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Air Conditioning Systems

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Please note

The basic function of an air conditioning system is to supply treated air throughout a building at the rate and condition required to counteract heat and moisture gains and losses (loads) so that temperature and humidity are maintained within acceptable limits. The choice of a particular system to achieve this objective will depend largely on the tolerance specified for any variation in room conditions and on the magnitude and variation of the loads.

Close control at all times of temperature and humidity in every room may require a complex and costly system. Some rooms, particularly interior ones, will require only cooling, whereas exterior room loads may alternate between heating and cooling on a seasonal or even a daily basis. At any given time, some spaces may require heating while others require cooling. Moisture loads also may vary with time and location. An ideal system, therefore, would have to be versatile enough to provide heating or cooling, humidification or dehumidification in every occupied space at all times.

Such a system might be specified for a particular industrial application, but for comfort air conditioning the precise and independent control of both temperature and humidity is seldom justified. Humidity can usually be allowed to vary over a broad range, simplifying both the control system and the air conditioning process (**CBD 102**, **CBD 108**). Temperature can be controlled independently, although the designer is still faced with the problem of selecting the optimum heating and cooling system.

Close control of temperature may demand that heating and cooling are available at all times in all spaces. It must be realized that this will add to the complexity and cost of the system. If some variation in temperature can be permitted, a simpler system that provides only heating or only cooling at a given time might be satisfactory. The temperature deviation that occurs on a change of load from heating to cooling, and vice versa, is a function of the magnitude and duration of the load reversal, which depends, in turn, on the characteristics of the building and its occupancy.

The selection of a particular building construction and fenestration and the arbitrary specification of temperature and humidity control can have a serious influence on the design of the air conditioning system. Not only are the maximum loads to be handled influenced by these decisions, but the complexity of the system and its control are similarly affected. The extent of these effects are perhaps best illustrated by examining the capabilities and limitations of some of the more common systems.

Central Air Systems

This category includes all systems that treat air in a central plant and deliver it to various spaces. The simplest air system is probably a warm air system that provides only heating. Air is withdrawn from the space, circulated through a heater and sent back to the space or spaces. The heater may be a fuel fired furnace, electric heating elements, or a steam or hot water heating coil. Supply ductwork can be large low velocity ducts (600 to 2200 ft per minute) or small high velocity ducts (2500 to 4000 ft per minute). Smaller ducts require less space but much larger fan horsepower. Returns are normally large low velocity ducts.

A maximum supply temperature must be selected and an air supply rate calculated for one of the spaces that will satisfy its maximum heat loss. The air flow rate for all other spaces can then be established in the same proportion. Temperature control is achieved by regulating the heater operation in response to a thermostat in one of the spaces. Satisfactory control of all spaces will only result if the heat loss from each space varies in the same proportion as the heat loss from the space containing the thermostat.

Heat losses from all spaces seldom if ever vary in the same proportion. Spaces on the windward side of the building usually have a higher heat loss than those on the leeward side; and internal and external heat gains from lights, people, equipment and solar radiation will vary from space to space, thus upsetting the net heat loss ratio for the various spaces. In a small building such as a residence the spaces are usually interconnected to the extent that temperature variation between them stays within tolerable limits. In larger buildings this is usually not the case, and the desired space temperature can only be maintained if adjustments are made in either the supply temperature or air flow rate required for each space (or for each group of spaces or zones having similar heat loads). If solar and internal gains exceed heat loss, as often happens, a simple heating system cannot prevent the temperature from rising above the desired level.

To the simple air system for heating may be added an air filter, a humidifier to add moisture when the humidity drops to some predetermined level, and a fresh air supply to mix with the return air from the space. The fresh air supply could also be used to provide space cooling whenever the outside air temperature drops below the desired space temperature.

A further refinement to such a system could provide cooling and dehumidifying, either by supplying cold water to the coil used for heating or by the installation of a separate cooling coil. In its simplest form dry-bulb temperature would be controlled and the humidity allowed to float between predetermined limits. An adiabatic spray might also be used for cooling when outside conditions provide low enough wet-bulb temperatures. Again, such a system cannot properly handle loads that change from heating to cooling. It can only satisfy the requirements of one of a number of spaces unless the loads in all spaces vary proportionately.

Cooling-Reheat Air Systems

To cope with cyclical changes from heating to cooling and with variation between spaces air systems are often designed as basic cooling systems with reheat. Air from all spaces is returned to the central plant, mixed with at least the minimum quantity of fresh air desired, the mixture conditioned to some temperature below space temperature and supplied through reheat coils in the supply ducts for each of the spaces. The supply temperature to each space can thus be either above or below the space temperature, whichever is appropriate to handle either heating or cooling loads. The moisture content of the air leaving the central plant is limited to that at saturation; hence, its temperature can be selected to limit the maximum space humidity to some desired level.

The air supply rate to each space is established on the basis of the design cooling load of the space and the temperature of the air leaving the central plant. If the cooling load is small, the supply rate might have to be based on the minimum required to provide adequate air circulation and fresh air. The actual cooling load will be considerably less than the design load for most of the time, so that the reheat coils must supply this difference plus any net heating load. When outside temperatures are low enough, return air from the space can be mixed with outside air in a proportion to produce the desired temperature. During cold weather, the minimum fresh air quantity may cool the mixture too far, so that preheating and humidifying may be necessary. Refrigeration is required whenever the outside air temperature exceeds the central supply air temperature.

If humidity control is specified, the air leaving the plant must always be saturated at the dew-point temperature required and then reheated to achieve the desired space temperature. When several spaces are involved, the air may have to be over-dehumidified as well as overcooled in the central plant and reheated and rehumidified in separate units for each space. If the moisture loads and their variations are small, the rehumidifier may be omitted. Conditioning in the central plant can be accomplished in an adiabatic spray whenever outside temperatures enable the mixing of outside air and return air to produce a wet-bulb temperature in the mixture equal to the desired leaving temperature.

A cooling-with-reheat system, with or without humidity control, provides a flexible system for year round use. No particular change is required for summer and winter operation, and heating and cooling are available at all times. The operating expense of the system is rather high, however, because it essentially operates on the principle of overcooling and then reheating as necessary. In effect, the load on the refrigeration system is always near the maximum design load.

Variable Volume Cooling-Reheat Air System

The energy requirements associated with a constant volume "cooling-reheat air system" can be reduced considerably by the use of a variable volume system. The air supply rate to each space is controlled by a room thermostat so that as the cooling load decreases the air supply rate is reduced until some minimum is reached, as predetermined on the basis of air circulation or fresh air requirements. If this provides too much cooling, the reheat coil is activated to increase the supply air temperature. The system is identical in other respects to the constant-volume system. The varying air flow rates introduce some complications in the design of the air supply and distribution system and add to the initial cost.

The energy requirements for both refrigeration and reheat are lower for the variable-volume system than for a constant-volume system. When none of the spaces on a variable-volume system requires reheat, the refrigeration plant has to extract only the cooling load for the spaces and that of the ventilating air.

Dual Duct System

Still another type of air system is the dual duct system in which both heated and cooled air at relatively high pressure are supplied to each space and a terminal unit in or near the space mixes heated and cooled air in the proportion required to maintain the desired temperature. The terminal unit usually keeps the total air flow to the space constant. During summer conditions the cold air is usually maintained between 50 and 55°F and nearly saturated; the warm air is kept about 5 F deg above the space return air temperature. In winter the cold air temperature may for economy be raised from 5 to 10 F deg above that for summer and the warm air kept hot enough to supply the heat loss; the warm air may be humidified.

This type of system is not normally designed for close humidity control but merely to limit the range of variation. It provides for cyclical load changes and differences between spaces. The energy consumption for both refrigeration and heating is rather high, since the operation is essentially one of overcooling and reheating in many of the spaces supplied by the system.

Conditioning Equipment in the Space

The convector commonly used in heating is one form of conditioning equipment in the space. The heating medium can be water, steam or electricity. In the simplest of systems it will provide for winter heating only, with ventilation requirements fulfilled by infiltration through doors and windows. The temperature of water or steam supplied to convectors is often controlled so as to rise as outside temperature falls. The final room temperature control might then be by manual or thermostatic control of the water or steam flow, or by control of the convective air flow over the coil by dampers.

A fan can be added to the convector to provide forced circulation over the coil. If it is a water coil, it may be adapted to both heating and cooling. A three-speed fan is often used and room temperature can be manipulated by adjusting either the fan speed or the water flow through the coil, or both. A two-pipe water supply (i.e. supply and return) arrangement necessitates a seasonal changeover from hot to cold water and can only provide either heating or cooling, which is not always satisfactory. As has already been pointed out, there is no specific time when the heating season begins and the cooling season ends. To overcome this deficiency, a three-pipe (hot and cold water supply, common return) or a four-pipe arrangement (hot and cold water supply and separate return, either a single coil or separate coils for heating and cooling) is often used so that heating and cooling can be made available at all times. In some cases, a duct through an outside wall may be installed to provide ventilation.

Fan-coil-spray units and the necessary ductwork are often installed in the space to circulate space air and provide any one or all of the desired functions - heating, cooling, humidifying or dehumidifying. Ventilation air may also be taken from outside or supplied by a central system to the inlet side of the room conditioner.

Split Systems

This group includes systems where some conditioning equipment is in the space and some air is supplied from a central system. Room convectors for winter heating might supplement a central ventilation system. Convectors at exterior walls and under windows provide warm air at the exterior to counteract the cold air that would otherwise flow down the wall and across the floor. The warm air also increases window temperatures, thus decreasing the condensation potential and reducing the radiation loss from occupants. The ventilation air temperature must be controlled and could provide humidifying in winter and cooling and dehumidifying in summer.

Another split system uses an induction unit in the room. A relatively small quantity of high-pressure air from a central plant is discharged through nozzles to induce room air flow over a heat exchanger coil. Temperature control is achieved by either control of the water flow to the coil or a bypass damper to direct the air flow through or past the coil. In summer, induction air is usually dehumidified to handle the moisture load and the coil temperature is kept above the space dew-point temperature to avoid condensation on the coil and the problems associated with its drainage. In the fall, the system is changed over from cooling to heating operation and back again in the spring. At these times hot water and cool induction air or cold water and warm induction air may be supplied. The induction air permits the system to provide heating or cooling, as required, to cope with small fluctuations in load from heating to cooling and with non-uniformity in the loads in different spaces. A three-pipe or four-pipe water supply will more effectively deal with varying loads. In addition, induction air can be used to greater advantage for humidity control.

Conclusion

The design of a building and the selection and design of its air conditioning system must go hand in hand. It is always desirable to minimize heating and cooling loads and their variation. If this adds to the cost of the building, the added expense must be weighed against the saving in the air conditioning system. The selection of the air conditioning system and the zoning required can only be made after a careful study of the loads on all rooms and the deviations that will result if all the corrective actions necessary to cope with cycling loads are not provided. The extent to which outdoor air rather than refrigeration can be used for cooling also requires a study of the loads and corresponding outdoor conditions. The space in the building required for the air conditioning equipment, ductwork and piping should be considered in the selection.

The complexity of the system and its initial and operating cost are usually higher if unnecessarily rigid tolerances are specified. The selection and detailed design of an air conditioning system requires the services of an expert consultant working with the building designer through all phases of the design. Close cooperation between the two is necessary to achieve the desired degree of environmental control in the most acceptable and economical way.