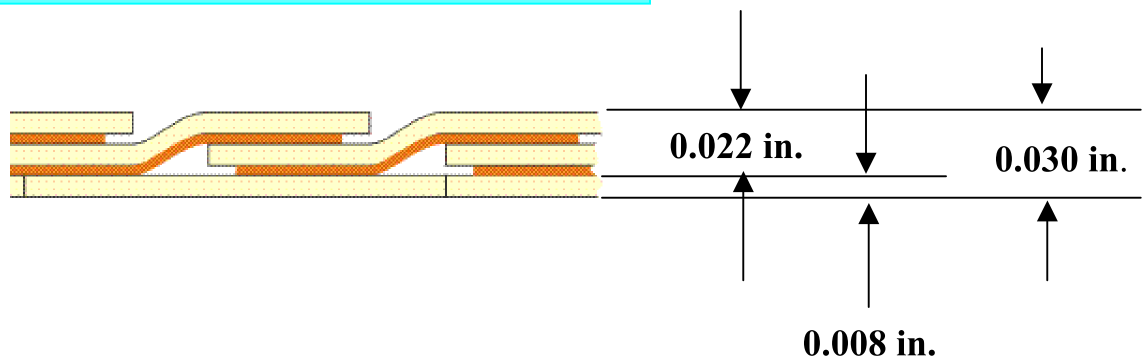
Evaluation of Modular Coil Cooldown Time with Thicker Insulation and Comparison of Original and Proposed Insulation Design

H.M. Fan
PPPL
January 15, 2003

Turn Insulation Build

Outer wrap glass insulation = 0.030”

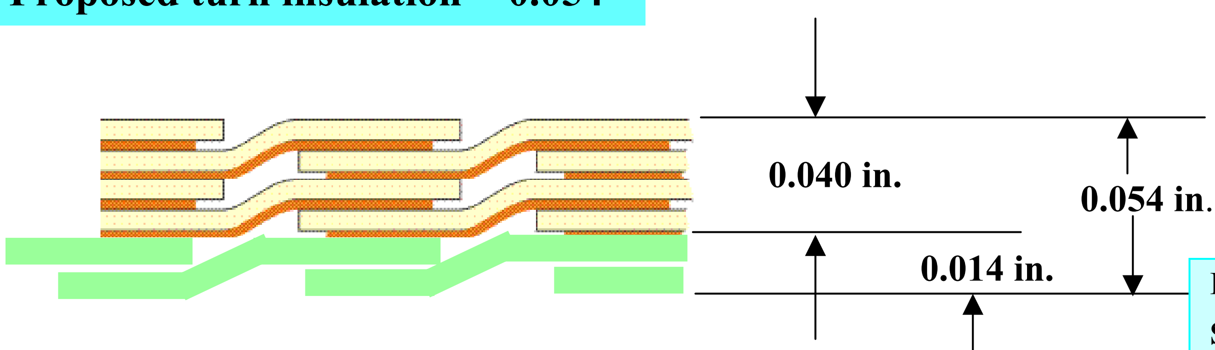
Original turn insulation = 0.030”



Two layers Kapton insulation

Three layers glass insulation (CTD101K)

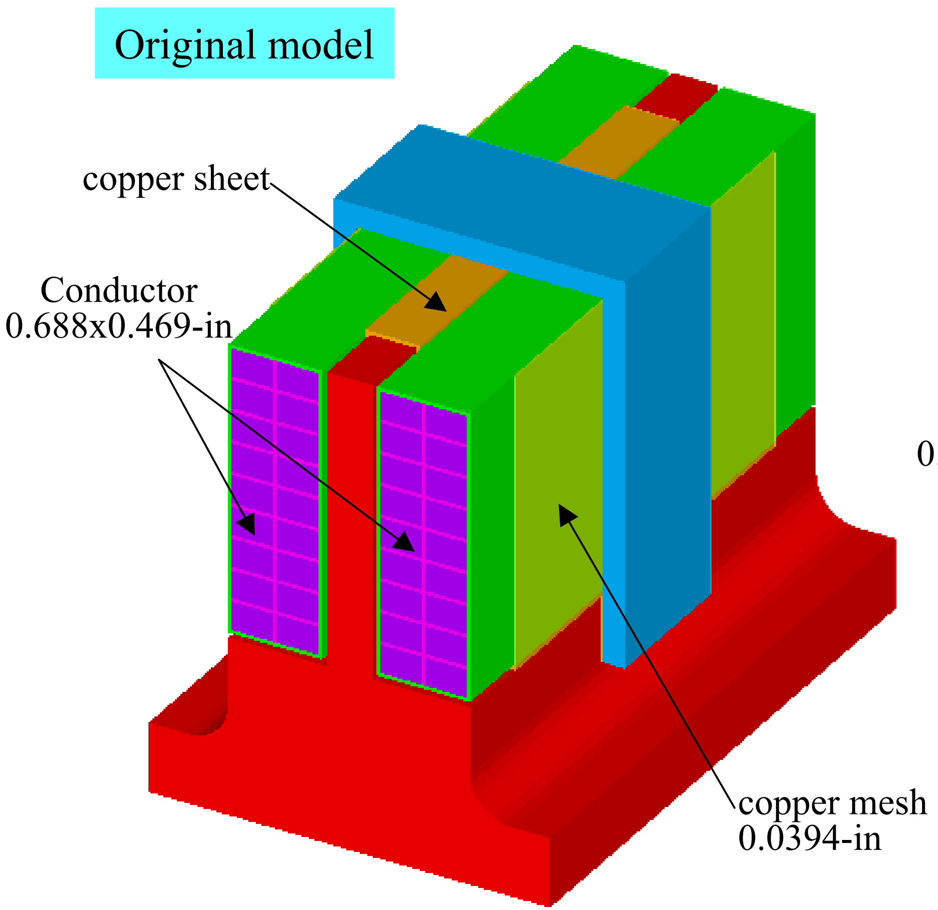
Proposed turn insulation = 0.054”

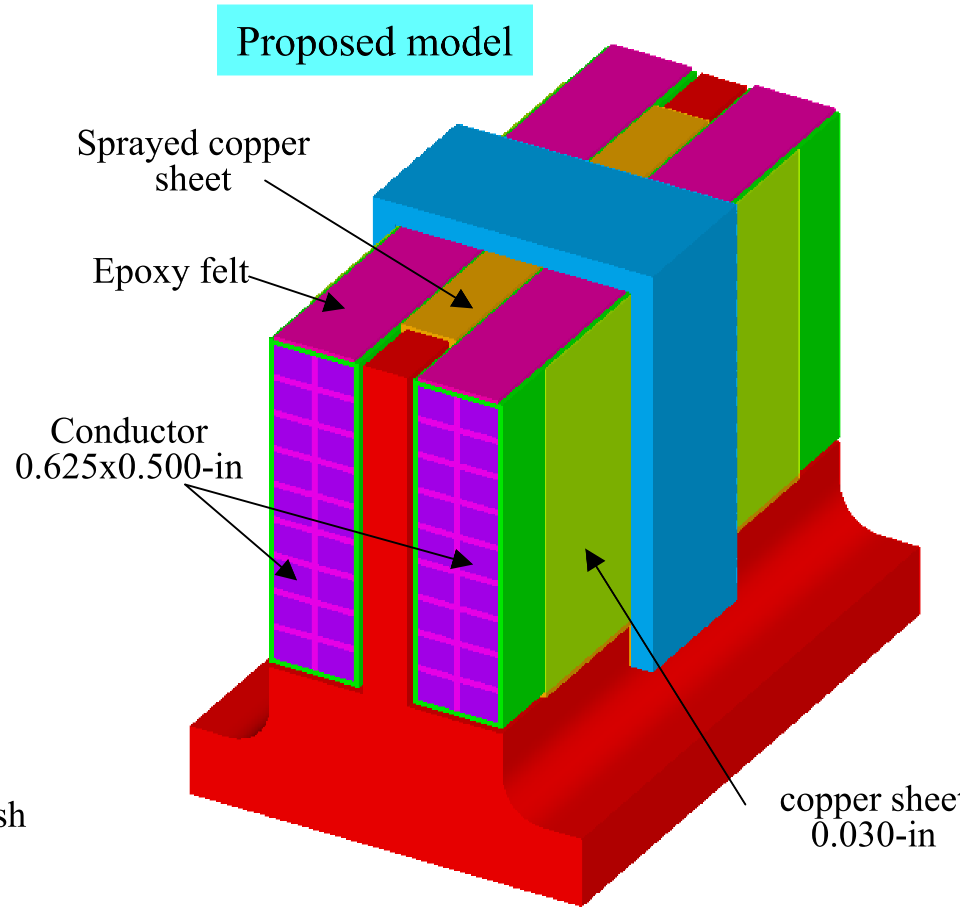


Four layers Kapton insulation

Six layers glass insulation (CTD101K)

Other Changes Between Two Designs



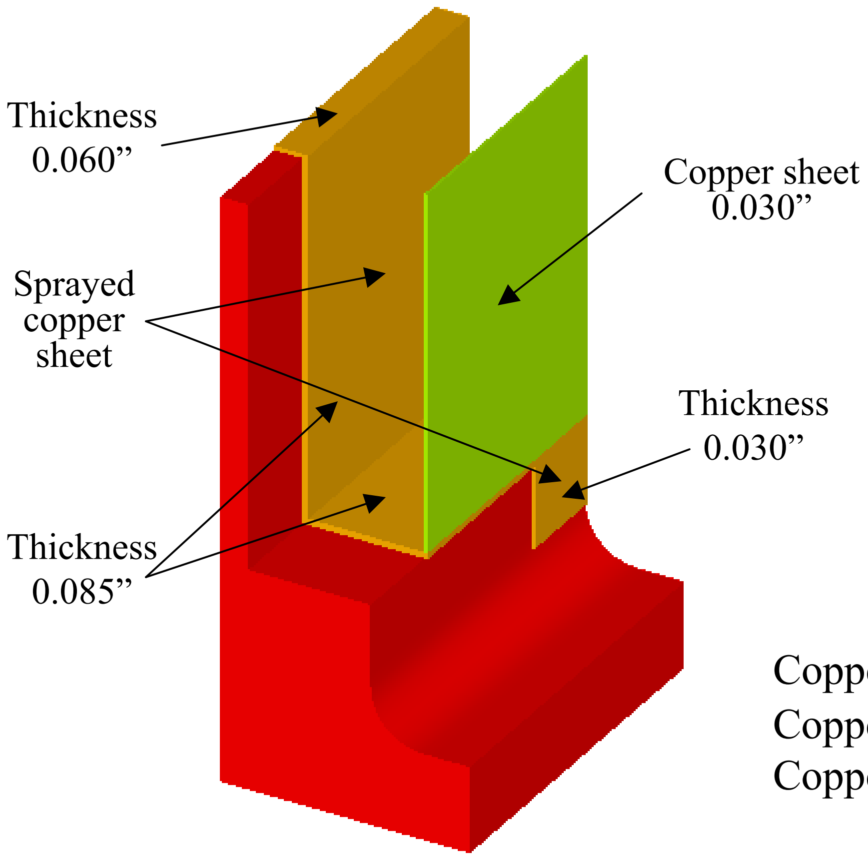


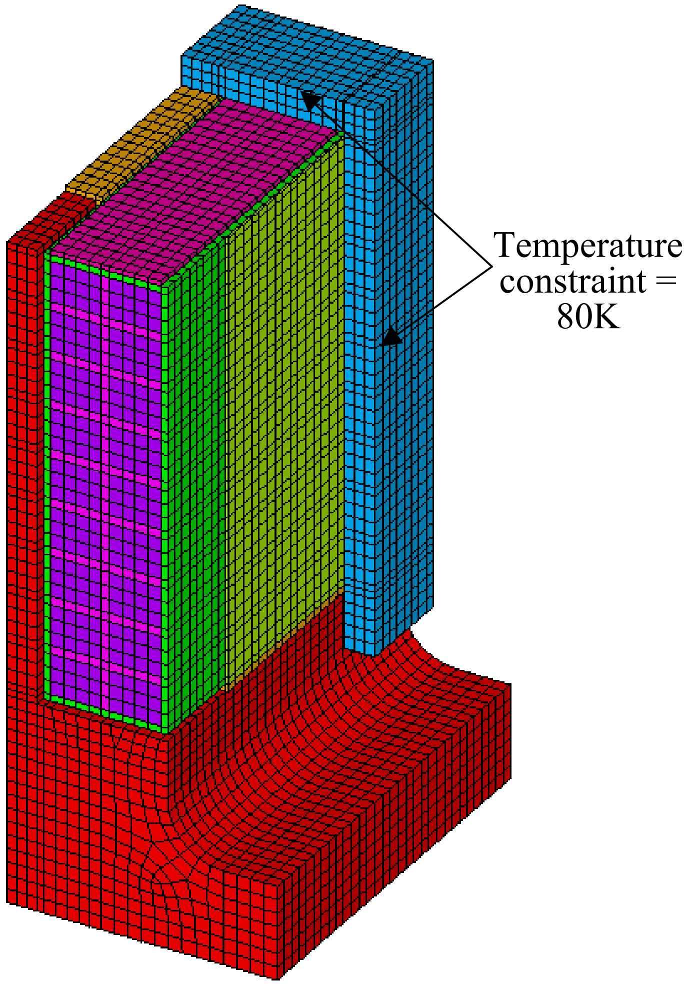
Thermal Conductivity (W/m-K)

	80K	100K	150K	200
Copper sheet	529.3	461.5	418.1	407.0
Sprayed copper sheet	Assuming 85% of the above values			
Copper mesh	Assuming 50% of the above values			

FEA Model

- Initial Temperature = 85K
- Temperatures on edges of copper clamp = 80K
- All surfaces are fully contacted or bonded
- Temperature-dependent material Properties
- Conductor cable: 75% copper and 25% epoxy





Copper clamp spacing = 10”
Copper clamp width = 2.5”, thickness = 0.375”
Copper sheet width = 7.5”

Cryogenics Material Properties

- Specific Heat (J/kg-K)

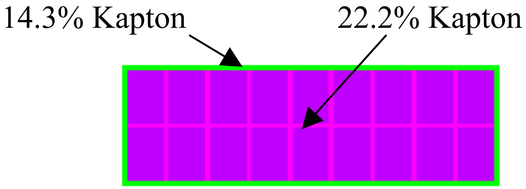
	80K	100K	150K	200K
Cable	171.4	212.3	270.1	300.7
Cooling plate	205.1	255.3	324.1	359.0
Insulation	348.9	413.7	537.0	626.8
Shell & T-beam	215.3	275.5	362.1	416.4

- Thermal Conductivity (W/m-K)

	80K	100K	150K	200K
Cable	397.0	346.2	313.7	305.2
Cooling plate	529.3	461.5	418.1	407.0
Outer Insulation	0.227	0.252	0.396	0.322
Inner Insulation	0.212	0.236	0.275	0.299
Shell & T-beam	8.114	9.224	11.17	12.63

Equivalent thermal conductivity:

$$L_e/K_e = L_1/K_1 + L_2/K_2$$



Coil Currents and Ohmic Heating

A. PVR design -- http://www.pppl.gov/me/NCSX_Engineering/Technical_Data/MOD00/Inputs_1.7T.htm

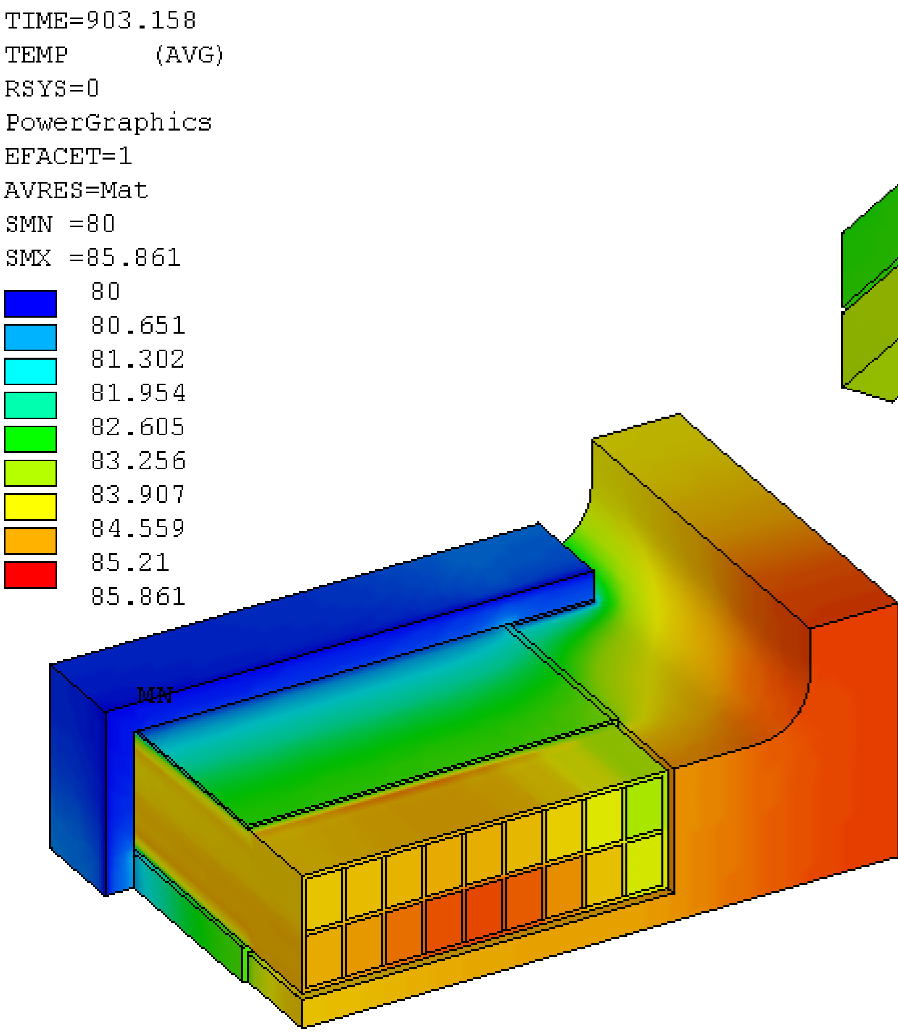
Time (s)	-1.5	0	0.1	0.158083	0.258083	0.458083	1.658083
Current(A)	0	20287	20287	16626	17755	17755	0
μ (ohm/m)	2.36E-09	3.52E-09	3.78E-09	3.91E-09	4.11E-09	4.55E-09	5.52E-09
Power(W/m^3)	0	3.56E+07	3.83E+07	2.66E+07	3.19e+07	3.53E+07	0

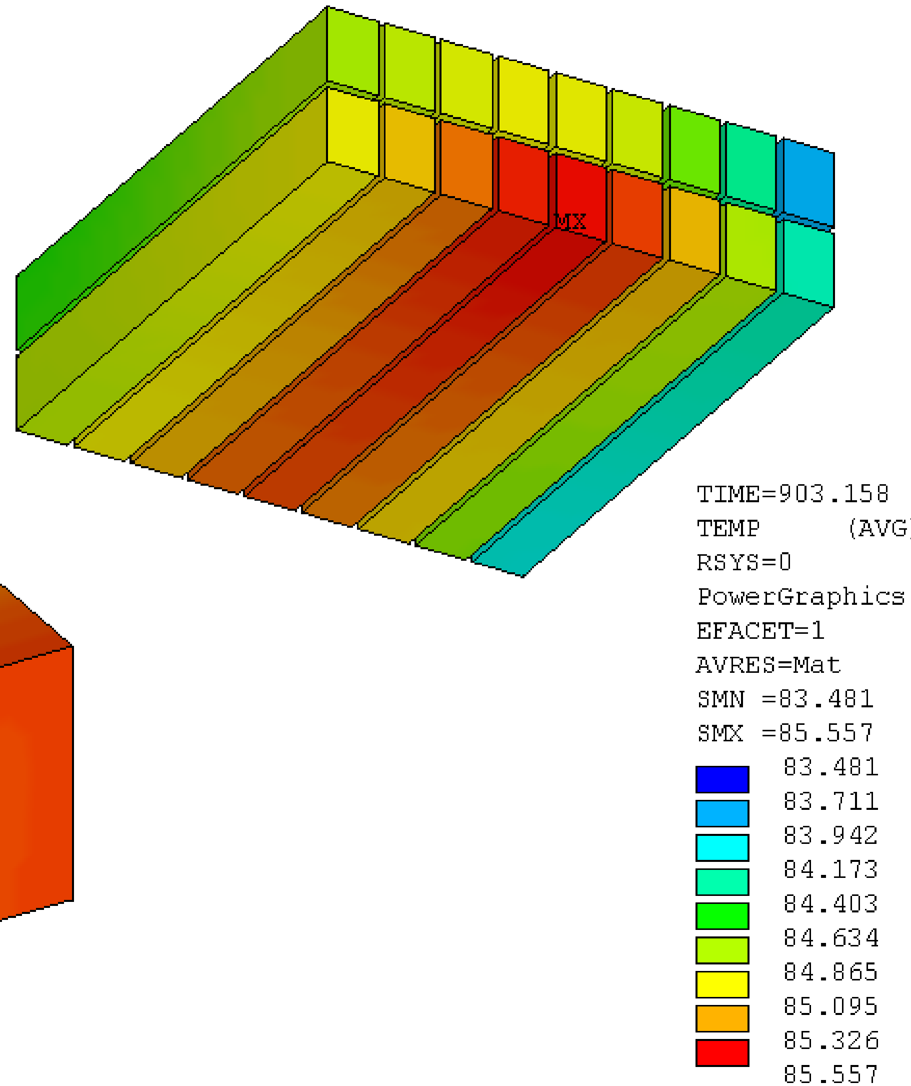
B. CDR design -- http://www.pppl.gov/me/NCSX_Engineering/Technical_Data/c01r00/Waveforms.htm

Time (s)	-1.2	0	0.1	0.196	0.296	0.496	2.677
Current(A)	0	19535	19535	17023	17023	17023	0
μ (ohm/m)	2.36E-09	3.84E-09	4.04E-09	4.25E-09	4.41E-09	4.78E-09	5.34E-09
Power(W/m^3)	0	3.61E+07	3.79E+07	3.03E+07	3.14e+07	3.41E+07	0

Modular Coil Temperature at The End of 1st Cooling Cycle (15 Minutes) for The Original Model

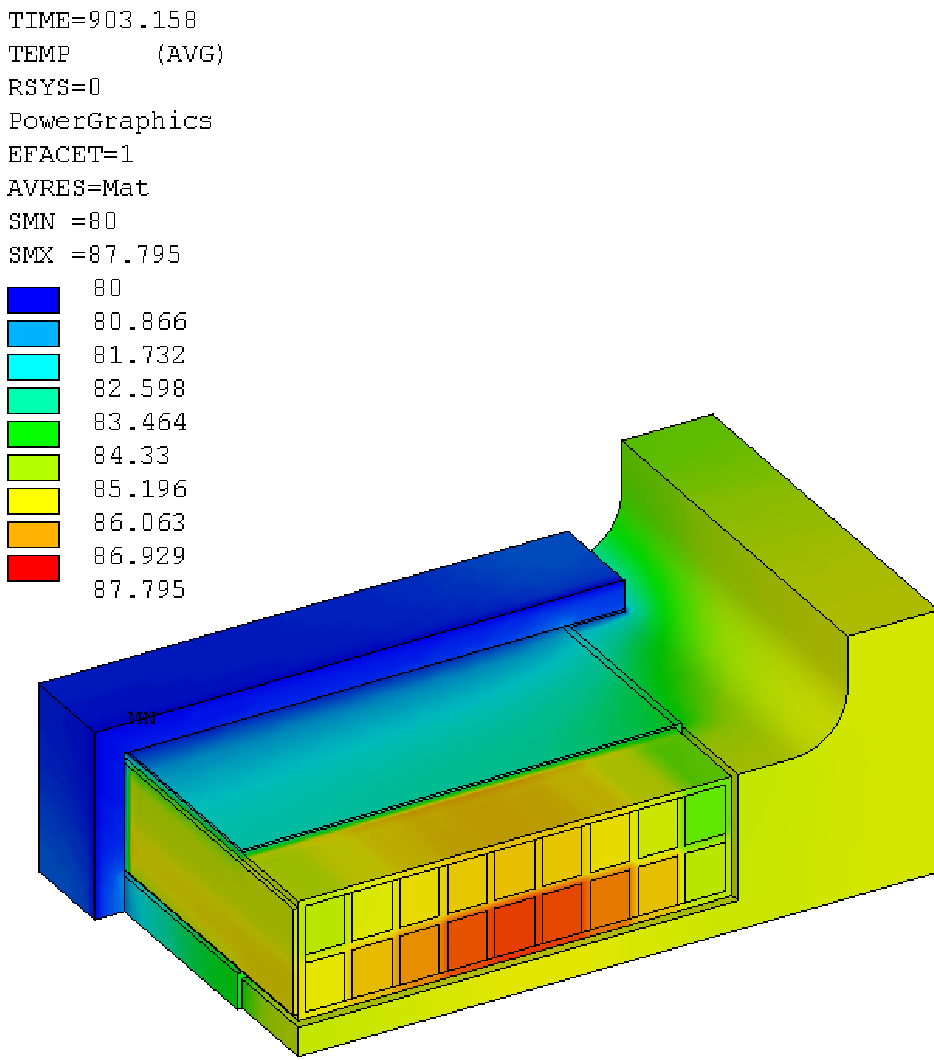
-- Based on PVR Currents and a 20% Increases of Heating Power

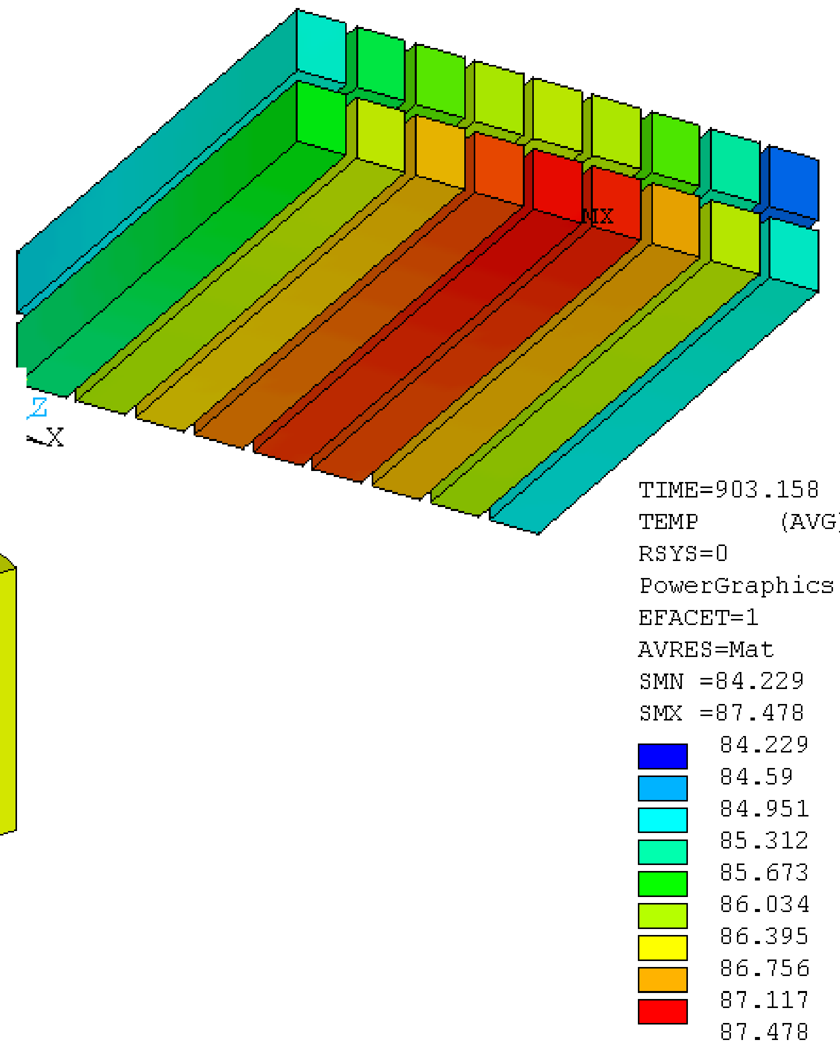




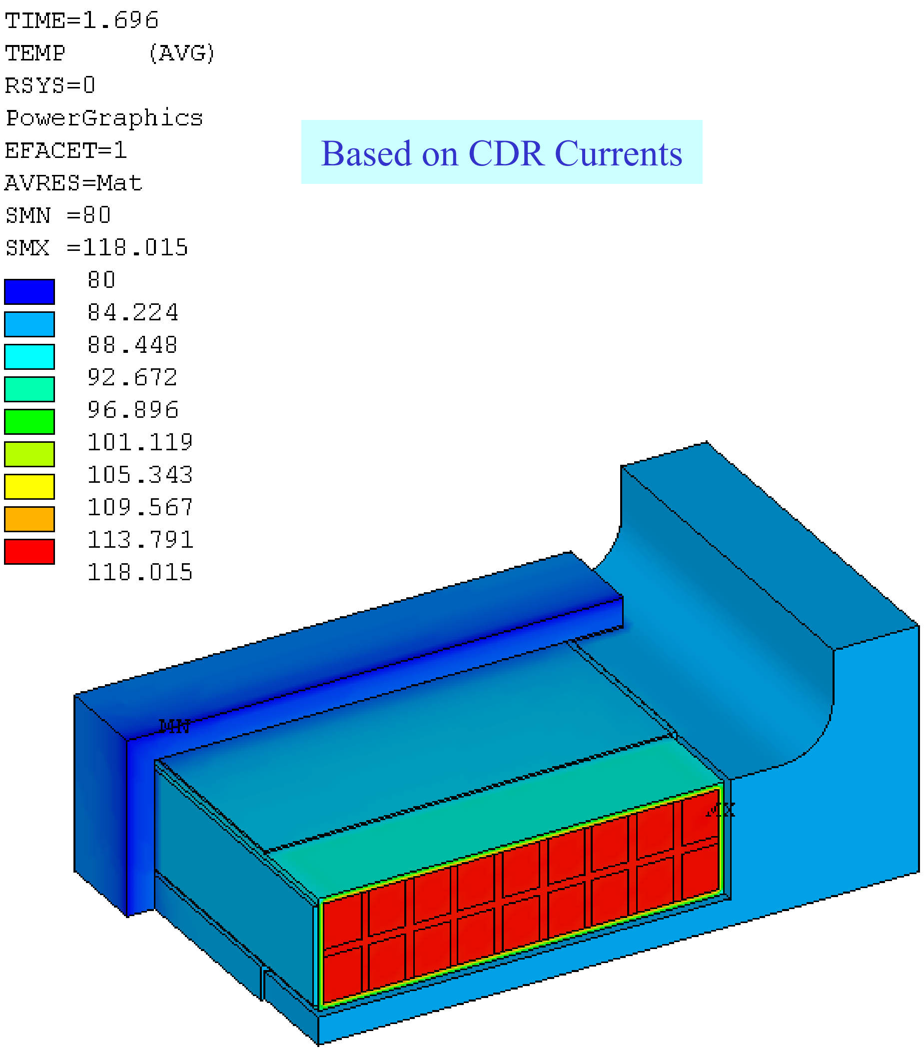
Modular Coil Temperature at The End of 1st Cooling Cycle (15 Minutes) for The Proposed Model

-- Based on PVR Currents and a 20% Increases of Heating Power

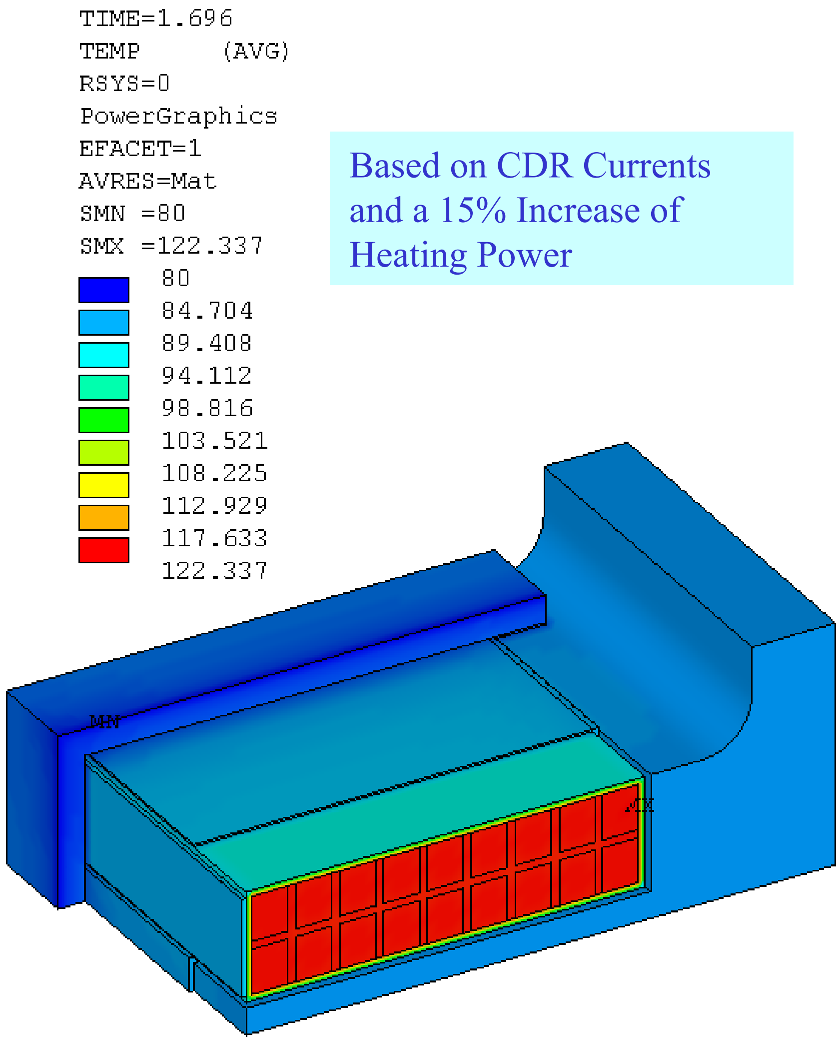




Modular Coil Temperature at The End of 1st heating Cycle for The Proposed Model

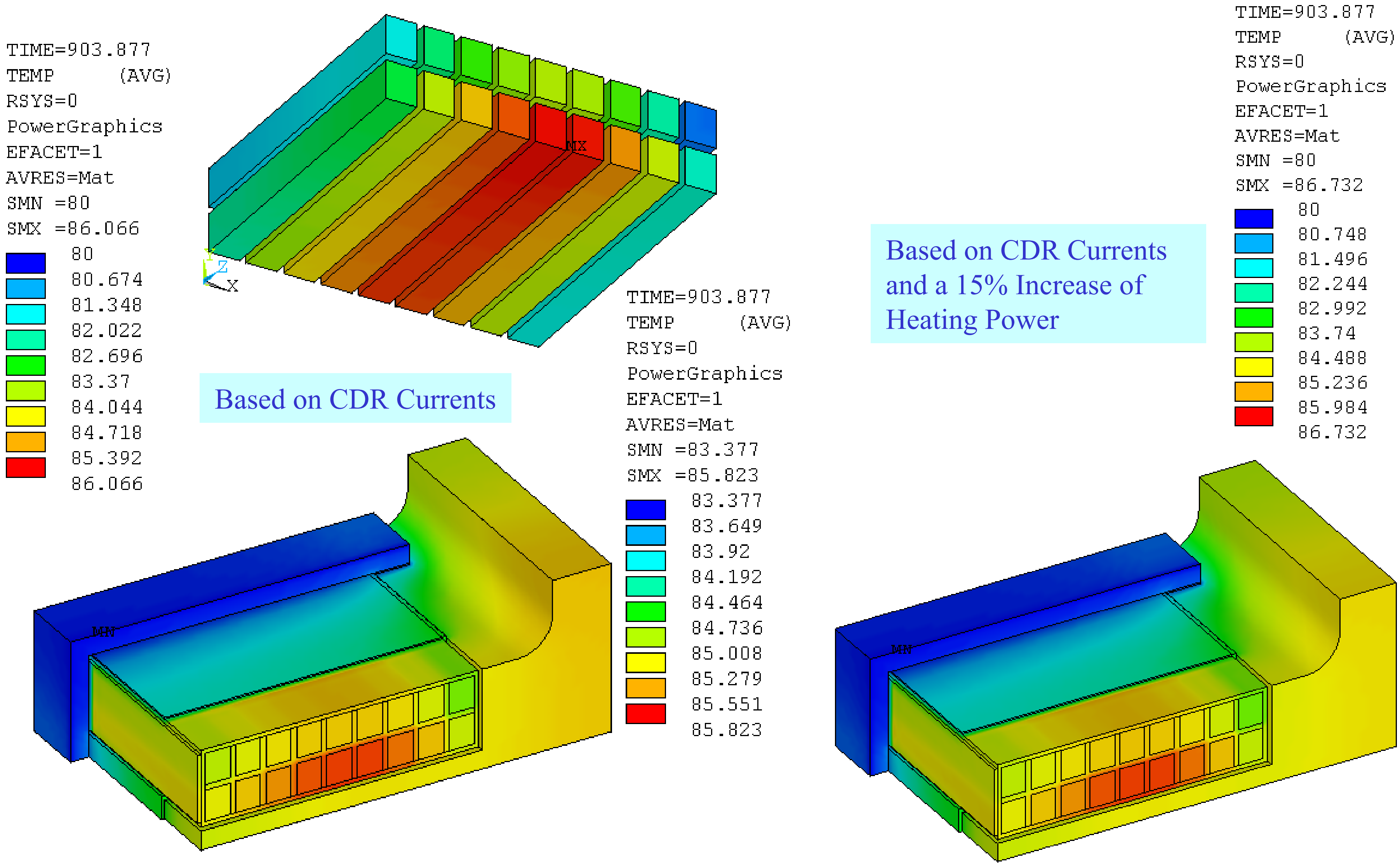


Based on CDR Currents



Based on CDR Currents and a 15% Increase of Heating Power

Modular Coil Temperature at The End of 1st Cooling Cycle (15 Minutes) for The Proposed Model



Modular Coil Temperature at The End of 1st Cooling Cycle (18 Minutes) for The Proposed Model