- White Paper -

State of the Art Energy Efficient Data Centre Air Conditioning

- Dynamic Free Cooling® -

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STULZ

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Abstract

Increasing energy costs and limited resources of available electricity are driving the data centre industry to the use of energy efficient technical equipment. Dynamic Free Cooling® is a control concept for data centre's air conditioning systems combining Hybrid Indirect Free Cooling Precision Air Conditioning Units, fan speed controlled drycooler and speed controlled central pumps to a highly efficient precision cooling system. All system components are centrally controlled to minimise overall energy consumption depending on the ambient temperature and the room load conditions.

1. Why do I need an Energy Efficient Cooling System

There are two major reasons to use an Energy Efficient Precision Cooling System for your Data Centre. The first reason is saving operating cost during the lifetime of the data centre. In today's data centre 40% of the entire data centre power input is consumed by the cooling equipment. In worst cases it reaches up to 60%.

Secondly, electrical power is becoming a scarce resource and it should be used to maximise the use of the servers and not be wasted unnecessarily on powering cooling equipment. Apart from reducing costs and more efficient power management there is always an argument for "green" data centres with low carbon footprints using energy efficient cooling systems.

2. Energy use of Data Centre Air Conditioning Systems

Data centres need air conditioning systems to remove the heat generated by the servers and other heat sources and the air conditioning systems need to be reliable and available 24/7 with built in standby redundancy. Temperature, humidity and air cleanliness have to be supplied to within the IT equipment manufacturer's specifications. There are various air conditioning systems available but all of them require significant electrical power to run the fans, compressors and pumps. Fans in the CRAC units within the room circulate the conditioned air to transfer heat from the IT equipment to the CRAC units.

Refrigerant compressors absorb the heat directly in a direct expansion (DX) air, water or glycol system or indirectly in a chiller where chilled water is used as a secondary refrigerant. The refrigerant compressor is the largest user of electricity in the air conditioning systems. Other components that use power are the chilled water or glycol circulating pumps and condenser, drycooler or cooling tower fans that are located outside the building where heat is ultimately rejected to atmosphere.

3. Reduction of energy use of Data Centre Air Conditioning Systems

Data centre air conditioning systems are usually oversized by design for further growth, redundancy and a safety factor. The additional air conditioning plant can be used to reduce overall energy. Standby units can be used to share the airflow to all units. This leads to huge amount of power savings. By doing so, heat exchanger surface of the standby units is in use as well which increases the efficiency of the total system.

Logically, the mechanical refrigeration in the air conditioning system is only required when the outside ambient temperature is higher than the internal temperature of the data centre. If the ambient temperature is low, there is no need for the refrigeration compressor to operate and the room's heat can easily be transferred directly to a water/glycol solution and pumped outside the building where the heat will be transferred from the water/glycol directly to the ambient air. Ethylene glycol is added to the water to prevent the drycooler freezing in winter.

The temperature of the glycol has a major influence on the efficiency of the Air Conditioning System. The higher the glycol temperature, the lower the CRAC unit's cooling capacity, but as a positive the number of hours per year where the system runs in free cooling mode increases dramatically. These circumstances can easily be used to the advantage of reducing air conditioning running costs, and is used by the DFC® system.

4. The Air Conditioning System with DFC®

The system described in this article consists of hybrid CRAC units located in the data centre, drycoolers located outside the building and pumps that circulate the glycol in a closed hydraulic circuit between the CRAC units and the drycooler. The hybrid CRAC units consist of speed controlled EC fans for air circulation in the data centre, closed refrigerant circuit with scroll compressors and an air-to-glycol heat exchanger for free cooling operation. The drycooler consists of a glycol-to-air heat exchanger coil with variable speed EC fans for circulating ambient air through the heat exchanger coil. The central inverter driven variable speed pump circulates the glycol between the CRAC unit and the drycooler and out of the data centre. All components involved in the air conditioning process are controlled by the microprocessor in the CRAC units with outside ambient air sensors and return air sensors in the air intake of the CRAC units.

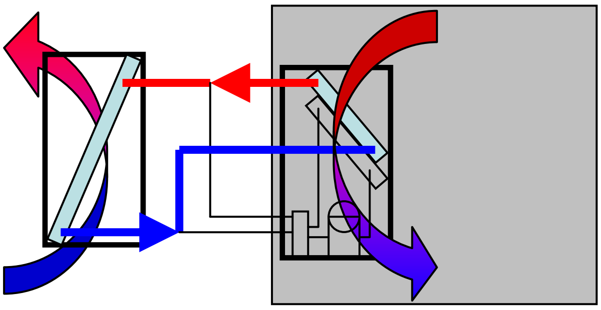


Figure 1: Free Cooling

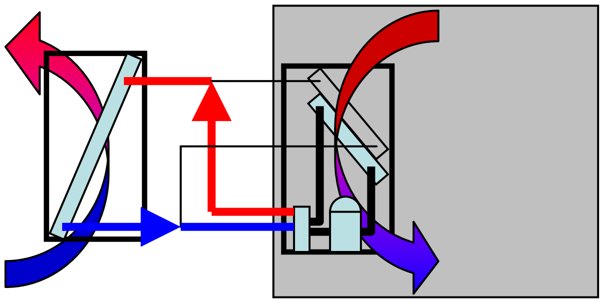


Figure 2: Compressor Cooling

5. Dynamic Free Cooling® – How does it increase efficiency

There are various elements that make the Dynamic Free Cooling® what it is and as efficient as it is. The most important elements are described here:

a. Dynamic Water Temperature Control

Standard indirect freecooling systems operate with fixed water or glycol temperatures for regular compressor operating mode of say 35°C at high ambient temperatures and about 7°C in free cooling mode at low ambient temperatures.

The period of usable free cooling is very limited as the number of hours per year when the ambient air is say 3°C or lower and cold enough to produce glycol of 7°C is few. By means of DFC® the glycol temperature is not fixed but fully dynamic depending on the requirements of the system. Why? It must be understood, that this system operates like a chilled water system in free cooling mode. The cooling capacity of chilled water systems depends on the water temperature, the higher the water temperature, the lower the cooling capacity. It sounds negative at this point but this behavior is used by the DFC® control as a benefit.

A data centre operating at full load requires in free cooling a water temperature of say 10.5°C. This 10.5°C water can be produced by the external drycooler with ambient temperatures of up to 7°C. The same data centre operating at part load of 60% also only requires 60% cooling capacity. The air conditioning system in free cooling mode can produce this 60% cooling capacity already at a much higher glycol temperature of 16°C and this glycol temperature can be achieved with an ambient temperature of 14°C. What does this mean for the period of free cooling per year: In London, 32% = 2,800h per year are below 7°C while 74% = 6,500h per year are below 14°C (Figure 3). This means, there are additional 3,700 hours or 154 days per year usable for freecooling. Traditional systems operate already in mix mode or even full compressor operation at this outdoor temperature.

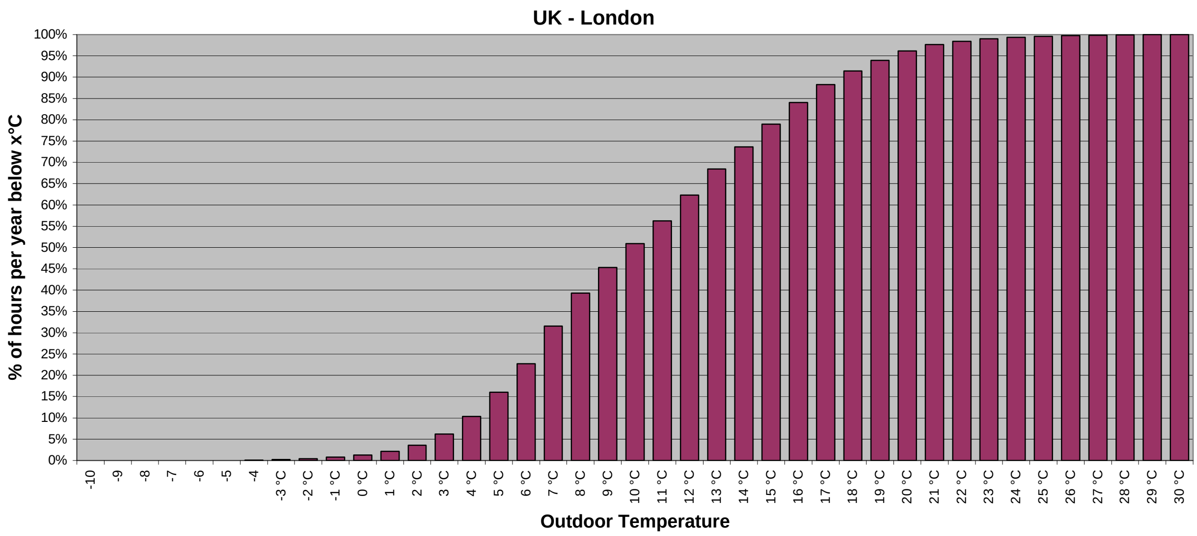
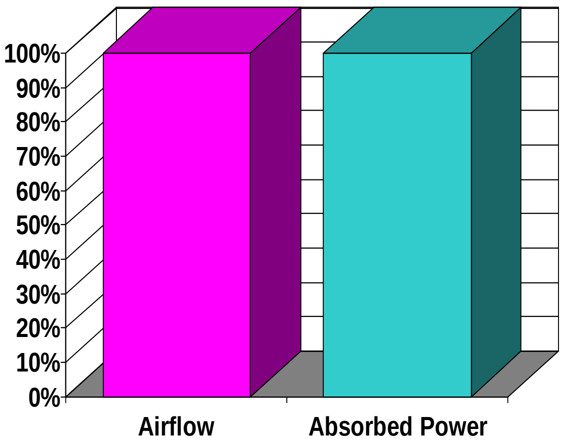


Figure 3: London, hours below x °C per year

b. Free Cooling Standby Management

Most data centres are designed with standby redundancy to cater for CRAC unit maintenance or failure. To save energy the standby units are designed to be sequenced off as they are not needed to handle the cooling load. By means of DFC® the CRAC units operate in freecooling mode in a new, different way. The use of high efficiency EC fans allows automatic control of fan speed. Fan laws dictate that air volume is directly proportional to fan speed and that fan power is a cube of the fan speed (Figure 4). Therefore, by running the stand-by CRAC units at reduced speed (air volume) the overall fan power consumption is drastically reduced. It is more energy efficient to run all units including the standby CRAC units at lower speed than to shut off or sequence off the standby unit(s). This technique also provides a more even and predictable air distribution throughout the raised floor. DFC® controls the CRAC units in free cooling mode in this new way and huge savings on fan power are realised. Should a DFC controlled CRAC unit be switched off the remaining units ramp up their fan speed automatically to ensure full air circulation.



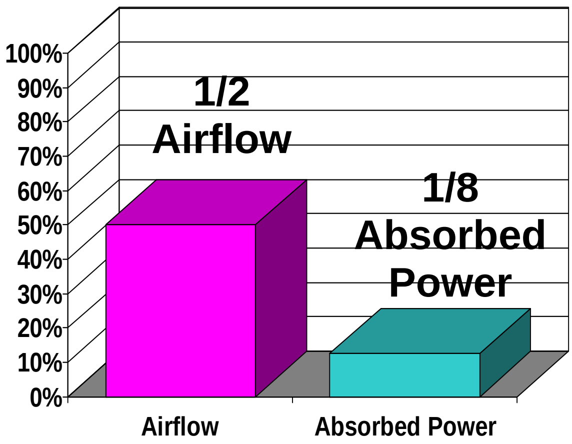


Figure 4: Standby Management and Cube Law

c. Indirect Free Cooling

Dynamic Free Cooling® is an indirect freecooling system. Indirect free cooling (Figure 5) uses glycol as heat transfer medium between the data centre air and ambient air at low ambient air temperatures and there is no need to introduce ambient air directly into the data centre and therefore preserving the data centres vapour seal. A very small amount of fresh air is required in the data centre to meet the local code regulations for ventilation standards.

Direct freecooling systems (Figure 6) use ambient air which is must be preconditioned and pre-filtered before entering the room. Ambient air quality and conditions normally forbid the use of direct free cooling. Induced smoke can activate fire suppression systems. Dirty air requires a high degree of filtration and very regular (expensive) filter maintenance programme. Low specific moisture levels in winter require huge amount of expensive pre-humidification.

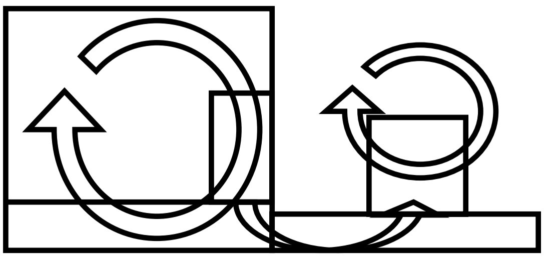


Figure 5: Indirect Free Cooling

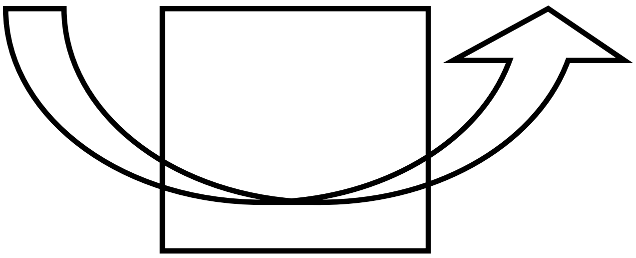


Figure 6: Direct Free Cooling

d. Dynamic Component Control

There are four major components in the air conditioning system using energy, the compressor in the CRAC units, the fans in the CRAC units, the central pump and the fans on the drycooler outside the building. Dynamic Free Cooling® controls these components depending on the room load conditions. The microprocessor controller analysis the ambient air temperature and the difference between actual and design room temperature to optimize the CRAC units components to reduce energy consumption but still maintain room conditions. The main focus is to minimise the running time of the compressors, the component using the most energy.

Next priority is to control the remaining components as there are CRAC unit fans, drycooler fans and the central pump such that the total absorbed power is at its minimum.

e. Optimised Casing Design

The CRAC units used for the DFC system are optimised for high efficiency. The airflow pattern and internal components are designed to minimise air resistance. The casing itself is enlarged compared with units without freecooling for the same reason. These design measures reduce the fan power by up to 40%.

f. Dual 2-Way Valve System

The hydraulic system is designed with the use of two 2-way valves in a way that the glycol quantity circulating in the system is absorbing the largest possible amount of heat in the CRAC unit, either in freecooling, mix or compressor cooling mode. The glycol quantity circulating the system is reduced and the required pump power is minimised.

6. Dynamic Free Cooling® – How much can be saved

By use of Dynamic Free Cooling® savings up to 60% can be reached. The savings depend on several points. The geographical location (annual temperature profile), the comparison system, the standby quantity, the design room temperature and the percentage of actual IT equipment cooling load installed compared with the peak design. Calculation software to compare different systems taking into consideration all the above variables is helpful for a selection. Manual calculations are complex but possible and usually take several days for one comparison only.

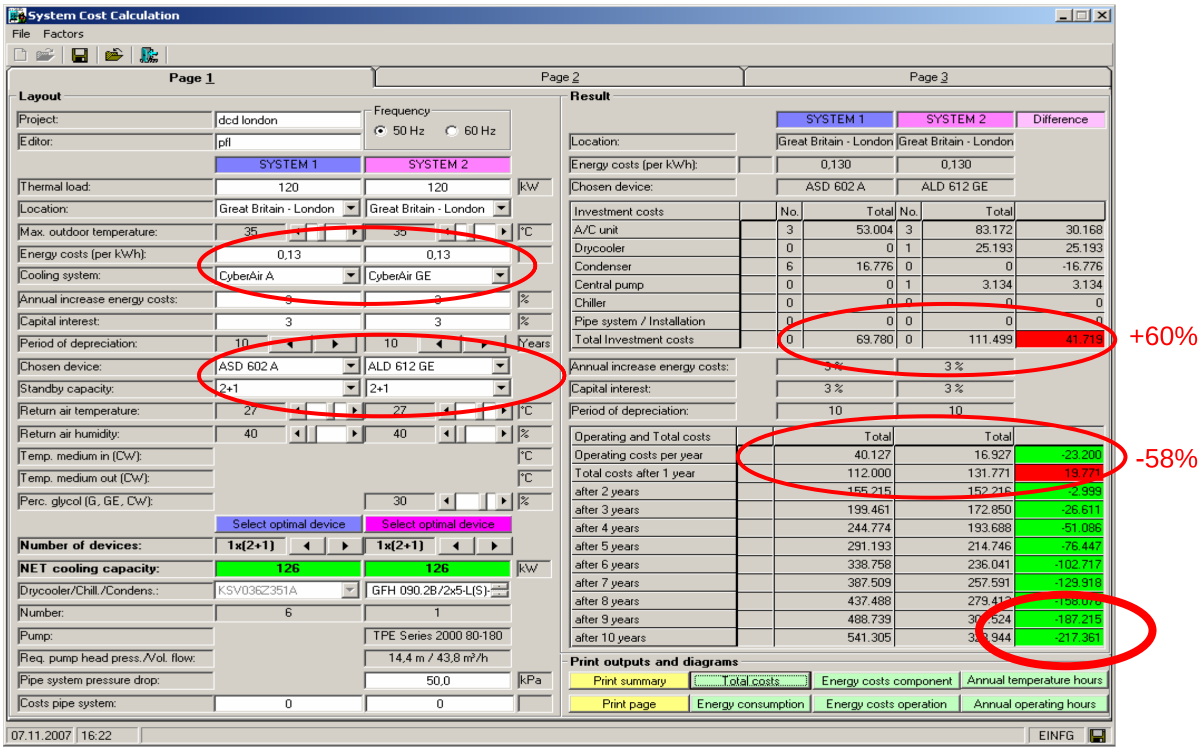


Figure 7: Example, 120kW Data Centre, London

7. Dynamic Free Cooling® – What does it cost and what is the payback period

The capital cost for a Dynamic Free Cooling® system compared with a basic air cooled system can be up to 50% more. However, the savings of operating cost are huge; typically the payback period is from less than 1 year up to 3 years.

About the Author:
Benjamin Petschke is Head of Product Management and Sales Support. After studying physics he 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 precision air conditioning for data centres. Being a true global player Stulz is present today in over 100 countries worldwide with production sites in Germany, USA, Italy, China and India.