Thermal Result for the Proton Absorber (Mu2e) based on both 250 &165 CFM for normal operating case-July 31, 2015

Ang Lee and Andy Stefanik

July 31, 2015

*Both geometry and boundary condition has been updated as of July 30, 2015

Note:

a) Updated on Sept 15, 2015 with an additional 1/16” SS plate as shown in Appendix B

b) Updated on Sept 30, 2015 by changed the insulation material from ceramic fiber to the concrete as required. The result is shown at appendix C.

Both Geometry and Convective film has been updated (up to July 30, 2015 version)

- As part of the continuing loop after July 7 version (reference 1)
- Updated the convective film coefficient and air temperature based on both 250 CFM and 165 CFM (by Andy Stefanik as).
- The geometry including the core plate thickness, shielding steel on the top, air gap size and others has been updated to July 30, 2015.
- The FEA thermal model updated accordingly to reflect the above change.

Convective film coefficient (provided by Andy Stefanik_ use shaded area as convective film coefficient and film temperature

These numbers are for channel height of 3".

250 cfm	Air Inlet Temp - First core plate [°C]	Air Outlet Temp - First core plate [°C]	Air Outlet Temp - Mixed, all air flows [°C]	Air heat transfer coefficient - First core plate [W/(m^2-K)]
Top channel [°C]	34.3	42.9	25	1
Vertical side channels [°C]	17.1	34.3		1
Bottom channel [°C]	12.2	17.1		0.57

165 cfm	Air Inlet Temp - First core plate [°C]	Air Outlet Temp - First core plate [°C]	Air Outlet Temp - Mixed, all air flows [°C]	Air heat transfer coefficient - First core plate [W/(m^2-K)]
Top channel [°C]	45.6	58.7	30	1
Vertical side channels [°C]	19.6	45.6		1
Bottom channel [°C]	12.2	19.6		0.57

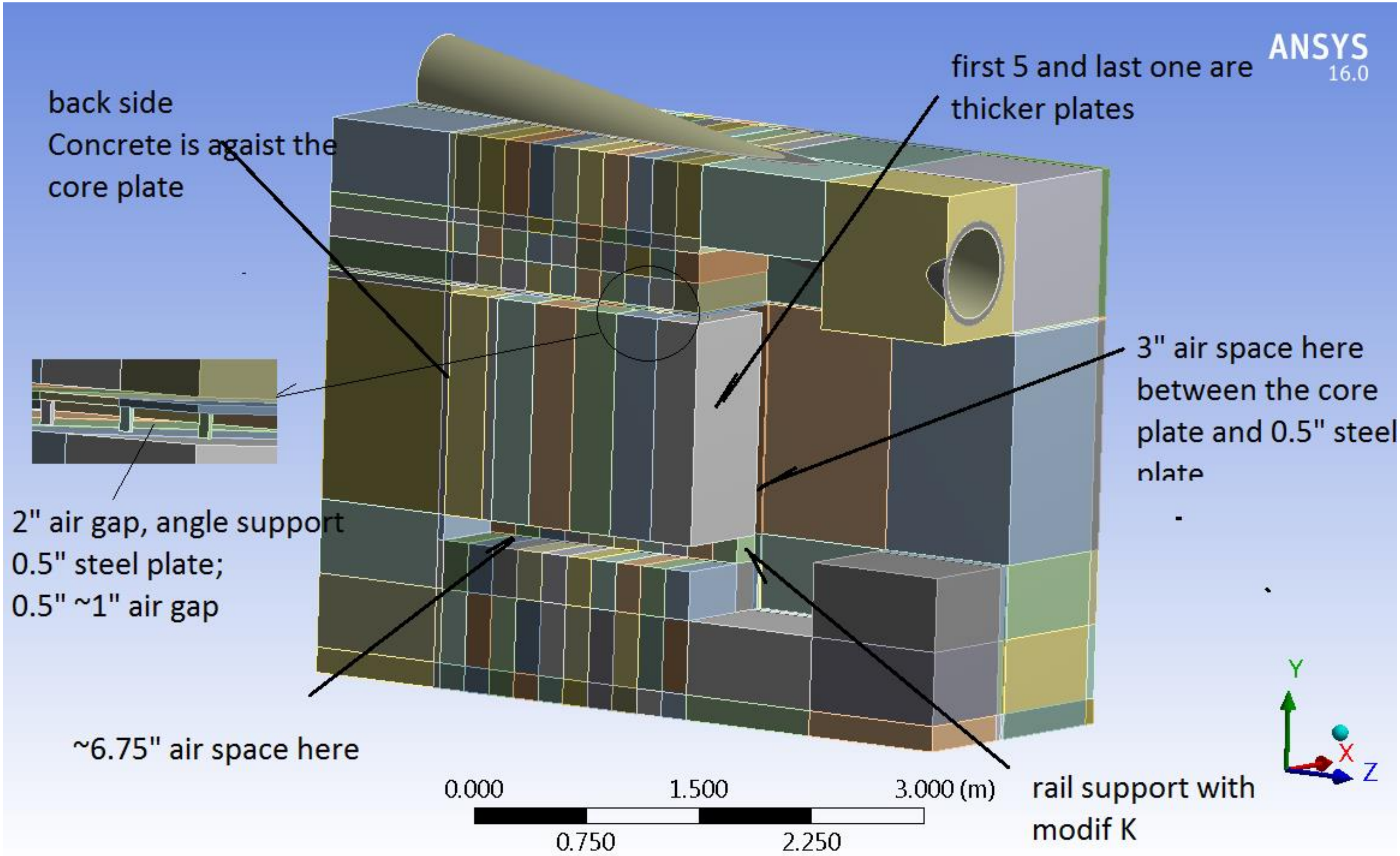
Convective film coefficient both 250 cfm and 165 cfm(Provided by Andy Stefanik)

These numbers are for channel height of 3".

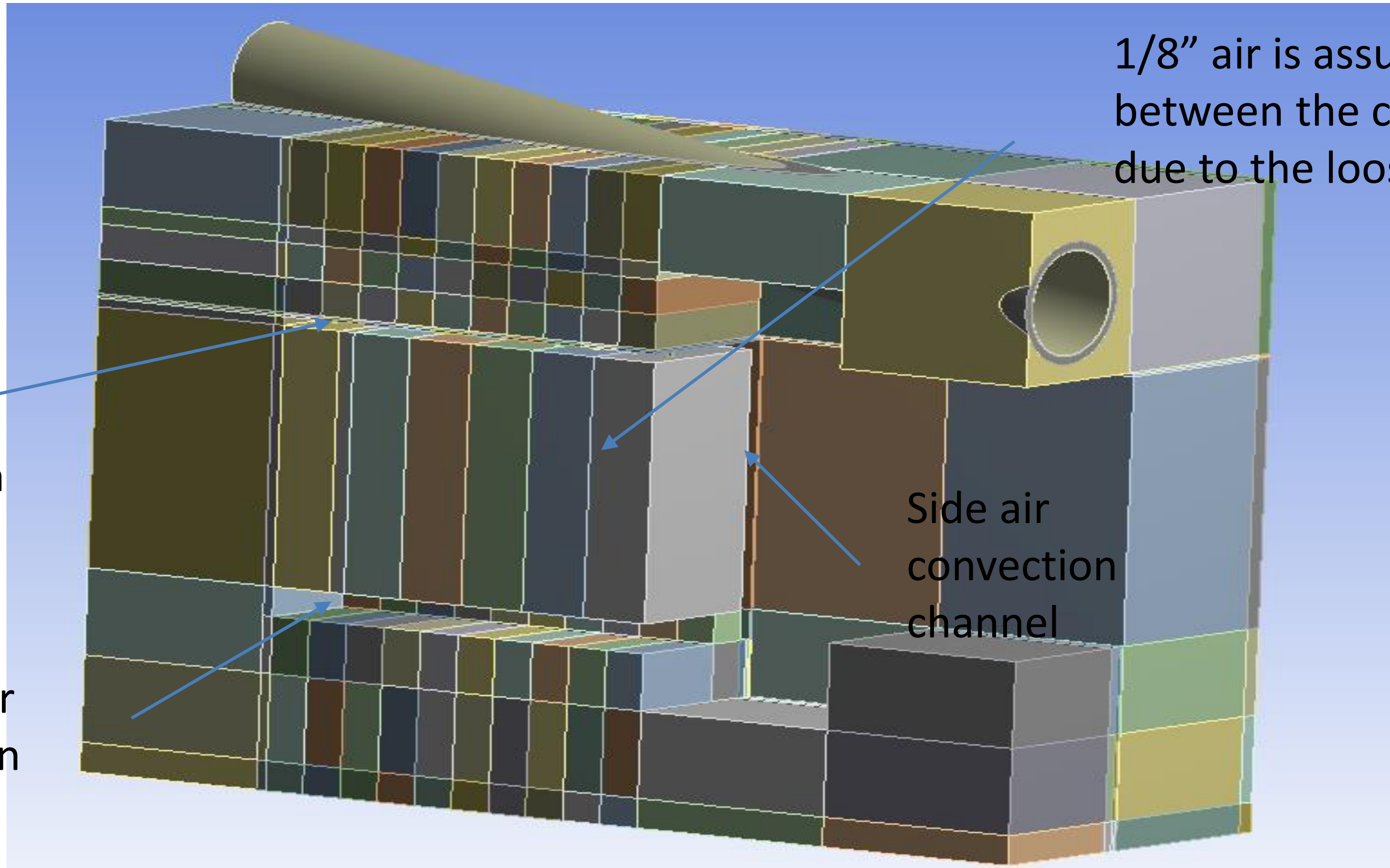
250 cfm	Film temperature [°C]	Air heat transfer coefficient - First core plate [W/(m^2-K)]
Top channel [°C]	25 (mixed)	1
Vertical side channels [°C]	34.3	1
Bottom channel [°C]	17.1	0.57

165 cfm	Air Outlet Temp - Mixed, all air flows [°C]	Air heat transfer coefficient - First core plate [W/(m^2-K)]
Top channel [°C]	30(mixed)	1
Vertical side channels [°C]	45.6	1
Bottom channel [°C]	19.6	0.57

Updated FEA model
(up to July 30, 2015)

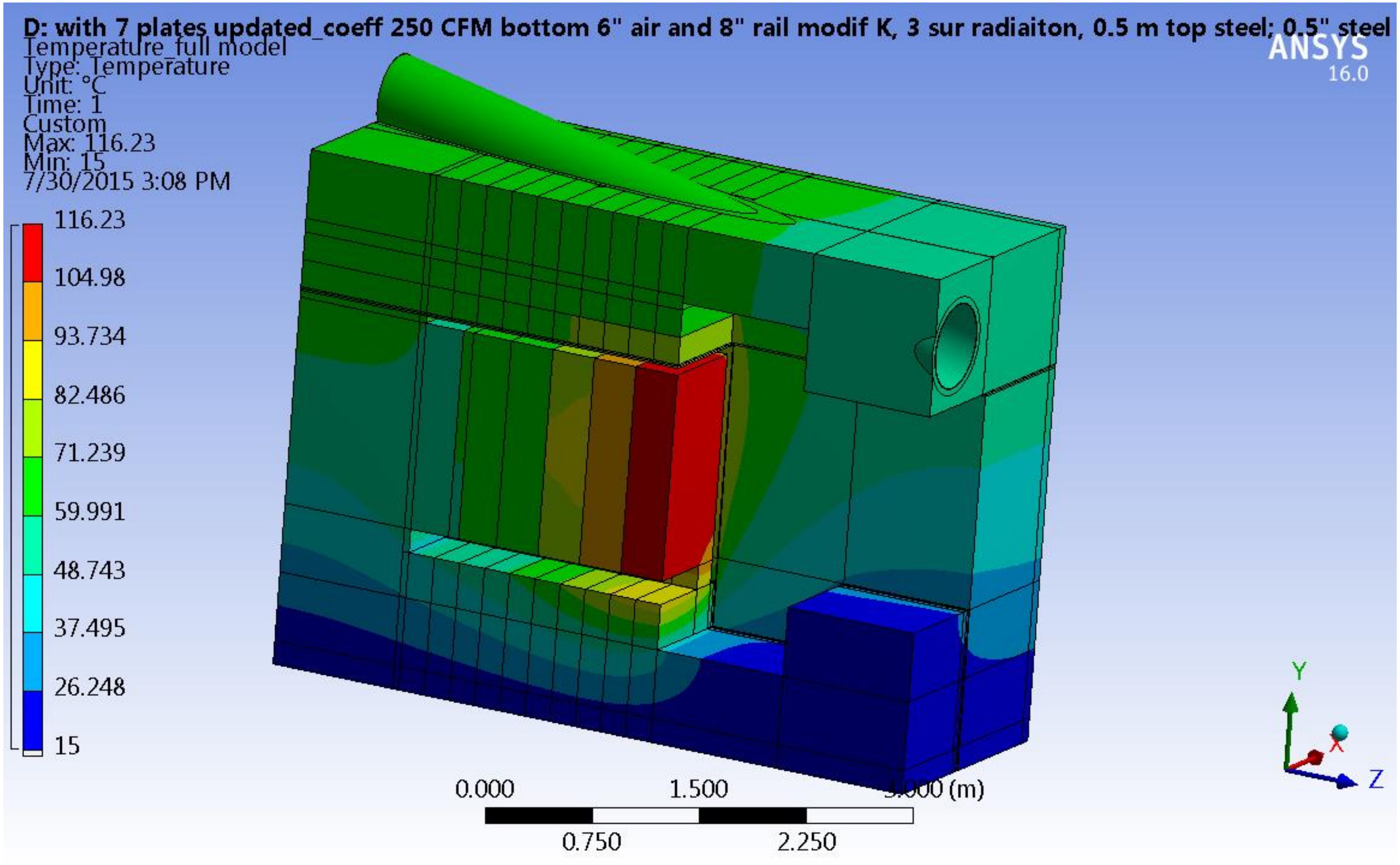


FEA boundary condition

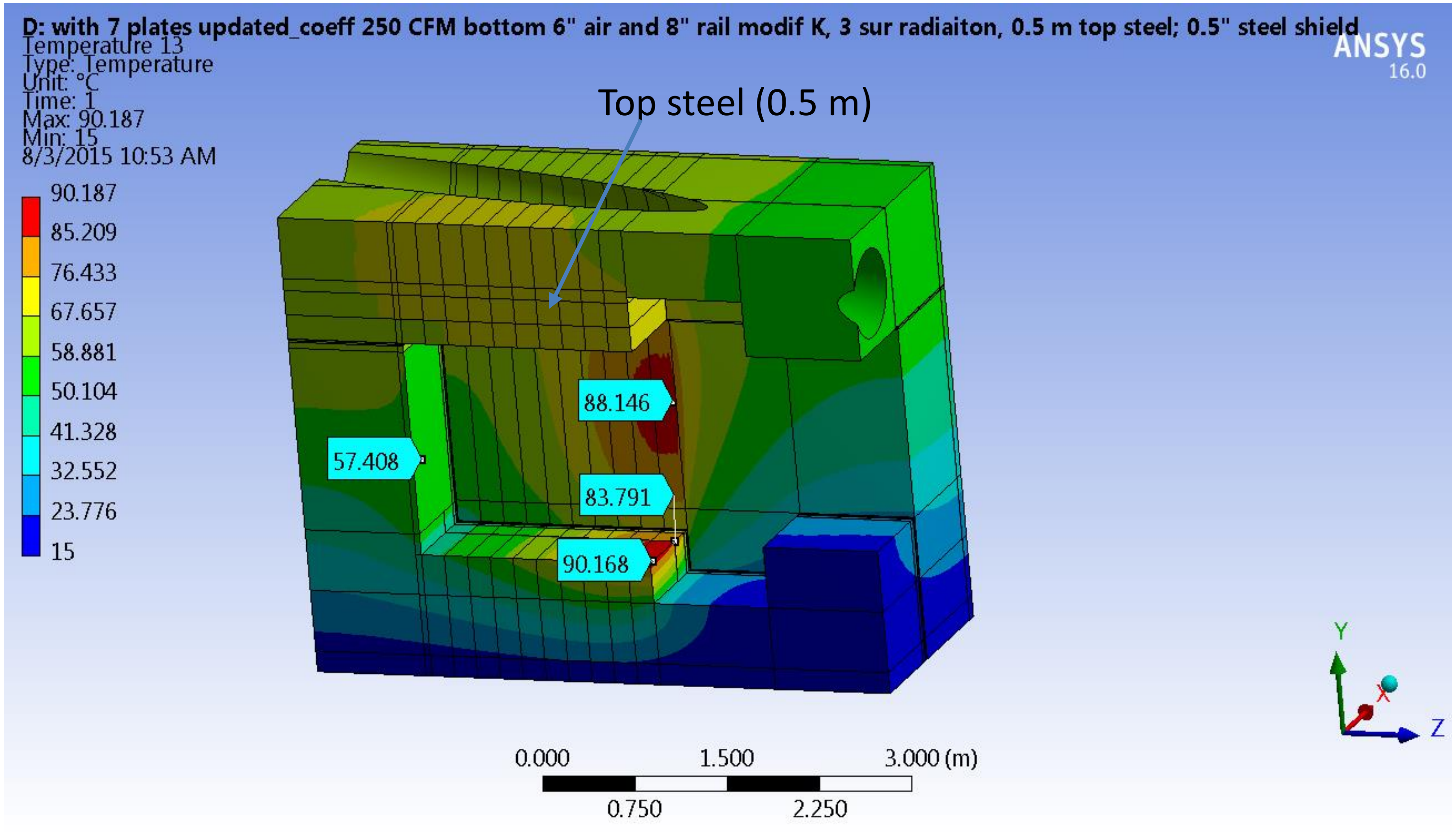


-The Radiation effect is turn on for the top, bottom and side channel.
-The exterior of the concrete is assumed to be "insulated" with the exception of the bottom where a fixed 15 C is assumed/
-

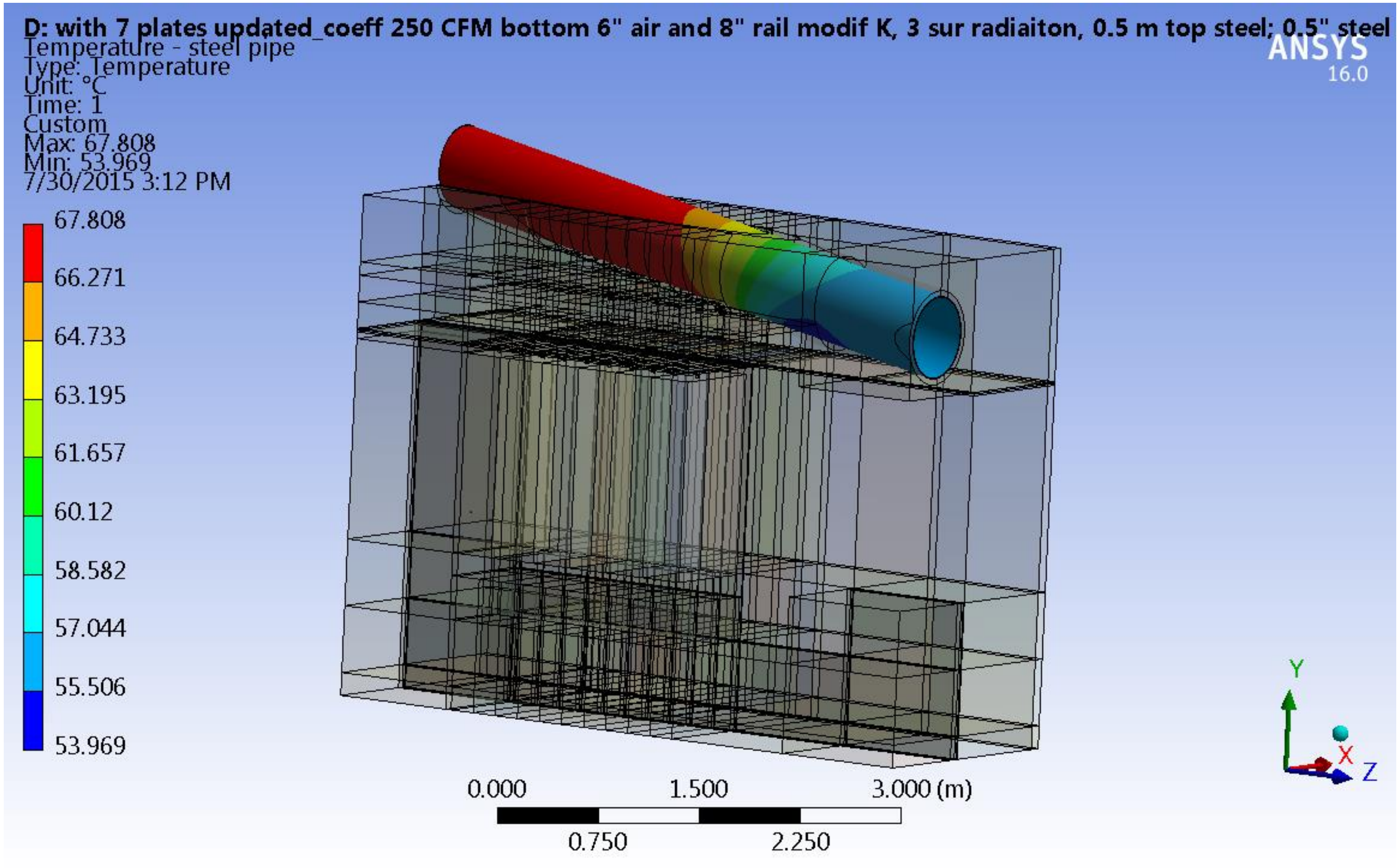
Result Based 250 CFM Temperature (C)



Result based on 250 CFM
Temperature _C for the Concrete and upper steel section



Result based on 250 CFM
Temperature _C for the steel pipe



Summary of Result

with the consideration of the radiation effect at top, 2 side surfaces and the bottom

Flow rate (CFM)	Tmax (steel plate) _C	Tmax (concrete) _C	Tmax (concrete at the rail support area)_C
250 CFM	116.23	90.18	84
165 CFM	121.51	95.25	89

Note:
1) The difference between 250 CFM and 165 CFM is about ~6 C due to its similar convective film coefficient (laminar flow).

2) Just as a reference, if we use the same model as above with a "old" convection film coefficient base on 800 CFM _ ref (2), Tmax (core steel) will be=68 C and Tmax (concrete)=41 C, respectively.

Estimate the thermal expansion

n	ΔT (C)	α (steel) m/mK	L(m)	Total expansion ΔL (m)	Or ΔL (mm)
Steel Core plate	120	1.20E-05	(Width) 1.5	2.16E-03	2.16 mm
	120	1.20E-05	(Longitudinal) 2 m	2.88E-03	2.88 mm <1/8”

Note:

1) For the first plate (~330 mm thick), the longitudinal expansion will be 2.88 mm*(330/2000)=0.47 mm < 1/32”_very very small.

Work plan _ What we do from here

- Accident case based either 165 CFM or 250 CFM?
- Extinction monitor pipe movement ?
- Or other items?

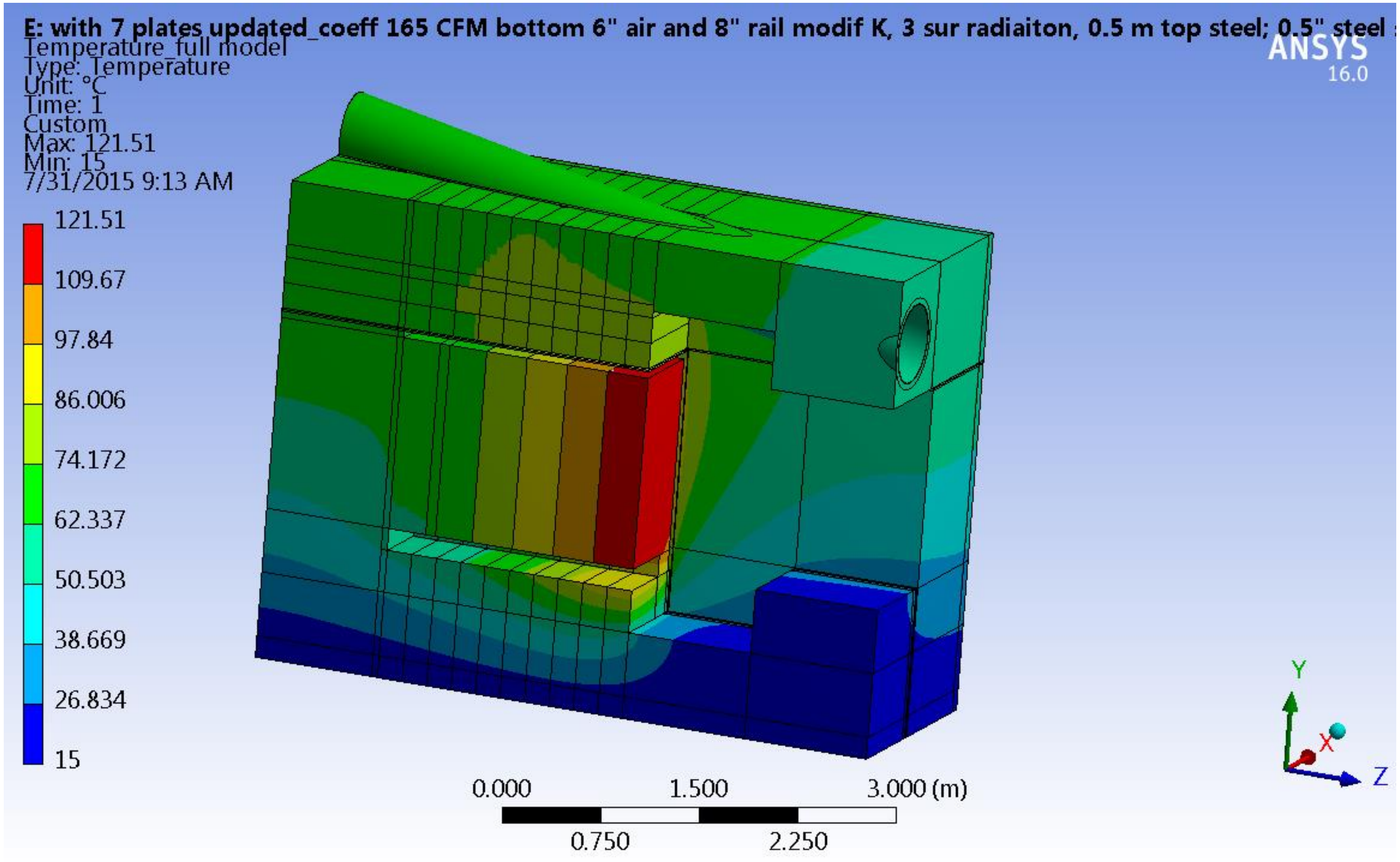
Reference

1) Ang Lee and Andy Stefanik, “Updated Thermal Result for the Proton Absorber (Mu2e) based on 165 CFM air flow rate for the beam normal operating –V2”, Mu2e-Docdb-5731-V2, July 7, 2015
2) Ang Lee and Andy Stefanik, “The Proton Absorber for Normal Operation _Mu2e”,Mu2e-docdb-5048-v1 Jan 14, 2015

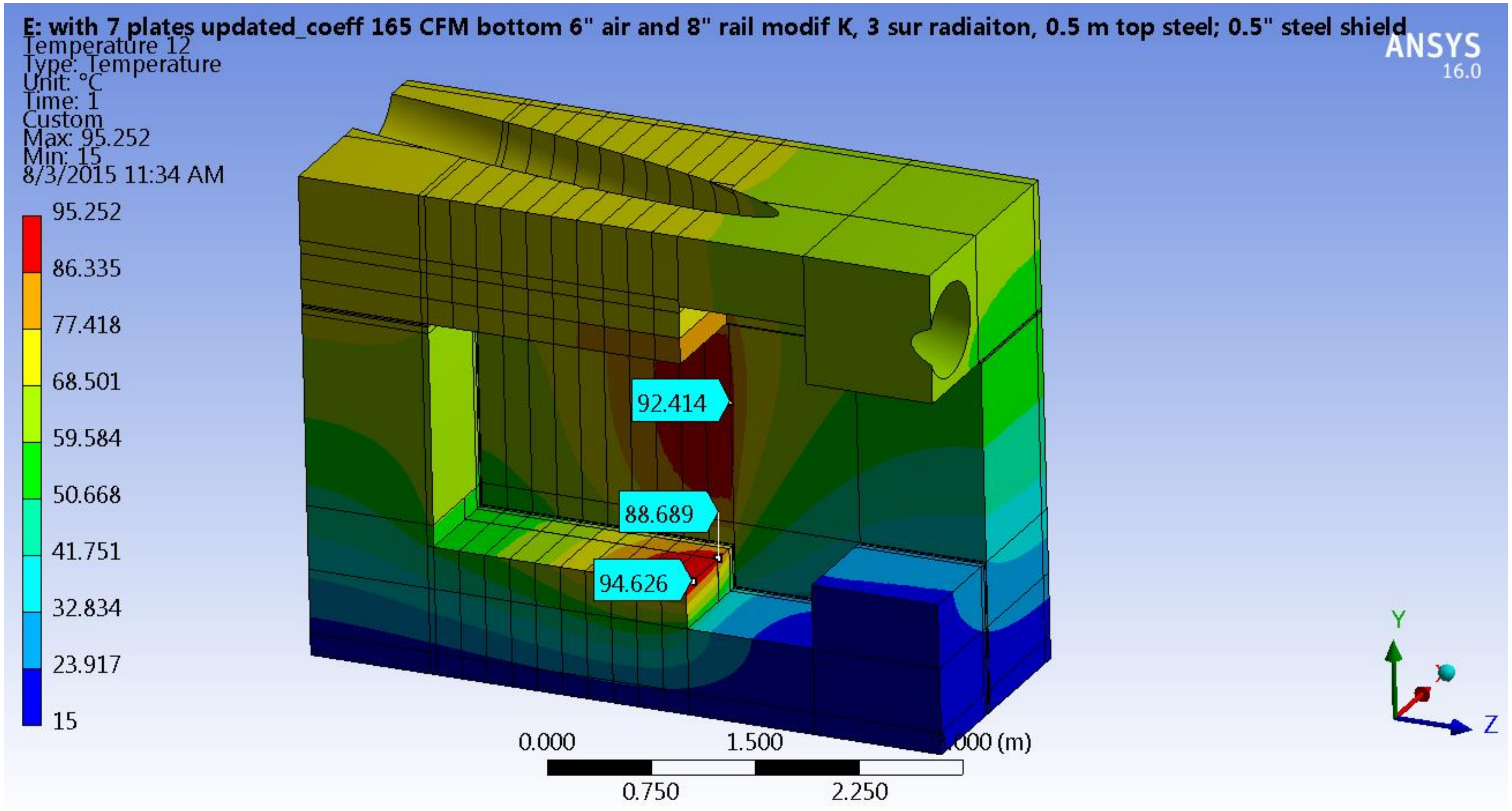
Appendix A

- Temperature result for 165 CFM
- Kmod of the rail support

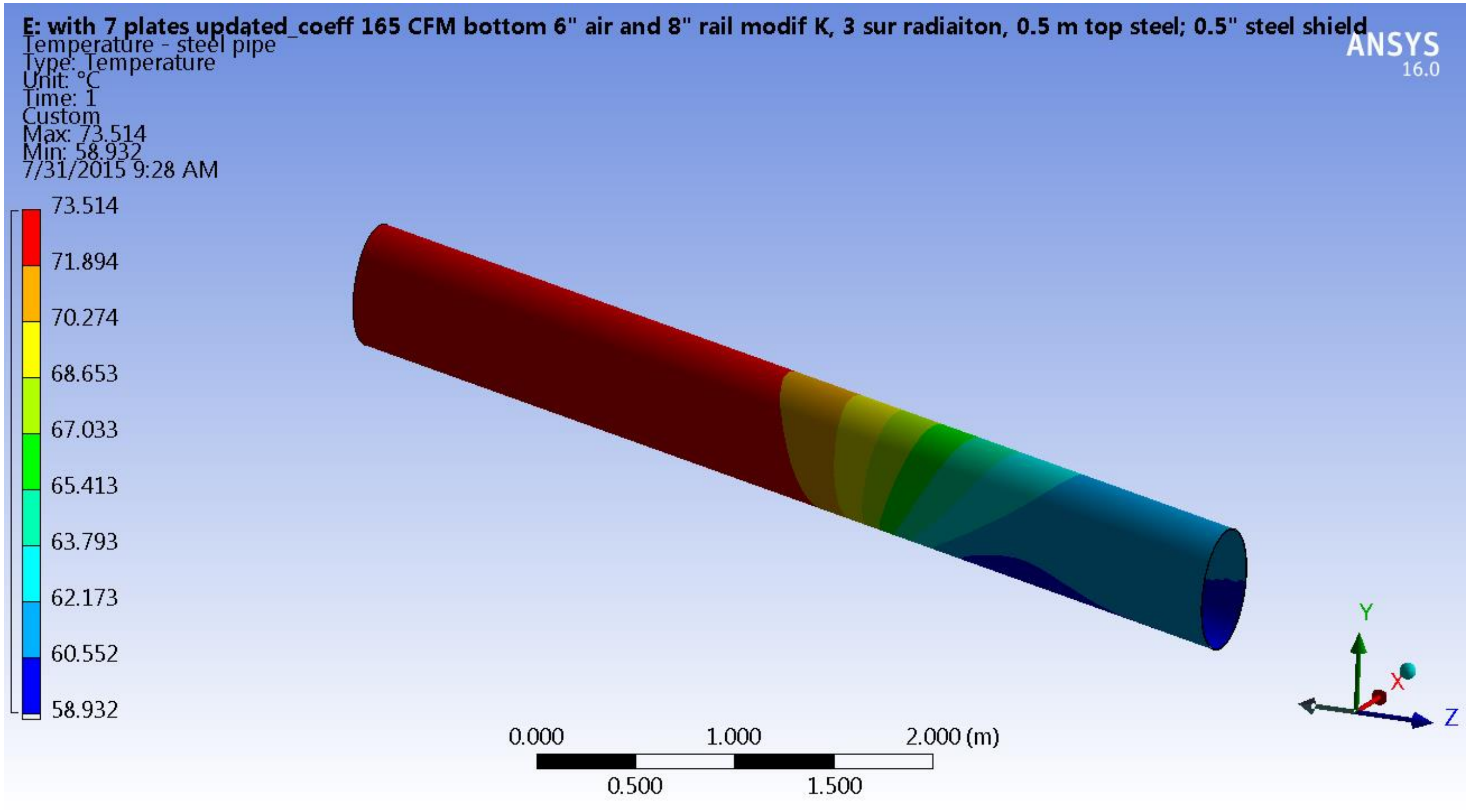
Result based on 165 CFM Temperature (C)



Result based on 165 CFM
Temperature (C)_ Concrete and upper steel section



Result based on 165 CFM Temperature (C) for the steel pipe



Kmod of rail support

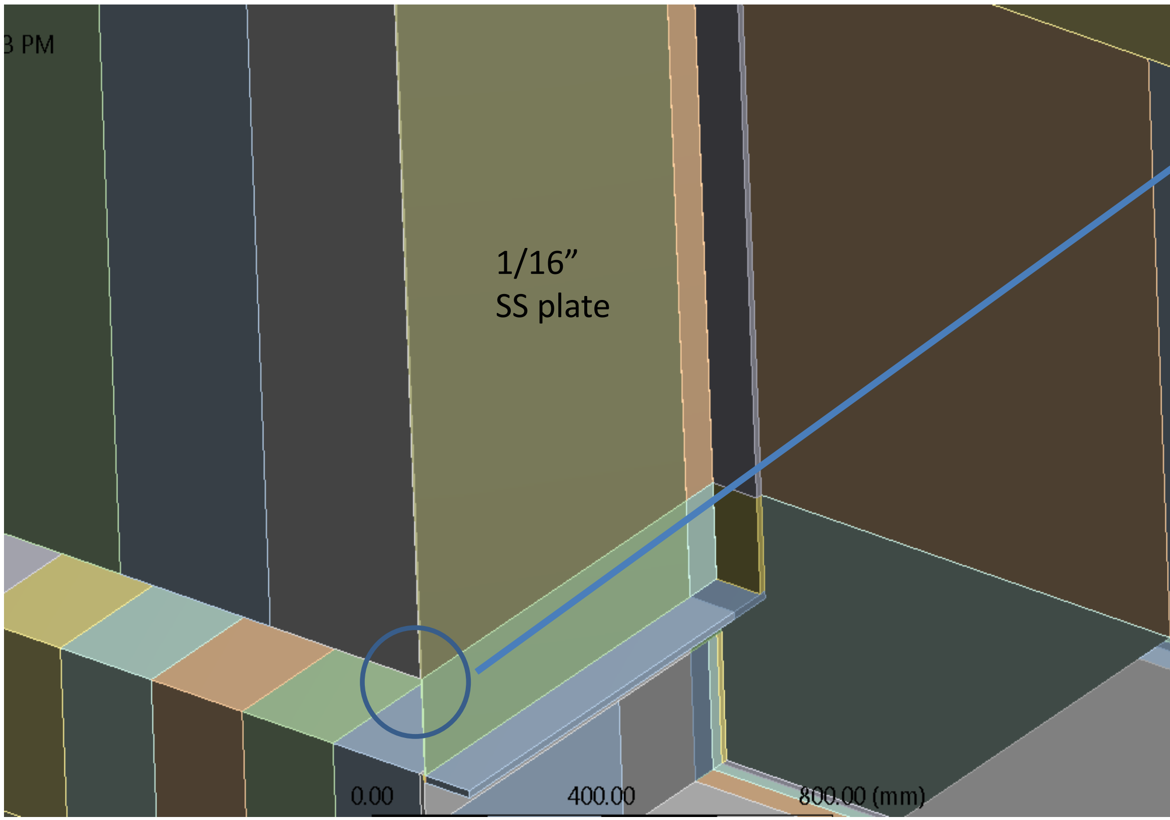
Ksteel	L1	A1	L2	A2_PIPE	L3	A3	K stainless	for K(Mod)	
50	0.01905	0.04064	0.13335	0.002047	0.01905	0.04064	20	1.29	W/m^2*K
R1_0.75" steel plate	0.009375								
R2 (pipe)	3.257634								
R3_0.75" steel plate	0.009375								
RTOTAO	3.276384								

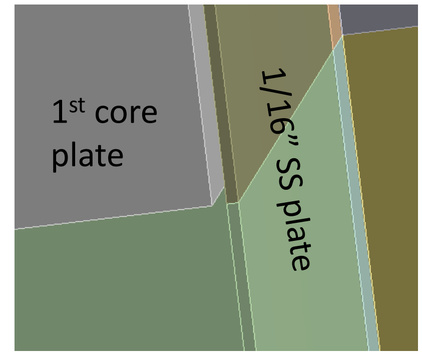
Appendix B

- This applendix B is added on Sept 15, 2015.
- A 1/16” SS thin plate is added at the front_ 2mm away from the first core plate to form an air block _U shape

Appendix B

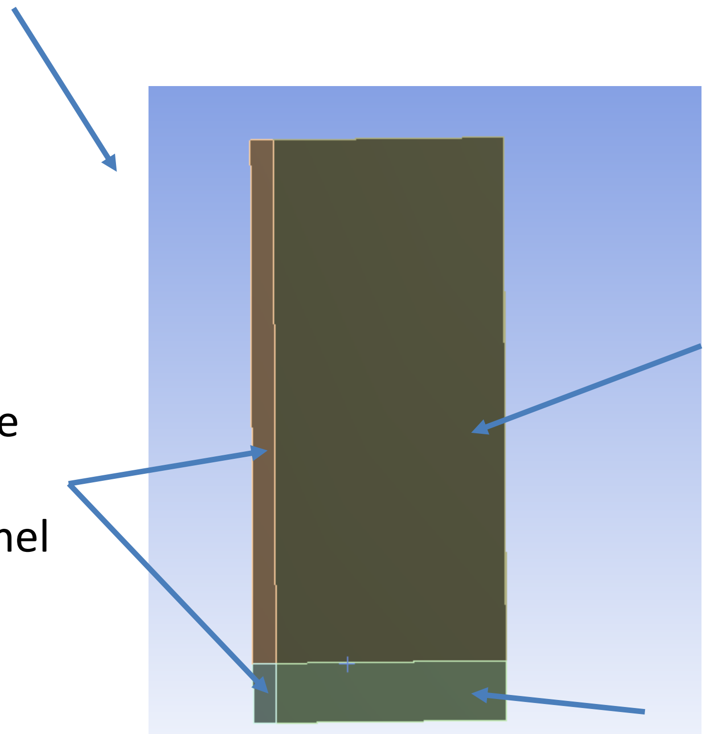
- A front SS (1/16”) sheet is added as an air flow block as shown below.





- A 2 mm air gap between 1st core plate and 1/16” SS plate
- “U shape” with the side plate and front L angle.
- Using first layer EDEP from MARS for this SS thin plate.
- Lower section of the SS plate , exposure to the lower air channel has a convection surface at the one side. (see next slide).
- Radiation effect is on for both down stream side surface of SS and upstream side surface of the 1st core plate .

1/16" SS plate _The surface at the down stream side

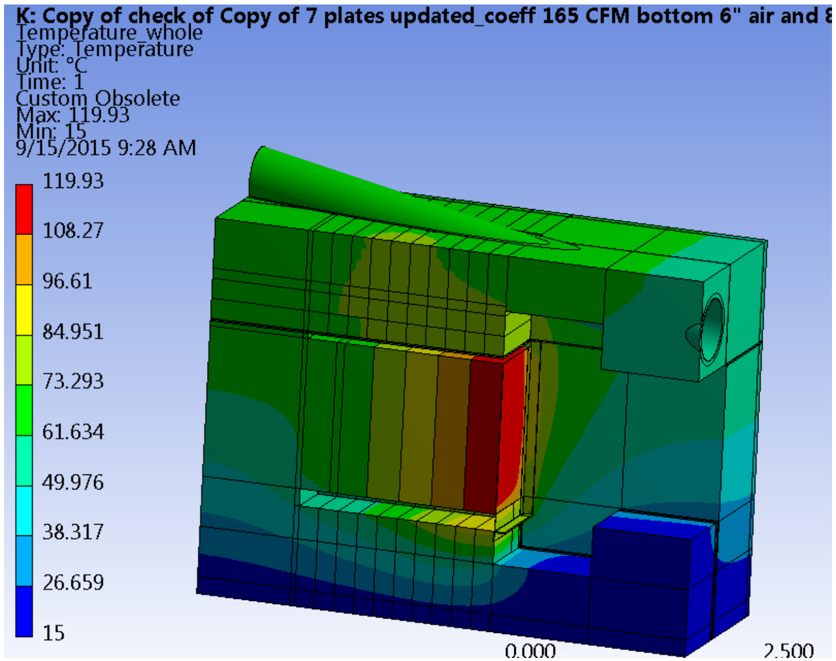


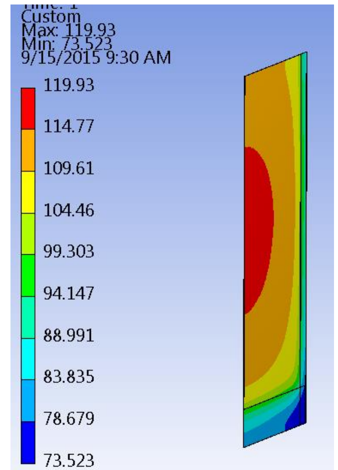
Convective surface _ side channel

Radiation effect in "on" for this surface

Convective surface_ lower channel

The temperature for 165 CFM. Operating case with 1/16” S.S. plate





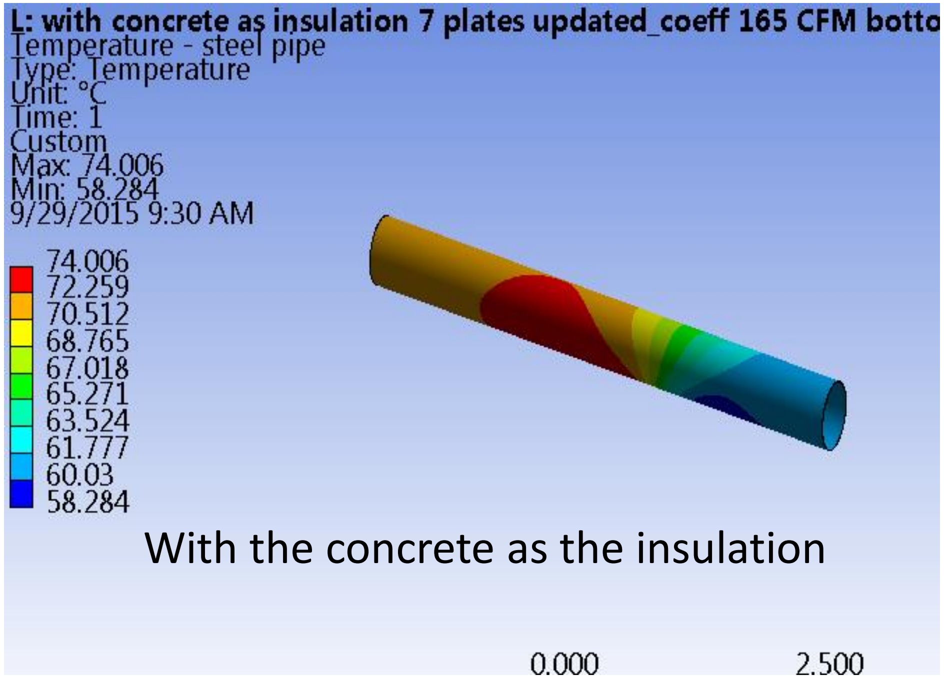
1/16” SS plate

The SS plate temperature is very similar to the 1st core plate, as expected.
The heat deposited into the 1/16” SS plate is about ~3.2 Watt only_ very small.

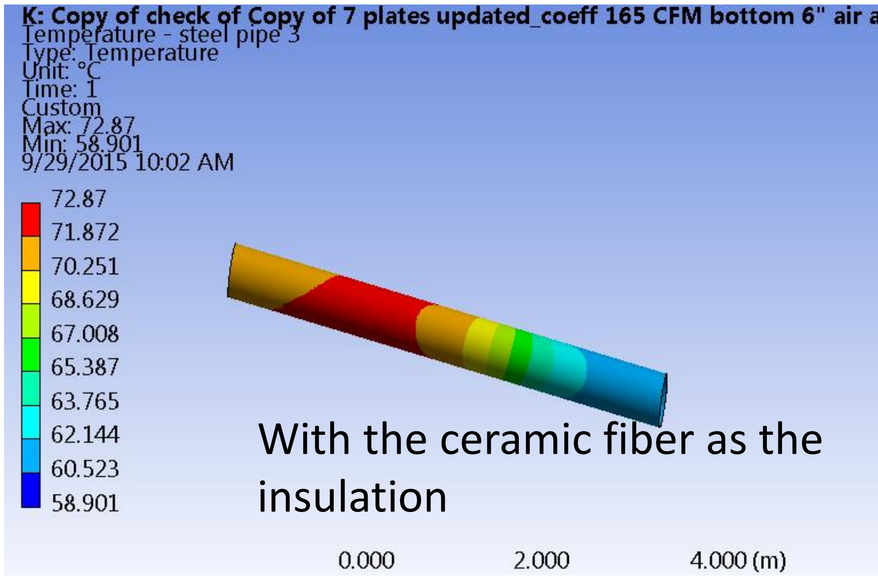
Appendix C (Sept 30,2015)

- The same model as appendix B with the exception of the changing the insulation material from the ceramic fiber to the concrete as requested.
- The difference is very small as a secondary effect

The Temperature for the steel pipe



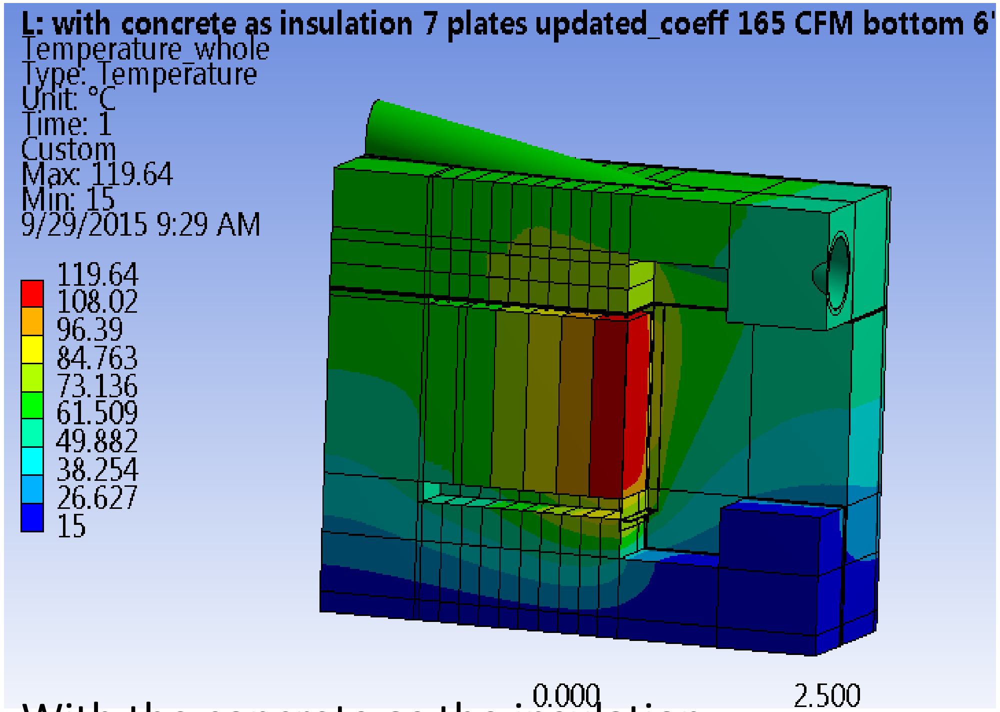
With the concrete as the insulation



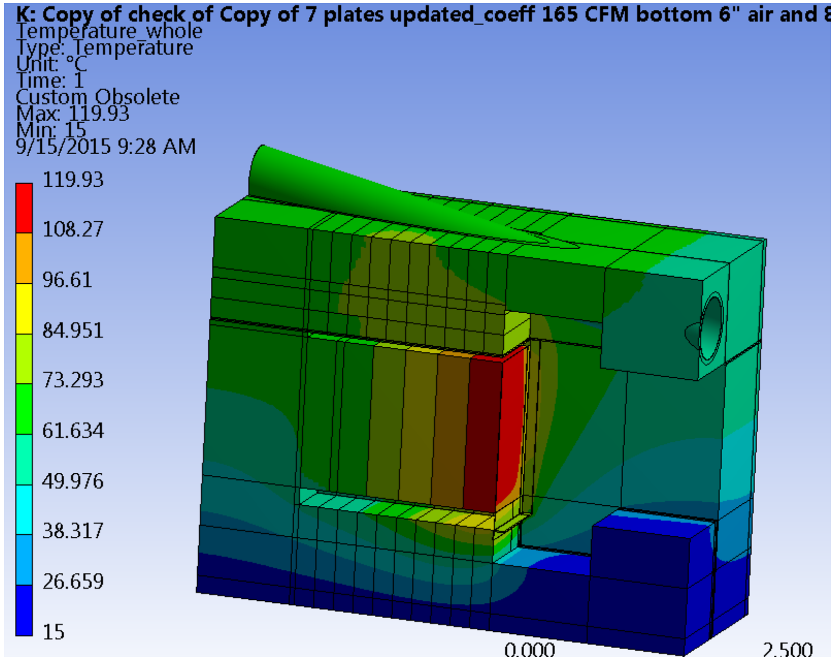
With the ceramic fiber as the insulation

<u>The difference between the concrete and ceramic fiber is very small <1.5 C for the steel pipe</u>

The temperature of the core plate



With the concrete as the insulation



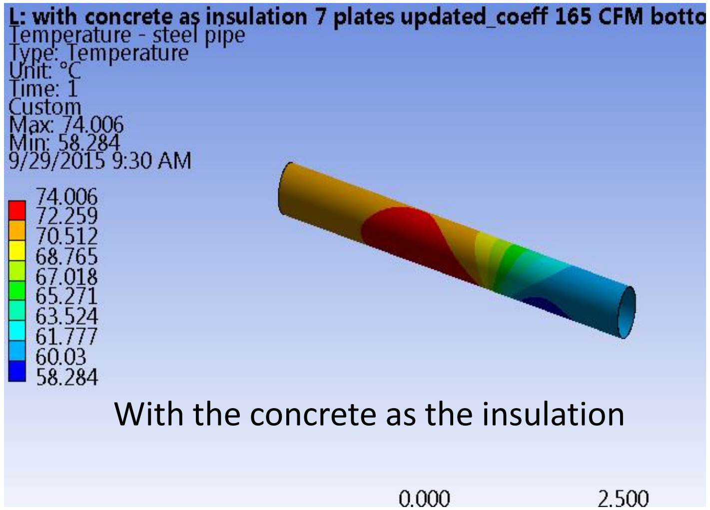
With the ceramic as the insulation

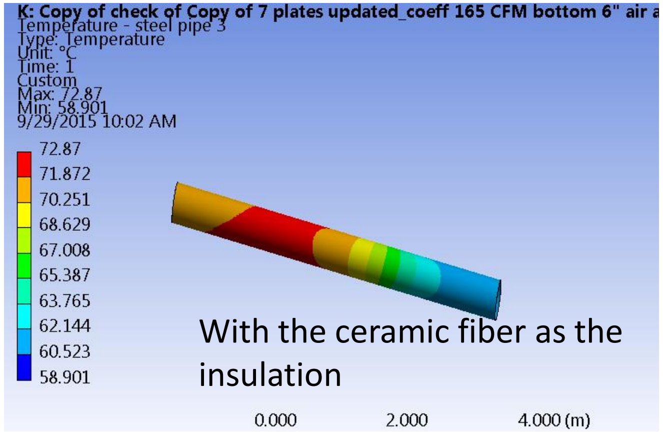
The difference is very limited < 0.5 C.

Appendix C (Sept 30,2015)

- The same model as appendix B with the exception of the changing the insulation material from the ceramic fiber to the concrete as requested.
- The difference is very small as a secondary effect.
- The difference in terms of the temperature is < 1.5 C for the extinguish monitor (steel) pipe and < 0.5 C for the core plate, respectively.

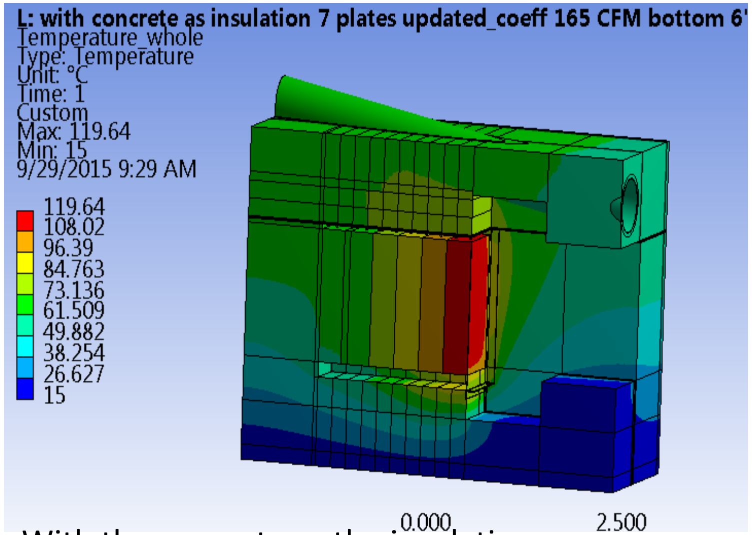
The Temperature for the steel pipe



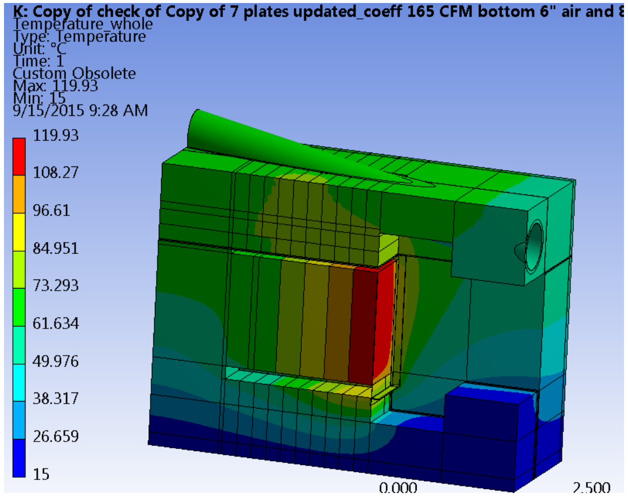


<u>The difference between the concrete and ceramic fiber is very small <1.5 C for the steel pipe</u>

The temperature of the core plate



With the concrete as the insulation



With the ceramic as the insulation

The difference is very limited < 0.5 C.