The Different Types of Air Distribution for IT Environments

White Paper 55

Revision 4

by Neil Rasmussen

> Executive summary

There are nine basic approaches to distribute air in data centers and network rooms. These approaches vary in performance, cost, and ease of implementation. These approaches are described along with their various advantages. The proper application of these air distribution types is essential knowledge for Information Systems personnel as well as Facilities Managers.

Contents

Click on a section to jump to it

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Introduction

Data center heat removal is one of the most essential yet least understood of all critical IT environment processes. As the latest computing equipment becomes smaller and uses the same or even more electricity than the equipment it replaced, more heat is being generated in data centers. Precision cooling and heat rejection equipment is used to collect and transport this unwanted heat energy to the outside atmosphere.

This paper describes the nine types of air distribution. The information presented here is a foundation allowing IT professionals to successfully manage the specification, installation, and operation of IT environment cooling systems. For definitions of various terms used throughout this paper, see White Paper 11, *Explanation of Cooling and Air Conditioning Terminology for IT Professionals*.

Link to resource
White Paper 11
Explanation of Cooling and Air Conditioning Terminology for IT Professionals

How air conditioners work

White Paper 57, *Fundamental Principles of Air Conditioners for Information Technology* provides information regarding the nature of heat in the IT environment, operation of the refrigeration cycle, and the basic functionality of precision cooling devices and outdoor heat rejection equipment.

Link to resource
White Paper 57
Fundamental Principles of Air Conditioners for Information Technology

Cooling architectures

A cooling architecture is fundamentally described by:

1. A particular heat removal method
2. A particular air distribution type (the subject of this paper)
3. The location of the cooling unit that directly supplies cool air to the IT equipment

These three elements are briefly described below, along with their white paper references, in order to provide context around the entire data center cooling system.

Heat removal
The heat rejection system provides bulk cooling capacity and transports or pumps the heat energy from the IT environment to the outdoors. White Paper 59, *The Different Technologies for Cooling Data Centers* describes the seven basic cooling technologies and their components.

Link to resource
White Paper 59
The Different Technologies for Cooling Data Centers

Air distribution
Air distribution is the subject of this paper.

Location of the cooling unit
The cooling unit is defined in this paper as the device that provides cool supply air to the IT equipment. There are four basic cooling unit locations. In general, the cooling unit is separate from the other heat rejection system devices. In some cases, the entire cooling architecture is “containerized” and located outdoors adjacent to the data center. The location of the cooling unit plays a significant role in data center design including overall cooling efficiency, IT power density (kW / rack), and IT rack space utilization. For more information see White paper 130, *The Advantages of Row and Rack-Oriented Cooling Architectures for Data Centers*.

Link to resource
White Paper 130
The Advantages of Row and Rack-Oriented Cooling Architectures for Data Centers

The nine types of air distribution

Unlike power distribution, where flow is constrained to wires and clearly visible as part of the design, airflow is only crudely constrained by the room design. Controlling the airflow is the main objective of the different air distribution types. **The primary distinctions that determine the effectiveness of a data center cooling system are rooted in the air distribution.**

There are three basic approaches to distribute air in a data center:

- Flooded
- Targeted
- Contained

In a FLOODED supply and return air distribution system, the only constraints to the supply and return air flow are the walls, ceiling, and floor of the room. This leads to heavy mixing of the hot and cold air flows.

In a TARGETED supply and return air distribution system, a mechanism (e.g. duct, perforated tile, cooling unit placed within IT rows) directs the supply and return airflow within 3 meters (10 feet) of the IT equipment intake and exhaust.

In a CONTAINED supply and return air distribution system, the IT equipment supply and return air flow is completely enclosed to eliminate air mixing between the supply and the return air streams.

Each of the three approaches; flooded, targeted, or contained, can be used in either the supply path or the return path. This results in 9 possible combinations, or types of air distribution. All of these types have been used in various circumstances, and occasionally different types are mixed together in the same data center.

The 9 air distribution types are illustrated in **Table 1**. The graphics represent traditional room-based cooling implementations and do not necessarily allow for the maximum power densities indicated. **Table 2** shows non-traditional implementations that are becoming more common in data centers today. **Air distribution implementation and air management practices strongly influence the achievable power density in all 9 air distribution types.** For example, cooling units can be placed on the perimeter (**Table 1)** or they can be placed in the row or outdoors (**Table 2**). In general, the cost, complexity, and power density (kW / rack) capability of the air distribution implementations is lowest at the top and left of the table, and increases for the types that are down and to the right.

Table 1

The 9 types of air distribution (traditional room-based cooling implementations)

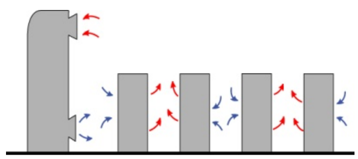
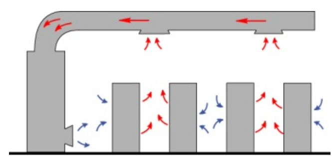
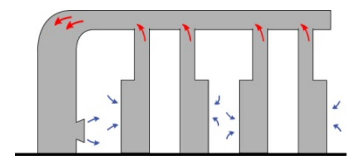
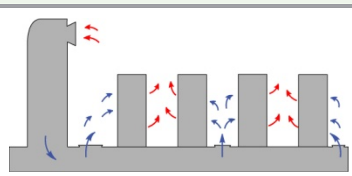
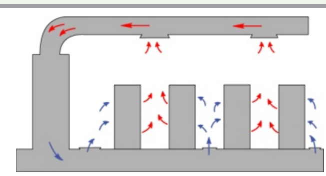
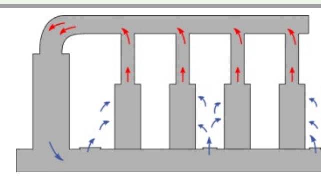
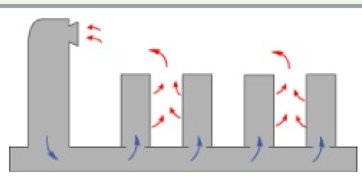
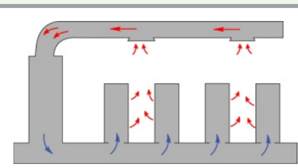
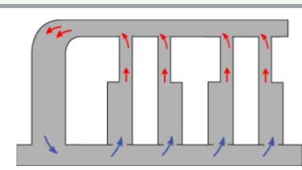
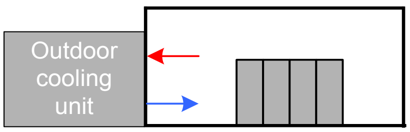
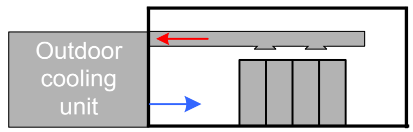
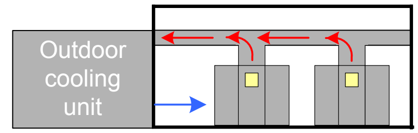
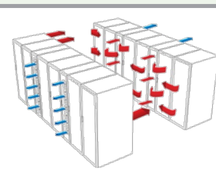
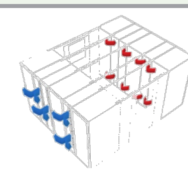
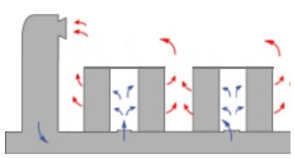
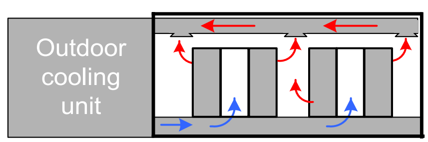
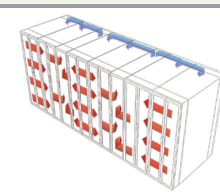
	Flooded return	Targeted return	Contained return
Flooded supply			
	Small LAN rooms < 40kW Not recommended for most data centers Low cost, simple installation Least energy efficient of all air distribution architectures because 100% of the cold supply air is allowed to mix with hot return air. Supply air temperature extremely unpredictable above. Distribution type can cool up to 3kW per rack	**General use** Not recommended for most data centers Low cost, ease of install More energy efficient than flooded return since 40-70% of IT hot exhaust air is captured and delivered back to the cooling unit. Supply air more predictable than flooded supply since less hot air is allowed to mix with cold supply air. Distribution type can cool up to 6kW per rack	**Large data center / colocation** Upgradeable (vendor specific) Most energy efficient of all air distribution architectures since it allows increased cooling unit supply temp resulting in increased economizer hours. 70-100% of IT equipment hot exhaust air is captured and delivered back to the cooling unit. Supply air is most predictable since no hot air is allowed to mix with cold supply air. Distribution type can cool up to 30kW per rack
Targeted supply			
	Data centers with static power densities Not recommended for new designs – unable to keep up with power density projections More energy efficient than flooded supply since more IT equipment hot exhaust air is diverted back to the cooling unit. Distribution type can cool up to 6kW per rack	**Small to medium data centers** More energy efficient than flooded return since 60-80% of IT equipment hot exhaust air is captured and delivered back to the cooling unit. Supply air more predictable since less hot air is allowed to mix with cold supply air. Distribution type can cool up to 8kW per rack	**Hot spot problem solver** Upgradeable (vendor specific) More efficient than targeted supply and return since 70-100% of IT equipment hot exhaust air is captured and delivered back to the cooling unit. Supply air is most predictable since no hot air is allowed to mix with cold supply air. Allows increased cooling unit supply temp resulting in increased economizer hours. Distribution type can cool up to 30kW per rack
Contained supply			
	Mainframes / racks with vertical airflow More energy efficient than targeted supply but less efficient than contained return. Containing the supply air, forces the rest of the room to become the hot aisle which limits the number of economizer hours. Supply air is more predictable since little hot air is allowed to mix with cold supply air. Distribution type can cool up to 30kW per rack	**Mainframes / racks with vertical airflow** More energy efficient than targeted supply but less efficient than contained return. Containing the supply air, forces the rest of the room to become the hot aisle which limits the number of economizer hours. Supply air is most predictable since no hot air is allowed to mix with cold supply air. Distribution type can cool up to 30kW per rack	**Harsh non-data center environments** Slightly less efficient than contained return with flooded or targeted supply - requires more fan energy. Allows increased cooling unit supply temp resulting in increased economizer hours. Distribution type can cool up to 30kW per rack

Table 2

Non-traditional implementations

	Flooded return	Targeted return	Contained return
Flooded supply			
	Hard floor, cooling unit located outdoors Not recommended for most data centers. Not effective because air mixing prevents predictable IT inlet temperatures.	**Hard floor, cooling unit located outdoors** Not recommended for most data centers. Not effective because air mixing prevents predictable IT inlet temperatures.	**Hard floor, cooling unit located outdoors** Recommended for new data centers. Variable speed fans on cooling units controlled by IT temperature.
Targeted supply			
	No non-traditional alternative	**Hard floor, row-based cooling units** Recommended for data centers below 1MW. Variable speed fans on cooling units controlled by IT temperature.	**Hard floor, row-based cooling units** Recommended for data centers below 1MW. Variable speed fans on cooling units controlled IT temperature.
Contained supply			
	Raised floor, perimeter cooling units Not recommended for new data centers. Good solution for existing data centers. Variable speed fans on cooling units controlled by pressure and active tiles controlled by IT temperature.	**Raised floor, cooling unit located outdoors** Targeted return doesn't add much value since supply is contained therefore not recommended. Variable speed fans on cooling units controlled by pressure and active tiles controlled by IT temperature.	**Hard floor, row-based cooling units** Only recommended for harsh environments or existing data centers where complete containment is required for a single row of racks (e.g. squeezing a row into an existing hot aisle). Variable speed fans on cooling units controlled by IT temperature.

Air distribution recommended for new data centers

A critical goal of a data center air distribution system is to separate the IT equipment exhaust air from the IT equipment intake air in order to prevent IT equipment from overheating. This separation also significantly increases the efficiency and capacity of the entire heat rejection system. Depending on location of cooling unit (i.e. perimeter or row-based, when equipment power density increases, the corresponding increase in exhaust air volume and intake air volume requires an air distribution type that mitigates the propensity for mixing between the supply and exhaust airstreams. For this reason targeting or complete containment (depending on location of cooling unit) of the supply air to the equipment intake or return air from the equipment exhaust becomes necessary as power density increases. For more information see White Paper 135, *Hot-Aisle vs. Cold-Aisle Containment for Data Centers*.

Related resource
White Paper 135
Hot-Aisle vs. Cold-Aisle Containment for Data Centers

The cooling of data centers and network rooms has emerged as a significant challenge for traditional raised floor air distribution systems as the density of computing equipment increases and as IT loads become more dynamic. Server consolidation and virtualization projects, along with the shrinking physical size of servers and storage systems, have resulted in high power density and high heat density. Even though the typical per-rack power consumption in a data center remains on the order of 3 kW, equipment may be configured that draws over 30 kW per rack. This strains the capability of the traditional raised floor flooded return air distribution system, which is only capable of reliably cooling 5-6 kW per rack by design. Furthermore, the adoption of virtualization and the associated migration of virtual machines, lead to the potential for dynamic "hot spots" within the room.

While the common concept of the data center includes a raised floor, data centers of any size can be, and commonly are, constructed without a raised floor. The vast majority of LAN and Network rooms do not use a raised floor. Many newer multi-megawatt data centers do not use a raised floor.

> Considerations to Implementing Raised Floors:

There are several things to consider when using a raised floor including specialty engineering, cost, design time, headroom requirements, earthquake susceptibility, safety hazard, security hazard, floor loading, access ramps and other problems. These factors are discussed in more detail in White Paper 19, *Re-examining the Suitability of the Raised Floor for Data Center Applications*.

Selecting the right type of air distribution for new data center construction

Related resource
White Paper 19
Re-examining the Suitability of the Raised Floor for Data Center Applications

The understanding of the various types of air distribution is an essential foundation to establishing when it is appropriate to use each type. Despite the variations in individual circumstances, it is possible to give general guidance as to when each type should be used.

The key to an effective design approach is this: to design an air distribution system for the required average power density but have the cooling capability to adapt to peak power density racks where they occur. High density racks typically represent only a fraction of the total load but their location in the data center cannot be reliably predicted in advance. The fear of not being able to adequately cool potential "hot spots" within a data center using conventional designs has led to extensive oversizing of the cooling plant and air distribution system, causing an extensive increase in capital and operational costs yet still not achieving the desired result. Containing the return air addresses high density areas while avoiding the costs of oversizing the bulk cooling system. **Figures 1**, **2** and **3** provide examples hot aisle containment solutions (i.e. contained return) found in new data centers.

Related resource
White Paper 153
Implementing Hot and Cold Air Containment in Existing Data Centers

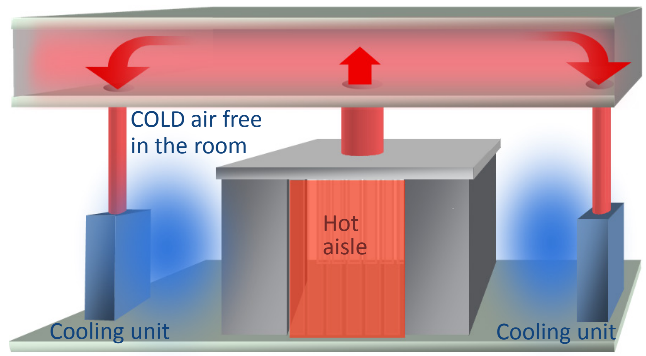
Related resource
White Paper 134
Deploying High-Density Pods in a Low-Density Data Center

For information on air distribution for existing data centers, see White Paper 153, *Implementing Hot and Cold Air Containment in Existing Data Centers* and white paper 134, *Deploying High-Density Pods in a Low-Density Data Center*.

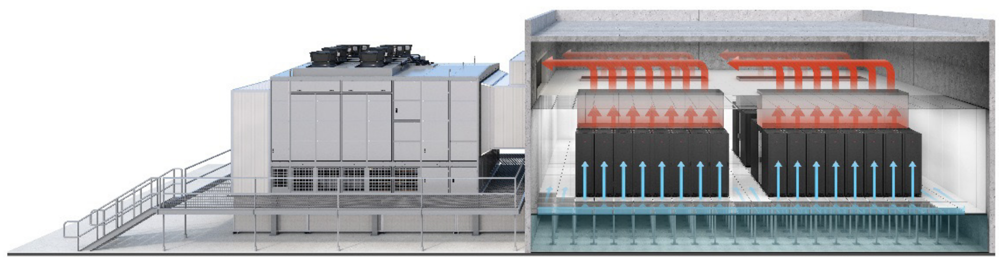
Note that containing a single air stream is enough to prevent mixing. Therefore, using both contained supply and contained return is not recommended due to the extra cost of containing both air streams without added benefit. Exceptions to this rule include cases where complete isolation of IT racks is required as in the case of harsh environments.

Figure 1

Examples of containment for new data centers - Flooded / targeted supply and contained return



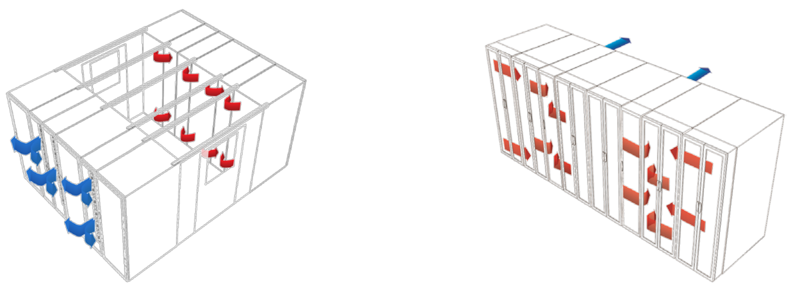
Flooded supply and contained return with cooling units located on perimeter



Targeted supply and contained return with cooling units located on outdoors

Figure 2

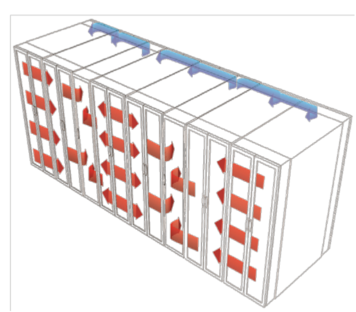
Examples of containment for new data centers - Targeted supply and contained return



Targeted supply and contained return with cooling units located in the row

Figure 3

Examples of containment for new data centers - Contained supply and contained return



Contained supply and contained return with cooling units located in the row

Conclusion

Cooling systems for data centers and network rooms are primarily differentiated in the way they distribute air. Air supply and air return systems each have 3 different configurations which can be combined to create 9 basic types of air distribution. Each of the 9 types of air distribution has capabilities and benefits, which cause them to be preferred for various applications.

An understanding of the 9 types of air distribution and their attributes can be used to develop guidelines for when each type should be used, and such guidelines are provided in this paper for new data center construction, existing raised floor data centers, and special applications.

The preferred method for building data centers is to use a hard floor in most cases. Contrary to popular belief, cooling methods for hard floor installations can provide the same or better capabilities and performance as the raised floor.

In general, contained supply or contained return is used for providing cooling to racks which are operating at power levels in the range of 5-15 kW. Containing both supply and return is not recommended unless IT racks are located in harsh environments. Since racks drawing 5-15 kW typically represent a small fraction of the racks in a data center, this method is typically used in combination with simpler methods. The use of contained supply or return allows data centers to be designed to average heat load but still be able to handle high density racks when needed.

About the author

Neil Rasmussen is Senior 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 25 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 the MIT Lincoln Laboratory on flywheel energy storage systems and solar electric power systems.

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Click on icon to link to resource

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White Paper 11

Fundamental Principles of Air Conditioners for Information Technology
White Paper 57

The Different Technologies for Cooling Data Centers
White Paper 59

The Advantages of Row and Rack-Oriented Cooling Architectures for Data Centers
White Paper 130

Hot-Aisle vs. Cold-Aisle Containment for Data Centers
White Paper 135

Re-examining the Suitability of the Raised Floor for Data Center Applications
White Paper 19

Implementing Hot and Cold Air Containment in Existing Data Centers
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