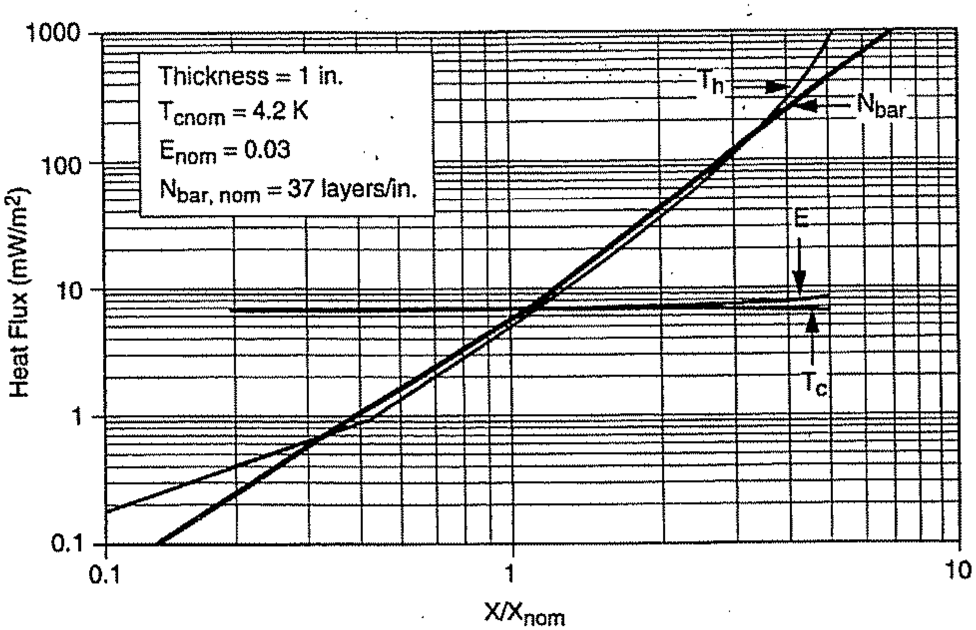
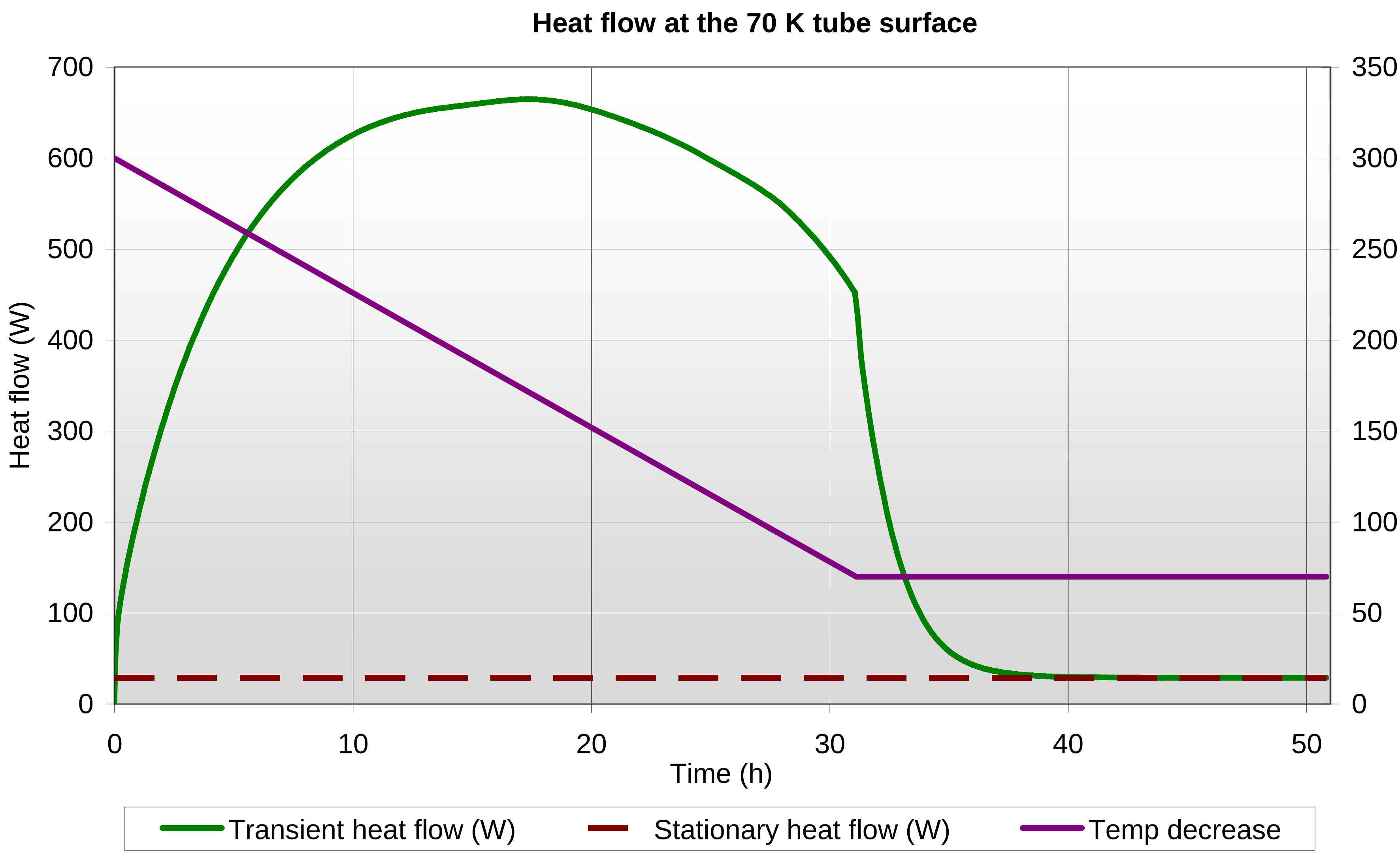


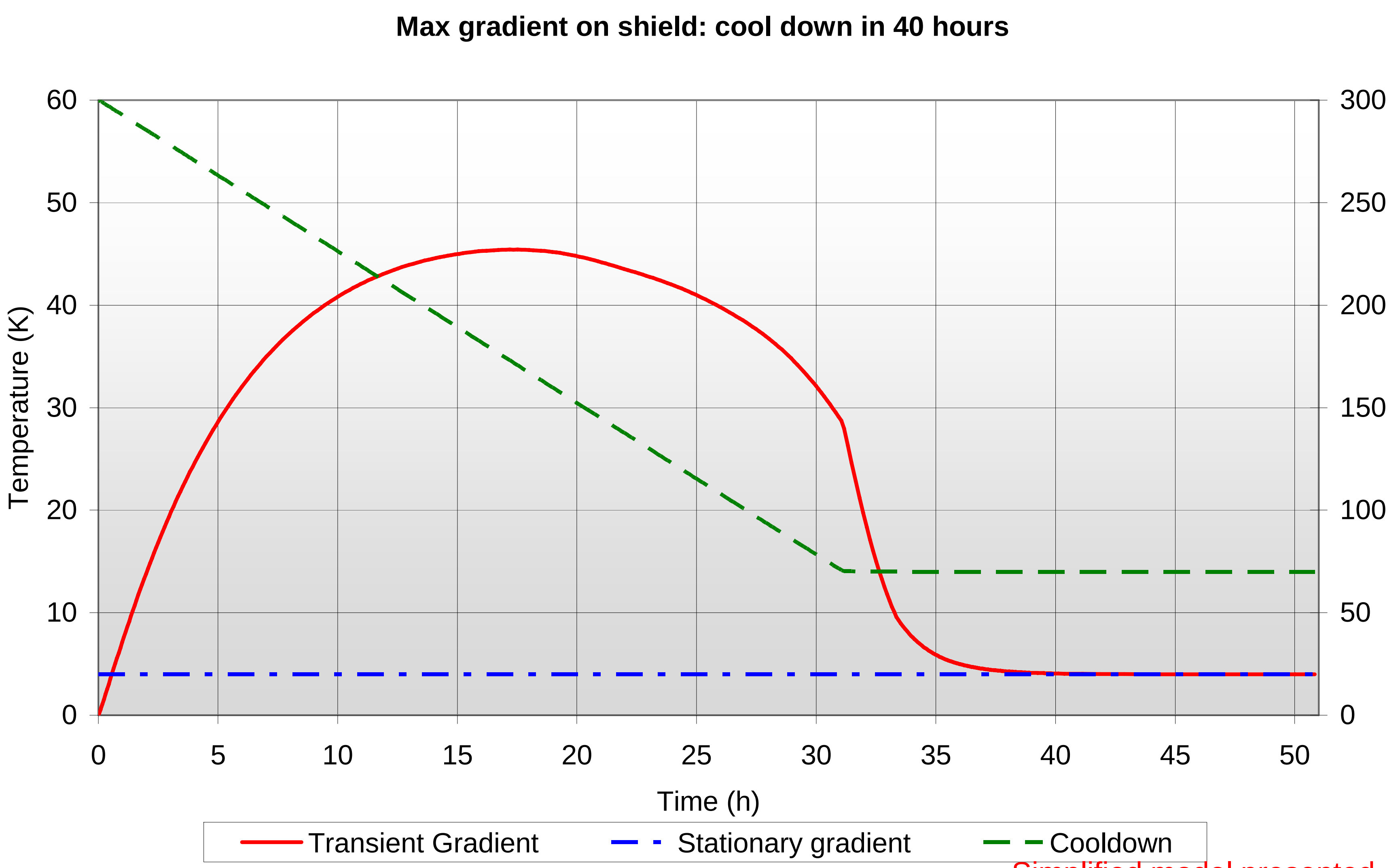
Figure 3-31 X/X_{nom} effects for nominal warm boundary temperature of 77 K.

Heat flow on 70 K pipe during cooldown



Simplified model presented at Sendai, simple linear loads

Gradient on 70 K shield



Simplified model presented at Sendai, simple linear loads

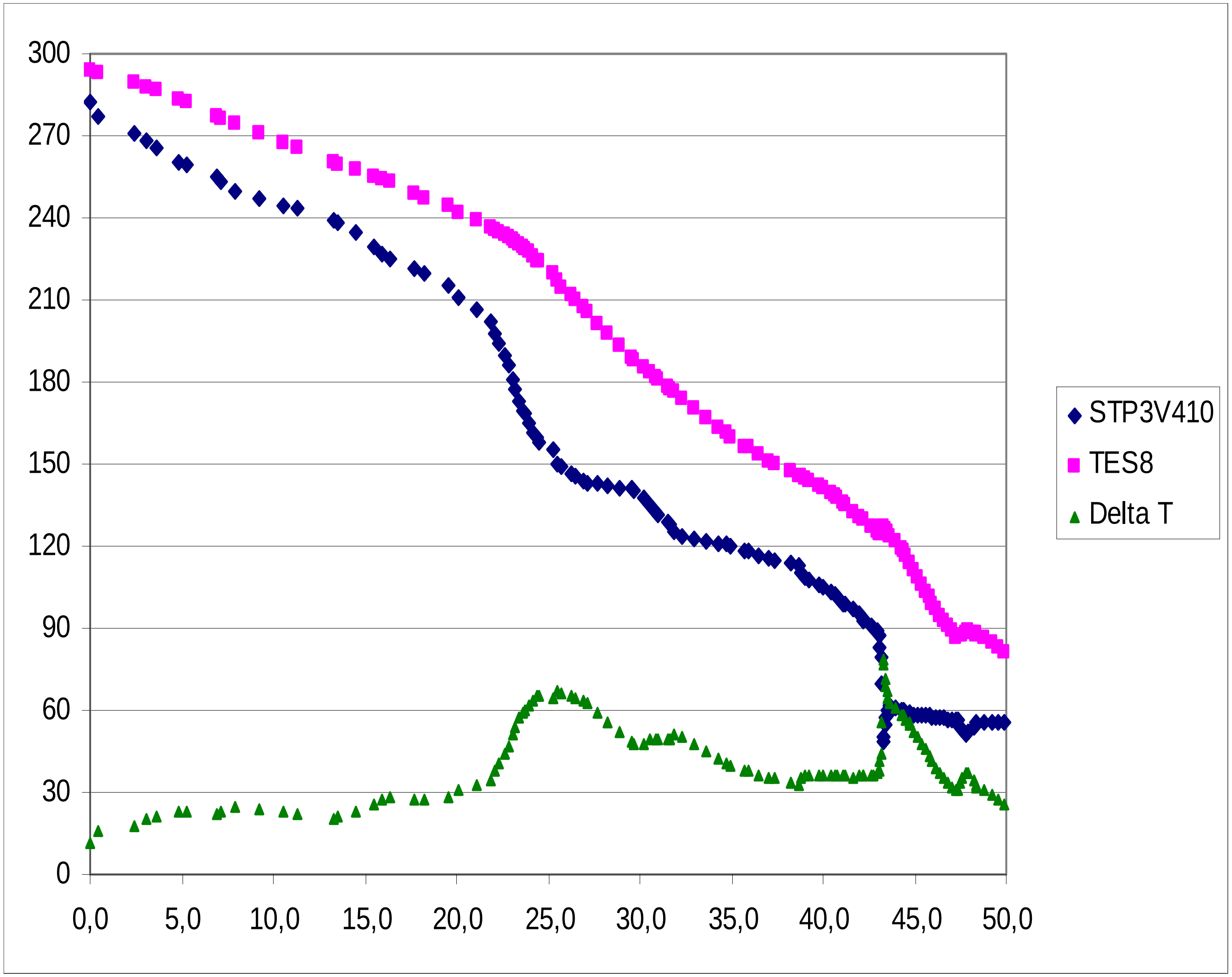
Work still in progress…

- Further implementation of heat load sources and complexity of loading conditions

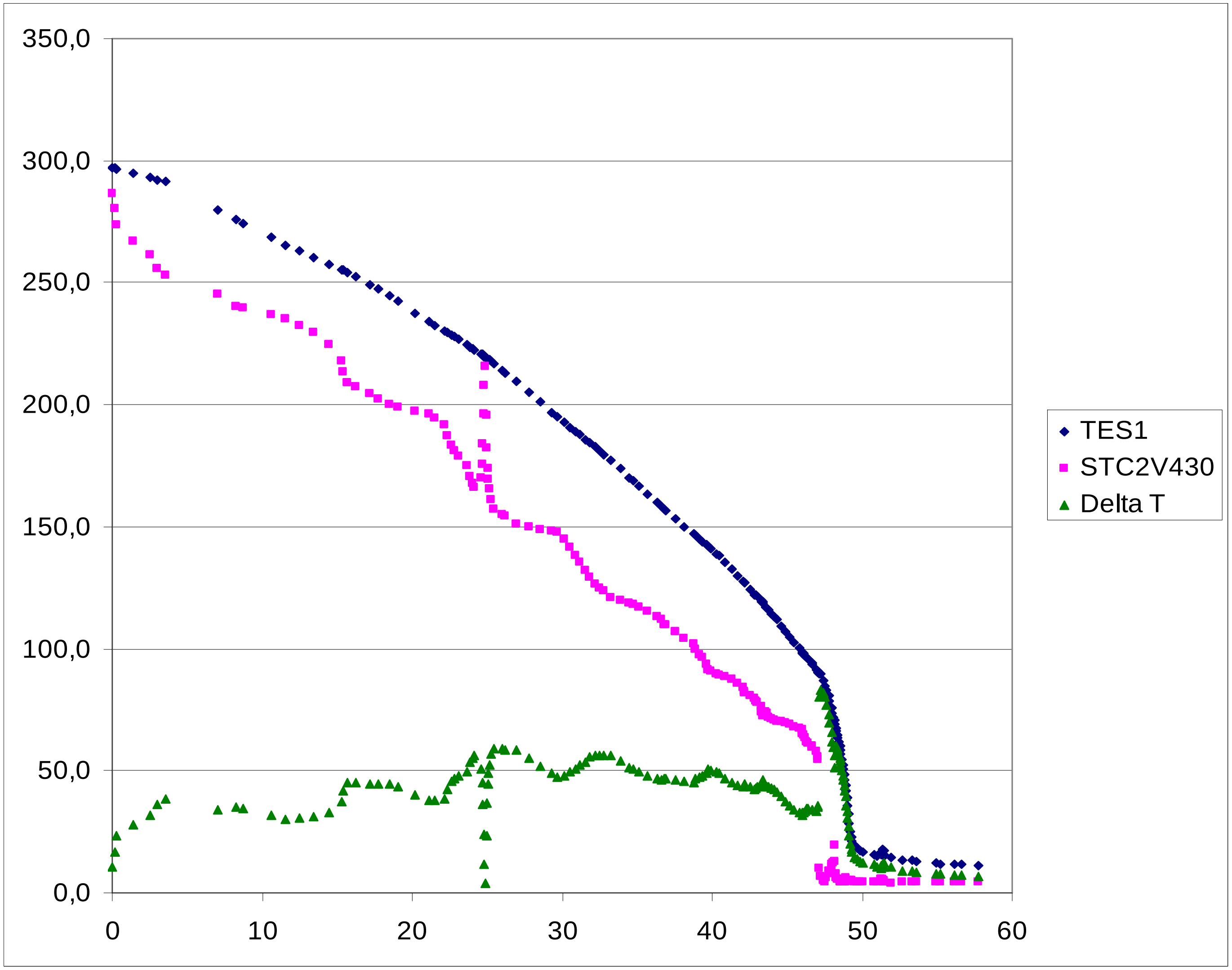
- Using CMTB cooldown data
- Getting CMTB data from DESY to be analyzed
  - provides model benchmark
- TO DO: Structural analysis at maximum gradients
  - mechanical interferences
- Model can be extended for exploring different cooldown procedures or thermal intercept strategies

- Big help from W. Maschmann, K. Jensch, R. Lange

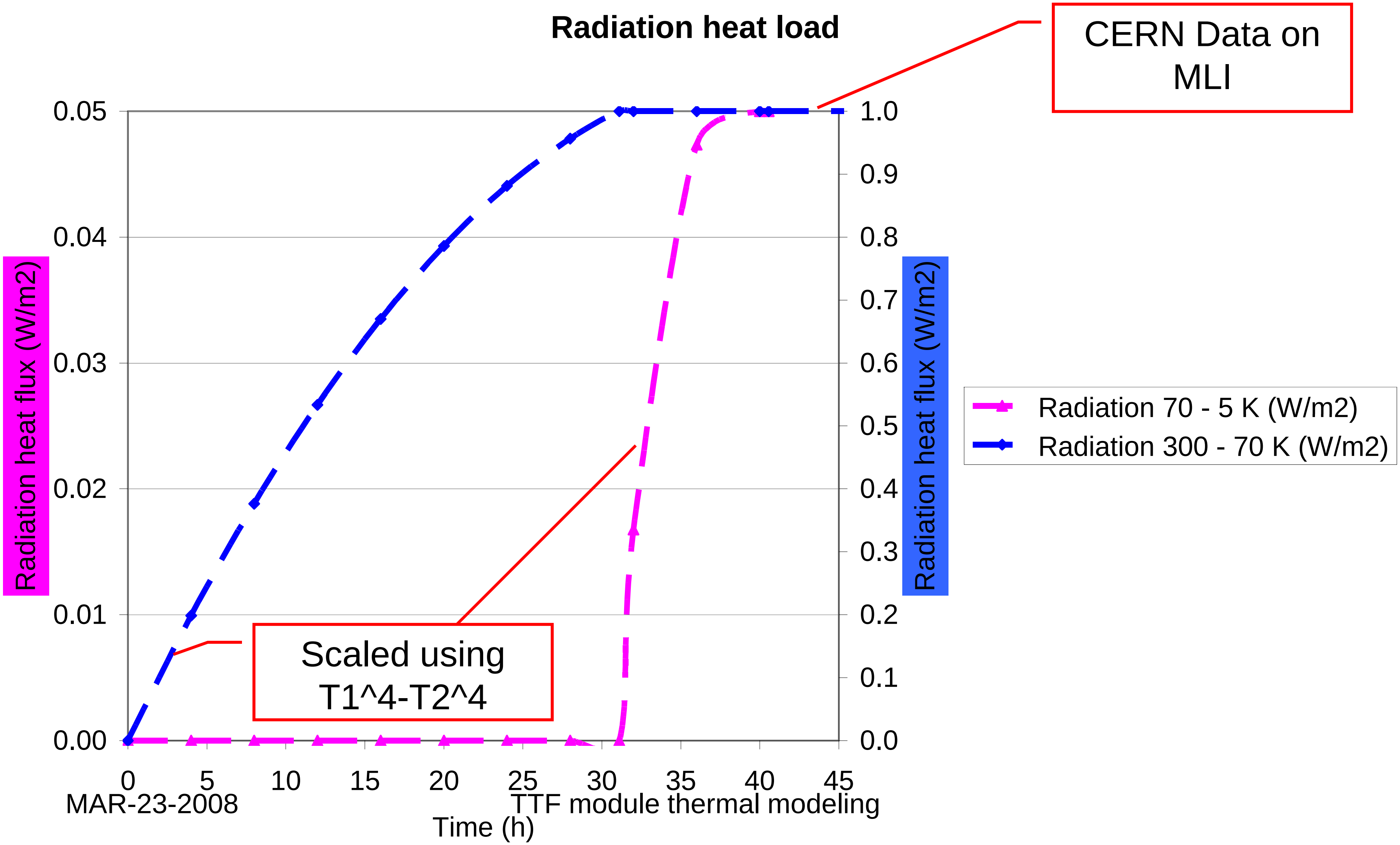
Measured data at CMTB – outer shield



Measured data at CMTB – inner shield



Shield radiation



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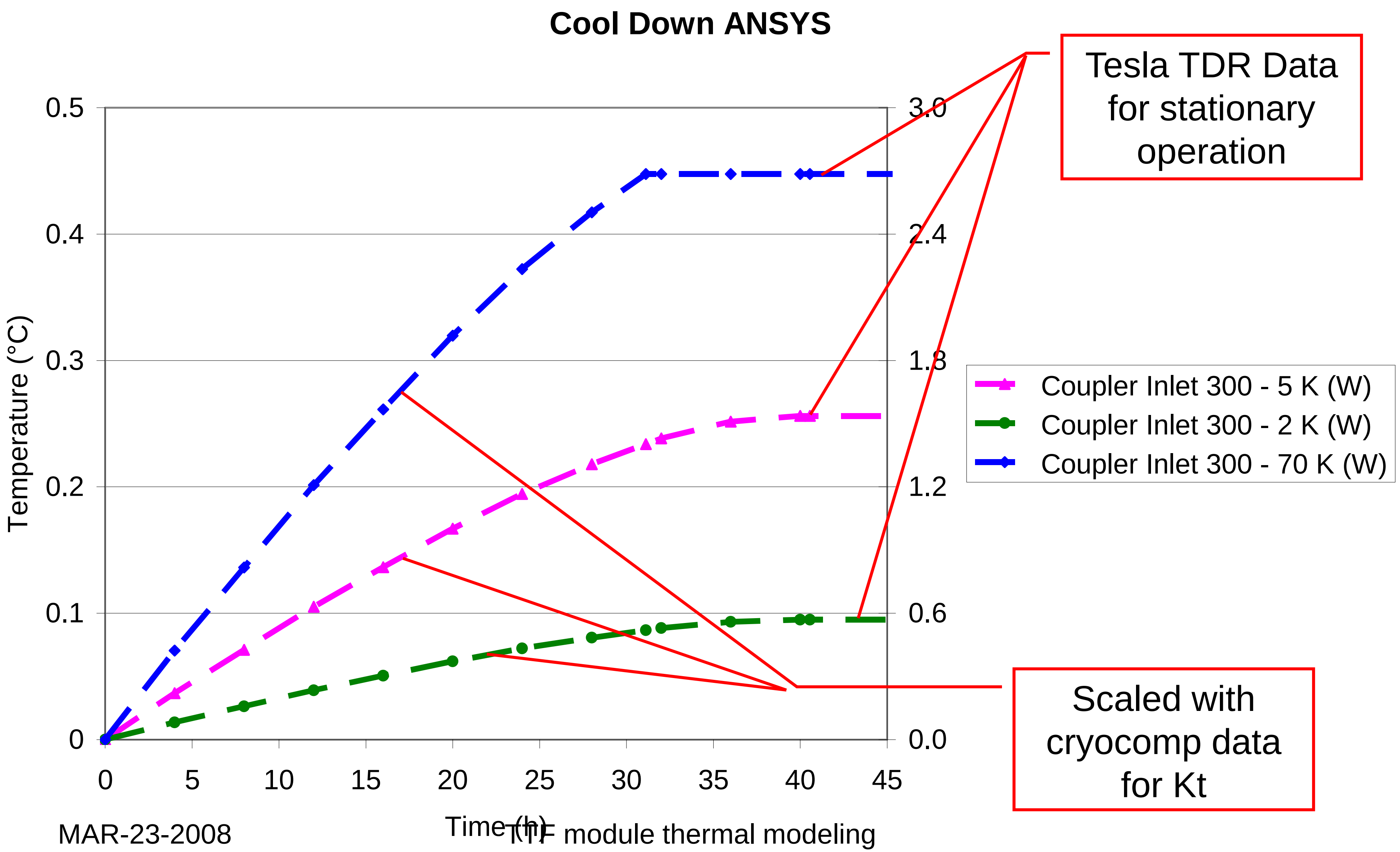
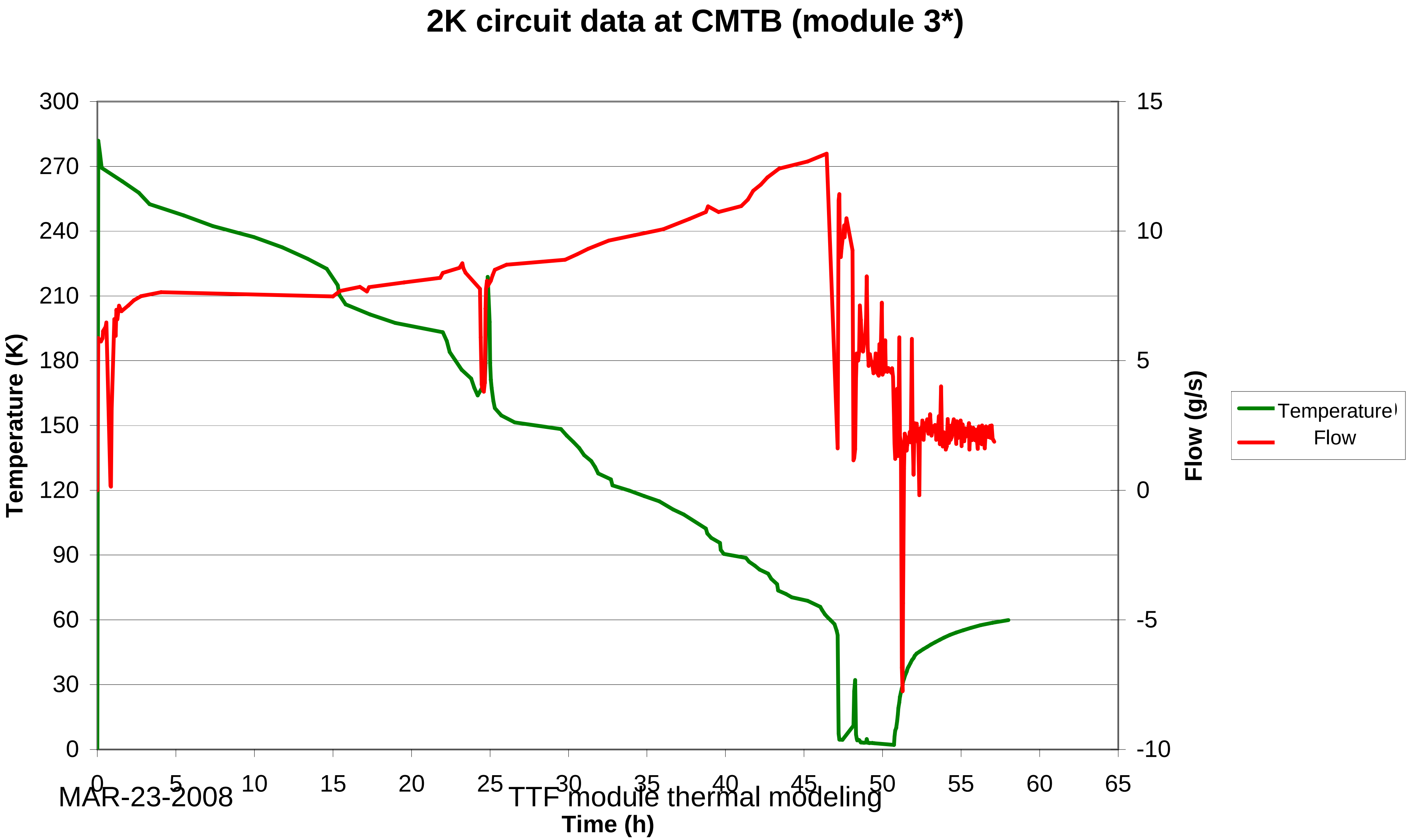
TTF module thermal modeling

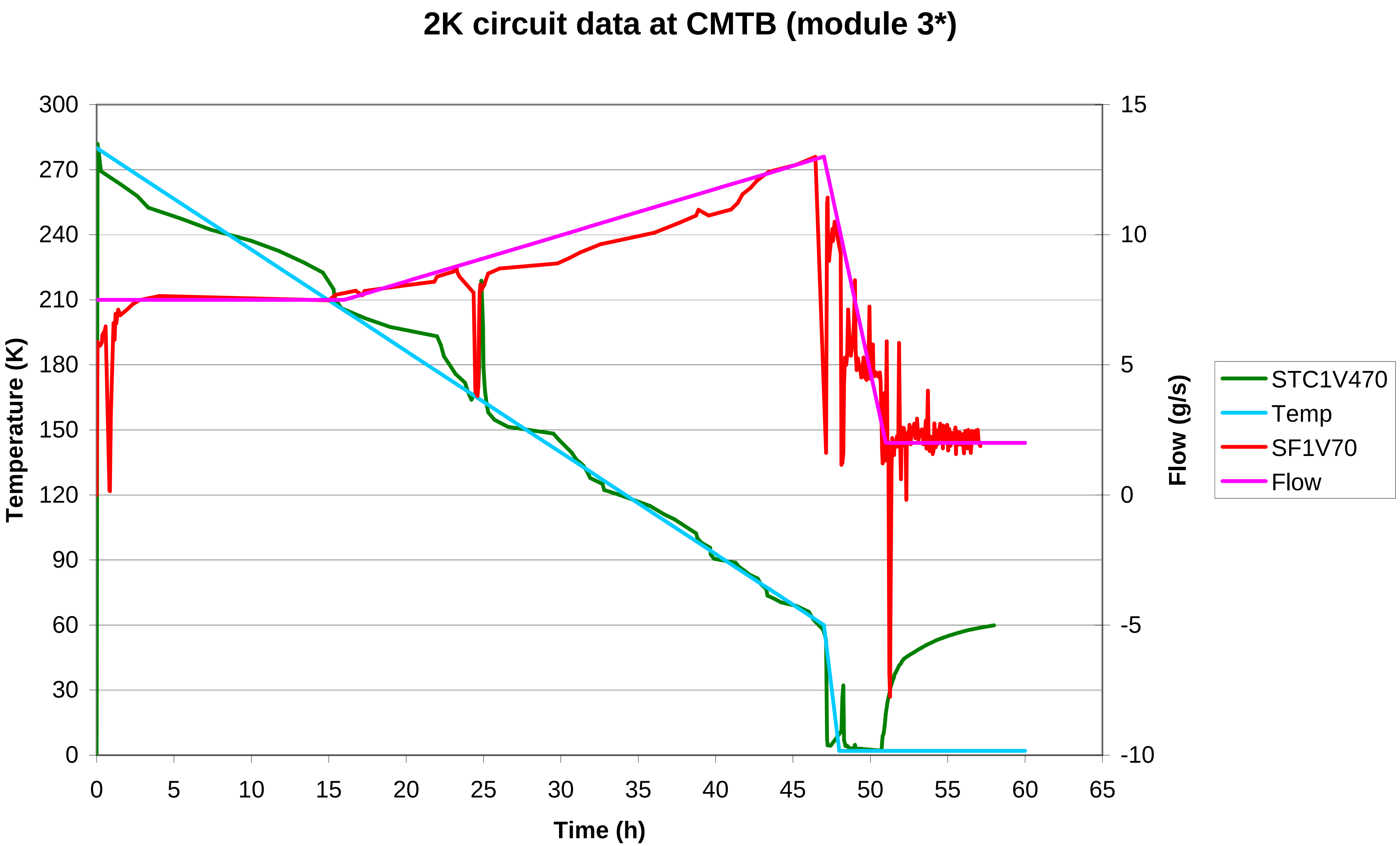
Conduction at couplers



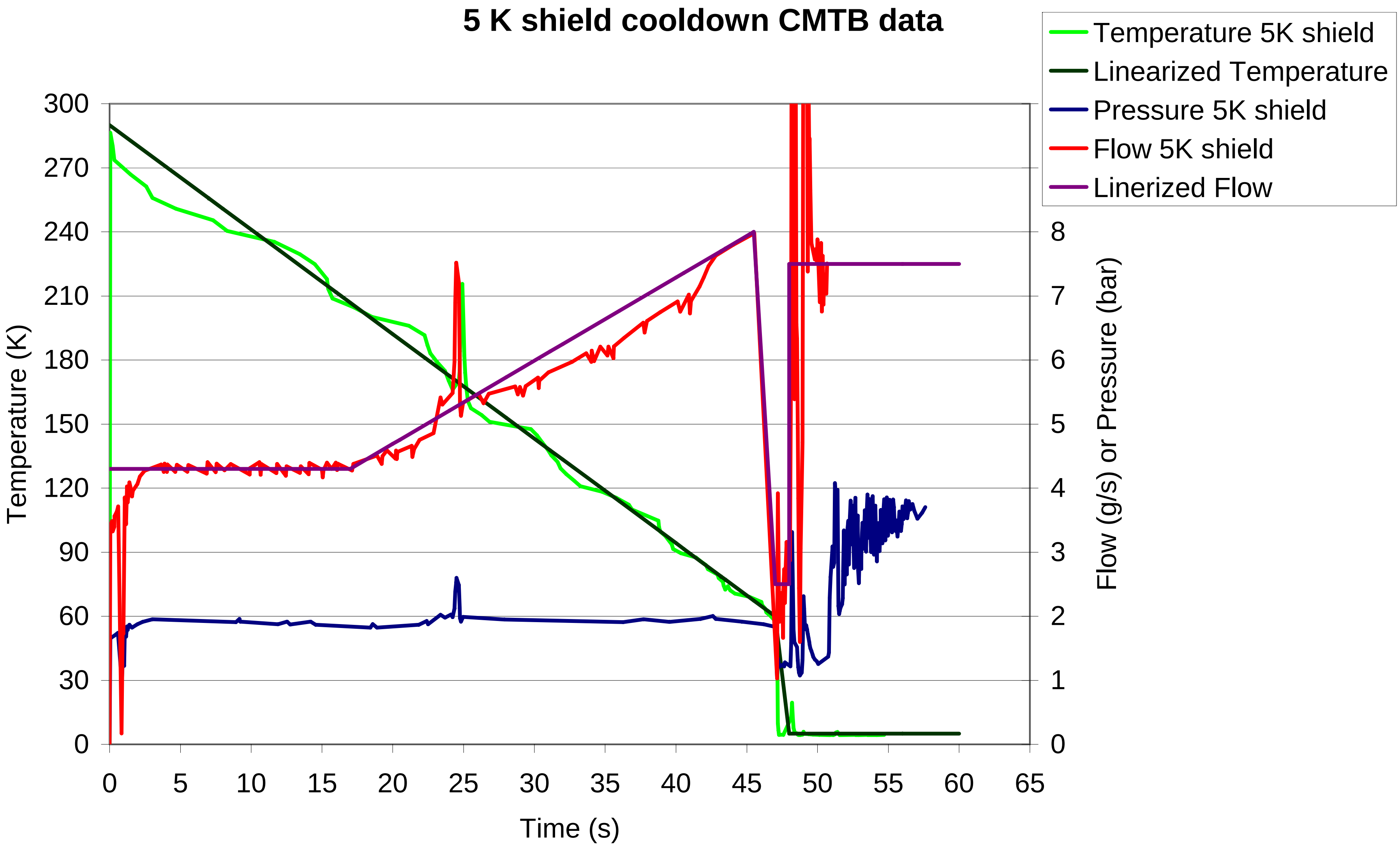
Real data at DESY - CMTB



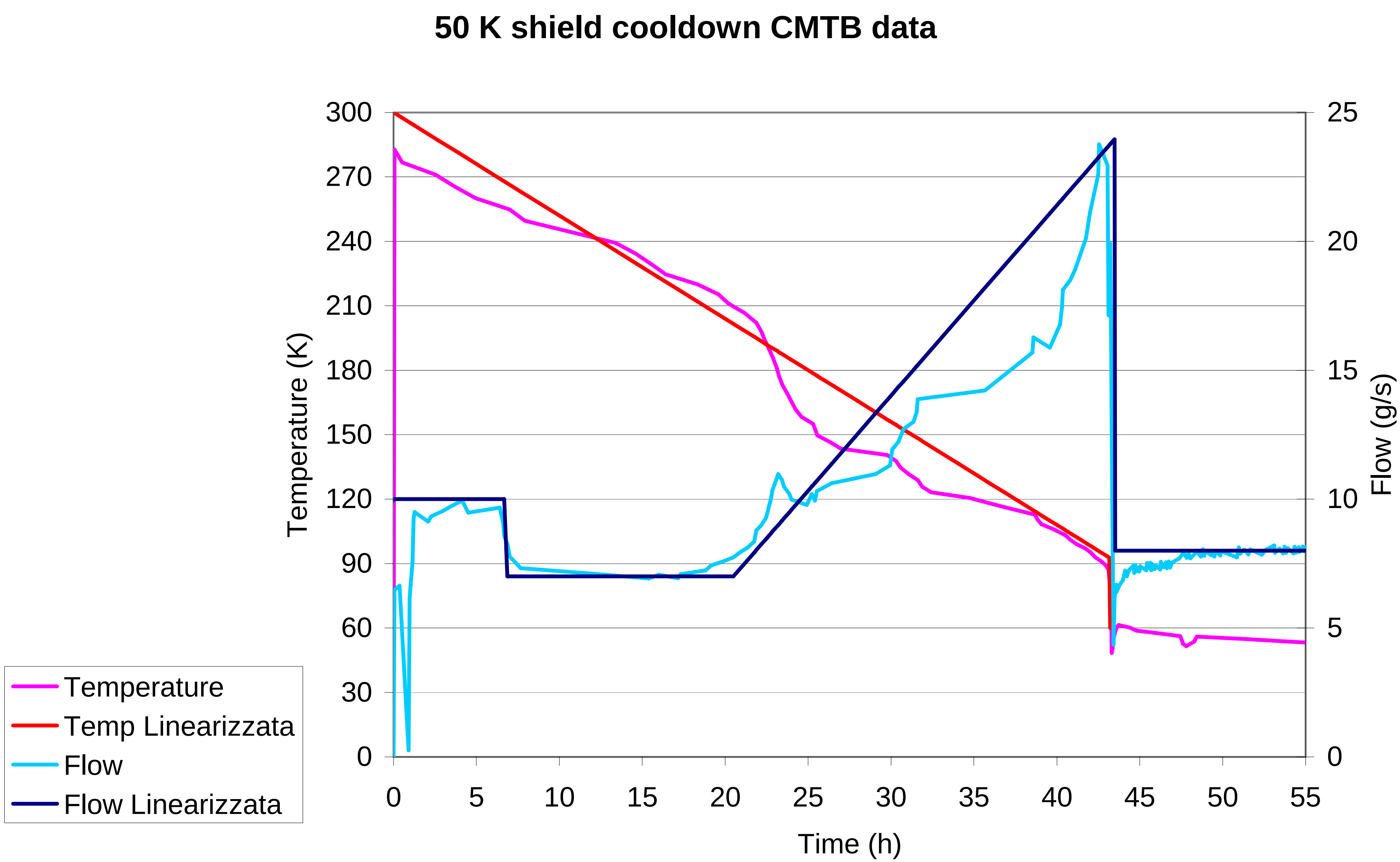
Fluid parameters, 2 K circuit



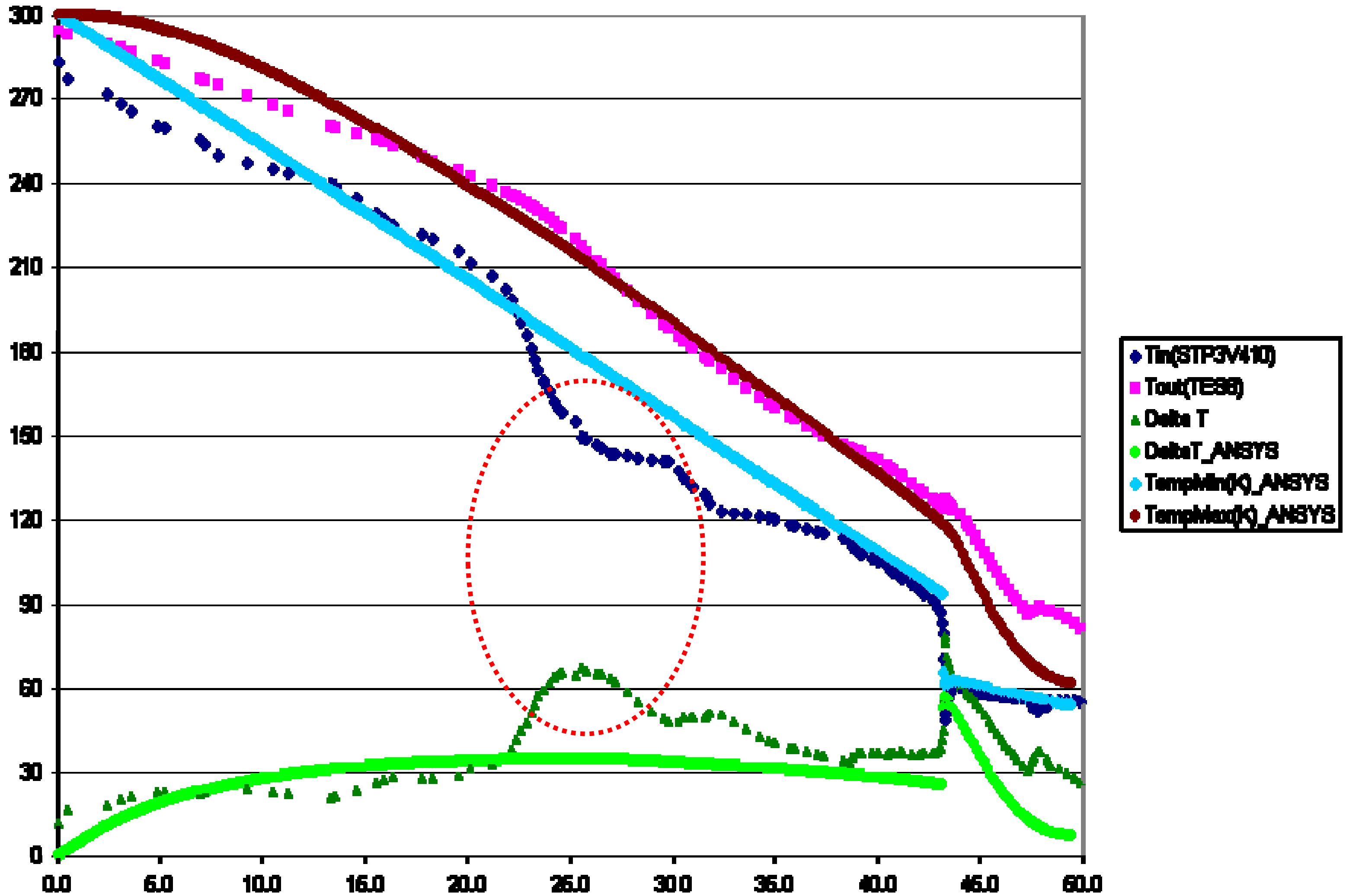
Fluid parameters, 5 K circuit



Fluid parameters, 70 K circuits

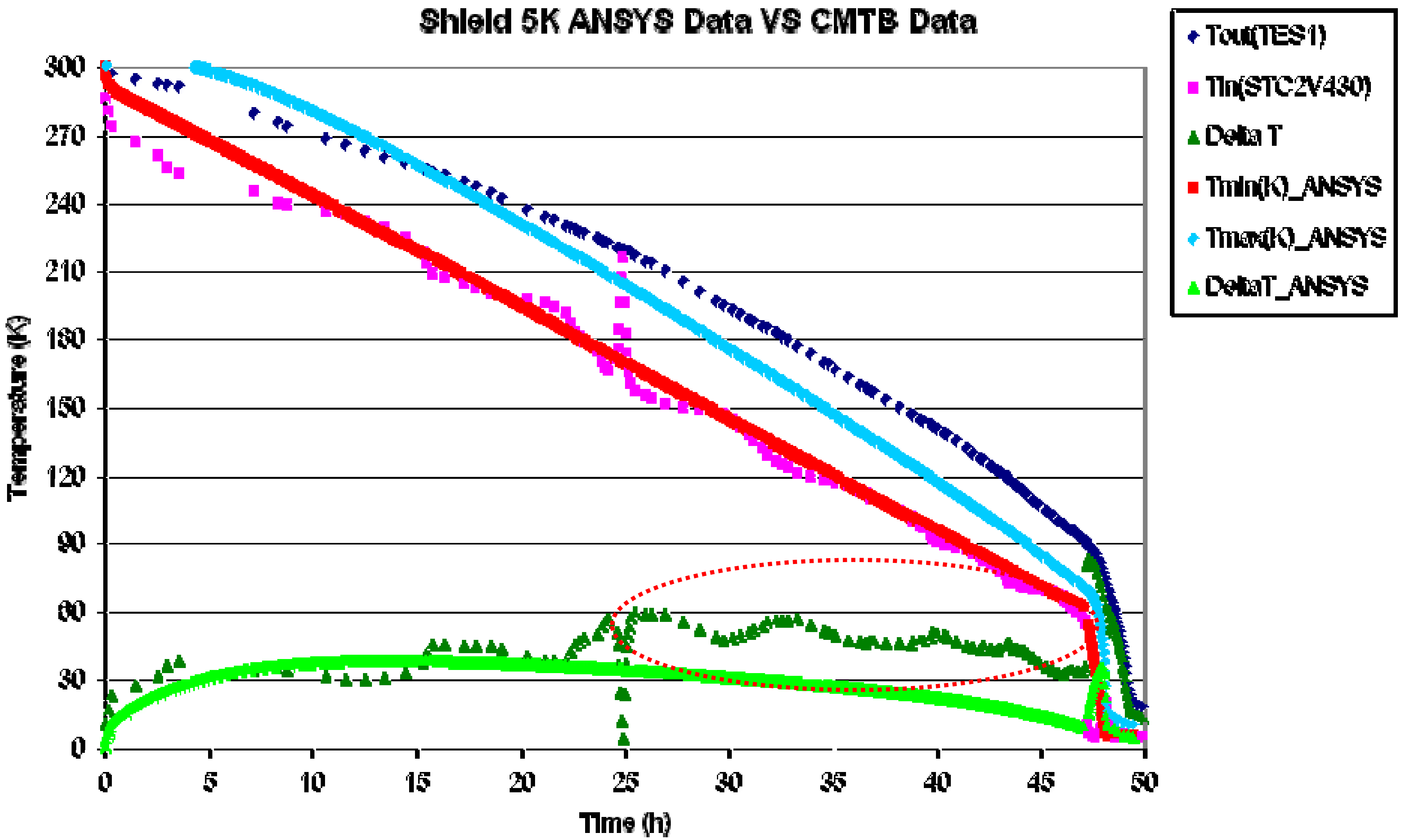


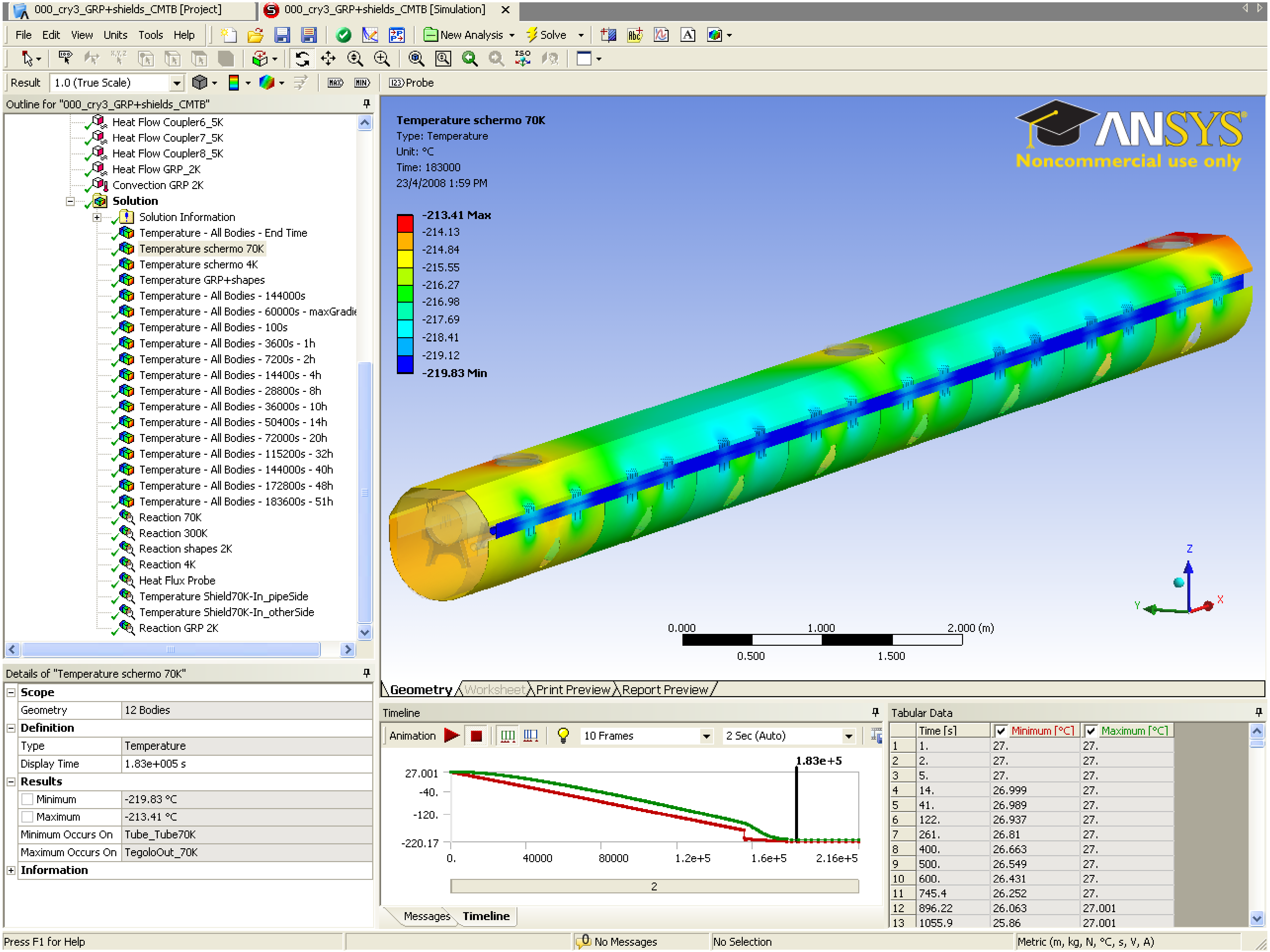
Results with CMTB cooldown – 70 K



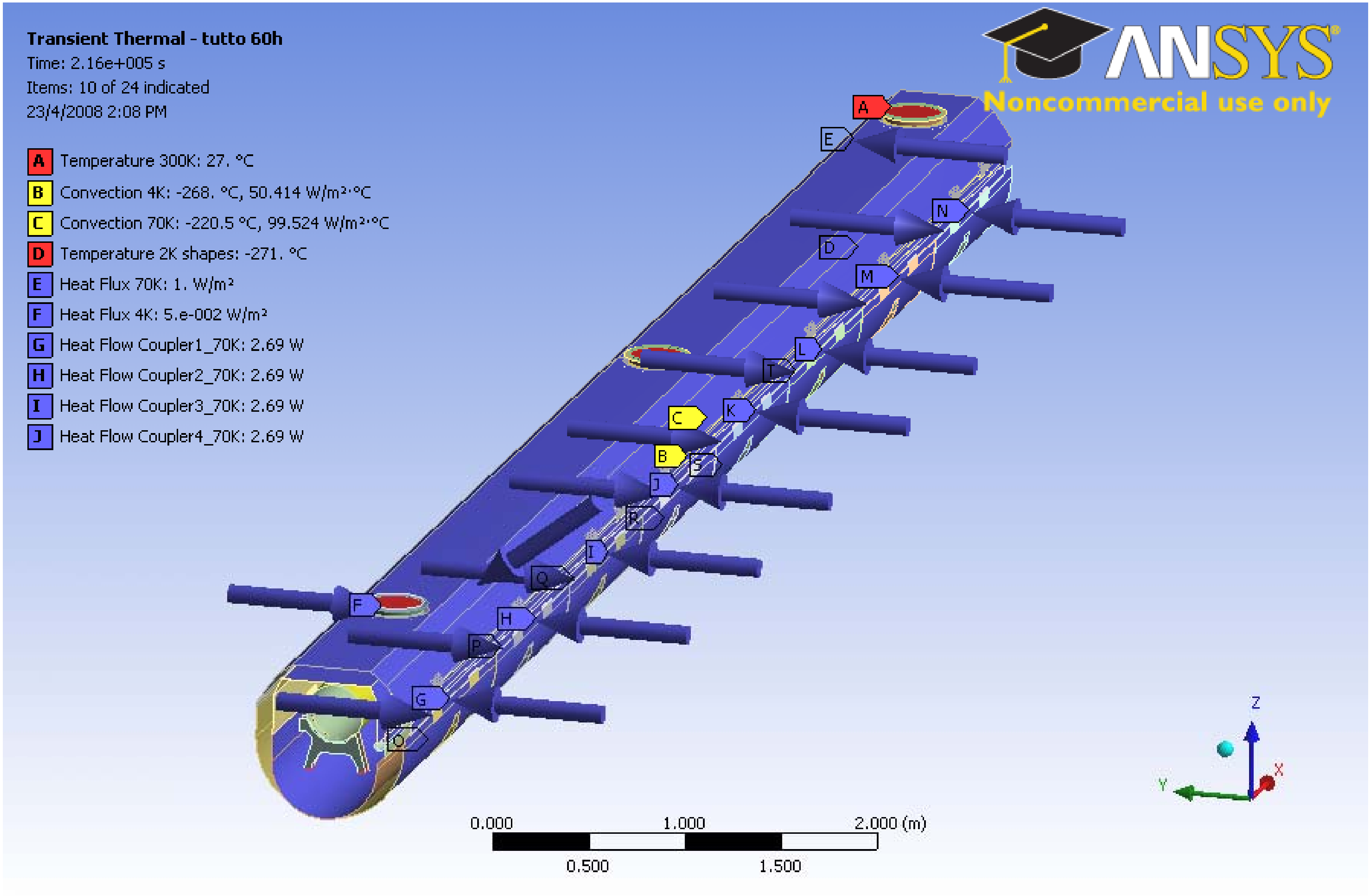
MAR-23-2008 TTF module thermal modeling

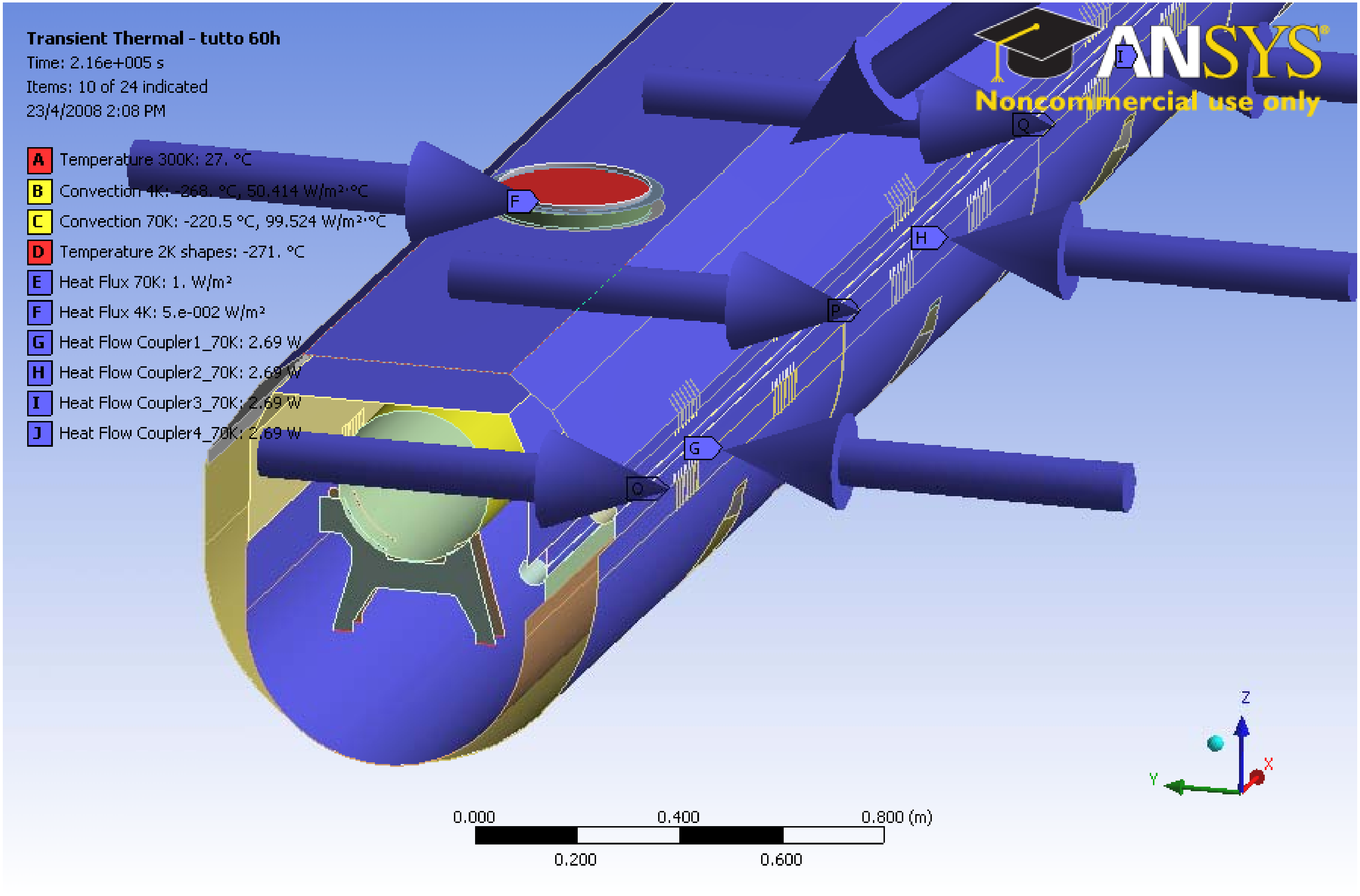
Results with CMTB cooldown – 5 K

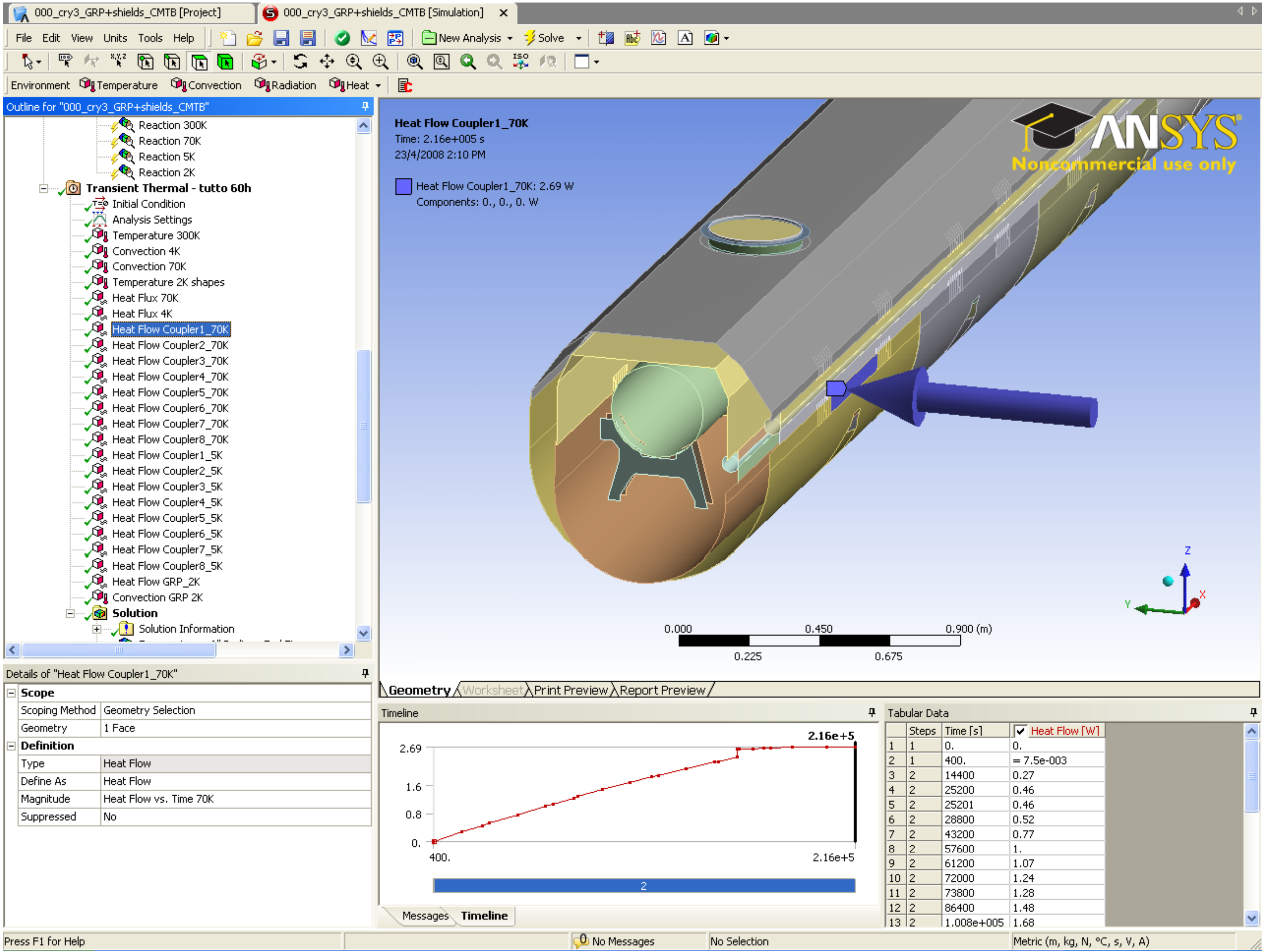



000_cry3_GRP+shields_CMTB [Project]
000_cry3_GRP+shields_CMTB [Simulation]
File Edit View Units Tools Help
New Analysis
Solve
Result 1.0 (True Scale)
Probe
Outline for "000_cry3_GRP+shields_CMTB"
Heat Flow Coupler6_5K
Heat Flow Coupler7_5K
Heat Flow Coupler8_5K
Heat Flow GRP_2K
Convection GRP 2K
Solution
Solution Information
Temperature - All Bodies - End Time
Temperature schermo 70K
Temperature schermo 4K
Temperature GRP+shapes
Temperature - All Bodies - 144000s
Temperature - All Bodies - 60000s - maxGradie
Temperature - All Bodies - 100s
Temperature - All Bodies - 3600s - 1h
Temperature - All Bodies - 7200s - 2h
Temperature - All Bodies - 14400s - 4h
Temperature - All Bodies - 28800s - 8h
Temperature - All Bodies - 36000s - 10h
Temperature - All Bodies - 50400s - 14h
Temperature - All Bodies - 72000s - 20h
Temperature - All Bodies - 115200s - 32h
Temperature - All Bodies - 144000s - 40h
Temperature - All Bodies - 172800s - 48h
Temperature - All Bodies - 183600s - 51h
Reaction 70K
Reaction 300K
Reaction shapes 2K
Reaction 4K
Heat Flux Probe
Temperature Shield70K-In_pipeSide
Temperature Shield70K-In_otherSide
Reaction GRP 2K
Details of "Temperature schermo 70K"
Scope
Geometry 12 Bodies
Definition
Type Temperature
Display Time 1.83e+005 s
Results
Minimum -219.83 °C
Maximum -213.41 °C
Minimum Occurs On Tube_Tube70K
Maximum Occurs On TegoloOut_70K
Information
Temperature schermo 70K
Type: Temperature
Unit: °C
Time: 183000
23/4/2008 1:59 PM
-213.41 Max
-214.13
-214.84
-215.55
-216.27
-216.98
-217.69
-218.41
-219.12
-219.83 Min
ANSYS
Noncommercial use only
0.000 1.000 2.000 (m)
0.500 1.500
Geometry Worksheet Print Preview Report Preview
Timeline
Animation 10 Frames 2 Sec (Auto)
1.83e+5
27.001
-40.
-120.
-220.17
0. 40000 80000 1.2e+5 1.6e+5 2.16e+5
Messages Timeline
Tabular Data
Time [s] Minimum [°C] Maximum [°C]
1 1. 27. 27.
2 2. 27. 27.
3 5. 27. 27.
4 14. 26.999 27.
5 41. 26.989 27.
6 122. 26.937 27.
7 261. 26.81 27.
8 400. 26.663 27.
9 500. 26.549 27.
10 600. 26.431 27.
11 745.4 26.252 27.
12 896.22 26.063 27.001
13 1055.9 25.86 27.001
Press F1 for Help
No Messages
No Selection
Metric (m, kg, N, °C, s, V, A)

Loads

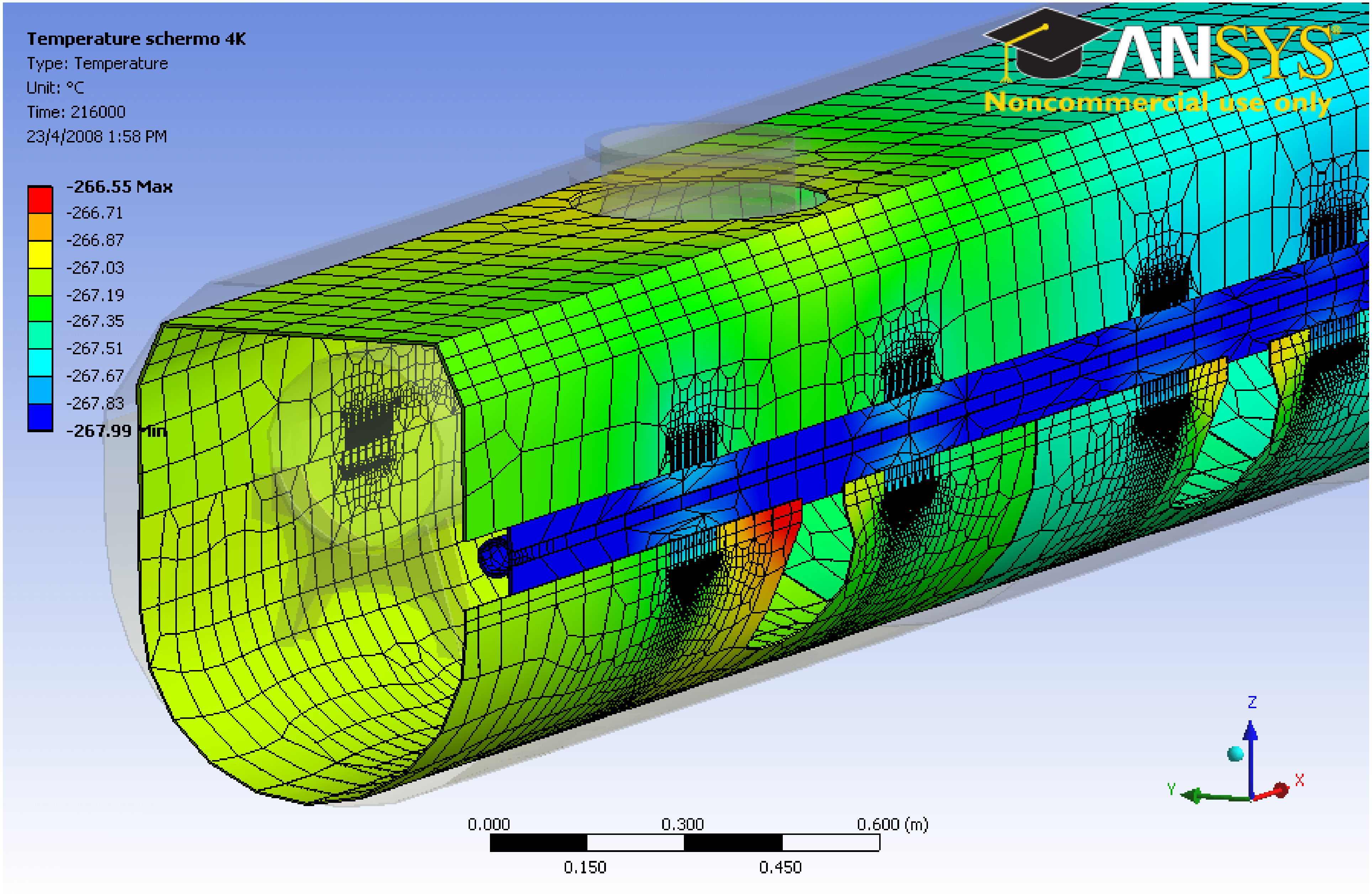

Transient Thermal - tutto 60h
Time: 2.16e+005 s
Items: 10 of 24 indicated
23/4/2008 2:08 PM
A Temperature 300K: 27. °C
B Convection 4K: -268. °C, 50.414 W/m²·°C
C Convection 70K: -220.5 °C, 99.524 W/m²·°C
D Temperature 2K shapes: -271. °C
E Heat Flux 70K: 1. W/m²
F Heat Flux 4K: 5.e-002 W/m²
G Heat Flow Coupler1_70K: 2.69 W
H Heat Flow Coupler2_70K: 2.69 W
I Heat Flow Coupler3_70K: 2.69 W
J Heat Flow Coupler4_70K: 2.69 W
ANSYS
Noncommercial use only
0.000
1.000
2.000 (m)
0.500
1.500
Z
Y
X


Transient Thermal - tutto 60h
Time: 2.16e+005 s
Items: 10 of 24 indicated
23/4/2008 2:08 PM
A Temperature 300K: 27. °C
B Convection 4K: -268. °C, 50.414 W/m²·°C
C Convection 70K: -220.5 °C, 99.524 W/m²·°C
D Temperature 2K shapes: -271. °C
E Heat Flux 70K: 1. W/m²
F Heat Flux 4K: 5.e-002 W/m²
G Heat Flow Coupler1_70K: 2.69 W
H Heat Flow Coupler2_70K: 2.69 W
I Heat Flow Coupler3_70K: 2.69 W
J Heat Flow Coupler4_70K: 2.69 W
ANSYS
Noncommercial use only
0.000
0.400
0.800 (m)
0.200
0.600
Z
Y
X



000_cry3_GRP+shields_CMTB [Project]
000_cry3_GRP+shields_CMTB [Simulation]
File Edit View Units Tools Help
New Analysis
Solve
Environment Temperature Convection Radiation Heat
Outline for "000_cry3_GRP+shields_CMTB"
Reaction 300K
Reaction 70K
Reaction 5K
Reaction 2K
Transient Thermal - tutto 60h
Initial Condition
Analysis Settings
Temperature 300K
Convection 4K
Convection 70K
Temperature 2K shapes
Heat Flux 70K
Heat Flux 4K
Heat Flow Coupler1_70K
Heat Flow Coupler2_70K
Heat Flow Coupler3_70K
Heat Flow Coupler4_70K
Heat Flow Coupler5_70K
Heat Flow Coupler6_70K
Heat Flow Coupler7_70K
Heat Flow Coupler8_70K
Heat Flow Coupler1_5K
Heat Flow Coupler2_5K
Heat Flow Coupler3_5K
Heat Flow Coupler4_5K
Heat Flow Coupler5_5K
Heat Flow Coupler6_5K
Heat Flow Coupler7_5K
Heat Flow Coupler8_5K
Heat Flow GRP_2K
Convection GRP 2K
Solution
Solution Information
Details of "Heat Flow Coupler1_70K"
Scope
Scoping Method Geometry Selection
Geometry 1 Face
Definition
Type Heat Flow
Define As Heat Flow
Magnitude Heat Flow vs. Time 70K
Suppressed No
Heat Flow Coupler1_70K
Time: 2.16e+005 s
23/4/2008 2:10 PM
Heat Flow Coupler1_70K: 2.69 W
Components: 0., 0., 0. W
ANSYS
Noncommercial use only
0.000 0.450 0.900 (m)
0.225 0.675
Geometry Worksheet Print Preview Report Preview
Timeline
2.16e+5
2.69
1.6
0.8
0.
400.
2.16e+5
2
Messages Timeline
Tabular Data
Steps Time [s] Heat Flow [W]
1 1 0. 0.
2 1 400. = 7.5e-003
3 2 14400 0.27
4 2 25200 0.46
5 2 25201 0.46
6 2 28800 0.52
7 2 43200 0.77
8 2 57600 1.
9 2 61200 1.07
10 2 72000 1.24
11 2 73800 1.28
12 2 86400 1.48
13 2 1.008e+005 1.68
Press F1 for Help
No Messages
No Selection
Metric (m, kg, N, °C, s, V, A)

Detail of inner shield



Position of coupler load on model