- White Paper -

Data Centre Cooling

Best Practice

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STULZ

Contents

Introduction

This paper summarises today's best practise for data center cooling systems. The raised floor design, cold and hot air separation, perforated tile issues and design air and water conditions are described. Target of these best practise collection is to design and build data center cooling systems as efficient as possible.

1. Air Flow Leakage

Air Flow Leakage leads to dramatic inefficiencies due to air circulation back to CRAC units without taking sufficient amount of heat from the equipment (short air circuit). A huge amount of fan power is wasted to circulate the air in such unwanted way.

Measures:

- Close all unwanted openings on the floor
- Close all unwanted openings below the racks, some raised floors all fully open underneath the racks even if perforated tiles are used for the regular airflow through the room.
- Close all cable cut outs where e.g. 10% of the openings are used for cables and 90% are simply open and air leaks to the room.
- Close all unwanted openings near walls where just some cut tiles would be necessary to seal the gap.

Target is to create a certain overpressure of e.g. 20 Pa to realise an even air supply to the data center at all areas. This is only possible if the raised floor is able to create such overpressure due to a proper design with as low as possible amount of unwanted airflow leakage. If this overpressure is realised, all perforated tiles will supply an even airflow.

2. Perforated Tiles: Number and Opening Factor

The number of perforated tiles must be in line with a) the design and b) actual/real total airflow. The perforated tiles have their specific characteristic, this means at a certain design pressure difference e.g. 20Pa the required air volume is supplied. If the CRAC units are designed for e.g. 50,000m³/h at an external static pressure of 20Pa, the number and design air volume of the perforated tiles must be equal to the total design air volume. E.g. 500m³/h @ 20Pa tiles will be installed, so 100 pieces are required. If the real airflow (required due to any reason) is lower, e.g. 30,000m³/h, the 20Pa external static pressure still must be achieved to ensure equal air supply anywhere in the room, the number of perforated tiles must be reduced to 60 instead of 100. If 100 perforated tiles will remain at reduced airflow, it will lead to a reduced static pressure in the raised floor (according to the perforated tile characteristic) of e.g. 5Pa. This low static pressure leads to an uneven air distribution and eventually lack of cooling in some areas.

3. Perforated Tiles: With adjustable damper

Perforated tiles with integral adjustable dampers can be used to avoid having to replace perforated tiles with solid tiles. In this case the number of perforated tiles can remain unchanged, but all of them need to be adjusted. It's also possible to operate with different adjustments to vary the amount of air in different areas. It is important to keep the static pressure in the raised floor at the design level.

4. Perforated Tiles: Placement

Perforated tiles should be placed only at positions, where cold air is really required to cool equipment. Do not place perforated tiles near CRAC units; keep at least 2m distance. Perforated tiles near CRAC units can induce warm room air into the raised floor (negative airflow) instead providing cold supply air from the raised floor into the room. This happens due to high air velocity and corresponding high velocity pressure in these areas in the raised floor near the CRAC units.

5. Close unused units in the racks with blanking panels to avoid airflow short circuit inside the rack

Recirculation of cooling air inside the rack leads to overheating of servers. Air will always take the path of least resistance and blanking plates are required to fill gaps in racks where servers have been removed or not installed, otherwise hot exhaust air from the server will circulate through the "gap" back to the air intake of the server.

Measures:

- Use blanking panels to close any unused server slot in racks.

6. Airflow philosophies

- The old/traditional way

  Uncontrolled placement of perforated supply air tiles anywhere in the room in any aisle. Cold air is supplied in an uncontrolled way to the low density equipment. Uncontrolled recirculation and supply and return air mixing happens. Hot exhaust air of one blade center can enter the equipment of a rack in the next row which leads to equipment overheating. NOT RECOMMEND NOWADAYS. Very inefficient.

- Hot Aisle, Cold Aisle Concept

  Racks will be positioned in rows front to front and back to back. Cold aisles only will be equipped with perforated tiles. No perforated tiles in the hot aisle. This concept helps to reach a certain level of separation between cold supply air and hot return air. There is still the risk of mixing between supply and return air through the top of the racks and at the end of the rows.

- Hot Aisle Containment

  Racks will be positioned in rows back to back. The hot aisle in between racks will be covered on the top and at the end of the rows and ducted back to the CRAC unit. A full separation between supply and return air is achieved. Cold supply air will be delivered into the room and the room itself will be at a low temperature level.

- Cold Aisle Containment

  Racks will be positioned in rows front to front. The cold aisle in between racks will be covered on the top and at the end of the rows. A full separation between supply and return air is achieved. Cold air will be supplied through the raised floor into the contained cold aisle; hot return air leaves the racks into room and back to the CRAC unit. The room itself will be at a high temperature level.

- Direct In-Rack Supply, Room Return Concept

  Cold supply air from the CRAC enters the rack through the raised floor directly in the bottom front area. Hot return air leaves the rack directly into the room. A full separation between supply and return air is achieved. The room itself will be at a high temperature level.

- Room Supply, Direct Rack-Out Return Concept

  Cold supply air from the CRAC enters the rack through the room. Hot return air leaves the rack through a duct and suspended ceiling directly back to the CRAC unit. A full separation between supply and return air is achieved. The room itself will be at a low temperature level.

- Close coupling of CRAC units and Racks on Supply and Return Side

  Cold supply air from the CRAC enters the rack through the raised floor directly in the bottom front area. Hot return air leaves the rack through a duct and suspended ceiling directly back to the CRAC unit.

A full separation between supply and return air is achieved. The room itself will be at an average temperature level.

- Aisle Separation Concept
  Base on the hot aisle, cold aisle concept the separation between supply and return will be realised as complete as possible, e.g. by installation of panels between top of the rack and ceiling to reduce supply and return air mixing to the minimum.

Airflow philosophies summary
Target of these various philosophies are the separation of cold supply air from the CRAC unit and hot return air back to the CRAC unit. This leads to an increased temperature difference between supply and return air thus increasing the efficiency of the CRAC unit and therefore the efficiency of the data center in general. If each m^2 of circulating air takes the design amount of heat from the IT equipment, the highest level of efficiency is reached.

7. Raised Floor Height

The raised floor height has a major influence on the efficiency of the air circulation in a CRAC unit based cooling system. Usually the raised floor contains cabling, piping and cold air. A certain obstruction free area is required for a proper supply of cold air to any area of the room. The required free height depends on the room size, the heat density and the number and position of installed CRAC units, finally on the total amount of air which has to circulate through the raised floor. General rule of thumb: The higher the better. A 1,000m^2 room with an heat density of 1kW/m^2 needs approx. 300.000m^3/h air and a free raised floor height of at least 500mm.

8. Return Air Conditions

Traditional CRAC based cooling systems are designed and will be operated at return air (the warm air coming back from the room to the CRAC unit) of 22°C to 24°C sometimes even lower.

By doing so the cold supply air delivered from the CRAC through the raised floor to the room has a temperature of approx. 14°C to 16°C. In the past when totally uncontrolled airflow and a huge amount of mixing and bypassing took place it was necessary to have low room temperatures to compensate. Nowadays, where the airflow through the data centre is more and more defined and mixing, leaking, bypassing, recirculation of air is reduced to a minimum, the cooling system can operate at much higher temperatures. The server equipment to be cooled operates easily at inlet temperatures of 20°C and above and the supply temperature level can be increased 5°C to 6°C and return air temperatures of around 30°C will become common practice.

At such conditions CRAC units operate much more efficiently and free cooling systems can run many more hours per year in free cooling mode. These higher return air temperatures can easily achieved with chilled water CRAC units. Compressor based CRAC units can also operate at these higher return air temperatures, but typically at reduced air volumes to ensure proper conditions in the refrigeration circuit.

9. Chilled Water System Water Conditions

The entering water temperature (EWT) and leaving water temperature (LWT) of chilled water systems (chilled water CRAC units in the data centre and chiller with or without free cooling outside) have a major influence on the efficiency and energy consumption.

Heat loads in Data Centres are nearly all sensible cooling load with only a small latent cooling load associated with fresh air ventilation. Therefore, the chilled water temperature leaving the chiller can be elevated from a normal 6° or 7° for air conditioning applications to 10°C or even higher. It should be considered as not only the CRAC unit provide all sensible cooling but the efficiency of the chiller will increase.

The higher the chilled water temperature the longer the freecooling season will be available for systems designed to utilise low ambient freecooling. Chilled water freecooling is a technique where drycoolers or chillers with an integral drycooling coil are piped in series with the chillers evaporator to pre-cool the chilled water when the outside ambient temperature is low. A glycol solution is introduced into the chilled water to prevent the drycooler coil from freezing and controls bypass the drycooler to prevent the drycooler from pre-heating the glycol / chilled water when the outside ambient temperature is high and no longer a freecooling source.

Designers need to balance the chiller efficiency and freecooling benefits with the drop off in cooling capacity of the CRAC unit when supplied with elevated chilled water temperatures and the introduction of glycol.

10. Standby Unit Operation

Fan laws dictate that air volume is directly proportional to fan speed and that fan power is a cube of the fan speed. Therefore, by running the stand-by CRAC units at reduced speed (air volume) the overall fan power is greatly reduced. The use of high efficiency EC fans allows automatic control of fan speed as dictated by standby operation, room cooling load or underfloor static pressure. It is more energy efficient to run all units including the standby CRAC units at lower speed than shut off or sequence off the standby unit(s). This technique also provides a more even and predictable air distribution.

11. Use CRAC units with state of the art Compressor and Fan Technology

State of the art compressor technology is scroll technology which operates more energy efficient then piston compressors. Today’s state of the art fan technology is the plug type fan with EC motor which is also much more efficient then centrifugal fans with external motor and belt or plug fans with AC motor. Anything else than EC fans is not recommended to be used anymore in modern CRAC units. The use of speed controlled compressors (digital or with frequency converter) is discussed frequently; however, it is advisable only for small rooms with variable loads larger than 40% as in large installations the on-off control of a number of compressors is more energy efficient.

12. Use of raised-floor-pressure controlled airflow

The raised floor pressure (also called ESP, external static pressure) is a key parameter for energy efficient air movement through the data centre. By doing so, only the really required amount of air will be moved through the data centre which saves fan absorbed power in the CRAC units. Traditional data centres are designed for an ESP of approx. 20Pa for an even air supply at any area of the room. Reality is different; values vary typically less than 10Pa with corresponding uneven air distribution. Latest designs operate with raised-floor-pressure controlled airflow. Depending on the difference of the measured pressure and its desired value the airflow will be varied to keep the pressure constant.

This is possible with the latest EC fan technology. Pressure variations happen especially in systems, where the cold air will be delivered through the raised floor directly into the racks. The rack mounted servers vary the speed of their internal fans due their load status. This variation leads to pressure variations in the rack in front of the server and this area is directly connected to the raised floor. This control system adapts automatically the required total airflow to the demand of the servers in the racks. Other applications with perforated tiles with adjustable dampers for raised-floor-pressure controlled airflow can be achieved by varying the opening degree of the dampers. The actual raised floor pressure will be altered and the airflow will be adapted accordingly to keep the pressure constant to ensure even air supply at any area in the room.

About the Author:
Benjamin Petschke is Head of Product Management and Sales Support. After studying physics Benjamin joined Stulz in 1996 as R&D engineer. In 1997 he changed to the sales department and worked in different positions. Benjamin Petschke is specialised in data center design regarding air conditioning, energy saving and acoustic issues.

About Stulz GmbH:
Founded in 1947 in Germany, Stulz has specialized in areas requiring technological expertise and entrepreneurial flexibility. The family owned company looks back at more than 30 years of experience in the design & built of data centres in terms of air conditioning. Being a true global player Stulz is present today in over 100 countries worldwide with production sites in Germany, USA, Italy, China and India.