How and Why Mission-critical Cooling Systems Differ from Common Air Conditioners

White Paper 56

Revision 3

by Tony Evans

> Executive summary

Today's technology rooms require precise, stable environments in order for sensitive electronics to operate optimally. Standard comfort air conditioning is ill suited for technology rooms, leading to system shutdowns and component failures. Because precision air conditioning maintains temperature and humidity within a very narrow range, it provides the environmental stability required by sensitive electronic equipment, allowing your business to avoid expensive downtime.

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Introduction

Precision environmental control requirements now reach far beyond the confines of the traditional data center or computer room to encompass a larger suite of applications, referred to as “technology rooms”. Typical technology room applications include:

1. Medical equipment suites (MRI, CAT scan)
2. Clean rooms
3. Laboratories
4. Printer/copier/CAD centers
5. Server rooms
6. Hospital facilities (operating, isolation rooms)
7. Telecommunications (switch gear rooms, cell sites)

Why precision air conditioning?

Information processing is the lifeblood of all critical operations. Therefore your company’s health is dependent on the technology room reliability. IT hardware produces an unusual, concentrated heat load, and at the same time, is very sensitive to changes in temperature or humidity. A temperature and/or humidity swing can produce problems ranging from processed “gibberish” to a complete system shutdown. This can create huge costs for the company, depending on the length of the interruption and the value of time and data lost. Standard comfort air conditioning is not designed to handle the heat load concentration and heat load profile of technology rooms, nor is it designed to provide the precise temperature and humidity set point required for these applications. Precision air systems are designed for close temperature and humidity control. They provide high reliability for year-round operation, with the ease of service, system flexibility and redundancy necessary to keep the technology room up and running 24 hours a day.

Temperature and humidity design conditions

Maintaining the temperature and humidity design conditions is critical to the smooth operation of a technology room. Design conditions should be 72-75°F (22-24°C) and 35-50% relative humidity (R.H.). As damaging as the wrong ambient conditions can be, rapid temperature swings can also have a negative effect on hardware operation. This is one of the reasons hardware is left powered up, even when not processing data. Precision air conditioning is designed to maintain temperature at ±1°F (0.56°C) and humidity at ±3-5% R.H. 24 hours a day, 8760 hours a year. In contrast, comfort systems are designed to maintain 80°F (27°C) and 50% R.H. only during summer conditions of 95°F (35°C) and 48% R.H. outside conditions. Usually there is no dedicated humidity control and the simple controllers cannot maintain the set point tolerance required for temperature, allowing potentially harmful temperature and humidity swings to occur.

Problems caused by the wrong environment

A poorly maintained technology room environment will have a negative impact on data processing and storage operations. The results can range from data corruption to complete system shutdowns and failures.

1- High & low temperature

A high or low ambient temperature or rapid temperature swings can corrupt data processing and shut down an entire system. Temperature variations can alter the electrical and physical characteristics of electronic chips and other board components, causing faulty operation or failure. These problems may be transient or may last for days. Even transient problems can be very difficult to diagnose and repair.

2- High humidity

High humidity can result in tape and surface deterioration, head crashes, condensation, corrosion, paper handling problems, and gold and silver migration leading to component and board failure.

3- Low humidity

Low humidity greatly increases the possibility of static electric discharges. Such static discharges can corrupt data and damage hardware.

Differences between precision air and comfort air conditioning

1- Sensible heat ratio

A heat load has two separate components: sensible heat and latent heat. Sensible heat removal or addition causes corresponding changes in air-dry bulb temperature. Latent heat is associated with the increase or decrease in the moisture content of the air. The total cooling capacity of an air conditioner is the sum of the sensible heat removed and the latent heat removed.

Total Cooling Capacity = Sensible Cooling + Latent Cooling

The sensible heat ratio is the fraction of the total cooling that is sensible.

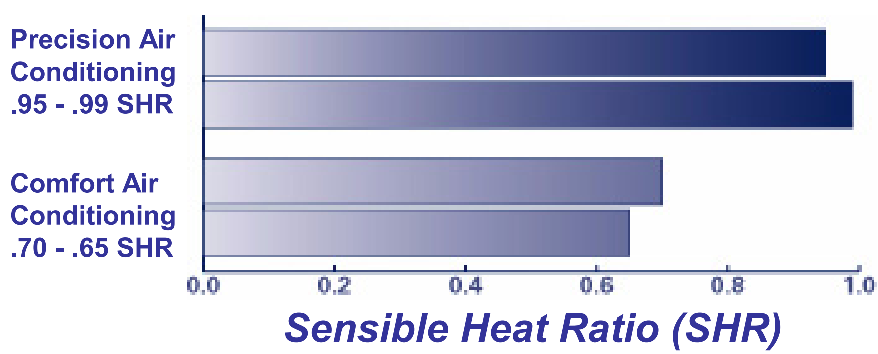
$$\text{Sensible Heat Ratio (SHR)} = \frac{\text{Sensible Cooling}}{\text{Total Cooling}}$$

In a technology room, the cooling load is made up almost entirely of sensible heat coming from IT hardware, lights, support equipment, and motors. There is very little latent load since there are few people, limited outside air, and usually a vapor barrier. The required SHR of an air conditioner to match this heat load profile is very high, 0.95-0.99. Precision air conditioning is designed to meet these very high sensible heat ratios.

In contrast, a comfort air conditioner typically has a SHR of 0.65-0.70, thereby providing too little sensible cooling and too much latent cooling. The excess latent cooling means that too much moisture is continually being removed from the air. In order to maintain the desirable 35-50% relative humidity band, continuous humidification would be necessary, which by definition consumes large quantities of energy.

Figure 1

Sensible heat ratio (SHR)



2- Precise temperature and humidity

Precision air conditioners have the sophisticated, fast-acting, microprocessor-based controls necessary to react quickly to changing conditions and maintain the tight tolerances required for a stable environment. Precision air systems usually include multiple stages of cooling and heating, a humidifier, and a dedicated dehumidification cycle, allowing them to satisfy any and all temperature and humidity control requirements.

Comfort air conditioners generally have basic, limited controls unable to react quickly enough to maintain the required tolerance. Comfort systems do not usually include heat or the humidification/dehumidification cycles necessary for a stable technological environment. The components, if available, are frequently “add-ons” and not part of an integrated system.

3- Air quality

Precision air conditioners operate at a high air flow rate per unit heat removed, generally, 160 CFM (76 Lps) per kW or greater. This high volumetric rate moves more air through the space improving air distribution and reducing the chance of localized hot spots. Modern technology equipment generally consumes around 160 CFM for each kW of electrical power consumption, so it is important that this quantity of cool supply air be available at the equipment inlet. If it is not, the equipment will obtain some of its air from other areas of the room, often resulting in dangerously high inlet temperatures. The high CFM / kW of precision cooling equipment also allows more air to move through filters, ensuring a cleaner environment. Precision air conditioners typically use a moderate- to high-efficiency, deep-pleated filter bank, to minimize airborne particles.

Comfort air conditioners operate at a much lower 85-115 CFM / kW (40-54 Lps / kW). Low CFM can lead to poor air distribution and more airborne contaminants. Filters for comfort air conditioners are usually flat, low-efficiency media that do not remove a sufficient percentage of airborne particles.

4- Hours of operation

Precision air conditioners are designed and built to run non-stop 8760 hours a year. The systems are designed - with components selected and redundancy incorporated - to ensure minimal downtime. System controls maintain room conditions for the full range of outside ambient conditions, summer or winter.

Comfort air conditioners are designed to run during summer days, up to an expected maximum of 1200 hours per year. The system is not designed or expected to operate non-stop, year round. Neither the controls nor the refrigeration system is designed for zero downtime or winter operation.

Design criteria

1- Load density

Due to the high equipment concentration, the load density within a technology room can be five times higher than that in a typical office. Systems must be designed to handle this extremely high-density load. Sensible capacity and air distribution are very important.

Load Density
Office 5 – 15 watts / sq. ft. (54 – 161 watts / sq. m)
Technology Room 50 – 200 watts / sq. ft. (538 – 2,153 watts / sq. m)

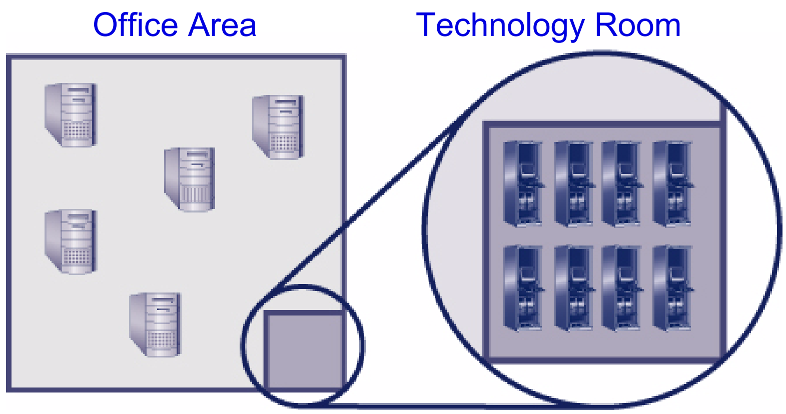


Figure 2

Load density

2- Temperature and Humidity

Design goal conditions should be 72-75°F (22-24°C), 35-50% R.H.

3- Air Quantity

The high CFM / kW (Lps / kW) inherent to precision systems contributes to the high sensible heat ratio, improves air distribution, and increases filtration rates. The high CFM does not cause discomfort to personnel as it is distributed under the raised floor and drawn up through equipment and into the space around the room.

4- Air Cleanliness

Without filters, airborne dust can damage equipment. Filters should be deep pleated for moderate to high efficiency. Filter sizing is also important; the filter must operate with face velocities low enough to be effective. Regular filter changes are necessary.

5- Vapor Barrier

Because almost all construction materials are transparent to moisture, a well-designed technology room must include a vapor barrier. Without a vapor barrier, the technology room will lose humidity in the winter and will gain it in the summer. This makes humidity set point control very difficult and increases the run times of energy-expensive compressors and humidifiers.

To create an effective vapor barrier, ceilings should be sealed with a polyethylene film, concrete walls should be painted with a rubber or plastic base paint, doors should seal tightly, and all pipes and cable penetrations should be sealed.

6- Outside Air Requirements

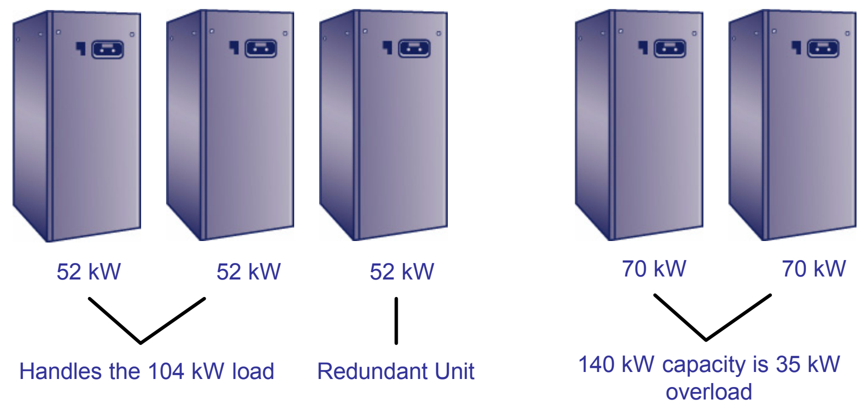
Technology rooms tend to be sparsely populated and do not require much outside air for personnel. Outside air should be minimized to limit the latent load brought into the room. A quantity of 20 CFM (9.4 Lps) per person is currently sufficient to satisfy Indoor Air Quality (IAQ) concerns in the U.S.

7- Redundancy

Redundancy is achieved by operating additional equipment to provide 100% of the required cooling capacity even after a unit shutdown or failure of one or more units. The cost of redundancy should be weighed against the projected cost of technology room downtime.

Figure 3

Redundancy



The difference between redundancy and over capacity should be noted. A 70 kW load with 3 x 52 kW systems or 4 x 35 kW systems provides redundancy. A run-time-based rotation of equipment operation and a controls interface that provides automatic start up are required for standby equipment to be considered redundant.

9- Security

The security of the air conditioners is as important as that of the technology room hardware since the hardware cannot operate without them. The indoor units must be located within the technology room and should be subject to the same restricted access as the IT hardware. The outside heat rejection equipment should be placed on a roof or some other secure area within the facility.

System selection factors

Related resource
White Paper 25
Calculating Total Cooling Requirements for Data Centers

1- Load calculations

Heat in technology rooms is generated by hardware, lights, people, outside air, transmission loads, sun, and support equipment (PDUs, UPS, etc.).

- As a rule of thumb, use 15 sq. ft. / kW (1.39 sq. m. / kW) for load calculations. For a more detailed load calculation see White Paper 25, *Calculating Total Cooling Requirements for Data Centers*.

2- Unitary systems

a- Air cooled

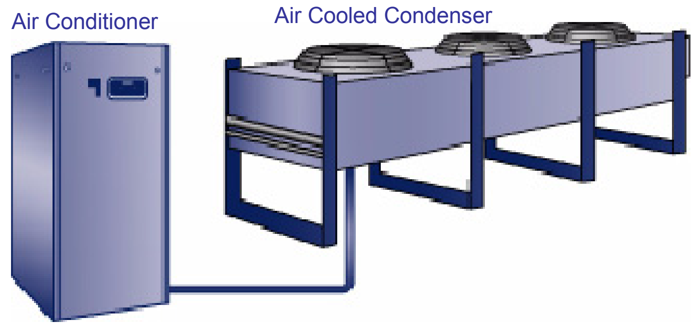


Figure 4

Air cooled system

System configuration

- Refrigeration system is "split" between indoor air conditioner and outdoor air-cooled heat rejection unit.
- Compressors can be located in the indoor or outdoor equipment. For security and maintenance, compressors are usually located in the indoor unit.
- Refrigerant pipelines (two per compressor) interconnect two halves of the system.
- Refrigerant piping design is critical. The design must address pressure losses, refrigerant velocities, oil return, and traps.
- Qualified expert contractors should install the service unit.
- Excellent for multiple units and expanding installations. Each system is a self-contained, stand-alone module.

b- Water cooled

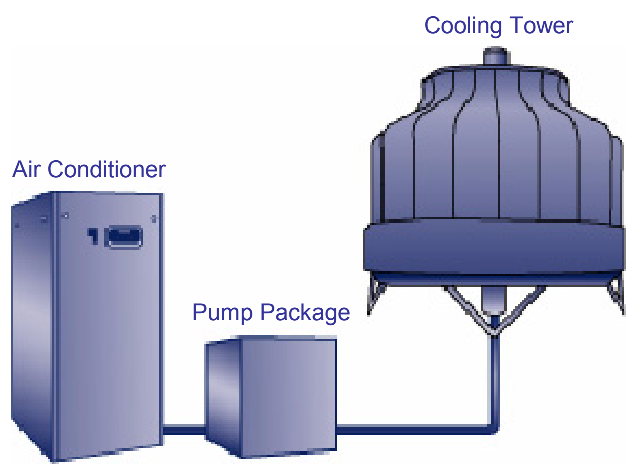


Figure 5

Water cooled system

System configuration

- Indoor air conditioner is a complete, self-contained refrigeration system.
- Heat is rejected to a coolant water supply via a heat exchanger in the indoor unit. The coolant water is then usually pumped to a cooling tower and re-circulated. Other water sources such as wells also can be used.
- Cooling tower should be winterized in cold and temperate climates.
- Tower should be designed with redundancy, or an emergency back-up water supply should be available.

- Water treatment is required when a cooling tower is used.
- Water pipe design is a lot less critical and easier to install than refrigerant piping.
- The refrigeration system arrives factory charged and tested.

c- Glycol cooled

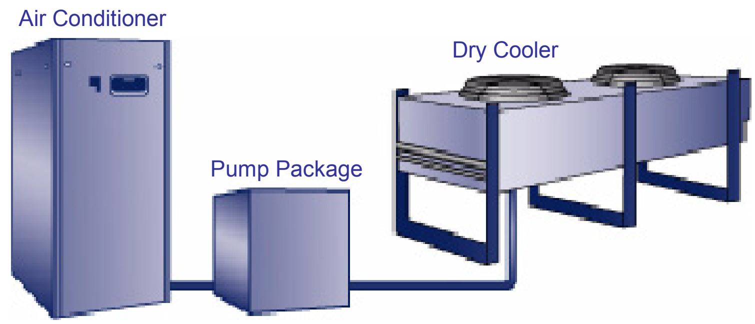


Figure 6

Glycol cooled system

System configuration

- Indoor unit is similar to water-cooled system.
- A glycol solution is circulated in place of water and the heat rejection occurs in an outdoor liquid to air heat exchanger or "dry cooler."
- Dry coolers are lower maintenance than cooling towers.
- Presents excellent opportunities for heat recovery application.
- System E.E.R. is lowest of three unit types.
- Multiple units can be linked to single large dry coolers and pump packages. Be aware of redundancy requirements if this is done.

d- Free-cooling glycol
System configuration

- Product is identical to glycol-cooled but also includes an additional free-cool coil for energy savings.
- When the outside temperature drops, cool glycol solution is run through the supplementary free-cool coil and cooling is obtained without running the compressors.
- Presents excellent operating cost reductions in appropriate climates.
- Extra coil means more blower motor HP.
- Look for systems with larger free-cool coils for more cost savings. Free-cool coils should be installed before the DX coil for assisted capacity during mild, ambient temperatures.

e- Supplementary chilled-water coil
System configuration

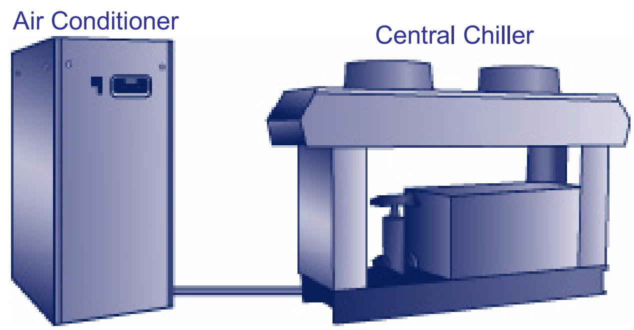
- A supplementary chilled-water coil can be included in a DX system to provided complete redundancy in a single unit.
- Unit may operate as a chilled water system with 100% modular DX back up in the event of an emergency.
- Unit may act as a DX system with emergency central plant chilled-water back up if required.

- Unit may use chilled water when available. For instance, if chiller runs primarily to support a manufacturing process in a factory or to support summertime comfort systems, and switch to DX when chilled water is routinely no longer available.

f- Chilled water

Figure 7

Chilled water system



System configuration

- Chilled water is supplied from a central chiller to packaged units in the technology room. The refrigeration system is contained in the packaged chiller.
- Indoor air conditioners contain controls, chilled-water coil, chilled-water control valve, blowers, filters, humidifiers and reheat.
- Chilled-water temperature should be as high as possible to keep a high sensible heat ratio (47°F / 8.33°C or higher).
- Redundancy should be extended to central chilled plant and pump packages.
- Central plant should be winterized for year-round operation.
- May require operating personnel in some cities.
- Do not combine with comfort cooling chillers since chilled-water supply temperatures should differ (42°F / 5.6°C for comfort, 47°F+ / 8.3°C+ for technology room).

Cost of ownership

1- Operating costs

Technology room air conditioning costs are typically ten times higher per square foot than office or comfort air conditioning. This is because of year-round rather then seasonal operation and the greatly increased heat load density. However, precision air conditioning operating costs are far less than comfort air conditioning if both systems are applied to a technology room.

Precision air conditioning costs are lower than comfort air conditioning for comparable use because of the following:

- Under-floor system - A high sensible heat ratio eliminates over-dehumidification and subsequent humidifier operation.
- High Energy Efficiency Ratio (E.E.R). With the oversized coils, high CFM, and heat pump duty compressors, computer grade systems have higher sensible cooling energy efficiency ratios than conventional comfort cooling.
- Precision air equipment is designed with high-efficiency components for year-round operation.
- Look for the following:
    - Oversized, shallow cooling coil

- High efficiency blower motors
- Steam canister humidifiers
- Heat pump duty rated compressor
- High S.H.R.'s
- Dedicated dehumidification cycle
- Low FLA
- 100,000 HR L rated bearings
- Extended warranties

2- Service costs

The largest costs incurred during the service or repair are generally in technology room downtime. For this reason, redundancy should always be designed in first. However, to further reduce this exposure, equipment can be selected with features that will reduce required service and repair time dramatically. Look for the following:

- Bolt in refrigeration components. Compressor and filter dryer should be removable without gas torches.
- Primary and secondary engineering drain pans.
- Quick-change canister humidifier.
- Components should be out of the air stream in a separate mechanical section.
- Removable fan deck assembly.
- Color-coded and numbered electrical wiring.
- Motor start protectors instead of fuses.
- Easily removable and/or hinged access panels.
- Run-time-based maintenance calls.

Conclusion

Technology rooms house sensitive electronics that need precise environmental conditions to run optimally. By providing the environmental stability that this type of electronic equipment requires, precision air conditioning helps your business avoid expensive system shutdowns and component failures.

About the author

Tony Evans is an engineer with APC by Schneider Electric in West Kingston, RI. He has 14 years of experience in power and cooling system design and is a member of ASHRAE Technical Committee 9.9 (Mission Critical Facilities, Technology Spaces, & Electronic Equipment).

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White Paper 25

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