



HVAC Instrumentation and Control

An Online Continuing Education Course for Engineers

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HVAC Instrumentation and Control

The application of Heating, Ventilating, and Air-Conditioning (HVAC) controls starts with an understanding of the building and the use of the spaces to be conditioned and controlled. All control systems operate in accordance with few basic principles but before we discuss these, let's address few fundamentals of the HVAC system first.

Why Automatic Controls?

The capacity of the HVAC system is typically designed for the extreme conditions. Most operation is part load/off design as variables such as solar loads, occupancy, ambient temperatures, equipment & lighting loads etc keep on changing through out the day. Deviation from design shall result in drastic swings or imbalance since design capacity is greater than the actual load in most operating scenarios. Without control system, the system will become unstable and HVAC would overheat or overcool spaces.

HVAC systems

HVAC systems are classified as either self-contained unit packages or as central systems. Unit package describes a single unit that converts a primary energy source (electricity or gas) and provides final heating and cooling to the space to be conditioned. Examples of self-contained unit packages are rooftop HVAC systems, air conditioning units for rooms, and air-to-air heat pumps.

With central systems, the primary conversion from fuel such as gas or electricity takes place in a central location, with some form of thermal energy distributed throughout the building or facility.

Central systems are a combination of central supply subsystem and multiple end use subsystems. There are many variations of combined central supply and end use zone systems. The most frequently used combination is central hot and chilled water distributed to multiple fan systems. The fan systems use water-to-air heat exchangers called coils to provide hot and/or cold air for the controlled spaces. End-use subsystems can be fan systems or terminal units. If the end use subsystems are fan systems, they can be single or multiple zone type. The multiple end use zone systems are mixing boxes, usually called VAV boxes.

Another combination central supply and end use zone system is a central chiller and boiler for the conversion of primary energy, as well as a central fan system to delivery hot and/or cold air. The typical uses of central systems are in larger, multistoried buildings where access to outside air is more restricted. Typically central systems have lower operating costs but have a complex control sequence.

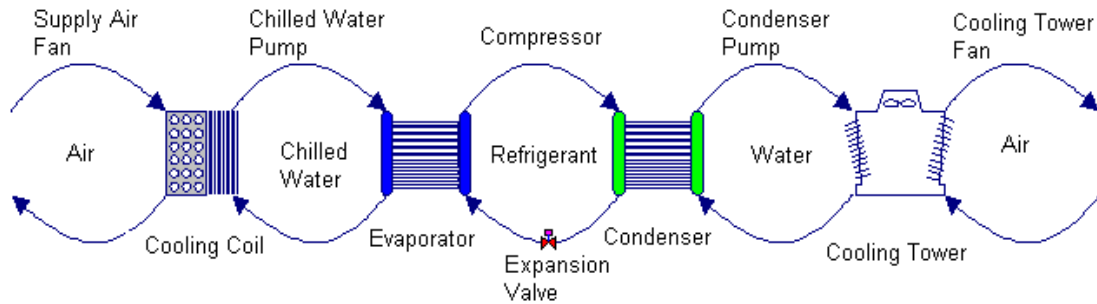
How does central air-conditioning system work?

Cooling Cycle (chilled water system): The supply air, which is approximately 20° F cooler than the air in the conditioned space, leaves the cooling coil through the supply air fan, down to the ductwork and into the conditioned space. The cool supply air picks up heat in the conditioned space and the warmer air makes its way into the return air duct back to the air handling unit. The return air mixes with outside air in a mixing chamber and goes through the filters and cooling coil. The mixed air gives up its heat into the chilled water tubes in the cooling coil, which has fins attached to the tubes to facilitate heat transfer. The cooled supply air leaves the cooling coil and the air cycle repeats.

The chilled water circulating through the cooling coil tubes, after picking up heat from the mixed air, leaves the cooling coil and goes through the chilled water return (CHWR) pipe to the chiller's evaporator. Here it gives up the heat into the refrigeration system. The newly "chilled" water leaves the evaporator and is pumped through the chilled water supply (CHWS) piping into the cooling coil continuously and the water cycle repeats.

The evaporator is a heat exchanger that allows heat from the CHWR to flow by conduction into the refrigerant tubes. The liquid refrigerant in the tubes "boils off" to a vapor removing heat from the water and conveying the heat to the compressor and then to the condenser. The heat from the condenser is conveyed to the cooling tower by the condenser water. Finally, outside air is drawn across the cooling tower, removing the heat from the water through the process of evaporation.

The figure below provides a conceptual view of chilled water air-conditioning system with water-cooled condenser.



Chilled Water System With Water Cooled Condenser

The main equipment used in the chilled water system is a chiller package that includes

- 1) A refrigeration compressor (reciprocating, scroll, screw or centrifugal type),
- 2) Shell and tube heat exchanger (evaporator) for chilled water production
- 3) Shell and tube heat exchanger (condenser) for heat rejection in water cooled configuration (alternatively, air cooled condenser can be used, where water is scarce or its use is prohibited)
- 4) A cooling tower to reject the heat of condenser water
- 5) An expansion valve between condenser and the evaporator

The chilled water system is also called central air conditioning system. This is because the chilled water system can be networked to have multiple cooling coils distributed through out a large or distributed buildings with the refrigeration equipment (chiller) placed at one base central location.

The heating cycle also follows the same cycle with a difference that the chilled water is replaced with hot water/steam and the chiller is replaced with boiler. The condenser and cooling tower circuit is not needed.

What Parameters are controlled?

A proper environment is described with four variables: temperature, humidity, pressure and ventilation.

Temperature

The comfort zone for temperature is between 68°F (20°C) and 75°F (25°C). Temperatures less than 68°F (20°C) may cause some people to feel too cool. Temperatures greater than 78°F (25°C) may cause some people to feel too warm.

ASHRAE 55-1992 suggests the following temperature ranges for overall thermal comfort.

Season	Clothing	Optimum Temperature	Temperature Range
Winter	Heavy slacks, long-sleeve shirts and sweaters	22°C 71°F	20 -23.5°C 68-75°F
Summer	Light slacks and short sleeve shirt	24.5°C 76°F	23 – 26°C 73 -79°F

While no single environment can be judged satisfactory by everybody, it varies between people, regions and countries. Uniformity of temperature is important to comfort. The temperatures should not vary within single zone or change suddenly or drastically.

Humidity

Humidity is the presence of water vapor in air and it affects human comfort. ASHRAE 55-1992 recommends the relative humidity (RH) to be maintained between 25 and 60%. Humidity less than 20% RH causes the room to be too dry, which has an adverse effect on health, computers, printers, and many other areas. Humidity greater than 60% RH causes the room to be muggy and increases the likelihood of mildew problems.

Ventilation

ASHRAE Standard 62-1999: "Ventilation for Acceptable Indoor Air Quality" recommends minimum ventilation rates per person in the occupied spaces. In many situations, local building codes stipulate the amount of ventilation required for commercial buildings and work environments. The recommended value of outside air is typically 20 CFM for each occupant.

The ventilation rates specified by ASHRAE effectively dilutes the carbon dioxide and other contaminants created by respiration and other activities; it supplies adequate oxygen to the occupants; and it removes contaminants from the space. The ventilation rates greater

than recommended by ASHARE criteria are sometime required controlling odours and where cooling is not provided to offset heat gains.

Pressure

Air moves from areas of higher pressure to areas of lower pressure through any available openings. A small crack or hole can admit significant amounts of air, if the pressure differentials are high enough (which may be very difficult to assess). Rooms and buildings typically have a slightly positive pressure relative to the atmosphere. This helps in keeping out dust and pollutants. A pressure differential of "0.01-.05" is typical. If the indoor air quality is poor, smoke

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The load on the system varies with the temperature swings in the space. Trying to find a system that allows adequate comfort without excessive wear on the equipment is *modulation* or proportional control. Under this concept, if a building is calling for half the rated capacity of the chiller, the chilled water is supplied at half the rate or in case of heating furnace; fuel is fed to the furnace at half the design rate: the energy delivery is proportional to the energy demand. While this system is better than cycling, it also has its problems. Equipment has a limited turn-down ratio. A furnace with a 5:1 turn-