System Cooling of Outdoor Wi-Fi Antenna

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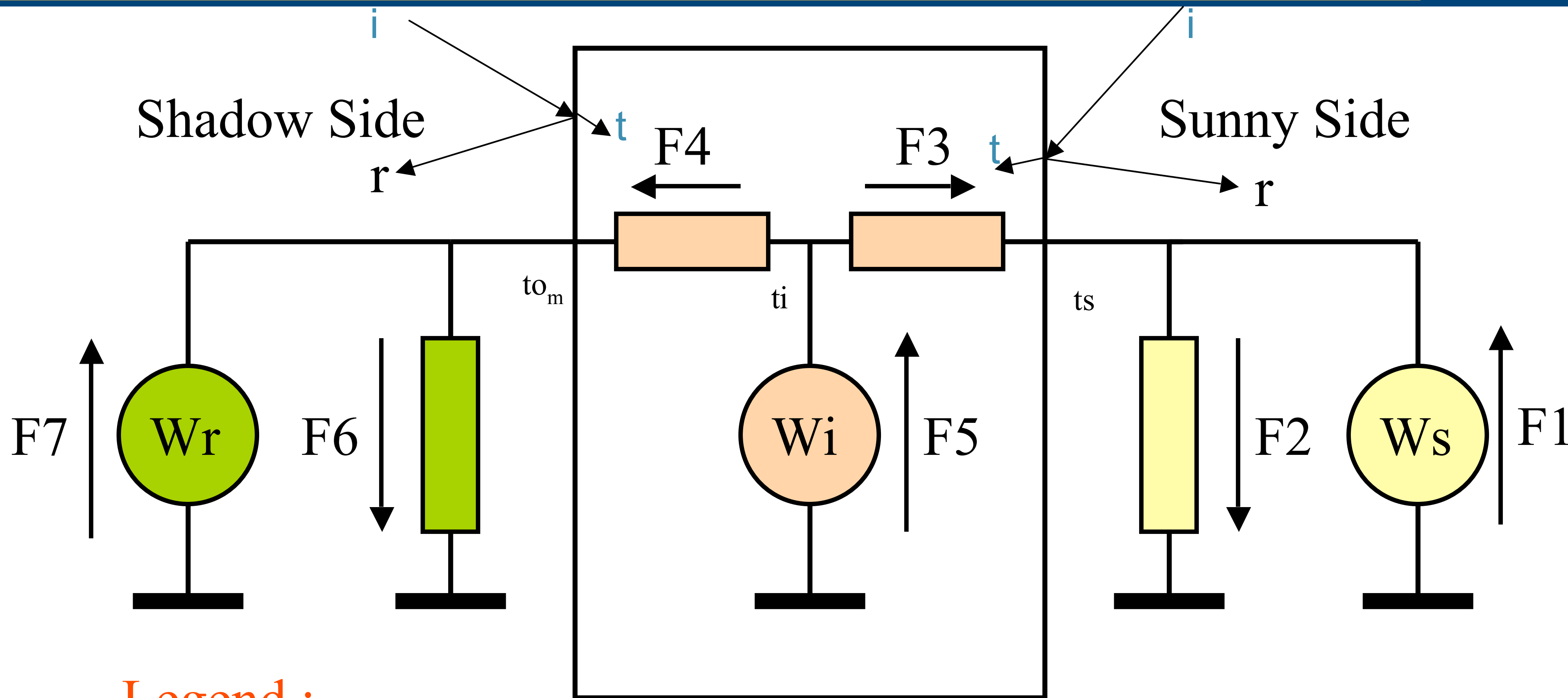
Topics

- Requirements and Constraints
- Cooling Methods and Trade off Analysis
- System Cooling Simulation
- Thermal Testing Results and Comparison to Simulation

Requirements and Constraints

- **Thermal Requirements:**
  - ✓Max. Allowable Temp at **Inlet** of Electronics Compartment: 60 deg C
  - ✓Max. Allowable Temp in Electronics Compartment: 66 deg C
  - ✓Max. External Ambient Temp: 46 deg C
  - ✓Internally Generated Heat Load: 200 W distributed as follows:
  - ✓Solar Heat Loading: 753 W/sq. m, Evenly distributed on Front, One Side, and Top Surfaces (Total 3 Surfaces) ~ 200 W
- **Other Constraints**
  - ✓Maximum Weight Budget for Thermal Management Components: 12 lbs
  - ✓Maximum Cost for Thermal Management Components: $120

Thermal Model of a Sealed Box Exposed to Sun



Legend :

F = Heat Flux,

Wr = Reflected Solar Radiation Shadow Side

Wi = Internal Heat Load

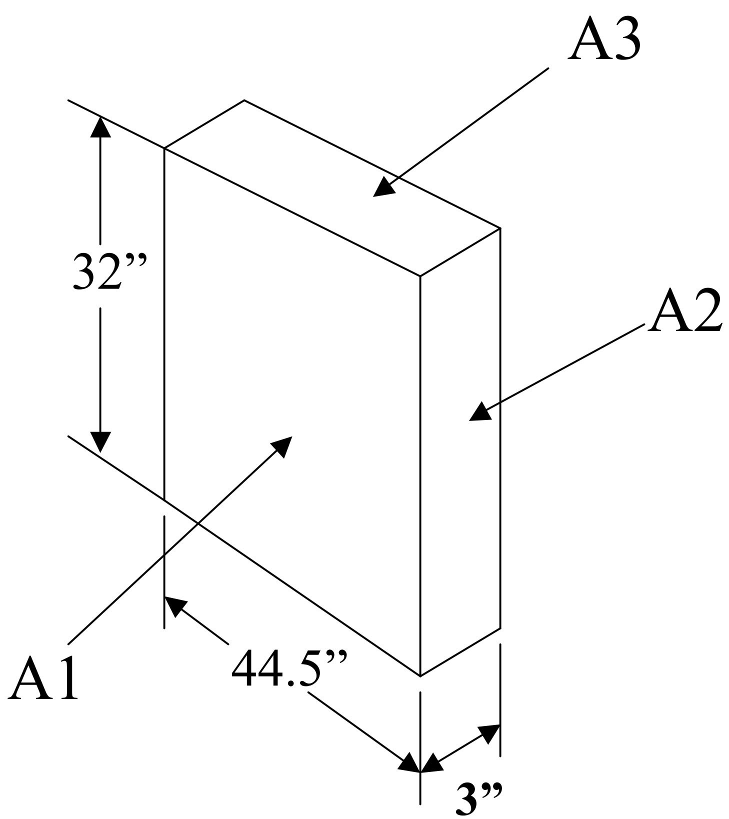
Ws = Incident Solar Radiation

to_m = Surface Temp., Shadow Side

ti = Avg. Internal Air Temperature

ts = Surface Temperature Sunny Side

Solar Radiation Heat Loading



	Area in^2	Area m^2
A1	1424	.917
A2	961	.062
A3	133.5	.086
Total	1653.5	1.067

Use Method-1 : GR-487-CORE Sec 3.25

Incident Solar Load

$$W_i = 753\ W/m^2 \times 1.067\ m^2 = 803\ W$$

α = Absorptance of Surface

$W\alpha$ = Absorbed Solar Load = $W_i \times \alpha$

For Painted white surface, $\alpha \approx .20$

$W\alpha = 803 \times .20 = 160\ W$

Cooling Methods Investigated

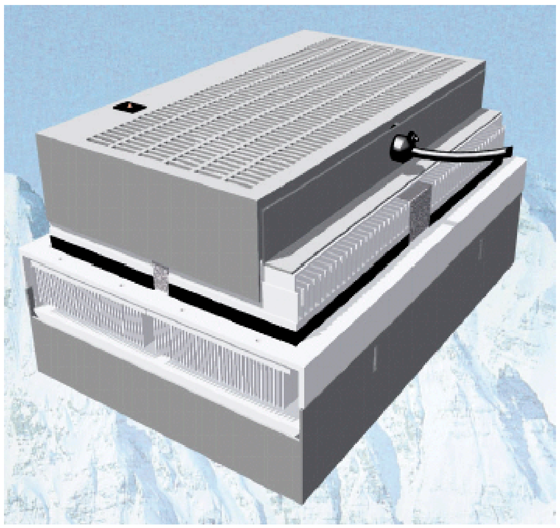
- **Thermo-Electric Cooling**
- **Rankin Cycle A/C or Refrigeration Unit**
- **Phase-Change Materials (PCM) Heat Storage**
- **Air-to-Air Heat Exchanger**

Thermo-Electric Cooling

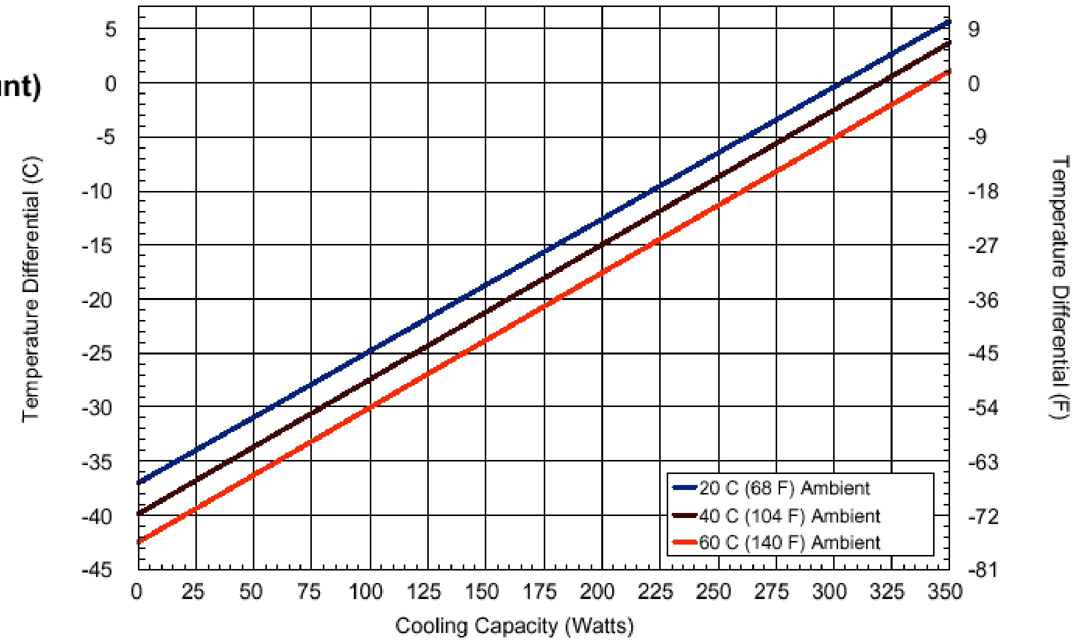
AHP-1800XP

1035-1180 Btu/Hr

Class 1, Division 2, Nema-4X (Thru Mount)



Performance:



Ambient Temp	20• C	40• C	60• C
Enclosure Air	y=.122x-37	y=.122x-39.7	y=.122x-42.3
Cold Sink	y=.09x-37	y=.09x-39.7	y=.09x-42.3

Specifications

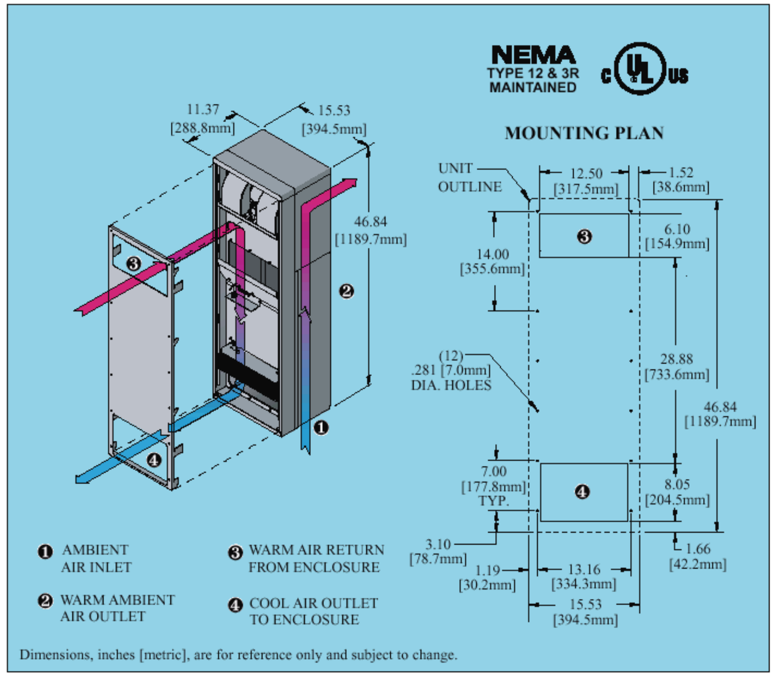
- High Cost
- High Weight

AC / Refrigeration

ADVANTAGE KXRP47 AIR-TO-AIR PANEL-MOUNTED HEAT EXCHANGERS

KOOLTRONIC

KXRP47



STANDARD FEATURES

Precision Ball-bearing Motors
Closed-Loop Cooling
M/TAB Mounting System
NEMA 12 & 3R Rating Maintained (UL50)
Epoxy-coated Element
Six foot [1.8m] (minimum) SJT 3-wire Cord
UL/CUL Listed

*ACCESSORIES AND OPTIONS**

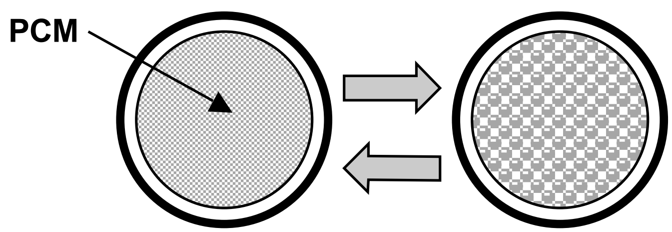
- Filter Recoating Adhesive
- Permanent Filters
- Heater Kit
- Other voltages and frequencies
- Special materials or finishes
- Special motors, line cords or connectors

*TECHNICAL DATA***

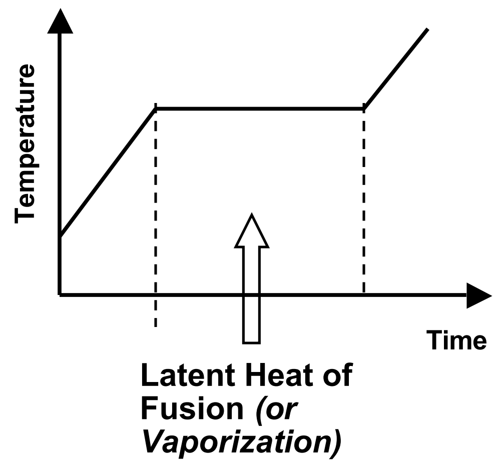
Model	UL/CUL Listed or Recognized	Volts	Power Amps	Power Watts	Maximum Allowable Temperature °F/°C Enclosure	Maximum Allowable Temperature °F/°C Ambient	Performance Watts/°F (Watts/°C) Air In
KXRP47	Listed	115	3.60	386	160/71	131/55	54 (97)
K2XRP47	Listed	230	1.66	384	160/71	131/55	54 (97)

- High Cost
- High Weight

Phase-Change Materials (PCM) Heat Storage



Phase change of PCM with temperature



Phase Change Material:

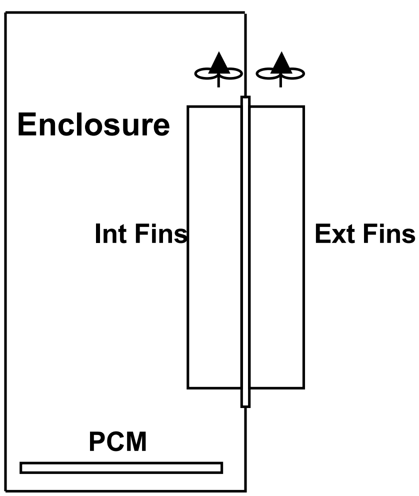
TH29 Inorganic Salt

Melting Temperature : 29C

Latent Heat : 180 J/gm

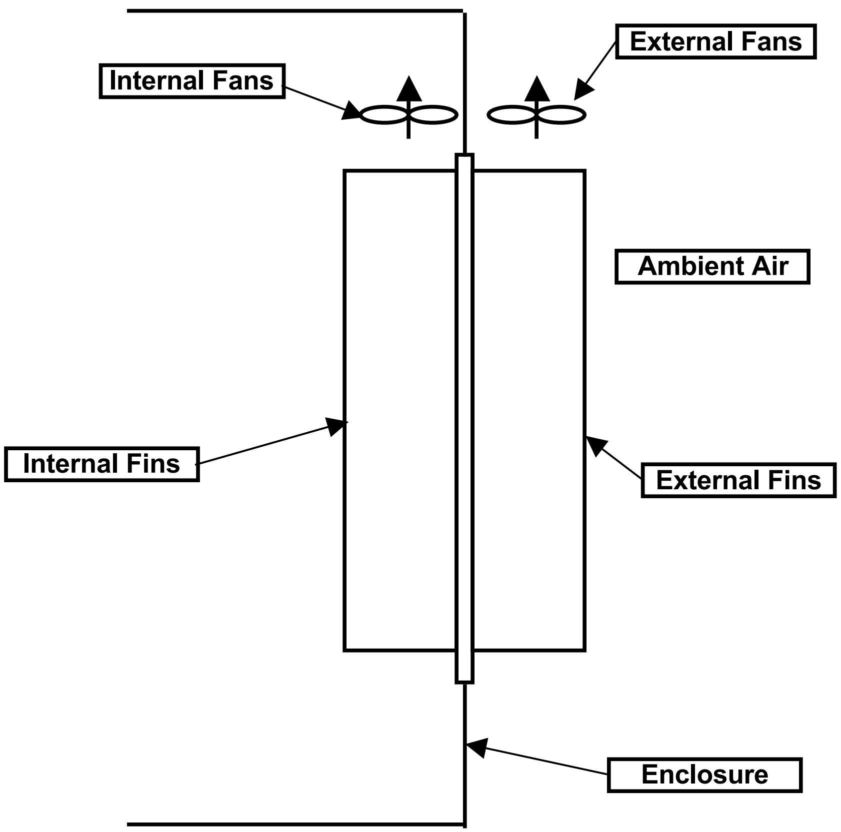
Density : 1500 kg/m^3

Weight Required: 100 lbs.



- High Cost
- High Weight

Air-to-Air Heat Exchanger



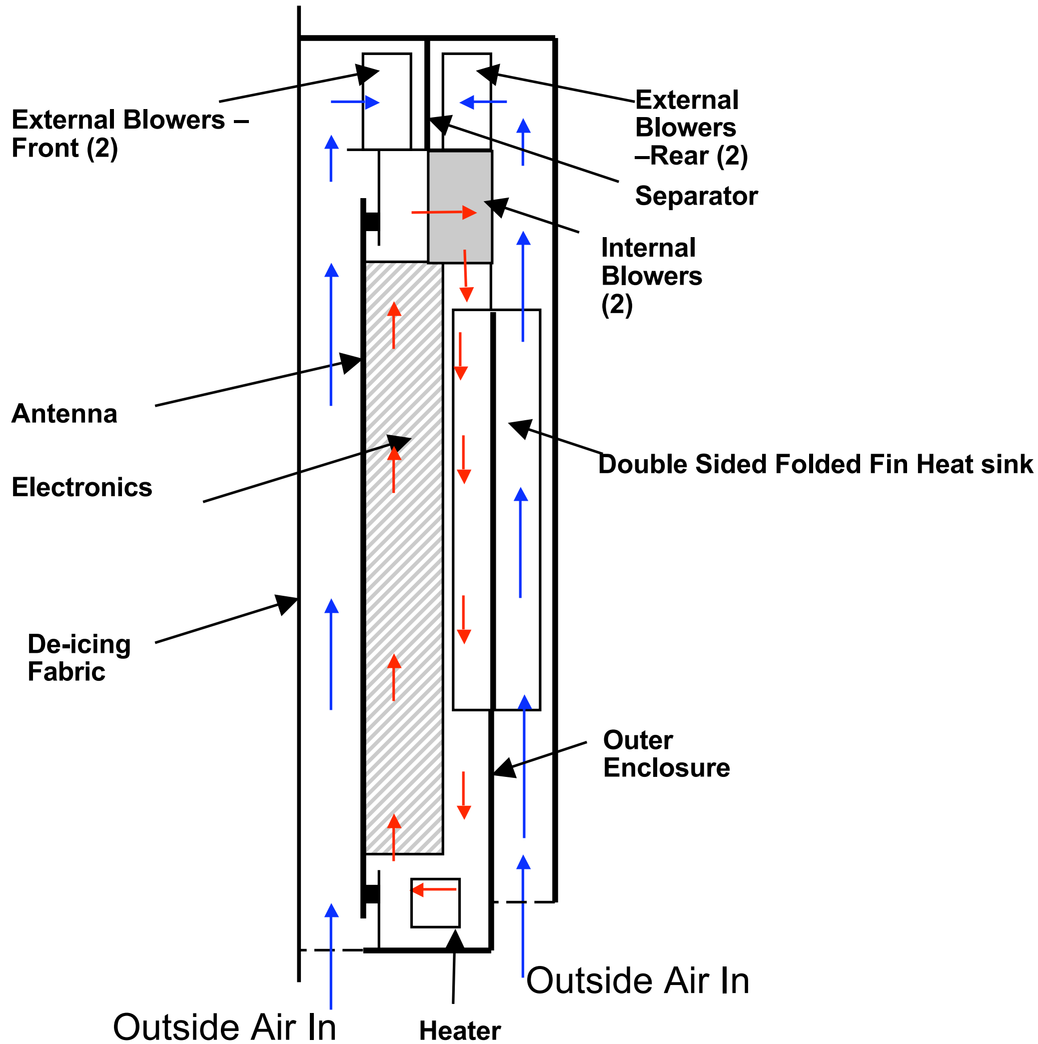
- Internal fans provide air circulation over internal fins
- External fans ensure airflow of ambient air over external fins.
- Heat transfer is by a combination of convection to and from the fins to the air and conduction between internal and external fins
- The internal and ambient air do not mix

Cooling Methods
Selection Criteria, Ranking & Recommendation

Criteria	TEC	A/C or Refrigeration Unit	PCM	Air-to-Air Heat Exchanger
Thermal Performance	***	****	**	*
Cost	*	**	**	****
Weight / Volume	*	*	**	****
Reliability	***	**	****	****
Ease of assembly & field service	***	*	**	****

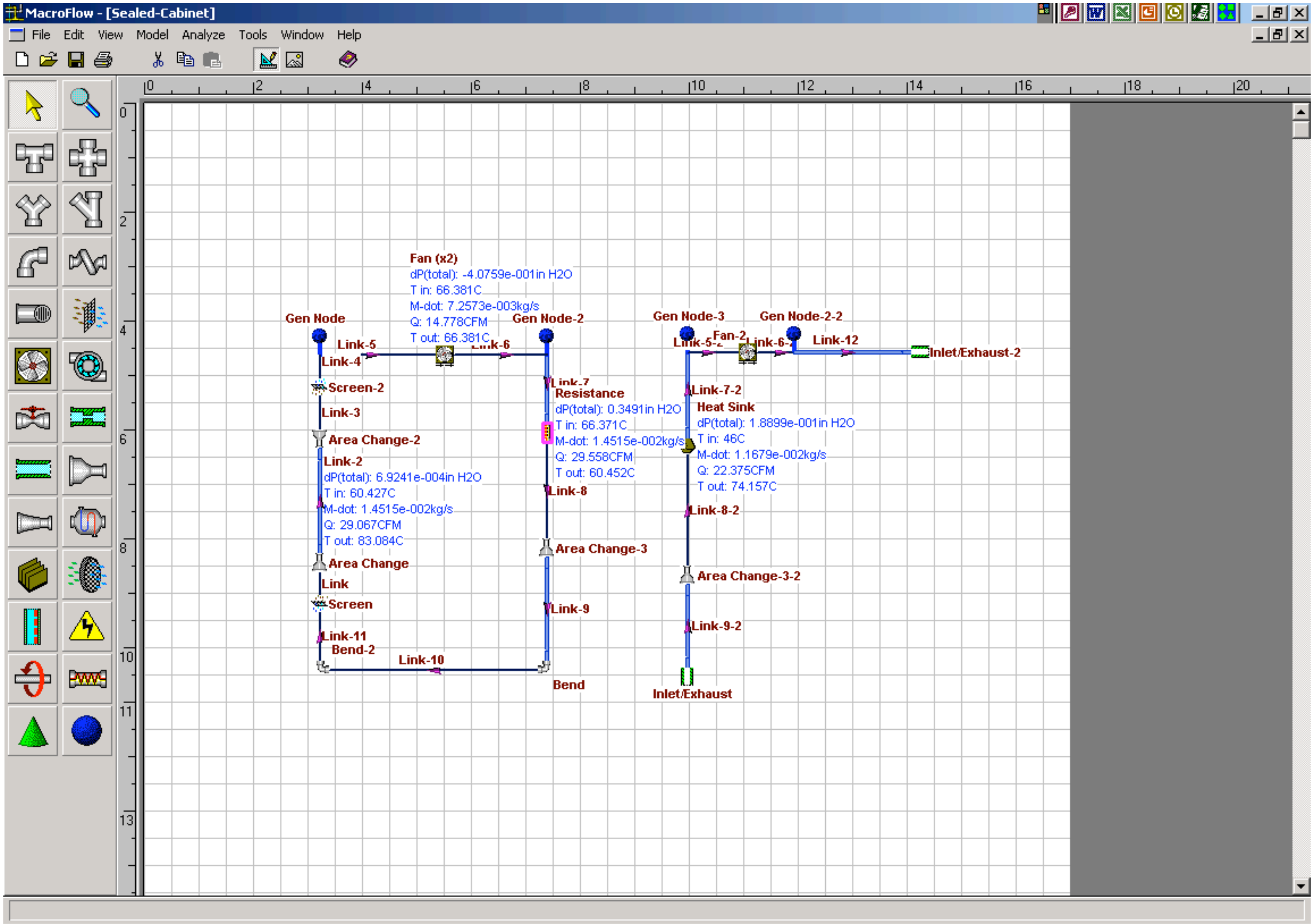
Air-to-Air Heat Exchanger Wins For This Application

Air-to-Air Heat Exchanger
Air Flow Schematic



Vertical Section

Simulation with Macroflow



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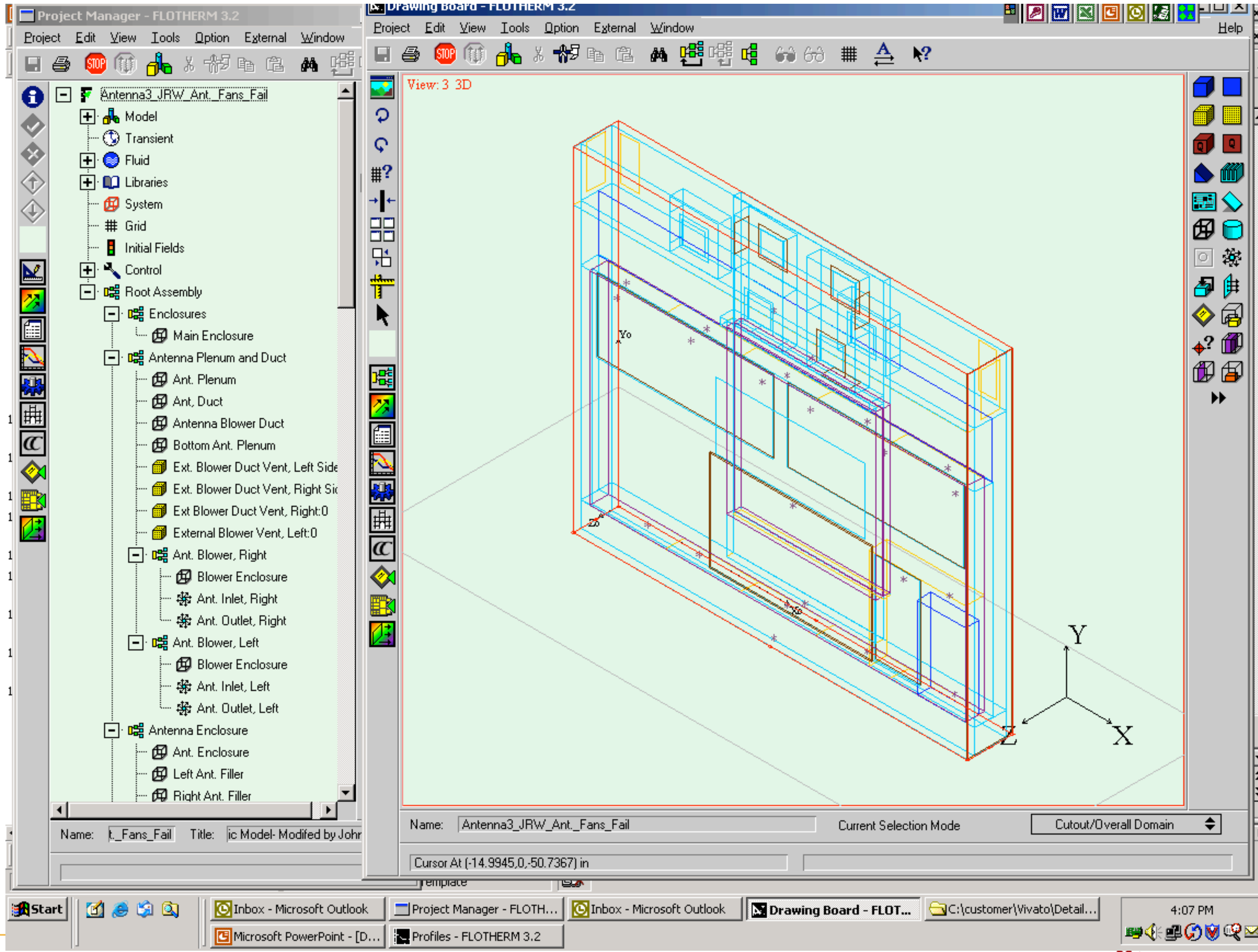
Summary of Results: Macroflow

Location	T in deg C	T out deg C	Flow Rate CFM
Electronics Compartment	60	83	29
Internal Blowers	66	66	29
Heat Exchanger	66	60	29

Max Delta T to Ambient: 83 - 46 = 37 deg C at outlet of electronics area

Flotherm CFD Model



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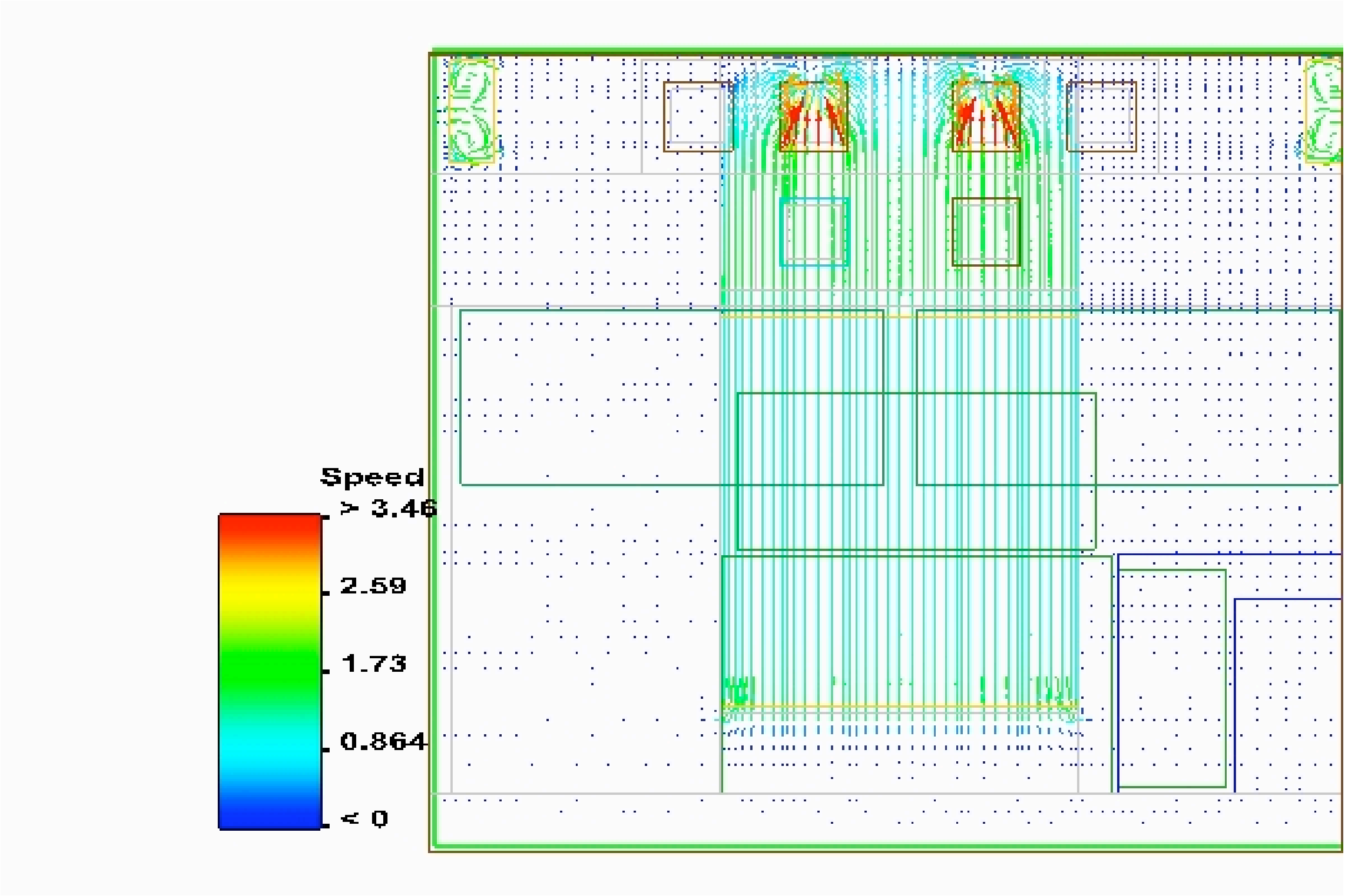
Air Vel @ Z=.7", External Heat Sink



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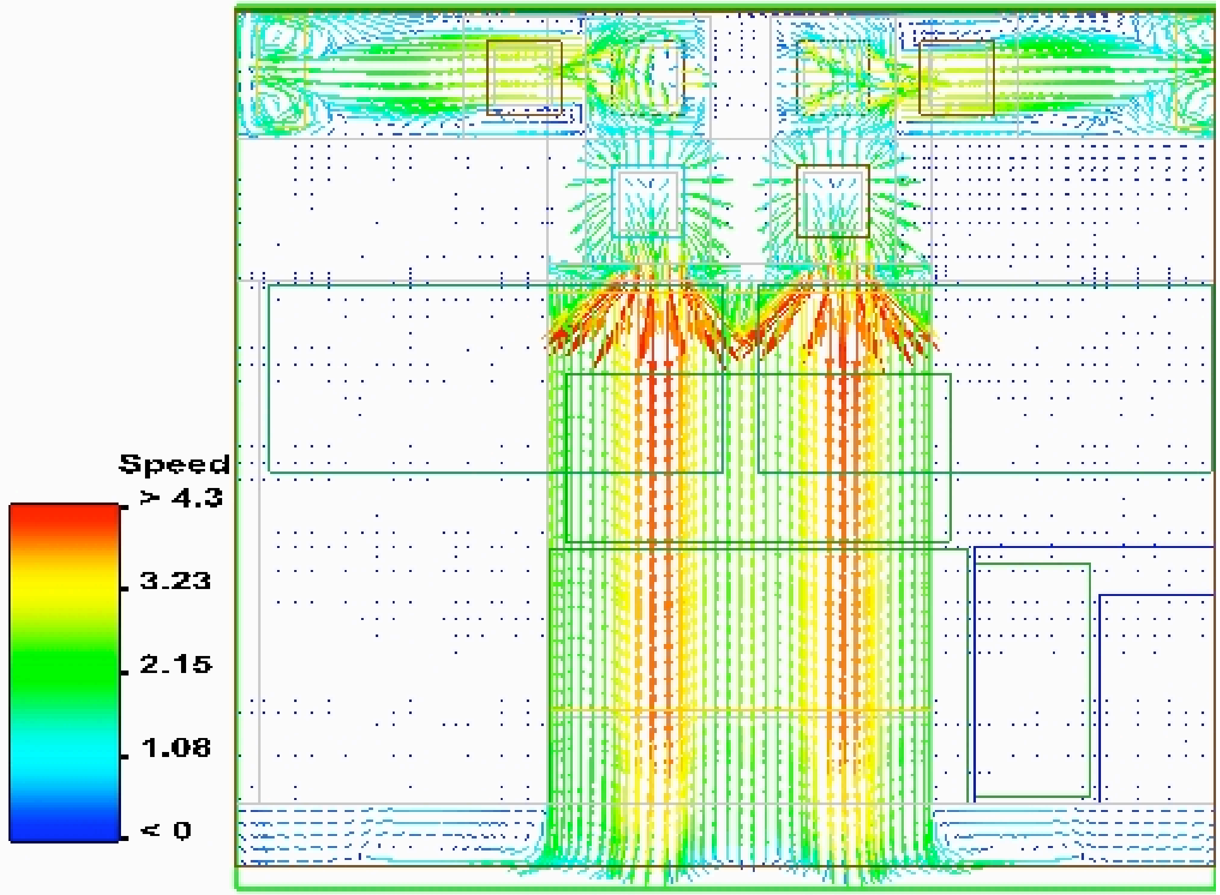
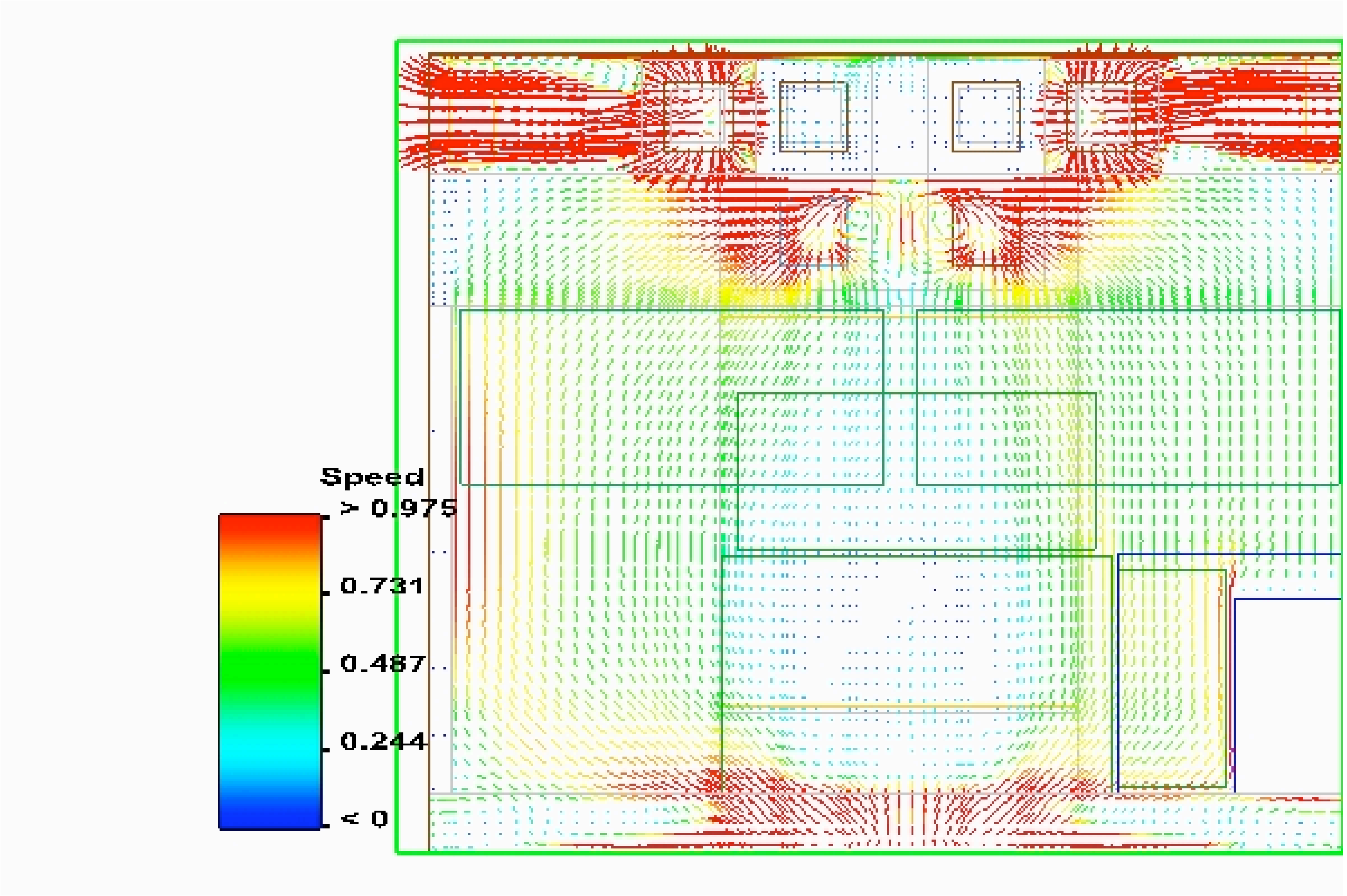
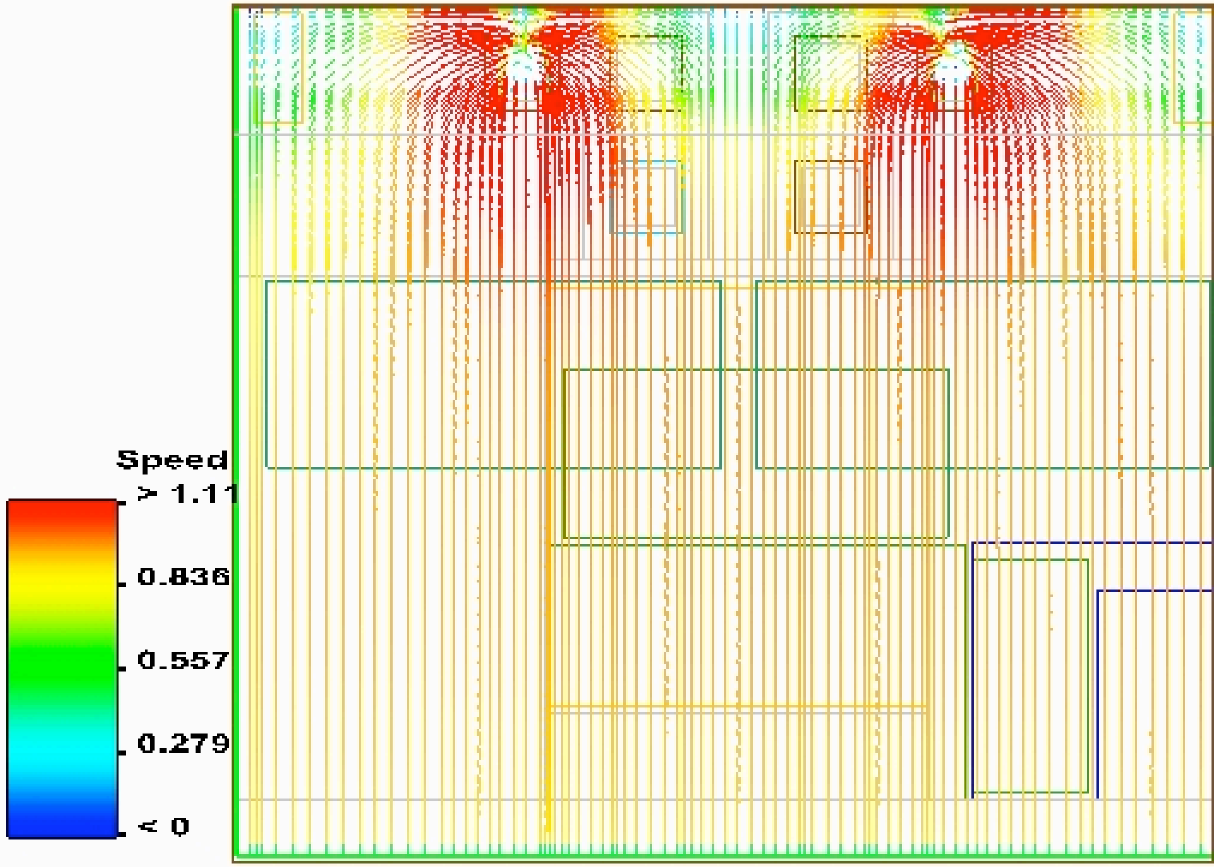
Air Vel @ Z=1", Internal Heat Sink



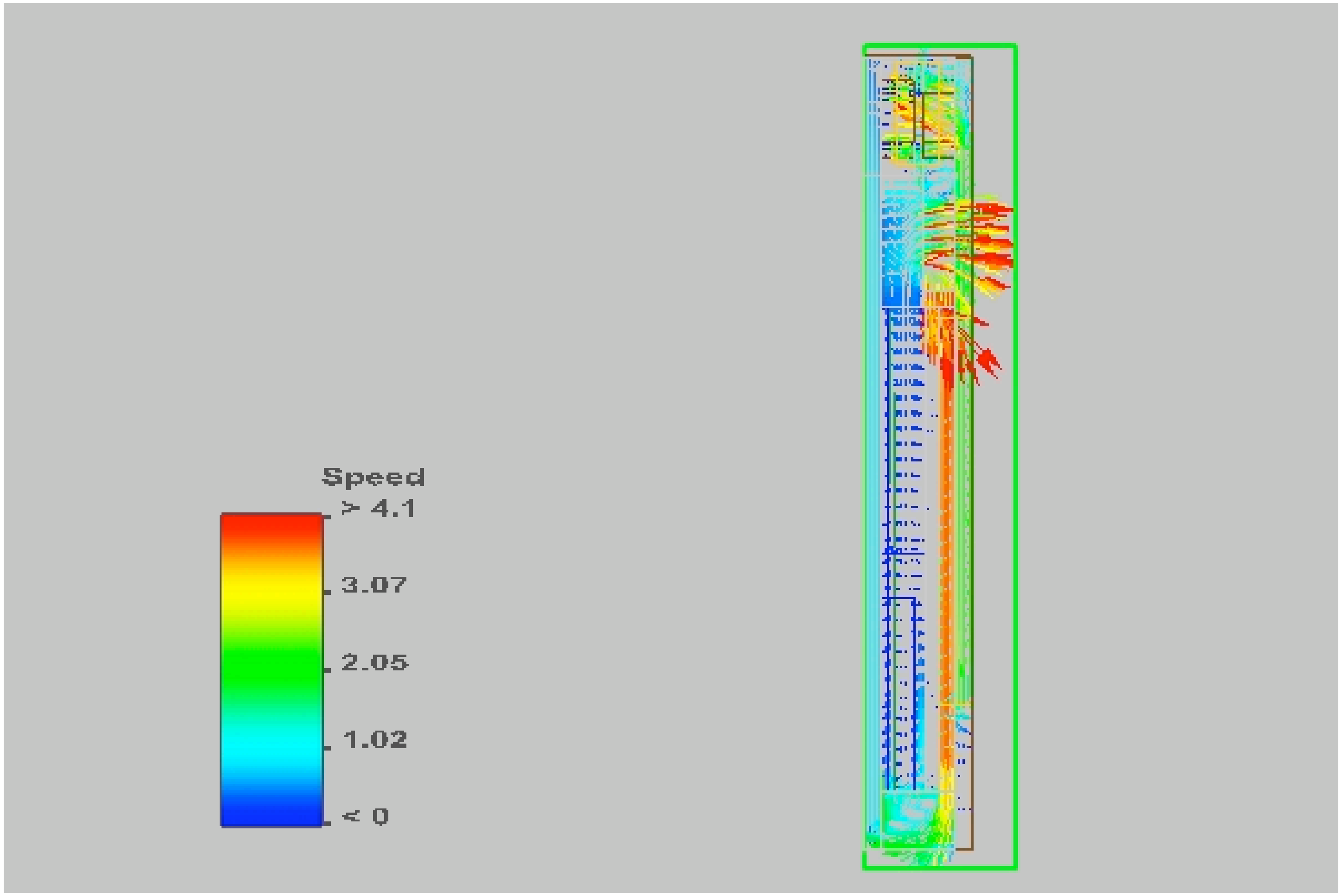
Air Vel @ Z=3”, Electronics Compartment



Air Vel @ Z=3.7", Antenna/Fabric Gap



Air Vel @ X=20.5", Through Heat Sinks



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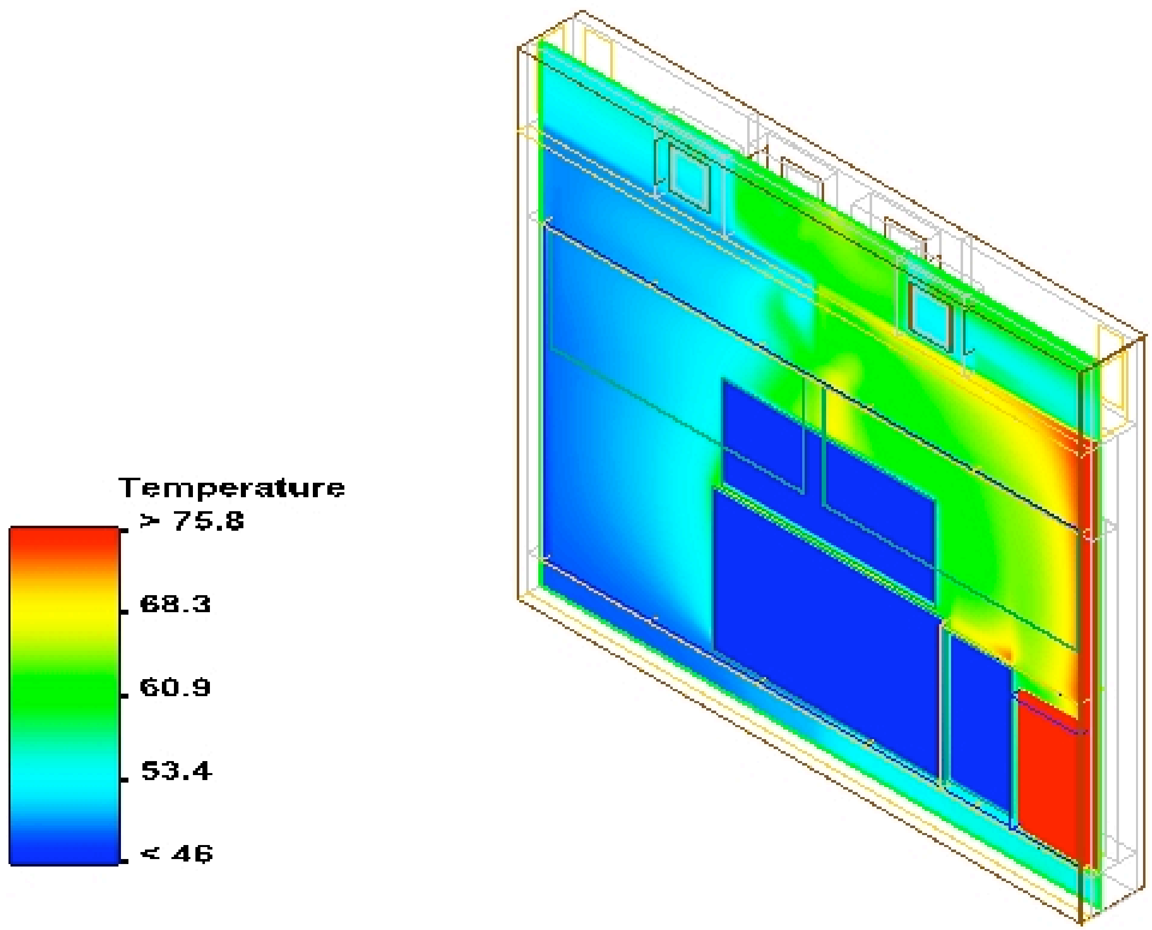
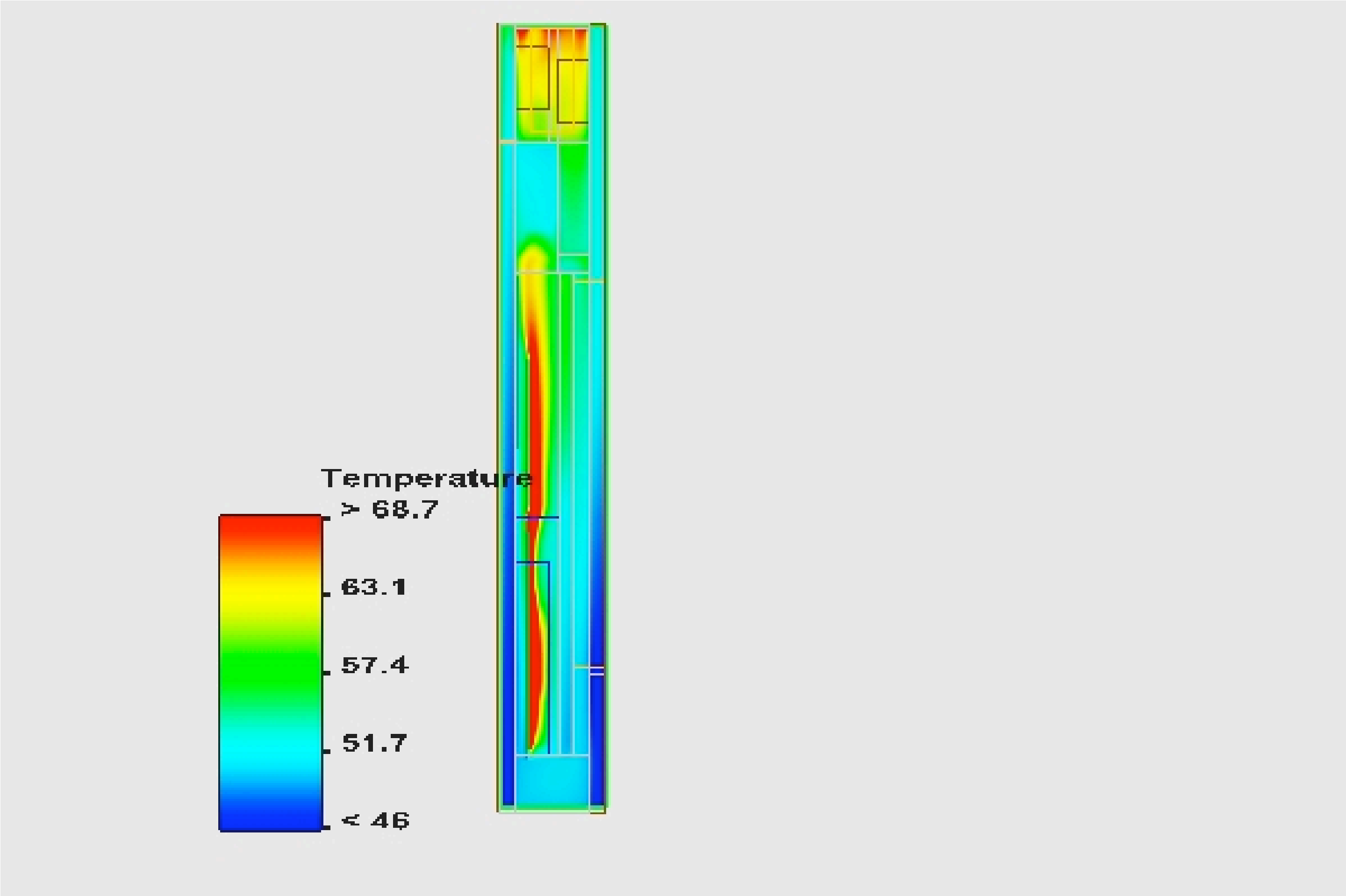
Air Temp. @ Z=3.5"



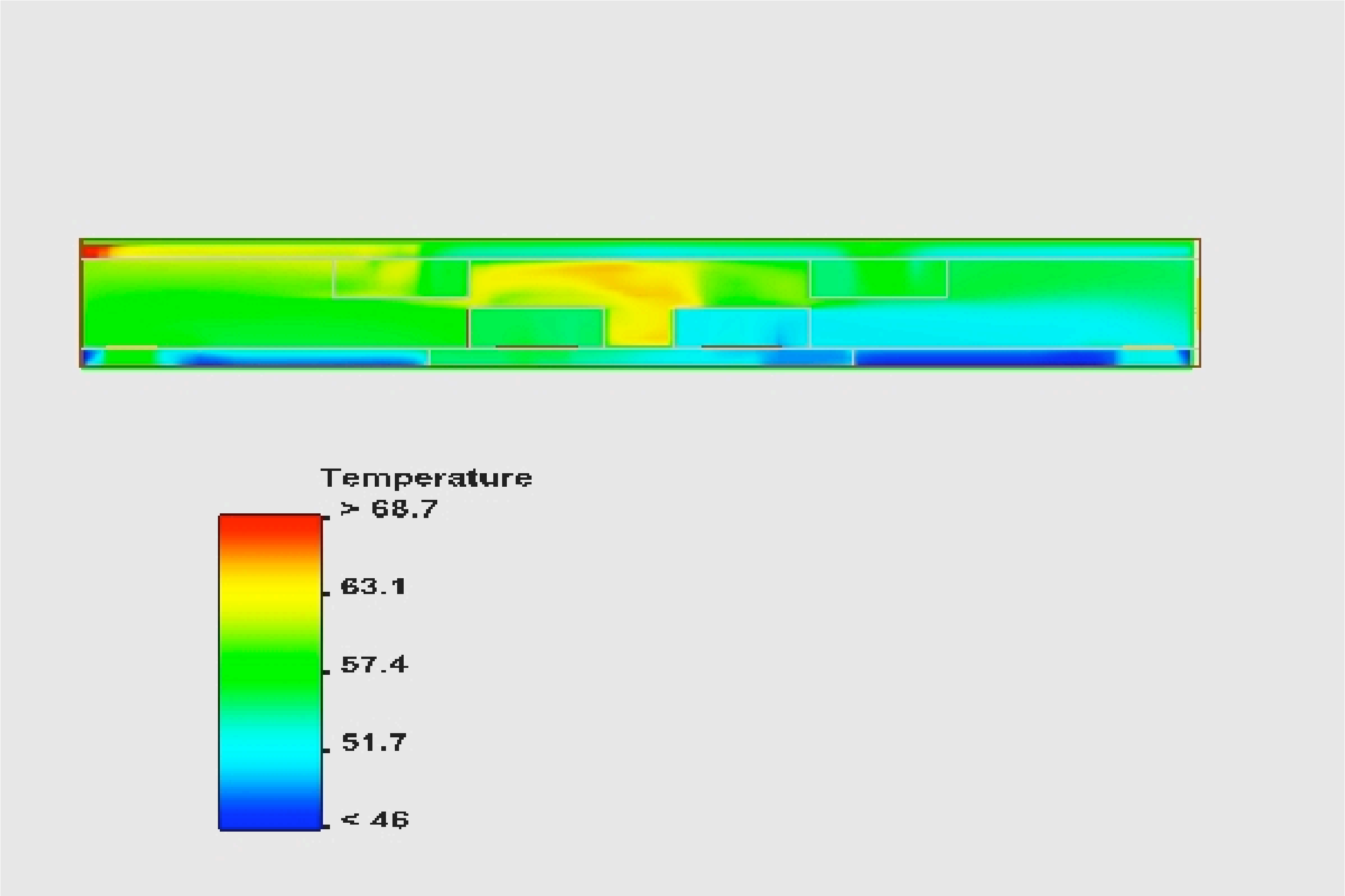
Isometric View

Air Temperature @ X=21.3”



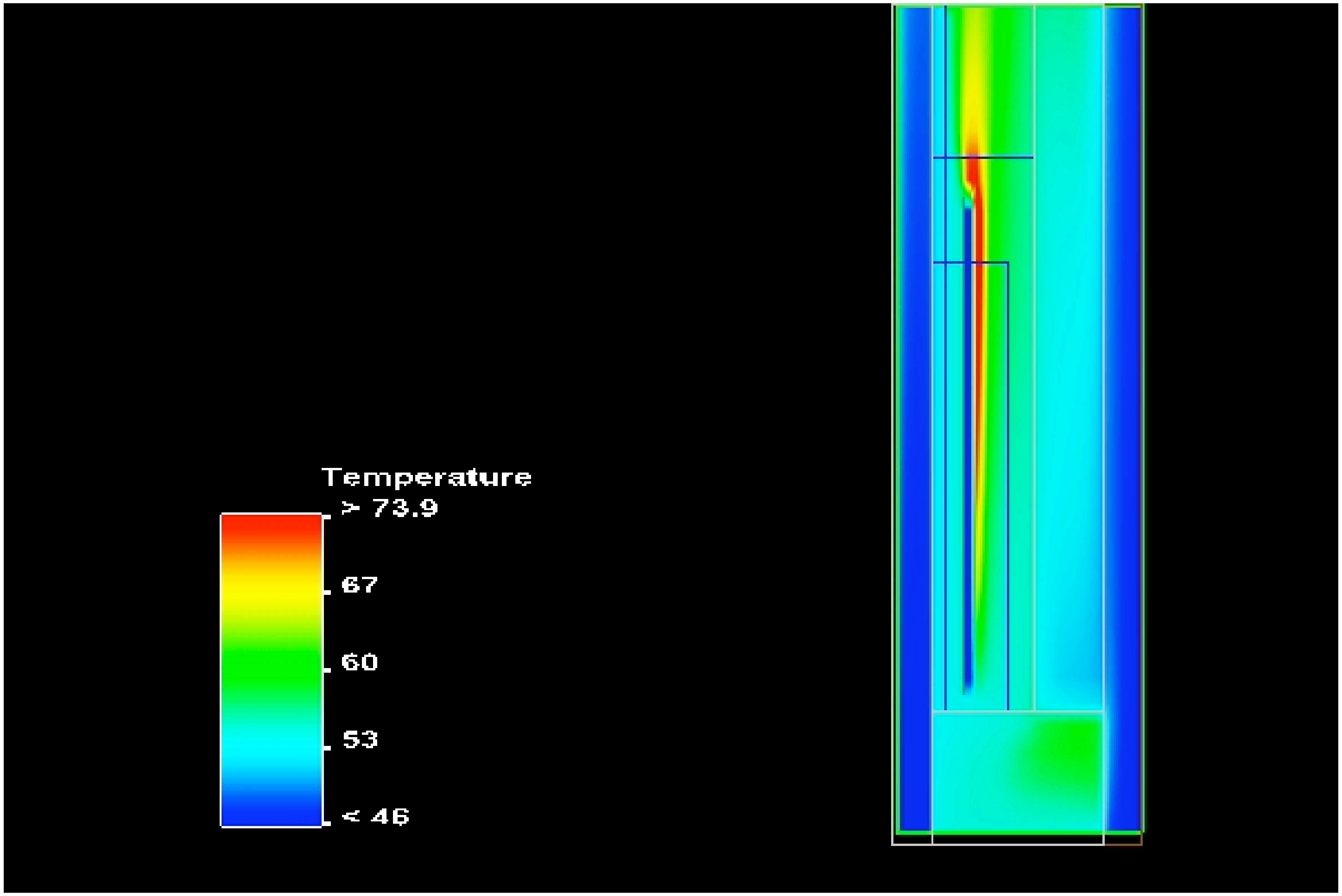
Vertical Section View

Air Temperature @ Y=35”



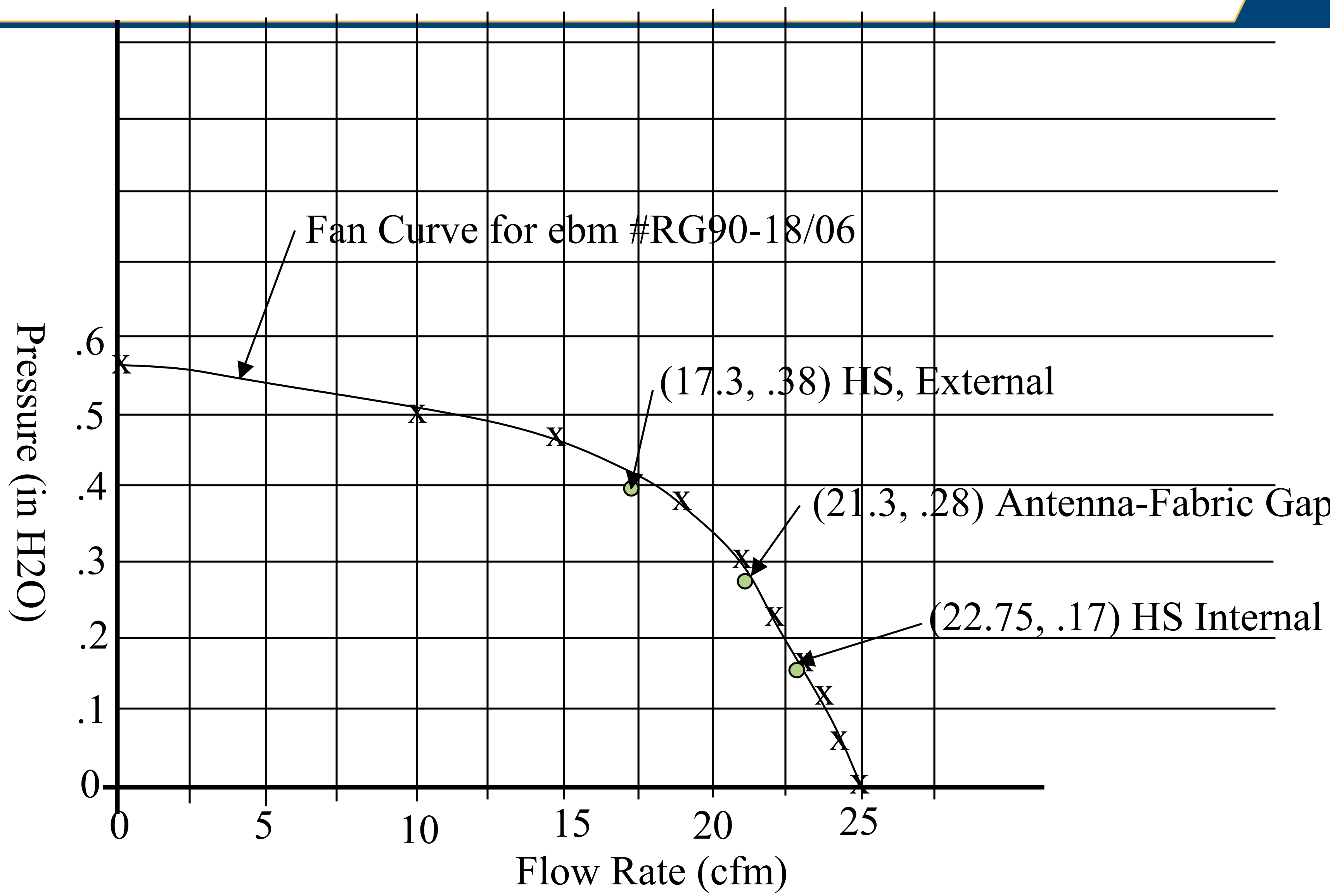
Horizontal Section View

Air Temp. @ X=35.7”, CPU

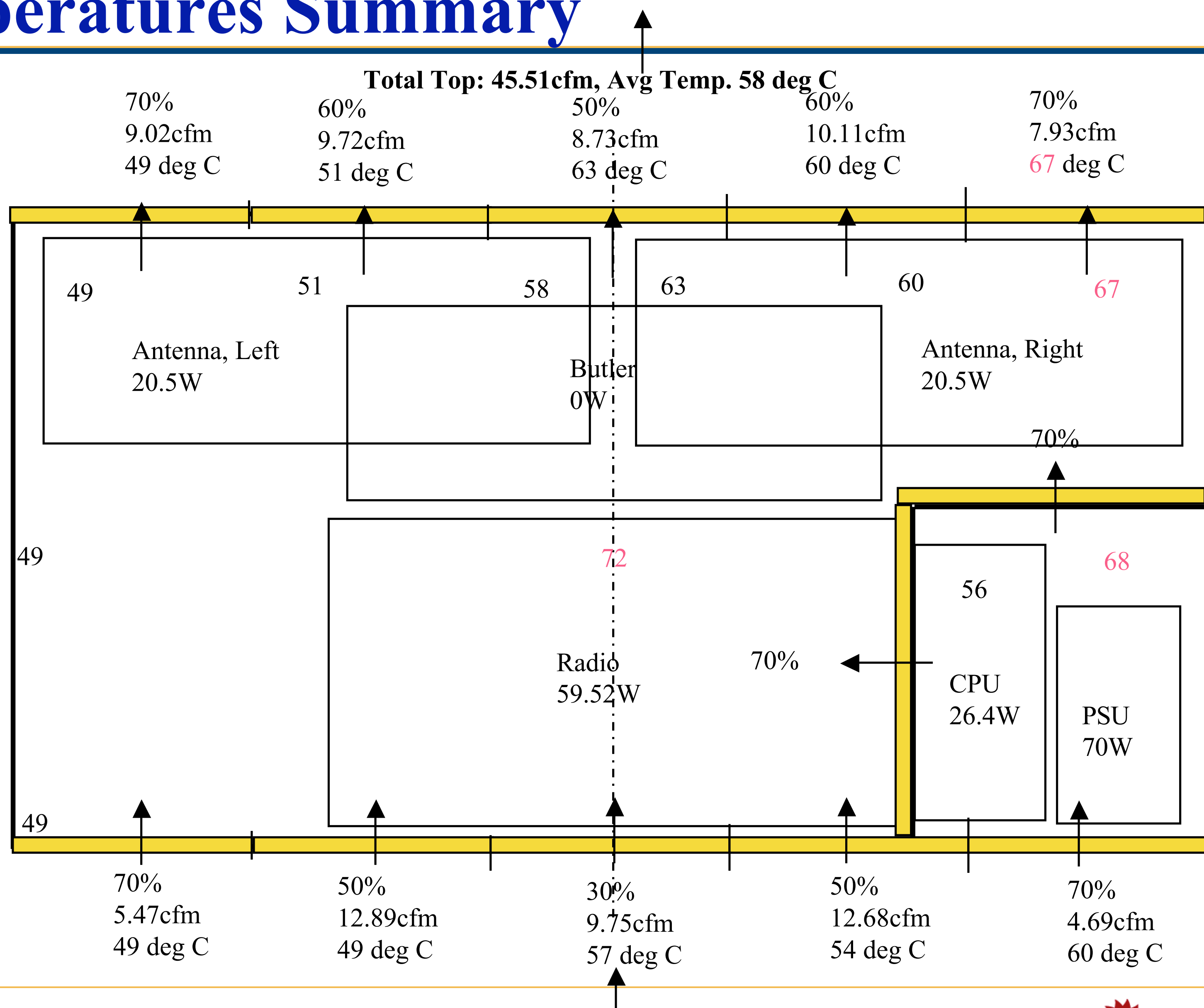


Vertical Section View

Fan Curve vs. System Performance



Electronics Compartment Air Flow and Temperatures Summary



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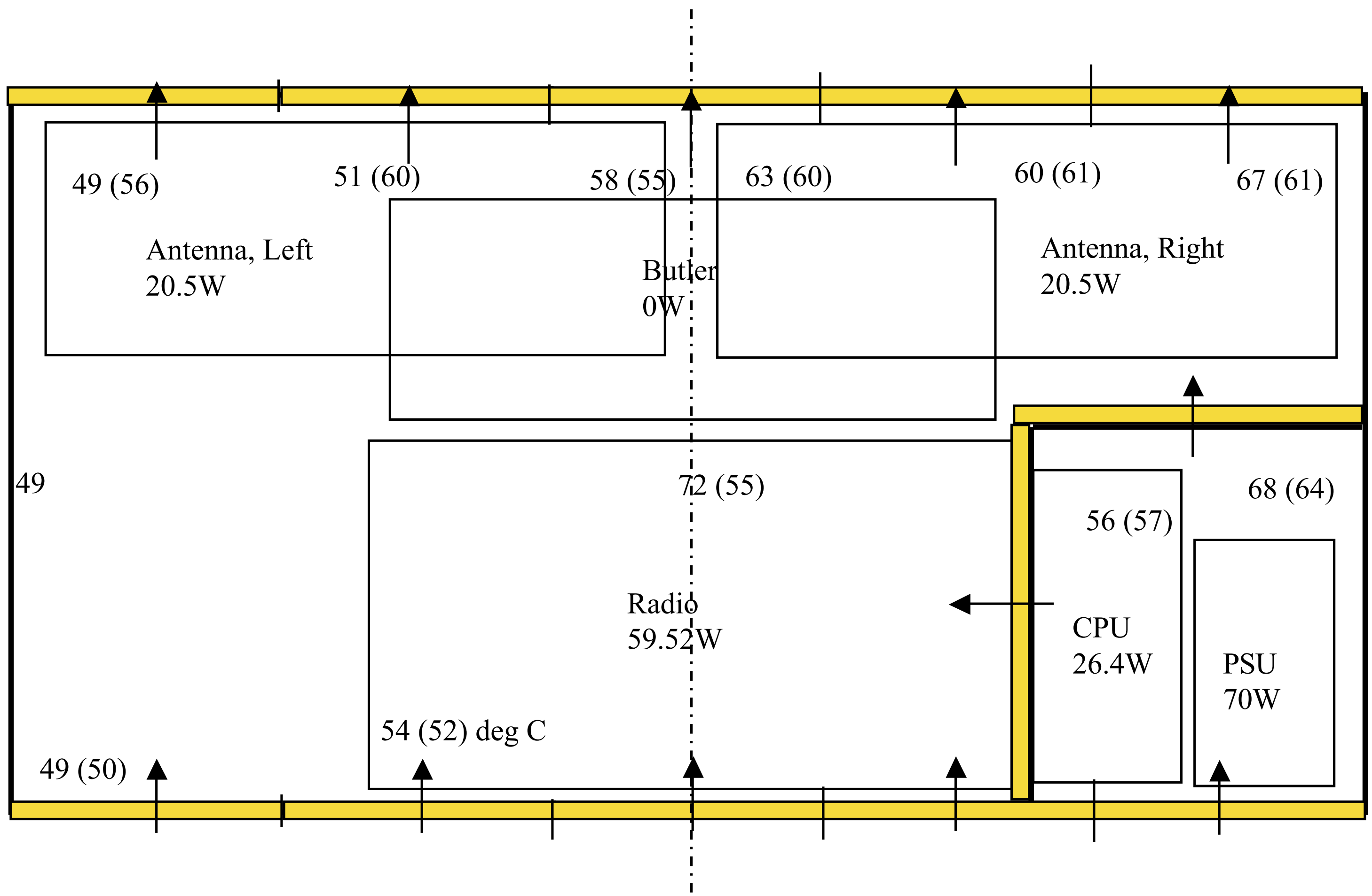
Max. Air Temperature Violation Summary

Maximum Allowable Air Temperature: 66 deg C

Max. Air Temp. deg C	Location	Mitigation Plan
72	Top of Radio PCB	Open Up Vent from 30% to 50 %
68	Top of PSU Module	Add an internal fan for PSU Exhaust
67	Right Corner of Right Antenna PCB	None (within margin of error)

Electronics Compartment Predicted vs. Measured Temperatures Summary



(X) = Measured

Air Temperature Simulation vs. Measurement Comparison

Location	Simulation Temp. deg C	Measured Temp deg C	Delta deg C	Error %
Inlet, Left 1	49	50	2	4
Inlet, Left 2	54	52	2	4
Inlet, Center	49	52	3	6
Top of Radio PCB	72	55	17	31
Top of CPU PCB	56	57	1	2
Top of PSU	68	64	4	6
Outlet, Left 1	49	56	7	13
Outlet, Left 2	51	60	9	15
Outlet, Center	58	55	3	5
Outlet, Right 1	63	60	3	5
Outlet, Right 2	60	61	1	2
Outlet, Right 3	67	61	6	10

Conclusion

- High power dissipation sealed outdoor enclosures can be effectively cooled with low cost air-to-air heat exchangers.
- CFD simulation tools like Flotherm are very effective in predicting the internal air temperatures and in helping to optimize the thermal design for this type of application.