Target Chase Air Cooling

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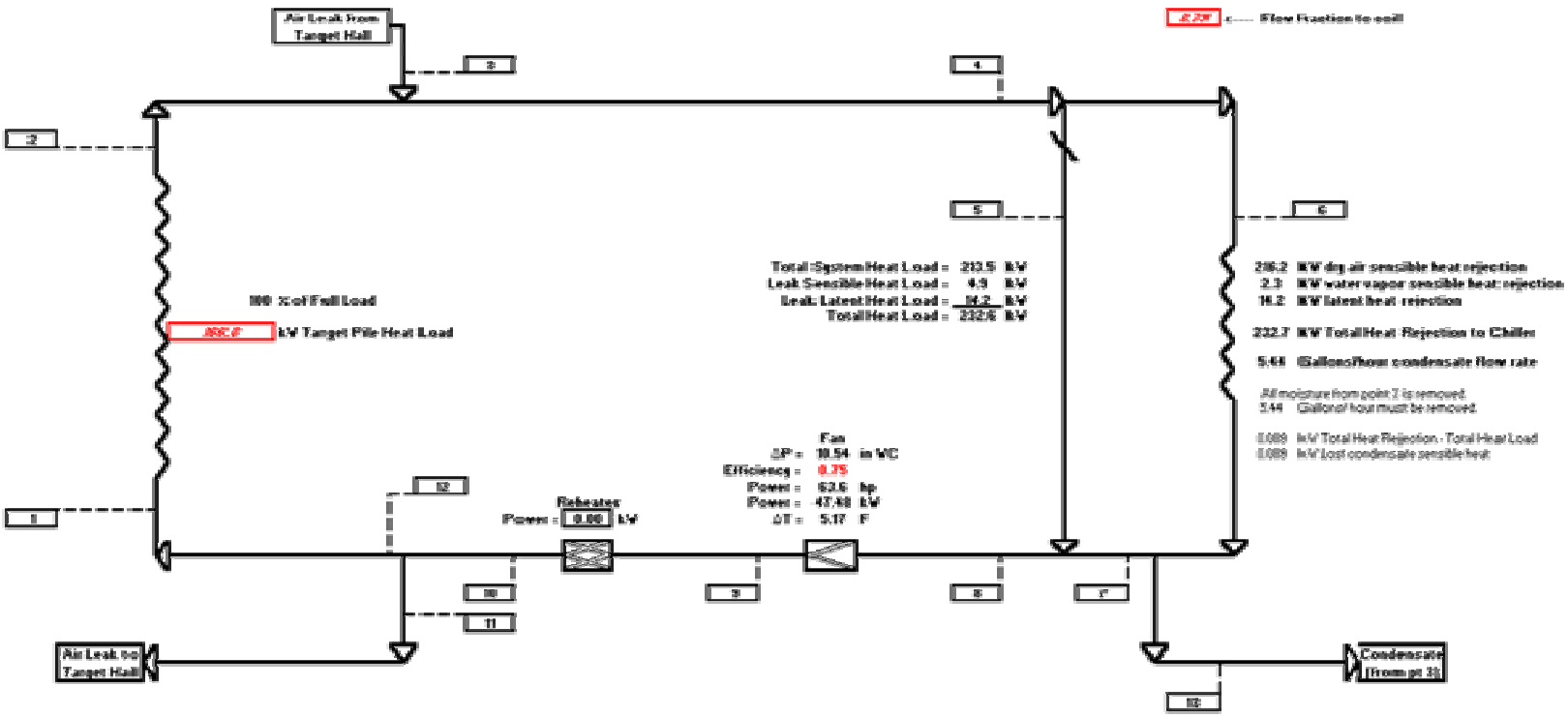
ANU Target Hall Infrastructure, WBS X.0.3.3.3.1

CD-2/3a Director's Review Breakout

Overview

- Existing target chase cooling system
- Target chase cooling system modifications for NOvA
  - New Surface Water Chiller
  - Heat loads
  - Air System & Coil box
  - Instrumentation and Control
- Refined 2D NuMI FEM & future work
- Target pile peak operating temperatures & paint dry heat resistance
- Fan
- Summary

NuMI Existing Process Flow Sheet



Point Number —>		1	2	3	4	5	6	7	8	9	10	11	12	13
Dry air flow rate	scfm	28000	28000	750	28750	848	28040	28040	28750	28750	28750	750	28000	0
Dry air flow rate	Lbm-dry air/hr	120000	120000	3075	123075	27846	95529	95529	123075	123075	123075	3075	120000	0
Dry bulb temp.	F	55	72.55	75	72.53	72.53	72.53	40.00	43.93	55.00	55.00	55.00	55.00	40
Dew point temp.	F	40.66	40.66	75.00	42.25	42.25	42.25	40.00	40.66	40.66	40.66	40.66	40.66	-
Specific humidity	Lbm water/Lbm dry air	0.0053	0.0053	0.0188	0.0057	0.0057	0.0057	0.0052	0.0053	0.0053	0.0053	0.0053	0.0053	-
Moisture flow rate	Lbm water/hr	673	673	63	707	216	521	476	592	592	592	16	573	45
Relative humidity	-	0.59	0.01	1.0	0.32	0.32	0.32	1.0	0.71	0.59	0.59	0.59	0.59	-

New Surface Chiller & Target Hall De-humidification System

- New surface chiller & dehumidification system planned for NuMI (installation during this summer shutdown)– this will replace the existing chiller unit in raw room & includes all piping that will accommodate NOvA needs
- NOvA will require an additional surface water chiller unit (plus instrumentation) & will pipe into the existing coolant loop
- Might also require additional heat exchanger cooling coil units in Target Hall (ongoing work)

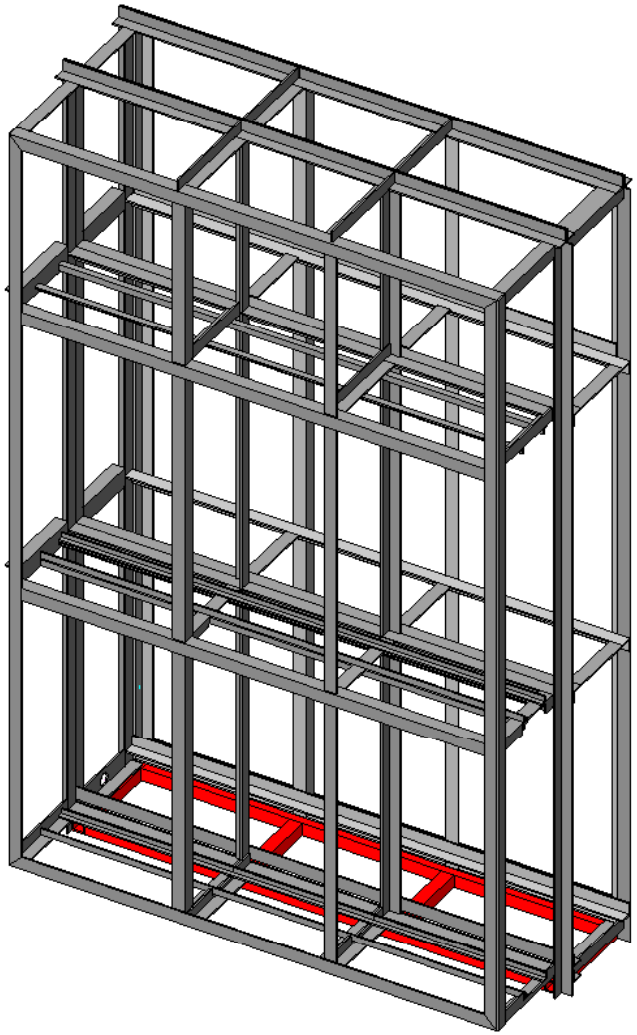
Target pile heat loads [kW]

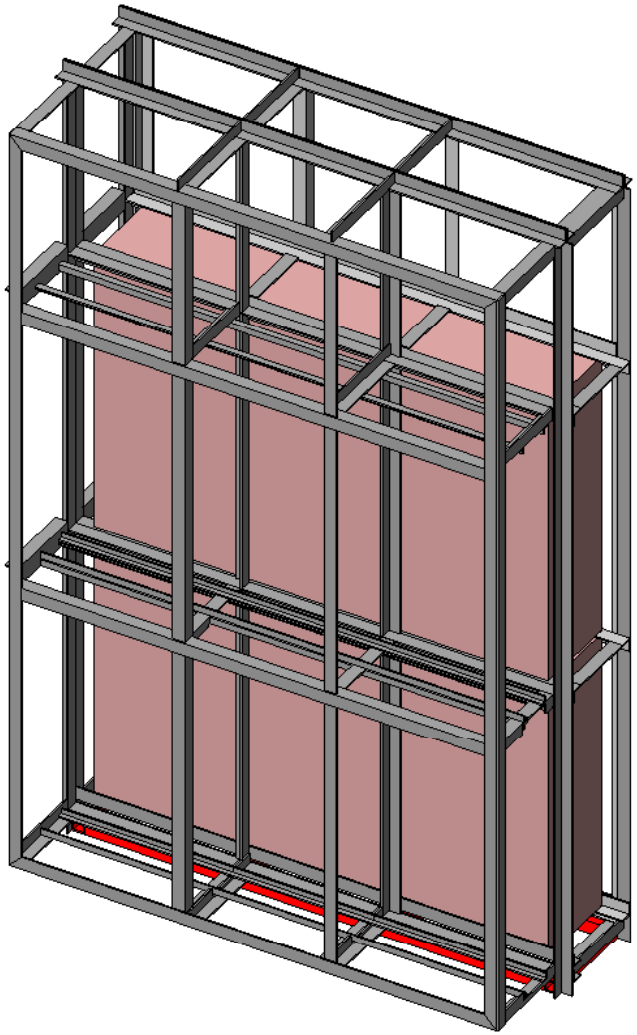
	NuMI	NOvA (scaled)	NOvA (recent MARs results)
• Beam power	400	700	700
• Target pile	166	291	210
• Air leak	19	19	19
• Fan	55	65	65
• Dehumidifier Sys.	-	-	30
• TOTAL	240	375	324
• INCREASE	(375 – 240 = 135 kW)		(324 – 240 = 84 kW)

- NuMI Chiller/Dehumid. project is installing (3 + 1) 160kW chillers– 480kW normal load with spare unit; additional unit for NOvA
- Other chiller system loads: CHW pump load, condensate load

Air System

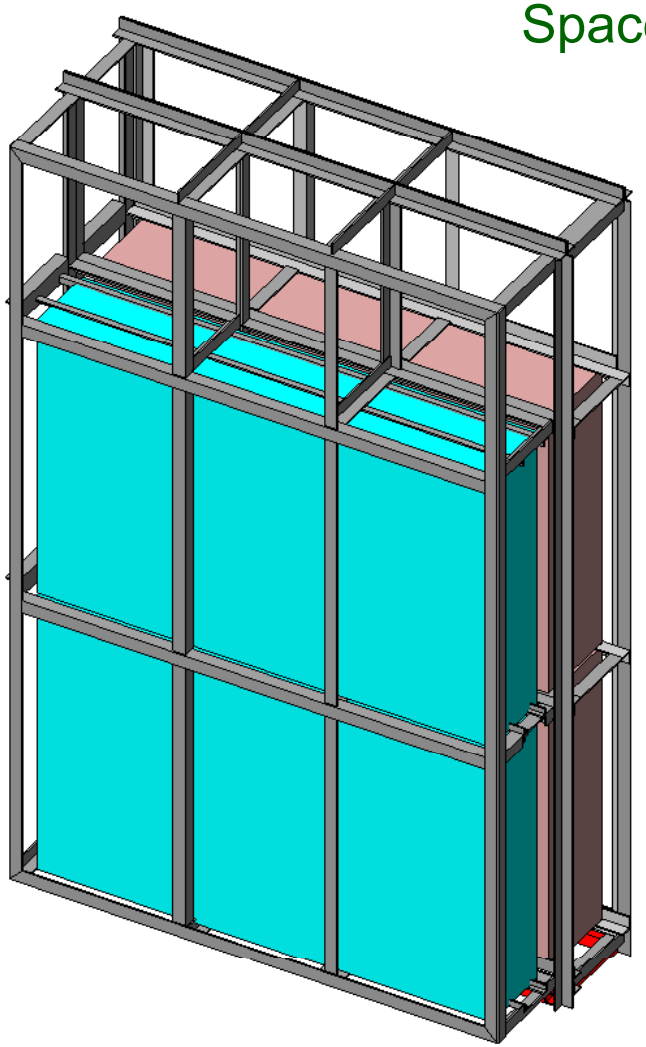
Coil Box - NuMI





Coil box - NOυA

Space available for additional coils (if needed)



Instrumentation and Control

- Automatic control of the chilled water flow control valve. The PID controller is located in the power supply room.
- Process variables that will be transmitted to the PLC and displayed on ACNET (if new coils are required):
  - exit air temperature for each new coil
  - chilled water flow rate for each new coil
  - chilled water exit temperature for each new coil
  - chilled water supply temperature
- Local instruments:
  - temperatures transmitted to the PLC
  - chilled water supply pressure
  - chilled water pressure drop across each new coil

Target pile FEM – 2D

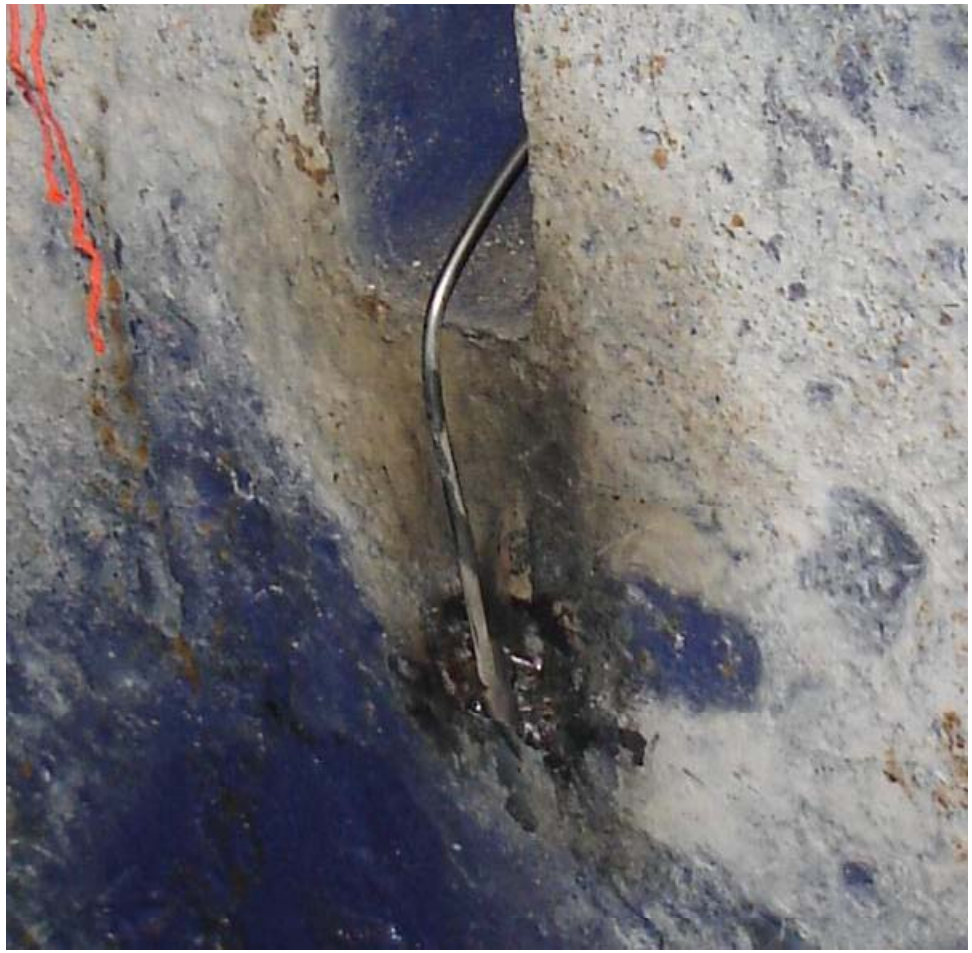
- NuMI target pile 2-D FEM refined using two measured target pile temperatures.

Case	Basis	Beam Power	E:TPCT06	E:TPCT07	Air Supply Temperature	ΔT for E:TPCT06	ΔT for E:TPCT07
		[kW]	[C]	[C]	[C]	[C]	[C]
NuMI Case 1 - Full NuMI beam heating	Calculated NuMI FEM	400	98	98	15	83	83
NuMI Case 2 - 65% of full NuMI beam heating	Calculated NuMI FEM	260	69	69	15	54	54
NuMI Case 2 - 65% of full NuMI beam heating	Measured	260	39	44	15	24	29
NuMI Case 2 - 65% of full NuMI beam heating	Calculated NOvA FEM	260	48	48	15	33	33
NOvA Case 1 – 700kW beam heating	Calculated NOvA FEM	700	115	115	20	95	95

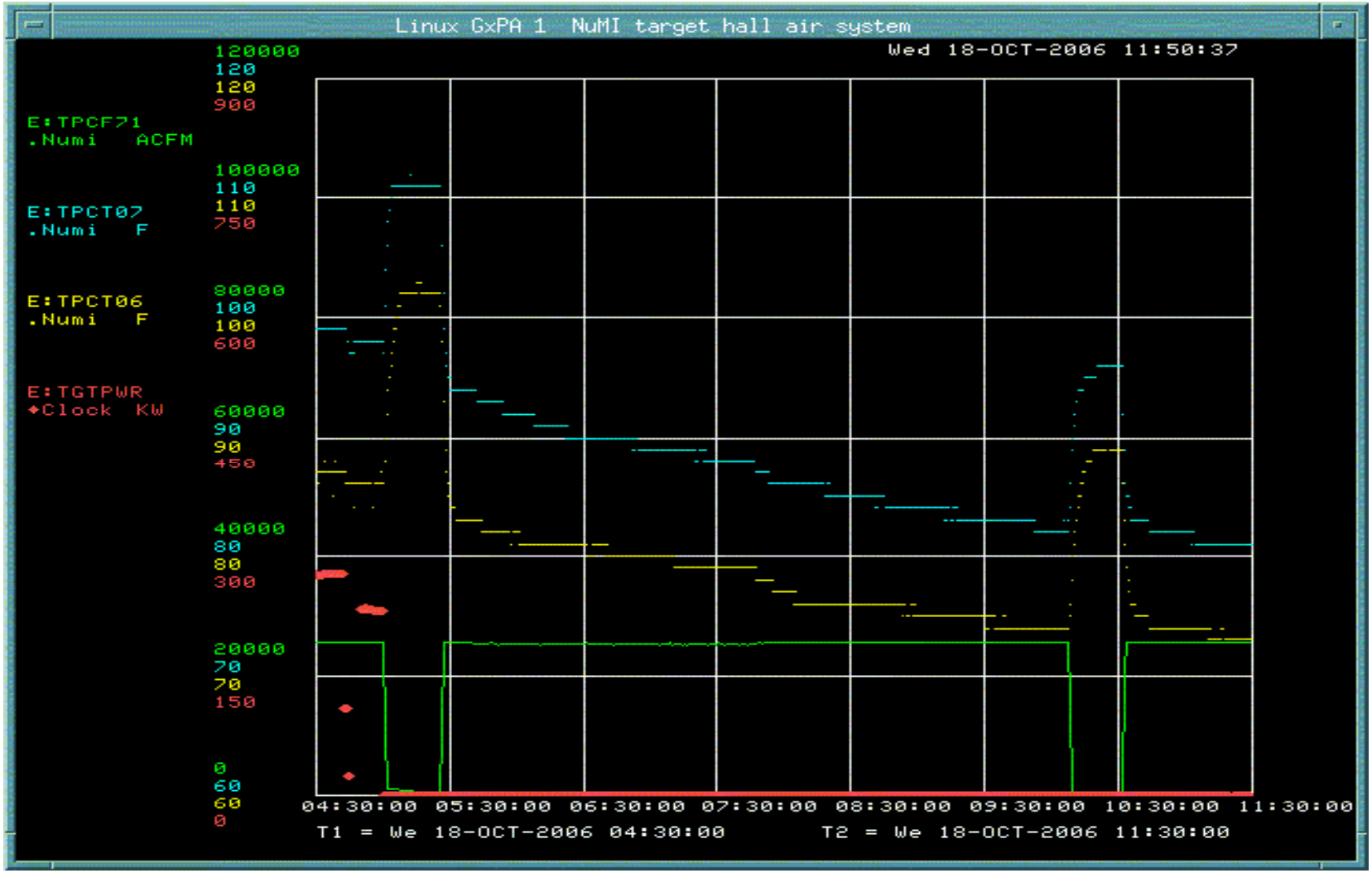
Target pile temperature thermocouples E:TPCT06 and E:TPCT07

- Theoretical point of peak beam heating is located just downstream of horn 1 stripline.
- E:TPCT06 and E:TPCT07 are welded to Duratek steel shielding blocks at the theoretical point of peak beam heating, directly across from each other.
- E:TPCT06 is on the east wall of the chase and E:TPCT07 is on the west side.
- Duratek block cool down test: Stop beam. Shut off the fan. Measure initial temperature rebound. Start fan. Measure transient temperature response. Shut off the fan. Measure final temperature rebound.
- Use measured temperature response to estimate average chase heat transfer coefficients for the Duratek blocks.
- Use the average chase heat transfer coefficient from the cool down test to refine the NuMI 2-D FEM --> NOvA 2-D FEM.

Target pile temperature thermocouples E:TPCT06 and E:TPCT07



Cooling test data

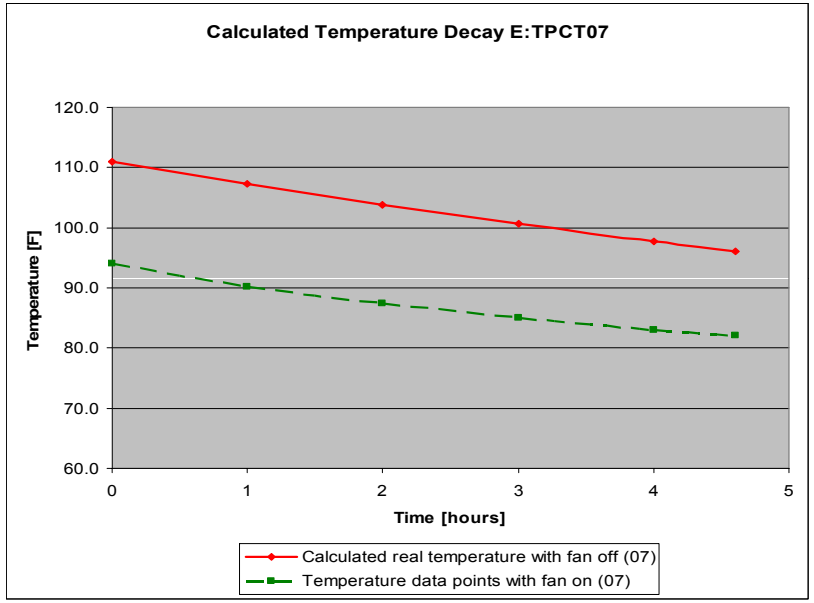


Average heat transfer coefficient

E:TPCT07

Average heat transfer coefficient	2.13	Bu/hr-ft^2-F
Surface area	76.0	ft^2
Volume	41.5	ft^3
Thermal conductivity	26	Btu/hr-ft-F
Density	490	Lbm/ft^3
Specfic heat	0.11	BTU/Lbm - F
Thermal diffusivity	0.48	ft^2/hr
Initial temperature	111	F - After rebound
Final temperature	96	F - After rebound
Air temperature	58	F
Cooldown time	4.6	hours
Temperature data points with fan on (07)		
0	94	F- Thermocouple reading
1	90	F- Thermocouple reading
2	88	F- Thermocouple reading
3	85	F- Thermocouple reading
4	83	F- Thermocouple reading
4.6	82	F- Thermocouple reading
Characteristic Length	0.55	ft
Bi	0.04	

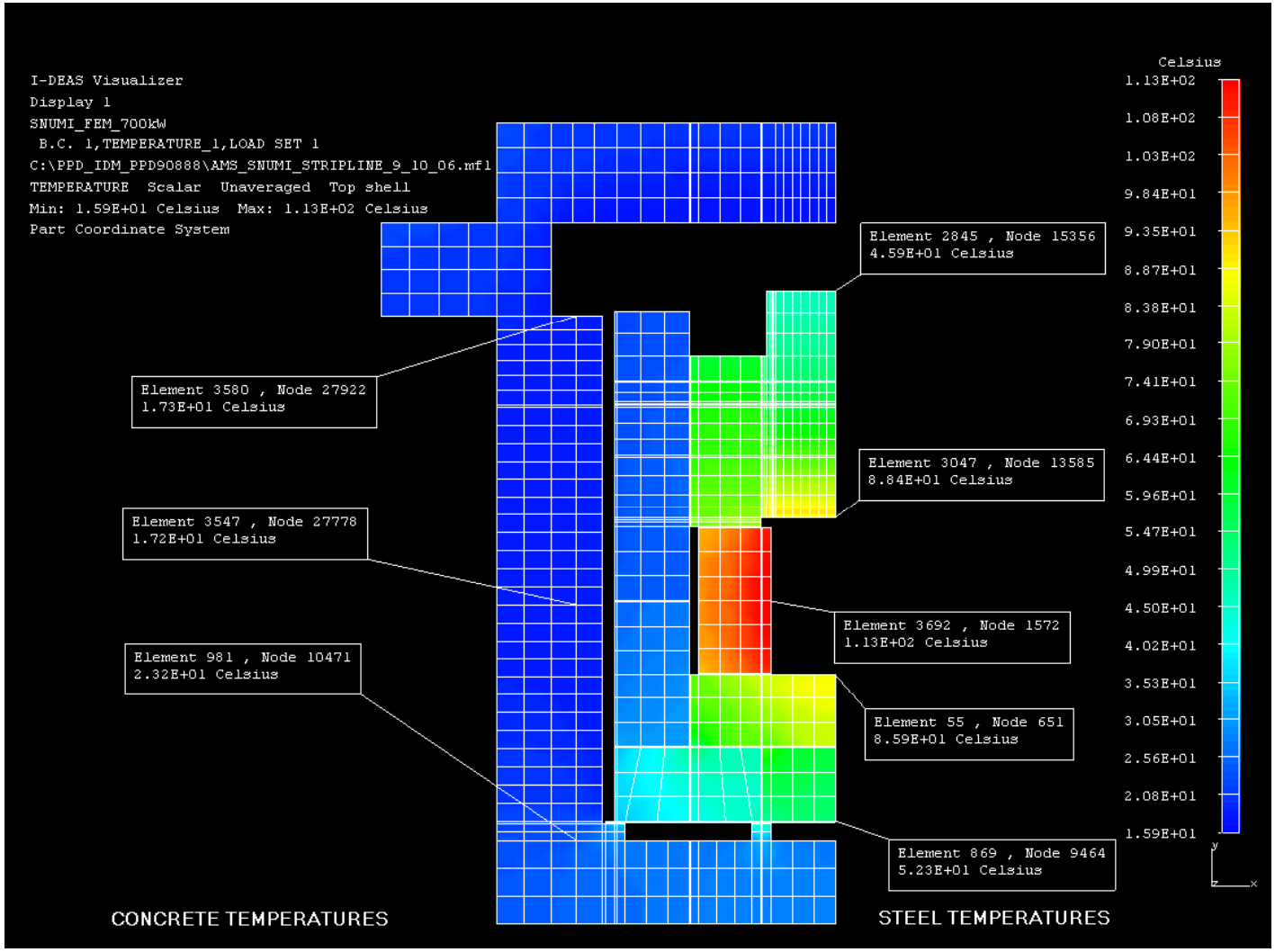
Time [hours]	Fo	Calculated real temperature with fan off (07) [F]
0	0.00	111.0
1	1.62	107.3
2	3.24	103.9
3	4.86	100.7
4	6.47	97.7
4.6	7.44	96.0
Temperature at time 0 hrs minus Temperature at time 4.6 hrs	**15.0**	
1.8	2.13	76
1.64	2.84	57
	4.27	37.9



Heat transfer from Duratek block in chase wall:

Surface that faces the chase	47%
Surface that faces the slot	18%
Top surface	8%
Bottom surface	11%
Upstream surface	8%
Downstream surface	8%

Estimated target pile peak temperatures using refined 2D FEM– NOvA 700 kW



Future work – Target Pile 3D FEM

- Building on the work done in the 2D simulation, expand the model in 3D to perform a FEM thermal simulation of the entire Target Chase region using latest MARs energy deposition data
- Compute amount of radiation heat transfer to sensitive chase components (target, horns, stripline assembly)
- Calculate changes in component alignment due to the higher temperatures (see NOVA-doc-2049, Horn 1 Alignment Offsets)
- Identify critical locations where additional temperature monitoring might be required (e.g. modules and chase shielding blocks).

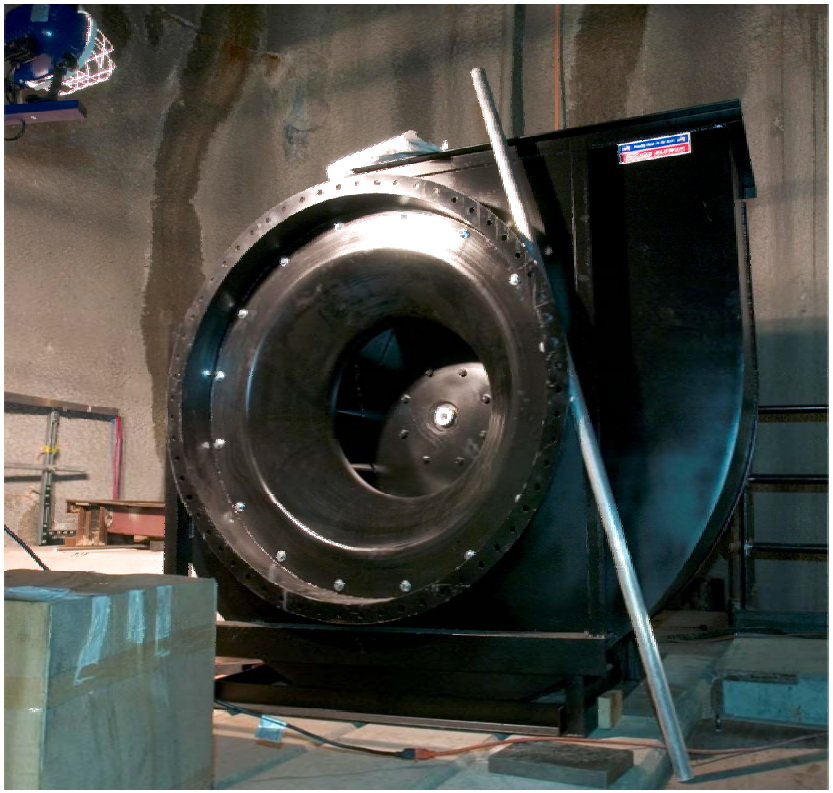
Target pile peak operating temperatures & Paint dry heat resistance

- Target pile peak operating temperatures estimated with NuMI 2-D FEM.
- Paint dry heat resistance temperatures obtained from manufacturers.

Component	Calculated component peak operating temperature [C] for 700 kW beam	Paint	Paint dry heat resistance [C]	Paint dry heat resistance test method	Paint dry heat resistance determined by Fermilab [C]
Duratek blue block	115	Sherwin Williams DTM Acrylic Primer/Finish (B66W211) Sherwin Williams DTM Acrylic Gloss Acrylic Coating (B66T104)	150	ASTM D2485	In Progress
Horn module	90	Lord Aeroglaze 9924 Wash Primer Lord Aeroglaze 276 Polyurethane	120	Customer testing	TBD
Horn T-block	115 (estimate)	Rust-Oleum 769402 Damp Proof Red Primer	175	Vendor estimate based on testing a primer with very similar composition, X 60.	In progress

Fan operation - 700 kW beam

- Flow rate – 25,000 cfm (same as for 400 kW beam).
- Variable speed drive. Currently running at 1455 rpm.
- ΔP chilled water coil – 1“ WC
- Operating speed increases about 5% to increase fan boost 1” WC.
- The existing fan does not need to be upgraded.



Summary

- Described existing target chase cooling system for the 400 kW beam.
- Described chiller upgrade & modifications to the existing system to operate with the 700 kW beam.
- Discussed how we used two target pile temperature measurements to refine the NuMI 2-D FEM.
- Presented an estimate for target pile temperature distribution with the 700 kW beam, and future work on a 3D FEM.
- Showed that the paints in the target pile will operate below their respective dry heat resistance temperatures.
- Checked to make sure the existing fan will produce the differential pressure needed with the new chilled water coils added to the system.