

# Emerson Network Power Data Center Assessment Report of Findings



Customer Name

Customer A

Project Name

Data Center Assessment

Address

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Somewhere, MN 55555

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Surveys Completed

Electrical Infrastructure Power Audit.....May 27<sup>th</sup> 2008  
Data Center Thermal Assessment.....June 11<sup>th</sup> 2008

# Executive Summaries

## Emerson Electrical Reliability Services Electrical Infrastructure Power Audit

Emerson Electrical Reliability Services performed the facility power audit for the Any Data Center, Somewhere, MN. Some issues were found such as no one-line diagrams and the feeder circuit breaker for 'TU-D-1' transformer could not be located. The transformer label 'TU-D-2' is used twice in the building. A single point of failure was found on the automatic transfer switch which does not have a bypass capability. The building and computer room would not be able to switch to the emergency generator in the event of failure. Additional single point of failure is all computer room racks that are supplied from the single transformers and not supplied through a static switch.

## Emerson Network Power Data Center Thermal Assessment

The Any Data Center at Somewhere, MN has hot spots throughout the area which can be attributed to several things. The most important of these is the fact that a hot/cold aisle arrangement is not being utilized. This causes several issues within the data center. Problems associated with aisle arrangement as well as additional important factors leading to data center hot spots are summarized below.

- Short circuiting of room air causes elevated temperatures at server inlets and decreased temperatures at computer room air conditioning (CRAC) return.
  - Hot exhaust air is pushed directly to other server inlets because of the data center layout which greatly increases the temperature of the equipment.
  - Hot exhaust air also mixes with cold supply air which can and does short circuit back to the CRAC unit. These lowered return air temperatures reduce the cooling capacity of the CRAC unit.
  - Many racks are not equipped with block off plates allowing hot exhaust air to pass through the rack into the cold aisle.
- Incorrectly placed/balanced ceiling air supply grilles
- Under floor plenum in conjunction with perforated floor tiles is not used to cool racks in this data center. Under floor cooling is the preferred method for conventional cooling of data centers because of its precisely located CRAC air as well as assisting in the 'hot air rises' principle.

The purpose of this report is to deliver field observations and recommendations to Any Data Center about problems identified at the Lake Elmo Data Center along with Liebert recommended solutions that can be used for future expansion considerations of equipment space.

Examples of how these things affect airflow and cooling in the data center are explained in further detail later in the report.

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# Standards for Evaluation for Power Audits

Emerson Network Power subscribes to the industry-wide standards used for the evaluation of the electrical systems for computer installations, which are:

Federal Information Processing Standards Publication 94, "Guideline on Electrical Power for ADP Installations", published by the U.S. Department of Commerce/ National Bureau of Standards, 1983.

Institute of Electrical and Electronic Engineers Standard 1100-1999, "Grounding and Powering Electronic Equipment", 1999.

Both of these standards conform to the requirements of the National Electrical Code (NFPA 70).

# System Load Review

1) The TU-D-1 transformer is rated for 150 kVA, 416 amps @120 –208 volts, with an 80% load factor, the transformer is capable of handling 332 amps.

The TU-D-2 transformer is rated for 45 kVA, 125 amps @120 –208 volts, with an 80% load factor, the transformer is capable of handling 100 amps.

2) The present average load on the TU-D-1 transformer is 198 amps @120 –208 volts. That supplies power to PDU circuit breaker panels ULP-D-1A & 1B.

The present average load on the TU-D-2 transformer is 7.2 amps @120 –208 volts. That supplies power to PDU circuit breaker panel ULP-D-1C.

3) Spare capacity remaining from TU-D-1 transformer =  $332 - 198 = 134$  amps, TU-D-2 transformer =  $100 - 7.2 = 92.8$  amps.

**Base on the above measurements there is room for a future expansion.**

# Single Point of Failure

The main distribution switchboard is supplied through a 3000 amp automatic transfer switch, which does not have bypass capability. To perform maintenance safely, the entire building would require de-energizing. Also, if the automatic transfer switch would fail, the building and computer room would not be able to switch to the emergency generator or visa versa.

The present load to all of the computer room racks is supplied from the 150-kVA and 45-kVA transformers located in the electrical room (C185) adjacent to the data center. In the event of a failure of these units, the data center will be out of commission for a minimum of 2 days. It may be necessary to have a spare transformer be kept in stock.

## Drawings / Sketch

See simplified one line drawing. Power flow is from the main transformer to computer room circuit breaker panel boards.

# Electrical Distribution Equipment Inventory

Equipment Type	Manufacturer	Model	Serial #	Tag #
Main switch board, metal enclosed	Electro-Mechanical Industries	480/277, 3000 amp	N/A	None
Main Circuit breaker	Merlin Gerin	Masterpact MP30 H2, 3000 amp, 600 volt	N/A	None
Automatic transfer switch	ASCO	7000 series 3000 amp	9999999	None
Generator	Caterpillar	Model 3516, 2500 kW, 1800 rpm 3007 amps, 480/277 volt	8888888	None
Generator Main circuit breaker	Merlin Gerin	CM3200N, 3200 amp, 690 volt	N/A	None
Power Module 1 Power Module 2	MGE	EPS 6000, 72-131104-00 EPS 6500/44/66P, 500 kVA, 400 kW	7777777 6666666	None
Batteries – 240 cells/string, 3 strings/UPS	C&D Technologies	UPS12-370FR	N/A	None
UPS transformer (TU-D-1 feeds ULP-D-1A/1B)	Hammond Power	150 kVA, 480-120 volt, 150/220 C, Z=3.2% @170C, type K	N/A	None
UPS Transformer (TU-D-2 fed from UDP-E-2)	General Electric	45 kVA, 480-120 volt, 150 / 220 C Z=3.0%, type QL, K factor.	5555555	None
A/C	Liebert	Model VH290AHAAEI	444444-4, 460 volt, 3 phase, 60 Hz, 73 amp	None

# Electrical Audit

<b>Main / Distribution Breakers</b>					
Breaker (name)	Rating			Measured (amps)	Go / No Go
	Amps	Volts	Phase		
Main Switch board	3000	480/ 277	3 ph 4 w	550 / 528 / 541	GO
Main Circuit breaker	3000	480/ 277	3 ph 4 w	550 / 528 / 541	GO
Power Module #1 Input (UPS)	800	480/ 277	3 ph 3w	97 /96 /105	GO
Power Module #2 Input (UPS)	800	480/ 277	3 ph 3w	93 /97 /104	GO
UDP-E-1	400	480/ 277	3 ph 3w	26 / 38 / 40	GO
UDP-E-2	250	480/ 277	3 ph 3w	87 / 92 / 84	GO

### PDU Main Breaker (Panels ULP-D-1A, -1B, -1C )

Breaker (name)	Rating			Measured (amps)	Rack (Name)	Go / No Go
	Amps	Volts	Phase			
Main Breaker from transformer TU-D-1 to ULP-D-1A panel.	400	120/208 volt	3 ph 4 wire	111/127/117	Various racks on Breaker panel Schedule.	Go
Main lug from ULP-D-1A panel to ULP-D-1B panel.	400	120/208 volt	3 ph 4 wire	81/87/71	Various racks on Breaker panel Schedule.	Go
Main lug from transformer TU-D-2 to ULP-D-1C panel.	125	120/208 volt	3 ph 4 wire	6.1/5.9/9.5	Various racks on Breaker panel Schedule.	Go

## ULP-D-1A Panelboard

<b>Circuit Number</b>	<b>Measured current</b>	<b>Circuit Number</b>	<b>Measured current</b>
1	0.14	2	11.19
3	0.1	4	15.58
5	6.1	6	11.89
7	2.16	8	13.93
9	2.97	10	14.91
11	1.93	12	15.01
13	8.43	14	12.66
15	0.1	16	13.7
17	11.96	18	14.6
19	14.92	20	12.7
21	16.26	22	15.1
23	12.29	24	14.5
25	9.29	26	11.5
27	13.45	28	14.3
29	4.21	30	7.9
31	1.85	32	0.1
33	4.14	34	17.7
35	4.77	36	12.3
37	12.58	38	0.4
39	7.62	40	1.2
41	1.4	42	0.9

<b>ULP-D-1B Panelboard</b>			
<b>Circuit Number</b>	<b>Measured current</b>	<b>Circuit Number</b>	<b>Measured current</b>
1	0	2	-
3	0	4	-
5	14.2	6	-
7	16.1	8	-
9	16.5	10	3.4
11	0.3	12	3.4
13	13.1	14	3.4
15	14.1	16	3.4
17	11.7	18	13
19	13.9	20	14.3
21	9.0	22	7.39
23	15.9	24	7.9
25	0.1	26	11.6
27	16.4	28	11.5
29	5.5	30	0.6
31	0	32	5.9
33	5.5	34	0.1
35	0	36	0.1
37	0	38	4.4
39	0	40	4.4
41	0	42	0.47

<b>ULP-D-1C Panelboard</b>			
<b>Circuit Number</b>	<b>Measured current</b>	<b>Circuit Number</b>	<b>Measured current</b>
1	1.3	2	1.9
3	1.3	4	1.9
5	0	6	0.9
7	0	8	0.9
9	-	10	0
11	-	12	0
13	-	14	0
15	-	16	0
17	-	18	3.4
19	-	20	3.4
21	-	22	3.4
23	-	24	3.4
25	-	26	-
27	-	28	-
29	-	30	-
31	-	32	-
33	-	34	-
35	-	36	-
37	-	38	-
39	-	40	-
41	-	42	-

<b>Generator / UPS Information</b>							
<b>Equipment (name)</b>	<b>Rating (output)</b>			<b>Measured (output)</b>			<b>Go / No Go</b>
	<b>Volts</b>	<b>KW</b>	<b>KVA</b>	<b>Volts</b>	<b>KW</b>	<b>KVA</b>	
Generator (Did not run for measurement)	480 /277	2500	3125	-	-	-	-
UPS 1	480 /277	400	500	278	62	70	Go
UPS 2	480 /277	400	500	279	61	69	Go

## Analysis

- 1) Each UPS is Presently Running @ an average of 20%
- 2) Readings are based on instantaneous measurements
- 3) Further expansion is possible based on the existing UPS configuration and usage.
- 4) Total UPS Rating (Single UPS) 500 KVA. (.8 PF =400 KVA). In the event of a loss of one UPS, the load can safely transfer to the online unit
- 5) Combined present KVA usage = UPS1 + UPS 2 =62+61= 123 KVA
- 6) Remaining UPS (one UPS) Balance KVA =400-123 =277 KVA @ 480/277 volt.

## Future Growth Considerations

Base on the onsite evaluation of the site, expansion growth will be possible.  
The residual capacity on the UPS running in N+1 is approximately 200amps.  
This value can be lower, since the readings are an instant in time value.

## Projected Site Improvement

As per discussion with Any Data Center staff the possible expansion is to handle all of the data center loading plus an additional spare capacity for future development.

# Power Audit Observations

During the site audit the following observations were made, recommend corrective action be taken to reduce the risk of loss of power and or damage to property and even loss of life.

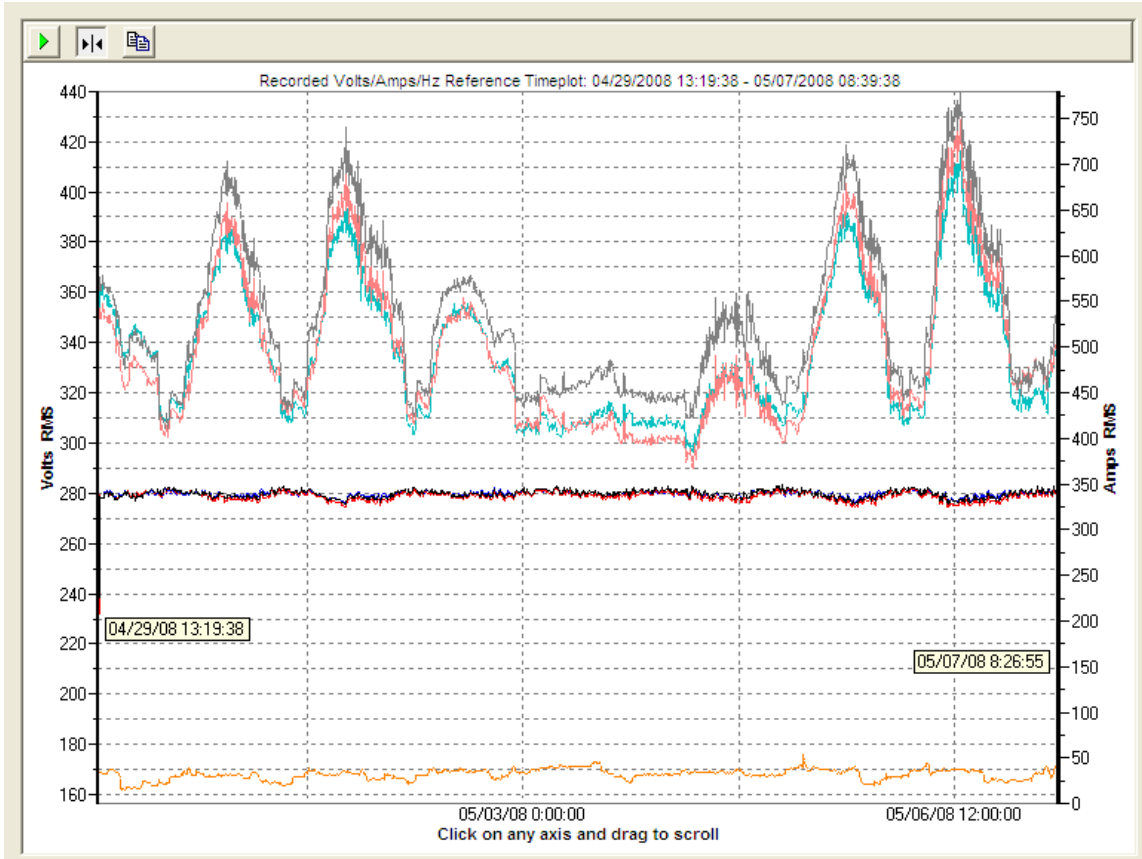
- 1) The electrical over-all one line diagram was created. This drawing needs to be laminated and mounted in the main electrical room.
- 2) The feeder circuit breaker for transformer 'TU-D-1' in electrical room C185 could not located. This transformer feeds the 'ULP-D-1A' and 'ULP-D-1B' panelboards which feed the computer room equipment. This transformer may need to have new feeder conductors routed to it, if it is found that the supplied power is not on the UPS system.
- 3) The equipment label 'TU-D-2' is used on two transformers in the electrical system. Transformers in electrical room C185 and also in electrical room D281 in the Risk Management area. To conform with the original labeling scheme of the building, the 45 kVA transformer in electrical room C185, which supplies power to panel 'ULP-D-1C', should be changed to from 'TU-D-2' to 'TU-D-1C'. The label on the feeder circuit breaker in panel 'UDP-E-2', also needs to be changed.
- 4) Generator load bank testing is performed annually by Ziegler (Caterpillar). No documentation was found on any load bank tests performed on the UPS battery pack. It is recommended to perform regular maintenance including load bank tests on the ATS, UPS and the batteries, in order to determine their ability to supply the design load at rated voltage and frequency for the designed period of time.



- 5) The ULP-D-1A, -1B and -1C panelboards in the computer room were found with stacks of boxes stored in front of the three panelboards. The National Electrical Code article 110.32 states “Work Space about Equipment. Sufficient space shall be provided and maintained about electrical equipment to permit ready and safe operation and maintenance of such equipment. Where energized parts are exposed, the minimum clear work space shall be not less than 2.0 m (6 1/2 ft) high (measured vertically from the floor or platform) or not less than 914 mm (3 ft) wide (measured parallel to the equipment). The depth shall be as required in 110.34(A). In all cases, the work space shall permit at least a 90 degree opening of doors or hinged panels.” The boxes must be stored in a designated storage area away from electrical equipment.

# Main Switchgear Load Recording

## Main Switchgear Recorded Volt/Amp



Phase AN

Voltage

Phase BN Voltage

Phase CN Voltage

Phase A Current

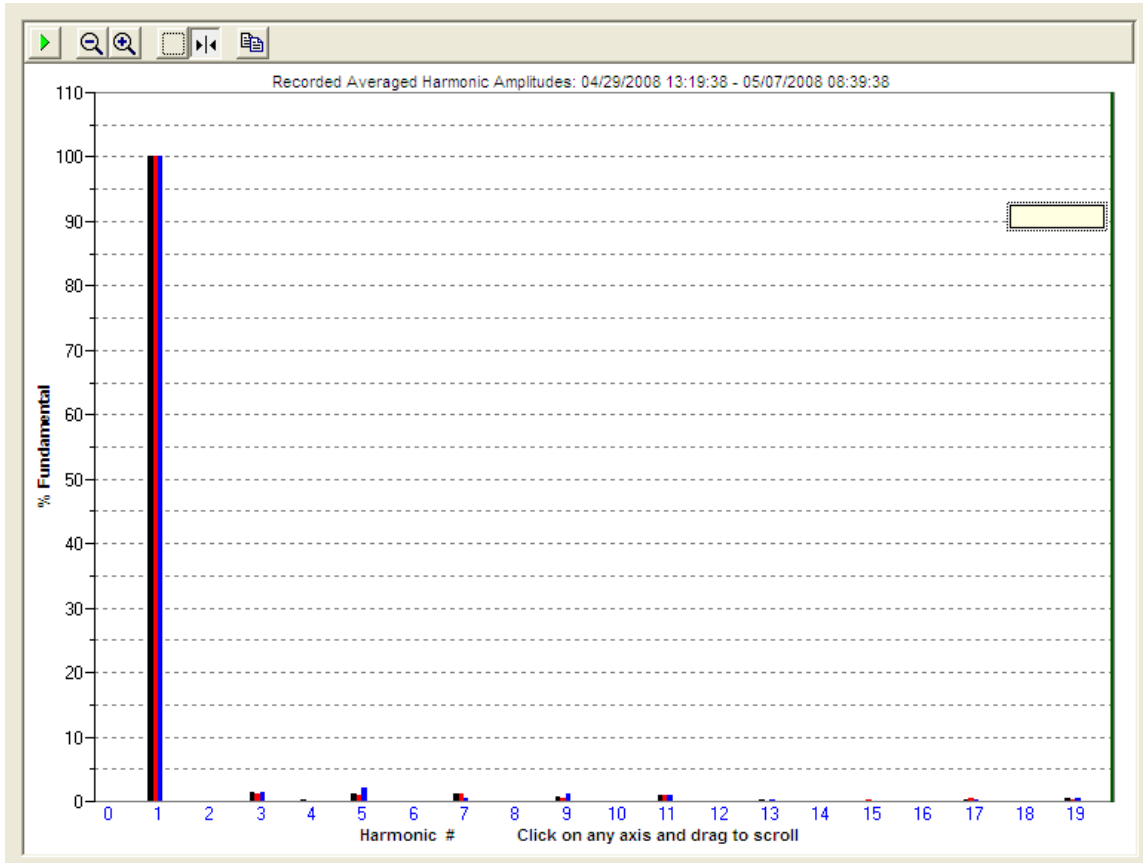
Phase B Current

Phase C Current

Phase N Current

Viewed as: Phase to Neutral

# Main Switchgear Recorded Voltage Harmonics



Phase AN

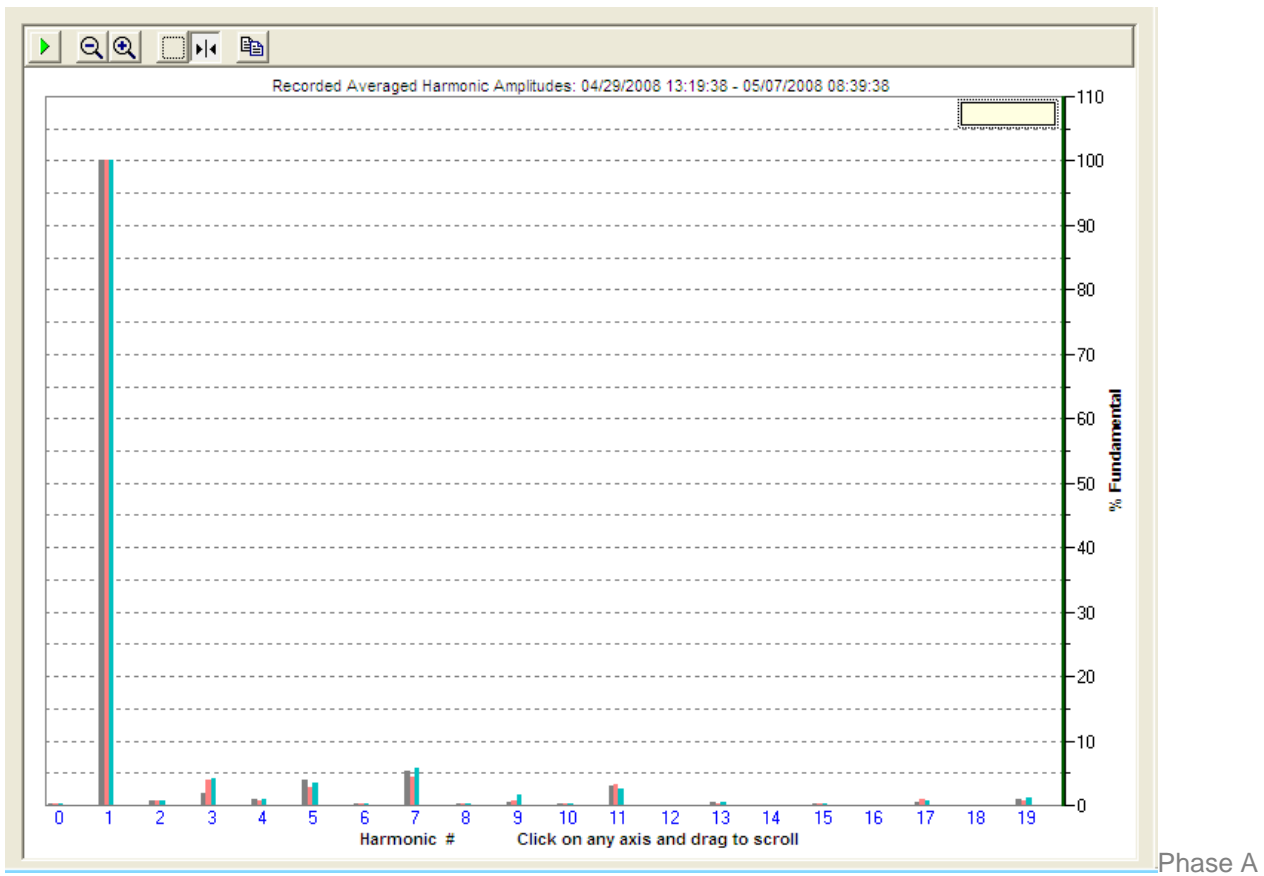
Voltage

Phase BN Voltage

Phase CN Voltage

Phase Selection: Voltage

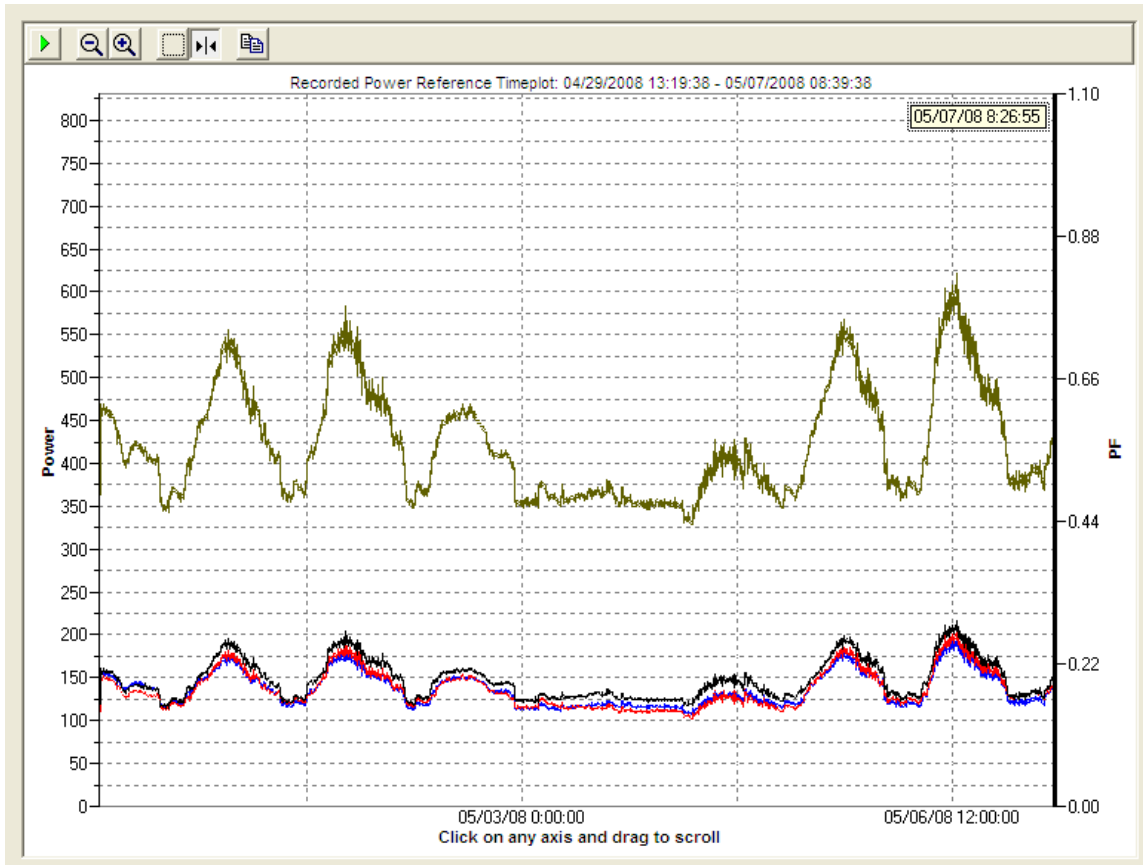
# Main Switchgear Recorded Current Harmonics



Current  
Phase B Current  
Phase C Current

Phase Selection: Current

# Main Switchgear Recorded Power

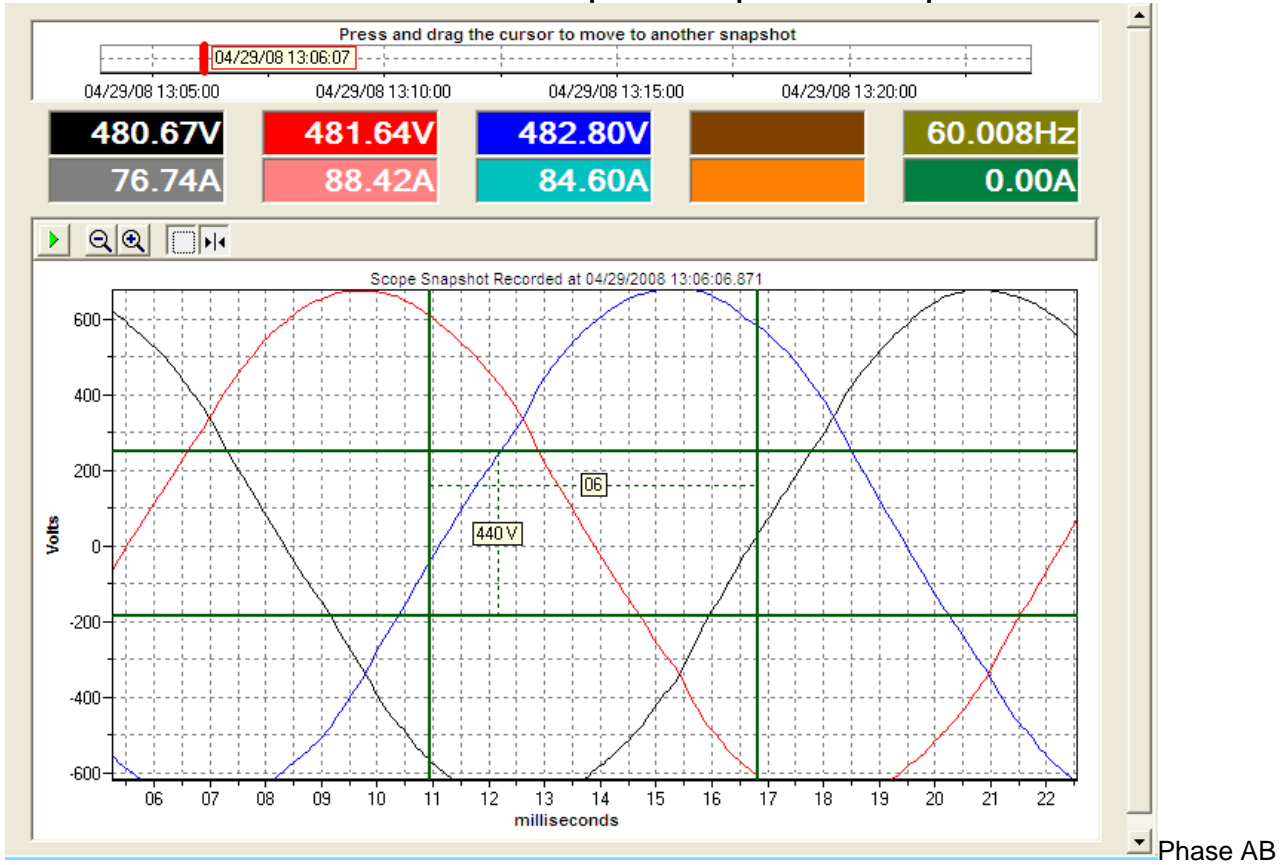


kW: A

- kW: B
- kW: C
- kW: Total
- kVA: A
- kVA: B
- kVA: C
- kVA: Total

# UPS 1 Output Harmonics Snapshot

## UPS 1 Output Snapshot Scope



Voltage 480.67V

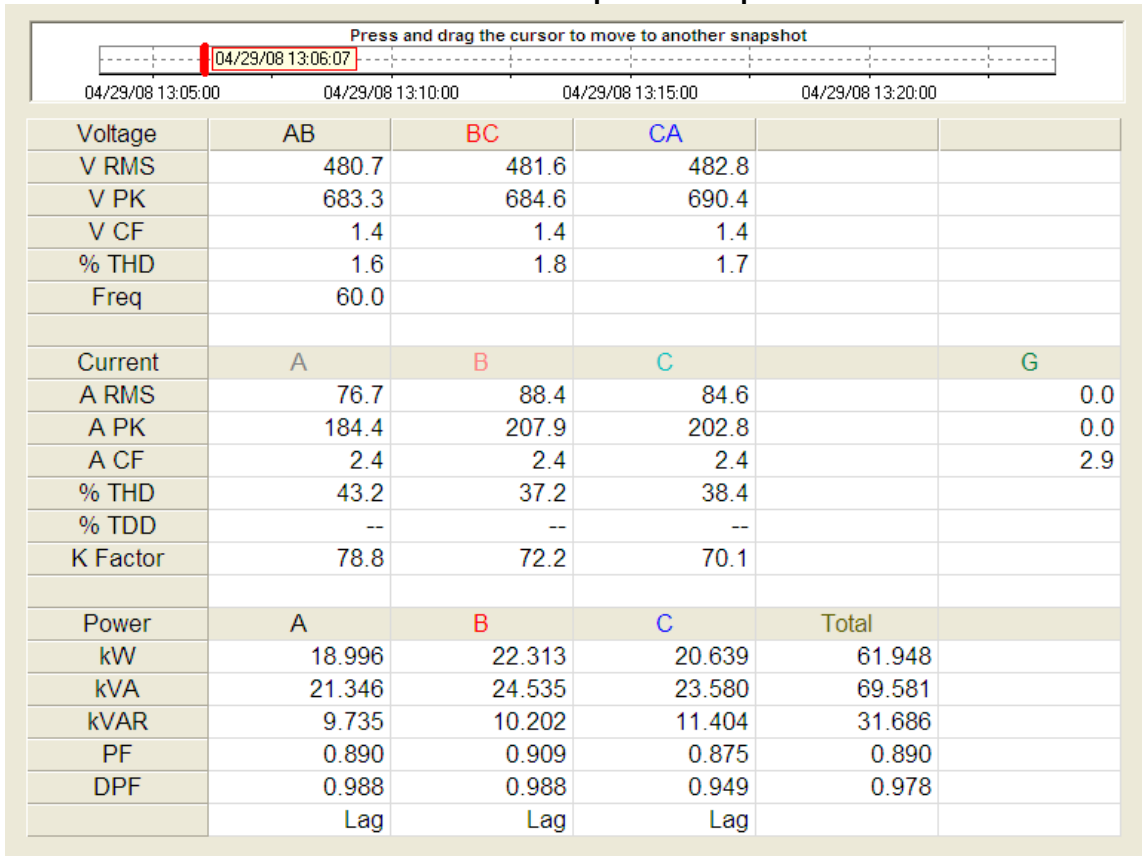
Phase BC Voltage 481.64V

Phase CA Voltage 482.80V

Snapshot time: 04/29/2008 13:06:07

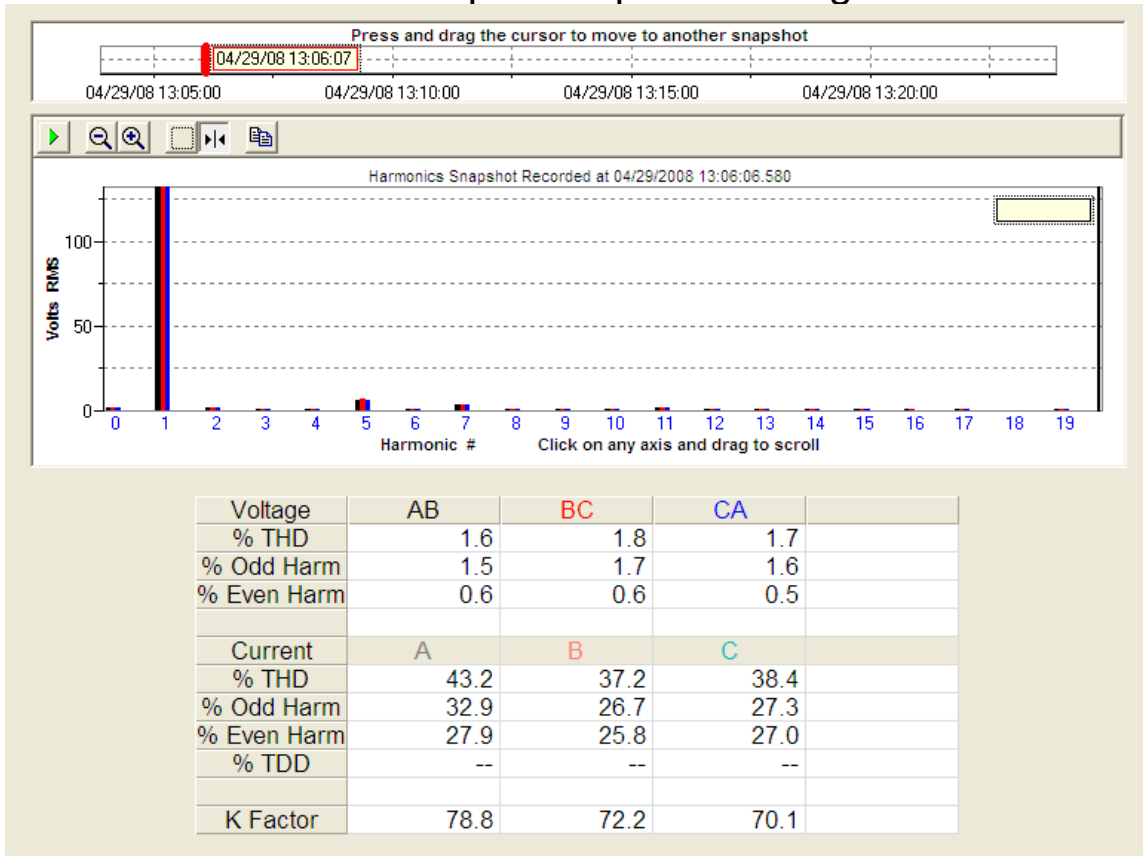
Viewed as: Phase to Phase

# UPS 1 Output Snapshot Meter



Snapshot time: 04/29/2008 13:06:07

# UPS 1 Output Snapshot Voltage Harmonics



Phase AB

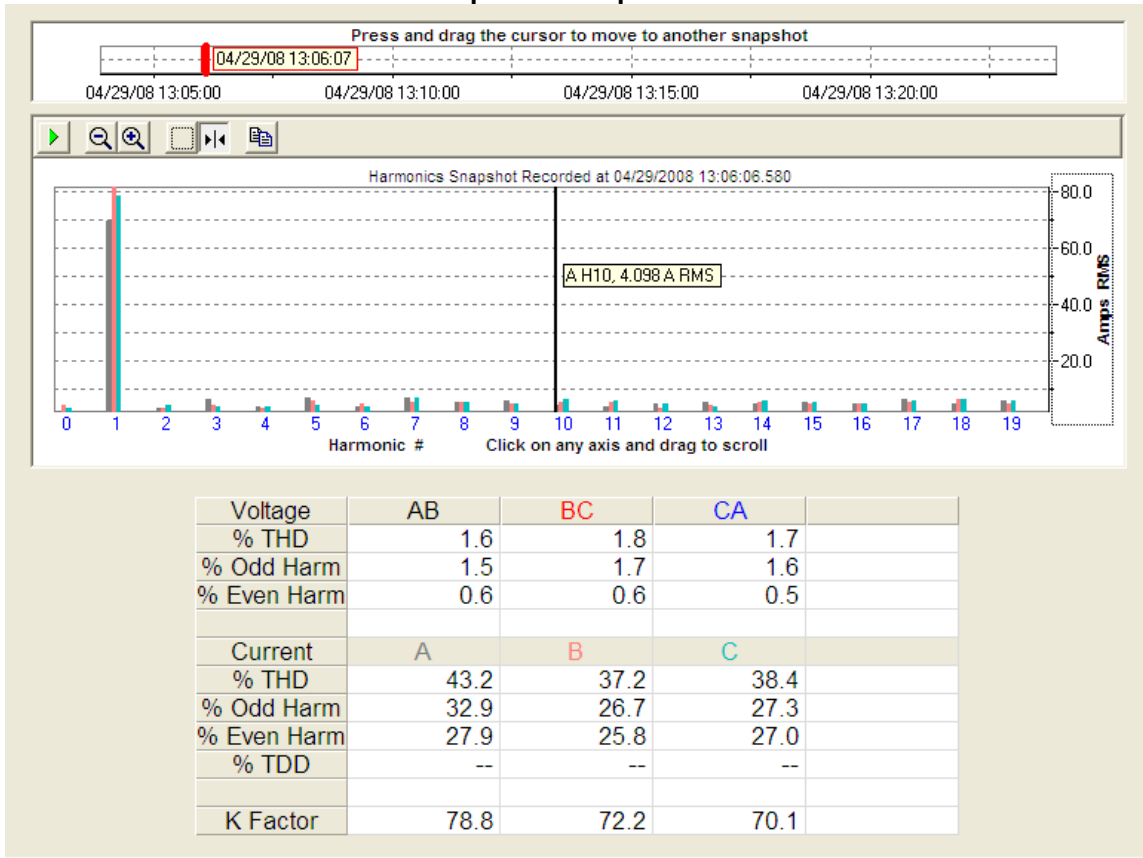
Voltage

Phase BC Voltage

Phase CA Voltage

Snapshot time: 04/29/2008 13:06:07

# UPS 1 Output Snapshot Current Harmonics



Phase A

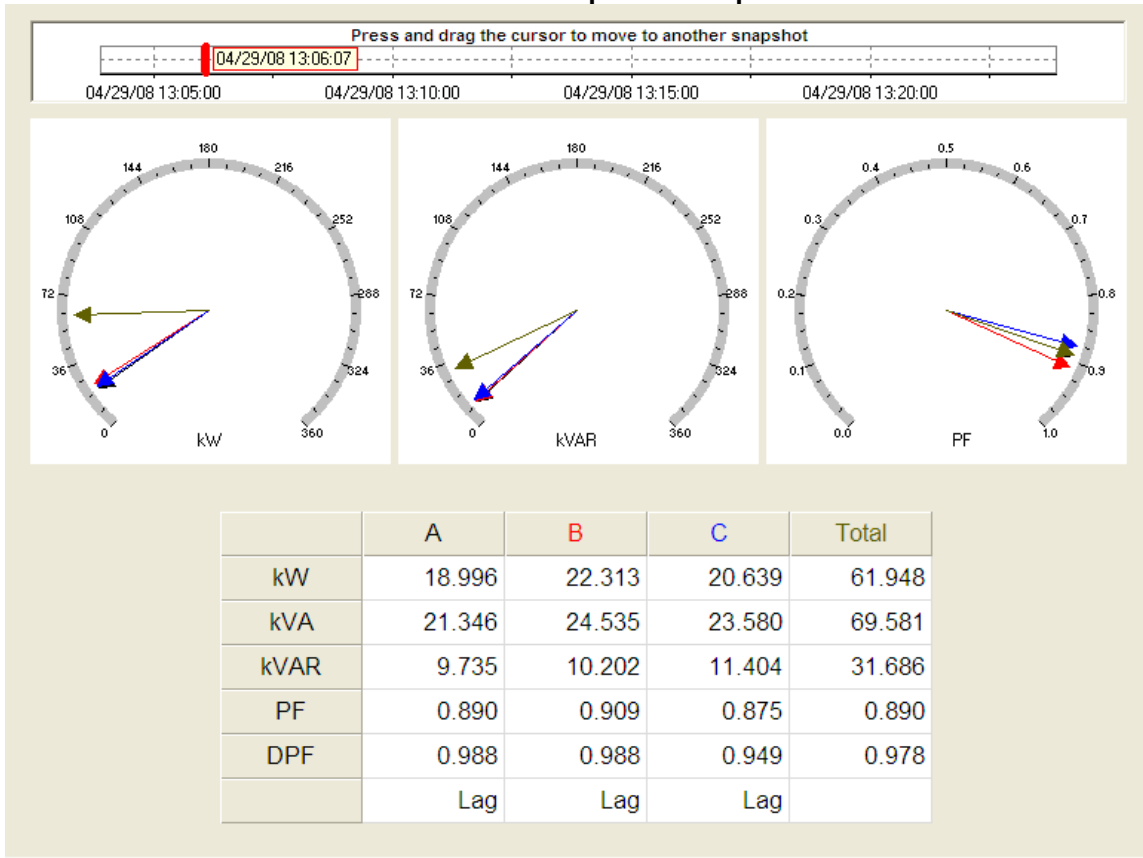
Current

Phase B Current

Phase C Current

Snapshot time: 04/29/2008 13:06:07

# UPS 1 Output Snapshot Power



Phase

Selection: A

Phase Selection: B

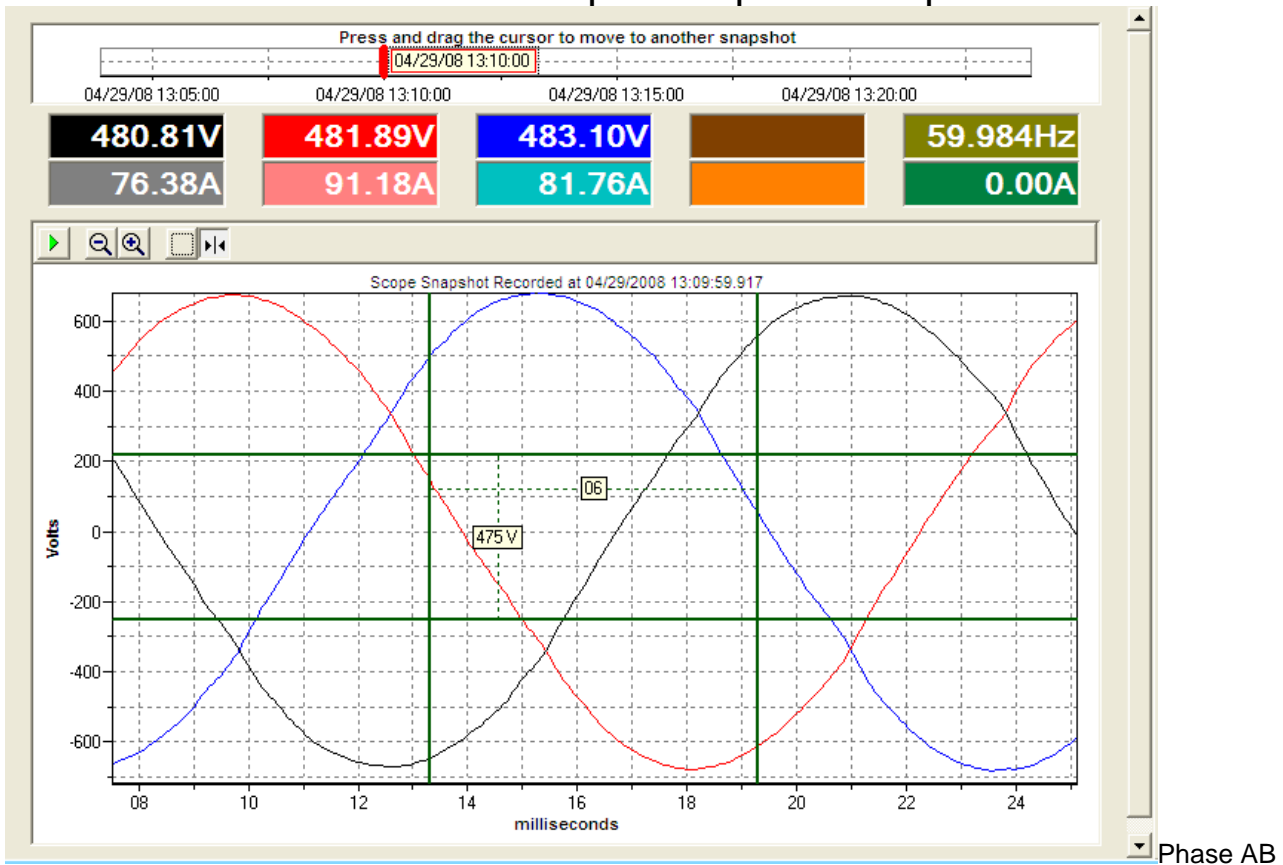
Phase Selection: C

Phase Selection: Total

Snapshot time: 04/29/2008 13:06:07

# UPS 2 Output Harmonics Snapshot

## UPS 2 Output Snapshot Scope



Voltage 480.81V

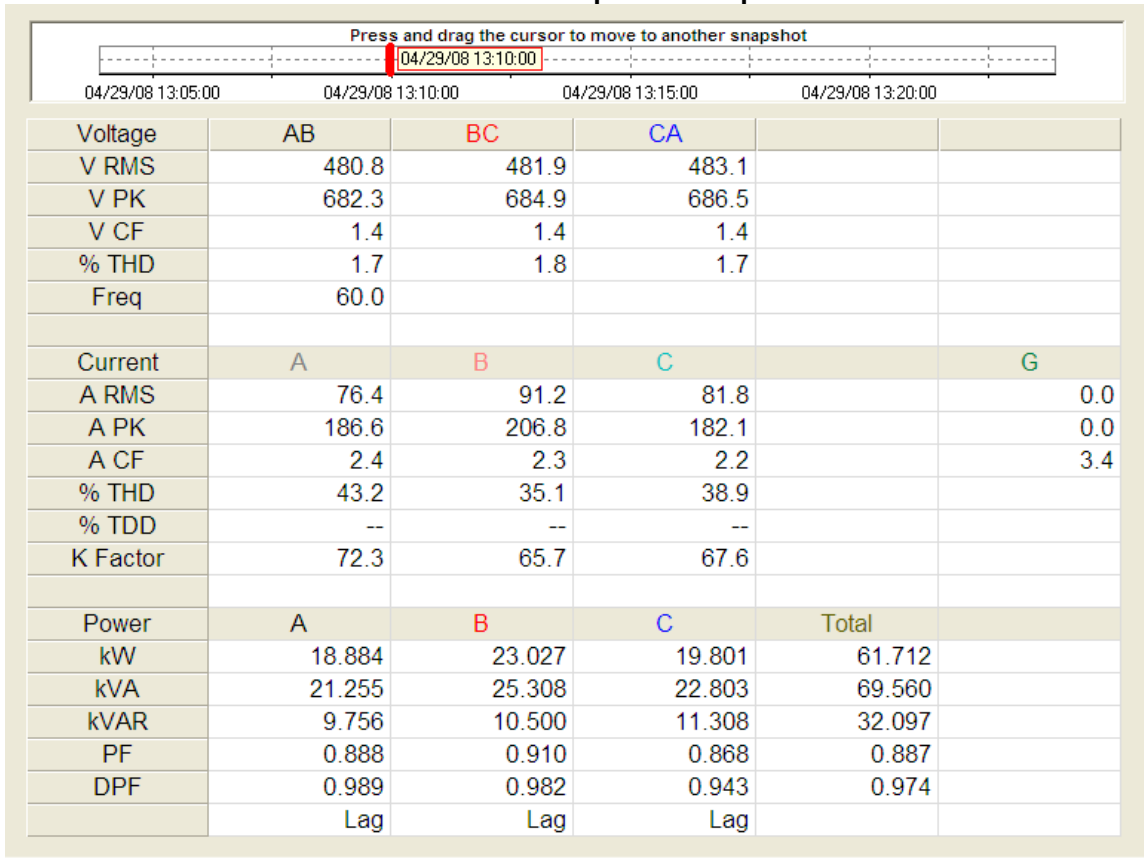
Phase BC Voltage 481.89V

Phase CA Voltage 483.10V

Snapshot time: 04/29/2008 13:10:00

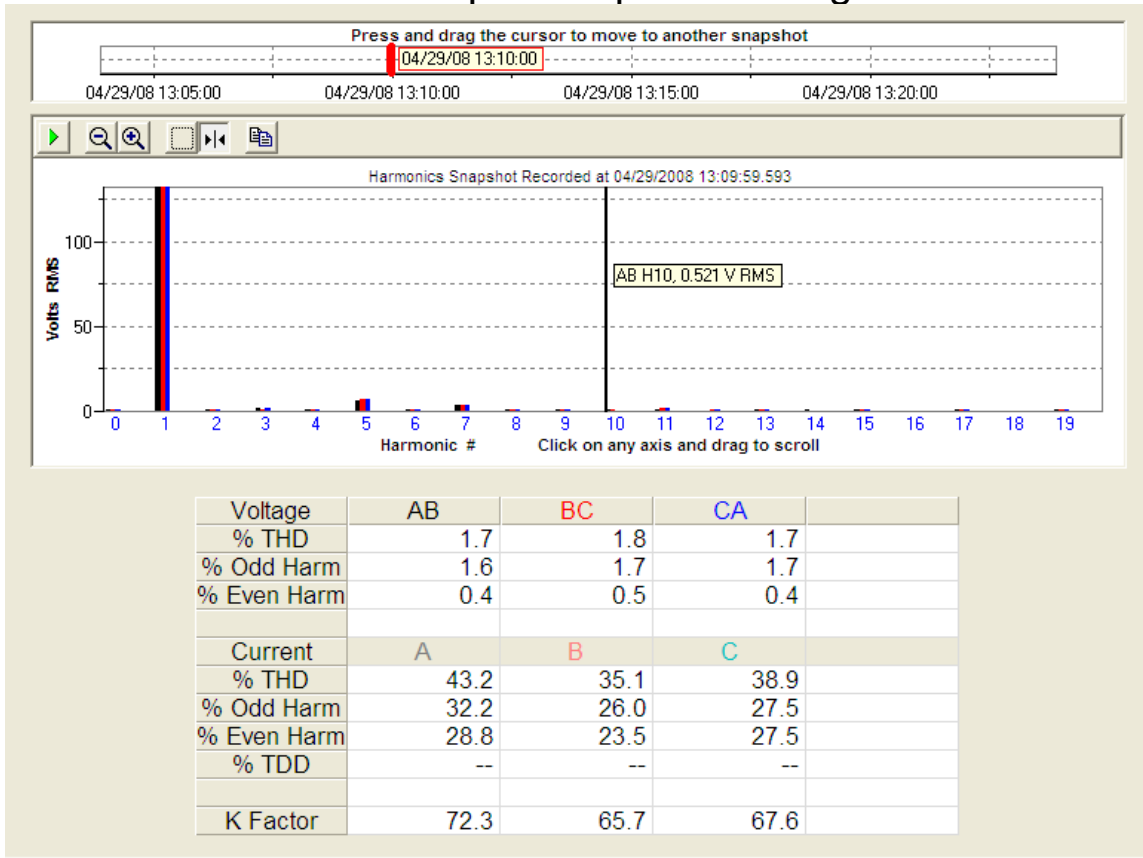
Viewed as: Phase to Phase

## UPS 2 Output Snapshot Meter



Snapshot time: 04/29/2008 13:10:00

# UPS 2 Output Snapshot Voltage Harmonics



Phase AB

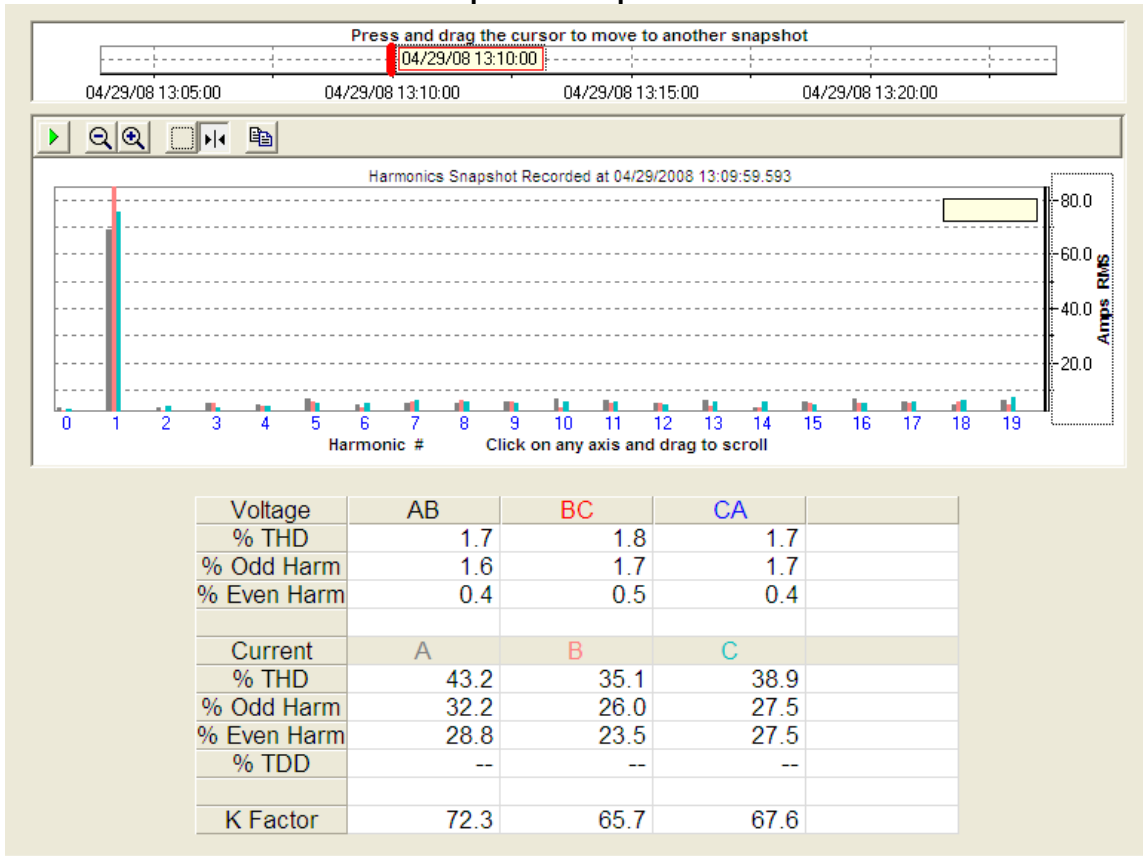
Voltage

Phase BC Voltage

Phase CA Voltage

Snapshot time: 04/29/2008 13:10:00

# UPS 2 Output Snapshot Current Harmonics



Phase A

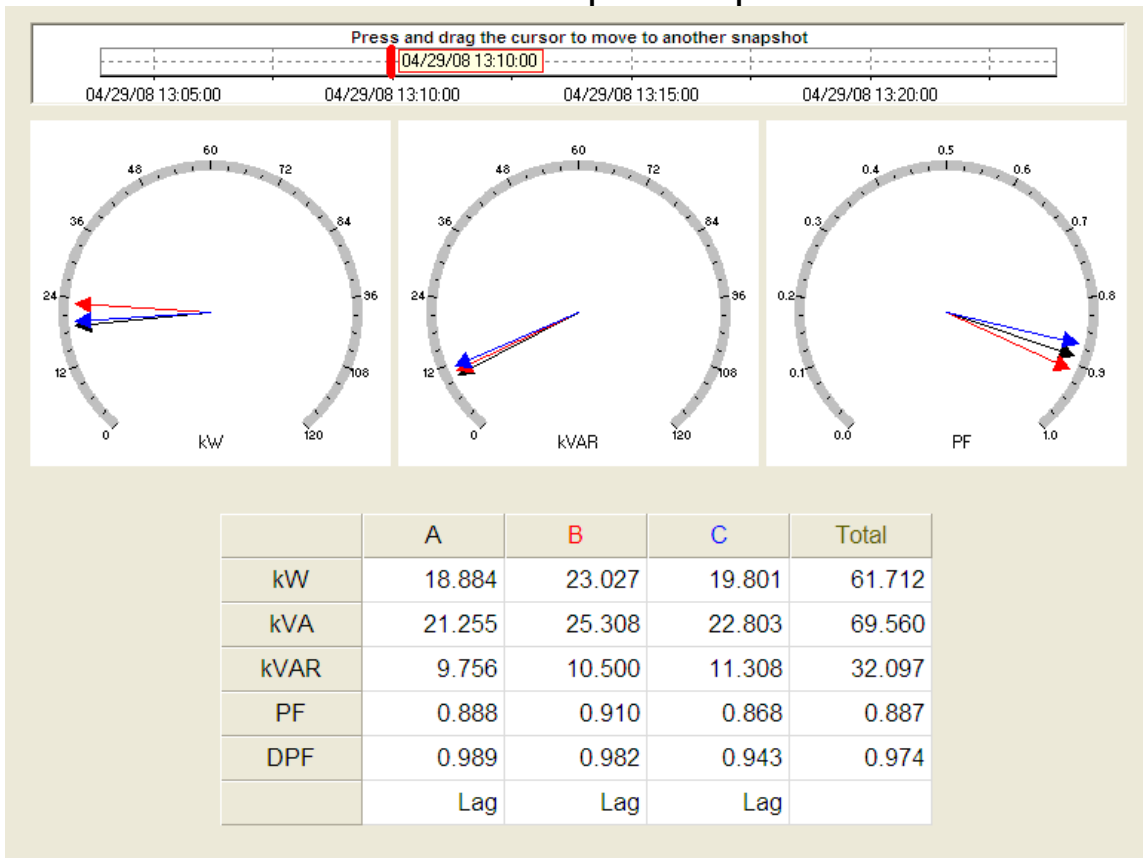
Current

Phase B Current

Phase C Current

Snapshot time: 04/29/2008 13:10:00

## UPS 2 Output Snapshot Power



Phase

Selection: A

Phase Selection: B

Phase Selection: C

Snapshot time: 04/29/2008 13:10:00

Power Factor: PF

# Thermal Assessment Section 1

## 1.1 Objectives

The objectives of this study are to:

- Provide a site inspection of the Any Data Center at Anywhere, MN is approximately 1100 sq-ft.
- Collect information about the computer room environment including but not limited to cooling equipment and thermal evaluations
- Provide a floor plan showing the location of existing equipment, server racks, airflow obstructions, etc...
- Provide a CFD report showing the airflow characteristics
- Generate a written report documenting the findings
- Give recommendations for the replacement/relocation of cooling units and use of above ceiling plenum and under floor space

## 1.2 Survey Process

The Data Center Assessment tasks performed onsite include:

1. Site Survey
2. Cooling Environment Evaluation of
  - Under floor observation
  - As-is floor plan
  - Above ceiling observation
  - Vapor barrier observation
  - Rack observation
  - CRAC unit performance
  - PDU/UPS Readings
  - Rack inlet temperatures
  - Supply air diffuser air flows

# Thermal Assessment Section 2

## 2.1 Observations

### Facility

The Any Data Center is located at 1243 Happy Days Lane, Somewhere, MN 55555. The assessment and data collection took place on April 29, 2008. It is approximately 1100 sq-ft with 9' high walls, a 5" under floor and a 70" above ceiling plenum. The room contains (37) server and telecomm racks with varying heat loads, wall mounted communication equipment, (1) 22 ton CRAC unit, (3) temporary 5 ton MovinCool cooling units and other miscellaneous equipment and devices. The floor is made up of 2'x2' tiles. There are floor penetrations at each rack for cabling along with other cutouts along the perimeter of the room for conduits. The ceiling is made up of 2'x4' heavy duty tiles, 2'x4' fluorescent light fixtures, and 2'x2' diffusers associated with the ducted supply air. The pressure difference between the data center and the adjacent area is positive 0.007 inches of water. The room is located in the interior of the one story building with only one entry location that is access controlled. The area surrounding the data center is comprised mainly of open office space.

### Racking

Various computer rack manufacturers were employed in the data center. Most racks had doors on their inlet and exhaust sides. Those that did had fully perforated exhaust doors and glass panel inlet doors with a perforated border for airflow. The width between rows was between 2-1/2 and 3 feet. Many of the racks did not contain side panels or blanking plates for empty U slots. This can lead to short circuiting which is when exhaust air from a server is pulled into the inlet of another server in a neighboring rack before it is cycled back through a CRAC unit. This leads to higher server temperatures and possible failure of equipment. Also, some racks had wires resting over a large portion of the exhaust side of the servers. Wiring can act as an air obstruction which reduces airflow through the servers and holds unwanted heat near the racks. This can dramatically raise server temperatures. Wiring that serves rack computer equipment should be kept to a minimal length and organized along the sides of the rack to avoid obstructing hot exhaust airflow. Examples of this seen in the data center are shown on next page.

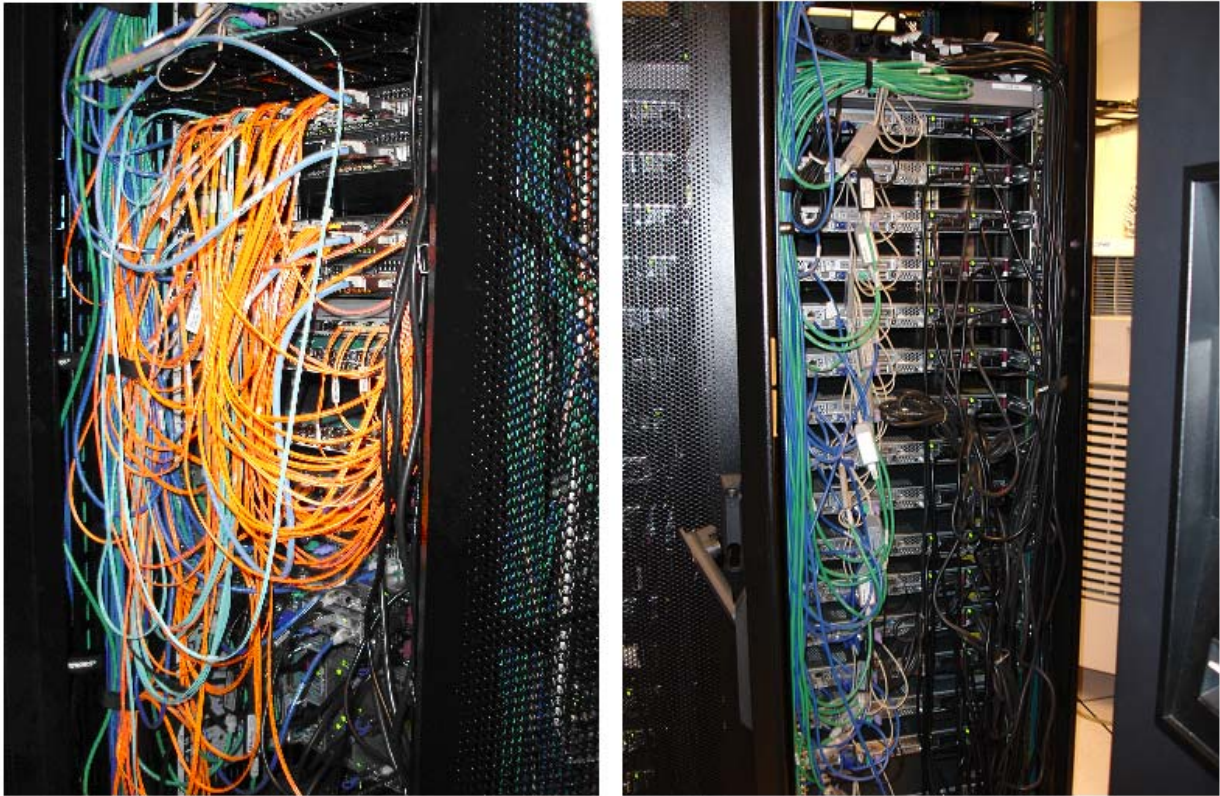


Figure 2.1.1 – Dense Cabling Restricting Server Air Flow

Approximately 18% of the racks in the data center were experiencing inlet temperatures above 77 degrees F. Any air above 77 degrees F supplying rack equipment is considered a “hot spot” and can have a very negative effect on the performance and life of the data center’s servers. The largest contributing factor to this is the layout of the data center. Currently a hot/cold aisle configuration is not being used. When this system is not implemented, short circuiting of air is almost always present. This is when hot exhaust air from servers is directed into the inlet of other servers either in neighboring racks or within the same rack before it is returned back to the CRAC unit. Short circuiting significantly raises temperatures seen by server inlets. In this particular situation, hot air is being short circuited up to four times! Air is moving through servers in Row B directly through Row C, through Row D and finally through Row E because of rack configuration. See Figure 2.3.1 for an illustration of this. Liebert recommends that hot and cold aisles are utilized throughout the data center to ensure that cool CRAC air is being provided to each server inlet. This will help eliminate hot spots in the data center and improve both server and CRAC unit efficiency and uptime. Below is an illustration of the preferred rack arrangement.

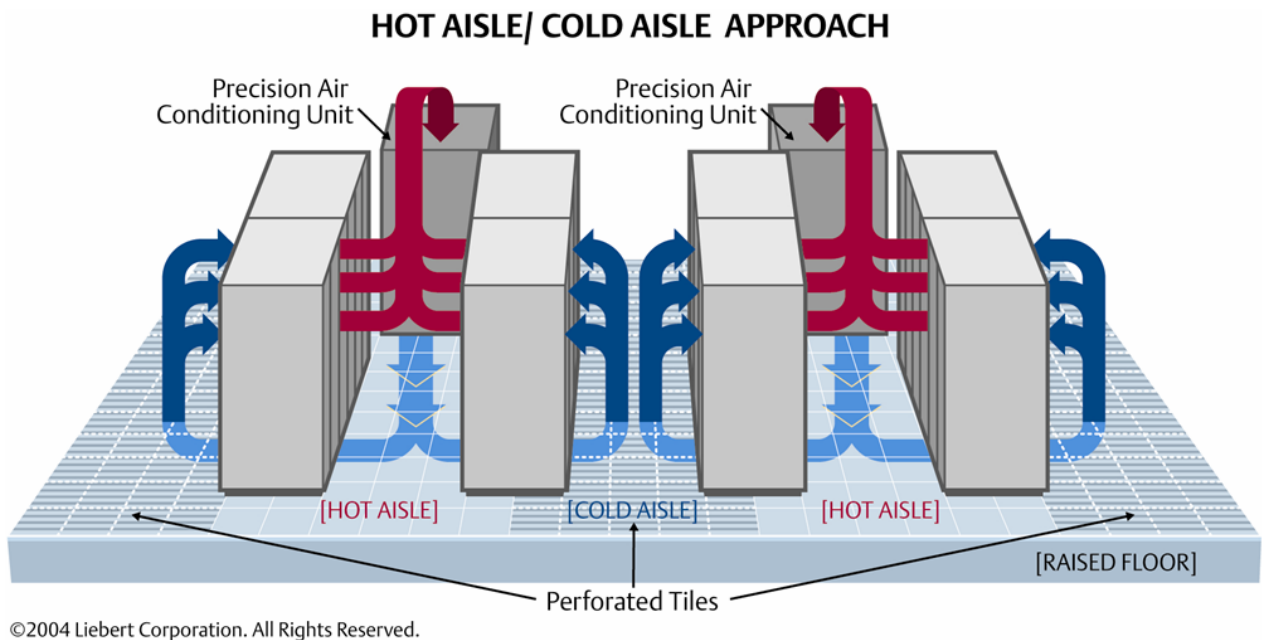


Figure 2.1.2 – Diagram of a True Hot/Cold Aisle Configuration

One of the most important things shown in this diagram is the location of the CRAC units at the end of the hot aisles. By having the CRAC units located here, the exhaust air can rise freely to the level of the CRAC unit's intakes while not being pulled into the intakes of the computer equipment. As most racks in the data center have room for additional equipment, there is the potential for higher heat loads being incorporated into the data center. As more computer equipment is added to this area or new, faster, and higher watt density equipment replaces existing equipment, higher rack temperatures are to be expected if changes to the availability of airflow are not made. This availability could be in the form of changes to the current airflow configuration or additions of more or newer cooling means.

Nearly every rack in the data center has its own cable floor opening. These raised floor openings not only allow cable to pass through but also air. This does not present any problems now due to the fact that there is no under floor airflow in the room. However, it is something that should be considered for the future during the data center expansion. Unaccounted air flow through cable penetrations presents a problem when trying to balance the air within the data center. Cable openings in the raised floor should be as small as possible or sealed up to ensure CRAC air is being directed to the appropriate locations.

### Floor Characteristics

The raised floor is 5" high and consists of 2'x2' floor tiles. There is no system of tile designation present. The under floor in the data center is not currently used as a supply air plenum for cooling the server racks. Rather, it is only used for routing cable to power the equipment inside the racks. Consequently, there were no perforated floor tiles for air flow but there were some openings in the floor (e.g. gaps between the floor tiles and the wall and cable openings under racks) which can compromise the vapor barrier of the room. When data centers share air with outside areas, air with uncontrolled levels of

humidity are able to mix with data center air which can negatively affect the security of the equipment in the room. The under floor cabling is very dense and in several areas it takes the entire depth of under floor space. Along with cabling, the under floor is also occupied by metal boxes, outlet boxes and CRAC unit supply/return lines.

## Ceiling

The data center has a dropped ceiling that utilizes 2'x4' heavy duty tiles with recessed lighting fixtures. The above ceiling is very congested with insulated ductwork coming from the 22 ton CRAC unit within the room and a 25 ton rooftop unit being ducted down. The ceiling holds (22) 2'x4' fluorescent lighting fixtures and (13) 2'x2' air grilles. Each lighting fixture contains (3) 32 W bulbs which adds a heat load to the room that must be accounted for also. The total lighting heat load for the room is 2.1 kW.

There were some issues with vapor barrier integrity within the above ceiling plenum. Any hole or unsealed penetration in the wall is a path for air to enter the data center from neighboring areas. This unwanted air does not have temperature and humidity controls that meet the demands of data center conditions. Examples found in the above ceiling plenum have been recorded and are shown below.

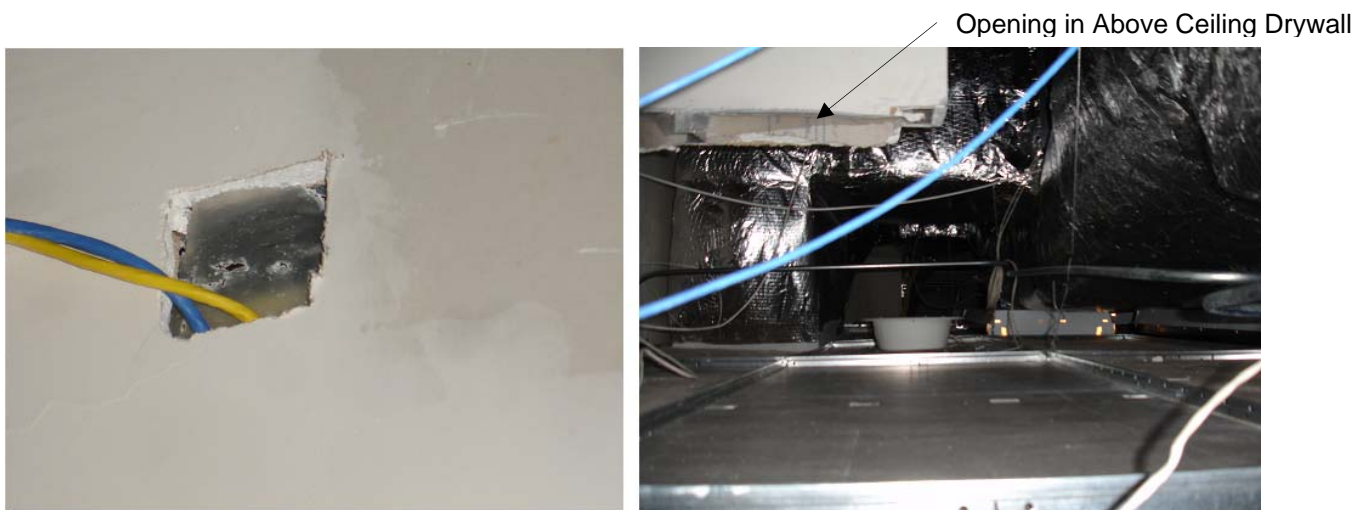


Figure 2.1.3 – Wall Penetrations in Above Ceiling Plenum

## Air Conditioning

(1) 22 ton Liebert Deluxe up flow unit is located inside the data center and (1) 25 ton Aeon rooftop unit is ducted down from the roof into common ductwork. These two units provide temperature and humidity control to the room. There are also (3) temporary 5 ton MovinCool units that are being used to supplement the room cooling. These units were shut off while room and rack temperatures were taken. The pre-filters on the 22 ton CRAC unit are showing signs of dirt which adds external static pressure to the unit and reduces unit airflow.

Table 2.1.1 CRAC Unit Properties

Unit #	Brand	Model Number	Nominal Tonnage	Set Point (°F)	Set Point RH(%)	Intake Temp. (°F)	Intake RH (%)	Fan Amps (A)	Unit Volts (V)	Fan RPM	Measured Unit Airflow (CFM)	Actual Tonnage
A	Liebert	VH290AUHAAEI	22	69 +/-3	45 +/-5	69	29	11.7	480	1063	10544	18.6
B	Aaon	AK25-3-E0-750	25	73	None	68.8	N/A	19.6	460	N/A	7545	17.4

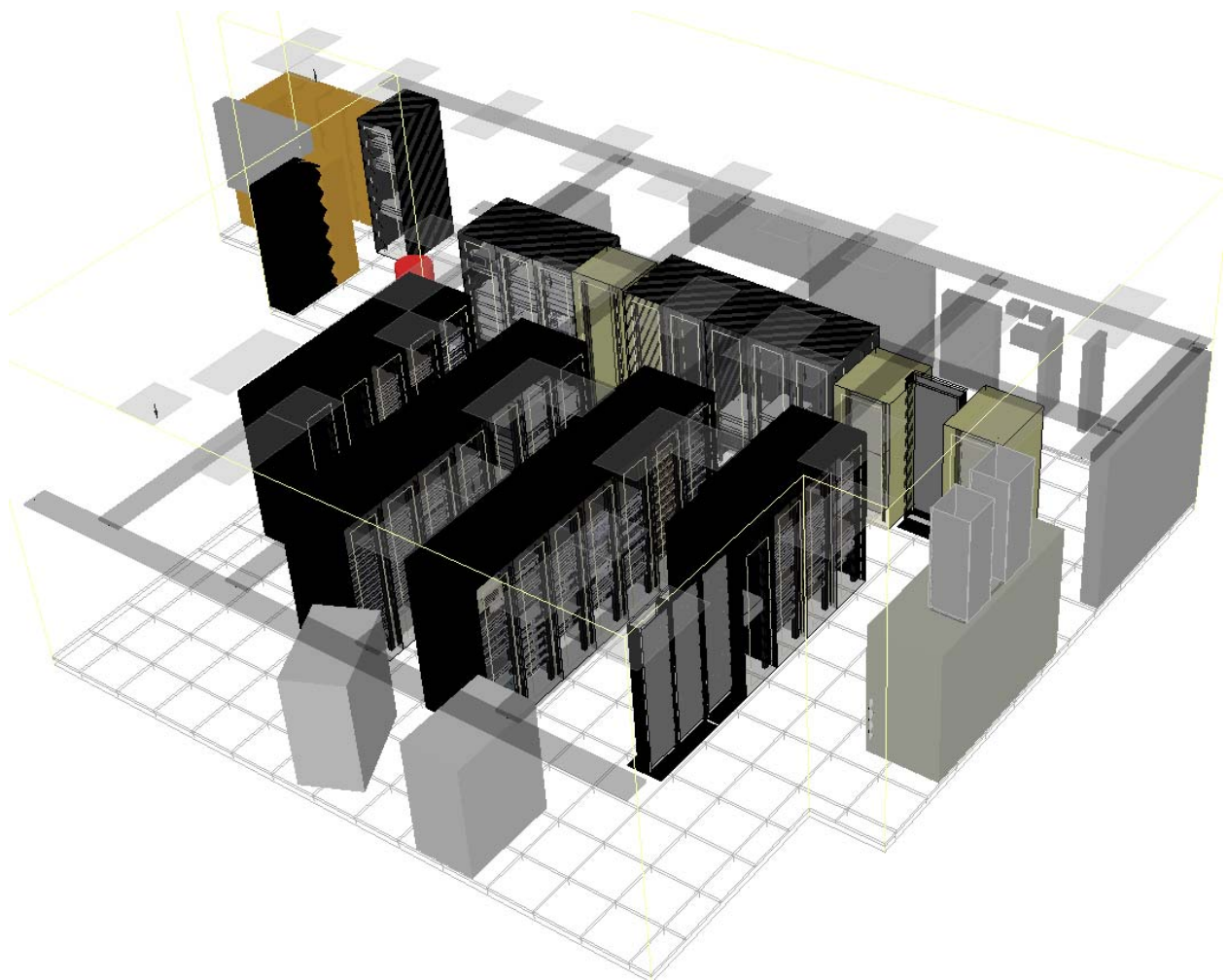
Unit #	Comments
A	Filters show signs of dirt but still in good condition. Could not see oil level of compressor. This should be investigated and adjusted appropriately soon. Overall condition of unit is good.
B	Unit is in good condition. Unit does not have low ambient head pressure control on compressors or enthalpy control. Economizer dampers are locked in closed position.

See appendix for cooling unit performance data.

## 2.2 CFD Study

This section begins the computational fluid dynamics, CFD, study for the data center. A CFD is a simulation tool that was designed to show how airflow is being accomplished for data centers, based on the height of the raised floor (if used), blockages under the floor, air supply locations, air handler locations, and any other obstructions or room characteristics that would affect the delivery of air to the equipment.

The CFD study confirmed all field conclusions made in that the problem is not with the cooling capacity available to the room. The problem is with rack configuration and CRAC placement. Additionally, despite up flow supply being an option, it is not preferred and lacks the cooling capabilities of an under floor supply.



Any Data Center – Anywhere, MN As-Is 3D View

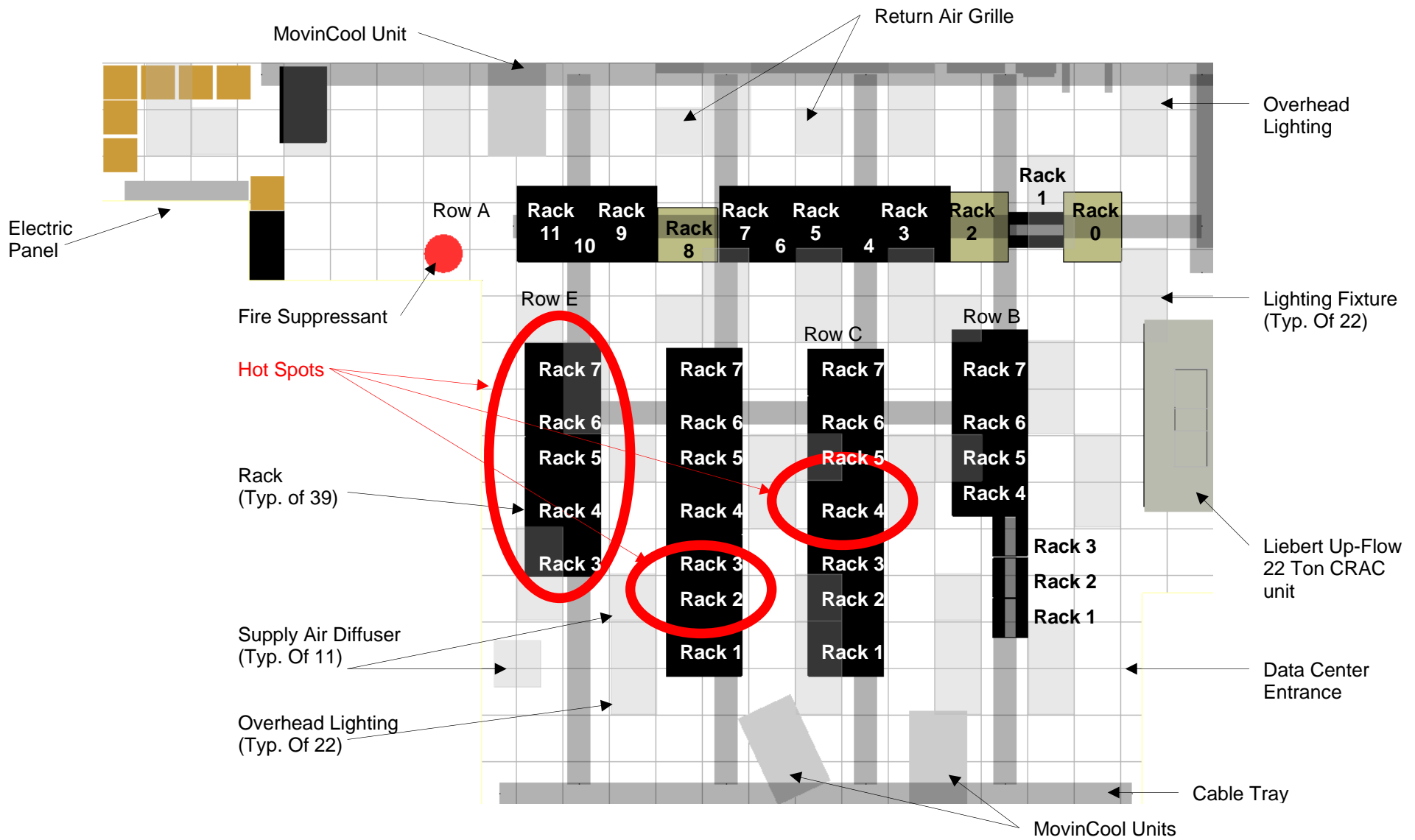


Figure 2.2.1 – As-Is Floor Plan

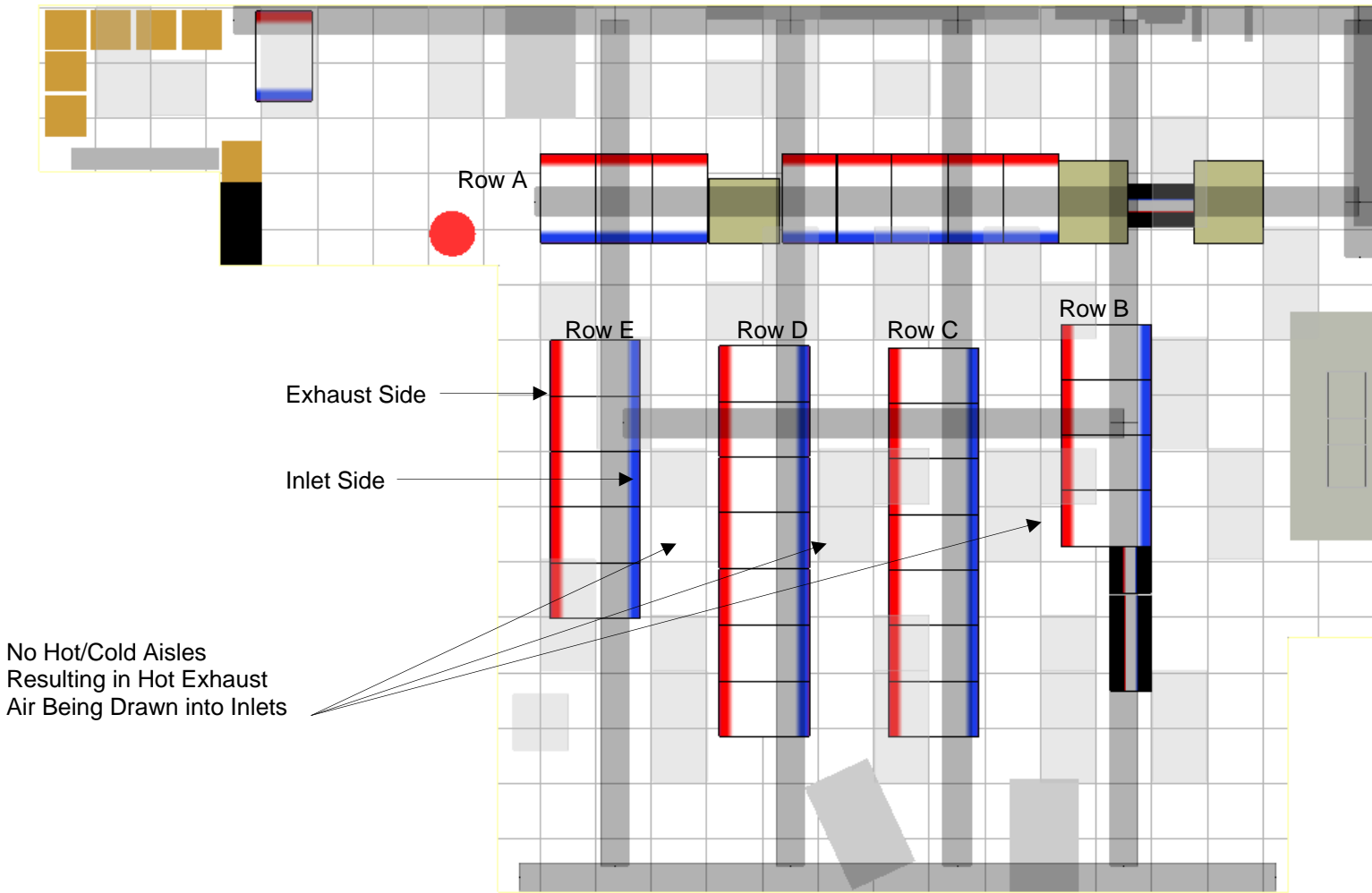


Figure 2.2.2 – Data Center Rack Inlet and Exhaust Plan

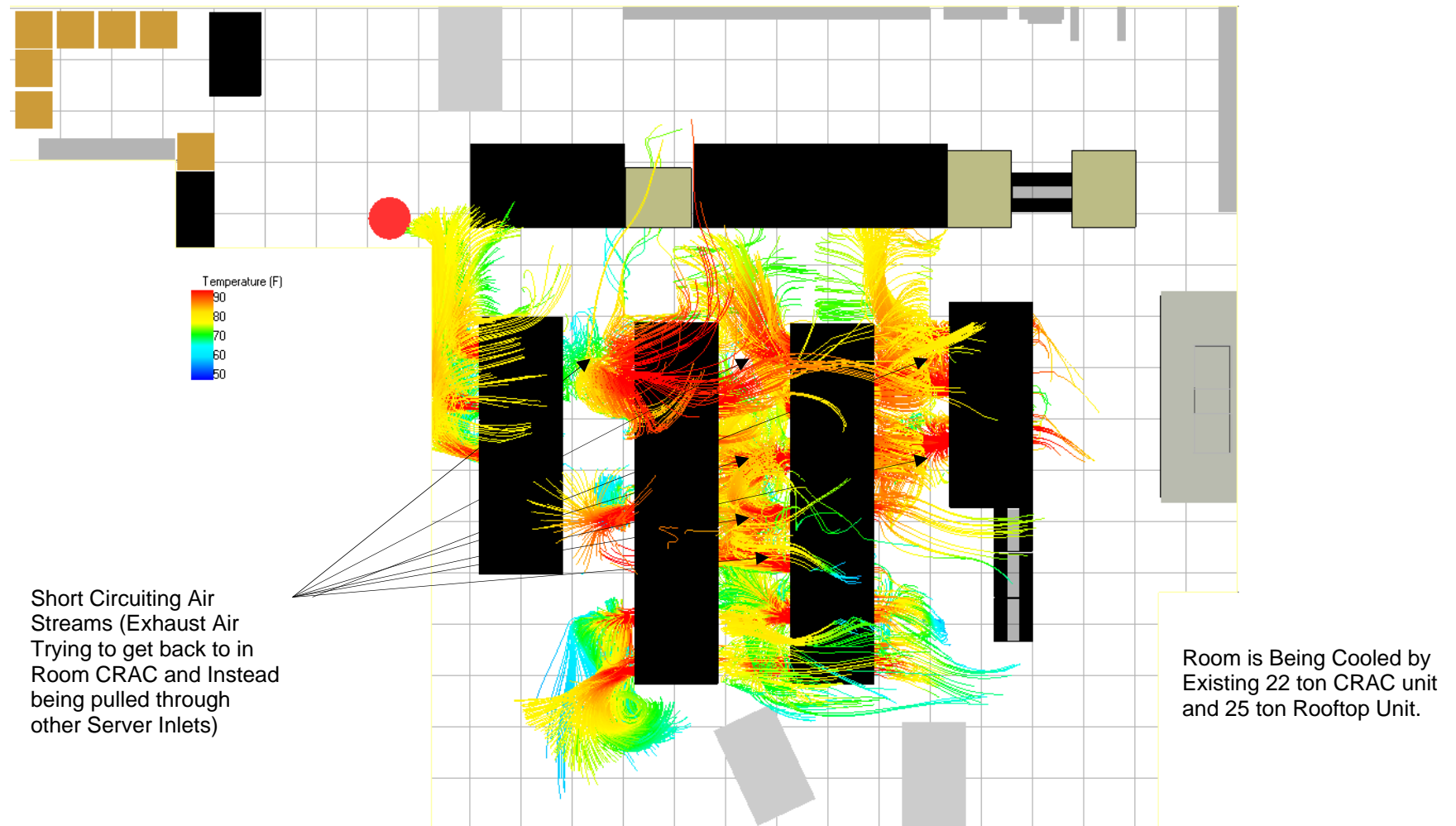


Figure 2.2.3 – Simulated Server Exhaust Airflow

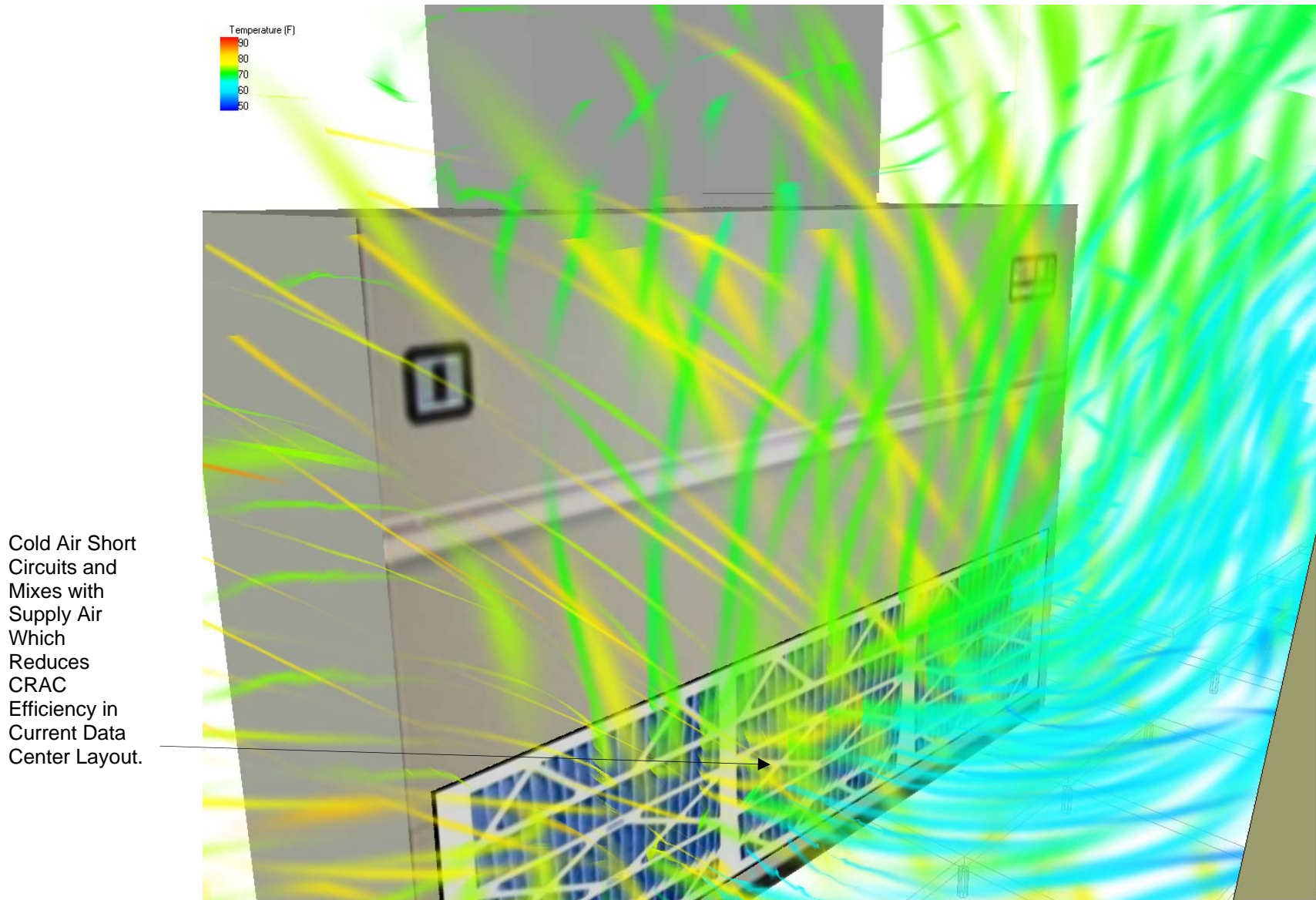


Figure 2.2.4 – Simulated Return CRAC Air

## 2.3 – Thermal Conclusions

The electrical power level being used for the server racks was 73.91 kW. This value was calculated using (2) 3 phase UPS units, the first one with phase 1 = 208 V / 192 A, phase 2 = 208 V / 214 A, and phase 3 = 208 V / 188 A, and the second one with phase 1 = 208V / 6.1 A, phase 2 = 208 V / 5.9 A, and phase 3 = 208 V / 9.5 A. This value does not include the power used by the (22) 3 bulb fluorescent lights (32 Watts/bulb). The data center lighting creates an additional load of 2.11 kW. Therefore, the total heat needing to be removed in the data center is approximated at (73.91 kW + 2.11 kW =) 76.02 kW.

Examining the results of the data center energy analysis, the total heat load is 76.02 kW and the maximum nameplate cooling capacity is 158.22 kW (45 Tons) given both the CRAC unit located in the room as well the rooftop unit are on and operating at maximum efficiency. However, these cooling units are not accounting for the entire load in the data center. This results in high server inlet temperatures being seen throughout because of poorly configured racks and a CRAC unit unable to effectively return room air. Another important consideration dealing with the available cooling for the data center is the weather conditions. The day of the assessment the outdoor temperatures were in the mid to upper 50s (degrees F) with approximately 50% relative humidity which requires minimal additional conditioning from the rooftop unit. In more severe conditions experienced during the summer months, hot and humid outside air will only reduce the available cooling capacity for the data center.

ASHRAE's Design Consideration for Datacom Equipment Centers recommends inlet temperatures between 68 and 77 deg. F with a maximum temperature to the computer equipment of 90 deg. F for Class 1 - Data Center Processing Environments (ASHRAE, 2004h). The rack with designation E5 experienced the highest measured inlet temperature at its top of 85.7 deg. F. There are several factors within the data center that contributed to these elevated inlet temperatures. First, rack E5 is located at the opposite end of the room from the CRAC unit. Because of this, exhaust air cannot be returned to the CRAC unit as efficiently as it should and becomes stagnant. This allows for nearby servers, including those in E5 to recycle hot exhaust air. Additionally, rack E5, as well as all of row E is backed up very close to a wall. When the exhaust air leaves the racks, it is forced up the wall. This air then can travel over top of the racks and be pulled back into the server inlets. Finally, the current aisle configuration is also greatly contributing to the hot temperatures seen at the inlet of rack E5. All of the hot exhaust air leaving the racks of row D is being forced directly to the inlets of row E. Approximately 18% of all the racks had high inlet temperatures above the recommended 77 deg. F. Computer equipment allowed to operate above the maximum inlet air temperature range may see problems arise like shortened life, equipment failure, decreased performance, etc. Hot spots are caused by the inability of the air to cool the equipment either by insufficient air flow or intake air temperatures that are too high to change the equipment temperature effectively. Consequently, there is no redundancy in the room which is well known as emergency cooling units are currently assisting to manage the data center heat load.

Vapor barrier integrity of the data center is fair. There are many spots where wall penetrations are sealed well ensuring no air transfer between the data center and exterior areas with less

control of temperature and humidity. However, there are also several areas that compromise the vapor barrier within the data center. There are some unsealed penetrations in the above ceiling which decrease the ability of the CRAC unit to maintain the set point humidity level. Also, there are no baseboards between the floor and the wall. It is good practice to have baseboards to reinforce the vapor barrier to safeguard against any unintentional or unknown wall penetrations. Similarly, the recessed lighting in the drop ceiling contains holes in the fixtures which are a place for air of varying temperature and humidity to enter the data center. A rooftop unit provides considerably less control in maintaining the room at a specific temperature and humidity. It is very important to match the set point of this unit to that of the CRAC to ensure the two units are not competing against each other.

The Any Data Center did not follow a hot/cold aisle configuration. All of the rack exhausts faced neighboring rack inlets. This prohibits hot air from effectively returning to the cooling units and more importantly allows short circuiting of warmer air back into the rack inlets in the same area. In the current layout, air is being pulled through up to four rows of racks before it is ever returned to the CRAC unit! When the exhaust from one rack becomes the intake air for another, problems arise very quickly. Another cause of short circuiting air is the narrow aisles between racks. A significant amount of air is being forced through these areas from both CRAC supply as well as the fans in the servers to meet the demand of the heat load. When there is limited area for this to happen, high generalized air velocities occur which creates low pressures. As a result, exhaust air from other areas of the room is forced into the aisle often replacing the much needed cold supply air. The recommended aisle width is 4 ft. A simulated illustration of this can be seen below where air is moving both straight through series of racks as well as back over the tops of racks to the same inlet areas.

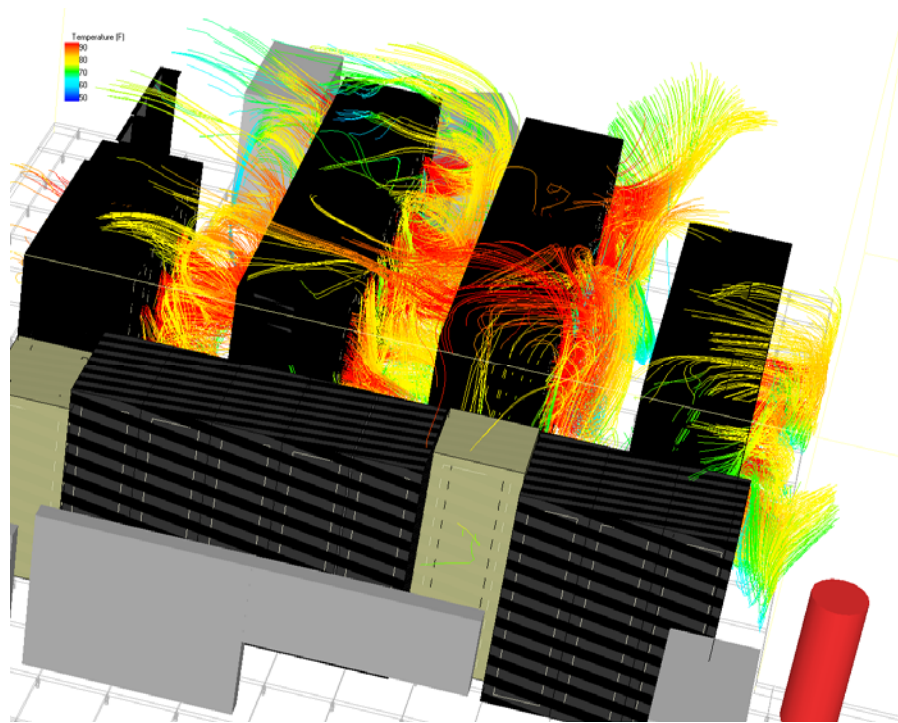


Figure 2.3.1 – Short Circuiting Exhaust Air

There is also a concern with the rack placement relative to CRAC unit location. Rack intakes should not be placed between rack exhausts and a CRAC unit return. There should also be sufficient distance between the cold air supply and CRAC units. Both of these scenarios cause short circuiting of air whether it be exhaust air being drawn through rack intakes or cold air short circuiting directly back to the CRAC unit which decreases efficiency and lowers capacity. As shown in Figure 2.2.4, this is an existing problem for the data center. Cold air is being mixed with hot exhaust air before and during its return to the CRAC unit. Decreased return air temperatures ultimately result in less cooling capacity available from the CRAC unit. In addition to this, the CRAC unit is sitting parallel to the aisles which also results in poor air circulation. The return grille pulls hot air from the exhaust aisles through cold aisles back to the unit. This mixing air increases the air seen at server inlets (see Table 2.3.1). The Liebert recommended location for CRAC units is at the end of hot aisles to promote quick hot air return.

There are a lot of benefits to using a raised floor for cooling including the ability to pin point cooling to specific areas, maintaining cable management, and executing overall organization of a Data Center. The Any Data Center did not utilize the raised floor layout. This, along with some disorganization of cabling and equipment has created a decrease in overall Data Center cooling ability.

Blockages under the floor should also be kept to a minimum in the case that the data center moves towards an under floor cooling solution. There are currently a large number of cables under the floor powering all the equipment. These obstructions block nearly the entire depth of the under floor in many spots.

Table 2.3.1 Field Temperature Measurements

Measured Rack Inlet Temperatures				
Row	Rack	Temperature (Degrees F)		
		Low (6 in.)	Middle (4 ft.)	High (6 ft.)
A	0	69.3	70.7	73.5
	1	68.1	69.9	74.6
	2	69.2	68.8	73.8
	3	68	68.5	69.8
	4	67	65.8	62.5
	5	67.3	66.3	68.9
	6	66.6	67.5	71
	7	66.1	67.5	71.3
	8	67.1	67.9	71.5
	9	68.6	68.5	69.4
	10	67.7	70.2	71
	11	68.3	70.9	71.9
B	1	67.2	67.7	67.6
	2	67.3	67.3	67.5
	3	67.8	68.1	72.6
	4	71.2	72.5	<b>81.2</b>
	5	72.4	70.9	76.1
	6	42.3	72.7	76.1
	7	72.2	74.2	75.4
C	1	65.7	65.4	68
	2	65.7	66.7	72.1
	3	67.1	68.9	72.1
	4	69.8	68.7	71.6
	5	69.1	65.5	71.3
	6	68.3	67.9	68.8
	7	69.4	69.8	70.5
D	1	65	64.8	73
	2	68.4	73.5	<b>78.3</b>
	3	69.7	71.6	73.8
	4	67.7	67.8	69.4
	5	67.4	66.6	60.6
	6	68	66.6	65.8
	7	67.8	68.7	71.5
E	3	67.5	70.1	<b>78.7</b>
	4	67.1	72.3	<b>82.6</b>
	5	66.3	76.5	<b>85.7</b>
	6	65.3	75.3	<b>82.7</b>
	7	64.3	74.3	<b>81.4</b>

Worst Case

Values in red denote data center "hot spots"

## 2.4 – Thermal Recommendations

1. Organize racks to create a hot/cold aisle arrangement to improve air flow in the data center and CRAC unit performance. Also increase the aisle widths to 4 ft. when space becomes available. This can be accomplished by rotating the racks in aisles C and E by 180 degrees.
2. Provide a redundant CRAC unit to ensure the safety of the data center in the event that the primary unit fails.
3. Relocate existing supply air diffusers to better place cold air in critical areas and conform to a hot/cold aisle arrangement of the data center.
4. Provide blanking plates to all empty U slots in the racks and replace missing rack side panels. This prevents both cold air from bypassing server inlets as well as exhaust air from short circuiting back to the inlets.
5. Organize all cabling at exhaust side of racks to the sides of the servers, thus enabling unrestricted flow of exhaust air.
6. Seal off the Data Center from other areas to maintain a vapor/temperature barrier so fluctuations in environmental conditions are eliminated.
7. Minimize the amount of fresh air entering the data center per local code to prevent the outside influence of moisture, temperature, and dirt. If the rooftop unit remains, enthalpy control should be added as well as low ambient control for the compressors.
8. Establish a tile designation system to compliment the current rack identification.
9. Monitor rack inlet temperatures regularly and keep ongoing records. This will help identify potential temperature rise trends allowing Any Data Center to correct by altering airflows. Proactive vs. reactive. Liebert offers “Follow-up Assessments” to assist with critical relocation of air grilles or equipment due to changing heat loads.
10. Set all cooling units to the same temperature and humidity set points. Ensure temperature/humidity sensors are calibrated periodically to prevent cooling units from fighting one another. Teamwork controls will allow cooperative cooling in all equipment to enhance this.

# Thermal Assessment Section 3

## 3.1 Data Center As-Is Solution

There are many steps that can be taken to improve the condition of the data center. Three significant modifications are needed and highly recommended at this point in time due to space limitations and an attempt to remain as non-invasive as possible to data center operation. The following CFD simulations are to be taken as representative only.

### Liebert Recommended Solution 1

- Provide side panels for racks and blanking plates for all empty U slots.
- Rotate the racks in rows C and E 180 degrees to form a hot/cold aisle configuration.
- Upgrade the cooling system.
  - Add (1) new 20 ton floor mounted cooling unit and place it at the end of the hot aisle.
    - Existing ductwork will need to be modified
  - Relocate existing CRAC unit to adjacent wall at end of other hot aisle
  - Provide redundancy with existing rooftop unit
    - Enthalpy control must be installed on unit if economizer is to be used to provide lower than 10 deg F compressor operation
    - Low ambient control must be installed on compressors
  - Relocate supply grilles to cold aisles (see plan).

The addition of only one CRAC unit has obvious advantages financially. If enthalpy and low ambient control can be added to the rooftop system, it can be used as the redundant cooling source for the data center. The existing CRAC unit can then be moved to the adjacent wall (as shown below) and work in combination with the new 20 ton unit. The above ceiling ductwork will need to be slightly reworked to accommodate the changes.

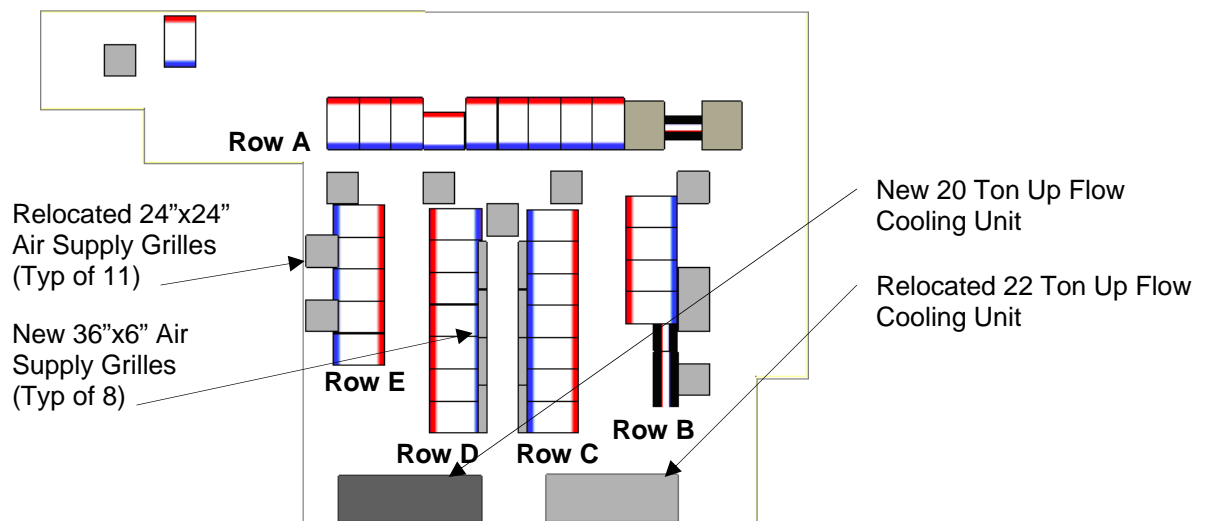


Figure 3.1.1 – Solution 1 Plan

## Liebert Recommended Solution 2

- Provide side panels for racks and blanking plates for all empty U slots.
- Rotate the racks in rows C and E 180 degrees to form a hot/cold aisle configuration.
- Upgrade the cooling system.
  - Add (2) new 20 ton floor mounted cooling units and place at ends of hot aisles.
  - Provide redundancy with existing 22 ton CRAC unit.
  - Relocate supply grilles to cold aisles (see plan).
- Use rooftop unit for other building needs or sell.

There are many difficulties associated with renovating a data center while it is in operation. There are two major considerations that would result in Solution 2 being the best plan of action. First, if it is not desired to move the existing CRAC unit, the two additional units can be added and ducted into the existing ductwork with some reworking required. Also, if enthalpy and low ambient control is not available for the rooftop system, the rooftop unit will not be recommended for use as it can't provide reliable redundancy. This will require the two new units specified to ensure N+1 redundancy.

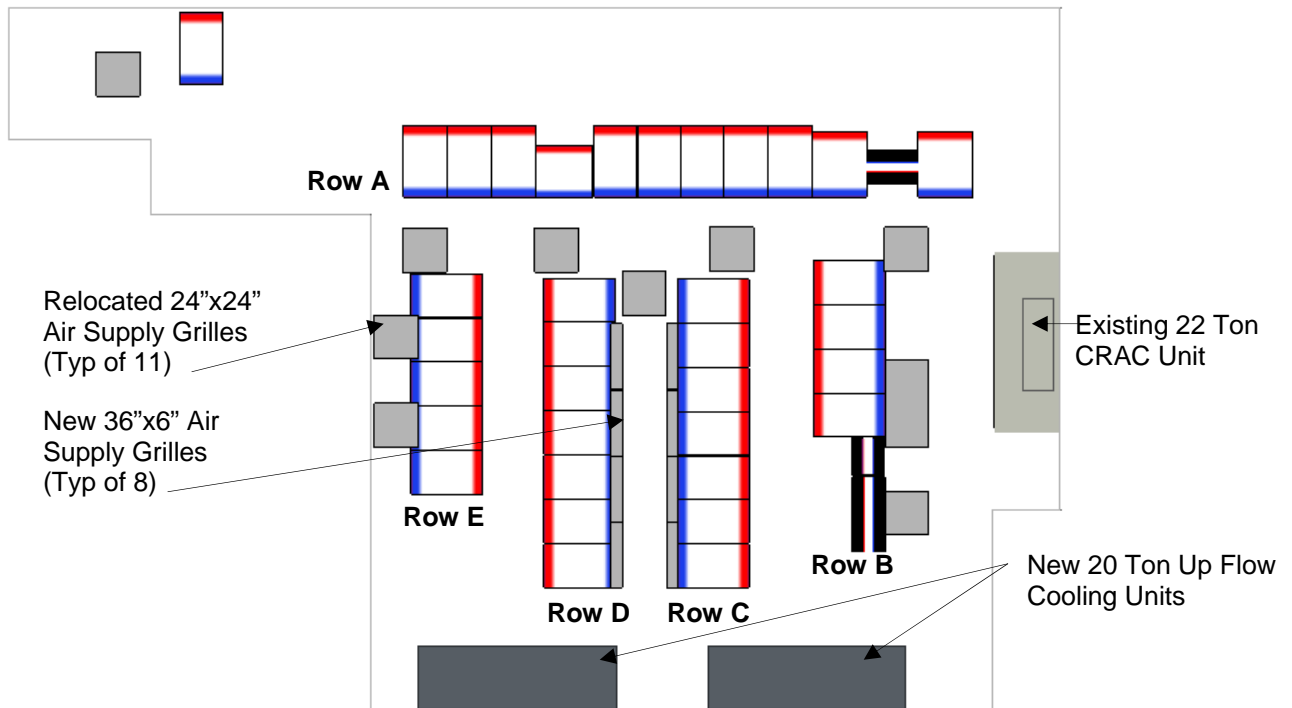


Figure 3.1.2 – Solution 2 Plan

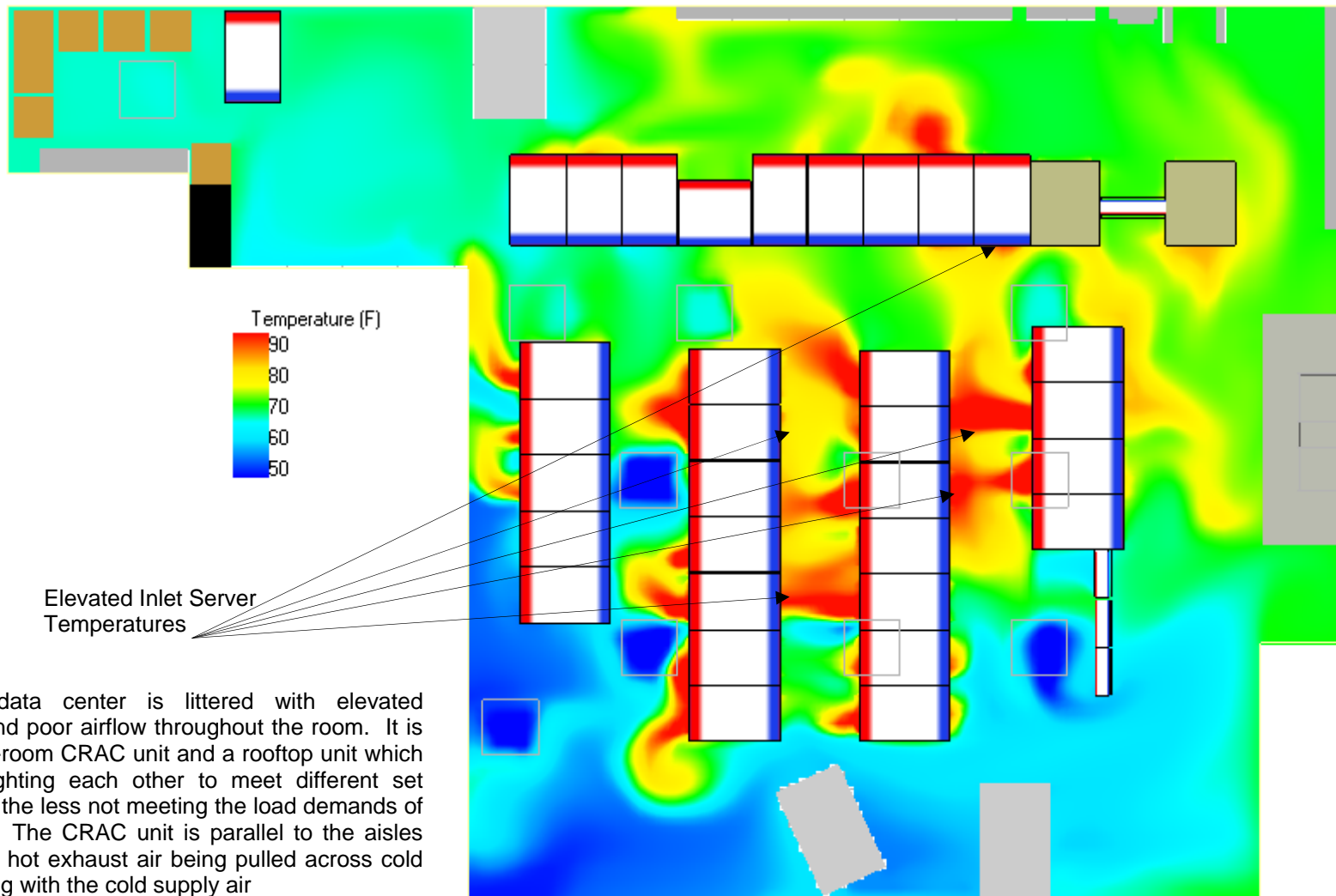


Figure 3.1.3 – As-Is Worst Case Temperatures (6ft.)

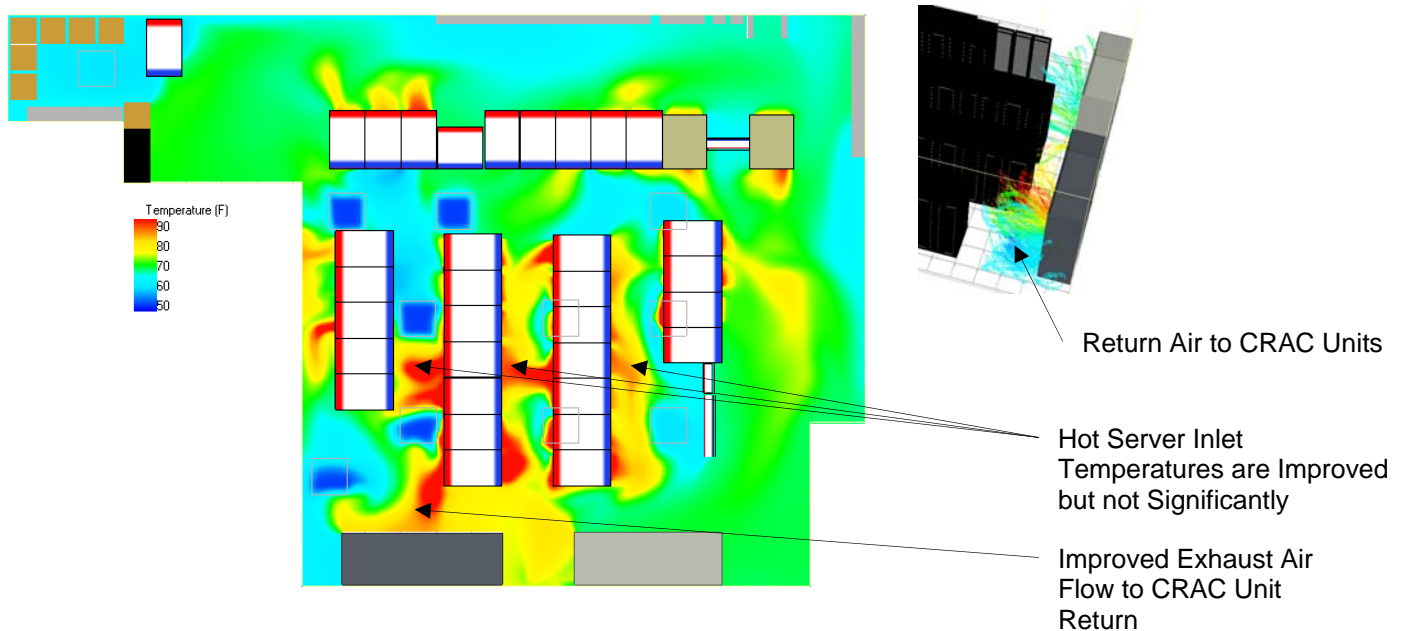


Figure 3.1.4a – Solution 1 – Without Blank Plates (6ft.)

Placing two CRAC units at the end of the rack aisles improves air flow efficiency and reduces hot air mixing with cold supply air. Due to the rack configuration though, there is still an abundance of short circuiting air present.

The addition of blank plates helps eliminate localized short circuiting which is caused by server inlets pulling exhaust air through open space in the rack. This happens when the quantity of air on the inlet side is not satisfying the needs of the servers. With blank plates installed, the hot exhaust air is unable to be pulled back through the rack which allows for cooler air from other areas of the room to be pulled in.

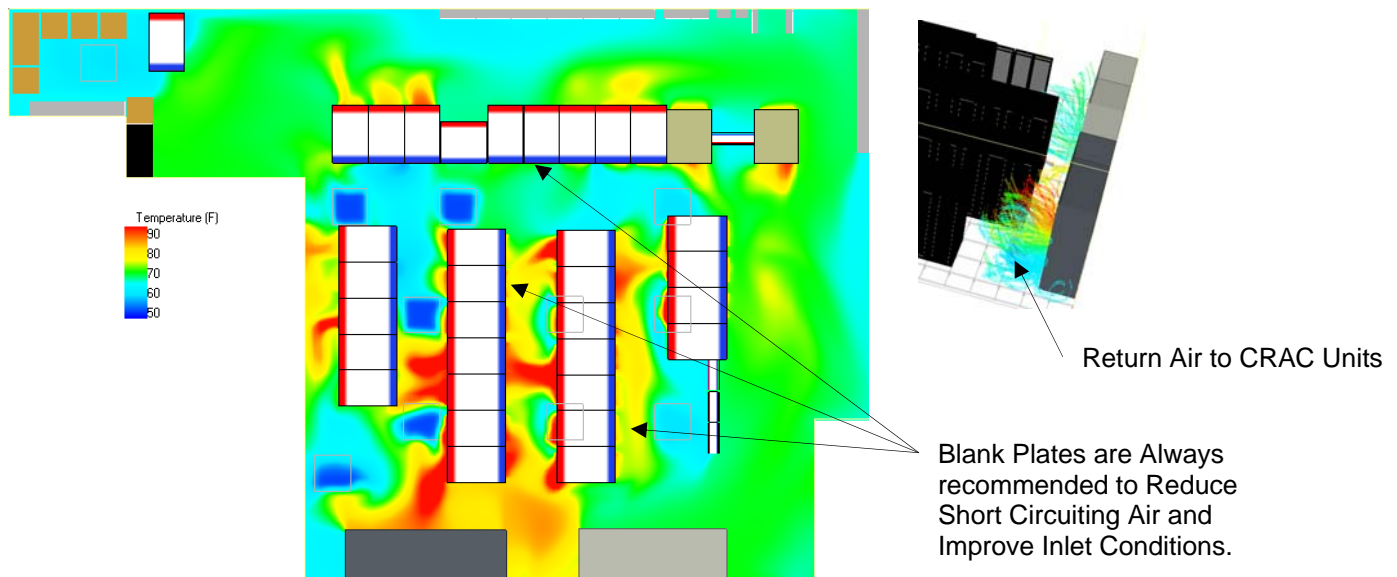


Figure 3.1.4b – Solution 1 – Blank Plates Added (6ft.)

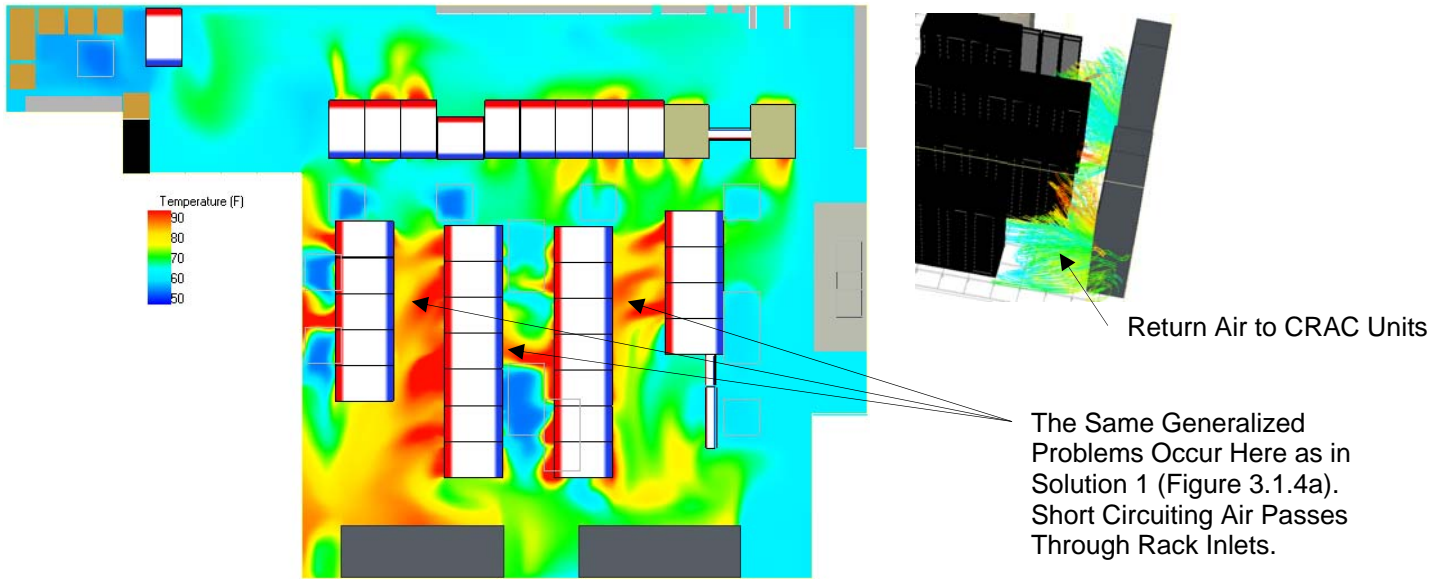


Figure 3.1.5a – Solution 2 – Without Blank Plates (6ft.)

Placing two CRAC units at the end of the rack aisles improves air flow efficiency and reduces hot air mixing with cold supply air. Due to the rack configuration though, there is still an abundance of short circuiting air present.

The addition of blank plates helps eliminate localized short circuiting which is caused by server inlets pulling exhaust air through open space in the rack. This happens when the quantity of air on the inlet side is not satisfying the needs of the servers. With blank plates installed, the hot exhaust air is unable to be pulled back through the rack which allows for cooler air from other areas of the room to be pulled in.

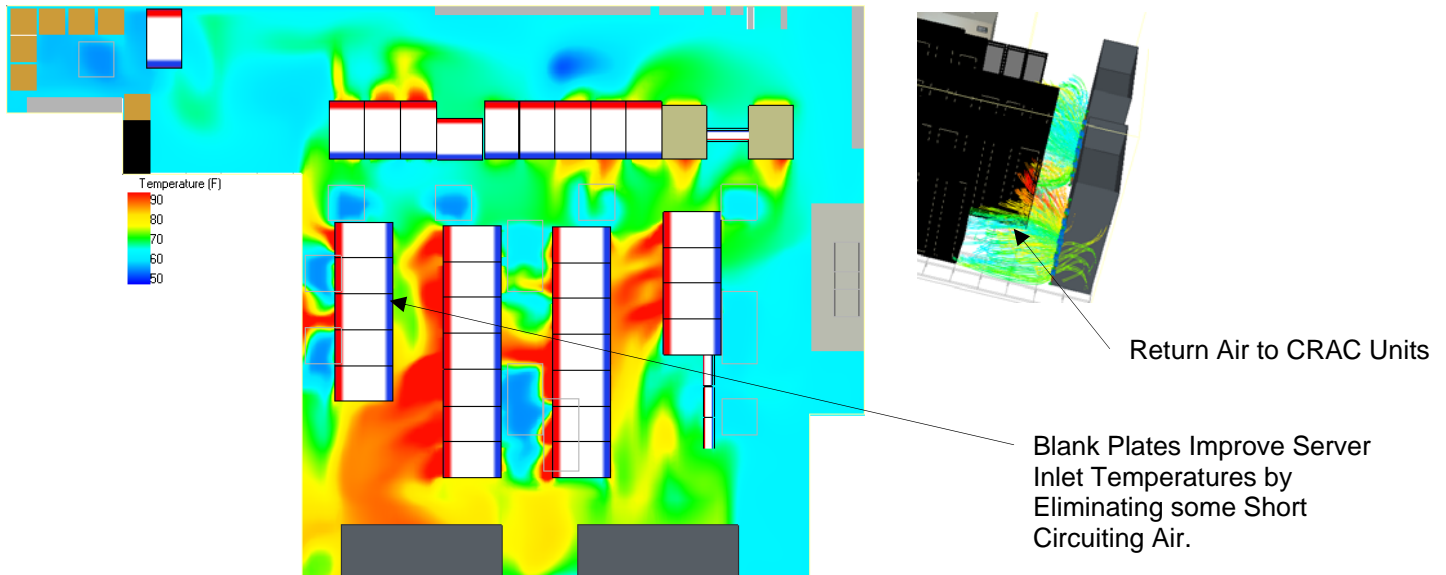


Figure 3.1.5b – Solution 2 – Blank Plates Added (6 ft.)

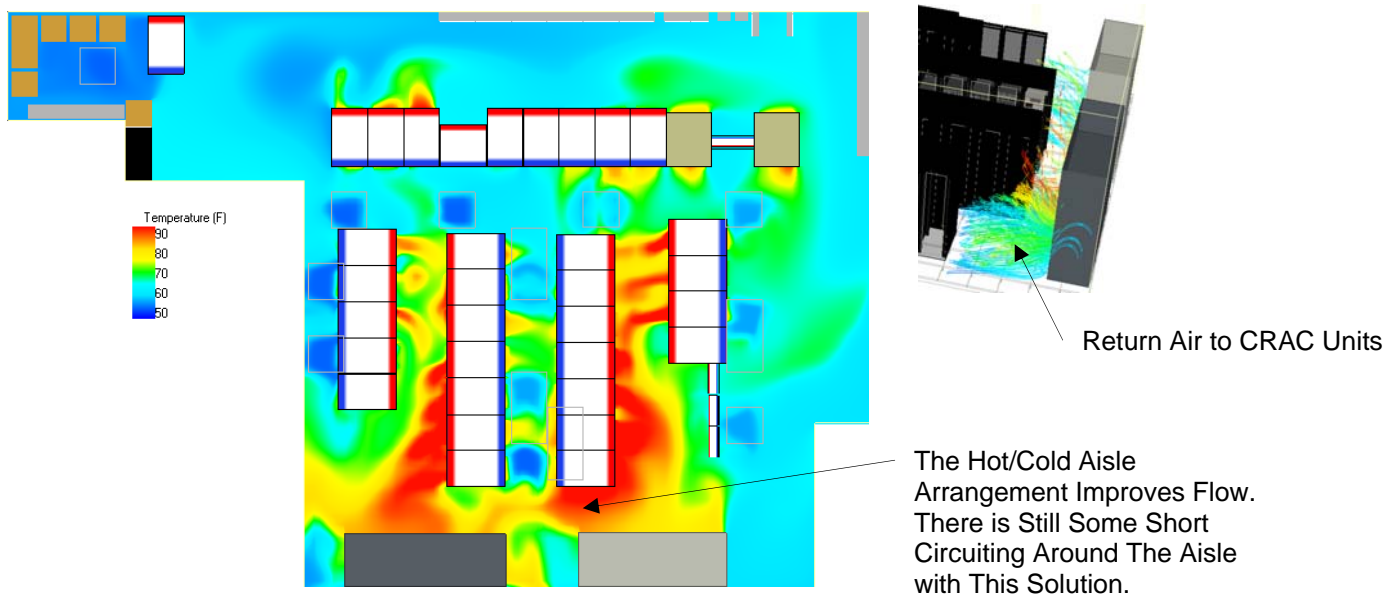


Figure 3.1.6a – Solution 1 – Hot/Cold Aisle w/out Blank Plates (6ft.)

Reconfiguring the rack layout to a hot/cold aisle arrangement provides immense improvements to data center efficiency. The hot exhaust air is isolated away from server inlets much more efficiently, especially with blank plates installed on all empty U slots. In this layout, air supply grilles can be relocated to provide cold air only where it is needed.

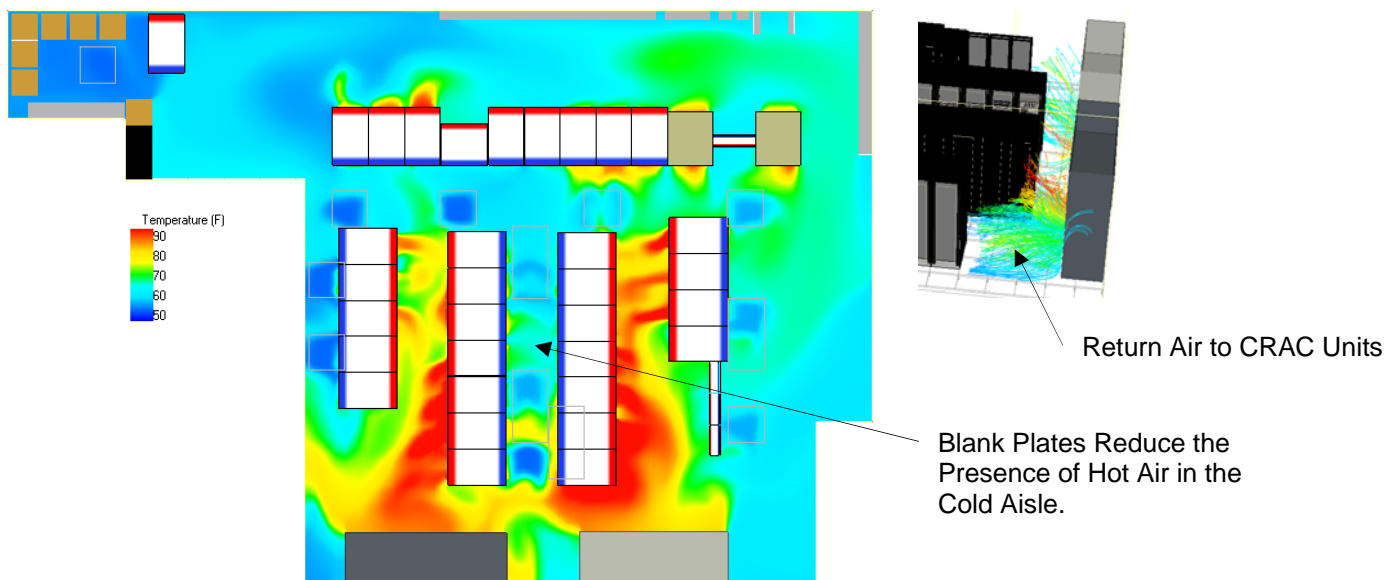


Figure 3.1.6b – Solution 1 – Hot/Cold Aisle w/Blank Plates (6ft.)

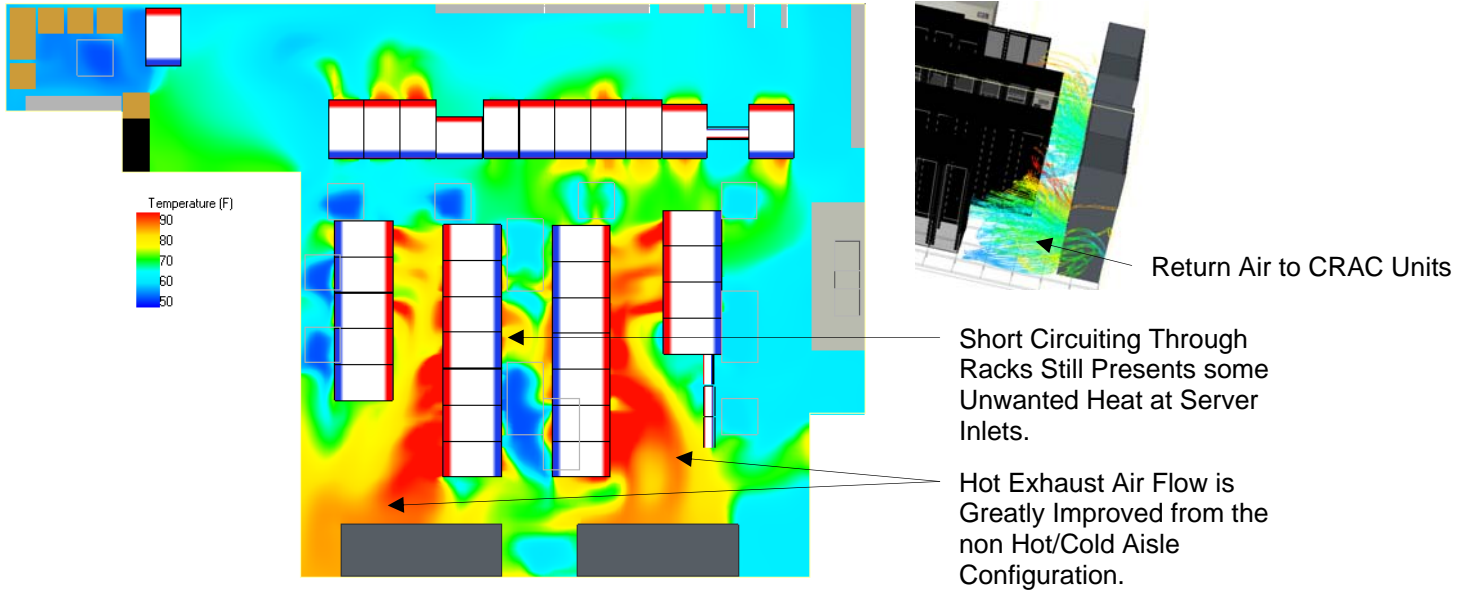


Figure 3.1.7a – Solution 2 – Hot/Cold Aisle w/out Blank Plates (6ft.)

Reconfiguring the rack layout to a hot/cold aisle arrangement provides immense improvements to data center efficiency. The hot exhaust air is isolated away from server inlets much more efficiently, especially with blank plates installed on all empty U slots. In this layout, air supply grilles can be relocated to provide cold air only where it is needed.

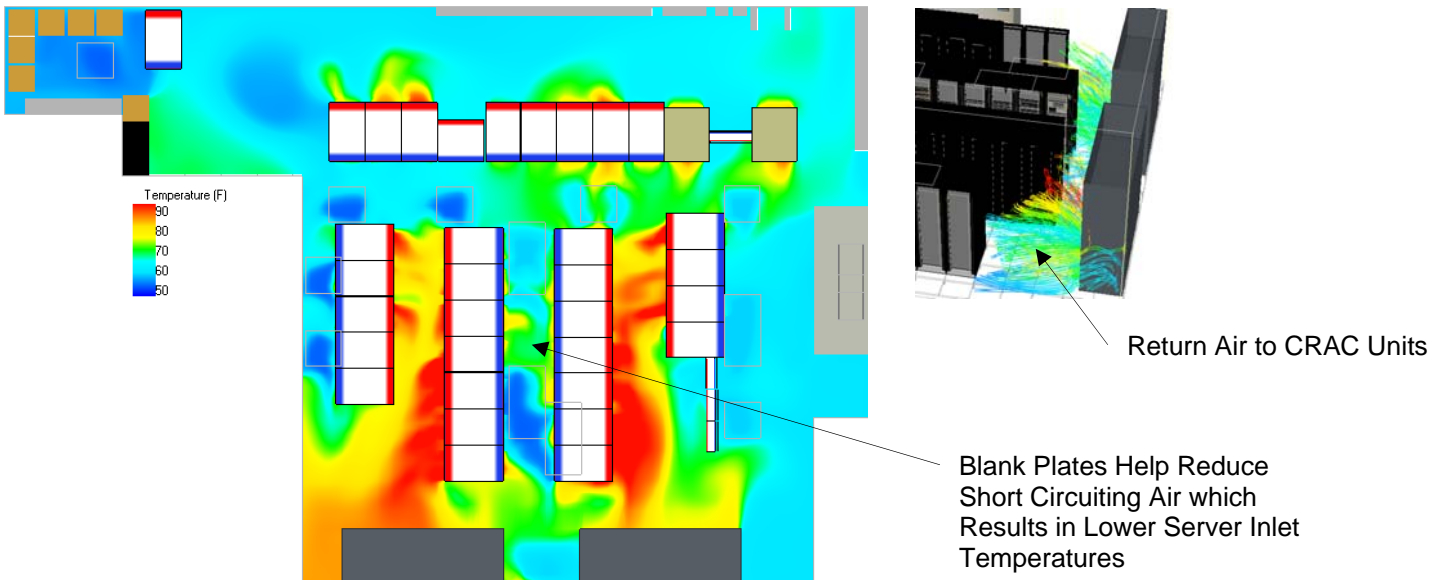


Figure 3.1.7b – Solution 2 – Hot/Cold Aisle w/Blank Plates (6ft.)

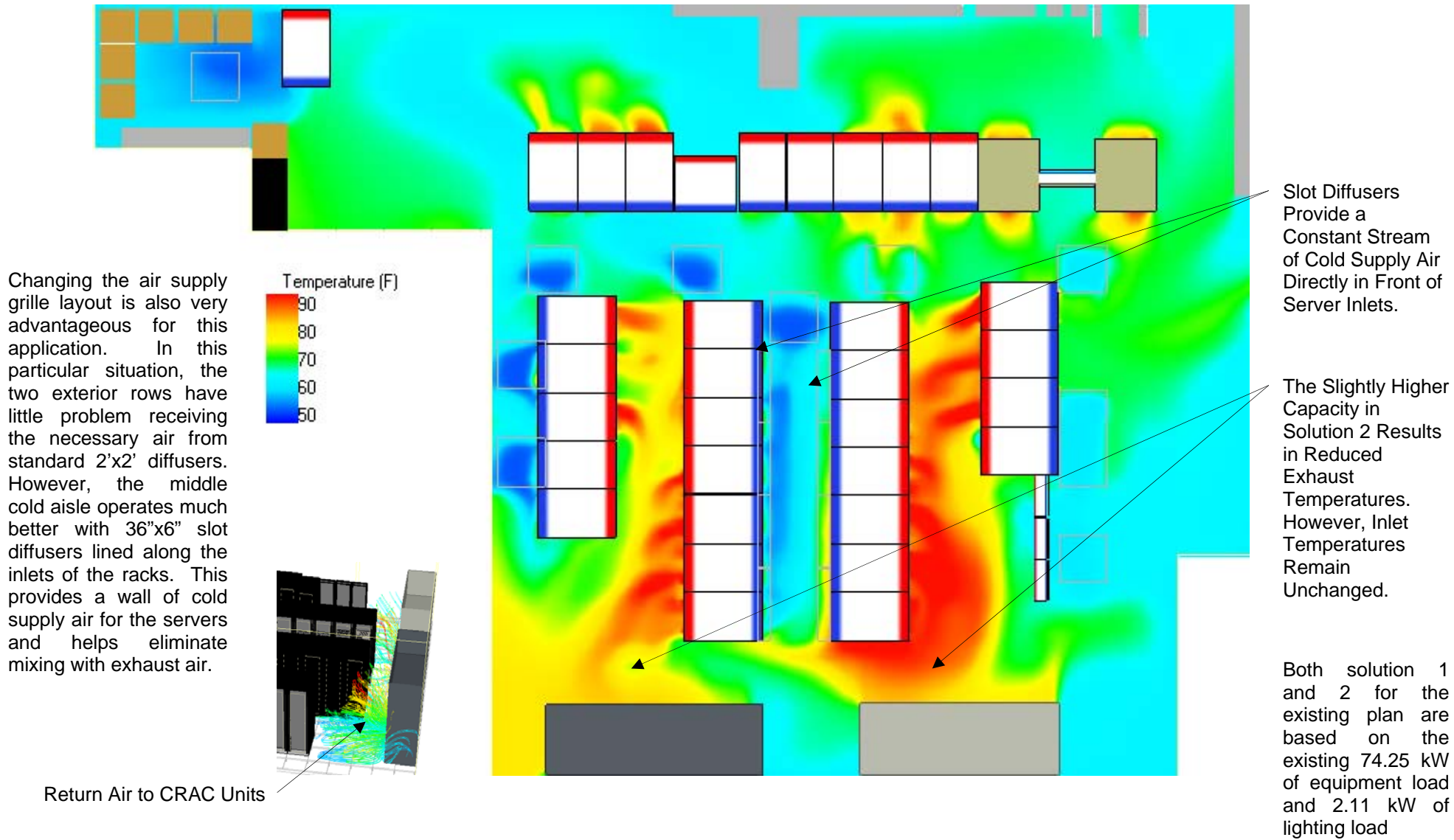


Figure 3.1.8 – Solution 1 – Complete with New Supply Grilles (6ft.)

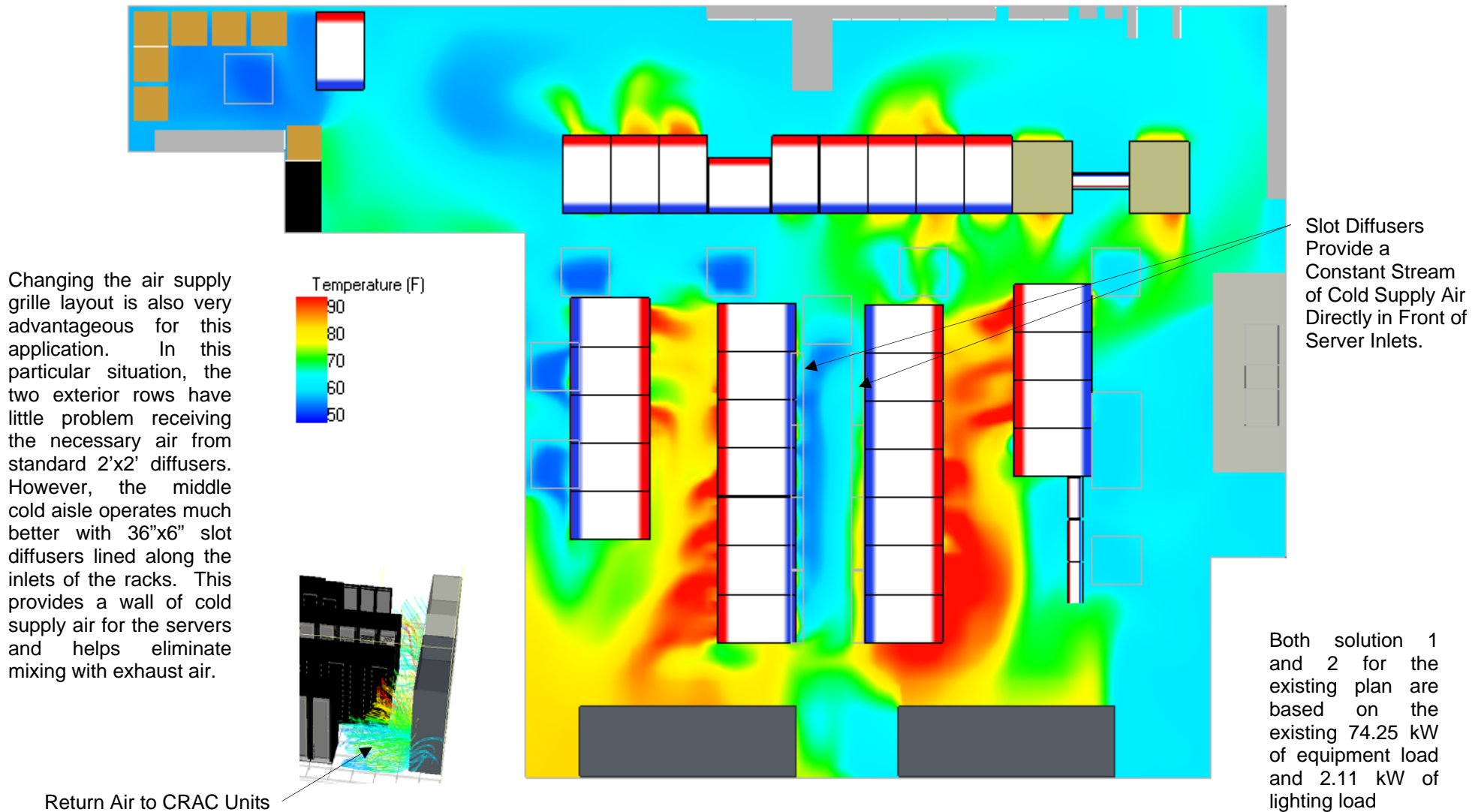
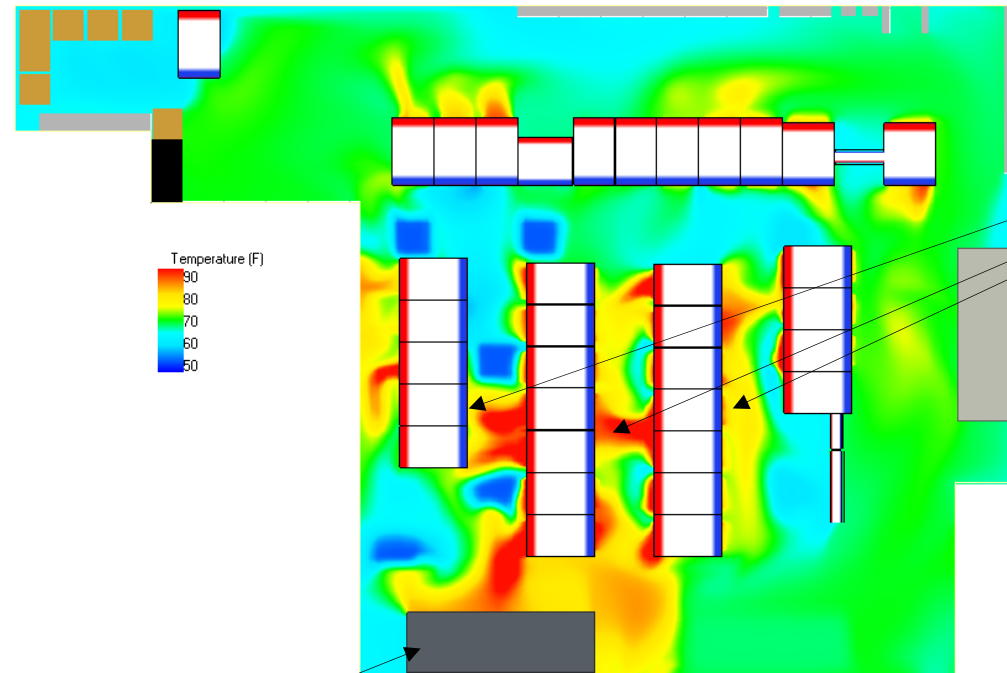


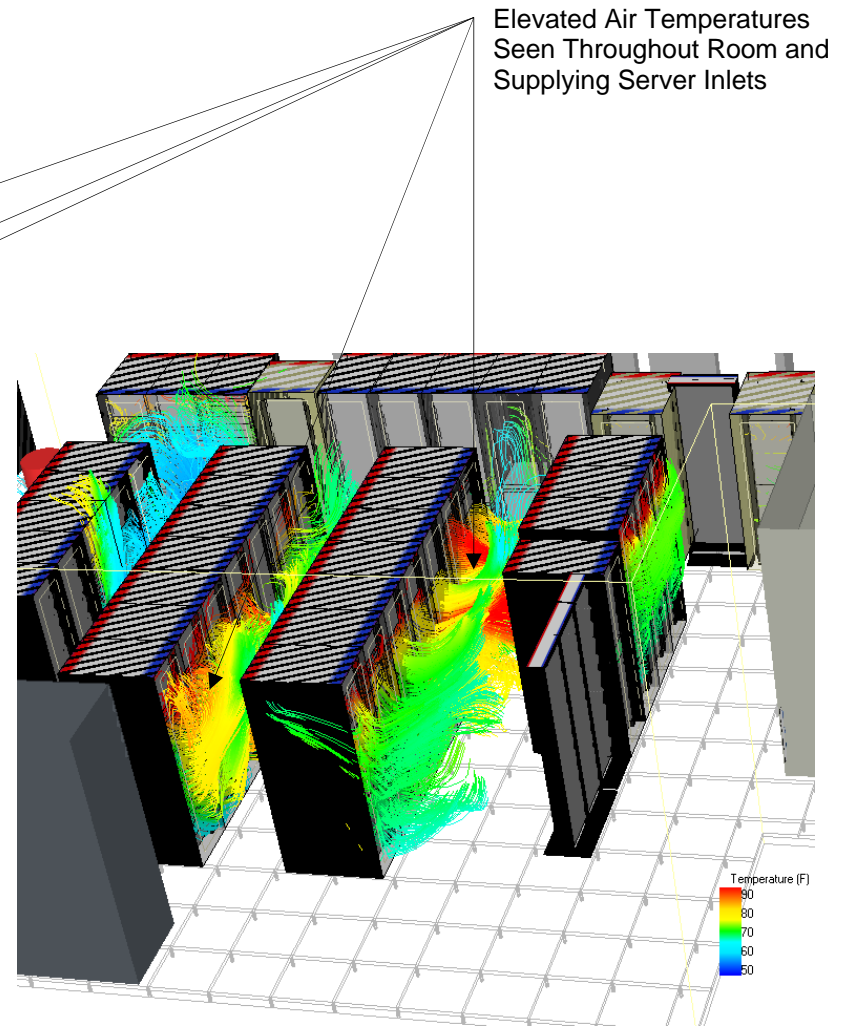
Figure 3.1.9 – Solution 2 – Complete with New Supply Grilles (6ft.)



New 20 Ton CRAC Unit

### Air Temperatures at 6 ft

Simply adding more cooling to the room is not the answer for the problems in this data center. The changes previously discussed in this section must be completed to see a real improvement in the data center cooling and server well being.



### Server Inlet Air Streams

Figure 3.1.10 – Data Center with the Addition of a Second CRAC Unit Only

## 3.2 Liebert Recommended Data Center Expansion Solution

Growth in a data center is inevitable for a growing business. Whether it is more servers per rack or more data center floor space, additional heat load will be realized. That creates the need for additional cooling either from new units or pushing the existing units for more capacity. Below, two expansion plans are outlined, one for expansion in the existing space and one for expansion into the adjacent area.

### Expansion in Current Data Center

All of the new CRAC units installed in the existing solutions outlined above have fans operating slightly below their rated value. Increasing the fans to max output provides sufficient cooling for a 25% increase in heat for both solutions. Once the room load begins to expand beyond this initial 25% load increase, additional space and cooling will be needed to ensure all of the equipment is being properly cooled. The following images are when all of the previously discussed changes have been made including blank plates, rack orientation, and additional units added. Room loads here consist of 92.75 kW of equipment load and the same 2.11 kW of lighting load.

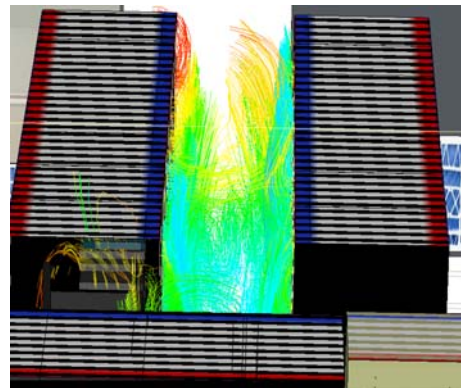
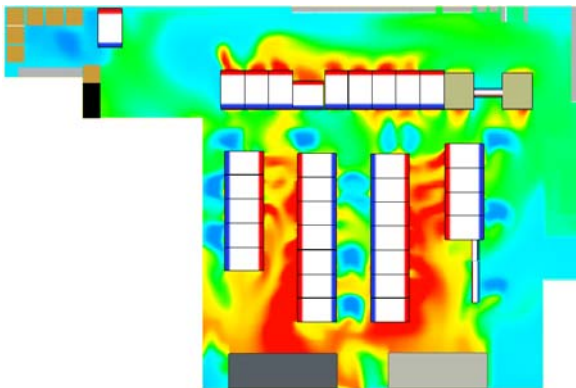


Figure 3.2.1 – Solution 1 with 25% Load Increase

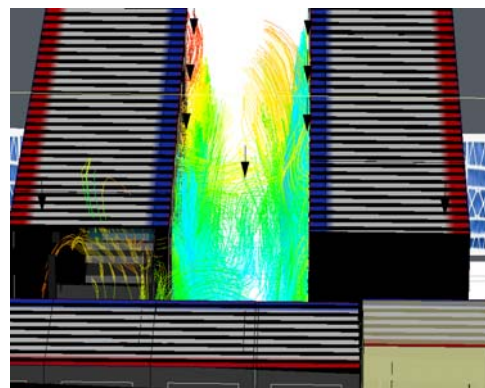
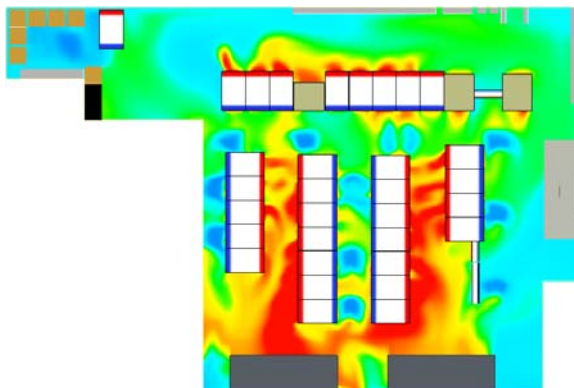


Figure 3.2.2 – Solution 2 with 25% Load Increase

## Phase 1 Expansion - Opening Adjacent Area

The first phase of the data center's physical expansion should be performed as follows:

1. Demolition of existing adjacent office space and set up new data center.
  - Provide room with 22" raised floor and open above ceiling space.
  - Provide perforated floor grilles with dampers in hot aisles and ceiling exhaust grilles.
    - (24) 2'x2' perforated floor tiles with 56% open area and dampers
    - (6) 2'x4' egg crate ceiling return grilles
  - The new raised floor data center should be sealed off from the rest of the building including the existing data center until the remodel of both areas is complete.
2. Install (3) 20 ton down flow CRAC units. (2) CRAC units will be cooling while the third is used for redundancy. (see plan below) Turning vanes should not be installed on CRAC supply grilles.
3. Sell or find other needs for existing up flow cooling units.
4. Move existing racks and servers over from adjacent data center.
5. All CRAC units have return air plenum connecting the unit to the ceiling. Refrigerant Piping will extend up through return air the plenums to rooftop condensers.

This room is based on  
73 kW of equipment load  
and 2.11 kW of lighting.

108 kW of Available  
Cooling Capacity with  
N+1 Redundancy.

19,200 CFM Provided  
From Two CRAC Units.

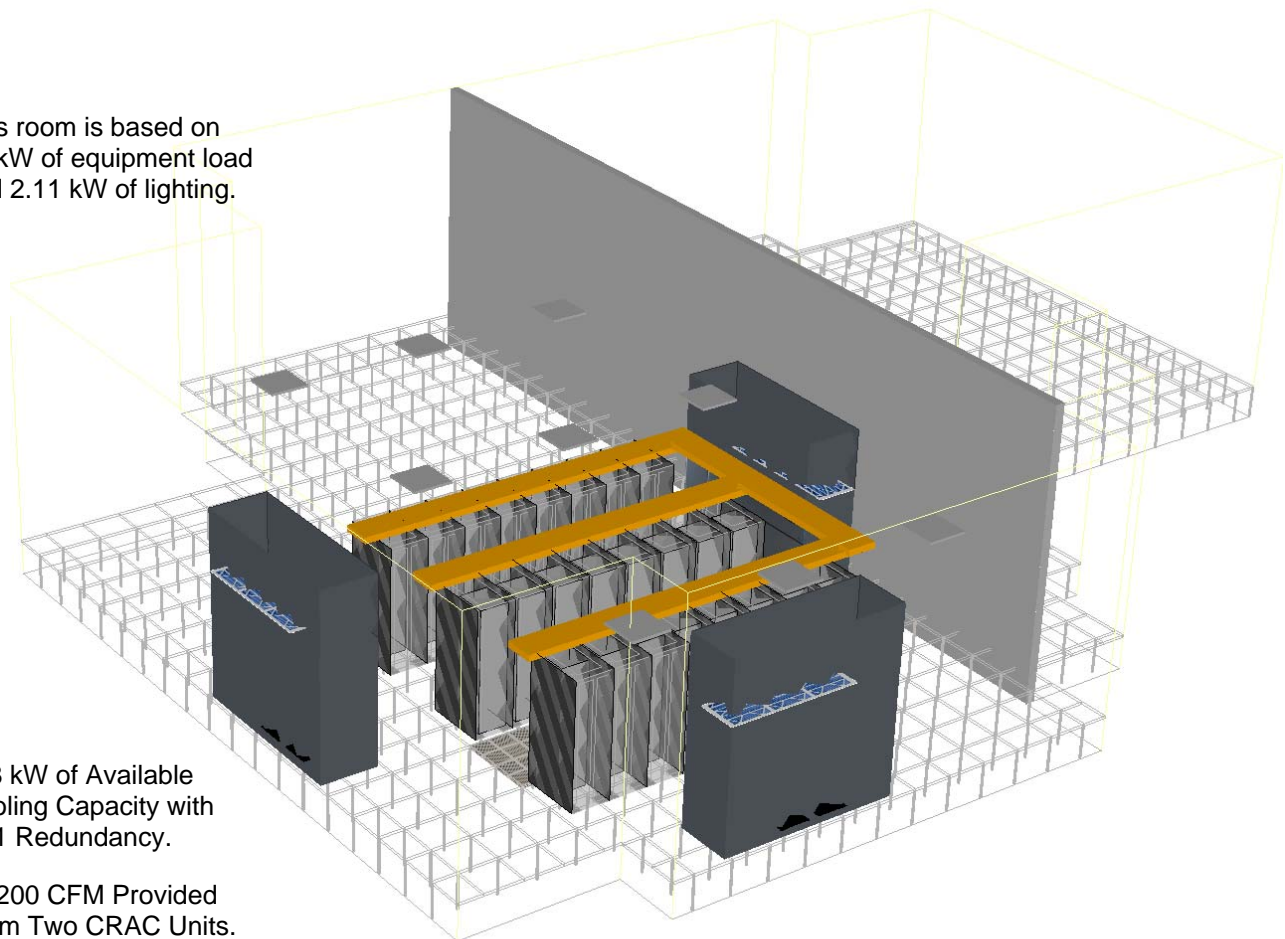
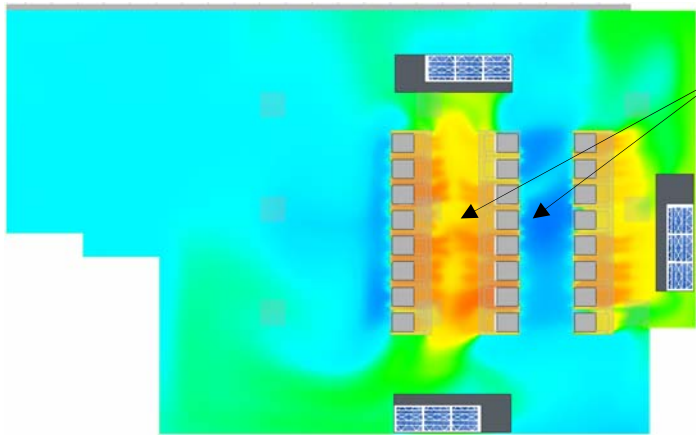


Figure 3.2.3 – Phase 1 Expansion - Isometric

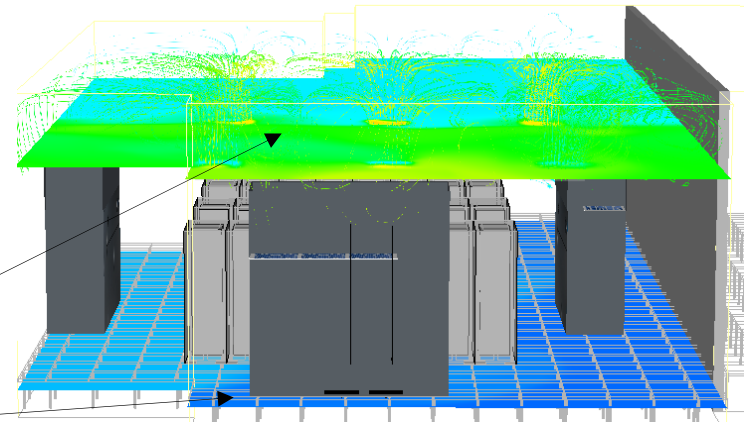


Worst Case Temperature Plane (6 ft.)

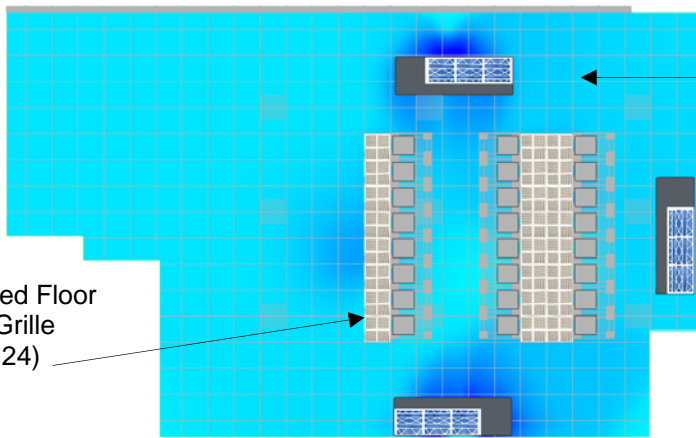
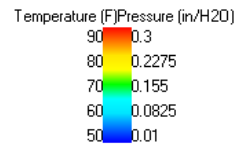
Excellent Isolation of Air Between Hot and Cold Aisles.

Exhaust Air is Quickly Evacuated Through Ceiling Grilles with Minimal Mixing.

Cold Under Floor Supply Air Temperatures



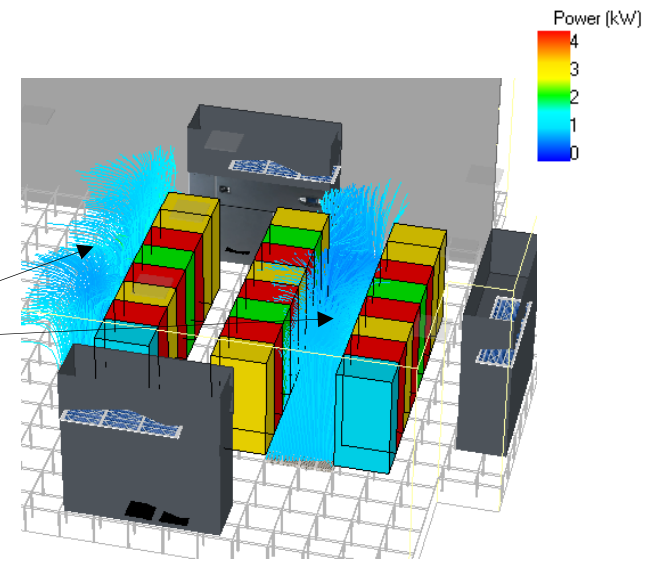
Return Air Stream Plot and Temperatures



Perforated Floor Supply Grille (Typ. of 24)

Consistent Under Floor Air Pressures Produces Good Air Flow at Floor Grilles.

Abundant Supply Air Flow for Server Inlets.



Supply Air Stream Plot

Figure 3.2.4 – Phase 1 Results

## Phase 2 Expansion - Filling Adjacent Area

The second phase of the data center's physical expansion should be performed as follows:

1. Install (2) more 20 ton down flow CRAC units into space.
  - Place at end of future hot aisles (see plan).
  - Power on units as equipment is installed and demands additional airflow.
  - The floor mounted units should not have turning vanes installed on the supply grilles.
2. Add racks, servers and other equipment as needed
  - (16) additional 2'x2' perforated floor tiles with 56% open area and dampers needed
  - (3) additional 2'x4' egg crate ceiling return grilles needed (placed above hot aisle)
3. Begin the remodel of the old data center to match the layout of the current.
4. All CRAC units have return air plenum connecting the unit to the ceiling. Refrigerant Piping will extend up through the plenums to rooftop condensers.

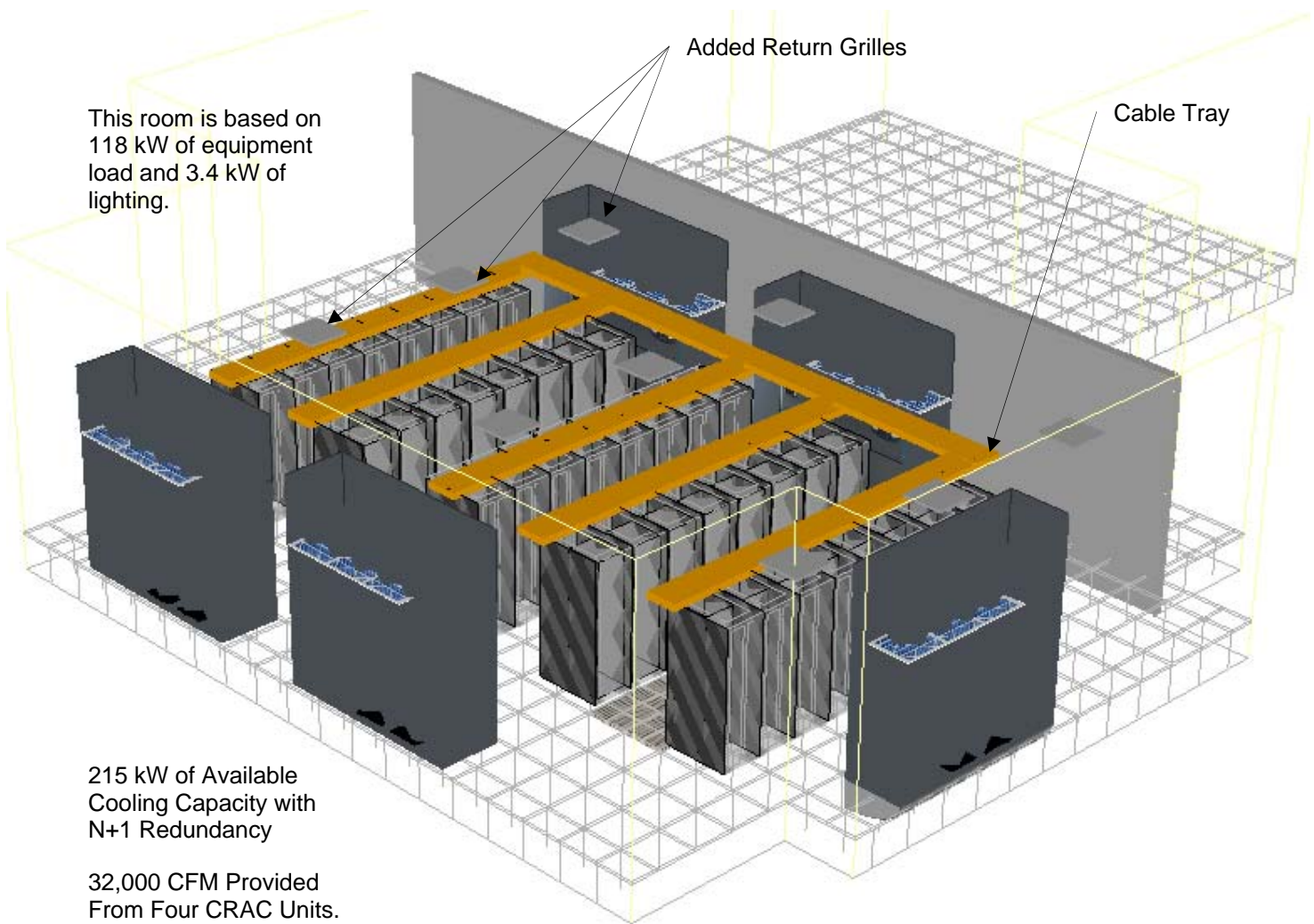
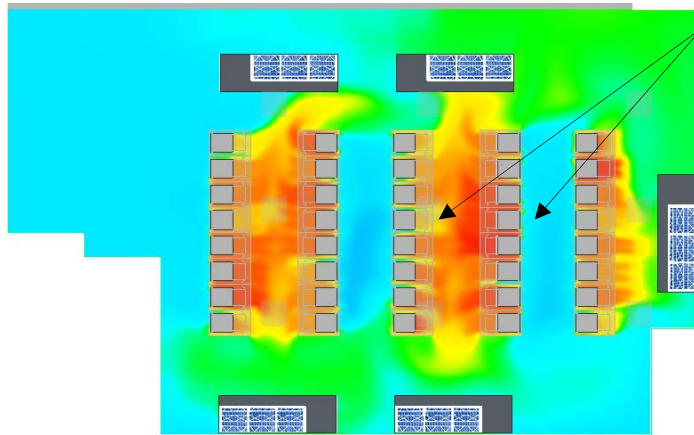
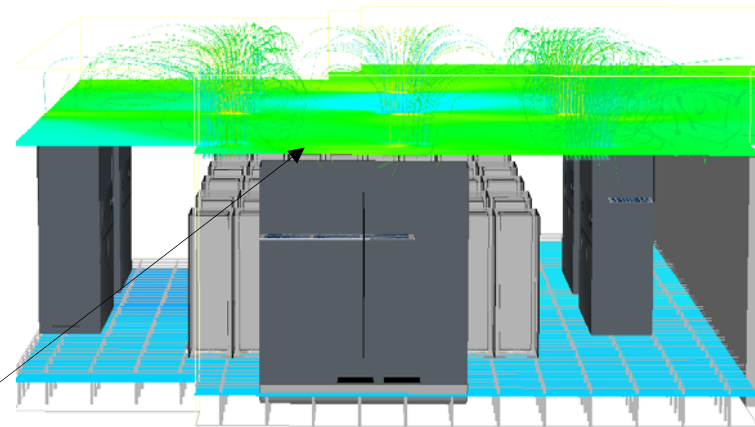


Figure 3.2.5 – Phase 2 Expansion - Isometric



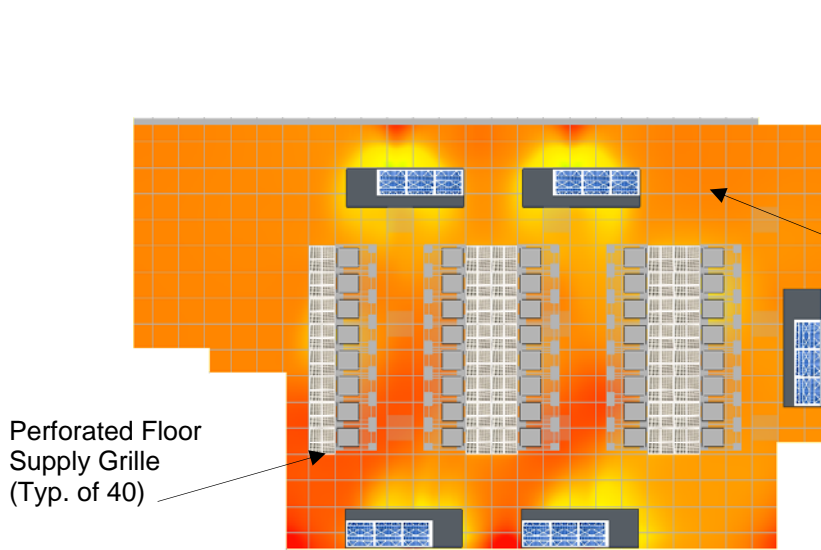
Continued Excellent Isolation of Air Between Hot and Cold Aisles.

A fully loaded room produces a higher concentration of warm air in the above ceiling resulting in improved CRAC performance.



Worst Case Temperature Plane (6 ft)

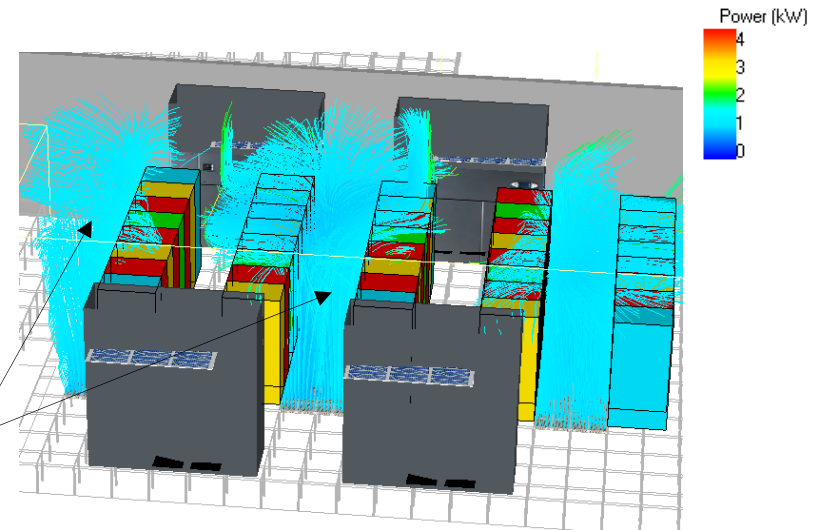
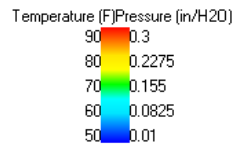
Return Air Stream Plot and Temperatures



Perforated Floor Supply Grille (Typ. of 40)

Added Airflow from the New Units Help Pressurized the Under Floor. This Increases Supply Flow Through Floor Grilles.

Servers Experience no Shortage of Supply Air.



Supply Air Stream Plot

Under Floor Pressure Plane (6 in under)

Figure 3.2.6 – Phase 2 Results

## Phase 3 Expansion – Refill Old Data Center, Introduce High Density Racks

The third phase of the data center's physical expansion should be performed as follows:

1. Open space between the two existing data centers.
  - Under floor and above ceiling space can be shared between the two areas.
  - Open a 14 ft. section in the existing wall to allow access between the two areas.
  - Maintain limited access to the data center.
2. Install overhead high density cooling units on racks with more powerful sets of servers.
3. Install (2) 15 ton down flow units in remodeled area (see plan) for additional cooling and humidification control. One unit will remain off and act as redundant source.
4. Install racks, servers and other equipment throughout data center as needed.
  - (24) additional 2'x2' perforated floor tiles with 56% open area and dampers needed
  - (6) additional 2'x4' egg crate ceiling return grilles needed in remodeled area hot aisles
5. All CRAC units have return air plenums connecting the unit to the ceiling. Refrigerant Piping will extend up through the plenums to rooftop condensers.

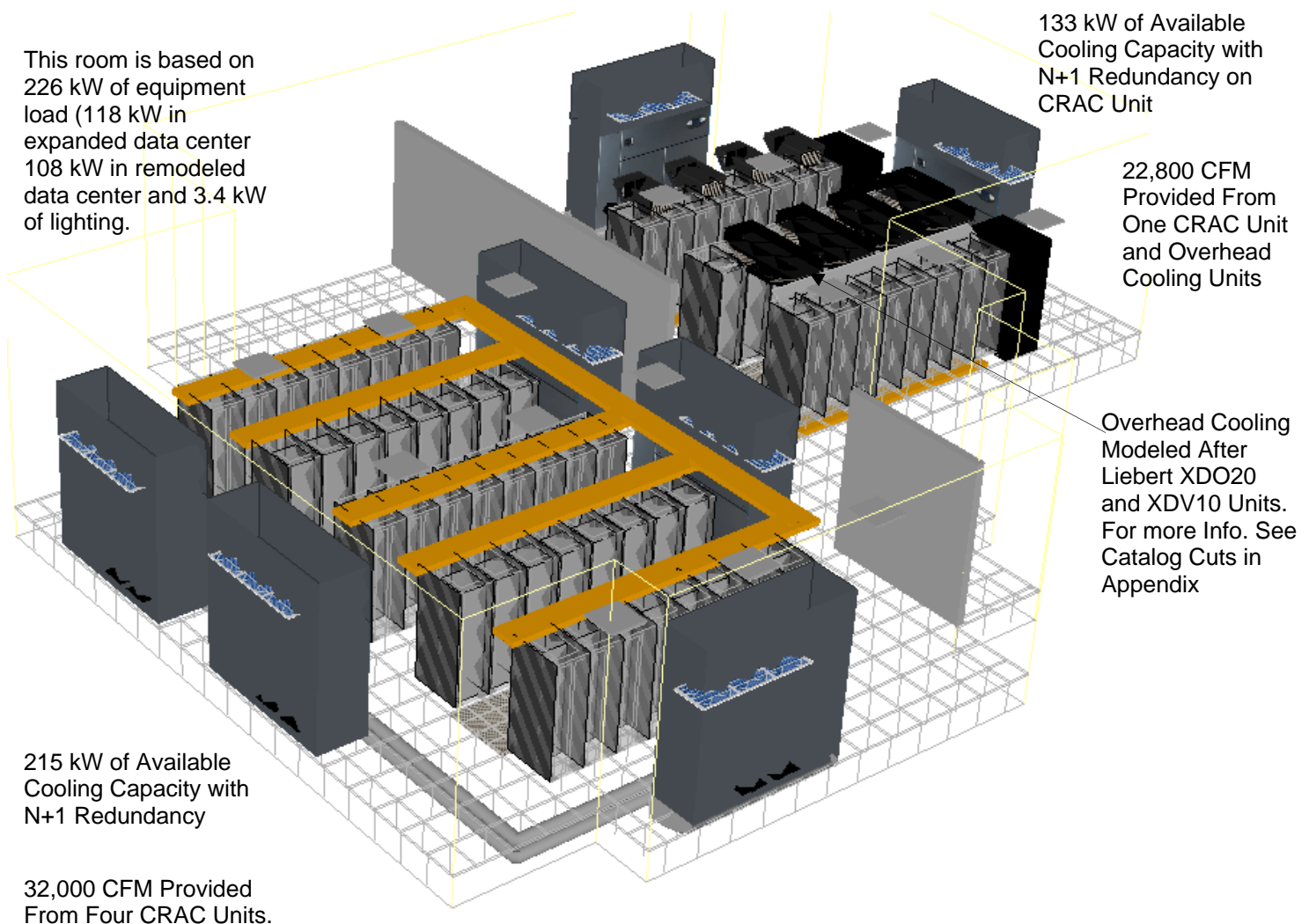


Figure 3.2.7 – Phase 3 Expansion - Isometric

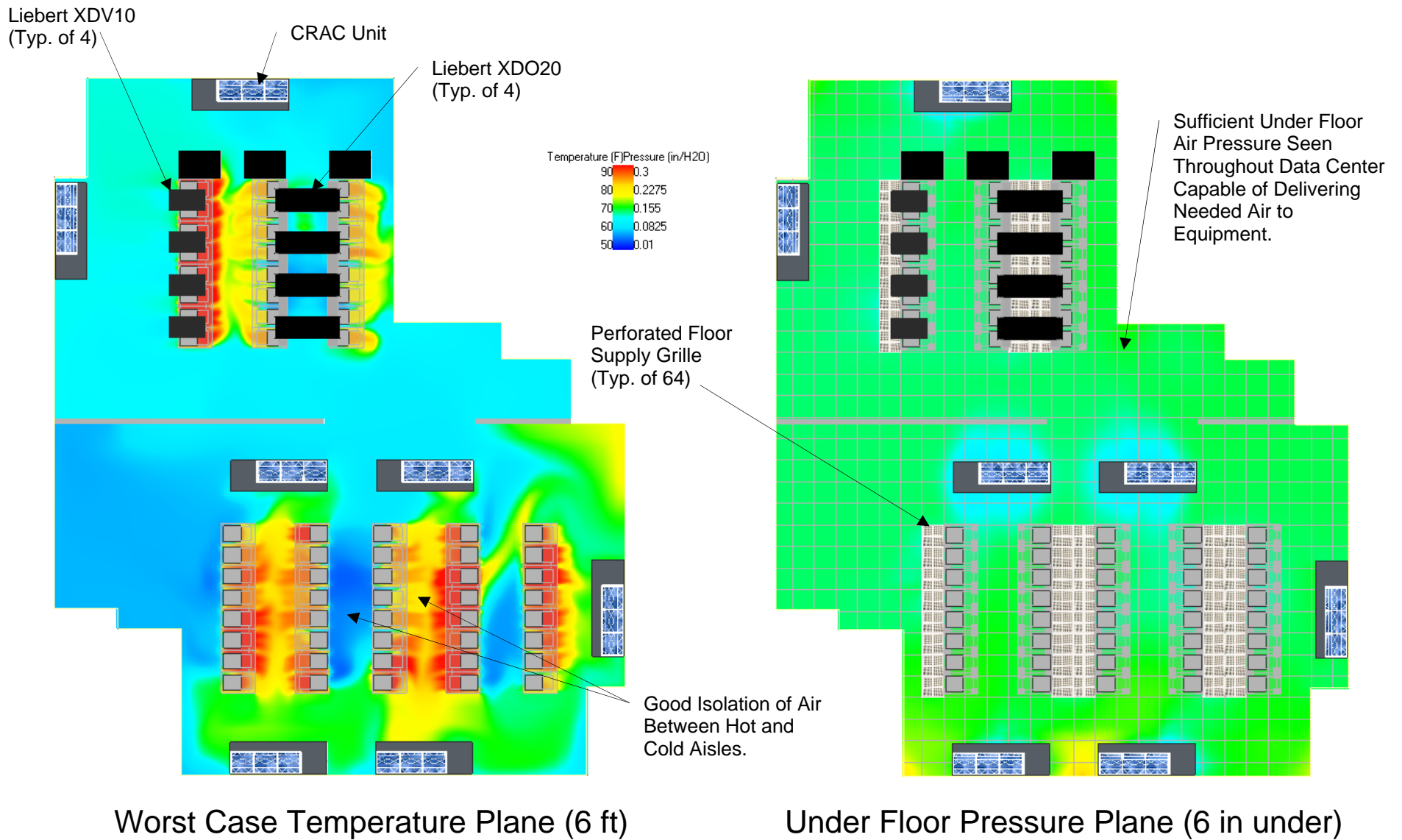
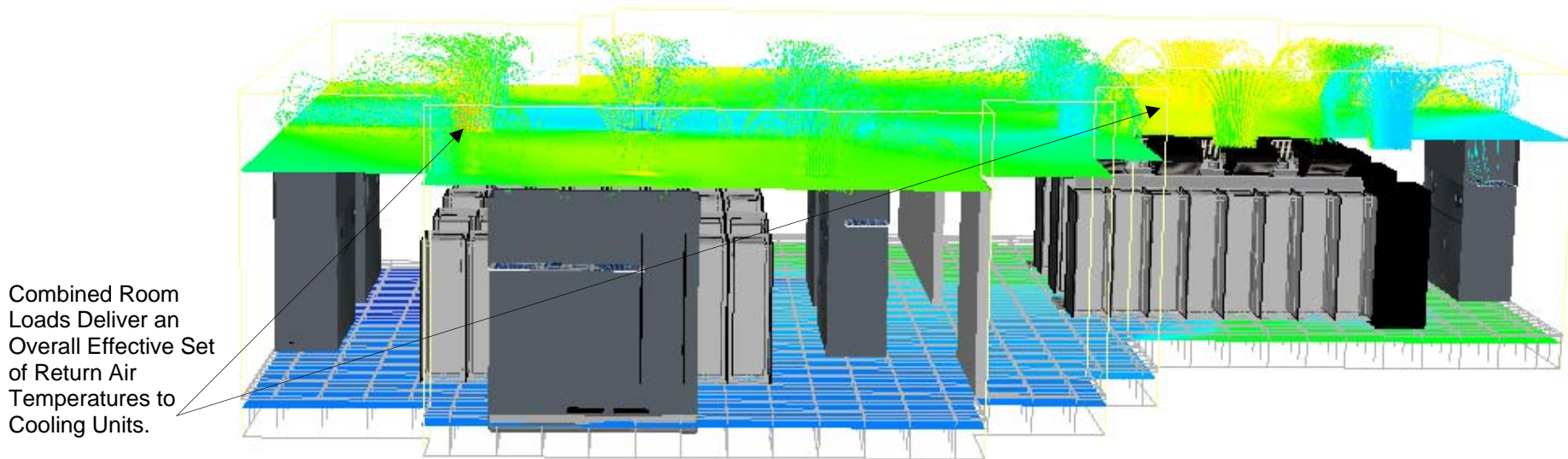
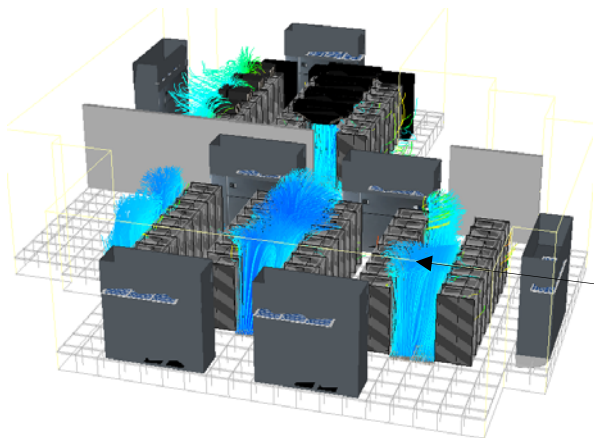


Figure 3.2.8 – Phase 3 Expansion Results (1 of 2)

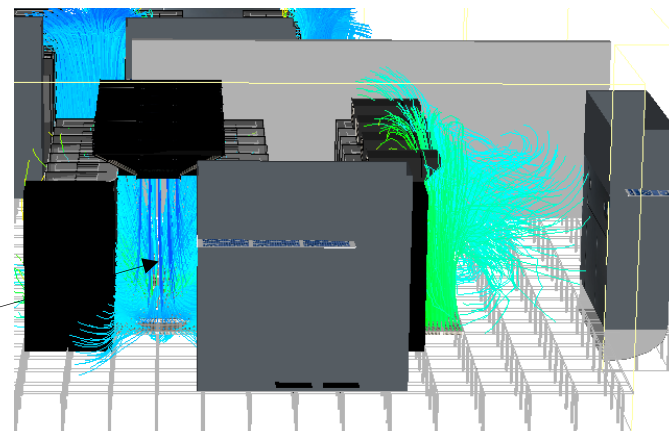


Return Air Stream Plot and Temperatures



Supply Air Stream Plot

Abundant Cold Supply Air Available For Equipment Cooling.



Supply Air Stream Plot

Figure 3.2.8 – Phase 3 Expansion Results (2 of 2)

# Thermal Assessment Section 4

## 4.1 – Liebert HVAC Preventive Maintenance Worksheet



### HVAC PREVENTIVE MAINTENANCE WORKSHEET



Inspection Date

\_\_\_\_\_

Indoor Unit Model #

\_\_\_\_\_

Condenser/Drycooler Model #

\_\_\_\_\_

Room Temperature/Humidity

\_\_\_\_\_ ° / \_\_\_\_\_ %

Job Name

\_\_\_\_\_

Indoor Unit Serial Number #

\_\_\_\_\_

Condenser/Drycooler Serial #

\_\_\_\_\_

Ambient Temperature

\_\_\_\_\_ °

#### FILTERS

- Check/Replace Filters
- Grille Area Unrestricted
- Wipe Section Clean
- Coil Clean

#### BLOWER SECTION

- Blower Wheels Free of Debris
- Check Belt Tension and Condition (Replace if Needed)
- Check/Lube Bearings
- Check Sheave/Pulley (Replace if Worn)
- Check Motor Mount
- Motor Amp Draw L1 \_\_\_\_\_ L2 \_\_\_\_\_ L3 \_\_\_\_\_
  - Compare to name plate amps

#### REHEAT

- Inspect Elements
- Check Wire Connections (Inside Reheat Box)
- Reheat Amp Draw #1 \_\_\_\_\_  
#2 \_\_\_\_\_  
#3 \_\_\_\_\_

#### STEAM GENERATING HUMIDIFIER

- Check Drain Valve/Drain Lines/Trap for Clogs
- Check Water Make-up Valve and all hoses for Leaks
- Clean Strainer
- Replace Humidifier Bottle If Necessary
- Check Operation of Humidifier
- Humidifier Amp Draw L1 \_\_\_\_\_ L2 \_\_\_\_\_ L3 \_\_\_\_\_





## HVAC PREVENTIVE MAINTENANCE WORKSHEET (CONTINUED)

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### GLYCOL PUMP

- Check Pump Rotation
- Check for Glycol Leaks
- Pump Pressures    #1    Suction\_\_\_\_\_                  Discharge\_\_\_\_\_
- #2    Suction\_\_\_\_\_                  Discharge\_\_\_\_\_
- #3    Suction\_\_\_\_\_                  Discharge\_\_\_\_\_
  
- Amp Draw            #1    L1\_\_\_\_\_                  L2\_\_\_\_\_                  L3\_\_\_\_\_
- #2    L1\_\_\_\_\_                  L2\_\_\_\_\_                  L3\_\_\_\_\_
- #3    L1\_\_\_\_\_                  L2\_\_\_\_\_                  L3\_\_\_\_\_
- Pump Changeover (If Multiple Pumps)

### NOTES:

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Signature    \_\_\_\_\_

Company     \_\_\_\_\_

*Make Photocopies for your records. Compare readings / information to previous maintenance worksheet*

To locate your local Liebert Representative for Liebert engineered parts, check the Liebert website:

[www.liebert.com](http://www.liebert.com) or call 1-800-Liebert.

## 4.2 – Appendix

Table 4.2.1 Equipment Summary

Rack ID	Front Door Style	% Rack Utilized	Total Rack Load (kW)	Server Manufacturer	Server Model	Slot
<b>Row A Rack 5</b>	<b>Perforated</b>	<b>23</b>	<b>1.2</b>			
				Cisco	7400 ASR	5
				Cisco	Catalyst 2960-24TC	6
				Cisco	Catalyst 2960-24TC	7
				Cisco	Catalyst 2960-24TC	8
				Cisco	Catalyst 2960-24TC	9
				Cisco	11500	10
				Cisco	ASA 5510 Series	11
				Cisco	ASA 5510 Series	12
				Co-Radiant	TS 520	13
				Cisco	N/A	16
<b>Row A Rack 6</b>	<b>Perforated</b>	<b>21</b>	<b>1.303</b>			
				Raritan	N/A	3
				Cisco	1711 Access Router	5
				St. Bernard	M500	7
				Cisco	PIX 515E	8
				Cisco	IDS 4215	9
				Cisco	N/A	10
				Cisco	Catalyst 2950T-24	11
				Cisco	PIX 515E	13
				Cisco Systems	2811	14
<b>Row A Rack 9</b>	<b>Perforated</b>	<b>68</b>	<b>2.656</b>			
				Argus	RST 48/30 Switch Mode Rectifier	1
				Hp	G5	11
				Dell	PowerEdge 1850	17
				Hp	Proliant DL320 G3	18
				Hp	Proliant DL320 G3	20
				Cisco Systems	2811	21
				Cisco Systems	2811	23
				Compaq	Proliant DL380	25
				Avaya	P133G2	31
				Avaya	P133G2	33
				Avaya	P133G2	35
				Cisco	MCS 7845-H2	37
				Cisco	MCS 7845-H2	39
				Cisco	MCS 7845-H2	42
				Cisco	4400	44
				Cisco	4400	45
				Cisco	4400	46

Rack ID	Front Door Style	% Rack Utilized	Total Rack Load (kW)	Server Manufacturer	Server Model	Slot
<b>Row A Rack 10</b>	<b>Perforated</b>	<b>55</b>	<b>2.743</b>			
				N/A	N/A	4
				Cisco	MCS 7835-H2	5
				Cisco	MCS 7835-H2	7
				Cisco	2621XM Router	10
				Cisco	2610 Router	11
				Cisco	2610 Router	12
				Cisco	PIX 515E	13
				Cisco	PIX 515E	14
				Cisco	2621XM Router	15
				Cisco Systems	2600	16
				Cisco	2610 Router	17
				Cisco	7400ASR	18
				Cisco	7400ASR	19
				Cisco	7400ASR	20
				Dell	Poweredge SC 1435	21
				Dell	PowerEdge 1950	22
				Hp	Proliant DL360 G5	27
				Cisco	7400ASR	28
				N/A	f5	30
				N/A	f5	32
				Cisco	IDS 4235	36
				IBM	Proventia GX4004	37
<b>Row A Rack 11</b>	<b>Perforated</b>	<b>51</b>	<b>0.8753</b>			
				Kalatel	KTD-440	10
				Kalatel	DVS	12
				ADT	N/A	15
				Kalatel	DVS	16
				ADT	N/A	19
				Kalatel	DVS	20
				ADT	N/A	23
				Kalatel	DVS	24
				ADT	N/A	27
				Hp	Proliant DL360 G4	35
				Network Intelligence	N/A	36
				IBM	System Storage DS4800	37
<b>Row B Rack 4</b>	<b>Perforated</b>	<b>8.5</b>	<b>0.1</b>			
				Network Instruments	Disc Storage	19

Rack ID	Front Door Style	% Rack Utilized	Total Rack Load (kW)	Server Manufacturer	Server Model	Slot
<b>Row B Rack 5</b>	<b>Perforated</b>	<b>36</b>	<b>3.713</b>			
				Hp	Proliant DL360 G3	7
				Hp	Proliant DL360 G3	10
				Hp	Proliant DL380 G3	13
				Hp	Proliant DL360 G3	16
				Hp	Proliant DL360 G5	19
				Hp	Proliant DL360 G5	21
				Hp	Proliant DL360 G3	25
				Hp	Proliant DL360 G3	26
				Hp	Proliant DL360 G3	28
				Hp	Proliant DL360 G3	30
				Hp	Proliant DL360 G3	31
				Hp	Proliant DL360 G3	32
				Hp	Proliant DL360 G3	34
				Hp	Proliant DL360 G3	36
				Hp	Proliant DL360 G5	37
				Hp	Proliant DL360 G5	38
<b>Row B Rack 6</b>	<b>Perforated</b>	<b>32</b>	<b>3.518</b>			
				Hp	Proliant DL360 G5	8
				Hp	Proliant DL380 G5	11
				Hp	Proliant DL360 G5	14
				Hp	Proliant DL380 G4	17
				Hp	Proliant DL360 G5	22
				Hp	Proliant DL360 G5	24
				Hp	Proliant DL360 G5	26
				Hp	Proliant DL360 G5	28
				Hp	Proliant DL360 G4	29
				Hp	Proliant DL360 G5	30
				Hp	Proliant DL360 G5	32
				Hp	Proliant DL360 G3	34
				Hp	Proliant DL360 G5	36
<b>Row B Rack 7</b>	<b>Perforated</b>	<b>43</b>	<b>2.519</b>			
				Hp	Proliant DL380 G5	9
				Compaq	Proliant DL380	12
				Hp	Proliant DL360 G5	15
				Hp	Proliant DL360 G5	16
				Hp	Proliant DL360 G5	18
				Hp	Proliant DL360 G3	25
				Hp	Proliant DL360 G3	26
				IBM	xSeries 445 eserver	28
				Compaq	Proliant DL380	32
				Hp	Proliant DL360 G5	35
				Hp	Proliant DL380 G2	37

Rack ID	Front Door Style	% Rack Utilized	Total Rack Load (kW)	Server Manufacturer	Server Model	Slot
<b>Row C Rack 1</b>	<b>Perforated</b>	<b>47</b>	<b>2.423</b>			
				Hp	Proliant ML370	6
				Hp	Proliant DL360 G3	14
				Hp	Proliant DL360 G3	15
				Hp	Proliant DL360 G5	21
				Hp	Proliant DL380 G3	23
				Hp	Proliant DL380 G3	26
				Hp	Proliant DL360 G3	30
				Hp	Proliant DL360 G5	31
				Hp	Proliant DL360 G5	32
				Compaq	Proliant ML570	35
<b>Row C Rack 2</b>	<b>Perforated</b>	<b>40</b>	<b>3.375</b>			
				Hp	Proliant DL380 G5	6
				Hp	Proliant DL380 G5	9
				Hp	Proliant DL380 G5	12
				Hp	Proliant DL380 G5	15
				Hp	Proliant DL380 G5	18
				Hp	Proliant DL380 G5	21
				Hp	Proliant DL380 G3	27
				Hp	Proliant DL360 G5	32
				Hp	Proliant DL360 G3	34
				Hp	Proliant DL385	37
				Hp	Proliant DL360 G3	40
<b>Row C Rack 3</b>	<b>Perforated</b>	<b>36</b>	<b>3.38</b>			
				Hp	Proliant DL380 G5	10
				Hp	Proliant DL380 G5	12
				Hp	Proliant DL360 G5	20
				Hp	Proliant DL380 G5	22
				Hp	Proliant DL380 G5	25
				Hp	Proliant DL360 G3	28
				Hp	Proliant DL360 G5	30
				Hp	Proliant DL360 G4	31
				Hp	Proliant DL360 G5	32
				Hp	Proliant DL360 G5	33
				Hp	Proliant DL360 G3	35
				Hp	Proliant DL380 G3	36

Rack ID	Front Door Style	% Rack Utilized	Total Rack Load (kW)	Server Manufacturer	Server Model	Slot
<b>Row C Rack 4</b>	<b>Perforated</b>	<b>45</b>	<b>3.075</b>			
				Hp	Proliant DL380 G5	9
				Hp	Proliant DL360 G3	12
				Hp	Proliant DL360 G4	14
				Hp	Proliant DL360 G5	16
				Compaq	Proliant DL380	17
				Hp	Proliant DL360 G5	21
				Hp	Proliant DL360 G5	24
				Hp	Proliant DL360 G5	25
				Hp	Proliant DL360 G3	26
				Hp	Proliant ML570 G2	27
				Hp	Proliant DL360 G4	35
				Hp	Proliant DL360 G5	36
<b>Row C Rack 5</b>	<b>Perforated</b>	<b>36</b>	<b>2.312</b>			
				Hp	Proliant DL380 G3	6
				Hp	Proliant DL360 G4	9
				Hp	Proliant DL380 G4	11
				Hp	Proliant DL360 G4	16
				Hp	StorageWorks Modular Smart Array 30	17
				Hp	StorageWorks Modular Smart Array 30	21
				Hp	StorageWorks Modular Smart Array 30	25
				Hp	Proliant DL360 G5	29
				Hp	Proliant DL360 G4	30
				Hp	Proliant DL320 G3	31
				Hp	Proliant DL360 G4	33
<b>Row C Rack 6</b>	<b>Perforated</b>	<b>76</b>	<b>1.448</b>			
				Hp	Proliant DL380 G4	6
				IBM	TotalStorage FASt T600	8
				IBM	EXP400 Storage Enclosure	11
				IBM	EXP400 Storage Enclosure	14
				IBM	EXP400 Storage Enclosure	17
				IBM	EXP400 Storage Enclosure	20
				IBM	EXP400 Storage Enclosure	23
				IBM	EXP400 Storage Enclosure	26
				IBM	EXP400 Storage Enclosure	29
				IBM	EXP400 Storage Enclosure	32
				IBM	EXP400 Storage Enclosure	35
				IBM	EXP400 Storage Enclosure	38

Rack ID	Front Door Style	% Rack Utilized	Total Rack Load (kW)	Server Manufacturer	Server Model	Slot
<b>Row C Rack 7</b>	<b>Perforated</b>	<b>70</b>	<b>1.902</b>			
				IBM	TotalStorage FASt T600	5
				IBM	EXP300 Storage Enclosure	8
				IBM	EXP300 Storage Enclosure	11
				IBM	EXP300 Storage Enclosure	14
				IBM	EXP300 Storage Enclosure	17
				IBM	EXP300 Storage Enclosure	20
				IBM	EXP300 Storage Enclosure	23
				Hp	Proliant DL360 G5	27
				Hp	Proliant DL380 G3	30
				Hp	Proliant DL380 G3	33
				Cisco Systems	2811	39
				Cisco Systems	2811	42
				Cisco Systems	2811	44
				Cisco Systems	3548G XL	46
<b>Row D Rack 1</b>	<b>Perforated</b>	<b>38</b>	<b>3.576</b>			
				Compaq	Proliant DL380	4
				Hp	Proliant DL360 G3	8
				Hp	Proliant DL360 G3	10
				Hp	Proliant DL360 G3	12
				Hp	Proliant DL360 G3	14
				Hp	Proliant DL360 G3	16
				Hp	Proliant DL360 G3	18
				Hp	Proliant DL360 G3	20
				Hp	Proliant DL360 G3	22
				Hp	Proliant DL360 G3	24
				Hp	Proliant DL360 G3	26
				Hp	Proliant DL360 G3	28
				Hp	Proliant DL360 G3	30
				Hp	Proliant DL360 G3	32
				Hp	Proliant DL360 G3	34
				Hp	Proliant DL360 G3	36
<b>Row D Rack 2</b>	<b>Perforated</b>	<b>32</b>	<b>3.645</b>			
				Hp	Proliant DL360 G3	10
				Hp	Proliant DL360 G3	12
				Hp	Proliant DL360 G3	14
				Hp	Proliant DL360 G3	16
				Hp	Proliant DL360 G3	18
				Hp	Proliant DL360 G3	20
				Hp	Proliant DL360 G3	22
				Hp	Proliant DL360 G3	23
				Hp	Proliant DL360 G3	25
				Hp	Proliant DL360 G3	27
				Hp	Proliant DL360 G3	29
				Hp	Proliant DL360 G4	31
				Hp	Proliant DL360 G4	33
				Hp	Proliant DL360 G4	35
				Hp	Proliant DL360 G4	37

Rack ID	Front Door Style	% Rack Utilized	Total Rack Load (kW)	Server Manufacturer	Server Model	Slot
<b>Row D Rack 3</b>	<b>Perforated</b>	<b>34</b>	<b>3.595</b>			
				Hp	Proliant DL360 G5	6
				Hp	Proliant DL360 G3	8
				Hp	Proliant DL360 G3	10
				Hp	Proliant DL360 G3	12
				Hp	Proliant DL360 G3	14
				Hp	Proliant DL360 G3	16
				Hp	Proliant DL360 G3	19
				Hp	Proliant DL360 G3	21
				Hp	Proliant DL360 G3	23
				Hp	Proliant DL360 G3	26
				Hp	Proliant DL360 G5	28
				Hp	Proliant DL385	30
				Hp	Proliant DL360 G3	33
				Hp	Proliant DL360 G3	35
				Hp	Proliant DL360 G5	37
<b>Row D Rack 4</b>	<b>Perforated</b>	<b>47</b>	<b>3.772</b>			
				Hp	Proliant DL360 G5	6
				Hp	Proliant DL360 G5	7
				IBM	xSeries 445 eserver	8
				Hp	Proliant DL385	12
				IBM	xSeries 445 eserver	15
				IBM	xSeries 445 eserver	20
				Hp	Proliant DL385	24
				Hp	Proliant DL360 G3	26
				Hp	Proliant DL360 G4	31
				Hp	Proliant DL360 G4	35
				Hp	Proliant DL360 G4	37
<b>Row D Rack 5</b>	<b>Perforated</b>	<b>38</b>	<b>1.769</b>			
				IBM	TotalStorage DS4300	3
				IBM	System Storage DS4000 EXP 810	6
				IBM	System Storage DS4000 EXP 810	9
				IBM	System Storage DS4000 EXP 810	12
				IBM	System Storage DS4000 EXP 810	15
				IBM	System Storage DS4000 EXP 810	18
<b>Row D Rack 6</b>	<b>Perforated</b>	<b>66</b>	<b>3.196</b>			
				Avaya	G650 Gateway	1
				N/A	Keyboard	17
				Cisco	MCS 7845-H2	19
				Cisco	MCS 7845-H2	21
				Cisco	MCS 7845-H2	23
				Cisco	MCS 7845-H2	25
				N/A	Computer Monitor	27
				Hp	Proliant DL380 G4	29
				N/A	Keyboard and large monitor	32

Rack ID	Front Door Style	% Rack Utilized	Total Rack Load (kW)	Server Manufacturer	Server Model	Slot
<b>Row D Rack 7</b>	<b>Perforated</b>	<b>47</b>	<b>2.83</b>			
				N/A	N/A	3
				N/A	N/A	9
				Compaq	Proliant DL380	13
				Compaq	EVO W4000 Small Form Factor	17
				N/A	Monitor	26
				Avaya	N/A	27
<b>Row E Rack 5</b>	<b>Perforated</b>	<b>32</b>	<b>3.189</b>			
				Hp	Proliant DL380 G5	3
				Hp	Proliant DL380 G5	6
				Hp	Proliant DL380 G5	9
				Hp	Proliant DL380 G5	12
				Hp	Proliant DL360 G5	25
				Hp	Proliant DL360 G5	27
				Hp	Proliant DL360 G5	29
				Hp	Proliant DL360 G5	31
				Hp	Proliant DL360 G5	33
				Hp	Proliant DL360 G5	35
				Hp	Proliant DL360 G5	37
<b>Row E Rack 6</b>	<b>Perforated</b>	<b>23</b>	<b>2.266</b>			
				Hp	Proliant DL580 G4	5
				Hp	Proliant DL580 G4	9
				Hp	Proliant DL360 G5	31
				Hp	Proliant DL360 G5	33
				Hp	Proliant DL360 G5	35
<b>Row E Rack 7</b>	<b>Perforated</b>	<b>36</b>	<b>3.583</b>			
				Hp	Proliant DL360 G3	5
				Hp	Proliant DL360 G3	7
				Hp	Proliant DL360 G3	9
				Hp	Proliant DL360 G3	11
				Hp	Proliant DL360 G3	13
				Hp	Proliant DL360 G3	15
				Hp	Proliant DL360 G3	17
				Hp	Proliant DL360 G3	19
				Hp	Proliant DL360 G3	21
				Hp	Proliant DL360 G3	23
				Hp	Proliant DL360 G3	27
				Hp	Proliant DL360 G4	29
				Hp	Proliant DL360 G5	31
				Hp	Proliant DL380	33
				Hp	Proliant DL360 G3	37

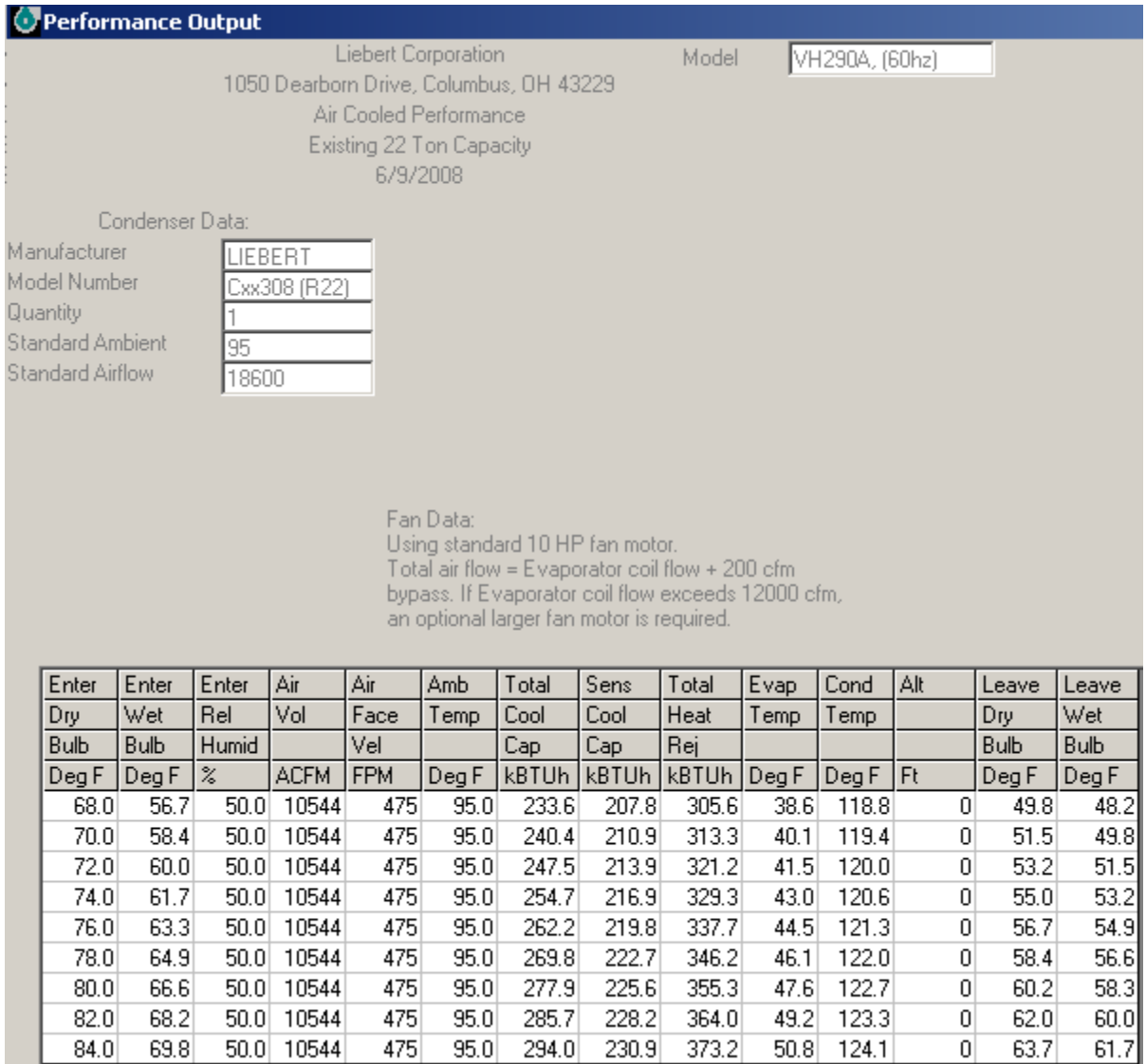


Figure 4.2.1 – Existing Liebert 22 Ton Performance Data

Refrig. R-22			6 Row Evaporator Coil			
EDB (°F)	EWB (°F)	Air Flow (CFM)	Ambient Air Temperature (°F)			
			95		120	
			Total MBH	Sensible MBH	Total MBH	Sensible MBH
75	62	4100	242.43	162.00	217.48	148.90
		8350	293.15	231.31	258.60	216.31
		12600	311.84	289.49	272.13	271.04
	67	4100	263.96	138.88	236.98	125.80
		8350	316.92	184.11	281.34	170.06
		12600	339.01	221.12	300.02	206.87
	72	4100	288.51	115.61	260.19	103.37
		8350	344.72	137.56	307.54	124.24
		12600	362.66	151.30	322.79	138.11
80	62	4100	241.25	182.95	216.57	169.86
		8350	292.84	274.49	258.73	257.97
		12600	299.68	299.68	269.37	269.37
	67	4100	263.22	160.20	236.22	147.10
		8350	316.37	227.64	281.95	214.01
		12600	338.28	285.70	299.19	270.70
	72	4100	287.54	137.00	259.34	124.77
		8350	344.12	181.31	306.75	167.91
		12600	362.22	216.15	322.36	202.93
90	62	4100	238.07	223.14	213.83	210.35
		8350	295.19	295.19	267.91	267.91
		12600	329.79	329.79	298.39	298.39
	67	4100	261.77	201.58	234.72	188.64
		8350	317.22	313.13	276.82	276.82
		12600	330.11	330.11	298.61	298.61
	72	4100	285.61	178.71	258.24	166.76
		8350	343.97	266.67	305.42	252.98
		12600	361.33	342.66	319.72	319.72

Figure 4.2.2 – Existing Aeon 25 Ton Rooftop Performance Data

\*Airflow for rooftop unit was measured to be 7545 cfm.

Disclaimer:

“Liebert” will be used in reference to Emerson Network Power and “Site” will be used in reference to the Customer’s Data Center Location.

- Data Collection
  - The data used in this report is Site, date, and time specific
  - The amount of data collected is dependant on the conditions of the Site
    - Access to different areas of the Site
    - Relative safety concerns of Liebert
    - Time constraints imposed by the Customer if applicable
    - The nature of the report previously agreed upon by the Customer and Liebert
  
- Accuracy of Data
  - No field collected data is 100% accurate
  - Liebert will do everything in its power to accurately read measurements
  - Liebert will not be held responsible for future comparisons of report findings and actual data measured
  - The recommendations from Liebert are based on past experience, computer simulations, and/or recommendations from experts on Data Center Assessments

Liebert does not accept any responsibility or liability in any manner for how this report is used by the Customer.

If the Customer has any questions about the results presented in this report, they should please contact the Liebert representative who prepared the Data Center Assessment Report.