Power and Cooling for Ultra-High Density Racks and Blade Servers

APC White Paper #46
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American Power Conversion Company

What has changed?

<table>
<thead>
<tr>
<th>20th Century</th>
<th>vs.</th>
<th>21st Century</th>
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</thead>
<tbody>
<tr>
<td>Data Center is fixed in time and place</td>
<td></td>
<td>Data Centers are virtual and mobile, and dynamic</td>
</tr>
<tr>
<td>Data Center is a protected repository</td>
<td></td>
<td>Important data can be anywhere, anytime</td>
</tr>
<tr>
<td>Data Center information is processed in batches</td>
<td></td>
<td>Information is processed in real time</td>
</tr>
<tr>
<td>Data Center is a low power investment (&lt; 50 w/sq.ft.)</td>
<td></td>
<td>Data Centers demand high power densities (&gt;100 w/sq.ft.)</td>
</tr>
</tbody>
</table>
20th Century solutions that don’t work

Welcome to 21st Century Computing!

What do we learn from Blade Server Technology?

Blade servers are designed to take less time to install and fewer people to maintain, helping reduce IT infrastructure costs.
The fastest computers (Nov 2004)

**TOP 5 SUPERCOMPUTER SITES (November 2004)**

1. BlueGene/L
   ROCHESTER, USA
   Nameplate power consumption: 5400 watts per frame
   Rmax: 77.73 TFlops

2. Columbia
   NASA/Ames
   Mountain View, USA
   SGI Altix/Voltaire
   Rmax: 54.87 TFlops

3. Earth Simulator
   Earth Simulator Center
   Yokohama
   NEC
   Rmax: 35.16 TFlops

4. MareNostrum
   Barcelona Supercomputer Center
   Barcelona, Spain
   eServer BladeCenter J530/Myrenet
   Rmax: 20.53 TFlops

5. Thunder
   Lawrence Livermore National Lab
   Livermore, USA
   Intel Itanium2 Tigris/Qumdrics
   Rmax: 15.04 TFlops

The ability to configure is the key!

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Basic IBM blade server attributes

- Nameplate power consumption: 5400 watts per frame
- Measured power consumption: 4050 watts per frame, 100% CPU utilization
- Standard power supply: 2000 watts each, 4 per chassis
- Voltage requirement: 200-240 VAC, 50-60HZ, single phase
- Input power conductor configuration: IEC C20
- Power supplies are hot-swappable.
- 24 power supplies in fully configured rack, each with its own power cord
- Power per 42U rack (6 frames): 24.3 Kilowatts

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### Recommended power solutions

<table>
<thead>
<tr>
<th>Number of chassis per rack</th>
<th>Solution</th>
<th>APC Part Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(2) Rack PDU, Metered, 20amp, ZeroU, 5.7kW, 3 phase, 208vAC</td>
<td>(2) AP7864</td>
</tr>
<tr>
<td>2-3</td>
<td>(4) Rack PDU, Metered 20amp, ZeroU, 5.7kW, 3 phase, 208vAC</td>
<td>(4) AP7864</td>
</tr>
<tr>
<td>4-6</td>
<td>(4) Rack PDU, Metered 50amp, ZeroU, 12.5kW, 3 phase, 208vAC</td>
<td>(4) AP7868</td>
</tr>
</tbody>
</table>

For “2N”, plug power supplies 1 and 3 into power supply A, and power supplies 2 and 4 into feed B!
It’s hot and getting hotter!

- 1 kilowatt of power consumption by a server requires 160 cubic feet of air per minute.
- The air must be capable of producing a 20 degree F. temperature drop across the server.
- Most servers can operate with inlet air of 85-90 degrees F.
- ASHRAE STANDARDS: “Thermal guidelines for Data Processing Environments” TC 9.9
  - Allowable temperature range: 59-90 degrees F.
  - Recommended range: 68-77 degrees F.
  - Humidity range: 20-80%RH
  - Recommended range: 40-55%RH

* A 24 KW Blade Server rack will require 3840 Cubic Feet of Air per Minute!
A conventional data center layout with one vented tile per rack simply cannot cool racks over approximately 6 kW per rack over a sustained area.

Limits are limits

• No matter how well you manage a raised floor, or how well you use current technologies, the upper limit for raised floor cooling is about 3-4 KW per rack.
• This equates to an average density of 100-140 watts/sq. ft.
• Beyond this limit, you have more space allocated to cooling than to the IT servers.
Floor Tile Cooling Ability

Rack Power (kW) that can be cooled by one tile with this airflow

Floor Tile Cooling Ability

Tile Airflow (cfm) [L/s]

Rack Power (kW)

Typical Capability

With Effort

Extreme

Impractical

Perf tile

Grate tile

0          100         200         300        400         500   600        700        800        900       1000

0        [47.2]       [94.4]       [141.6]     [188.8]     [236.0]     [283.2]     [330.4]    [377.6]     [424.8]     [471.9]

24 KW Load

"2N" UPS and cooling required for 24 kW load

Blade Servers

UPS

PDU

CRAC

PDU

UPS

30 kW

40 kW

30 kW
Increased Density and Total Floor Area

<table>
<thead>
<tr>
<th>Power Density kW per Rack</th>
<th>Area occupied by IT equipment</th>
<th>Area occupied by power and cooling infrastructure</th>
<th>Total area of IT equipment + infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50 ft² / kW</td>
<td>50 ft² / kW</td>
<td>100 ft² / kW</td>
</tr>
<tr>
<td>2</td>
<td>45 ft² / kW</td>
<td>45 ft² / kW</td>
<td>90 ft² / kW</td>
</tr>
<tr>
<td>3</td>
<td>40 ft² / kW</td>
<td>40 ft² / kW</td>
<td>80 ft² / kW</td>
</tr>
<tr>
<td>4</td>
<td>35 ft² / kW</td>
<td>35 ft² / kW</td>
<td>70 ft² / kW</td>
</tr>
<tr>
<td>5</td>
<td>30 ft² / kW</td>
<td>30 ft² / kW</td>
<td>60 ft² / kW</td>
</tr>
<tr>
<td>6</td>
<td>25 ft² / kW</td>
<td>25 ft² / kW</td>
<td>50 ft² / kW</td>
</tr>
<tr>
<td>7</td>
<td>20 ft² / kW</td>
<td>20 ft² / kW</td>
<td>40 ft² / kW</td>
</tr>
<tr>
<td>8</td>
<td>15 ft² / kW</td>
<td>15 ft² / kW</td>
<td>30 ft² / kW</td>
</tr>
<tr>
<td>9</td>
<td>10 ft² / kW</td>
<td>10 ft² / kW</td>
<td>20 ft² / kW</td>
</tr>
<tr>
<td>10</td>
<td>5 ft² / kW</td>
<td>5 ft² / kW</td>
<td>10 ft² / kW</td>
</tr>
<tr>
<td>11</td>
<td>0 ft² / kW</td>
<td>0 ft² / kW</td>
<td>0 ft² / kW</td>
</tr>
</tbody>
</table>

The Cooling Challenge

- 24 kW POWER
- 30-amp circuits 208 / 230 V
- (Assume dual-corded blade chassis)

24 kW COOLING
The Cooling Challenge

CHALLENGE #1:

Supply 3840 cfm of Cool Air to the Rack
Typical Raised-Floor Airflow

One 300 cfm vented tile per rack

Perforated Tiles?

- 24 kW rack would require 13 perforated tiles
- Aisle width would need to be substantially increased
- Spacing between racks would need to be substantially increased

Perforated tiles cannot cool an 24 kW rack in a typical data center
**Floor Tile Cooling Ability**

Requires careful raised floor design, careful CRAC placement, and control of under-floor obstacles (pipes/wiring).

![Diagram showing floor tile cooling ability.](image)

**Increased Floor Depth?**

With grate-type tiles, airflow in some cases reverses!

Variation is large even for very deep plenum.

![Diagram showing increase in floor depth with different airflow variations.](image)
Grate-Type Tiles?

- Grate-type tiles dramatically alter under-floor pressure gradients, making cooling non-uniform and unpredictable
- Grate-type tiles in one area impact airflow in neighboring areas
- Large airflow variations when using grate-type tiles mean some locations will NOT receive enough cooling
- Even if an “extreme” cooling design could solve these large airflow variations, it would still take 3-4 grate-type tiles to cool one 18kW rack

Optimizing raised floor environments

- Blanking Panels in open “U” spaces in racks
- Seal cable panel cut out spaces
- Limit the number of perforated tiles
- Employ hot aisle/cold aisle layout
- Use no perforated tiles in hot aisles
- Monitor under floor static pressure at multiple points
- Use VFD’s to control CRAC fan speeds to stabilize static pressure
- Remove dead data and power cables- dictate routes for new cables
- Check airflow balance on a regular basis
- Use CFM modeling to engineer the air flow
- Balance critical loads-spread out high density loads
- Minimize latent cooling – raise chilled water supply temperature
- Raise computer room temperature
- Avoid air mixing between supply and exhaust air
- Eliminate turning vanes
Rack Air Distribution Unit Airflow Diagram

- **Conditioned Room Air is:**
  - Pulled in from underneath raised floor
  - Delivered from bottom to top of rack by dual fans
  - Drawn in by the IT equipment

- **Provides Cooler Air to the Rack**
  - Provides better cooling for IT equipment reducing heat related failures
  - Extends the life of equipment in the rack

ARU AIR FLOW
**CHALLENGE # 2:**

Remove 3840 cfm of Hot Air From the Rack

**3 Ways to Remove Heat:**

- Through the room
- Through a duct
- Through ceiling plenum

**Rack Air Removal Unit Airflow Diagram**

- Fans pull in rack equipment exhaust air
  - Cable impedance is overcome by high powered fans
- Ducted exhaust system (optional) delivers hot air to plenum
  - Eliminates hot air from mixing with room air
- Proper airflow through the enclosure is ensured
  - Cool inlet air moves freely to equipment in the rack
CHALLENGE # 3:

Keep Hot Exhaust Air Away From Equipment Intake
Blanking Panels

Before and after images showing the effect of blanking panels on rack front temperatures:

- **BEFORE**:
  - 90°F 32°C
  - 80°F 27°C
  - 95°F 35°C
  - Rack front
  - 83°F 28°C
  - 72°F 22°C
  - 70°F 21°C

- **AFTER**:
  - 79°F 32°C
  - 73°F 32°C
  - 73°F 32°C
  - Rack front
  - 72°F 32°C
  - 70°F 32°C

Blanking panels block internal recirculation.
Cooling the data center

 Ultimater Strategy
 Dedicated High-Density Area

- Supports maximum-density racks
- Doesn’t require spreading out of high-density equipment
- Optimal floor space utilization
- New technologies can deliver predictable, highly efficient cooling
Dedicated High-Density Area: Considerations

- Requires prior knowledge of number of high-density racks
- Need to plan high-density area in advance and reserve space for it
- Requires ability to segregate high-density equipment

Airflow patterns
Dedicated High-Density Area: Power / Cooling Technology

- Ambient-temperature air is returned to room
- Hot aisle
- Integral rack power distribution system (UPS is optional)
- Door access to hot aisle and rear of IT equipment
- All exhaust air is captured within chamber and "neutralized" to ambient temperature
- Integral rack air conditioner
- Equipment racks take in ambient air from front
- Can operate on hard floor or raised floor

Hot aisle containment – capture the heat

- Roof for Hot Aisle - Converts Hot Aisle to a plenum to minimize air mixing
- Chamber Doors - Access to hot aisle, locks for security
- Dedicated Air Unit – Back to front air flow
ISX High Density Air Flow Pattern

Questions?

Thank you!