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Air Conditioning Design for Data Processing Centres

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The information and communication technology (ICT) infrastructure is much like a central nervous system for today's business enterprises, public sector and government services. Data Processing Centres (DPC) are at the heart of such critical ICT operations. The reliability and availability of the mechanical and electrical infrastructure supporting such DPCs have, and will continue to become increasingly important as ICT continues to play an increasingly more important role in our society. The consequential losses resulting from an unscheduled interruption to the operations of a DPC can easily outweigh the capital cost of the appropriate preemptive measures within the supporting infrastructure. For financial institutions, where many thousands of transactions are processed every second, the resulting losses for just a single hour of system downtime can be catastrophic not just financially but also in terms of consumer confidence. It is against the backdrop of such implications that the market has, and is continuing to, increasingly recognise the importance of the reliability and uptime performance of the mechanical and electrical infrastructures supporting DPCs.

Air conditioning is just one of the key components that make up the critical infrastructure systems supporting today's DPCs. In many instances, system designs can fall short of clients' expectations in terms of reliability and availability. Perhaps naively, often too much importance is placed on the power supply availability without the same being applied to the air conditioning systems. Take the old saying 'a chain is only as strong as its weakest link', infrastructure designs often fail to meet expectations because the same level of reliability/redundancy is, in many instances, not applied to all the components of the supporting infrastructure. Whilst many people understand that only a short interruption in power supply to ICT equipment can mean loss of data, what is often not considered is that an interruption in air conditioning can be just as devastating. In today's DPCs, where cooling load densities can commonly be in the order of 800 watts/ sq.metre, an air conditioning outage of only a few minutes can have similar catastrophic effects.

This article addresses some of the key issues which designers should be aware of and address in the design of air conditioning systems for DPCs.

Air conditioning System Design For DPCs

The air conditioning systems supporting all DPCs need to satisfy a specific set of requirements, which are, in most instances, unique to each facility and the client's expectations. Air conditioning design is not a new application of engineering. A large proportion of the world's population come into contact with air conditioning on a daily basis either at home or in the workplace. And, design engineers are familiar with the parameters upon which a basis for design can be established. However, this may not be the case with respect to the design of air conditioning systems for DPCs.

Discussed below are some of the key parameters which engineers should consider in establishing a basis for the design of an air conditioning system for a DPC.

a) Temperature and Relative Humidity

Internal design conditions for a DPC air conditioning system are typically 22±1°C dry bulb and 50±5% relative humidity. While generally no one disputes these design conditions, it is a common misconception to assume that these design conditions form the basis of a performance specification and thus provide an expectation for the internal conditions that will be attained inside the DPC during operation. There is an important differentiation – the difference between design conditions and performance requirements. While design conditions are the parameters on which the system design and equipment selection should be based, the performance requirements are the actual indoor conditions expected during operation. But, why does this difference occur?

The difference lies in the fact that DPCs typically have characteristics of highly non-uniform load densities. This is due to a number of factors inherent to the different ICT equipment housed in a DPC. These factors include heat dissipation characteristics, internal forced ventilation configurations, rack design, equipment and rack arrangements. According to ASHRAE, "A set point of 22°C with constant volume precision air conditioning units generally permits equipment to remain at an acceptable temperature within the established range for satisfactory operation. This low control set-point temperature provides a cushion for short-term peak load temperature rise without adversely affecting computer operation." The point is that the distribution of air in the room and/or the response of controls will not match the non-uniform load density found in a DPC and this will result in a higher range of temperature and humidity variations throughout the space.

Though it may surprise many, the actual temperature and humidity conditions that can be expected in the occupied space of a DPC can, locally due to differing load densities, be in the range of 22±3°C dry bulb and 50±20% relative humidity. And even more surprising are the resulting vital in-rack temperatures, which can be as high as 30-35°C dry bulb.

b) Rate of Rise

Unlike the general impression that all remains well with the computer equipment so long as the temperature remains within the acceptable range, semiconductors are susceptible to 'rate of temperature rise', and an excessive rate of rise in temperature can significantly increase the failure rate of integrated circuits. In other words, even if the room temperature is maintained within the acceptable range, in the event of a temporary interruption in air conditioning, the rate of change can be potentially damaging to ICT equipment. Typically, the acceptable rate of rise figure is about 0.5°C/min. However, this should, if possible, be verified with ICT equipment manufacturers.

This parameter is particularly important as it is directly related to the response of controls and in particular, the re-start sequences associated with main refrigeration plant after a power supply changeover. It is this time associated with plant re-start sequences which is commonly overlooked in the design of air conditioning systems for DPCs and this is discussed in further detail in the subsequent section of this article titled 'Engineering Solutions'.

c) Dust Control

Keeping the computer room dust-free is also an important requirement. Dust can adversely affect the operation and reliability of data processing equipment and in most instances this results from stray currents. Generally, two factors should be considered in dust control: pressurisation and filtration. The first of these, pressurisation can be considered as a preventative measure incorporated into the system design. Specifications in many cases require DPC space to be positively pressurised with respect to the surrounding areas by the introduction of pre-treated outdoor air. Commonly a pressurisation level of 15 Pa is used as the basis for design. This positive pressurisation limits the infiltration of (possible unfiltered ambient) air from the surrounding spaces and thus can be considered as a preventative measure. Also, limiting infiltration in tropical environments–where high ambient humidity levels prevail, reduces the amount of moisture infiltration. This can result in significant energy savings particularly in equipment employing reheat as part of the dehumidification cycle.

For filtration in DPCs, the standards adopted are generally in accordance with recommendations of ASHRAE which specifies a filtration quality of 45% (minimum 20%) with reference to ASHRAE Standard 52.1 dust-spot efficiency test. System designers should ensure that these filtration efficiencies are clearly stated in the specifications of equipment as the standard filtration level offered by most manufacturers meets only the minimum requirements and increased efficiency filters are optional. It is important to ensure that this requirement is clearly specified beforehand, otherwise implementing such a requirement after the equipment is delivered to site could require fans to be upgraded to a higher static performance.

d) Outdoor Air Ventilation

In addition to the requirements for pressurisation discussed above, outdoor air is also required to maintain acceptable indoor air conditions for the occupants. In this context the outdoor air requirements should be in accordance with the local applicable codes of practice for this type of facility and estimated occupancy levels. In the absence of any such local codes of practice, it is recommended that those specified in ASHRAE Standard 62 be adopted. However, in almost all instances where the introduction of outdoor air is intended for pressurisation purposes it can be expected that the flow rates required will be in excess of that required for maintaining indoor air quality.

Generally, if outdoor air is introduced for pressurisation and some means of automatic control is used to regulate flow rates, possibly by means of a variable speed drive fitted to outdoor unit fan motors, then the provision for further extract systems should not be required in DPC areas. Extract may however be required, in many instances, by local codes of practice, for battery rooms to limit the build-up of hydrogen gas which can be emitted from some types of batteries used with Uninterrupted and DC power supply systems. Battery technology has over the years progressed considerably from the days of lead acid open type cells. Today's batteries are sealed and maintenance free. Generally, the requirements for extract systems are less onerous with contemporary sealed batteries but locally applicable codes of practice should always be considered in conjunction with the type of batteries specified and the manufacturers recommendations.

e) Cooling Loads

Cooling load calculations for DPCs are completed in the usual manner taking into account the various load components, which include outdoor air, lighting, people, building envelope gains/losses and equipment loads. But in the cooling load calculations of a DPC, it is the equipment load which in all cases will constitute the largest single component. In almost all instances, equipment load cannot be calculated because the information regarding the equipment to be installed is quite simply not available. Even if such information was available, in an industry where technology is developing so rapidly, it is unwise to impose a short-term limit on future flexibility of an air conditioning system by basing calculations on a fixed equipment list.

It is in the area of load estimating that DPC designers need to keep abreast of the latest technological developments in the ICT industries. System designers need to make a paradigm shift – from ‘equipment heat dissipation’ to ‘load density’. Load density, expressed in watts/sq.metre, reflects average heat dissipation per square metre in a DPC. Unfortunately there are no hard and fast rules in place for engineers to follow in establishing the required load density for the air conditioning design of a DPC. Presented in **table 1** below are typical load densities for some of the business sectors, which have extensive DPC facilities.

More often than not, financial and ICT industries, have adopted their own guidelines for system designers, but in the absence of such information, engineers must make objective decisions based on experience and the best information available before putting forward recommendations. Experience plays a significant role in establishing the right load density and wherever possible, valuable information can be obtained from conducting power audits of existing facilities.

The final agreed load density for all DPC projects should be the one which both the designer and client are comfortable with. In an industry where technology is rapidly changing, future growth must always be considered. Load densities have been following a growing trend almost in tandem with the increase in processor speeds.

Table 1 - Typical load densities

	Load Density (W/m²)		
	Low	**Medium**	**High**
Co-location facilities*	Below 1,000	1,000 –1,500	Above 1,500
Telecom facilities	Below 500	500 –750	Above 750
Bank/Financial institutions	Below 400	400 –700	Above 700

* where companies can outsource their data storage and processing requirements

f) System Availability and Redundancy

With the ever increasing reliance on ICT, businesses are slowly understanding the importance of system availability. But in many cases system availability is taken for granted and is only valued, when it is too late – sometimes after a major failure has occurred. Some business sectors have been faster than others in terms of appreciating the value of systems availability. The financial sector can be considered as one of the leaders. To maintain productivity levels and to ensure that system failures do not affect users, many ICT businesses have large budgets allocated for the purchase of software and hardware to achieve high levels of systems redundancy. However, in many instances, the same is not true of the supporting mechanical and electrical infrastructure systems. How can redundancy be achieved in IT systems when the same level of resilience and redundancy is not applied to the supporting infrastructure including the air conditioning systems?

In designing air conditioning systems for DPCs, engineers must have a clear understanding of client expectations. In the mature ICT business sectors, requirements for no downtime are increasingly common as companies strive for 99.9999% ("Six Sigma") system availability. In order to achieve this 99.9999% system availability, the allowable annual downtime is limited to less than 32 seconds a year. To achieve these levels of system availability, system designs are becoming increasingly complicated and expensive. Typical air conditioning system designs have in the past adopted a redundancy philosophy of n+1 for all major equipment, so that a single equipment failure can be tolerated without affecting system performance. However, this level of redundancy is simply not resilient enough to approach the 99.9999% system availability. A system designed around a n+1 philosophy for redundancy can have multiple points where a single failure could result in the system becoming inoperable e.g. common pipe work headers. The demands for availability are seeing more resilient redundancy philosophies being adopted and systems designed for instance on the basis of a 2(n+1) philosophy are becoming increasingly common, systems with dual independent refrigeration plants, pipe work systems, air handling equipment's and autonomous control systems.

Again, there are no rules in place for engineers to follow in designing systems to achieve redundancy. The clients required redundancy levels can, in many cases, only be determined through extensive consultation. Designers should also understand that a good resilient system design does not mean no downtime. Experience has shown that most system failures are caused by human error.

Engineering Solutions

Engineers are facing increasing pressure from clients for design solutions which provide better system availability, satisfy tightening budget constraints and increasingly aggressive construction programmes.

Precision air conditioning equipment has become one of the most common solutions engineers have looked toward for providing air conditioning in DPCs. This proprietary equipment could be said to provide engineers with a solution that is analogous to the "plug and play" technology which people are familiar with when upgrading personal computer hardware. Precision air conditioning equipment provides a comprehensive packaged solution which can conveniently contain all of the components required, including controls, to provide an effective out of the box solution to the temperature and humidity control for a DPC. Such equipment is available from a wide range of manufacturers and is commonly available as air/watercooled direct expansion packaged or chilled water type, with an air handling section suitable for either down downthrow or overhead ducted applications. Generally these are provided with cooling coils in a “V” arrangement to increase coil area and thus provide a high cooling capacity output from a small equipment footprint. In addition to cooling, systems for humidification, dehumidification and heating can also be incorporated.

The design of air conditioning for DPCs doesn't stop there. Whilst the use of precision air conditioning equipment solutions does provide ready-made solution to some of the requirements for air conditioning today's DPCs, it cannot always alone achieve the redundancy and resilience required to meet the needs of achieving 99.9999% system availability. Precision air conditioning equipment of the air-cooled direct expansion packaged type can however go a long way. If provided with n+1 redundancy, a similar redundant power supply arrangement and with each packaged unit coupled with its own discrete outdoor condenser for heat rejection, designs using these equipment can look towards achieving 99.9999% system availability. However, even with this type of solution, in many instances, engineering design solutions do not eliminate all points where a single failure could have potentially catastrophic results.

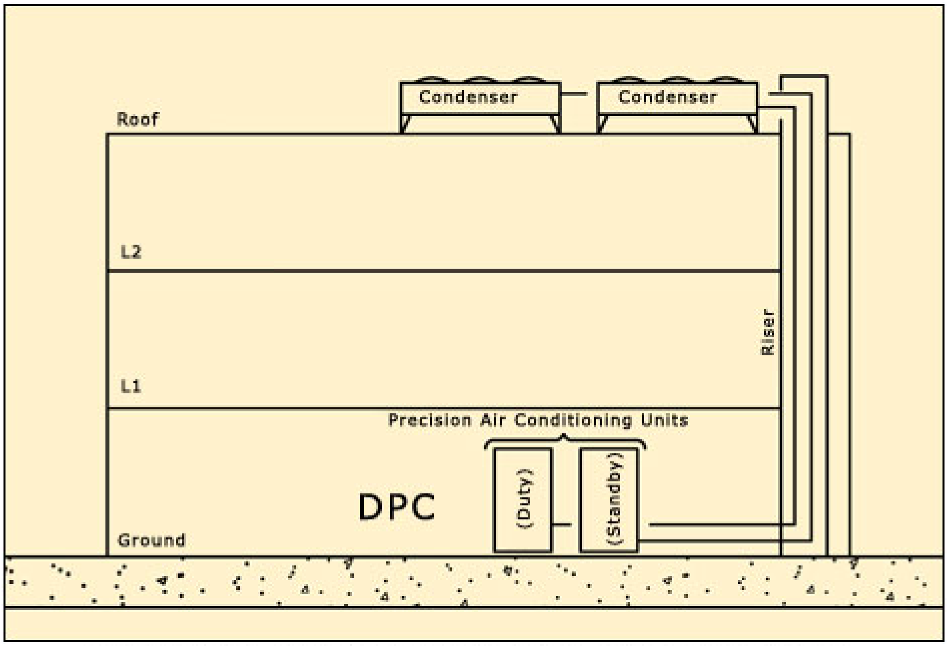

Figure 1[a] - Typical Air Cooled System Installation

a) Simple Air-Cooled DX Packaged Unit Solution

To illustrate this, take for example a DPC located in a multi-storey, multi-tenanted building. In designing an air conditioning system the air-cooled packaged units would be provided with at least n+1 redundancy and refrigerant pipes together with control and power supply wiring would be routed via a riser shaft to independent condensing units on the rooftop (see **Figure 1[a]**). Whilst this configuration does appear to provide a fully n+1 redundant system, it is not the case. The fact that the refrigerant pipes together with control and power supply wiring are routed in a common riser shaft can be considered as a physical (rather than technical) single point of failure, the same is true for the location of the condensing units on the rooftop. The common riser shaft and common location for condensing units could increase the chances of total system failure if say, the walls of the riser shaft were not fire rated and a fire which if started within one of the floors, spreads to the riser damaging control cabling. Or, in the case of the condensing units on the rooftop if a saboteur gained access. Whilst these examples may be considered unlikely, the fact is that they do exist and in albeit rare instances, could threaten the operation of the DPC. An alternative configuration which, could be considered more resilient is to locate the redundant condenser at the ground floor in some form of lockable compound (see **Figure 1[b]**). This alternative configuration does eliminate both single points of failure discussed above and may be considered a more reliable solution.

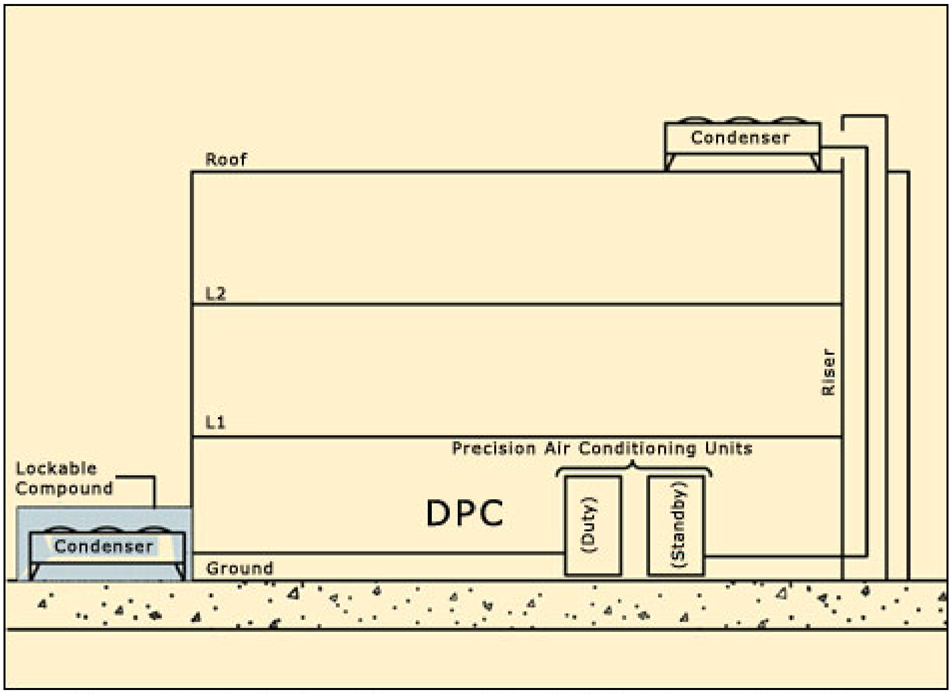

Figure 1[b] -Alternative Air Cooled System Installation

b) Hybrid Dual Source Cooling Systems

Whilst the example discussed above does demonstrate the principle of eliminating single points of failure, such ideas would be difficult, if not impossible to implement using air-cooled packaged units for some of today's large DPC facilities. In large DPCs, where cooling loads are in the order of thousands of kilowatts, air conditioning would be provided via a more efficient means incorporating say a centralised chilled water plant. However, with a central plant solution, the plant location itself becomes a physical single point of failure. To overcome this problem, precision air conditioning unit manufacturers have developed a range of equipment which can be termed as dual source.

Dual source units, as the term suggests, are provided with dual evaporator coils, which are served by independent and, in most cases, different cooling mediums. Generally these are available as a combination of chilled water/DX water-cooled packaged, chilled water/DX air-cooled packaged or even dual chilled water type. Such equipment allows system designers to achieve the required redundancy in central plant by providing two independent central plant systems each capable of satisfying the peak load requirements. In many instances it can be difficult for engineers to justify such system design to clients with low budget constraints and where the size of the DPC is relatively small. However, in countries where utility charges are a premium, life cycle cost analysis taking into account equipment efficiencies and a MTBF study would prove to be a useful tool.

When considering the use of a centralised chilled water plant in the design of any DPC air conditioning system, engineers must also carefully consider plant restart time and its effect on the rate of rise of temperature. For example consider a simple chilled water system incorporating two chillers, one duty and one standby, which are provided with a utility power supply and alternative emergency diesel generator supply via autochangeover (see **Figure 2**).

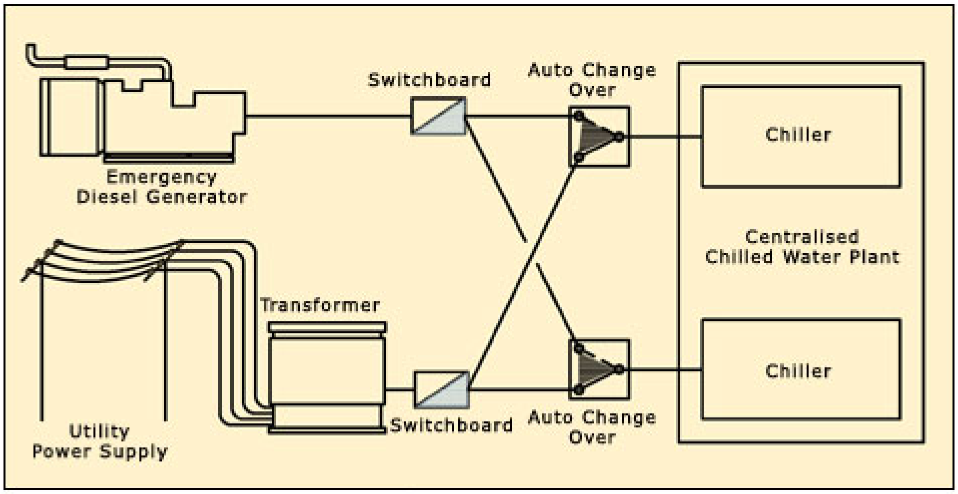

Figure 2 - Diagrammatic Chilled Water Plant With Redundant Power Supplies

In the event of an interruption to the utility power supply, the system would automatically changeover to the emergency diesel generator supply. However, the interruption in supply whilst the generator starts means there is a momentary power loss to the chillers. Whilst uninterrupted power supply systems make this transparent to ICT equipment, in most cases it is not considered practical to provide such systems for chilled water plant. This momentary interruption triggers the chillers' various safety devices and control checking sequences which, can result in time delay of more that 10 minutes before systems return to full capacity. Whilst this would be of no consequence in most comfort air conditioning applications, in a DPC where loads may be in excess of 1500 watts/sq.metre the rate of rise can very quickly result in critical indoor conditions. To overcome such problems, engineering solutions should consider fluid buffer tanks or some other means of thermal storage to reduce temperature rise during this period.

Future Trends

As the ICT industry continues to evolve and play an increasingly crucial role in society, it is clear that the demands on engineers to provide cost effective and reliable solutions will increase. The semiconductor industry, over the previous decades, has followed closely what is known as Moore's (co-founder of Intel) law: Capacity of semiconductors doubles every eighteen months or quadruples every three years. The increase in chip capacities has been accompanied with a proportional increase in heat dissipation. So, as chip performance continues to follow Moore's law, the load densities in DPCs will also continue to spiral upward. Already, engineers are commonly designing systems with cooling load densities in the order of 1200-1500 watts/sq.metre. The trend of increasing load densities and energy costs could lead to alternative solutions for ridding DPC's of heat. Possible engineering solutions in future may use spot cooling, localised heat extraction or a combination of these together with the air conditioning seen in today's DPCs. The increasing cooling load densities could even cause engineers to look further at mediums other than air for heat transfer.

What is sure is that as one continues to become more dependent on ICT, the importance of the supporting infrastructure, including air conditioning, will continue to increase dramatically. As a result, most businesses will strive for air conditioning systems with no downtime. And so, air conditioning of a DPC will continue to evolve from a seemingly isolated system to a critical and integral part of the overall infrastructure supporting the DPC.

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