TTF module thermal modeling

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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**	

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

	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**	

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

From Webex SCRF meeting on 5 K shield removal

FEB-29-2008

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

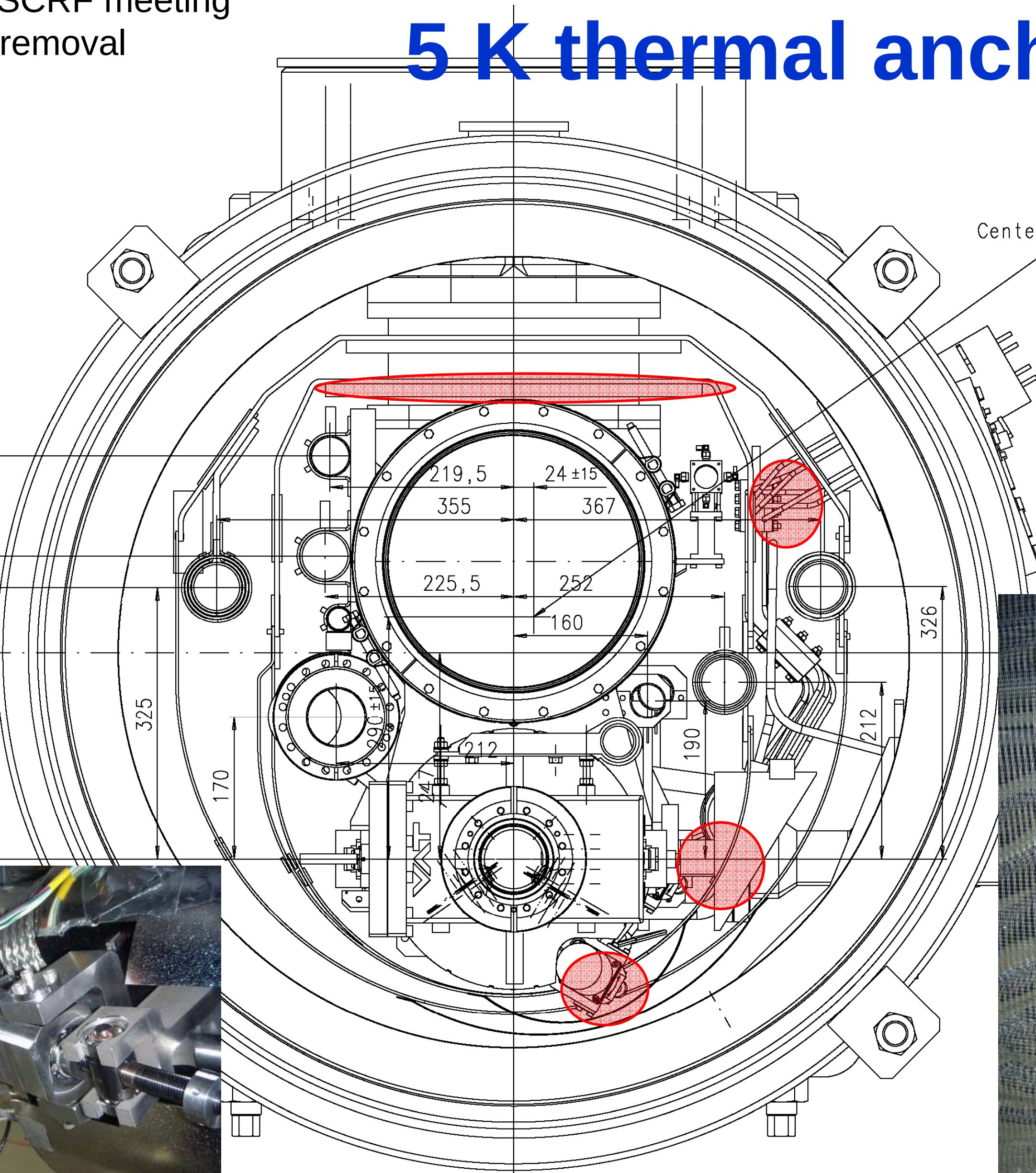
Metric of comparison

- Range of effect on plug power (operation cost) is 15% to 55% **without redesigning cross section** under rather 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)**
  - Main difference with LHC case
  - Couplers would not support weight of bulky braids
  - To be on the lower side we need anyway a 5K cryo circuit for 90% of the conduction heat removal
- What is the metric for the comparison of this operating cost hit?
  - The presence of the 5 K shield is in the module capital cost
    - if any, still questionable if many thermalization are needed

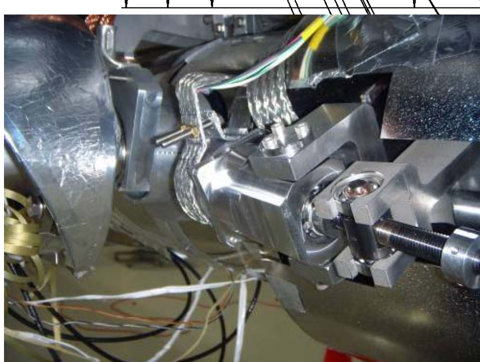
From Webex SCRF meeting on 5 K shield removal

From Webex SCRF meeting
on 5 K shield removal

5 K thermal anchors in TTF



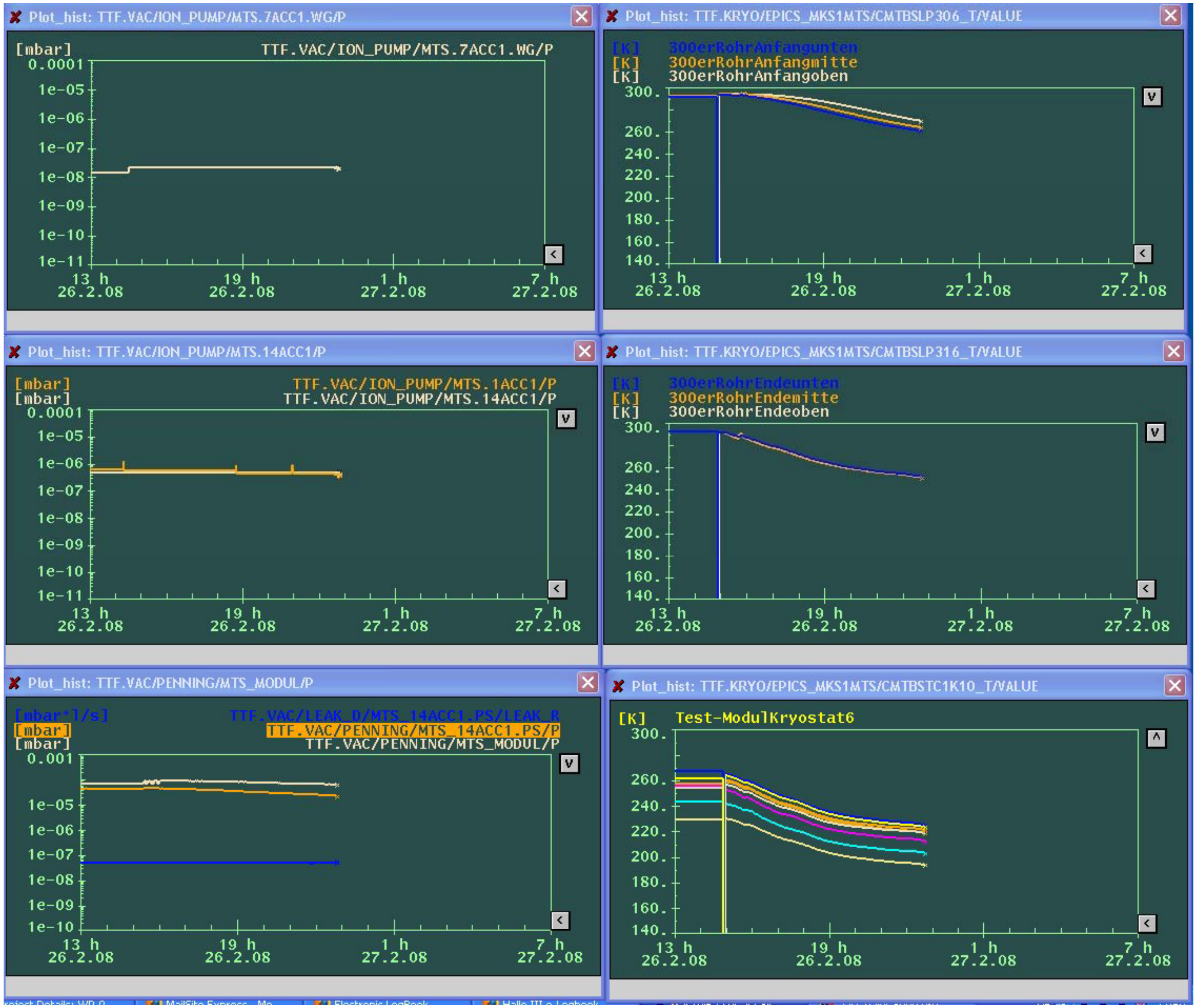
- 5 K shield surface provides convenient thermalization using small braids



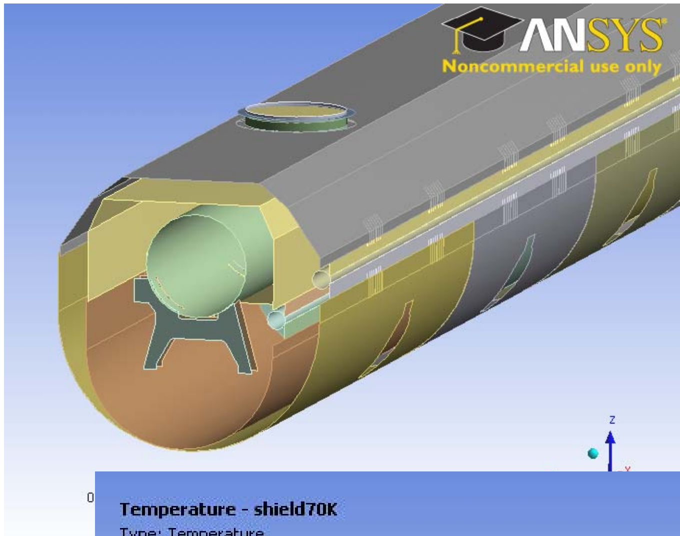
TTF Thermal analysis with ANSYS

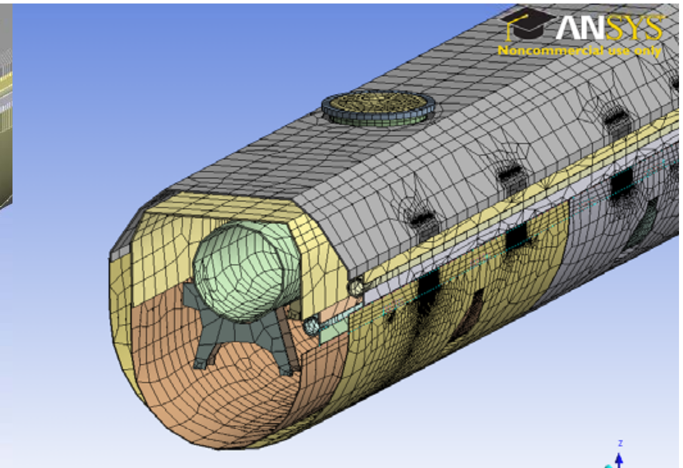
- Developed ANSYS model to reproduce static and transient thermal behavior
- Model aimed at evaluation of
  - static and transient heat loads,
  - thermal gradients on the shields, …
  - comparison of different cooling procedures (and fluids)
- To be benchmarked with **present M3* testing at CMTB**
  - The input data (cool down times, flow rates, …) from CMTB cryogenic system
  - The cool down started 26/02/08, tests will start soon.
  - A new set of thermal sensor has been implemented on the module to monitor temperature gradients on shield during cooldown and tests

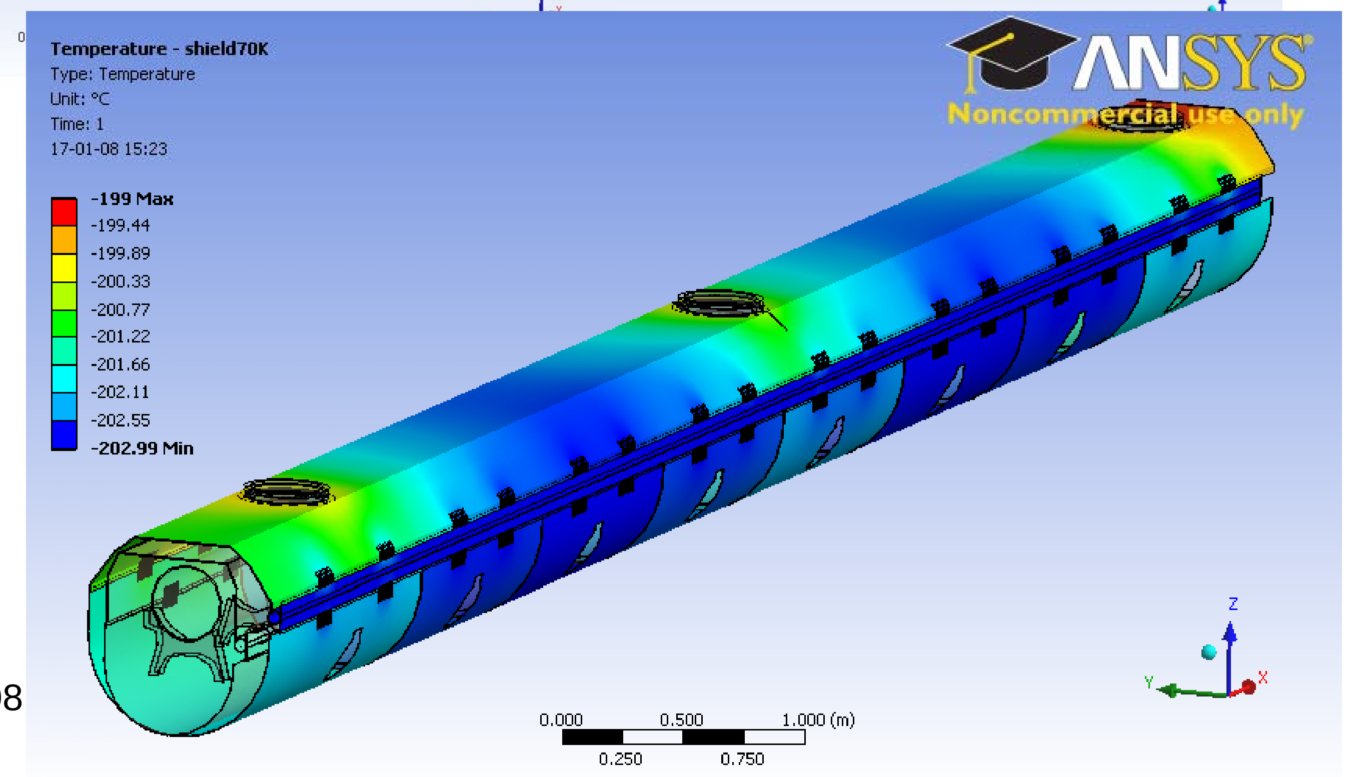
CMTB data at cooldown start



Model overview







Thermal conditions

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

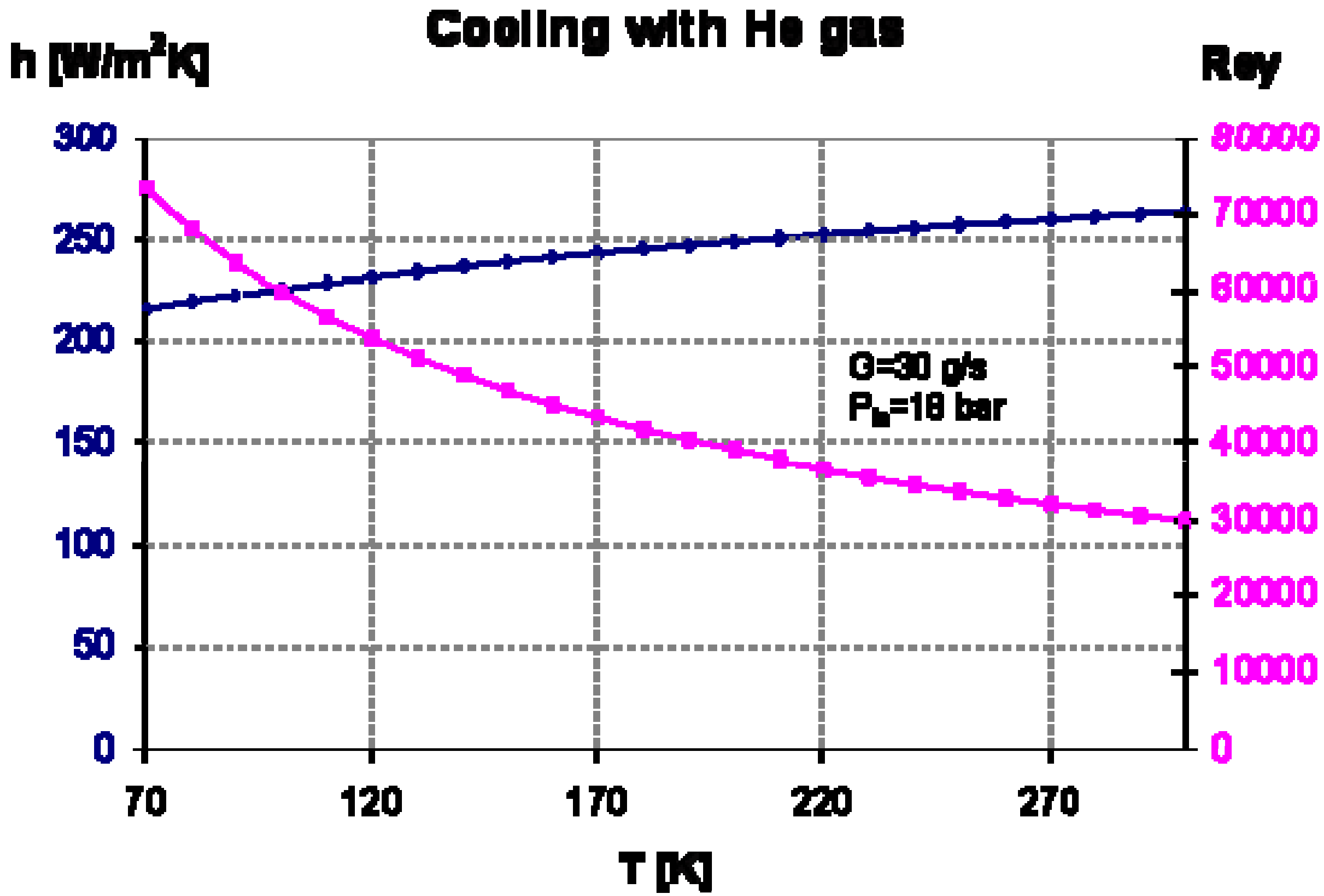
- Under development: still working on
  - Conduction at the couplers
  - Model so far has double shield and no radiation load at 2 K, so details of cavity tanks are still missing
    - Imposed temperature at the GRP and connections to tanks

Heat conditions in the transient analysis

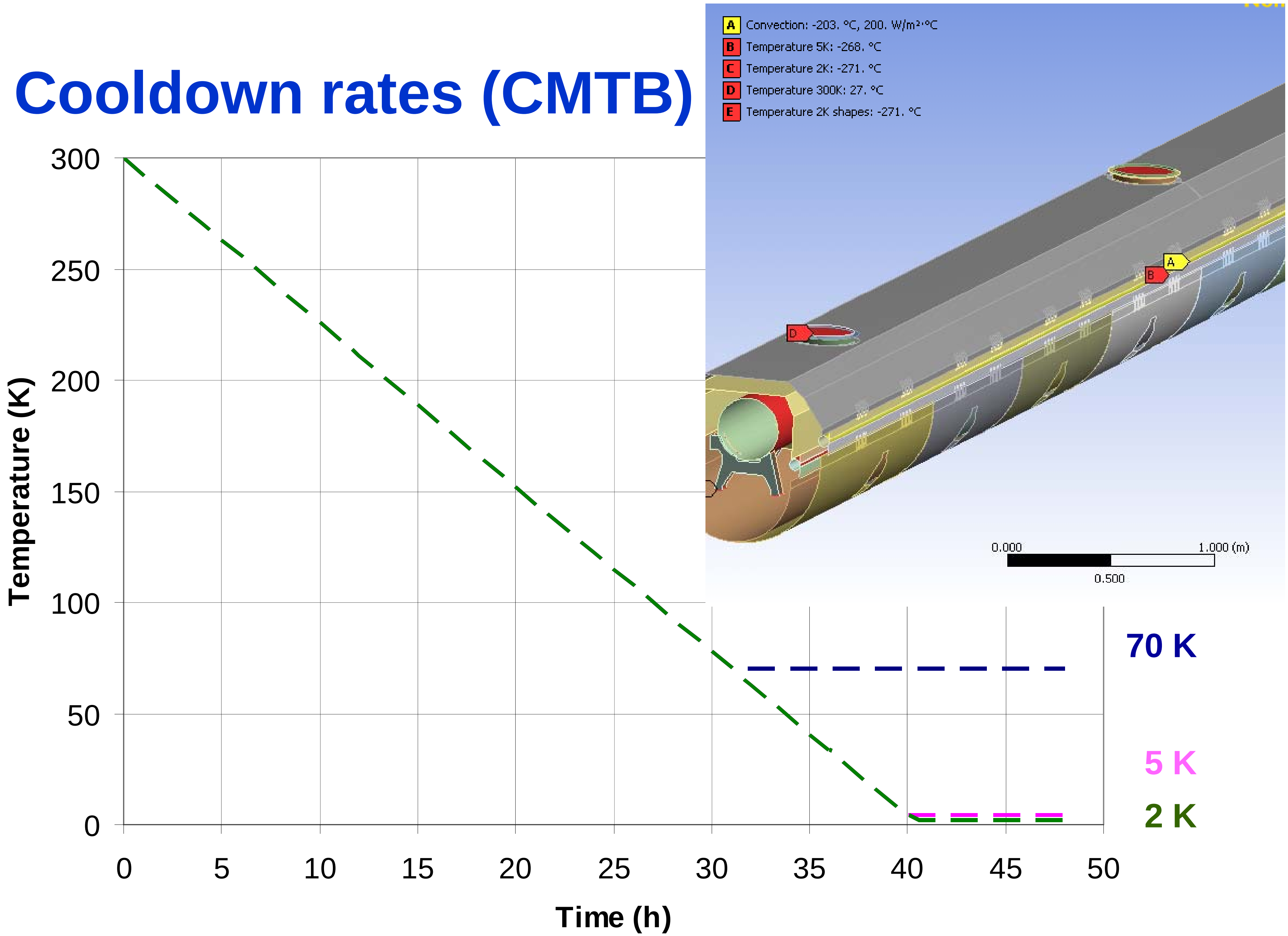
- Time dependent convection cooling at the 5 K and 70 K finned tubes
  - Linear T decrease
  - Used constant h_f, 200 W/m^2
- Imposed linear temperature decrease at the 2 K boundary
  - no limit to heat exchange
- Time dependent heat loads:
  - Radiation heat flux acting on the shields surfaces
  - Conduction 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



Cooldown rates (CMTB)



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

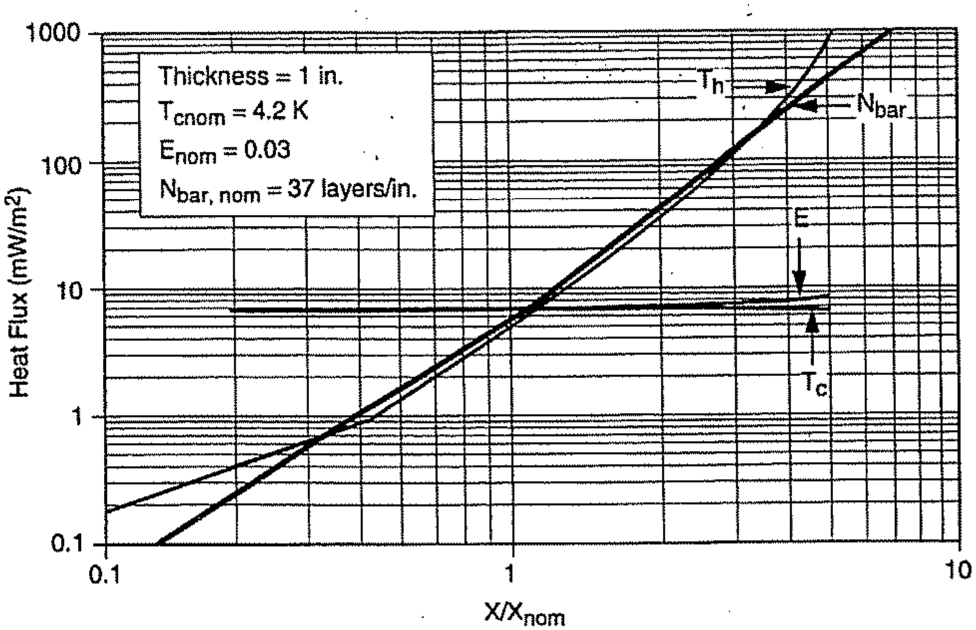
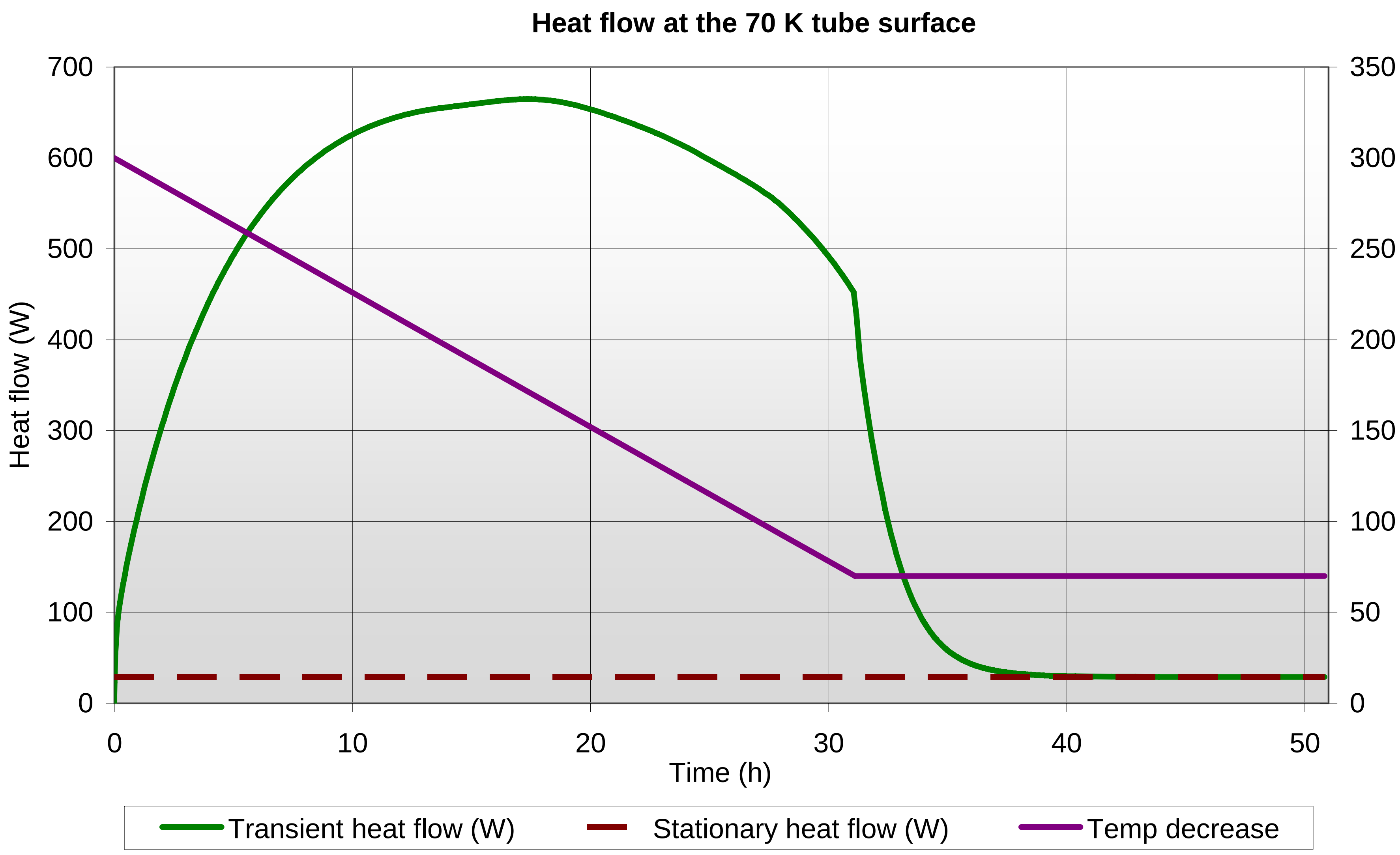
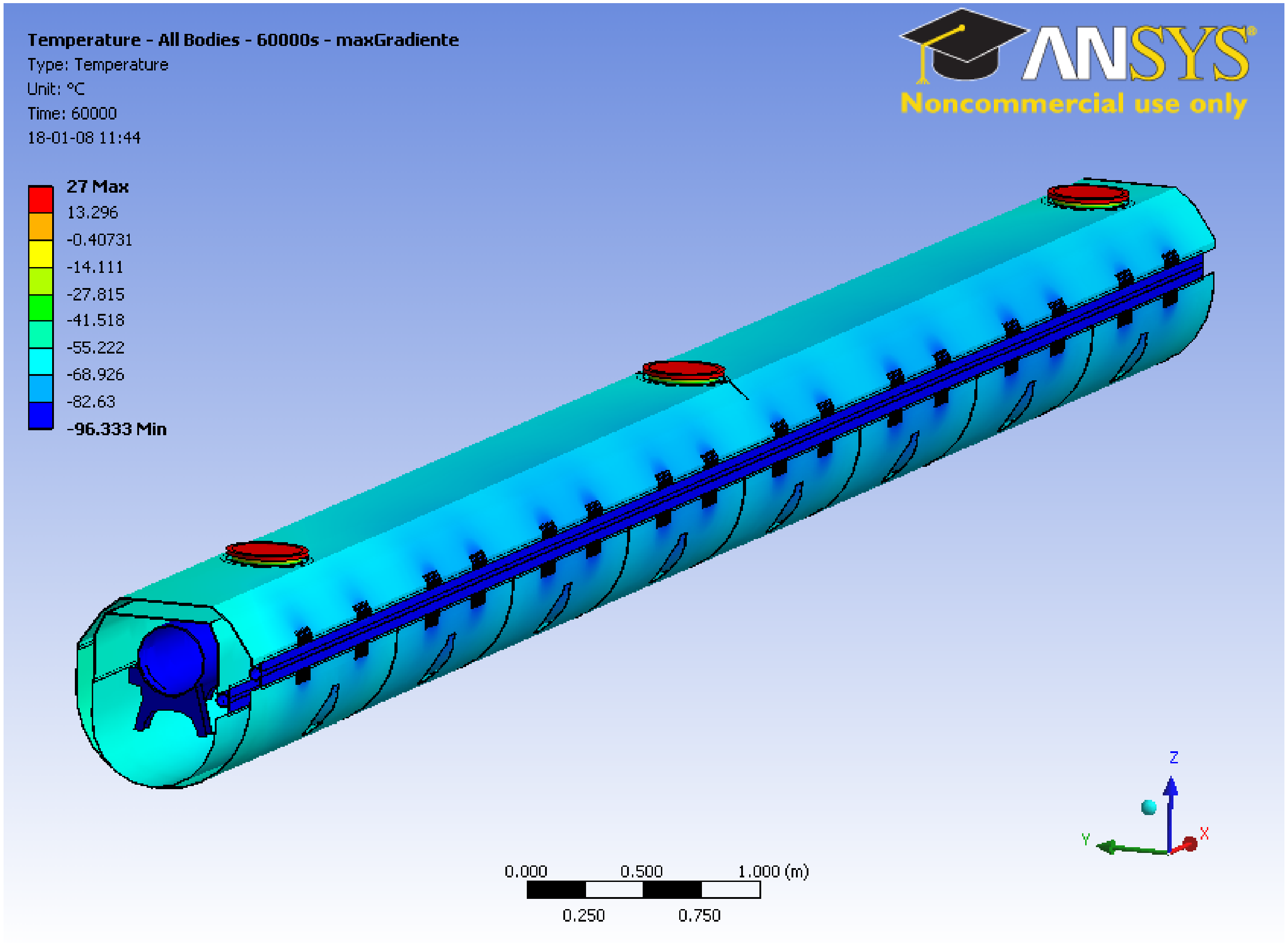


Figure 3-31 X/X_{nom} effects for nominal warm boundary temperature of 77 K.

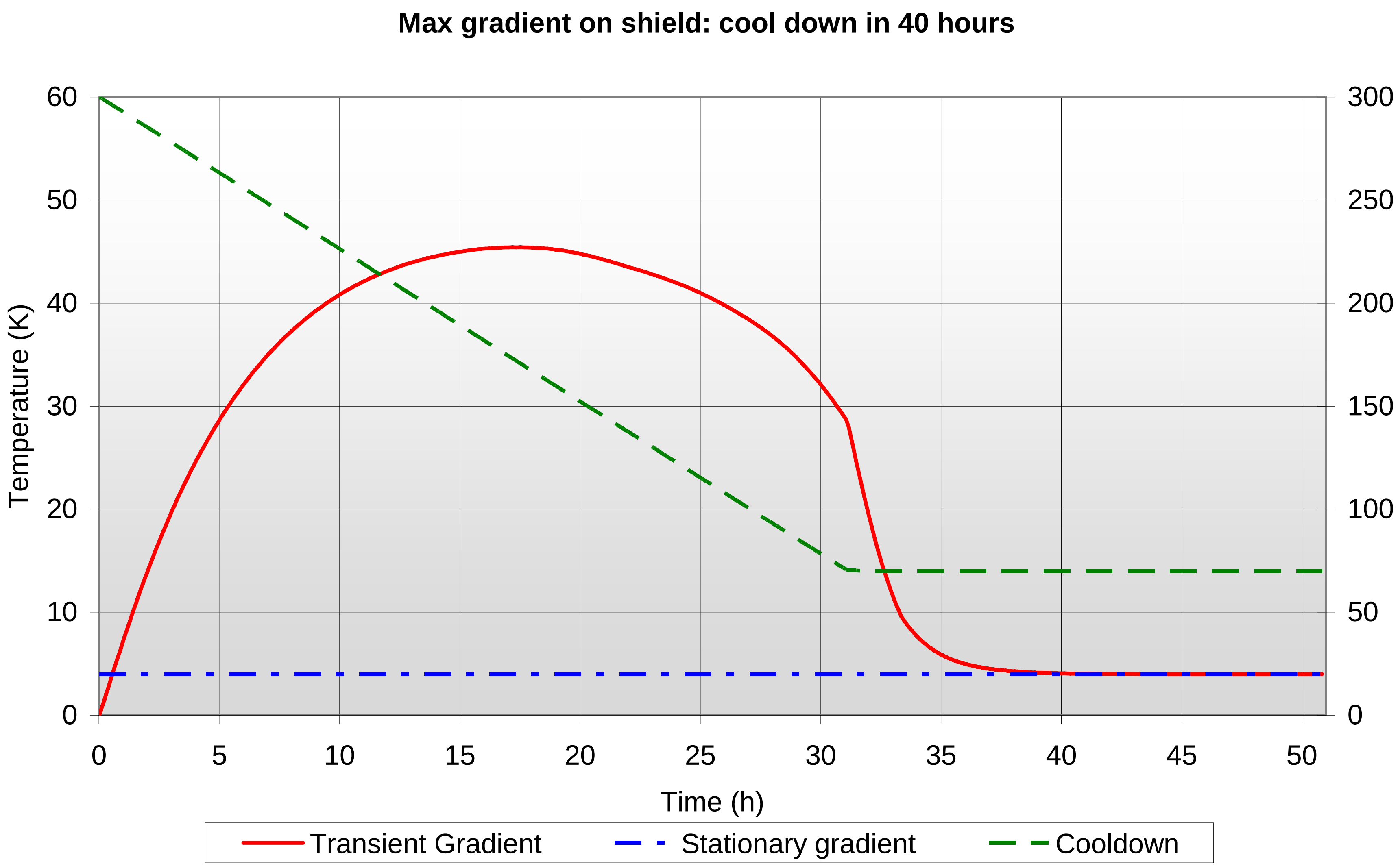
Heat flow on 70 K pipe during cooldown



Exploring max gradient during cooldown



Gradient on 70 K shield



Work in progress…

- Further implementation of heat load sources
- Waiting for CMTB data from Desy to be analyzed
  - will provide model benchmark
- Structural analysis at maximum gradients
  - mechanical interferences

- Once benchmarked, model can be extended for
  - different cooldown procedures
    - e.g. using LN in 70 K shield at ILCTA at FNAL
  - different thermal strategy for addressing the removal of 5 K shielding with redesigned cross-section