European Data Centre Association Technical Committee

Airflow Management in Data Centres – A Practical Approach

An EUDCA Technical Committee White Paper

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Overview

The purpose of this paper is to provide practical tools for calculating data centre cooling and airflow requirements, and to outline best practices regarding airflow management in data centres to maximise data centre cooling efficiency and minimise airflow waste. A lot has been written on this important subject, and much has been forgotten over the years. In some respects, this paper takes a step back in time to provide a reminder of the most important objectives of airflow management.

Based on the assumption that cooling infrastructure consumes approximately 30% of total data centre power (representing the 70 – 80% of the infrastructure energy consumption), by optimising cooling and airflow, the overall efficiency of a data centre can be improved, reducing the carbon footprint associated with its operation as well as operating expenses. On the other hand, considering commitments made by the CNDCP as well as the need for new data centres to have a PUE of less than 1.3 or 1.4 (depending on the climate), the need to improve airflow management will be effectively mandatory and therefore should be in sharp focus.

Further challenges emerge from the trend towards super densification, with rack power densities rising from around 1kW/sqm 5 years ago to 3kW/sqm today. At the same time, it has become important to raise temperature setpoints in order to operate data centre air conditioning systems at higher efficiency (ASHRAE classes A1 and A2), adding further importance to good airflow management practices.

The calculation of cooling requirements and airflow is a very complex part of the design process and employs various methods such as computational fluid dynamics (CFD) modelling. This paper should not be considered as a design tool, but it does provide practical ways to define where your facility stands and outlines best practices to improve both cooling and airflow efficiency.

The EU Code of Conduct (EUCoC) for Data Centers Energy Efficiency Best Practice Guidelines is a good source of further information: chapter 5 includes identified and recognised practices related to cooling energy efficiency improvement.

Defining Total Cooling Requirements

In data centres, information technology (IT) equipment produces heat which must be removed to prevent the equipment temperature from rising above an unacceptable level. In addition, in the calculation of total heat output of data centres, power distribution losses, lighting fixtures losses and the heat generated from the presence of people should be considered. The heat output of IT equipment is generally accepted to be the same as the IT load power in Watts. The following table (based on a Rasmussen table) provides a typical method for calculating the estimated total heat output:

Total White Space Cooling Requirements		
Item	**Data**	**Heat Output Formula (Watts)**
IT Equipment	Total IT load power in Watts	Total IT Load in Watts
Electrical Power Distribution	Power system rated power in Watts	(0.01 X Power System Rating in Watts) + (0.02 x Total IT Load in Watts)

Lighting	Floor area in square meters	8W x Floor square meters (considering LED lighting)
People	Max # of personnel in data centre	100W x Max # of Personnel
Total	-	Subtotal of the above calculations

This method ignores sources of environmental heat such as sunlight through windows and heat conducted from internal and external walls which should also be considered where appropriate.

If UPS with battery is in the same area with IT equipment, heat load should be included in the calculation worksheet.

Once the total cooling requirements are determined, it is possible to calculate the proper size and the operation of an air conditioning system.

Humidification / dehumidification loads is another factor that affects the cooling units' operation, but this should be treated separately from cooling loads. For the purpose of calculating the cooling units' output, we should use the net sensible cooling capacity.

Calculating Airflow Volume

The airflow volume delivery is directly related to the cooling capacity of a data centre. According to the ventilation heating load calculation formula (Folke, 2006), the amount of airflow required at a given temperature rise is computed.

$$\boldsymbol{CFM = \frac{Q}{1,08 \times \Delta T}}$$

CFM: the airflow volume required to remove the IT equipment heat expressed in cubic feet per minute
Q: the heat load to be removed expressed in Watts
ΔT: the difference between the inlet and outlet air temperature expressed in Fahrenheit

To convert to m^3/h → CFM x 0,589

The design ΔT is the temperature rise through IT equipment. For a conventional downflow system, it is generally accepted at 20°F or 11°C. Therefore, the required airflow for a server with rated power of 1kW is equal to 157.23 CFM (or approx. 267 m3/h). The specific value can be customised according to the requirements of the manufacturer of each IT equipment in order to ensure maximum hardware reliability.

Once the requirements of the IT equipment are specified and the total airflow volume requirements are calculated, the size of the air supply system of the air conditioner can be easily checked. Generally, achieving the desired airflow to a single rack requires special effort including careful raised floor design, CRAC / CRAH placement, and the control of underfloor airflow obstacles referred to in the optimisation chapter.

Care should be taken for older facilities that have been designed with ΔT in the region of 15 oC which when using newer IT equipment can result in a facility "running out of air" at less than full load. If this is the case, either cooling capacity should be redefined based on ΔT of 11°C, or complementary cooling solutions should be considered.

Airflow Management and Optimisation

The truth is that airflow management in a data centre is complicated and depends on several parameters. A challenge to establishing airflow management best practices is the lack of homogeneity in the IT industry. An invisible airflow mess increases energy consumption and consequently your data centre PUE.

Figure 1: Airflow in a data centre (Mike Peterson, 2016)

A key objective of good airflow management is to minimise or prevent mixing of the supply airstream (cold air) and the return or exhaust airstream (hot air), at the same time delivering the correct volume of cold air to cool the servers. In other words, to maintain the IT equipment at an operational temperature within warranty requirements. Partial or full containment should be considered in all cases, as this is one of the best practices to segregate supply and return air, achieving higher efficiency and increasing cooling capability for higher IT loads.

In order to increase data centre efficiency (cooling efficiency and consequently improve PUE), in addition to segregating supply and return airstreams, it is also vital to eliminate air losses in unwanted spots. The table below indicates the key contributing factors to low performing airflow management, their consequences, and ways for them to be controlled.

Airflow Management		
Contributing Factor	**Consequence**	**Control**
Room air losses	Unwanted air circulation between the data hall to other rooms or external areas. Increased energy consumption from cooling units. Reduced air volume to the racks.	Seal up every cable or pipe transit to isolate data hall from other rooms or external areas. All materials used to seal transits must be flame retardant.
Raised floor air losses (in unwanted spots)	Air losses in unwanted spots reduces air volume to the racks and increases energy consumption due to hot/cold air mixture.	Fix adjustments among raised tiles and seal up all finishes of tiles with other surfaces such as, walls or support frames (e.g., for cooling units).
Air losses from cable transits that pass through (crosses) the raised floor	Air loses in unwanted spots reduces air volume to the racks and increase energy consumption due to hot/cold air mixture.	Seal up every cable transit that passes through the raised floor, such as: – Power supply cables – Data cables – Cables inside floor standing electric panels – Cables on vertical trays
Air losses within racks	Reduces cold air supply to the IT equipment installed in higher level within a rack and increases energy consumption due to hot/cold air mixture.	– Install blanking panels in open spaces between IT equipment in racks. – Seal up the open spaces between mounting rails and edges of cabinets
Air losses under the racks	Reduces cold air supply to the IT equipment installed in higher level within a rack and increases energy consumption due to hot/cold air mixture.	Seal space under cabinets. A typical cabinet is approximately 2” above the raised floor.
Air losses between the racks	Reduces cold air supply to the IT equipment installed in higher level within a rack and increases energy consumption due to hot/cold air mixture.	Seal space between cabinets. Often, structural building columns prevent the placement of a cabinet. This often leaves a gap in the row.
Air mixture between hot/cold aisles	Reduces cold air supply to the IT equipment installed in higher level within a rack and increases energy consumption due to hot/cold air mixture.	Deploy certificated components that can isolate cold aisle and prevent hot/cold air mixture or create hot/cold containments.
Cables under the raised floor	Cables under the raised floor is the main "obstacle" that reduces air supply in the cold aisles.	Manage underfloor installations. Move data and power cables installed under the raised floor to the ceiling.

Airflow Management		
Contributing Factor	**Consequence**	**Control**
Conventional perforated tiles	Conventional perforated tiles are not adjustable to air direction and air volume	Replace conventional perforated tiles with directional and variable airflow grills

Control and Optimisation

A Data Centre is a live and dynamic environment. New IT equipment is constantly being installed or replaced, and therefore cooling requirements never remain the same. New technologies automatically control the airflow and the cooling units' operation based on ΔP or ΔT. Controlling ΔP (differential pressure between above and below of the raised floor) targets to keep a fixed pressure in the raised floor plenum. In this way, the air flow is continuously controlled and kept within the required / adjusted volume.

The most fundamental quote in business "If you can't measure it, you can't manage it" is also applicable for this case.

The following suggestions should be considered:

- For low / medium density racks, install temperature sensors distributed by row every 2 to 10 racks - depending upon expected granularity – and connect them to the BMS as initial solution.
- For advanced options, DCIM [1] (Data Centre Infrastructure Management software) can provide a CFD [2] (computational fluid dynamics) style visualisation in real time and analyses status vs thresholds, potential risks, capacity margin, alarms, together with recommended changes and a sequence of operations.
- It is important to know exactly the cooling needs and the airflow requirements for each rack. This should be done either using a software tool such as DCIM, or manually by measuring the air velocity and calculating the air volume (or directly measuring the air volume using a pitot tube device). In this way you can always revise and adjust the required airflow volume per rack.

It is also important to choose (or adapt) your cooling strategy, based on IT requirements / rack density.

  - Traditional hot / cold aisle arrangement can support rack densities up to 6-7 kW. Even if the layout includes a small proportion of racks up to 10kW, these can still be managed (although, that there may be an impact on energy efficiency). Traditional hot/cold aisle arrangement is not a recommendation anymore, since that mix of hot and cold air is unavoidable, resulting in inefficiencies.
  - Use semi-closed Hot / Cold aisle containment for rack densities close to 10kW. There are arrangements that are easy to retrofit in existing facilities.

[1] DCIM: Data Centre Infrastructure Management tools, measure and monitor IT equipment and infrastructure components (PDUs, CRACs, CRAHs, etc), providing means to manage data centre utilisation and operation, and increase efficiency.

[2] CFD: Computational Fluid Dynamics models, use numerical algorithms to analyse and model the air flow, considering surfaces, obstacles and real architecture inside a Data Centre.

- Use Hot or Cold Aisle Containment for high density racks (>10kW). This can easily support 20-25 kW per rack depending on the cold aisle width (2 or 3 tiles) and the Δt selected to operate.
- The use of In-row cooling units and Hot Aisle Containment deployment gives extra features in airflow management and cooling consumption optimisation, controlling the flow based on rack density.

Conclusion

Cooling and airflow management is highly complex and requires a deep analysis during the design process. Several tools are available for this purpose, including CFD modelling. Successive generations of CPUs are becoming increasingly power dense putting a greater strain on legacy data centre airflow/ cooling systems.

Despite new technologies for supporting cooling strategy in white spaces, the well-known method of utilising down flow with a raised floor plenum is still the most common approach for colocation providers, since it offers flexibility in implementing different deployments in the same area.

A data centre is a dynamic environment. Airflow is likely to be changed every time moves, adds and changes are made to the IT load.

Inefficient airflow management and the associated challenge of stranded capacity in data centres (a further source of inefficiency) can prevent data centres meeting their design intent and lowering ROI.

Using practical tools for calculating data centre cooling and airflow requirements, and implementing best practices on a regular basis, maximises data centre cooling efficiency and minimises airflow waste.

Improving cooling efficiency and therefore the overall efficiency of a data centre is neither an Opex or ROI objective, but a social responsibility.

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Peer reviewed by the European Data Centre Association Technical Committee