

AuditAC

Technical guides for owner/manager of an air conditioning
system : volume 1

**Are you sure you are not paying for
inefficient cooling?**

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Are you sure you are not paying for inefficient cooling?

Learn more about existing air conditioning systems and factors that affect their energy efficiency during their life



Air conditioning systems are nowadays very widespread in commercial buildings and their energy consumption has been recognised as an important issue for European emissions objectives in the Kyoto protocol.

This short guide aims to help the auditor of air conditioning plants to improve their operation and to identify and understand simple methods to obtain energy savings.

In the first part, we guide the reader through the description of the variety of air conditioning systems technologies existing on the market. (If you don't know what type of system you have in your building you can use our brochure on system recognition to easily identify your system!)

Then we analyse the causes of degradation of operation of an air conditioning system that decrease the energy efficiency of the system, increase the energy consumption, can lead to loss of comfort and, if neglected, can lead to the interruption of the operation of the system.

Maintenance and operation activities are considered as an important (but not sufficient) step to avoid the loss of efficiency of the system and most common activities are described for the main components of an air conditioning system.

At the end of this brochure you should be aware of the possibilities of imperfect operation of air conditioning systems, and of the need for an audit of your system. You will be able to identify some simple actions that can increase your energy efficiency and reduce your energy consumption!

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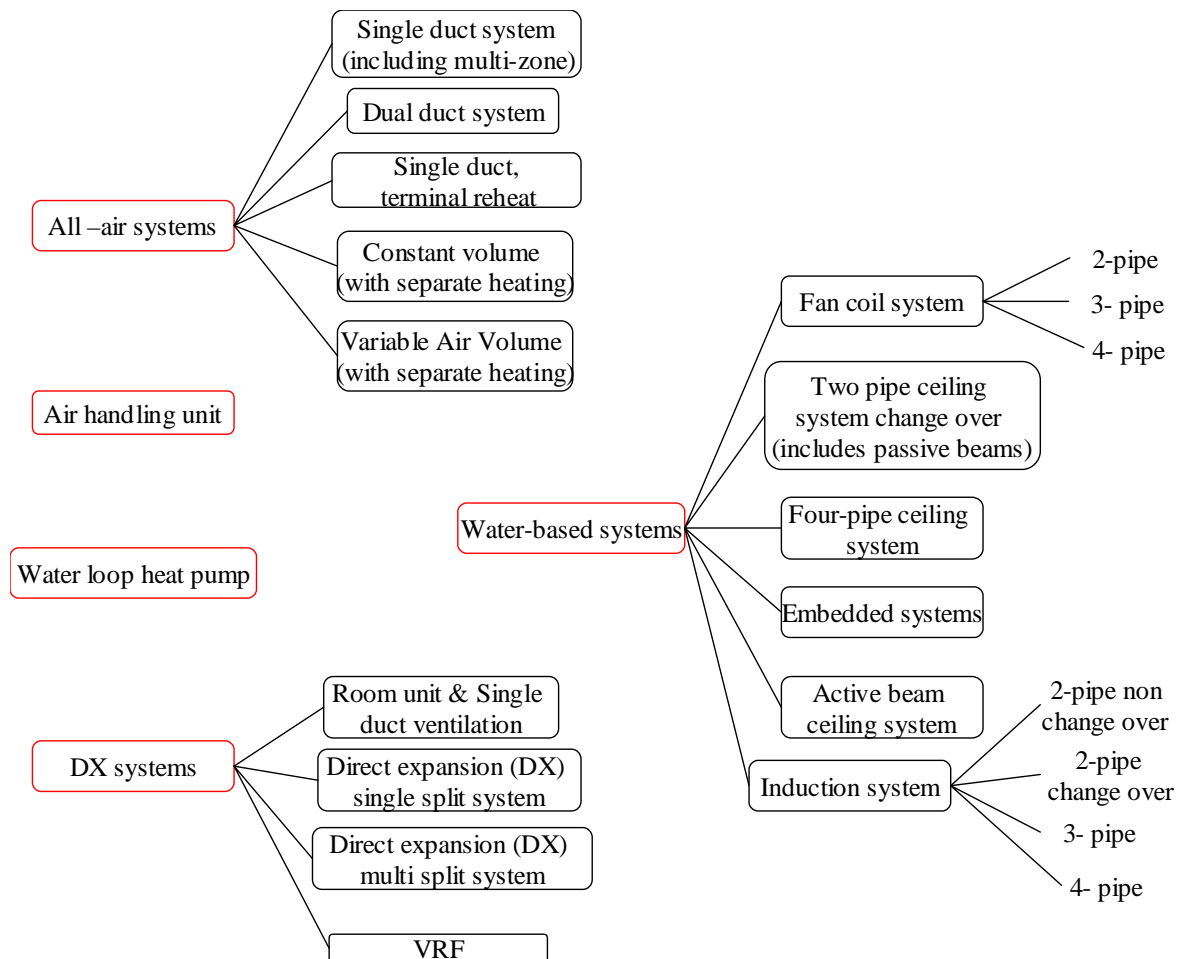
- Electric motors

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The air conditioning systems types

Many cooling technologies exist nowadays on the market. Although some are disappearing because of their intrinsically poor energy efficiency and high running costs, older are still present in older buildings.

The system classification we propose is based on the different fluids used to transfer cooling to the cooled space: air, water or refrigerant (in this last case we speak of direct expansion system: DX). This classification allows us to include most of the systems. Two cases have to be considered separately: air handling units and water loop heat pumps.



A fault classification for air conditioning plants

In order to properly distinguish the sources of energy efficiency degradation some definitions are necessary: faults, defects and failures:

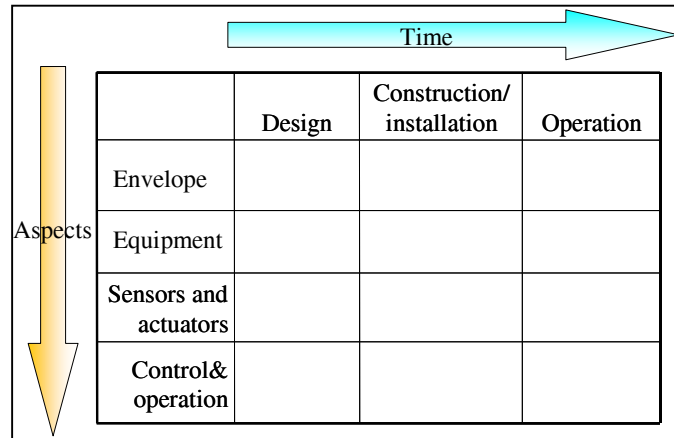
- ❑ a fault is a sign of malfunction, either coming from operational error or from some defect
- ❑ a defect is a hardware imperfection coming either from poor design or poor installation or lack of maintenance
- ❑ failure is a state of the system in which the main function is missing, as opposed to a degraded mode of operation of the main function.

Our main interest is to detect faults and defects during the life of the system in order to avoid failures resulting from constant negligence of faults and/or defects.

Different level of defects

We follow a defect classification on HVAC systems following two axes: the “aspect” axis and the “time” axis.

On the aspect axis, each type of defect can may relate to the building, the equipment, sensors, actuators or the control system. The occurrence of defects can be in all three phases of the lifecycle: the phase of design, during the construction or the normal operation of the system on the “time” axis. This classification can be represented in a matrix as in the following figure.



Some figures for rooftop

Occurrence in defect for rooftop systems has been studied by Braun and Baker in the article “Common Faults and Their Impacts for Rooftop Air Conditioners” (VOL. 4, NO. 3 HVAC&R RESEARCH JULY 1998). A database was analysed from a service company that primarily services rooftop air conditioners for stores. The database contains over 6000 separate fault cases from 1989 to 1995. Frequency of occurrence information helps to expose the “nuisance” faults, those faults that are not expensive to fix, but cause a periodic loss of comfort and frequent visits from service technicians. The following table shows the results of the study and is an example of the defects that can occur.

Causes for loss of comfort	% Total Occurrences
Controls error	21%
Electrical problem	20%
Refrigerant leak	12%
Condenser	7%
Air handling	7%
Evaporator	6%
Compressor	5%
Cooling water loop	4%
Plugged filters	2%
Personnel error	2%
Expansion device	2%
Can't classify	12%

More common defects for some system type

Air cooled chillers

For air cooled chillers the faults considered are:

1. Worn compressor
2. Low refrigerant level (due to refrigerant leakage)
3. Excessive Refrigerant charge
4. Corrosion of the condenser on the air side
5. Defects on fan
6. Fouling of air ductwork
7. Evaporator fouling on chilled water side
8. Evaporator corrosion on the chilled water side
9. Presence of non condensable gases in the refrigerant circuit
10. Obstruction in the chilled water circuit outside the evaporator
11. Defects on the expansion component TXV (too open /too close)

Split systems

For split systems, seven types of faults are considered:

1. refrigerant leakage
2. condenser corrosion or fouling,
3. evaporator filter fouling
4. restriction in liquid line
5. worn compressor
6. faults on indoor fan
7. faults on outdoor fan.

Air handling units

The defects considered are listed hereunder and the trees will not have the same effects for the case of constant or variable air volume systems:

1. Cooling coil fouling on the water side
2. Dirty exchanger fins and coils
3. Reduction of the transmission efficiency (for pulley misalignment or relaxed belt)
4. Dirty filters
5. Stuck outside air damper (open and closed)
6. Chilled water regulation vane stuck (open and closed)

Sizing

Problems on sizing are related to the **design** of the installations.

The assessment of the real needs for cooling of a building requires a detailed study and documentation of the possible uses and the construction of the building. Very often in the design phase this study is neglected, and empirical “rules of thumb” are used to determine the capacity of the system.

The consequences of **oversized** cooling equipment is the operation of the system either continuously at very low capacity (and for some equipment with poor performance), or for short ON/OFF cycles (many starting for very short time) and therefore with increased stress on the equipment, usually leading to a consequent reduction of equipment life time.

The main effect of **undersizing** the equipment is an occasional lack of comfort.

Defects in the building envelope

The structure and characteristics of the building envelope influence the need (and the energy consumption) for cooling. Depending on the building that may be more or less important.

These aspects that increase the cooling load have to be considered:

- the lack of **thermal insulation** and the existence of **thermal bridges**
- the **air infiltration**
- the lack of **solar protection**
- **glazing** not adapted.

The lack of insulation can be detected only by the deep knowledge of the structure of the walls and of the construction and through a thermal calculation of the exchange coefficient of the building. Each country has its own thermal regulation that establishes reference values for insulation.

More difficult is the detection and the measurement of air infiltration: only experimental pressure tests can assess with reliability the air infiltration rate. The major causes of excessive air infiltration are leaks in walls (frame of windows, electrical outlets, plumbing penetrations).

Addition of solar protection (if absent) or modifications to the existing protection can be important: the different impact on energy savings, for cold and hot season respectively, have to be carefully evaluated before any change.

The characteristics of glazing are important in managing the solar load in a building. Because of the development of new technologies and materials, the market offers nowadays a large variety of solutions to improve the sunlight filtration.

Actions on the building envelope are expensive (unless part of a general renovation) and can have a long time of return on investment. They are often hard to identify through a “walk-through” audit or quick inspection and need a deeper analysis of the building. The EPBD Energy Performance Certification process may help with this.

Attention should be paid to any change to the building envelope that influences the capacity of the cooling system. Sometime a modification to the building envelope can be combined with a decision to replace the cooling system by a system with a lower capacity, leading to important energy savings.

Defects on sensors and control

Every air conditioning system is controlled thorough a control system based on a certain number of sensors linked to controllers. The response of each controller acts on some device (actuator) that changes the air conditioning operation according to the current needs. This system (sensor-controller-actuators) maintains the comfort conditions for the occupants and its bad operation affects directly the behaviour of the air conditioning system and its consumption. Attention should be paid to avoid the following defects.

Defects on sensor²

A sensor responds to a change in the controlled variable (for example, room air temperature). The response, which is a change in some physical or electrical property of the primary sensing element, is available for translation or amplification by mechanical or electrical signal. This signal is sent to the controller.

Many sensor defects are unrelated to the specific type of sensor, and can appear regardless of the measurement arrangement. These general sensor defects can be subdivided into three categories. These categories are described below, along with examples.

² Adapted from “Typical faults observed in HVAC systems”, Jean Lebrun, Liège 20 May 2005, (Source: IEA-ECBCS annex 34 report). In the text the word “fault” has been replaced by “defect” in agreement with our definitions.

Location defects

Location defects are the most common defects occurring in HVAC systems. In the case of improper positioning, the sensor itself is working properly. However, because of a bad sensor location or placement, the reading obtained from the sensor does not give a value representative of the conditions for which measurements are required. Commonly, this defect occurs when the physical boundary conditions are not properly considered during design and installation. A possible defect, which can be related to a bad sensor location, is the influence of radiation from different sources such as heating or cooling coils. A location related sensor defect can also occur if sensors are placed in dead-legs (e.g. in ducts with insufficient air flow) or without sufficient straight duct lengths upstream of the sensor (e.g. with flow measurements).

Electrical installation defects

The sensing device of measuring systems is usually connected to the control system through wires. Shortcomings within these electrical connections can also cause sensor and measurement defects. One example of this is bad or possibly incorrect wiring (bad solder joint or exchange of two wires). Another reason for defects due to electrical installation can be the use of unshielded cables, which might result in increased amounts of noise on the measurement. Additionally, the use of an unsuitable power supply for the sensors (e.g. incorrect supply voltage) can also lead to measurement errors. Further defects, which could fall into this category, are grounding problems, incorrect scaling, or possibly conversion defects.

Sensor related defects

The defects in this category occur within the sensing device or within its electronic components. Output drift and bias are the most common defects that can be related directly to the sensor. A broken sensor, which gives no or a completely wrong signal can be put into this category. Also the use of inappropriate or unsuitable sensors (e.g. a sensor with a wrong range or a time constant which is too long) is classified as a sensor related defect. Sensor related defects can often be traced back to improper design or to mistakes made during the installation. As a result, it should always be noted that the accuracy of a measurement system is limited to the accuracy of the worst element composing this system.

Control system defects³

There are two main categories of defects that occur in building control: *hardware defects* and *software defects*. These defects might arise in all three phases of the control system life cycle: the *production*, *implementation* and *application* of control systems. The *production* phase includes the production and development of the hardware and standard software or “firmware”. The *implementation* phase includes the installation of the hardware, the development of application software, the initial commissioning of hardware and application software, and the tuning of control strategies (loops). The *application* phase is the period of normal operation after the initial commissioning phase. Unless they are eliminated, all of the defects eventually influence the control of the system control in the *application* phase.

Hardware Defects

The hardware defects are actuator defects, interface failures, controller hardware defects and sensor defects.

Actuator defects

Actuators are used to drive the dampers or valves in an air-conditioning system and can be divided into three types: electromagnetic, pneumatic and motor-driven. Defects therefore include defects such as blocked or burnt-out electrical coils, elastic failure (e.g., broken damper linkage), etc. In VAV systems, damper and cooling/heating valve actuator defects results in temperatures or airflows that are higher or lower than the associated set point.

³ Idem 1, S. Wang and J. Seem

Interface failure

Interface failure in the communication networks of building control systems is a complicated problem and the diagnosis and troubleshooting methods are different for different systems and problems. A hardware communication failure might be the results of physical connections (cabling) defects, defects in interface cards, or failure of the power supply (fluctuations).

Controller hardware defects

In modern building control systems, the controller is built from digital electronic devices. Controller hardware defects include short-circuits, broken circuits, degradation and burn-out of electronic components, and loose interface connections, battery failure, etc. These controller hardware defects can result in wrong values of the control signal or no control signal to actuator.

Additionally, electronic controllers are susceptible to transient electromagnetic interference, which can cause functional errors, often without damaging any of the controllers' components. This can also result in incorrect values of the control signal being sent to the actuators. In this case, there are two possible outcomes:

- The controller can generate the wrong control signal due to erroneous computation
- The controller can fail to update the control signal until the failure is detected and handled properly i.e. there will be a delay in the feedback control loop
- Poor designed anti-aliasing filters can cause the controller to oscillate in response to the high frequency electromagnetic interference

Software Defects

Poor tuning

Inappropriate selection of the parameters of the control strategies can cause both local and supervisory control loops to oscillate. The values of control parameters that result in stable control at one operating point can result in unstable control at another operating point. For example, poor tuning of the temperature and air flow rate controllers of a VAV box can cause both the temperature and the flow to oscillate about their set points. Any change in the characteristics of the HVAC equipment within a feedback control loop may also result in unstable or unsatisfactory behaviour of the control loop. On-line tuning of a local control loop is sometimes needed to fine-tune a controller during commissioning.

Building simulators and emulators provide an efficient method of testing control strategies and software during the development and commissioning stages. Dynamic simulation may be used to test a control algorithm at difficult operating conditions. Emulators can be used to check and commission the BEMS implementation of the control software in a simulated real-life environment.

Maintenance auditing for Energy Efficiency

Maintenance is very important to guarantee the operation of the AC system, ensuring the main function of the system and if well defined ensuring the constancy of the level of performances. The following items describe most common maintenance actions on equipment that should be included in your maintenance contract.

Basic Maintenance for chillers

Particular attention should be paid to the compressor (mechanical component wear sooner) and to the heat exchangers:

- **Heat exchangers cleaning** in order to reduce scale or fouling: the heat transfer surfaces in chillers tends to collect various mineral and sludge deposits from the water that is circulated through them. Any buildup insulates the tubes in the heat exchanger causing a decrease in heat exchanger efficiency and thus, requiring a large temperature difference between the water and the refrigerant.

- **Purge air from condenser** – Air trapped in the condenser causes an increased pressure at the compressor discharge. This results in increased compressor horsepower. The result has the same effect as scale build up in the condenser.
- Maintain adequate condenser water flow through **filter cleaning**: most chillers include a filter in the condenser water line to remove material picked up in the cooling tower. Blockage in this filter at higher loads will cause an increase in condenser refrigerant temperature due to poor heat transfer.
- Verify the **refrigerant level**: in high pressure chillers, refrigerant can leak out, reducing refrigerant charge and limiting the unit's heat transfer capacity. In low pressure chiller systems, air can leak into the unit, displacing refrigerant vapour, causing higher condenser pressure, and increasing energy use.
- **Maintenance on compressor**: verifying vibrations, oil level, the motor alignment and coupling for wear and make sure bolts are tight.

Basic Maintenance for cooling towers

An improperly maintained **cooling tower** will produce warmer cooling water, resulting in higher condenser temperatures than a properly maintained cooling tower. This reduces the efficiency of the chiller, wastes energy, and increases cost. The chiller will consume 2.5% to 3.5% more energy for each degree increase in the condenser temperature.

Common causes of cooling towers poor performance are:

- **Scale Deposits** – When water evaporates from the cooling tower, it leaves scale deposits on the surface of the fill from the minerals that were dissolved in the water. Scale build-up acts as a barrier to heat transfer from the water to the air. Excessive scale build-up is a sign of water treatment problems.
- **Clogged Spray Nozzles** – Algae and sediment that collect in the water basin as well as excessive solids that get into the cooling water can clog the spray nozzles. This causes uneven water distribution over the fill, resulting in uneven airflow through the fill and reduced heat transfer surface area. This problem is a sign of water treatment problems and clogged strainers.
- **Poor Air Flow** – Poor airflow through the tower reduces the amount of heat transfer from the water to the air. Poor airflow can be caused by debris at the inlets or outlets of the tower or in the fill. Other causes of poor airflow are loose fan and motor mountings, poor motor and fan alignment, poor gearbox maintenance, improper fan pitch, damage to fan blades, or excessive vibration. Reduced airflow due to poor fan performance can ultimately lead to motor or fan failure.

Usually, the tower manufacturer furnishes operating and maintenance manuals that include recommendations for procedures and intervals as well as parts lists for the specific unit. These recommendations should be followed when formulating the maintenance program for the cooling tower.

Accordingly, cooling tower owners should incorporate the following as a basic part of their maintenance program:

- **Periodic inspection of mechanical equipment**, fill, and both hot water and cold water basins to ensure that they are maintained in a good state of repair.
- Periodic **draining and cleaning** of wetted surfaces and areas of alternate wetting and drying to prevent the accumulation of dirt, scale, or biological organisms, such as algae and slime, in which bacteria may develop.
- Proper **treatment** of the circulating **water** for biological control and corrosion, in accordance with accepted industry practice.
- **Systematic documentation** of operating and maintenance functions.

Basic Maintenance for pumps

Proper maintenance is vital to achieving top pump efficiency expected life. Additionally, because pumps are a vital part of many HVAC and process applications, their efficiency directly affects the efficiency of other system components.

That's why pumps necessitate a proactive maintenance program. Most pump maintenance activities focus on **checking** packing and mechanical seals **for leakage**, performing preventive/predictive maintenance activities on **bearings**, assuring proper **alignment**, checking the **valves** and validating proper motor condition and function.

Basic Maintenance for fans

Most fan maintenance activities are on **cleaning** housings and fan blades, **lubricating** and **checking** seals, adjusting belts, checking bearings and structural members, and tracking vibration.

Basic Maintenance for cooling coils⁴

If the coil is to deliver its full cooling capacity, both its internal and its external surfaces must be clean. The tubes generally stay clean in pressurized water or brine systems. Should large amounts of scale form when untreated water is used as coolant, chemical or mechanical cleaning of internal surfaces at frequent intervals is necessary.

Water coils should be completely drained if freezing conditions are possible. When coils use evaporating refrigerants, oil accumulation is possible, and occasional checking and oil drainage is desirable.

While outer tube surfaces can be cleaned in a number of ways, they are often washed with low-pressure water and mild detergent.

The surfaces can also be brushed and cleaned with a vacuum cleaner. In cases of marked neglect—especially in restaurants, where grease and dirt have accumulated—it is sometimes necessary to remove the coils and wash off the accumulation with steam, compressed air and water, or hot water. The best practice, however, is to inspect and service the filters frequently.

Auditing operation for Energy Efficiency

Operation methods for Energy Efficiency improvements can be distinguished in two categories. The first methods type implies a correction action just on one component or on one element of the equipment; then, the consequences on the global system are analysed (analysis of sensitiveness of the system) and the improvements evaluated. The second method considers the system as a whole. Modifications are made to many components or parts of the equipment and the strategies and evaluation of energy efficiency improvements are more complex.

For the first method, a checklist can be developed with the most common actions. These actions are described for different equipment.

Chillers⁵

The following steps describe some (among many) possible ways to improve **chillers** performance, therefore, reducing its operating costs and energy consumption:

- Raise chilled water temperature – The energy input required for any liquid chiller increases as the temperature lift between the evaporator and the condenser increases. Raising the chilled water temperature will cause a corresponding increase in the evaporator temperature and thus, decrease the required temperature lift.
- Reduce condenser water temperature – The effect of reducing condenser water temperature is very similar to that of raising the chilled water temperature, namely reducing the temperature lift that must be supplied by the chiller.
- Reducing auxiliary power requirements – The total energy cost of producing chilled water is not limited to the cost of operating the chiller itself. Cooling tower fans, condenser water circulating pumps, and chilled water circulating pumps must also be included. Reduce these requirements as much as possible.

⁴ Source: ASHRAE handbook, Systems and Equipment, 2000.

⁵ Adapted from O&M Best Practices Guide, Federal Energy Management Project, www.eere.energy.gov

- Use variable speed drive on centrifugal chillers – Centrifugal chillers are typically driven by fixed speed electric motors. Practical capacity reduction may be achieved with speed reductions, which in turn requires a combination of speed control and pre-rotation vanes.
- Compressor change outs – In many installations, energy saving measures have reduced demand to the point that existing chillers are tremendously oversized, forcing the chiller to operate at greatly reduced loads even during peak demand times. This causes a number of problems including surging and poor efficiency. Replacing the compressor and motor drive to more closely match the observed load can alleviate these problems.
- Use free chilling – Cooling is often required even when the outside wet bulb temperature drops below the minimum condenser water temperature. If outside air wet bulb temperature is low enough, the chiller should be shut off and the chilled water can be produced by the cooling tower directly.
- Operate chillers at peak efficiency – Plants having two or more chillers can save energy by load management such that each chiller is operated to obtain combined peak efficiency. An example of this is the use of a combination of reciprocating and centrifugal compressor chillers.
- Use heat recovery systems – Heat recovery systems extract heat from the chilled liquid and reject some of that heat, plus the energy of compression, to warm water circuit for reheat and cooling.
- Use absorption chilling for peak shaving – In installations where the electricity demand curve is dominated by the demand for chilled water, absorption chillers can be used to reduce the overall electricity demand.
- Thermal storage – The storage of ice for later use is an increasingly attractive option since cooling is required virtually year-round in many large buildings across the country. Because of utility demand charges, it is more economical to provide the cooling source during non-air conditioning periods and tap it when air conditioning is needed, especially peak periods.

Pumps

Pumps are frequently asked to operate far off their best efficiency point, or are perched atop unstable base-plates, or are run under moderate to severe misalignment conditions, or, having been lubricated at the factory, are not given another drop of lubricant until the bearings seize and vibrate to the point where bolts come loose. When the unit finally stops pumping, new parts are thrown on the machine and the deterioration process starts all over again, with no conjecture as to why the failure occurred.

The following are measures that can improve pump efficiency:

- Shut down unnecessary pumps.
- Restore internal clearances if performance has changed.
- Trim or change impellers if head is larger than necessary.
- Control by throttle instead of running wide-open or bypassing flow.
- Replace oversized pumps.
- Use multiple pumps instead of one large one.
- Use a small booster pump.
- Change the speed of a pump for the most efficient match of horsepower requirements with output.

Fans

In many applications, **fan** control represents a significant opportunity for increased efficiency and reduced cost. A simple and low-cost means of flow control relies on dampers, either before or after the fan. Dampers add resistance to accomplish reduced flow, while increasing pressure. This increased pressure results in increased energy use for the flow level required. Alternatives to damper flow control methods include physical reductions in fan speed though the use of belts and pulleys or variable speed controllers.

Electric motors

An **electric motor** performs efficiently only when it is maintained and used properly. Electric motor efficiencies vary with motor load; the efficiency of constant speed motor decreases as motor load decreases. Below are some general guidelines for efficient operations of electric motors.

- Turn off unneeded motors – Identify motors that operate needlessly, even for a portion of the time they are on and turn them off. For example, there may be multiple HVAC circulation pumps operating when demand falls, cooling tower fans operating when target temperatures are met, ceiling fans on in unoccupied spaces, exhaust fans operating after ventilation needs are met.
- Reduce motor system usage – The efficiency of mechanical systems affects the run-time of motors. For example, reducing solar load on a building will reduce the amount of time the air handler motors would need to operate.
- Replacement of motors versus rewinding – Instead of rewinding small motors, consider replacement with an energy-efficient version. For larger motors, if motor rewinding offers the lowest life-cycle cost, select a rewind facility with high quality standards to ensure that motor efficiency is not adversely affected. For sizes of 10 hp or less, new motors are generally cheaper than rewinding. Most standard efficiency motors under 100 hp will be cost-effective to scrap when they fail, provided they have sufficient runtime and are replaced with energy efficient models.

Operation strategies for energy savings

The following strategies described allow obtaining energy saving through better performance or lower energy consumption acting on the operation of the ventilation and A/C system.

If various chillers are used, an optimised strategy on the sharing of load among the chillers following the changes of load can achieve important energy saving allowing the chillers to operate in the best conditions of performance. To do that, the chillers have to:

be controlled to supply chilled water at the same temperature

for equal chillers, the condenser water flows have to be controlled in order to have the same water outlet temperatures.

To determine the best sequence of operation of the chillers a detailed analysis is request to take in account capacities and performances at partial load for each chiller and the relative auxiliaries consumptions.

The energy for cooling can be reduced by using free chilling and free cooling whenever possible. Free cooling takes place when the external ambient air enthalpy (the term used for a combination of sensible heat and moisture content) is less than the indoor air enthalpy and when some cooling is transferred to the building envelope either directly or indirectly from the outside air.

The cooling energy can be lowered, moreover, by a night time over-ventilation that permit to start later in the morning and to recover the cooling energy due to the lower night temperatures. Keeping the ventilation requirement closer to the minimum can also lower the energy losses through the air renovation.

The fine-tuning of controls, namely through BEMS and the use of FDD thanks to BEMS can strongly influence the cooling energy consumption (see following chapter).

Another kind of strategy is to adapt the set point temperature control to the exterior condition (also called Adaptation to partial load), where the comfort conditions are not linked to a fixed temperature but to the difference of temperature with the outside/inside temperature difference. However this type of strategy can't be applied for case where the temperature level has to be kept constant as for server rooms.

Many systems include the possibility of terminal reheat of the air; this could be avoided by forbidding successive cooling and reheating of the air.

Using the BEMS for operations and commissioning⁶

A Building Energy Management Systems (BEMS) offers new opportunities to automate some parts of the commissioning process and can generate benefits over the entire life of a building. These benefits include a reduction of process cost and manual effort on site, improved quality assurance process and the adoption of automated energy audit capabilities to improve overall building performance.

In a BEMS-assisted commissioning, the control system is used to perform commissioning procedures. Typically, the control system is used as a means of interfacing to energy systems in buildings through sensor and control signals.

Automating this essentially manual process could allow its application on a regular basis, generating benefits over the entire life of a building.

The BEMS-assisted commissioning include a Fault Detection and Diagnostic Tool (FDD Tool) that can contribute to the continuous auditing of the system. This tool collects control information or other data and analyses them to detect symptoms of abnormal behaviour in various HVAC components, such as uncalibrated or failed sensors, actuator or linkage failure, controller instability, non-optimal sequence of operations, etc. The tool also diagnoses their possible causes and provides explanations. It goes beyond the capabilities of conventional BEMS single-point alarms and integrates information from multiple sensors to establish a more comprehensive understanding of the status of operation.

In the use of the BEMS for as a commissioning tool, particular attention has to be paid for the calibration and sensor location that should be verified periodically. Many HVAC components have sufficiently well known characteristics in order to be used as measuring devices. Manufacturers themselves are very often offering adapted sensors or adapted location for such sensors as part of their products. This is particularly true for control valves, refrigeration expansion valves, compressors, pumps, registers and fans.

These components are usually offered (in option with moderated extra-cost) with well-prepared pressure probe locations. Pressures measured at these locations are used to determine the corresponding flow rate, for each position of the control device (valve or register opening, pump or fan rotation speed...). Other "good candidates" to become measuring devices are all HVAC components having been previously tested in laboratory and/or for which calibrated simulation models are already available.

A few on site calibration tests might be sufficient to guarantee a good enough accuracy. Such tests are required if the location of the sensors is not fully satisfactory.

⁶ Source: Final report of IEA Annex 40.