



Cooling Techniques That Meet “24 by Forever” Demands of Your Data Center

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With the push to install high-density equipment in computer rooms, such as blade servers, many questions have been raised as to the room’s capability to handle such heat loads and maintain “24 by forever” expectations. Three critical aspects that are important to the operation of computer facilities are matching IT expectations with the capabilities of the installed site infrastructure, then matching expectations to facility staffing and finally matching electrical and mechanical infrastructure systems.

The Uptime Institute, Inc.[®] (*The Institute*) has experimentally measured cooling in 19 computer rooms comprising 204,000 ft² and concluded that most computer rooms cannot properly handle the computer equipment loads presently installed to say nothing of being able to properly cool high-density equipment like blade servers. The computer rooms measured had an average power consumption of only 2.1 kilowatts (kW) per rack. Overall, the air intake temperatures at 10 percent of the racks in the study exceeded the published guidelines for maximum server reliability. By comparison, a fully populated rack of servers can produce 12-14 kW of heat or six times what computer rooms are already having trouble cooling.

Other findings from the study found:

- Ten percent of the cooling units had failed, but were not providing an alarm
- The computer rooms had 2.6 times more cooling capacity running than they required and still had 10 percent hot spots. (One room had 25 percent hot spots yet had 10 times more cooling running than was required by the heat load)
- Only 28 percent of the available supply of cold air was directly cooling computer equipment
- The other 72 percent was bypassing the computer equipment, which dramatically reduced cooling effectiveness

A common management problem is the failure to match IT availability expectations with site infrastructure capability. Users demand “24 by forever” system availability without the required site infrastructure and facility staffing to support it. Often the facility was built some time ago and the infrastructure has not been upgraded to meet the increased IT system availability demand or, in newly built installations, the money was not spent to establish the necessary infrastructure systems to meet current IT demands. Inconsistent or inadequate facility staffing is often an issue as all too often “AUTO” is the only one in-charge after 6 pm.

Under these circumstances the infrastructure should be shut down once or twice a year for preventive maintenance. What usually happens is preventive maintenance is postponed until there is a catastrophic failure and an unscheduled system outage.

Either a more realistic and downgraded IT availability target must be established or expenditures must be made to upgrade the supporting infrastructure and facility staffing to meet the “24 by forever” availability target. The minimum site requirements are redundant components in all mechanical *and* electrical systems, and the ability to concurrently maintain all systems including the power and cooling distribution to the raised floor. Such a system will require at least one active path with redundant components and an inactive path that can be activated when preventive maintenance is performed. Such a system can be taken down for maintenance work while the IT load is not affected. See *The Institute’s* “Industry Standard Tier Classifications Define Site Infrastructure Performance” white paper for a further description of what is required at www.uptime.com/tuipages/tuiwhite.html.



Another problem is not matching the architecture and capacities of electrical and mechanical systems as the heat load dissipated by the IT load increases. Generally, the electrical system is installed to provide uninterruptible power and, at least, to be concurrently maintained while the cooling system relies on engine-generator power as a backup and

has to be shut periodically down for maintenance or reconfigurations. With the increase in heat density in computer rooms, re-circulation of hot exhaust air during a loss of cooling has caused servers to “thermal off” more frequently and/or experience an abnormally high component failure rate due to the high input air temperatures.

Some Cooling-Specific Barriers to Achieving “24 by Forever” Availability in Computer Rooms Today

The lack of a computer room layout master plan is one problem facing managers trying to achieve “24 by forever” levels of availability. Without a master plan, racks and cabinets are often installed in a haphazard arrangement; including the direction equipment rows run, the direction cabinets are facing, spacing between rows, and the orientation of equipment rows to the cooling units in the room. (“Legacy” layout of equipment cabinets, in which multiple rows of cabinets face the same direction, is a major problem: exhausting hot air from one row directly into the intake air of the row behind.) This approach, all by itself, reduces maximum potential cooling delivery by 50 percent.

Another problem is the uniform placement of cooling units around the perimeter of the computer room. This configuration produces uniformly distributed cooling capacity in what is often a high non-uniformly distributed heat load environment, which creates both cold and hot spots in the room depending on the local power dissipation zones.

Another impact of the lack of a master plan for the raised floor is the inability to monitor and manage the critical parameters of raised-floor space,

equipment mounting space within cabinets, branch power circuits and circuit breaker pole positions, cooling capacity, and weight on the floor. Without such monitoring and management, installation decisions are made at the last minute, with little consideration for power and breaker space availability. Cooling availability and floor loading are often not considered in the computer equipment location decision. The result is often chaos!

Another exposure is the existence of bypass airflow in the computer room. This is cold airflow that doesn’t directly cool computer equipment. Fifty-eight percent of the cold air bypassing computer equipment air intakes (i.e. 78 percent of the total bypass airflow) is caused by unsealed cabling holes in the raised floor, which allows cold air to circulate directly into the hot aisle. A further 14 percent of the available cold air supply (or 22 percent of the total bypass airflow) escapes through perforated tiles incorrectly installed in the hot aisle, or installed randomly around the room. Another source of bypass air, but one that was not found in the 19 computer rooms, is unsealed penetrations through the computer room’s perimeter walls, through the slab under the raised floor, and/or above the dropped ceiling.



Bypass airflow dramatically reduces underfloor static pressure, which reduces airflow volume through the perforated tiles in the cold aisle. Bypass airflow pre-cools hot exhaust air before it returns to the cooling units. The reduced temperature of the returning air causes the cooling unit to throttle back and not deliver the expected cooling capacity. As a result, the underfloor supply air temperature increases: the room’s ability to cool high heat load cabinets is significantly reduced, which results in hot spots in these cabinets, especially at the top. Above an average heat density of 50 Watts/ft²

or 1.5 kW per cabinet heat dissipation, critically high input air temperatures can be experienced when cooling and airflow is lost for several minutes. (At higher densities, an unacceptable rise happens within seconds.) After power losses, it can take cooling systems five or more minutes to cycle back on line under the best of circumstances. The problems caused by this delay is further compounded if the backup power does not come on line immediately due to problems with the engine generators not starting or, more likely, not switching to pick up the load.

Limitations on the Installation of High-Density Equipment

This white paper defines 27 steps you can take to meet “24 by forever” expectations. Even with all 27 of these steps implemented, great care must be taken when installing special, high-density equipment like blade servers. Under ideal conditions, air-cooling can handle up to 7 kW of heat load in a cabinet. If adjoining cabinets have low to no load installed, that number can be increased to 10 kW. Above these figures, supplemental cooling is required. The most effective way to minimize overheating of high power density servers is to spread the heat load out, either by limiting the load in any cabinet or by not installing multiple high-density cabinets in close proximity in the room. If that is not possible, supplemental cooling must be considered. Supplemental cooling comes in a variety of options. The power dissipated in each cabinet must be coordinated to the capacity of the supplemental cooling system installed. Some of the available options include:

Limitations on the Installation of High-Density Equipment:

- Self-contained cabinets with chilled water fan/coil systems, which provide a closed loop cooling cycle
- Supplemental rear doors with chilled water fan/coil units, which pre-cool the hot exhaust air before it returns to the normal cooling units
- Incline chilled water fan/coil units replacing equipment cabinets, which pull hot exhaust air from the hot aisle and blows cold air into the cold aisle
- Overhead fan/coils that pull hot air out of the hot aisle and blow cold air into the cold aisle



Twenty-Seven Things You Can Do to Meet "24 by Forever" Expectations

1. Create a Raised-Floor Master Plan
2. Install computer and infrastructure equipment cabinets in the Cold Aisle/Hot Aisle arrangement
 - a. 14' cold aisle to cold aisle separation with cabinets \leq 42" deep
 - b. 16' cold aisle to cold aisle separation with cabinets $>$ 42" to 48" deep
3. Utilize proper spacing of the cold aisles
 - a. 48" wide with two full rows of tiles which can be removed
 - b. All perforated tiles are only located in the cold aisle
4. Utilize proper spacing of the hot aisles
 - a. Minimum 36" with at least one row of tiles able to be removed
 - b. Do not place perforated tiles in the hot aisle
5. Place cooling units at the end of the equipment rows
 - a. Aligned with hot aisles where possible
6. Face cooling units the same direction
 - a. No "circle the wagons," a.k.a., uniformly distributed cooling
7. Limit maximum cooling unit throw distance to 50'
8. Create appropriate cooling capacity, with redundancy, in each zone of the room (zone maximum is one to two building bays)
 - a. Install minimum of two cooling units even if only one is needed
 - b. Install one-in-six to one-in-eight redundant cooling units in larger areas
9. Use only sensible cooling at 72°F/45 percent Rh when calculating the capacity of cooling units
10. Establish minimum raised-floor height
 - a. 24" if the cabling is overhead, with no chilled water or condenser water pipes under the floor blocking the airflow
 - b. Recommend 30" to 36" if there are airflow blockages
11. Place chilled or condenser water pipes in suppressed utility trenches if the computer room is built on grade
12. Establish a minimum clearance of 3' from the top of the cabinets to a ceiling
13. Put Power Distribution Units and Remote Power Panels in line with computer equipment cabinet rows occupying cabinet positions
14. The maximum number of perforated tiles is the total cooling unit airflow divided by 750 cfm = maximum number of perforated tiles to be installed
 - a. Install only the number of perforated tiles necessary to cool the load being dissipated in the cabinet/rack in the area immediately adjacent to the perforated tile.
 - b. Turn off cooling units that are not required by the heat load (except for redundant units)
15. Do not use perforated tile air flow dampers and remove all existing dampers from the bottoms of perforated tiles (reduces maximum air flow by 1/3, they often close unexplainably and they potentially can produce zinc whiskers).



Twenty-Seven Things You Can Do to Meet “24 by Forever” Expectations (Cont’d):

16. Ensure cabinets are installed with the front face of the frame set on a tile seam in the cold aisle
17. Require cabinet door faces to have a minimum of 50 percent open perforation, 65 percent is better
18. Seal all cable cutouts and other openings in the raised floor with closures. Triton KoldLok® grommets are one solution.
19. Seal all penetrations in the subfloor and perimeter walls under the raised floor and above the dropped ceiling
20. Spread power cables out on the subfloor, preferably under the cold aisle to minimize airflow restrictions
21. Place data cables in trays at the stringer level in the hot aisle
22. If overhead cable racks are used, the racks should run parallel to the rows of racks. Crossover points between rows of racks should be located as far from the cooling units serving the area as practical
23. Prevent internal hot air recirculation by sealing the front of cabinets with blanking plates, including empty areas in the equipment-mounting surface, between the mounting rails, and the edges of the cabinets (if necessary)
24. Ensure all cooling units are functioning properly:
 - a. Set points and sensitivities are consistent
 - b. Return air sensors are in calibration—calibrate the calibrator
 - c. Airflow volume is at specified level
 - d. Unit is functioning properly at return air conditions
 - e. Unit produces ≥ 15 F delta T at 100 percent capacity
25. Be sure the cooling unit’s blower motor is turned off if the throttling valve sticks (chilled water type units) or if a compressor fails (air conditioning type unit)
26. Adjust chilled water temperature to eliminate latent cooling
27. Monitor and manage the critical parameters associated with equipment installation, by area of the computer room (no more than two building bays)
 - a. Space: Number of cabinets and rack unit space available versus utilized
 - b. Power: PDU output available versus utilized
 - c. Breaker positions: available versus utilized
 - d. Sensible/Redundant cooling capacity available versus utilized
 - e. Floor loading: acceptable weight versus installed cabinet and equipment weight plus dead load of floor and cables, plus live load of people working in area. Compare the actual floor load with the subfloor structural strength



The Uptime Institute, Inc.
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Demands of Your Data Center

About The Uptime Institute, Inc.

Since 1993, *The Institute* has been a pioneer in creating and operating knowledge communities for improving uninterruptible uptime in Data Center Facilities and Information Technology organizations. *The Institute* also prepares industry white papers; offers insightful seminars and conferences; provides manufacturer focus groups; certification of products, processes, people, design topologies, and sites; provides training in IT and facilities site infrastructure uptime management; and conducts sponsored research.

Authorship

Robert "Dr. Bob" F. Sullivan, Ph.D., had a 32-year engineering career at IBM. He was part of the IBM team that first identified zinc whiskers. Dr. Bob originated the Cold Aisle/Hot Aisle concept in 1993. For *The Institute*, he is a staff scientist and has performed detailed research on how computer room cooling actually works and teaches *The Institute's* seminar on High Density Cooling. For Triton Technology Systems, Inc., he conducts computer room KoldPlans, KoldCheck cooling diagnostics and KoldWorks performance remediations. For ComputerSite Engineering, Inc.[®], Dr. Bob delivers raised-floor engineering services, including the Raised-Floor Environmental Audit, helping clients exceed gross computer room densities of 50 Watts/ft².

Ken Brill is founder and Executive Director of *The Institute* and the Site Uptime Network[®]. The 68 members of the Site Uptime Network represent mostly Fortune 100 companies who are very serious about infrastructure availability and who collectively and interactively learn from each other, as well as from *The Institute* facilitated conferences, site tours, benchmarking, best practices, uptime metrics, and abnormal incident collection and analysis. Over a period of 10 years, these members have steadily reduced their collective facility caused downtime frequency by a factor of 10. Many uptime innovations, such as dual power topology, can be traced back to Mr. Brill's original work.



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