Chapter 6

Single Zone Air Handlers and Unitary Equipment

Contents of Chapter 6

Instructions

Read the material in the chapter. Re-read the parts of the chapter emphasized in the summary.

Objectives of Chapter 6

After studying Chapter 6, you will be able to:

Identify the main components of a single zone air handler and describe their operation.
Describe the parameters that have to be known to choose an air-conditioning air-handling unit.
Describe how the vapor compression refrigeration cycle works.
Identify the significant issues in choosing a single-zone rooftop air-conditioning unit.
Understand the virtues of a split system.

6.1 Introduction

In the previous chapters we have discussed ventilation for maintaining indoor air quality, the thermal requirements for comfort, and reasons for zoning a building. In this chapter we are going to consider packaged single-zone air-conditioning equipment, examine issues of system choice, and provide a general description of system control issues. We will return to controls in more depth in Chapter 11.

The single-zone air-conditioning equipment we will be discussing is the piece of equipment that was introduced in Chapter 2, *Figure 2-12*. This unit is typically referred to as the **single zone air handler, or air-handling unit, often abbreviated to AHU**. In this chapter, we will refer to it as the **air handler** or the **unit**. The air handler draws in and mixes outside air with air that is being recirculated, or returned from the building, called **return air**. Once the outside air and the return air are mixed, the unit conditions the mixed air, blows the conditioned air into the space, and exhausts any excess air to outside, using the return-air fan.

Before getting into a discussion of the components of a single-zone package air-conditioning unit, we need some context as to where it fits into the whole building or site systems.

6.2 Examples of Buildings with Single-Zone Package Air-Conditioning Units

Figure 6-1 shows four identical single-story buildings, A, B, C, and D. Each has a single-zone package air-conditioning unit (marked "**AHU**") located on the roof.

Building A: This unit has only an electrical supply. This single electrical supply provides all the power for heating, cooling, humidifying, and for driving the fans.

Building B: This unit has the electrical supply for cooling, humidifying, and for driving the fans, while the gas line, shown as "gas supply," provides heating.

These first two arrangements are commonly available as factory engineered, off the shelf, rooftop packages. Among these packaged units, there is a great range in size, quality, and features. The most basic provide few, if any, options. They are relatively difficult to service and have a relatively short life. At the other end of the spectrum, there are large units with walk-in service access and numerous energy-conserving options. These are designed to last as long as any indoor equipment.

As well as the total pre-packaged units, there are units, typically in larger buildings or complexes of buildings, where the heating is provided from a central service. For example, a boiler room can produce hot water that is piped around the building or buildings to provide heat. Each air-handling unit that needs heating has hot water piped to it.

Building C: This unit has the electrical supply for cooling, humidifying, and for driving the fans. It also has supply and return hot-water pipes

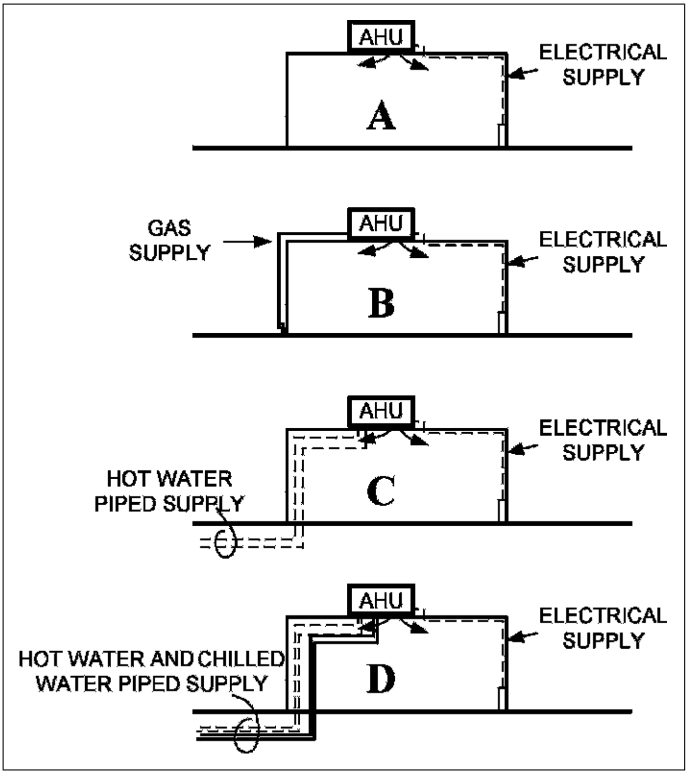

Figure 6-1 Single Zone Rooftop Air-Conditioning Unit, Energy Supplies

coming from a boiler room in another building. The unit contains a hot-water heating coil and control valve, which together take as much heat as needed from the hot water supply system.

Building D: In the same way, there may be a central chiller plant that produces cold water at 5.5 °C–9 °C, called **chilled water**. This chilled water is piped around the building, or buildings, to provide the air-handling units with cooling. Like the heating coil and control valve in Building C, there will be a cooling coil and control valve in each unit, to provide the cooling and dehumidification.

To recap, a packaged unit can require just an electrical source of power, or it may get heating in the form of a gas or hot water supply, and may get cooling from a source of chilled water. The basic operation of the unit stays the same; it is just the source of heating and cooling energy that may change.

6.3 Air-Handling Unit Components

You should recognize *Figure 6-2*, which was originally introduced in Chapter 2, *Figure 2-12*. It shows the basic air-handler unit with the economizer cycle. Some new details have been added in this diagram. In the following section, we will go through each of the components in the unit, we will discuss what

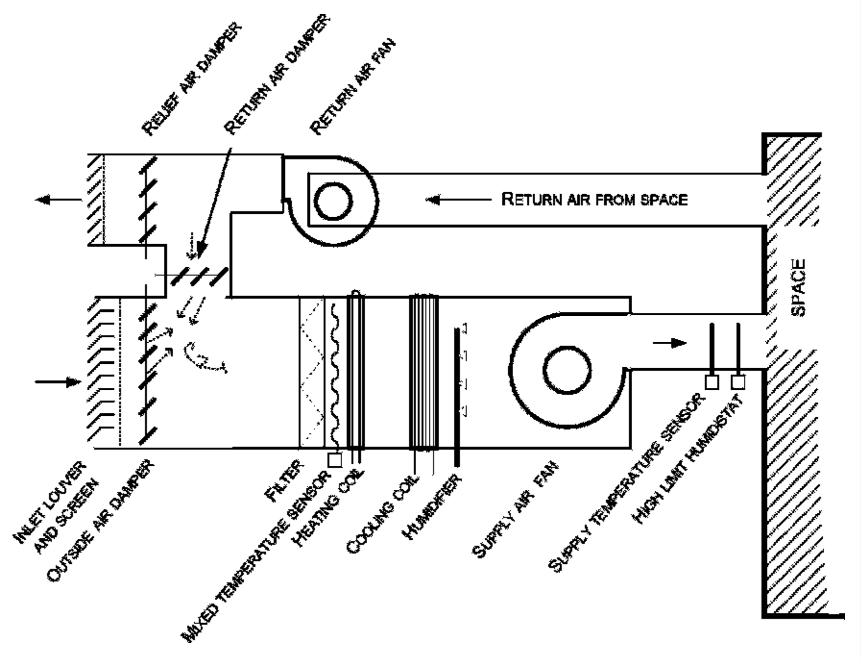

Figure 6-2 Air-Conditioning System: Single-Zone Air Handler

each component does, and, in general terms, how each component can be controlled. This unit is typically referred to as the **single-zone air handler**.

The overall functions of the air-handler are to draw in outside air and return air, mix them, condition the mixed air, blow the conditioned air into the space, and exhaust any excess air to outside.

Air inlet and mixing section

The inlet louver and screen restrict entry into the system. The inlet louver is designed to minimize the entry of rain and snow. A very simple design for the inlet louver is shown in the diagram. Maintaining slow air-speed through the louver avoids drawing rain into the system. More sophisticated, and more costly designs allow higher inlet-velocities without bringing in the rain. The screen is usually a robust galvanized-iron mesh, which restricts entry of animals, birds, insects, leaves, etc.

Once the outside air has been drawn in, it is mixed with return air. In *Figure 6-2*, a parallel blade damper

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is shown for both the outside air damper and the relief air damper.

These dampers direct the air streams toward each other, causing turbulence and mixing. Mixing the air streams is extremely important in very cold climates, since the outside air could freeze coils that contain water as the heating medium. A special mixing section is installed in some systems where there is very little space for the mixing to naturally occur.

It is also possible to install opposed blade dampers:

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These do a better job of accurately controlling the flow, but a somewhat poorer job of promoting mixing.

Some air will be exhausted directly to the outside from washrooms and other specific sources, like kitchens. The remainder will be drawn back through the return air duct by the return air fan and either used as return air, or exhausted to outside through the relief air damper. This exhausted air is called the **relief air**. The relief air plus the washroom exhaust and other specific exhaust air will approximately equal the outside air that is brought in. Thus, as the incoming outside air increases, so does the relief air. It is common, therefore, to link the outside-air damper, the return-air damper, and the relief-air dampers and use a single device, called an **actuator**, to move the dampers in unison. When the system is "off," the outside-air and relief-air dampers are fully closed, and the return-air damper is fully open. The system can be started and all the air will recirculate through the return damper. As the damper actuator drives the three dampers, the outside-air and relief-air dampers open in unison as the return-air damper closes.

Mixed Temperature Sensor

Generally, the control system needs to know the temperature of the mixed air for temperature control. A mixed-temperature sensor can be strung across the air stream to obtain an average temperature. If mixing is poor, then the average temperature will be incorrect. To maximize mixing before the temperature is measured, the mixed temperature sensor is usually installed downstream of the filter.

When the plant starts up, the return air flows through the return damper and over the mixed temperature sensor. Because there is no outside air in the flow, the mixed-air temperature is equal to the return-air temperature. The dampers open, and outside air is brought into the system, upstream of the mixed-air sensor. If the outside temperature is higher than the return temperature, as the proportion of outside air is increased, the mixed-air temperature will rise. Conversely, if it is cold outside, as the proportion of outside air is increased, the mixed-air temperature will drop. In this situation, it is common to set the control system to provide a mixed-air temperature somewhere between 13 and 16 °C. The control system can simply adjust the position of the dampers to maintain the set mixed temperature.

For example, consider a system with a required mixed temperature of 13 °C and return temperature of 23 °C. When the outside temperature is 13 °C, 100% outside air will provide the required 13 °C. When the outside air temperature is below 13 °C, the required mixed temperature of 13 °C can be achieved by mixing outside air and return air. As the outside temperature drops, the percentage required to maintain 13 °C will decrease. If the return temperature is 23 °C, at 3 °C there will be 50% outside air, and at −27 °C, 20% outside air.

If the building's ventilation requirements are for a minimum of 20% outside air, then any outside temperature below −27 °C will cause the mixed temperature to drop below 13 °C. In this situation, the mixed air will be cooler than 13 °C and will have to be heated to maintain 13 °C. The mixed-air temperature-sensor will register a temperature below 13 °C. The heating coil will then turn "on" to provide enough heat to raise the supply-air temperature (as measured by the supply-temperature sensor) to 13 °C.

Now let us consider what happens when the outside-air temperature rises above 13 °C. Up to 23 °C, the temperature of the outside air will be lower than the return air, so it would seem best to use 100% outside air until the outside temperature reaches 23 °C. In practice, this is not always true, because the moisture content of the outside air will influence the decision. In a very damp climate, the changeover will be set much lower than 23 °C, since the enthalpy of the moist, outside air will be much higher than the dryer return air, at 23 °C. Above the pre-determined changeover temperature, the dampers revert to the minimum ventilation rate, 20% outside air in this example.

The last few paragraphs have discussed how the system is controlled, called the control operation. These control operations can be summarized in the following point form, often called the **control logic**:

- When system off, the outside air and relief air dampers fully closed, return air dampers fully open.
- When system starts, if outside temperature above −7 °C, adjust dampers to provide x L/s of outside air.
- When system starts, if outside temperature below −7 °C, modulate dampers to maintain 15 °C mixed temperature with a minimum of x L/s of outside air.

The requirement for a minimum volume of outside air means that the controller must have a way of measuring the outside air volume. This can be achieved in a number of ways that are explained in the ASHRAE Course *Fundamentals of Air System Design*.[1]

The preceding text has talked about air volumes without getting into specific numbers. Note that the weight (mass if you leave earth) of outside air entering the building must equal the weight of air that leaves the building. The volume of air that is entering and leaving will usually be different, since the volume increases with increasing temperature. For example:

13.4 kg/s, 10000 L/s of outside air, at −10 °C, enters a building.

It is heated, and leaves the building as

13.4 kg/s, 11260 L/s at 23 °C (11% greater volume, same weight)

Filter

All packaged units include as least minimal filters. Often it is beneficial to specify better filters, as we discussed in Section 4.4.

Heating Coil

Some systems require very high proportions, or even 100% outside air. In most climates this will necessitate installing a heating coil to raise the mixed air temperature. The heat for the heating coil can be provided by electricity, gas, water, or steam.

The electric coil is the simplest choice, but the cost of electricity often makes it an uneconomic one.

A gas-fired heater often has the advantage of lower fuel cost, but control can be an issue. Inexpensive gas heaters are "on-off" or "high-low-off" rather than fully modulating. As a result, the output temperature has step changes. If the unit runs continuously with the heat turning on and off, then the supply temperature will go up and down with the heater cycle and occupants may experience a draft.

Hot water coils are the most controllable, but there is a possibility that they will freeze in cold weather. If below-freezing temperatures are common, then it is wise to take precautions against coil freezing. Many designers will, therefore, include a low-temperature alarm and arrange the controls to keep the coil warm or hot, when the unit is off during cold weather.

This is one of the times when the designer needs to take precautions against the consequences of the failure of a component. If, for example, the damper linkage fails, the unit may be "off," with the outside dampers partially open to the freezing weather. The consequence, a frozen coil, is serious since it will take time to get it repaired or replaced.

Cooling Coil

Cooling is usually achieved with a coil cooled by cold water, or a refrigerant. The cold water is normally between 5.5 °C and 9 °C. There are numerous refrigerants that can be used, and we will discus the refrigerant cycle and how it works in the next section. Whether using chilled water or a refrigerant, the coil will normally be cooler than the dew point of the air and thus condensation will occur on the coil. This condensation will run down the coil fins to drain away.

With refrigeration coils in packaged systems, there is limited choice in the dehumidification capacity of the coil.

Humidifier

A humidifier is a device for adding moisture to the air. The humidifier can either inject a water-spray or steam into the air.

The water-spray consists of very fine droplets, which evaporate into the air. The supply of water must be from a **potable** source, fit for human consumption. If impurities have not been removed by reverse osmosis or some other method, the solids will form a very fine dust as the water droplets evaporate. This dust may, or may not, be acceptable.

The alternative is to inject steam into the air stream. Again, the steam must be potable.

The humidifier will normally be controlled by a humidistat, which is mounted in the space or in the return airflow from the space. Excessive operation of the humidifier could cause condensation on the duct surface and result in water dripping out of the duct. To avoid this possibility, a high humidity sensor is often installed in the duct, just downstream from the unit. In addition, one might not want the humidifier to run when the cooling coil is in operation.

The unit control logic will then be:

- Humidifier off when unit off
- Humidifier off when cooling in operation

- Humidifier controlled by space humidistat when unit in operation
- Humidifier to shut down until manually reset if high limit humidity sensor operates

Fan

The fan provides the energy to drive the air through the system. There are two basic types of fan: the **centrifugal**, and the **axial**.

Within the **centrifugal fan**, air enters a cylindrical set of rotating blades and is centrifuged, thrust radially outwards, into a scroll casing. This fan is a very popular choice due to its ability to generate substantial pressure without excessive noise.

The other type of fan is the **axial fan**, where the air passes through a rotating set of blades, like an aircraft propeller, which pushes the air along. This is a simpler, straight-through design that works really well in situations that require high volumes at a low pressure-drop. When this type of fan is made for really low pressure-drops, wide pressed-sheet-metal blades are used and it is called a propeller fan.

Return fan

A return fan is usually included on larger systems, unless there is some other exhaust system to control building pressure. If there is no return fan, the building will have a pressure that is a bit above ambient (outside). In a hot, humid climate, this is beneficial since it minimizes the infiltration of outside air into the building, where it could cause condensation and mildew. In cold climates, the excess pressure above ambient can cause leakage of moist air into the wall, where it freezes and causes serious damage.

Having briefly reviewed the unit components, we are going to take time to consider the refrigeration cycle and its operation.

6.4 The Refrigeration Cycle

Heat naturally flows from warmer places to cooler places. Refrigeration equipment is used to transfer heat from a cooler place to a warmer place. In the domestic refrigerator, the refrigeration equipment absorbs heat from inside the refrigerator and discharges heat into the house. On a much larger scale, refrigeration machines are used to chill water that is then pumped around buildings to provide cooling in air-conditioning systems. The heat removed from the water is expelled into the atmosphere through a hot, air-cooled coil, or by evaporating water in a cooling tower.

The domestic refrigerator and most other refrigeration systems use the same basic process of vapor compression and expansion. An alternative process, absorption, is used but we are not covering it in this course. The vapor compression refrigeration system comprises four components: compressor, condenser, expansion valve, and evaporator. *Figure 6-3* shows the arrangement.

Compressor—compresses refrigerant vapor to a high pressure, making it hot in the process.

Condenser—air or water cooling reduces the temperature of the refrigerant sufficiently to cause it to condense into liquid refrigerant and give up its latent heat of evaporation. Latent heat of evaporation is the heat

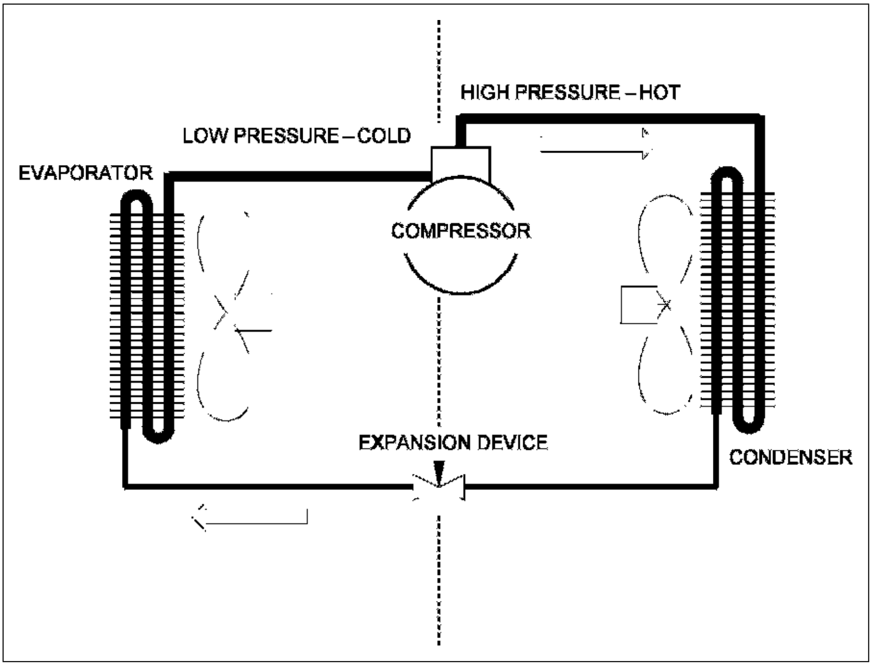

Figure 6-3 Basic Vapor Compression Refrigeration Cycle

required to convert a liquid to a vapor at a particular temperature and pressure and is the heat released when a vapor condenses at a particular temperature and pressure.

Expansion valve—allows a controlled amount of the liquid refrigerant to flow through into the low-pressure section of the circuit.

Evaporator—air or water heats the liquid refrigerant so that it evaporates (boils) back into a vapor as it absorbs its latent heat of evaporation.

As the refrigerant flows round and round the circuit, it picks up enthalpy, heat, at the evaporator and more heat as it is compressed in the compressor. The sum of the evaporator and compressor enthalpy is rejected from the condenser. The system effectiveness is higher, the greater the ratio of evaporator enthalpy to compressor enthalpy. One wants the most heat transferred for the least compressor work. The enthalpy flow into and out of the refrigerant is shown in *Figure 6-4*.

In a very small, simple system, such as the domestic refrigerator, the expansion device is a length of very small-bore tube that restricts the refrigerant liquid flow from the high-pressure side to the low-pressure side. A thermostat in the refrigerator turns the compressor "on" when cooling is required, and "off" again when the inside of the refrigerator is cool enough.

Moving up in size from the domestic refrigerator to the window air conditioner, *Figure 6-5* shows the refrigeration circuit with a box around it. The evaporator fan draws room air over the evaporator coil to cool it. The condenser is outside and the condenser fan draws outside air over the condenser coil to reject heat into the outside air.

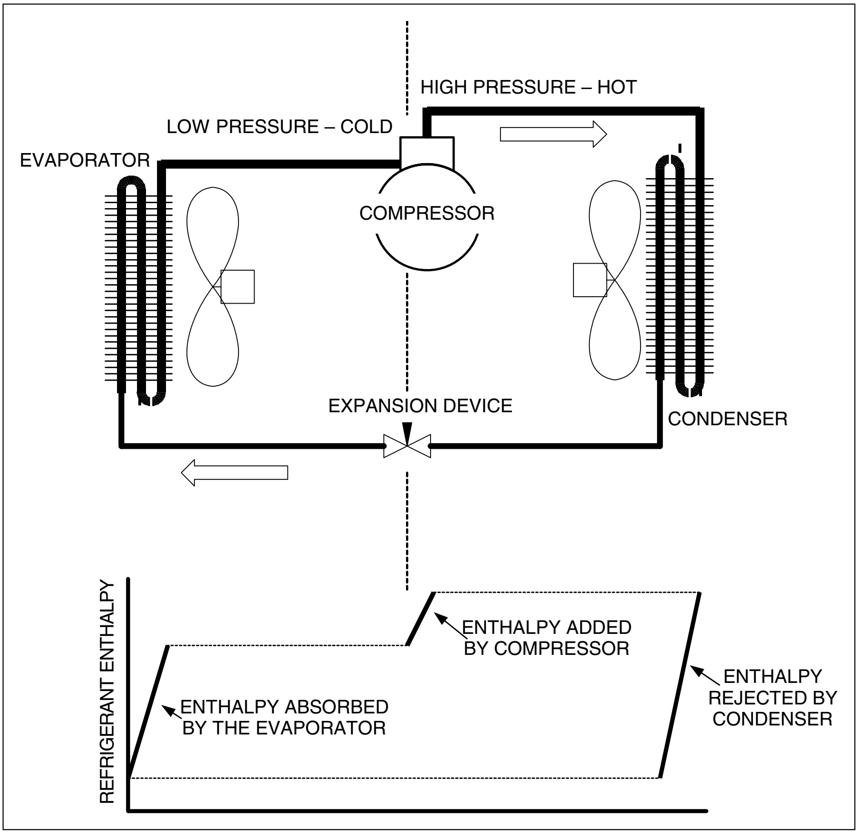

Figure 6-4 Enthalpy Flow in Vapor Compression Refrigeration Cycle

The evaporator coil is designed to operate cool enough to produce some condensation on the coil. This condensate water is piped through to the outside and may just drip out of the unit or be evaporated in the condenser airflow.

The capacity of the unit is highest when the inside and outside temperatures are close to each other. As the outside temperature rises, so the capacity of the unit falls. It is therefore very important to know the anticipated maximum temperature at which the unit is to perform.

The refrigerator and the window air conditioner have air flowing across both the evaporator and condenser to achieve heat transfer. Many systems use water as an intermediate heat-transfer medium. The evaporator coil can be in a water-filled shell to produce chilled water. This chilled water can then be piped around the building, or even from building to building, to provide cooling as and where it is needed.

This central water-chilling plant can consist of one or more chillers that are sequenced to match their capacity with the load. In this way the noisy refrigeration equipment can be separated from occupied areas, and maintenance does not take place in occupied areas.

Water can also be used on the condenser side of the refrigeration system. Here the condenser heats the water, which is generally then pumped to one or

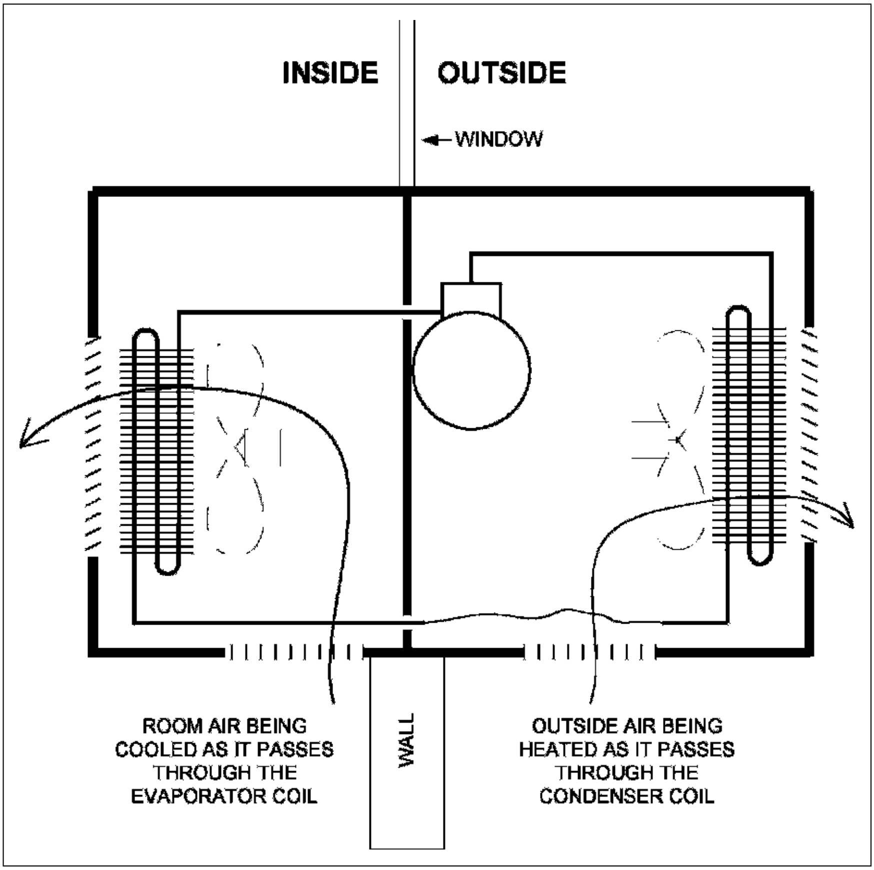

Figure 6-5 Window Air Conditioner

more cooling towers. A **cooling tower** is a piece of equipment for cooling water by evaporation. The warmed condenser water enters at the top through a series of nozzles, which spread the water over an array of wooden or plastic surfaces. Most cooling towers also have a fan to force air through the surfaces, causing some of the water to evaporate and cool the remaining water. The cooled water flows down into a sump, to be pumped back through the condenser.

Heat Pump

The previous discussion is focused on pumping heat from a cooled space and rejecting heat to outside. There are times when the reverse process is valuable. If the outside temperature is not too cold, one could install a window air conditioner back-to-front. Then, it would cool outside and warm inside. The total heat rejected to the inside would be the sum of the electrical energy put into the compressor, plus heat absorbed from the outside air. It would be pumping the heat into the space – hence we call it a **heat pump**. In milder climates, a heat pump can obtain useful heat from the ambient air.

In practice, one does not take out the window air conditioner and install it the other-way-round for heating, since the reversal can be achieved with a special valve in the refrigeration circuit. *Figure 6-6* shows the heat pump circuit.

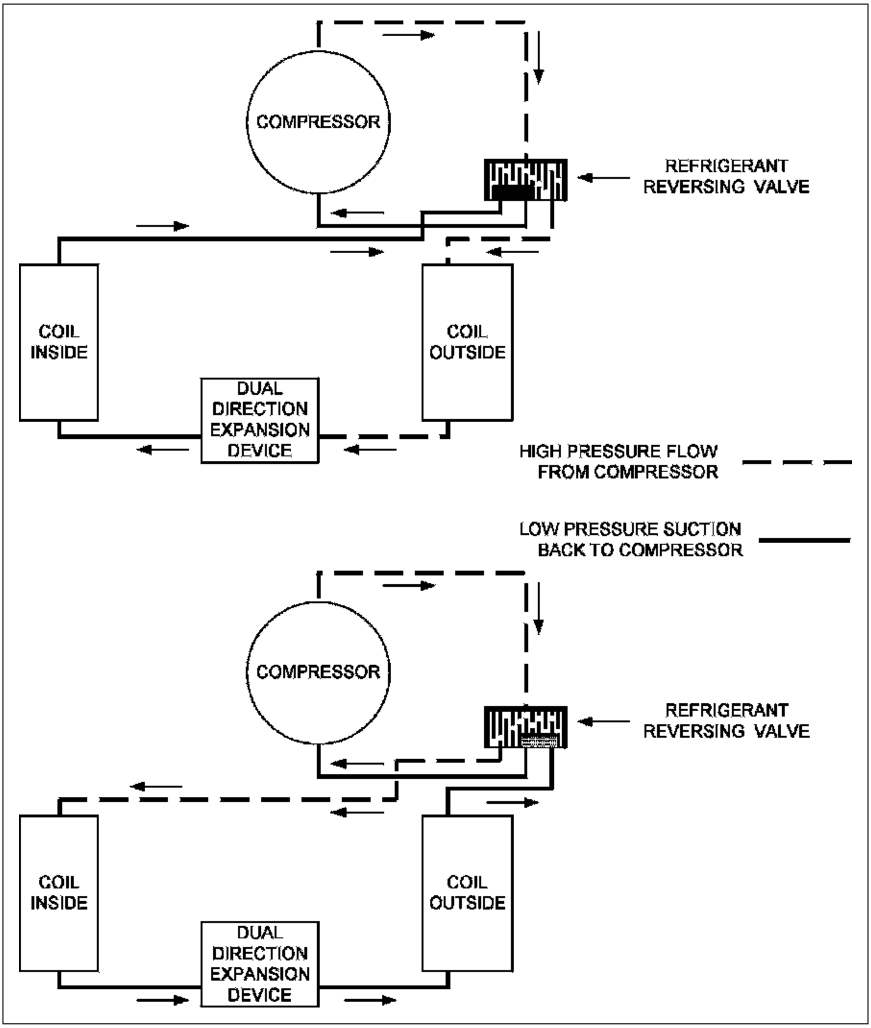

Figure 6-6 Heat Pump with Reversing Value

It has been drawn slightly differently from the previous two figures, but the circuit is the same, evaporator, compressor, condenser, and expansion device. In the upper diagram the refrigerant is flowing, as in previous diagrams, and heat is being "pumped" from the inside coil to be rejected by the outside coil. In the lower diagram the reversing valve has been switched to reverse the flow of refrigerant in the inside and outside coils. Heat is now absorbed from outside and rejected by the inside coil, heating the inside.

The performance of the air-to-air heat pump drops as the temperature difference increases, so they are not very effective with an outside air temperature below freezing.

Another source of heat, or sink for waste heat, is the ground. In many places, one can lay coils of pipe in the ground, in trenches or in vertical boreholes, and circulate water. The water will be heated by the surrounding soil, if it is cold, and cooled by the surrounding soil if it is hot. In the example, shown in *Figure 6-6*, the heat pump has a ground water heated/cooled coil and a cooled/heated air coil for the building. *Figure 6-6* shows the circuit, including the reversing valve operation.

Refrigeration is a very important part of the air-conditioning industry. The ASHRAE Course, *Fundamentals of Refrigeration*,[2] will teach you about the systems, components, system control, and cooling loads.

6.5 System Performance Requirements

Before choosing a system, you need an understanding of the types of loads you want the system to manage. Typically, the summer cooling loads will be the main determinant of the choice of unit. The heating loads are usually dealt with easily by choosing a suitable heater to go with the chosen unit. The summer loads, though, will be dependent on several, somewhat interrelated factors:

Outside summer design temperature. This affects the cooling load in three ways:

Interior load—The interior load is calculated using the outside temperature plus solar heat gain acquired due to heat transfer through the fabric of the building.

Outside air temperature—The load from the outside air temperature will also partly determine the cooling load of the outside air that is being brought into the building for ventilation.

Effectiveness of the refrigeration system—If the refrigeration system is air-cooled, the outside temperature will influence the effectiveness of the refrigeration system.

Outside summer design humidity. The outside design humidity will be a factor in the ventilation air load and the removal of moisture from any air that leaks into the building. Cooling tower performance is also directly affected by the humidity; performance falls as humidity rises.

Inside summer design temperature and humidity. The warmer and damper the inside is allowed to be, the smaller the difference between inside and outside, hence the lower the load on the system. This is particularly important when you are making system choices.

Slight under-sizing, which is cheaper to buy, means that occasionally the design temperatures will be exceeded. However, when the unit is slightly under-sized, it will be running nearer full load for more of the time. Depending on the situation, this may be the most economical choice.

Inside summer generation of heat and moisture. These will be added to the building loads to establish the total loads on the system.

Summer ventilation requirements. This is the ventilation for people, typically based on *ASHRAE Standard 62.1-2004*, plus any additional ventilation for specific equipment. The higher the ventilation requirements, the greater the load due to cooling and dehumidifying the outside air that is brought in.

Once these basic criteria are established, load calculation can be done. Depending on the situation, summer cooling and winter heating loads may be estimated with fairly simple hand calculation methods for the peak-load summer cooling and for the peak-load winter heating. In other cases, an hour-by-hour computer simulation of the building may be done, in order to assess peak-load and intermediate-load performance.

The following example illustrates some of the issues for system performance.

EXAMPLE: A building has the following conditions:

The design room condition is 24 °C and 50% relative humidity.
The outside design condition is 35 °C and 40% relative humidity.
The sensible heat load is 60,000 watts. **Sensible heat** is heat that causes change in temperature.
The moisture heat load, or "Latent heat" is 6,000 watts. **Latent heat** is the energy that is absorbed by water which causes the water to evaporate.

To calculate the loads, first divide the latent load by the sensible load. This provides us with the percentage of sensible heat that must be removed from the system.

For example, if the latent load is 6,000 watts per hour and the sensible load is 60,000 watts, the ratio would be 1/10. With an all-air system, the air supply must be at a temperature and moisture content that requires 10 times as much sensible heat as latent heat to reach room temperature. We can plot a line on which the air supply must be to meet the design room condition.

You can easily plot this on the psychrometric chart as is shown in *Figure 6-7*.

First, note the enthalpy of the air at the desired room condition.
Draw a vertical line downward from the room condition.
Mark on the line where the enthalpy line is 1 kJ/kg less than room conditions.
From this point, draw a horizontal line to the left. Mark off where the enthalpy is 10 kJ/kg less. Depending on the specific chart range it may be easier to use larger numbers, say 5 kJ/kg and 50 kJ/kg.
Draw a line from here to the room condition.

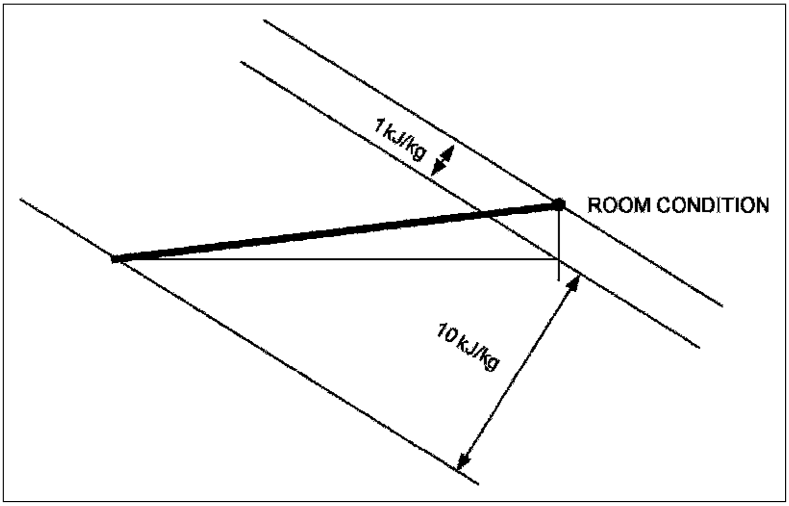

Figure 6-7 Space, Outside, and Mixed Conditions

This illustrates that, for the supply air to meet the designed room condition, it must be supplied at some point on this line. If it is supplied close to the designed room-condition the volume will have to be large.

The calculation of heating loads is relatively straightforward, but cooling-load calculation is more challenging, due to the movement of the sun and changing loads throughout the day. Calculating heating and cooling loads is the subject of the ASHRAE Course *Fundamentals of Heating and Cooling Loads*.[3]

Decision factors for choosing units

When choosing equipment, several factors must be balanced.

The initial cost to purchase and install versus the ongoing cost of operation and maintenance. Most heating and cooling systems reach peak load very occasionally and then only for a short period of time. Most of the time, the equipment is operating at loads much below peak. Equipment either improves in efficiency at lower load—a characteristic of many boilers—or it falls—a characteristic of many refrigeration units. When choosing refrigeration equipment, it can be very worthwhile to consider the part-load performance. It is in the part-load performance evaluation that hour-by-hour computer simulations become a really necessary tool.

Load versus capacity. Note that we have been talking about "loads," but when you look in manufacturers' data sheets, they talk about "plant capacity." "Loads" and "capacity" are the same issue, but **loads** are the calculated building requirements, while **capacity** is the plant equipment's ability to handle the load. When purchasing packaged plant equipment, the plant capacity often does not exactly match the calculated building loads. One of the challenges for the designer is choosing the most suitable package, even though it does not exactly match the calculated building loads. This issue is illustrated in the following section on rooftop units.

6.6 Rooftop Units

A typical rooftop system is diagrammed in *Figure 6-8*. The return air is drawn up into the base of the unit and the supply air is blown vertically down from the bottom of the unit into the space below. As an alternative, the ducts can project from the end of the unit to run across the roof before entering the building.

The major advantages of these units are

No working parts in the occupied space—so maintenance can be carried out without disrupting activities within the building and maintenance can be carried out without access to the building when the building is closed.

No space is built for the unit—which saves construction costs.

No delay for detailed manufacturer design work—because the unit is predesigned.

No wide access during construction—because the unit is outside the building envelope, the contractor does not have to keep an access available for the unit to be moved in during construction.

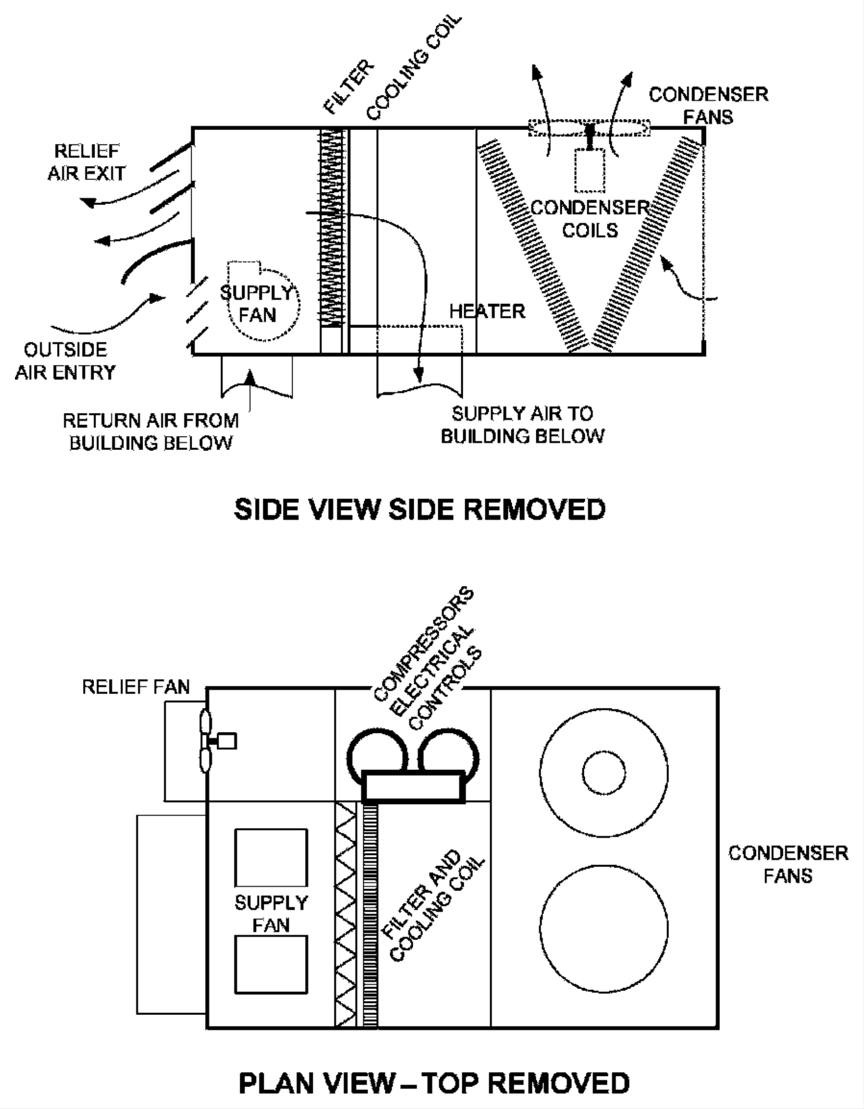

Figure 6-8 Rooftop Unit

There are, of course, disadvantages.

Critical units must be maintained regardless of the weather conditions—That means that maintenance could be required in heavy rain, snow, or high winds. This potential problem can be managed by having a maintenance access space located along one side of the unit.

Choice of performance is limited to the available set of components—This is often not enough of a problem to make the unit unacceptable, and can frequently be overcome by using a split unit, which we will be discussing in the next section.

Choosing a rooftop unit is fairly straightforward. One needs to know both inside and outside design-temperatures, required airflow, in L/s, mixed-air temperature, and the required sensible and latent cooling-loads.

The mixed-air temperature can be calculated based on the return-air temperature, the outside air temperature and the required proportion of outside air. Referring back to the example, shown in *Figure 6-7*, the room temperature, which we will consider to be return temperature, was 23 °C, and the outside ambient temperature was 35 °C. If 20% outside air is required, then the mixed temperature can be estimated by proportion

$$35\,°\mathrm{C}\cdot 0.2 + 23\,°\mathrm{C}\cdot 0.8 = 25.4\,°\mathrm{C}$$

The calculation of airflow is covered in detail in the ASHRAE Course *Fundamentals of Air System Design*.[1]

It is important for the airflow to be correctly calculated and for the unit to be set up and balanced to provide the correct airflow. With direct expansion refrigeration circuits, too little airflow over the evaporator can cause problems:

Imagine that the airflow is much slower than design. The slow speed past the coil will allow the air to cool further, and—if the coil is below freezing—for ice to start forming. The slow flow will also reduce the heat being absorbed into the evaporator, so the compressor's suction will be drawing with little refrigerant vapor coming in. As a result, the pressure in the evaporator will fall, causing the evaporator temperature to fall, which will also tend to cause freezing. Once ice formation starts, the ice starts to block the flow, causing even slower airflow until the coil is encased in ice. Ice formation on the evaporator can also be caused by too little refrigerant in the system – a common result of a slow refrigerant leak.

As noted in the previous discussion of loads versus capacity, air-handling units come in discrete sizes, so a perfect match of unit and calculated loads does not happen. From the example in *Figure 6-7*, for our loads of 60,000 watts sensible load and 6,000 watts latent load, let us assume the closest unit has a performance of 75,000 watts sensible and 11,000 watts latent capacity.

This looks excessively oversized, but the unit's sensible capacity does not take into account the heat from the supply fans in the unit. Suppose the fan load was 5 kW (5,000 watts), then the fan heat added to the cool air would be 5,000 watts if the fan and motor are in the air stream.

The effective sensible heat capacity of the unit is thus:

$$70{,}000 \text{ watts} - 5{,}000 \text{ watts} = 65{,}000 \text{ watts}$$

This is a very close match to the required capacity.

The 11,000 watts moisture removal, when compared to the required 6,000 watts, is a common issue in dry climates. The coil removes more moisture than required. There are two results. First, more energy is used than required to maintain the design conditions. Second, the real conditions will be drier than the design condition.

The converse problem, of too little moisture removal, occurs in hot moist climates, particularly where higher proportions of outside air are required. In this case, and others, it may not be possible to find a package rooftop-unit for the duty and it may be advantageous, or necessary, to take special measures to remove moisture. Some of these are discussed in Chapter 13.

Heating choices are generally less of an issue, but the designer still has to be aware of potential problems. As noted earlier, electrical heaters are normally available with stepped capacity, but gas heaters are often on-off or high-low-off. If the unit runs continuously at the gas-heater cycle, the air supply will fluctuate in temperature and sometimes blow warm, and sometimes blow cold. Take care to ensure that the occupants do not have an intermittent cold draft blowing on them.

Having considered the single-zone air handler, with particular emphasis on the rooftop unit, let us now consider another popular single-zone system, the split system.

6.7 Split Systems

In the rooftop unit, all the plant was in a single housing and was purchased as a manufacturer's pre-design. In general, the package rooftop-units are designed for popular duties, and to be as light and compact as possible, since they have to be lifted onto the roof. In the split system, the compressor/condenser part of the refrigeration system is chosen separately from the rest of the system and connected by the refrigerant lines to the air system, which includes the evaporator. The pipes, even with their insulation, are only millimeters in diameter, compared to ducts that are, typically, hundreds of millimeters in diameter. The separation of the two parts of the refrigeration system to produce the split system is diagrammed in *Figure 6-9*. The system can range in size from the small residential systems where the inside coil is mounted on the furnace air outlet to substantial commercial units serving a building.

The split system allows the designer a much greater choice of performance. For example, designing a unit for operation in an ice rink requires a low space temperature, hence a non-package situation. This requirement is well suited to the flexibility of the split system.

The other main advantage of the split system is that it allows the air handling part of the unit to be indoors, where it is easier to maintain and does not need to be weatherproofed. The noise of the compressor is outside and can be located at some distance from the air-handling unit. For example, in a three-story building, all the condensers can be mounted on the roof, while the air handlers are on the floor they serve. This allows the ducting to be run horizontally on each floor and only requires a small vertical duct for the refrigerant lines from the three units to the roof.

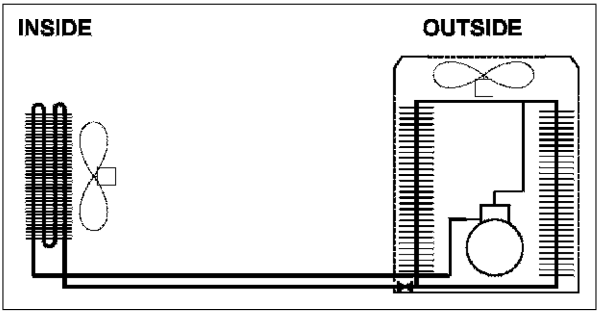

Figure 6-9 Split System

The Next Step

We have considered single zone air-conditioning systems in this chapter. We focused on rooftop and split systems. We considered the components they contain, how the components operate and some of the limitations of off-the-shelf equipment. Finally we looked at a simple choice of rooftop and spilt system and the resulting space conditions.

In the next chapter we will look at how these single zone systems can be modified to produce multi-zone systems.

Summary

In this chapter, we discussed issues of system choice and provided a general description of system control issues. We will return to controls in more depth in Chapter 11.

6.2 Examples of Buildings with Single Zone Package Air-Conditioning Units

For heating and cooling, a packaged unit may require only an electrical source of power, or a gas or hot water supply, and/or a source of chilled water. The basic operation of the unit stays the same; it is just the source of heating and cooling energy that may change.

6.3 Air-Handling Unit Components

The overall functions of the air handler are to draw in outside air and return air, mix them, condition the mixed air, blow the conditioned air into the space, and exhaust any excess air to outside. Components of the unit can include: inlet louver screen, the parallel blade damper, opposed blade damper, the relief air damper, actuator, the mixed temperature sensor, filter heating coil, cooling coil, humidifier, fan, return fan. The concept of control logic was introduced as a method to summarize the operation of the components of the system.

6.4 The Refrigeration Cycle

The vapor compression refrigeration cycle is generally the basis of mechanical refrigeration. The vapor compression refrigeration system comprises four components: compressor, condenser, expansion valve, and evaporator. This system can be used directly, to provide cooling to, typically, a local coil. To provide cooling for several coils at greater distances, refrigeration machines are used to chill water that is then pumped around buildings to provide cooling in air-conditioning systems. The heat removed from the water is expelled into the atmosphere through a hot, air-cooled coil, or by evaporating water in a cooling tower.

The components are matched to work together with a specific charge of refrigerant. If you operate the system with too little refrigerant or too little air or water flow over the evaporator or condenser, problems can arise.

While cooling is achieved by pumping heat from a cooled space and rejecting heat to outside, you can reverse the process, in a mild climate, with a heat pump, to obtain heat from ambient air. Similarly, the ground can be used as a source of heat or a sink for waste heat, by using a ground source heat pump.

6.5 System Performance Requirements

Before choosing a system, you need an understanding of the types of loads you want the system to manage. Summer cooling loads will be the main determinant of the choice of unit. These summer factors are used to determine the summer load: outside design temperature; outside design humidity; inside design temperature and humidity; inside generation of heat and moisture; ventilation requirements. Once you have determined summer loads, additional decision factors for unit choice are the initial cost to purchase and install, versus the ongoing cost of operation and maintenance; and load versus capacity.

6.6 Rooftop Units

In a typical rooftop unit, the return air is drawn up into the base of the unit and the supply air is blown vertically down from the bottom of the unit into the space below. As an alternative, the ducts can come out of the end of the unit to run across the roof before entering the building. Advantages and disadvantages of rooftop units were discussed.

Factors to choose a rooftop unit: inside and outside design temperatures, required airflow in L/s, mixed air temperature, and the required sensible and latent cooling loads.

It is important for the airflow to be correctly calculated and for the unit to be set up and balanced to provide the correct airflow. With direct expansion refrigeration circuits, too little airflow over the evaporator can cause icing problems.

Units come in discrete sizes, so a perfect match of unit and calculated loads does not happen. As a result, the design conditions may be jeopardized, and/or extra energy costs may arise.

6.7 Split Systems

In the split system, the compressor/condenser part of the refrigeration system is separate from the evaporator coil and connected by the refrigerant lines to the air system, which includes the evaporator.

Advantages of the split system: It allows the designer a much greater choice of performance; it allows the air handling part of the unit to be indoors, where it is easier to maintain and does not need to be weatherproofed. The noise of the compressor is outside and can be located at some distance from the air-handling unit.

Bibliography

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