Cooling Strategies for IT Wiring Closets and Small Rooms

White Paper 68

Revision 1

by Neil Rasmussen and Brian Standley

> Executive summary

Cooling for IT wiring closets is rarely planned and typically only implemented after failures or overheating occur. Historically, no clear standard exists for specifying sufficient cooling to achieve predictable behavior within wiring closets. An appropriate specification for cooling IT wiring closets should assure compatibility with anticipated loads, provide unambiguous instruction for design and installation of cooling equipment, prevent oversizing, maximize electrical efficiency, and be flexible enough to work in various shapes and types of closets. This paper describes the science and practical application of an improved method for the specification of cooling for wiring closets.

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Introduction

The design of data centers and large computer rooms always includes a cooling system. Yet many IT devices are located in distributed spaces outside of the computer room in closets, branch offices, and other locations that were never designed with provisions for cooling IT equipment. The power density of IT equipment has increased over time and the result is that distributed IT equipment such as VoIP routers, switches or servers often overheat or fail prematurely due to inadequate cooling.

The typical approach to this problem is to ignore it, deploy equipment, and then respond with corrective action if and when equipment overheats and / or fails. More and more users are finding this approach unsatisfactory and demand a more proactive approach to ensuring the availability of distributed IT equipment. The purpose of this paper is to outline the basic principles of cooling small, distributed IT environments and to provide guidance for the effective specification and design of supporting cooling systems.

Suitable operating temperature for wiring closets

To properly specify the appropriate cooling solution for a wiring closet, the temperature at which that closet should operate must first be specified. IT equipment vendors usually provide a maximum temperature under which their devices are designed to operate. For active IT equipment typically found in a wiring closet, this temperature is usually 104°F (40°C). This is the maximum temperature at which the vendor is able to guarantee performance and reliability for the stated warranty period. It is important to understand that although the maximum published operating temperature is acceptable per the manufacturer, operating at that temperature will not generally provide the same level of availability or longevity as operating at lower temperatures. Because of this, some IT equipment vendors also publish *recommended* operating temperatures for their equipment in addition to the maximum allowed. Typical recommended operating temperatures from IT equipment vendors are between 70°F (21°C) and 75°F (24°C).

In addition, The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) TC 9.9 publishes both recommended and allowable operating temperatures for IT equipment. The intent is to provide better guidance to ensure reliability and performance of equipment. These values are provided in **Table 1**.

Table 1

Operating temperature limits per ASHRAE TC9.9

Operating temperature	Temperature range
Recommended	68-77°F (20-25°C)
Allowable	59-90°F (15-32°C)

The goal should always be to maintain temperatures no higher than 77°F (25°C). However, if doing so is not possible, maintaining below the maximum allowable temperature of 90°F (32°C) can be a suitable solution for less critical closets. Any temperature above 90°F (32°C) should be avoided to reduce risk of equipment failure. Also, 90°F (32°C) is the maximum temperature organizations such as the Occupational Safety and Health Administration (OSHA) and International Organization for Standardization (ISO) deem permissible for light work loads. Further discussion on health and safety requirements can be found in White Paper 123, *Impact of High Density Hot Aisles on IT Personnel Work Conditions*.

Related resource
White Paper 123
Impact of High Density Hot Aisles on IT Personnel Work Conditions

More careful consideration must be given to closet environments where a UPS is deployed. Increases in temperature have a much more pronounced effect on battery longevity than other types of IT equipment. A user can expect a typical UPS battery operating at 104°F (40°C) to only last 1.5 years or less as compared to the usual 3 – 5 years at normal operating conditions. An operating temperature below 77°F (25°C) should be a requirement. Otherwise, consideration should be given to protect all wiring closets with a centralized UPS placed in an adequately conditioned space outside of the closets.

The basic principle of heat removal

To best understand the problem, it is advantageous to frame problem in terms of heat removal, rather than of cold air supply. If it is not removed, the heat within any space that houses IT equipment will accumulate, raising the temperature. **Every kilowatt of heat used by the IT equipment creates a kilowatt of heat power which must be removed.**

Heat can be thought of as a commodity that flows "downhill". It flows from a higher temperature object or medium to a lower temperature object or medium. If you want to remove it, you need to allow it to channel to a colder place. In many real world environments, this physical option may not exist.

Heat can leave a small confined space like an office or closet in five different ways. These are:

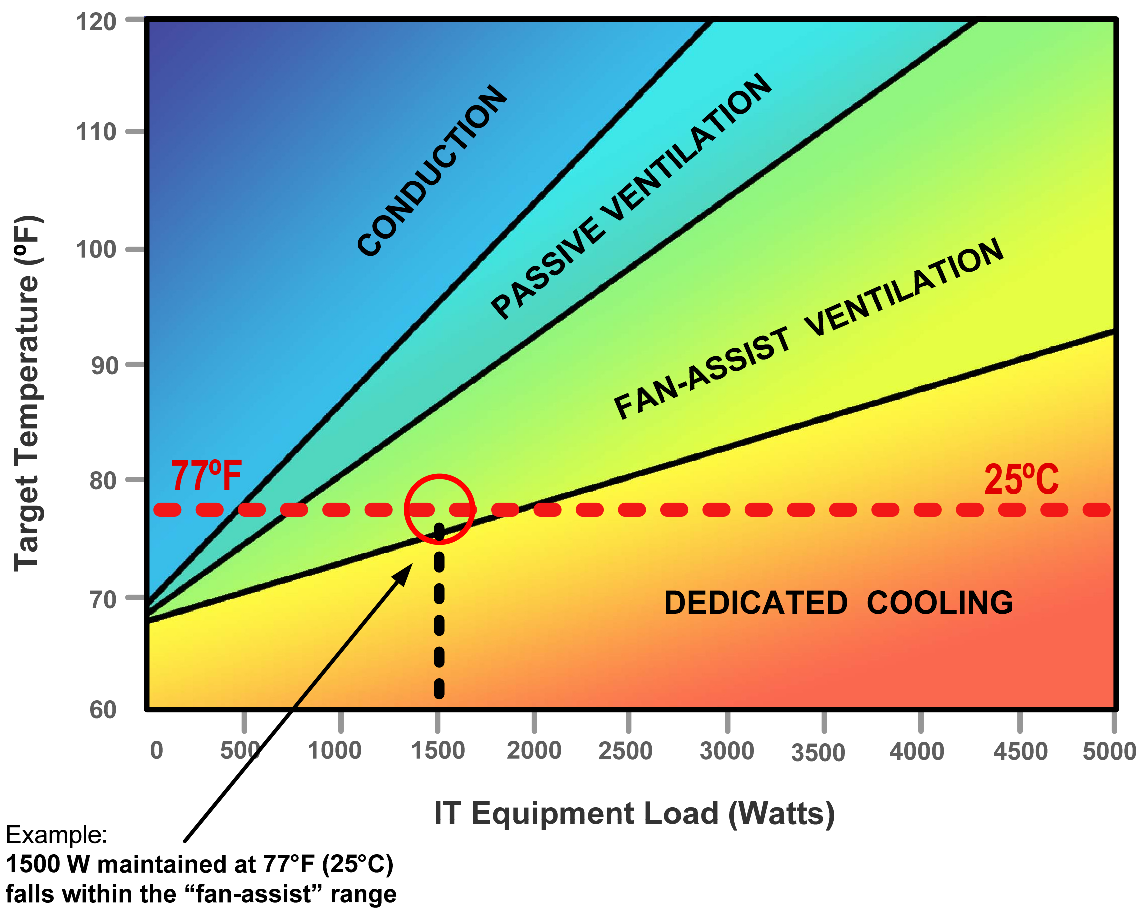
Conduction: Heat can flow through the walls of the space
Passive Ventilation: Heat can flow into cooler air via a vent or grille, without an air moving device
Fan-assisted Ventilation: Heat can flow into cooler air via a vent or grille that has an air moving device
Comfort Cooling: Heat can be removed by a building's comfort cooling system
Dedicated Cooling: Heat can be removed by a dedicated air conditioner

The five methods listed above differ in performance, limitations, and cost. For a given installation, a user should understand which method is being used or proposed, which method is most appropriate given the constraints and preferences, and how to go about specifying the design requirement.

Figure 1 provides a general guideline for cooling strategies based on room power and target room temperature, assuming no unusual circumstances. It illustrates the acceptable performance ranges for the various methods. These limits should *not* be considered absolute values, since strategies overlap and the final design must consider all variables that effect cooling. *Note that comfort cooling is not included in this chart because it is too variable and unpredictable.* More discussion on this is found later in the paper.

Figure 1

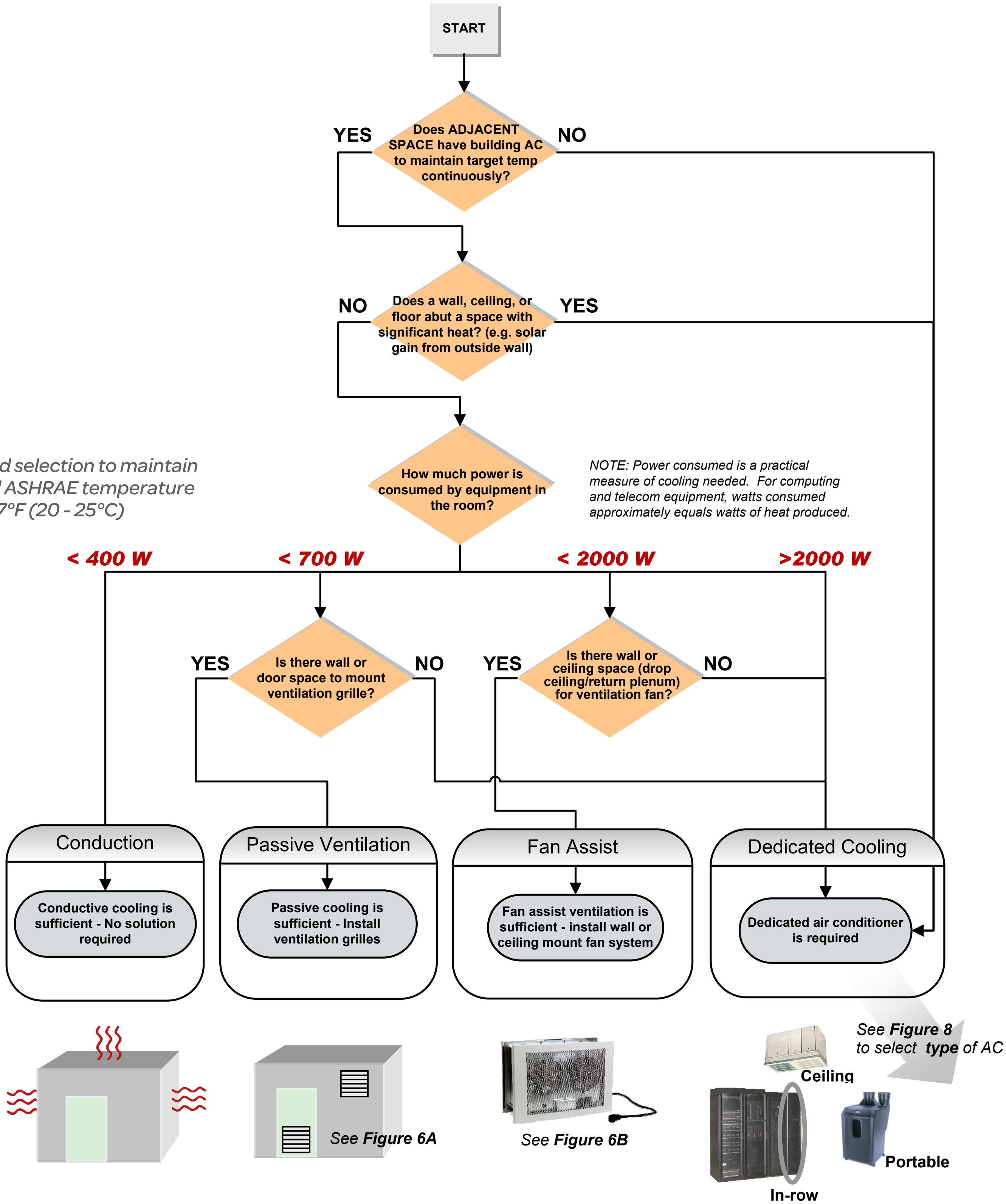
Cooling method guide based on power load and target room temperature



To help with the selection of the most appropriate method, given the variety of variables, a decision flow chart is presented in **Figure 2**. *Once again, note that comfort cooling is not a recommended solution*.

Figure 2

Cooling method selection to maintain recommended ASHRAE temperature range of 68 - 77°F (20 - 25°C)



The five methods of cooling closets

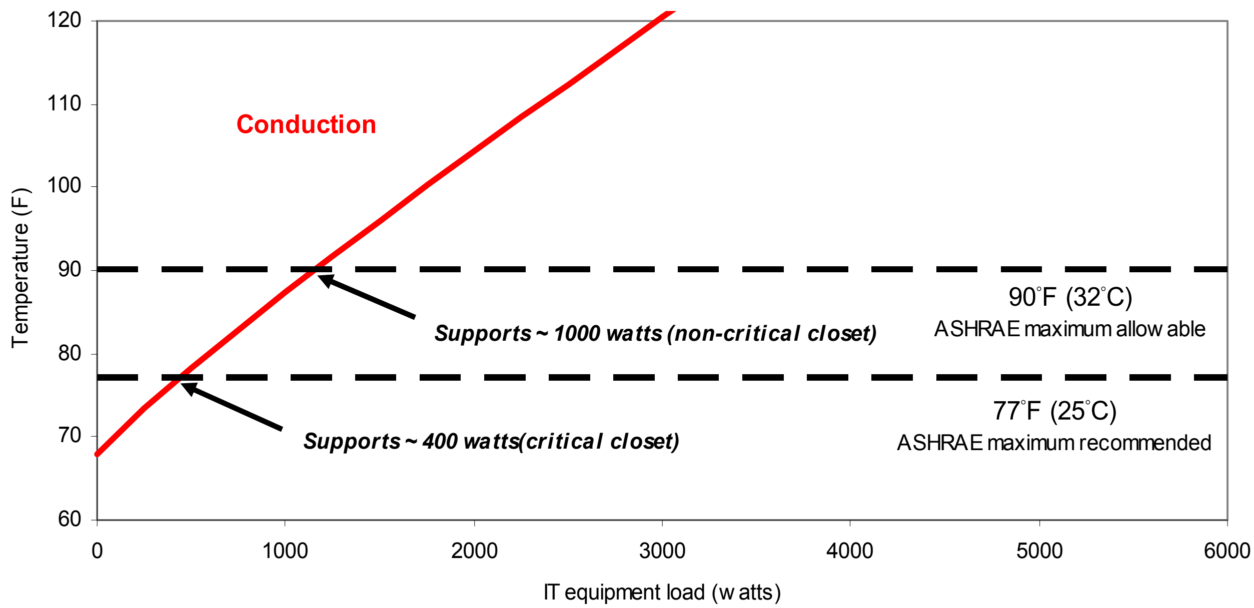
The five methods for closet cooling are each explained in more detail in order to provide a clear understanding of their performance and limitations.

Conduction: heat can flow through the walls of the spaces

If a closet is effectively sealed, as many utility closets are, then the only way for the heat to leave is by conduction through the walls. For this to work, the air in the closet must heat up to the point where it is hotter than the temperature that is on the other side of the closet walls. Practically, this means that the closet will always be hotter than the other ambient air within the building, and the degree of temperature rise will be greater as the power level of the IT equipment increases. An example of the relationship between average, well mixed closet temperature and the IT load is shown in **Figure 3**.

Figure 3

Closet temperatures versus IT equipment load: conduction performance



The relationship above assumes an effectively sealed 10 x 10 x 10 foot (3 x 3 x 3 meter) room with only 50 cubic feet per minute (23.6 liters per second) of air leakage, drywall construction, and all four walls opposite comfort cooled spaces at 68°F (20°C). See the **appendix** for further details and assumptions.

As can be seen, this typical closet can support up to 400 watts of IT load if its criticality requires temperature to be less than 77°F (25°C) and up to 1000 watts if less than 90°F (32°C) is acceptable.

However, closets vary in size and construction material, and are subject to other factors that influence this relationship – which ultimately limits the ability for this method to be used. **Table 2** summarizes these key factors and their impact.

Table 2

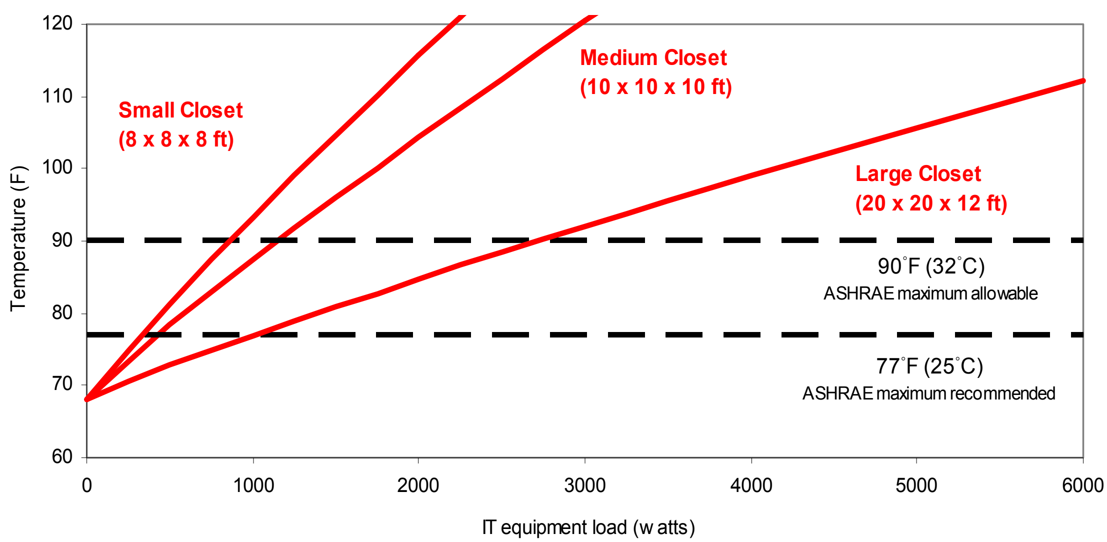
Factors that can influence closet temperature vs. load relationship and expected impact

Factor	Expected impact on closet temperature
Room dimensions	Temperature increases as room dimensions decrease
Wall, ceiling, floor material	Temperature increases as construction material thermal resistance increases
Setback of building air conditioner on nights / weekends	Every degree increase in building air conditioner increases closet temperature by same amount
One wall subject to sun exposure / outdoor temperature on hot sunny day	Temperature increases as wall area exposed to outdoor temperature and sun increase

The most obvious influencing factor is dimension of the room. The larger the room, the better the room's ability to dissipate heat because more wall, ceiling, and floor surface area handles the heat. Conversely, the smaller the room is, the lower the conductive cooling performance. This variation in performance is depicted in **Figure 4**.

Figure 4

Effect of closet dimensions on conduction cooling performance

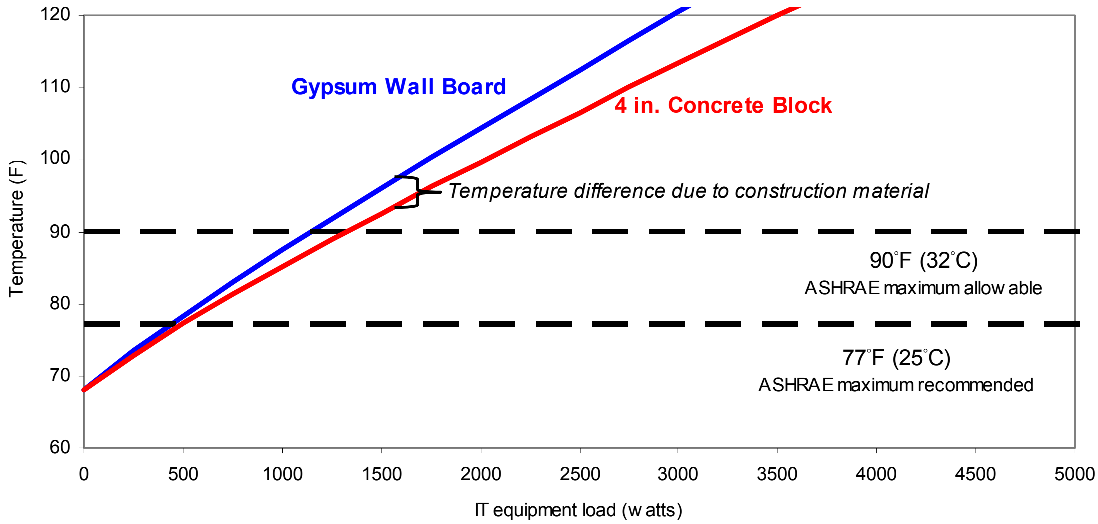


Material used for walls, ceiling, and floor will also provide a similar deviation in the relationship between temperature and load as the ability to transfer heat differs from one material to the next. If we substitute the gypsum board walls and acoustic tile ceiling in the example above for 4 inch (10 cm) concrete block walls and a 4 inch (10 cm) concrete slab floor, we see an increase in cooling performance. This is shown in **Figure 5**.

One common occurrence that impacts conductive cooling performance is a rise in the building ambient air temperature, due to weekend cooling setbacks. When this happens, the closet temperature will rise in step. In our example, if the building air conditioning is set back to 85°F (29°C) from 68°F (20°C) on the weekend (a rise of 17°F (9°C)), we can expect the same 17°F (9°C) increase in the closet. This means that for a critical closet that requires the temperature to be 77°F (25°C) or less, no load can be supported; and for a non-critical closet that allows the temperature to be 90°F (32°C) or less, only 250 watts can be supported.

Figure 5

Effect of construction material on conduction cooling performance



Another limitation of this method of cooling is that if one of the closet walls is an outside wall of the building, the closet temperature will be subject to the outdoor wall temperature, which is effected by both the ambient outdoor temperature and the heating due to sun exposure. Therefore, a closet with an outside wall may overheat on a hot or sunny day. For our 10 x 10 x 10 foot example, we can expect an 8 – 12°F (4 – 7°C) increase in temperature assuming outside ambient is equal to 100°F (38°C) and worst case sun exposure of 1000 watts / m2.

Sealed closets vary in conduction cooling performance based on size, construction, and the adjacent environments. **In general, it is recommended that conduction be used as a sole means of cooling for critical closets when the power load within the closet is less than 400 watts with consideration given to other factors as mentioned above that will impact cooling performance**. Likewise, for non-critical closets, conduction should only be used when the load in the closet is less than 1000 W. This limits the conduction method to very low power IT devices like small stackable network switches. As seen in the examples above, temperature rises quickly as load increases. Note that the addition of another heat source, like a light bulb, adds materially to this power level. Therefore, closet lights should be of the low power high efficiency type, and should automatically shut off when the door is closed, or they should be omitted.

Passive and fan-assisted ventilation: heat can flow into cooler air via a vent or grille

Closets can be cooled by venting them to the ambient building air. The venting can be passive using appropriately placed holes or vents, or it may be fan-assisted. The basic principle is to ensure that the closet air temperature does not rise substantially above the building ambient air temperature. Examples of venting systems are shown in **Figure 6**.

Figure 6

Examples of two types of closet ventilation

6A. (left)

Passive ventilation

6B. (right)

Fan-assisted ventilation

See **Figure 9** for placement of fan-assisted ventilation in closet

The temperature rise of a ventilated closet as a function of IT load power is shown in **Figure 7**.

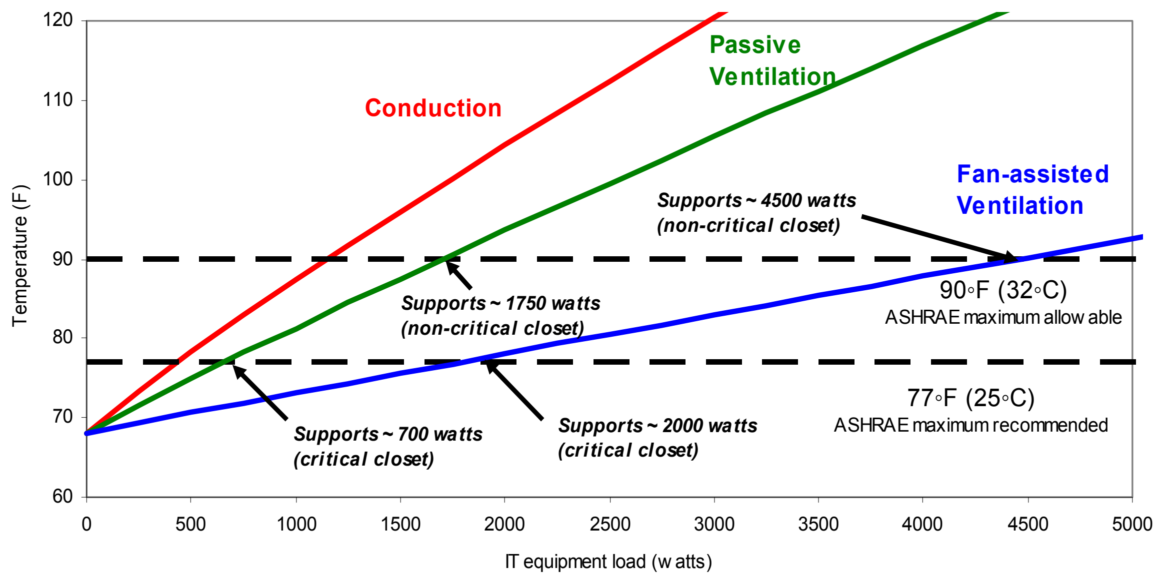


Figure 7

Closet temperature versus IT load – passive and fan-assisted ventilation

In the figure, note the two different ventilation curves. The passive ventilation curve is based on adding vents such as those shown in **Figure 6A**. Fan-assisted ventilation as shown in **Figure 6B** provides a lower temperature rise than passive ventilation. The fan-assisted ventilation curve shown assumes airflow of 480 cubic feet per minute (226.5 liters / second). Temperature rise will decrease as airflow is increased (accomplished with higher capacity fan system or by adding additional fan systems).

Ventilation is a very practical method for closet cooling. **For power levels below 700 watts, passive ventilation is effective for critical closets. For power levels of between 700 watts and 2000 watts, fan-assisted ventilation is appropriate for critical closets. Support of even higher power levels can be achieved if higher capacity or multiple fan assist units are used.** Likewise, for non-critical closets, passive ventilation is effective for up to 1750 watts, and fan-assisted ventilation is effective from 1750 watts to 4500 watts. Application considerations such as the placement of the air intake vent and fan-assist unit relative to the IT equipment can also increase cooling performance. It is also important to note that external effects such as those illustrated in **Figure 4** and **Figure 5** above must also be considered with this method.

Comfort cooling: heat can be removed by a comfort cooling system

Many buildings have an existing air conditioning system or combined heat and air conditioning system for creating a comfortable environment for personnel. These comfort cooling systems typically have air handling ductwork. It appears attractive to take advantage of this system by installing additional ducting to closets, in the same way that ducts are added when new offices or rooms are added. **However, simply adding ducts rarely solves closet cooling problems and often makes them worse.**

Comfort cooling systems cycle on and off. A thermostat placed somewhere in the zone, but not in the closet is the usual control mechanism. For a small space like a closet with IT devices, this means that the temperature will decrease when the cooling system is on, and increase when it is off. This results in significant swings in temperature that actually stress IT equipment more than sustained higher temperature conditions.

Furthermore, best practice for comfort cooling systems involves turning up the temperature set points on week nights and weekends to help conserve electricity. Some are actually shut off completely. If a wiring closet is simply part of a larger zone, the average temperature of the wiring closet will generally increase by the amount the temperature set point is increased. By simply adding ductwork, one is forced to choose between wasting electricity on nights and weekends and making the temperature swings in the wiring closet even worse.

In order to use a building comfort cooling system to cool a wiring closet, the wiring closet in question would have to be made into a dedicated zone with its own properly sized supply and return ducts, terminal units (i.e. fan coil unit, VAV box) and controls (i.e. thermostats). This is not practical.

Challenges in adding a dedicated wiring closet zone include:

- Assurance that static pressure is adequate and constant in the supply duct serving the VAV (variable air volume) box, especially on hot summer days when the building air conditioning system is working the most
- Very low power density capability – Most comfort cooling systems are designed to provide 4 – 5 watt / ft^2 (43 – 54 watt / m^2) of cooling which equates to 150 watts / rack (assuming 30 square feet per rack)
- Lack of scalability
- High cost of implementation

In addition, the central cooling system is also part of a main or supplemental heating system. In these situations, that supply duct installed to keep the closet cool will be providing heat into the space during the winter months. This is never desirable.

Tapping into a building air conditioning system to cool IT closets is, in general, not appropriate. If duct work already exists, it should be removed or shut off and either replaced or supplemented by one of the other approaches described in this paper.

Dedicated cooling: heat can be removed by a dedicated air conditioner

The most effective way to gain control of closet temperatures is by installing dedicated closet air conditioning equipment. However, dedicated air conditioning is much more expensive and complex than using passive or fan-assisted ventilation and should only be used when required.

In general, when the power level in a closet exceeds approximately 2000 W for critical closets or 4500 W for non-critical closets, dedicated air conditioning equipment is recommended. In making the determination of power, it is important to refer to detailed power consumption specifications from the IT vendor, and to establish the power level of the specific configuration of the IT equipment. Typically the actual power draw of specific equipment is well below the “nameplate” power rating on the back panel and a correct determination may save a considerable amount of cooling solution expense and complexity. For example, configurable routers with back panel nameplate power ratings of 5 – 6 kW only actually draw 1 – 2 kW in common user configurations. In this case a correct determination could eliminate the need for an air conditioner.

Cases exist where a dedicated air conditioner is appropriate even when ventilation appears to be a technically viable alternative. These cases include:

- The ventilation air outside the closet contains significant dust or other contaminants
- The ventilation air outside the closet is subject to excessive temperature swings
- Practical constraints such as leases or cosmetics make it impossible to add ventilation ducts

In these cases, ventilation that utilizes building ambient air is not a viable alternative and the only practical approach is dedicated air conditioning equipment.

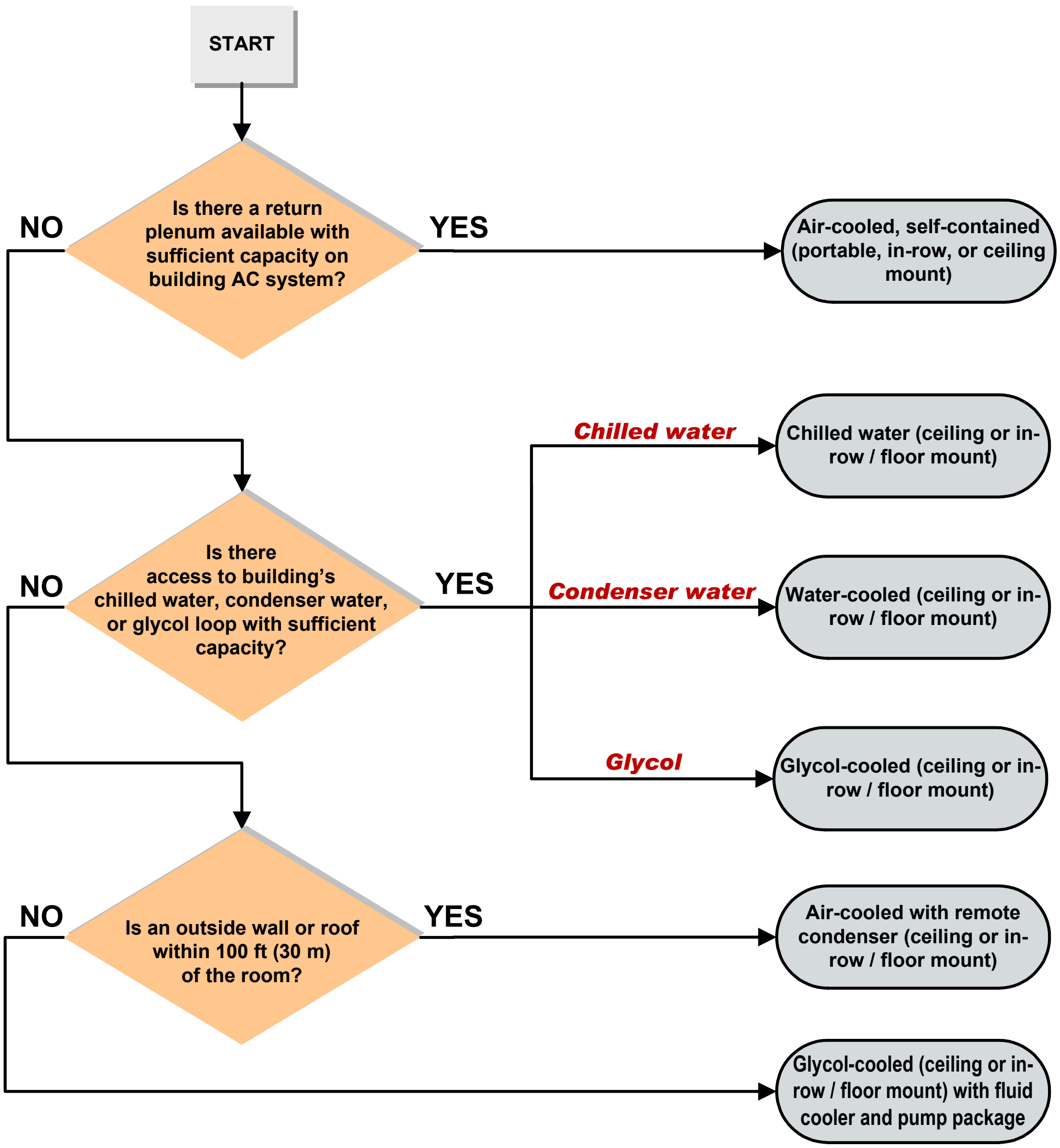
Related resource
White Paper 59
The Different Types of Air Conditioning Equipment for IT Environments

When the use of air conditioning equipment in a closet or small room is specified, a number of different types of air conditioning equipment options exist. See White Paper 59, *The Different Types of Air Conditioning Equipment for IT Environments* for more details.

The selection of the appropriate type of dedicated air conditioner for a given closet installation is guided primarily by the building constraints and can be accomplished by using the simple flowchart of **Figure 8**.

Figure 8

Dedicated air conditioner selection



Ceiling-mount air conditioning unit

In-row air conditioning unit

Portable air conditioning unit

Effect of UPS on closet cooling system

It is a common and recommended practice to use small distributed UPS systems in closets to assure business continuity. UPS systems may be sized to provide a brief power backup for the closet IT load, or the UPS may be selected to provide extended backup time (i.e. greater than an hour). In either case, the thermal load created by the UPS is typically much smaller than the IT load and can safely be ignored.

When a UPS is installed, the IT equipment will continue to create heat during a power outage. Therefore the cooling system must continue to operate. If the backup time of the UPS is less than 10 minutes, the thermal mass of the air and wall surfaces within the closet will keep the temperature within reasonable limits and no precautions need to be taken. However, if the UPS is designed to provide runtime in excess of 10 minutes, then the cooling system must continue to operate during this period. This means that if fan-assisted ventilation or air conditioning is used, the fan or air conditioner must be powered by the UPS. The need to power the fan or air conditioner must be taken into consideration when sizing the UPS. In the case of fan-assisted ventilation, this is not a significant problem, but for air conditioners this may require a much larger UPS and battery (often 4 – 6 times the nominal rated current draw of the air conditioner to account for compressor inrush current). This is another reason why fan-assisted ventilation should be used whenever possible instead of closet air conditioning.

A practical and cost effective alternative to putting a dedicated air conditioning unit on UPS is to install a fan-assisted ventilation system as a back up for the dedicated air conditioner. Ideally, the fan system will power on in the event of a power outage to provide some level of air exchange to the room, while the dedicated air conditioner is out of commission. Upon return of power (and air conditioning which should have an automatic restart feature), the fan-assisted ventilation system will power back off.

Attributes of effective fan-assisted ventilation

From the above discussions it is evident that excessive heat in a wiring closet is a legitimate concern, and the simpler solutions of passive or fan-assisted ventilation are preferred whenever feasible. While many options are available to users for the design of ventilation systems from commercially available parts, well-characterized packaged solutions designed specifically for closet cooling also exist. **Table 3** suggests what users should look for in a closet ventilation system.

Table 3

Ventilation system features and benefits

Feature	Benefit
Wall or ceiling mountable	More flexibility as one solution is compatible with many different closet types
Specified for calculated IT loads	Higher confidence that the solution will perform as expected
Remotely manageable	Lower mean time to recover (MTTR)
Multiple fan speeds	Ability to lower acoustic noise when max airflow is not required
More than one fan	Fan redundancy for fault tolerance
Tamper-proof mounting	Higher level of security
Easy installation	Requires minimal modification to closet environment and reduces the need for outside contractor involvement
Minimal assembly required	Fast, easy installation
Plug or hard wire configurations	Simple compliance with local electrical regulations
Broad capacity range	Ability to standardize on a single device for different installations
Specified and characterized for use with a UPS system	Higher overall system availability

An example of a fan-assisted ventilation unit meeting the above requirements is illustrated in **Figure 9**.

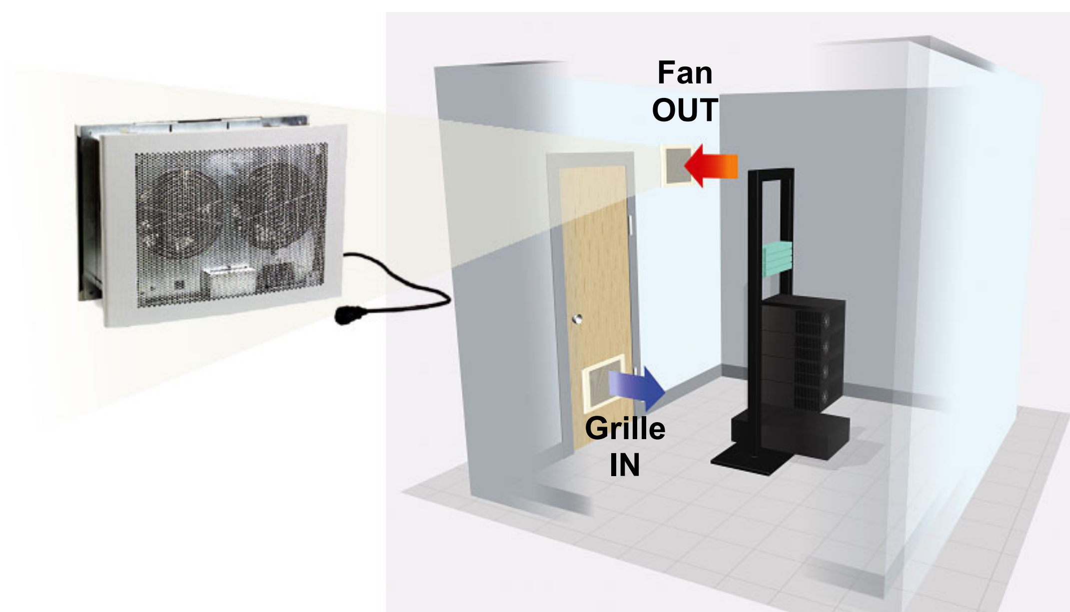


Figure 9

Closet fan-assisted ventilation unit

Conclusion

For most IT closets, ventilation is the most effective and practical cooling strategy. A well designed and implemented passive ventilation system is effective for lower power levels. For higher power closets with VoIP routers or servers, fan-assisted ventilation is recommended.

When the closet power level for critical closets is over 2000 watts (4500 watts for non-critical closets), or the ambient air outside the closet is hot, uncontrolled, or contaminated, dedicated air conditioning is appropriate. The use of existing comfort air conditioning systems for closet cooling is not recommended because it will almost always result in wide closet temperature fluctuations.

The guidelines provided in this paper assist with the selection of the appropriate closet cooling solution. The emergence of ventilation systems specifically designed and characterized for IT closets simplifies the selection process and allow for implementation of standardized closet cooling solutions.

About the author

Neil Rasmussen is a Senior VP of Innovation for Schneider Electric. He establishes the technology direction for the world's largest R&D budget devoted to power, cooling, and rack infrastructure for critical networks.

Neil holds 19 patents related to high-efficiency and high-density data center power and cooling infrastructure, and has published over 50 white papers related to power and cooling systems, many published in more than 10 languages, most recently with a focus on the improvement of energy efficiency. He is an internationally recognized keynote speaker on the subject of high-efficiency data centers. Neil is currently working to advance the science of high-efficiency, high-density, scalable data center infrastructure solutions and is a principal architect of the APC InfraStruXure system.

Prior to founding APC in 1981, Neil received his bachelors and masters degrees from MIT in electrical engineering, where he did his thesis on the analysis of a 200MW power supply for a tokamak fusion reactor. From 1979 to 1981 he worked at MIT Lincoln Laboratories on flywheel energy storage systems and solar electric power systems.

Brian Standley is the Product Line Manager for Small Cooling Systems at American Power Conversion. He has nine years of experience in product management and has been intimately involved with design, development, launch and support of products within multiple product categories including cooling solutions, InfraStruXure, and racks / enclosures. Brian has also held positions in sales and support.

Brian received his Bachelors of Science degree in Physics from Rensselaer Polytechnic Institute (RPI) prior to joining APC in 1994 and his Masters degree of Business Administration in 2001 from the University of Rhode Island (URI).

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Appendix: description of assumed conditions for typical wiring closet

The “typical” wiring closet described in this paper is based upon an extensive model that considers wall conduction, convection and radiation. "Convection" includes natural convection with the room walls plus a prescribed airflow (associated with leakage airflow). The conditions modeled for the “typical” wiring closet are as follows:

Table A1

Conditions of “typical” wiring closet

Feature	Benefit
Dimensions of room	10 x 10 x 10 feet (3 x 3 x 3 meter)
Building ambient temperature	68°F (20°C)
Room construction material: Interior side walls are plane air space insulated steel frame walls with gypsum wallboard finishing Floor is 4 inch concrete slab Ceiling is ½ inch thick acoustic tiles Exterior wall is a insulated concrete block with rigid foam insulating sheathing and gypsum wallboard finishing	Interior side walls: R-value =0.29 Floor: R-value = .1 Ceiling: R-value =0.22 Exterior wall: R=1.32
Exterior wall surface conductance (h) with wind of 3.4 m/s (12 km/h)	h = 22.7 (m² °C/W)
Relative humidity	50%
Leakage airflow (reasonable estimate for leakage through door cracks and/or a suspended ceiling)	50 cfm (23.6 L/s)