Chapter 13

Special Applications

Contents of Chapter 13

Instructions

Read the material of Chapter 13. Re-read the parts of the chapter that are emphasized in the summary and memorize important definitions.

Objectives of Chapter 13

Chapter 13 introduces a diverse group of subjects dealing with HVAC. When you have completed the chapter you should be able to:

State two reasons for using thermal storage.
Identify two good features of radiant heating and name three examples of where it can be an excellent system choice.
Describe at least three room air-distribution systems.
Explain why it can be advantageous to have a separate outside air unit as well as the main air-handler.
Explain the challenges of having **operable windows**, windows that people can open and close, with an HVAC system.

13.1 Introduction

This final chapter covers some special heating, cooling, and ventilation applications. We start with radiant heating and cooling, an idea that was partially introduced when we discussed radiant floors in Chapter 8.

From radiant heating and cooling we move on to **thermal storage**. Thermal storage is a method of reducing the need for large equipment and reducing energy expenses. Thermal storage is achieved by having the heating or cooling equipment operate during low load periods, to charge a thermal storage system for later peak-load use. Under certain circumstances, storage of heating or cooling capacity can reduce both installation costs and operating expenses.

From thermal storage systems, we move on to consider the ground as a vast heat source or sink. Following these three sections, we continue with sections dealing with ventilation. The first ventilation topic is a detailed discussion of the issues dealing with operable, "occupant controlled," windows and the HVAC systems serving these spaces. When occupants are in control of opening and closing windows, there is a largely uncontrolled movement of air in a space. Following this discussion, we examine the issues of air distribution in rooms that don't have operable windows.

We will discuss various standard ways of delivering air to rooms and their relative merits and popularity. Then, we will take a brief look at separate dedicated outside air units that are particularly valuable in dealing with locations where there is high humidity and substantial outdoor air requirements.

Then it is time to conclude, with some suggestions for your future.

13.2 Radiant Heating and Cooling Systems

As you recall from Chapter 3, radiant heat passes in straight lines from a hotter to a cooler body with no effect on the intervening air.

Radiant heaters and coolers are defined as units that achieve more than 50% of their cooling or heating output through radiation (as compared to convection and conduction). We have already discussed radiant floors and ceilings under the heading "**Panel Heating and Cooling**" in Chapter 8. These panel units operate well below 150 °C, and are classified as "low temperature." Radiant floors operate at a relatively low temperature, with a maximum surface temperature, for comfort conditioning, of 29 °C.

In this section, we will consider high temperature units that operate at over 150 °C, revisit radiant floors and briefly consider radiant ceiling panels.

High Temperature Radiant Units

High temperature, or infrared, units operate at over 150 °C. Examples range from units with a hot pipe, to ceramic grids heated to red/white heat by a gas flame, up to electric lamps. These are heaters that are far too hot to get really close to or to touch. There are three main types of high temperature units: high, medium, and low intensity.

- High intensity units are electric lamps operating from 1000–2750 °C.
- Medium intensity units operate in the 650–1000 °C range and are either metal-sheathed electric units or a ceramic matrix heated by a gas burner.

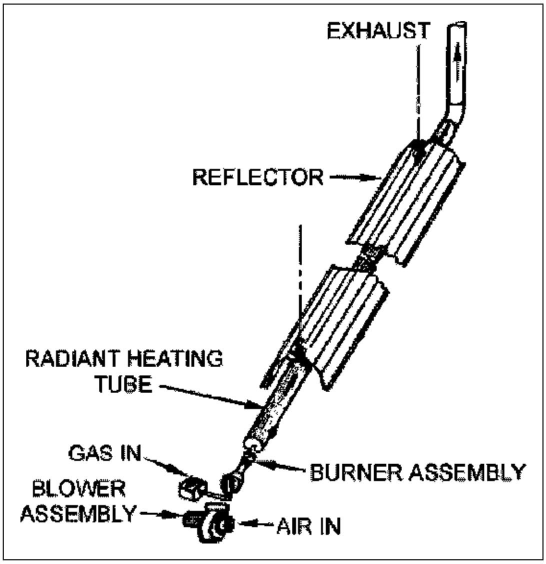

Figure 13-1 Tube Type Radiant Heater

- Low intensity units are gas-fired, using the flue as the radiating element—basically a gas burner with a flue pipe (chimney) typically 6–10 meters long, with a 100 mm diameter, as shown in *Figure 13-1.* A low-intensity unit operates as a flue that runs horizontally through the space. It will usually, but not always, vent outside and have a reflector over the flue to reflect the radiant heat downward.

  These low intensity units can run up to 650 °C, have a dull red glow, and take only three or four minutes to reach operating temperature. Since they are gas-fired, adequate combustion air must be provided, as required by local codes.

A single-burner, low-intensity unit is shown in *Figure 13-1.* The blower assembly provides the required forced draft through the burner and long flue. The flue gas temperature drops as it gives up heat along the tube. As a result, the output drops along the length of the unit. Manufacturers can use different strategies to offset this drop in output—either tube materials with a lower radiant output in the early sections, or larger tubes in the latter sections.

These strategies are not enough in larger installations, and so units with multiple burners are used. However, multiple-burner units introduce additional complexity into the system. For example, the same forced-draft method cannot be used, since, if one of the blowers failed, the others would blow fumes into the building through the inoperative blower. To avoid this possibility, multi-burner units have an exhaust fan, called a vacuum pump, to draw all the products of combustion from the flue. This is done to ensure that all flue gases are exhausted. This type of arrangement is shown in *Figure 13-2.* For further control of output, high-low, or modulating, burners can be used.

The burner controls are in the self-contained blower-burner assembly, with the whole unit controlled by a long-cycle (slow to respond) thermostat or a proprietary temperature control system. The location of this control is significant.

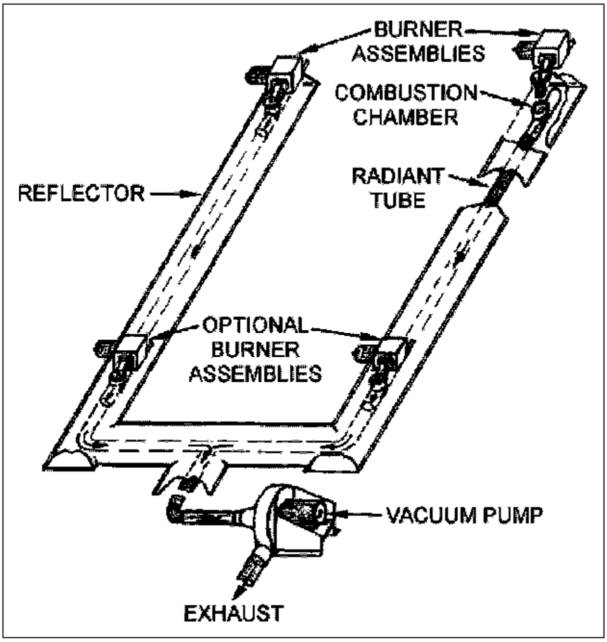

Figure 13-2 Multi-Burner Radiant Heater (Part of Figure 1, Page 15.2, from *2004 ASHRAE Handbook—HVAC Systems and Equipment*)

It is important to remember, from Chapter 3, that both ambient air temperature and the radiant effect of the heater(s) will affect the thermostat. Let us go back to the radiant floor for a simple example. If the thermostat is located on an inner wall (far away from the window), the floor and adjacent warm walls will predominantly influence it. As a result the room tends to be cool for occupants in cold weather, since the cool external wall and windows do not adequately influence the thermostat. This effect is significantly reduced if the thermostat is placed on a side wall (nearer the window), well away from the inner wall so that the cool outside wall and window will have a more significant effect on the thermostat. This alternative could result in the room becoming uncomfortably warm.

The effect of location is even more pronounced with radiant heaters. As a result, it takes skill and experience to make an effective choice of thermostat location. This is one of those occasions when asking, and taking, the advice of an experienced manufacturer can be really worthwhile.

Since the multi-burner radiant-heater units run very hot, they must be out of the reach of occupants. They must also be mounted so that they cannot overheat objects immediately beneath them.

For instance, suppose a machine shop was fitted with radiant heaters that were mounted 4.5 meters above the floor. This would provide a comfortable work environment for the staff. However, consider what would happen if the heaters were mounted directly above a floor space that was also used by delivery vehicles that drive into the shop to be loaded or unloaded. In that case, the top of the vehicles would be dangerously close to the heater and could end up with a burned roof. This problem can often be avoided by designing the heater layout so the heaters are above the work areas only, at a safe distance from vehicle access routes.

Radiant heaters are particularly suitable where high spaces must be heated without obstructing the space, as in aircraft hangers, factories, warehouses, and gymnasiums. They are also valuable where the staff and floor is to be kept warm, but not the space, such as in loading docks, outdoor entrances, and swimming pools.

Radiant heaters are also suitable for racetrack stands and spectator seating around ice rinks. In the ice rink they have the ability to be directed at the seating with a fairly sharp cutoff to prevent heating the ice surface, and they do little to raise the air temperature that would also affect the ice.

Radiant Cooling

Radiant cooling was introduced in Section 3 of Chapter 8. Radiant cooling is always achieved by using a "large area" panel system, since the transfer per square meter is quite limited. This is largely because the chilled-water temperature must be kept warm enough to avoid any condensation. The ceiling may be either a plastered ceiling with embedded pipes or a metal pan ceiling with the pipes attached to the panels.

Just like the radiant floor, the radiant cooling ceiling requires no equipment or floor space within the occupied area. With the plaster ceiling there is nothing in the room. This makes it an attractive choice in some hospital situations where cleaning needs to be minimized. Only ventilation air has to be moved around the building and supplied to each room. However, it is critical that the moisture level in the building be kept low enough to prevent problems that may occur due to condensation on any part of the ceiling panels.

The performance of radiant ceilings is well understood by manufacturers, and they and the architect should be involved early in the design stages. If a metal panel system is chosen, it must fit in with the dimensional requirements of the ceiling. Panels radiate upwards as well as downwards. An uninsulated panel will cool the space below as well as the floor or roof above it. If cooling is not desirable above the panel, the panel can have insulation placed on the top of it. Conversely, if the cooling *is* designed to radiate upwards, be sure that an acoustic pad is *not* specified above a panel, since the acoustic pad will also provide thermal insulation.

One negative of this system is the extended length of time it takes to return the space to comfort levels after the temperature has drifted up. Operators of radiant cooling panel systems need to be aware of the relatively slow response of these systems—even those with light metal panels. As a result, it is not a good idea to allow the temperature to drift up when the space is unoccupied, even though this strategy may *appear* to result in energy savings.

13.3 Thermal Storage Systems

Thermal storage systems normally involve the generation of cooling or heating, or both, at off hours while storing this energy for use at a later time, generally to be discharged during peak energy use periods such that overall energy costs are reduced. These systems can be "**active**" or "**passive**."

Passive Thermal Storage

"**Passive Thermal Storage**" refers to using some part of the building mass, or contents, to store heating or to store cooling capacity. The very simplest form of passive storage is the choice to construct a building using heavy construction; block walls, block partitions, concrete floors, and concrete roof decks.

During the cooling season, the mass of the building walls and roof can be cooled at night by the air conditioning system, and when favorable, by the cool night air. When the night air is sufficiently cool, then ventilating the building, by either opening the windows or running the ventilation system, can cool the structure. Then, during the day, the sun has to heat the mass of the structure before the inside temperature rises. In addition, the walls and roof have considerable stored heat when the sun goes down and the warm surfaces of roof and wall re-emit a proportion of heat back to the outside.

The interior mass acts as a thermal flywheel, absorbing heat through the day and re-emitting heat through the evening and night. The result is a lower peak cooling load, hence smaller refrigeration equipment is required. In addition, there is a lower total cooling load, due to the heat stored in the day and re-emitted outside during the night.

Passive water heating is also very popular in warmer climates. A black plastic water-storage tank on the roof will absorb heat through the day, warming the water. If this solar-warmed water is used for the domestic hot-water supply, to wash basins, and for the cold-water supply, to the showers, then hot water is not needed for hand-washing or cool showers. For a hot shower, the already warmed water must be additionally heated by a conventional water heater. This system has the further advantage of operating at low pressure. The system is very energy-efficient but there is the potential hazard of breeding legionella (see Chapter 4) in the solar-warmed storage tank.

There are many excellent books detailing the variations on solar-heated water storage and using the building to store, or reject, solar heat. One word of caution: the local climate makes a huge difference to the overall effectiveness of a solar heating project. For instance, in a climate where the temperature never drops to freezing, water systems need no protection against freezing. In climates where the temperature does drop to freezing, there are two issues to face: first is the shorter proportion of the year when the system can be used, and second, freeze protection is always more challenging than you would expect, so consult with an expert.

Active Thermal Storage

Active thermal storage takes place when a material is specifically cooled or heated, with the object of using the cooling or heating effect at a later time.

Perhaps the simplest example is the electric thermal storage (ETS) heater, called a "brick" or "block storage" heater in certain parts of the world. These units are commonly used in residences to provide off-peak electric power for heating. The ETS consists of an insulated metal casing filled with high-density magnetite or magnesite blocks. A central electric heater heats the blocks to a temperature as high as 750 °C during off-peak hours, during the night. The units passively discharge through the day and may have a fan to boost output when needed—particularly in late afternoon toward the end of their discharge period.

The units are relatively inexpensive, and, with suitable electrical rate incentives, ETS provide an effective way for a utility to move residential electric heating loads from the day to the night. This allows the utility to level their load, which is almost always to the utility's benefit. This benefit also lowers the energy cost for the consumer, a true win-win situation.

Since the issue of electrical rate structures has been introduced, this is perhaps a good moment to review some of their more typical features.

Electricity Rate Structures

Virtually all electric-utilities must have users for the power they produce **at the moment** they produce it. Unlike gas, electricity cannot be stored for later use. Electricity has its highest demand period during the weekdays and, in air-conditioned climates, primarily in the afternoon. In order to serve the peak, the utility must have that installed capacity available. That peak capacity sits idle the rest of the day, earning no revenue.

The following description is of a basic electrical rate structure, though there are many other features applied to encourage a balance between the particular utility and their users.

Consumption Charge and Demand Charge

To balance their costs and income, utilities use two methods of charging those with high peaks in their load. The high peaks are addressed by a "demand charge." The demand charge is typically based on the highest load in any 5–15 minute period in the month. The utility meter is continually checking the average load over the previous few minutes and recording the highest peak demand. In addition to the demand charge, the utility charges a consumption charge based on the quantity of electricity used. This consumption charge covers all the costs of production.

For example, each month, a utility charges for electricity based on two factors:

Demand Charge: $10 per kW of demand (kilowatt = 1,000 watts, equivalent to 10 100-watt light bulbs)
Consumption Charge: $0.07 per kWh. (a kilowatt hour, kWh, is the energy used by a 1 kilowatt load in one hour.)

Consider a one-kilowatt load on for one hour in a month. It will cost

Demand Charge	$ 10.00
Consumption Charge one hour * $0.07	$ 0.07
	$ 10.07

The same heater, on for the whole month (30 days of 24 hours) will cost

Demand charge	$ 10.00
Consumption Charge 30 days * 24 hours * $0.07=	$ 50.40
	$ 60.40

The effective cost of just one hour of operation in the month

$10.07/1 = $10.07 per hour.

The hourly cost for the whole month was

$$\$60.40/(30^*24) = \$0.084 \text{ per hour.}$$

This is significant encouragement to avoid short peaks!

Large peaks are easily produced with larger chillers. On one campus, the maintenance staff decided to test run two 1,000-ton chillers on a weekday in early spring, the last day of the month. They wanted to make sure the chillers would be ready when the weather warmed up. Adding the two chillers' demand charge for the test run cost over $21,000, simply because the chillers pushed the peak demand up for the month!

Time-of-use rate schedule

Next, the utility may have a "time-of-use" rate schedule. Earlier we mentioned that low rates encourage the use of night-storage heating through the use of electric-storage heaters. On the other hand, many utilities will charge a hefty premium for power between, for example, noon and 5 p.m. Here the utility is aiming to discourage use in this specific time period in order to minimize their peak.

Both peak demand and time-of-use pricing structures favor the use of thermal storage. In addition, many utilities will give substantial financial incentives to designs that reduce peak demand on their systems. It is always worth checking on what is available and whether the utility will provide financial incentives to help with design in order to maximize savings.

Chilled Water and Ice Storage Systems—Introduction

Now we are going to move on from passive storage systems and our discussion on electricity rates to consider water and ice storage systems. Why go to the extra effort to use storage? There are two common reasons: to reduce installation costs where possible, and to reduce operating costs. Storage is also being increasingly used as emergency cooling capacity for critical installations, such as computer data centers.

1. **To reduce installation costs**:

Consider a specialized-use building, like a church, that has a cooling system designed for the capacity based on the peak attendance that occurs one day a week. For the remainder of the week, though, small attendance is the norm. A small cooling plant and storage system may be much less costly to install and, generally, less costly in electricity bills.

Consider *Figure 13-3*. The chiller is shown running continuously producing almost ten units of cooling capacity. The solid line is the load on a particular day. Starting at the left, midnight, the chiller is serving the load—about 2 units—and the spare capacity is charging the storage. At about 13:00, the load equals chiller capacity and from then until 21:00, the load over-and-above chiller capacity is met from storage. Effectively, the excess chiller capacity at night has been stored for use during the high load in the afternoon.

In some situations this lower installation cost may be achieved even with full daily usage. Factors that can contribute include: smaller chiller, smaller electrical supply, a financial incentive from the utility, and, when ice is the storage medium, even smaller pumps, pipes, fans, and ducts are possible.

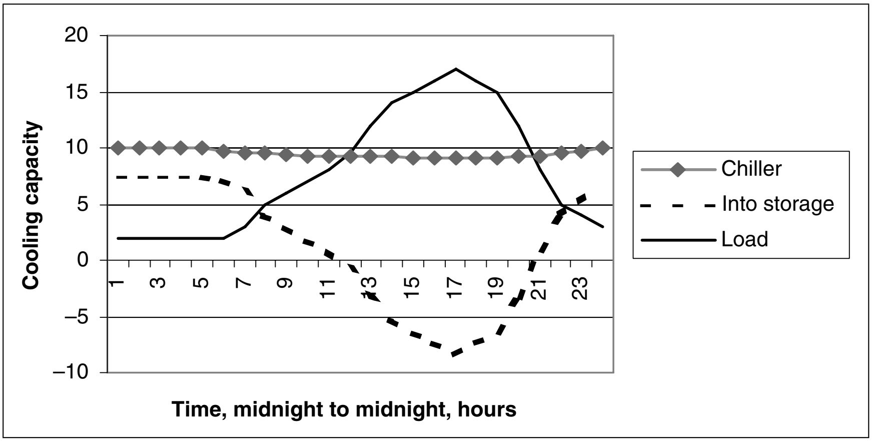

Figure 13-3 Twenty-Four Hour Cooling Load Profile

2. **To reduce operating costs**:

We have already discussed demand and time-of-day pricing structures that encourage night-time use and discourage afternoon use. As demonstrated, it can be worthwhile to run the chiller during the night and on weekends to avoid demand charges, and overnight and in the morning to avoid time-of-use charges.

Chilled Water Storage

Let's consider water first. Water holds 1.285 watts hours/kg for every 1 °C change in temperature. If our stored water is available at 5 °C and return temperature from the cooling coils is 13 °C, then every pound will have a storage capacity of $8 \cdot 1.285 = 10.28$ watts hours/kg. A cubic meter of water weighs 998 kg, so a cubic meter of our stored water represents:

$$10.28 \text{ watts hours/kg} \cdot 998\,\text{kg/m}^3 = 10{,}260 \text{ watts/hours/m}^3 \text{ or } 10.26\,\text{kWh/m}^3$$

In fact, it will require 10% to 50% more, since there are the inevitable losses in the system as the water is pumped in and out, as well as heat gains through the insulated tank wall.

Chilled-water storage is generally conducted with normal, or slightly lower than normal, chilled-water supply temperatures. As a result, producing chilled water for storage can be done using a standard chiller running at approximately the same efficiencies used for conventional chilled-water systems. Chilled-water storage systems tend to dominate the large-system market with tanks that have capacities of 14000 m^3 and more.

Now, let's consider the use of ice for thermal storage. One cannot make and store a solid block of ice; one needs a mechanism to get the heat in and out. For the sake of example, let's assume 70% of our storage volume is ice and our system simply recovers the "**latent heat of fusion**." The latent heat of fusion of water is 0.0931 kWh/kg (334 kJ/kg), which is the heat absorbed to melt one kilogram of ice or convert one kilogram of water to ice at 0 °C. The latent heat of fusion of 1 m^3 of ice is

$$0.0931\,\text{kWh/kg} \cdot 998\,\text{kg/m}^3 = 92.92\,\text{kWh/m}^3.$$

In our example, only 70% of the volume can be ice, so the latent heat of fusion storage would be

$$92.92\,\mathrm{kWh/m^3} \cdot 0.7 = 65\,\mathrm{kWh/m^3}.$$

This means chilled water requires about four to seven times the storage volume that ice requires for the same amount of cool storage volume. So, the big advantage of using ice storage is that a much smaller volume of storage is required. However, to achieve this small volume, the chiller must produce much lower discharge temperatures, below −3 °C, instead of +5 °C, so the chiller efficiency is lower. In addition, the production and handling of an ice storage system generally requires a more sophisticated plant. This smaller space requirement makes ice storage generally more popular for single buildings.

As a result, (to be very simplistic) there is a choice between:

1. Water: A relatively simple and more efficient chilled-water production with larger storage-space requirements.
   or
2. Ice: A relatively more complex system with a less efficient chiller, producing ice and using a smaller storage space requirements.

These underused techniques of water and ice storage are clearly explained in considerable detail in ASHRAE's *Design Guide for Cool Thermal Storage*.

In the next sections, we will discuss the basics of practical water and ice storage systems.

Chilled-water storage

Storing chilled water is normally done in a large **stratified tank**, cold at the bottom and warmer at the top. Stratification is required to avoid mixing warmer and cooler water while the tank is charged and discharged. Conveniently, water has a maximum density at 4 °C. So, water that is warmer than 4 °C will float above water that is at 4 °C.

Chiller water enters the bottom of the tank, at low velocity, through a diffuser, as shown in *Figure 13-4*. Typically, the diffuser is a loop, or an array of

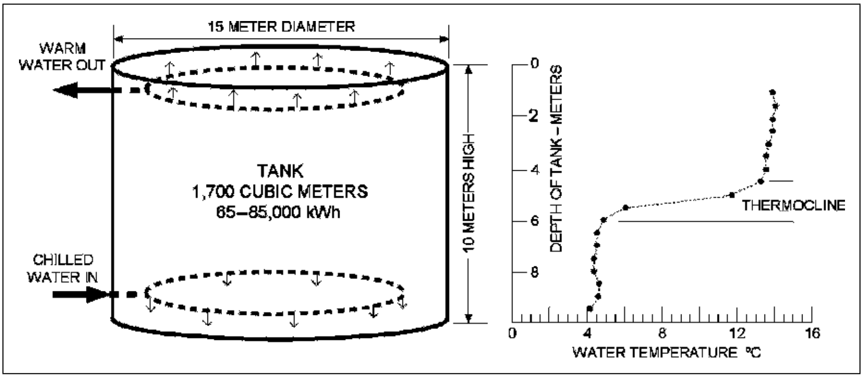

Figure 13-4 Chilled-Water Storage Tank with Typical Thermal Gradient

pipes with slots, to allow the water in or out with minimal directional velocity, to minimize mixing. The chilled water enters at 5 °C (just above 4 °C) and the warmer water at the top stays stratified above the 5 °C water. As more warm water is pumped from the top of the tank, through the chiller, and returned very gently to the bottom of the tank, the cold layer gradually moves up the tank. When discharging, chilled water is withdrawn at the bottom of the tank and an equal volume of warmed water is returned to the top of the tank. A similar diffuser at the top of the tank minimizes turbulent motion and mixing in the water. The process produces a thermal gradient in the tank, such as shown on the right of *Figure 13-4*.

In *Figure 13-5*, a simple circuit is shown with the loads and chiller-circuits below the water level of the storage tank. Valves to control the flows between tank and chiller are not shown in *Figure 13-5*, since there are several alternatives. There are two pipe-loops connected to the storage tank: one belongs to the chiller and the chiller pump, and the other is the load circuit, consisting of the variable volume pump and variable flow loads.

There are up to six possible operating conditions with a storage system, as shown in *Figure 13-6*.

To maximize savings, the designer must give special consideration to the control of larger storage systems. The seasons when full tank capacity is not required are a particular challenge. On one hand, it is wasteful to over store.

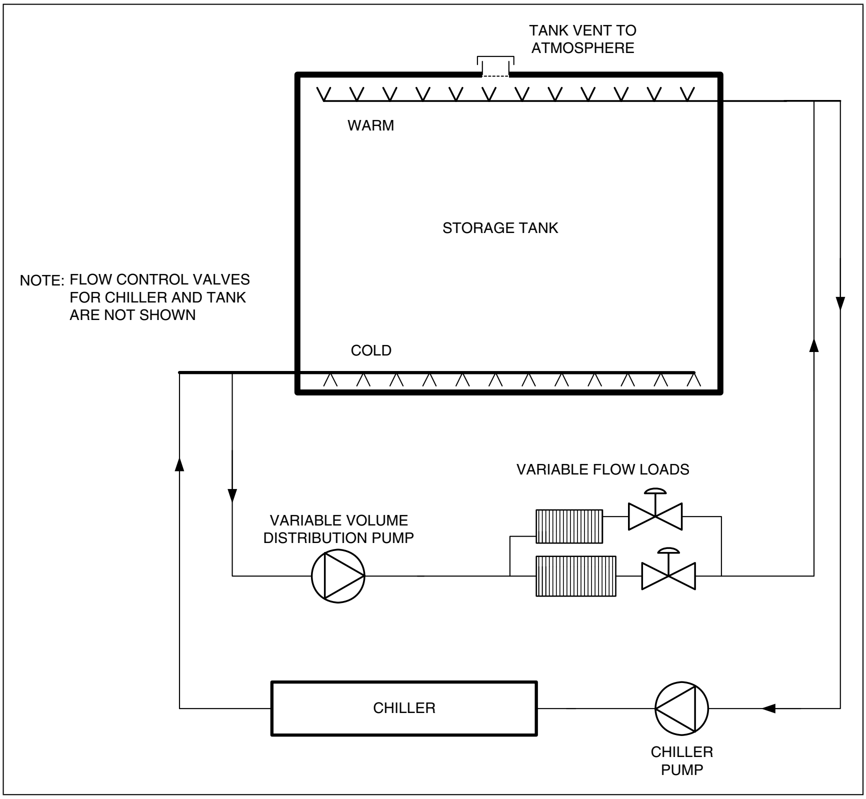

Figure 13-5 Simple Chilled-Water Storage System

STORAGE	Charging	Charging		Discharging	Discharging
CHILLERS	Charging	Meeting load	Meeting load	Meeting load	Off
LOADS	Off	On	On	On	On

Figure 13-6 Possible Storage Operating Modes

On the other hand, if you under-store, then you could be faced with much higher electricity charges, or a lack of sufficient capacity at peak load periods. Because these penalties are usually much more costly than any savings that could be achieved by reducing storage, full storage is generally used.

For maximum storage, the temperature difference between the chilled-water supply and return water must be as large as possible. In general, chilled-water storage is not economical with a temperature differential below 7 °C. A storage temperature difference of 11 °C should be the target to make the system as economical as possible.

Chilled-water storage is not high-tech. Water tanks are a common item in both steel and concrete and the controls do not have to be very complex. Chiller efficiencies are, often, lower because of the lower chilled-water supply temperature required. (Remember from Chapter 6, Section 6.3, the efficiency of a refrigeration circuit falls as the difference in temperature between evaporator and condenser increases.) However, the chiller efficiency that can be achieved is maximized, since the chiller can always run at full load and the operation is largely at night when ambient temperatures around the cooling towers are lower, allowing a lower condenser-water-supply temperature. Efficiency can also be improved by using a larger cooling tower, which will drop the condenser-water-supply temperature.

Exposed tanks should be insulated to minimize heat gain to the cooled stored water. The size of the storage tank should allow for:

- heat transfer and mixing between warm and cold water levels
- ambient heat gain
- pumping power.

The net useful cooling output typically varies between 80% and 90% of the input cooling.

One particularly effective use of chilled-water storage is in the capacity extension of existing facilities.

For example: suppose the client has a building that is running well and needs a substantial addition. You could choose to buy additional chiller capacity for the additional load. Alternatively, it may be far more economical, on space, installation cost, and operating cost, to add chilled-water storage and have the existing plant run more continuously through the evening to serve the increased load.

Ice Storage

There are four main methods of generating ice for ice storage systems: coils, with external melt; coils, with internal melt; ice harvesting; and water in numerous plastic containers.

In **External melt** systems, ice forms around coils of pipe in a tank. The coils are cooled, and may be steel or plastic. Just two of the pipes in the coil are

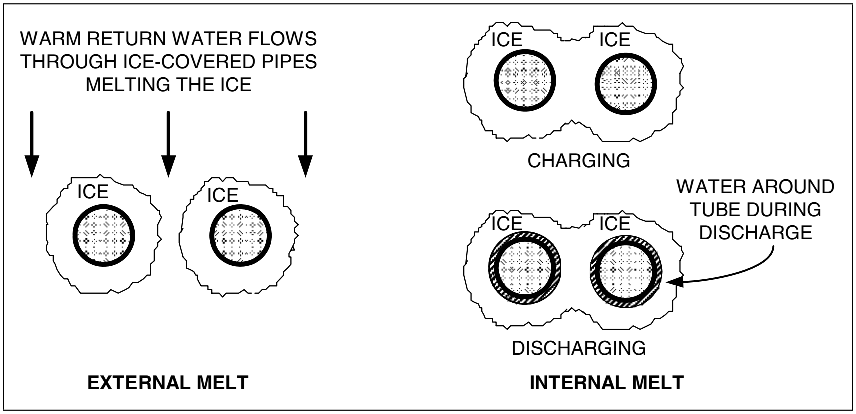

Figure 13-7 External Melt and Internal Melt Ice Storage Systems

shown in *Figure 13-7*. The pipes are spaced so that when fully charged with, for example, 60 mm of radial ice, there is still space for chilled water to flow between the iced pipes.

In **Internal melt** systems the pipes are closer together and cold brine—water containing an antifreeze chemical—passes through the pipes, which causes a block of ice to form around the pipes. To discharge, warm brine passes through the pipes, melting the ice around them.

Ice harvesting systems generally have a set of vertical flat, hollow panels above a tank of water, as indicated in the schematic, *Figure 13-8*. The panels cycle between two functions, first as a chiller evaporator, and then as a condenser, just like the heat pump circuit we discussed in Chapter 6.

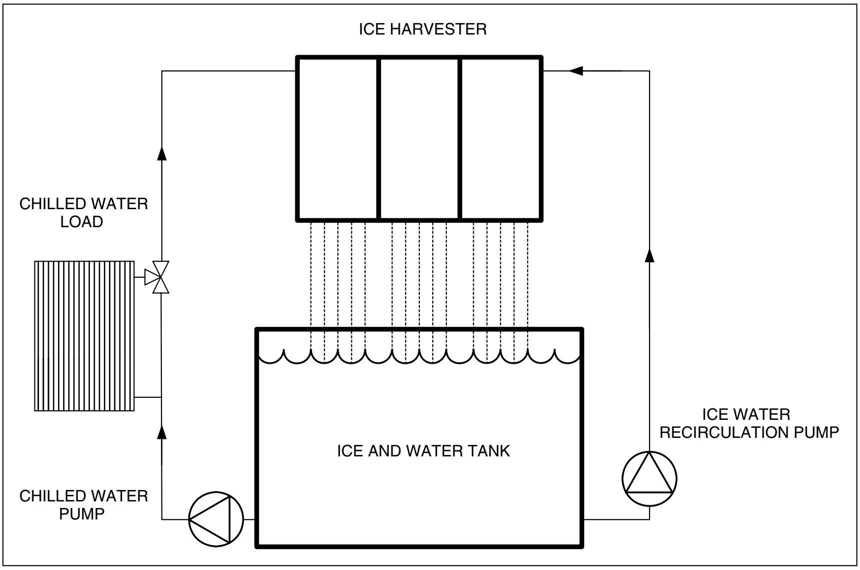

Figure 13-8 Ice Harvesting

The process begins with the panels acting as the chiller evaporator. Water is continuously pumped over the plates and a layer of ice begins to form on the plates. After 20–30 minutes the ice reaches an optimum thickness and the refrigerant cycle is reversed. Then the panels act as the condenser, with the hot condenser gas melting the ice at the plate surface, and the ice falls into the tank.

Ice harvesting systems are attractive since they can be purchased as factory designed-and-built systems. If needed, they can have a very high discharge rate, and the full 24-hour charge can be removed in as little as half an hour.

Cooling is removed by passing return chilled water through the ice harvester and ice-water storage tank to achieve a chilled-water supply temperature of 1–2 °C. This is much colder than the 5.5 °C, or warmer, water from standard chilled-water systems, even those using chilled-water storage.

Lastly, water can be contained in plastic spheres. The spheres are either partially filled with water with some air to allow for expansion on freezing, or the spheres have depressions which fill out as the freezing water expands. In these systems, chilled water containing an antifreeze flows through a tank full of these spheres, to either store or extract cooling.

The major advantages of ice-storage systems are smaller storage tanks and lower chilled-water-supply temperatures. The lower chilled-water-supply temperatures can be used to increase the system water-temperature differentials and to produce very cool, low temperature, supply-air for distribution to the building's occupied spaces. This results in smaller pipes and smaller air-distribution ducts and supply-air fans. The low-temperature air supply system does require carefully designed diffusers that do not dump cold air onto the occupants.

The cooler chilled-water supply temperature from ice storage can be very useful in extending an existing chilled-water system. Suppose there are several buildings on a main chilled-water loop and the client wants to add another building at the end, farthest from the chilled-water plant. The option of increasing the chilled-water pipe size may be prohibitively expensive and disruptive. By adding ice-storage, the chilled-water-supply temperature can be reduced from 5.5 °C to 2 °C. If the original system was designed for 5.5 °C chilled-water supply and 13 °C return, the temperature rise was

$$13\,^{\circ}\mathrm{C} - 5.5\,^{\circ}\mathrm{C} = 6.5\,^{\circ}\mathrm{C}.$$

Now with chilled water at 2 °C the temperature difference is

$$13\,^{\circ}\mathrm{C} - 2\,^{\circ}\mathrm{C} = 9\,^{\circ}\mathrm{C}.$$

With the same volume flow, the capacity of the piping mains has been increased by nearly 40%, which now allows this system's pipes to serve the remote building without replacing them with larger pipes. Adding insulation to the existing pipes may be necessary.

To achieve the projected savings in energy costs, if the system is not fully automated, the operating staff must completely understand and be able to apply the control strategies of the design. With today's technology, these can be performed by Direct Digital Controls (DDC), through software. Using DDC, the control sequences can be made fully automatic, and therefore less dependent on the operating staff. However, this does require that these systems be commissioned to ensure that the automatic control functions as intended.

Be warned that it is surprising how often operating and maintenance staff defeat the cleverest software by switching just one piece of equipment to "manual!"

There are several other, less popular, active storage methods that you can research elsewhere. Be aware that "less popular" does not mean "unpopular." Many systems are ideal choices for some specific situations but are not practical for every project. Local knowledge and your research can help find the best choice for your project.

13.4 The Ground as Heat Source and Sink

The ground can be treated as a large heat source or as a heat sink. In other words, one can extract heat from the ground or reject heat to the ground. The temperature only a few meters below the surface varies half as much as the ambient temperature. Below 3 meters the temperature remains fairly constant in most places.

There are three general methods of using the ground as a heat source or sink: the well, the vertical field, and the horizontal field.

The Well: The oldest method, and in some places the easiest, is to dig a well, then pump the water up and through the heat pump before piping it to drain. Many local codes will not permit this approach and will require you to have a second well some distance away to discharge the water back into the ground. This all assumes your location has a readily accessible, adequate and reliable flow of "sweet" water. "Sweet" meaning it has no undesirable characteristics, such as dissolved salts that will corrode away both pumps and heat exchangers very quickly. Local knowledge and test holes can be invaluable.

The horizontal field and vertical field refer to pipe loops in the ground that transfer heat to or from the ground.

The Vertical Field:

1. The field has been prepared and planned, and then vertical bore holes are drilled. The vertical depth for the boreholes ranges from 15 to 150 meters, depending on ground conditions and the cost to drill the holes to these depths. Boreholes must be spaced well apart to avoid having them thermally affecting each other. The effect is minimized with a row of holes, but this is not always an attractive alternative. A rule of thumb is 6 meters apart, but local conditions, such as underground water flow, can reduce this distance. A test hole can be bored and used to test the heat transfer characteristics of the local soil conditions to help determine the number of wells and spacing required.
2. Durable U-shaped plastic pipe loops are lowered into the boreholes.
3. Each borehole is back-filled with excavated material or with a special mixture to enhance heat transfer with the ground.
4. The ends of the pipes are connected to headers, which are routed back to a building to pumps within the building. The pumps are connected to piping that is circuited to one, or more, water coils, each on one side of a heat pump.

Vertical ground-source systems have the following advantages:

- They utilize smaller areas of land than the horizontal system.
- Their performance is quite stable (when spaced and sized properly), since the ground temperature does not vary with the seasons.

- They use the lowest pumping energy and the least amount of pipe.
- They often provide the most efficient performance.

Vertical ground source systems have two disadvantages that vary according to location:

- They are generally more expensive to install than horizontal systems and can be prohibitively expensive in hard rock areas.
- The availability of qualified contractors is very limited in some areas.

The Horizontal Field: This method involves burying pipe loops in trenches or open pits at a depth of at least 1.2 meters. There is a variety of pipe loop arrangements that are designed to take advantage of local conditions.

Horizontal systems have the following advantages:

- They are relatively easy to install with readily available, non-specialist equipment in areas without rock.
- For rural residential systems, the land requirement is usually not a restriction.
- They usually have a lower installed cost than vertical systems and they are potentially easier to repair.

Disadvantages:

- They require a much larger land area.
- They have a more significant variable system performance than the vertical arrangement, due to greater variations in ground temperature that arise from seasonal temperatures, rainfall, and shallower burial depth.
- Their efficiency is generally lower than the vertical arrangement, due to fluid temperature and slightly higher pumping requirements.

Correctly sizing a heat pump for winter heating and summer cooling can be a difficult task. In many climates with cold winters, the winter heating load can be much higher than the summer cooling load. Installing a heat pump that is big enough to do both tasks is often a mistake. If the unit is oversized for summer cooling, it will cycle excessively and dehumidification will be very poor to non-existent. The maximum over-sizing above summer load should not exceed 25% for reasonable summer performance. The winter heating load that is not supplied by the heat pump is best provided by supplemental heat.

One relatively new opportunity to deal with this issue is the two-speed compressor unit. Two-speed units may allow for correct sizing for the summer load by cooling at low speed, while high speed may allow the winter heating load to be more closely met. For heating in these climates, it is very efficient to use a radiant floor system. This is because the temperature difference between the ground and the heat pump heating-supply temperature is lower, thereby, providing a significantly higher efficiency.

An extension of the idea of using “natural” sources for heating or cooling is the idea of using natural ventilation from operable windows. This will be covered in the next section.

13.5 Occupant-Controlled Windows with HVAC

People like to think they have control of their environment. For air-conditioned buildings without operable windows, there is a desire “to have a thermostat in my office." In fact, many maintenance staff have discovered that the presence of a thermostat can be very satisfying even when it is not connected! Hence the use of the phrase "dummy thermostat."

This desire for control is often successfully exercised in the demand for occupant controlled windows, operable windows. Unfortunately, people are not good at assessing when to have the window open or when to close it. This is where good communication can have a very beneficial effect. People are generally cooperative if they understand why they should be cooperative. You would be surprised at how many buildings have occupants running window air-conditioners while the windows are open. The owners make no effort to explain the waste and lack of dehumidification that occurs when the air-conditioner is cooling while the window is open on a hot, humid day. The result is fewer satisfied occupants and the owner has a higher electricity, or energy, bill. If you are faced with a situation like this, try to let the occupants know the benefits that will affect them if they use the system more efficiently.

Actual ventilation depends on orientation, building height, wind direction, and wind speed. In narrow buildings with windows on both sides, a cross flow can be very effective. One problem is that on the incoming side occupants may experience an unacceptable draft if they are close to the windows.

In winter, in colder climates, the warm, less dense air in buildings tends to rise. As a result, there is a constant inflow of air through openings that are low in the building and a outflow high in the building. An occupant who opens a ground floor window in a three story apartment building receives an incoming icy blast. The window is quickly shut and remains closed. On the other hand, the person on the third floor can open their window wide and the warm air from the building will flow outward. They can leave their window open, letting the warm air, and energy, of the building continuously vent outside. In this situation, the windows are unusable low in the building and a great waste of energy for negligible ventilation high in the building. The problem of providing enough ventilation without a huge energy waste is addressed in Canada and parts of northern Europe by requiring mechanical ventilation in residences. This has, in turn, made a variety of heat recovery units quite popular, and in many places mandatory, although their cost is often not recovered from the energy savings when fan power is included in the calculations.

In mild climates, operable windows can be used to both ventilate the building and provide overnight pre-cooling with judicious building design and use.

The ventilation benefits of windows, and the challenges of their operation, are being addressed in some new buildings by having the windows controlled automatically. The control system may have sensors for wind direction and speed, solar intensity, as well as interior and exterior temperature sensors to aid in the decision making process.

13.6 Room Air Distribution Systems

Earlier in this course we talked about supplying air to spaces, but we have not discussed how achieve it. We will do that now. There are four main types of room air distribution systems: mixing, displacement, underfloor, and task control. "Mixing" is by far the most popular in North America and "task control" has yet to gain popularity.

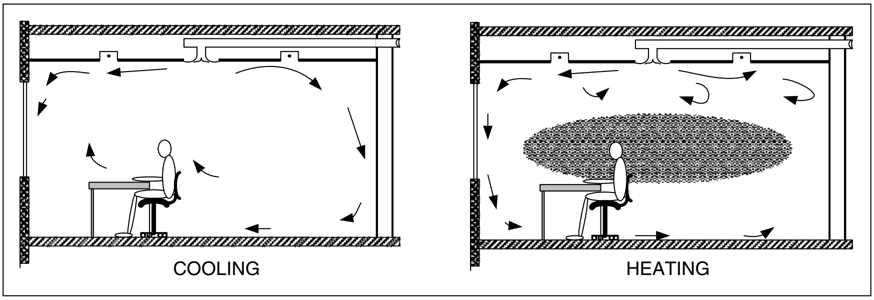

Figure 13-9 Ceiling Diffuser Airflow Pattern for Cooling and Heating

In **mixing** ventilating systems, the air is supplied, typically at 13–14 °C, at a velocity of over 0.5 m/s (meters per second), through an outlet diffuser or grill, at the ceiling or high in the sidewall. The objective is to have the supply air entrain and circulate the room air, to achieve good mixing.

The flow from a typical ceiling diffuser has a velocity profile as shown in *Figure 13-9*. The air velocity falls as more room air is entrained and the design should have the velocity no higher than 0.25 m/s in the occupied zone. When cooling, as shown on the left in *Figure 13-9*, the cool air is blown out across the ceiling and, although cool and dense, does not immediately drop due to the "Coanda" effect. The **Coanda effect** is the property of air to stay against a surface. For the cool air to drop from the ceiling, room air would have to move in above it, since otherwise a vacuum would be formed. This takes time to occur, with the result that the cool supply air travels further across the ceiling before dropping than would the same flow if it had been discharged well below the ceiling.

The ceiling diffuser works well in the cooling mode. Unfortunately, it does not work very well in heating mode, since the warm, less dense, supply air stays up at the ceiling, out of the occupied zone. The buoyancy effect is particularly problematic with the supply air temperature more than 8 °C higher than the general room temperature. The flow is shown on the right of *Figure 13-9*. The air enters the room and stays at the ceiling level except where the cool window creates a downdraft that provides a cool to cold draft over the occupants' feet.

Mixing works well for cooling and can produce an even temperature throughout the space. Disadvantages include:

- The air velocity has to be low enough throughout the occupied area to avoid drafts, so there is a tendency for inadequate air movement in some areas.
- Any pollutants in the space can be spread throughout the space.
- All loads must be absorbed within the mixed air.

Displacement ventilation is the opposite of mixing. Displacement ventilation aims to avoid mixing in the occupied zone. Air, a little cooler than the space, is introduced at a low velocity (< 0.5 m/s) through large area diffusers in the wall close to the floor. The air flows slowly and steadily across the space until it passes a warm object—a person or a piece of equipment. The warmth causes some of the air to rise up out of the occupied zone carrying pollutants and heat with it. Above the occupied zone, mixing occurs and the return outlet at

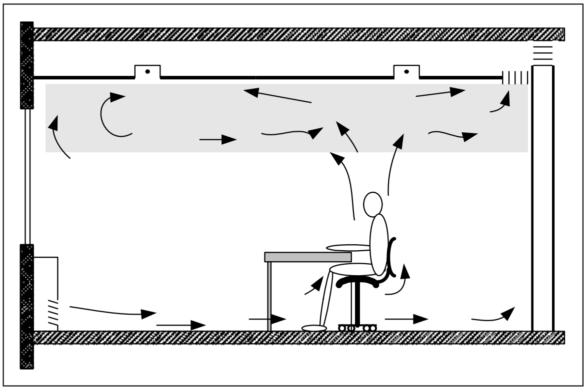

Figure 13-10 Schematic of Displacement Ventilation

the ceiling level draws the some of the mixed air out of the space. The flow pattern is shown in *Figure 13-10*.

The air supplied cannot be more than about 4 °C less than the occupied space temperature, in order to avoid excessive cooling on the people closest to the outlets. This restriction severely limits the effective cooling capacity of the system. For cooler climates, such as Scandinavia, where the system is very popular, this load restriction is not as significant. Where higher internal loads must be absorbed, there are methods of entraining room air into the supply air to increase the effective flow into the room while still staying within 4 °C less than room temperature.

The air movement in the space separates into the lower displacement zone with a recirculation zone above. In a well-designed space, the recirculation zone is just above the occupied zone.

The objective of the system is to have the occupants and the equipment in a flow of clean air, with their own heat causing convection around them. This will lift their pollutants up, out of the occupied zone. In addition, the convection heat from surfaces and lights above the occupied zone do not affect the temperature in the occupied zone. As a result the air leaving the room can be warmer than would be acceptable in the occupied zone.

Underfloor Air Distribution (UFAD) is supplied from a raised floor through numerous small floor grilles. The floor typically consists of 600 mm square metal plates, or tiles, supported by a 250–450 mm high supporting leg, or column, at each corner. Some of the tiles have outlet grilles installed in them. The tiles can be lifted and moved around, making grille re-location, addition, or removal, a simple task as shown in *Figure 13-11*.

Air, at 14.5–18 °C, is supplied to the cavity and discharges through the floor grilles. The floor grilles are designed to create mixing, so that the velocity is below 0.25 m/s within 1.2 meters of the floor. You can think of the air as turbulent columns spreading out above the 1.2 meter level to form a vertical displacement flow toward the ceiling. Return air is taken from the ceiling or high on the wall. The rising column of air takes contaminants with it up and out of the breathing zone. This sweep-away action is considered more effective rather than mix-and-dilute. As a result, the ventilation requirements of *ASHRAE Standard 62.1* can be satisfied with 10% less outside air.

There are numerous outlets, since the individual outlet volume is typically limited to 50 L/s. The entering air does not sweep past the occupants, as occurs

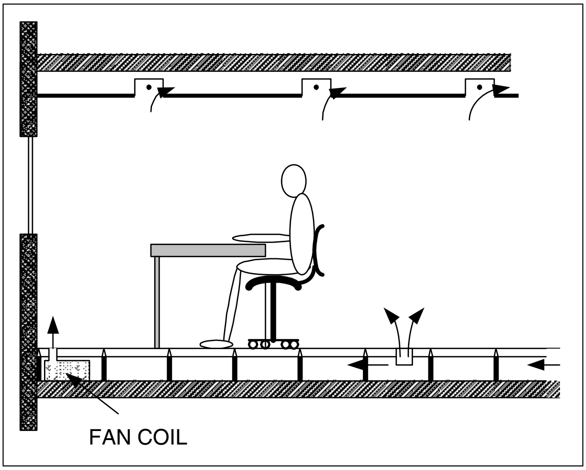

Figure 13-11 Underfloor Air Distribution (UFAD)

in displacement ventilation, so there is no restriction on cooling capacity. There is, however, a limit on how well the system will work with rapidly changing loads. For spaces with high solar loads, thermostatically controlled fans or other methods are required to modulate the capacity to match the changing load.

Since the air is rising toward the ceiling, the convection heat loads above the occupied zone do not influence the occupied zone temperature. Therefore, the return air temperature can be warmer than the occupied zone and a return air temperature sensor is a poor indicator of occupied zone temperature.

The cool air flows continuously over the structural floor that somewhat acts as a passive thermal storage unit. This storage can be used to reduce peak loads.

For perimeter heating, small fan-coil units can be installed under the floor, using finned hot water pipes or electric coils. In a similar way, conference rooms that have a highly variable load can have a thermostatically controlled fan to boost the flow into the room when it is in use.

A modification of the underfloor system with individual grilles is the use of a porous floor. The floor tiles are perforated with an array of small holes, and a porous carpet tile allows air to flow upwards over the entire tile area. This is a modification of the standard grill and has yet to gain popularity.

The underfloor air delivery system has the following advantages:

- Changing the layouts of partitions, electrical, and communications cables is easy. For buildings with high "churn" (frequent layout changes) this flexibility may, in itself, make the added cost of the floor economically justified.
- The flow of air across the concrete structural floor provides passive thermal storage.
- When the main supply duct and branches to the floor plenums are part of a well-integrated architectural design, the air supply pressure drop can be very low, resulting in fan-horsepower savings.
- Less ventilation outside air can potentially be used.

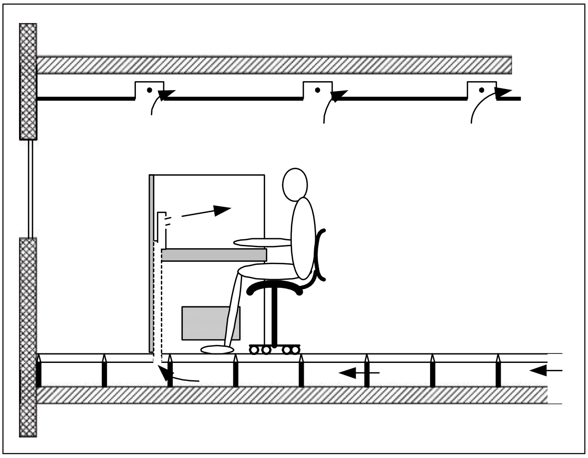

Figure 13-12 Task/Ambient Conditioning Supplied from Underfloor Distribution

Disadvantages include:

- A significant cost per square meter for the floor system supply, installation, and maintenance.
- A tendency to require a greater floor-to-floor height, since space for lights and return air ducts is still required at the ceiling level.

Our fourth and final type of air distribution system is most often a variation of the underfloor system. It is the **Task\Ambient Conditioning system, TAC**. With TAC each occupant workstation is supplied with cooling air and a degree of control over this airflow, airflow direction, and temperature, as shown in *Figure 13-12*. In a typical arrangement, one or two supply air nozzles are mounted above the work surface. The occupant can easily alter the velocity and direction of flow. Temperature may be controlled by mixing room air into the supply air, or by a resistance or radiant electric heater controlled by the occupant.

The ability to control their own environment is very popular with many occupants, though the measured conditions are not greatly different from occupants in the same building without a TAC. One specific advantage of the TAC for the occupant is the ability to modify the air speed. Since this system is in addition to the underfloor supply, there is significant research work being done to prove that the cost is more than recovered in improved staff productivity.

This completes our look at supplying air to occupied spaces. As with so many issues in HVAC, the climate and the local norms and experience will often drive decisions as much as technical merit.

Having discussed room air distribution we are now going to move to the other end of the system, where the ventilation air is brought into the building through the air handler.

13.7 Decoupled and Dedicated Outdoor Air Systems

Our last area of discussion relates to outdoor air. There are situations where mixing the outdoor air with return air and conditioning the mixture is not a good choice.

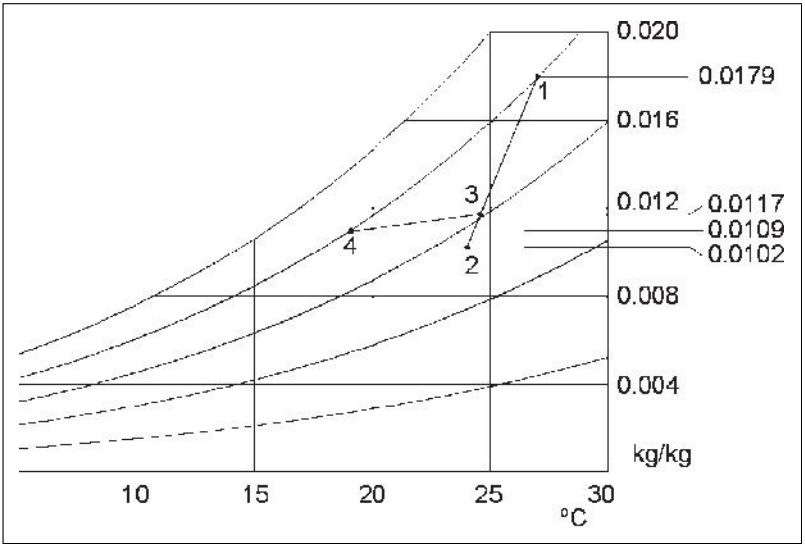

Figure 13-13 Ineffective Performance of Cooling Coil for Moisture Removal

Consider the following example: a humid climate, on a cloudy, very high humidity day that is warm, but not hot.

The typical package air-conditioning system will do a poor job, since the cooling coil will take out very little moisture because there isn't adequate sensible load to keep the unit running continuously. The challenge is shown on the psychrometric chart, *Figure 13-13*.

Point 1 is the outdoor air at 27 °C and 80% relative humidity.
Point 2 is the return air from the space at 24 °C and 55% relative humidity.
Point 3 shows 20% outside air (Point 1) mixed with 80% return air from the space (Point 2).
Let us assume that the cooling load only requires cooling the air to 19 °C.
Point 4 shows this air cooled to the required 19 °C. Unfortunately, the condition of the mixed and cooled air at Point 4 contains more moisture than the space.

If the system supplies this air into the space, the relative humidity would rise until some equilibrium balance was achieved. To prevent this uncontrolled increase in moisture, the air going through the coil must be cooled substantially more than is needed for sensible (temperature) cooling. This is generally not acceptable, as the overcooling would have to be offset by some form of reheating. Alternative methods of moisture removal are necessary.

Moisture removal can be achieved in many ways. We will describe two: pre-treating the outside air and providing a bypass.

Pre-treating the outside air

First consider the system where the outside air is pre-treated before it is introduced into the main air-handling unit. A single cooling coil, designed for the low outdoor air volume and high dehumidification load, may cool and

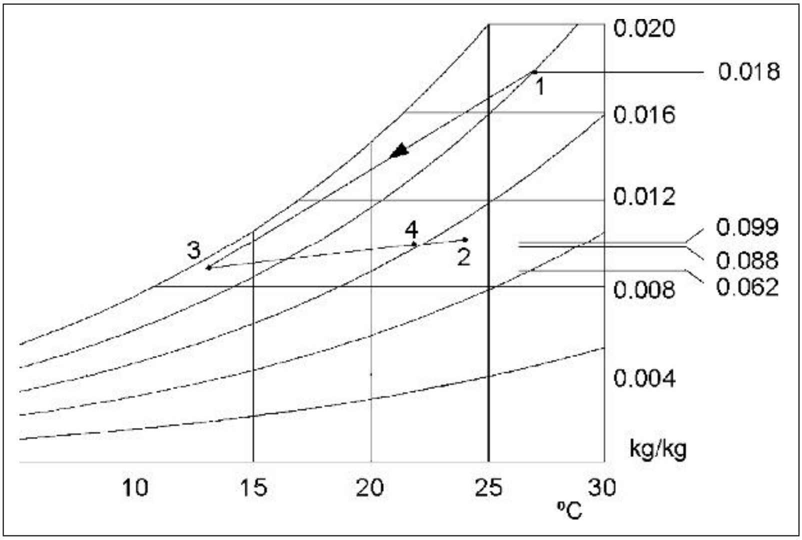

Figure 13-14 Cooling and Dehumidifying Outside Air Before Mixing with Return Air

dehumidify this outside air. Typically, this is a deep coil, with a low air-velocity that provides enough time for substantial moisture removal.

In *Figure 13-14*, we see the diagram illustrating this method:

Point 1 is outside air at the same conditions of 27 °C and 80% relative humidity.

Point 2 is the condition of the return air that is mixed with air from the **new Point 3**.

Point 3 is air that has been cooled and dehumidified to 13 °C and 95% relative humidity—a condition that has a much lower moisture content than the space. (Remember, the higher relative humidity at a lower temperature can still mean a lower moisture content.)

Point 4 shows that the mixed air has a lower moisture content than the return air from the space.

If the outside air is 20% of the mixture, it provides about 20% sensible cooling, leaving the main cooling coil to do only as much additional sensible cooling as is necessary.

Bypass around main cooling coil

Another method to achieve the required dehumidification is to provide a bypass around the main cooling coil. A part of the air, let us say 50%, flows through the main cooling coil. This 50% flows at half the velocity through the main cooling coil, allowing the air to cool down and condense significant moisture. The other 50% of the air bypasses the coil before mixing with the sub-cooled air. The two air streams then mix to produce a mixture with half the sensible cooling and well over half the latent cooling (moisture removal), much better than if no air bypassed the coil. Another variation of this is to bypass only drier room return-air around the cooling coil and have a portion of the return air mix with the outside air, which is then sub-cooled as it passes through the coil.

We have briefly considered using alternative arrangements to deal with high moisture removal. Now we will consider a situation where different requirements make a dual-path system attractive.

Consider a building that includes a large kitchen and an eating area. The building could be designed to have all the necessary kitchen makeup air come in through the main air handler. However, because the kitchen is a more industrial environment, rather than an office environment, the kitchen makeup air does not need to be conditioned to the same moisture and temperature conditions as the main air supply to the building. In addition, the kitchen may start operation before the rest of the building and shut down well before the rest of the building. This is a case of a mismatch in requirements and a mismatch in timing.

Therefore, it is often better to provide the kitchen makeup air from two sources. First, there is the air from the eating area. In order to avoid distributing food smells around the building, this air from the eating area should not be returned to the main air handler. Instead, it should form the first part of the kitchen exhaust hood makeup air. The transfer can be by a plain opening, an open door, or a duct with a fire damper, depending on local codes and design requirements. The rest of the kitchen exhaust makeup air can be provided from a separate air handler designed to condition the incoming air to provide suitable kitchen working conditions, often a much less onerous requirement.

Summary

13.2 Radiant Heating and Cooling Systems

Radiant heaters are defined as units that have more than 50% of their heating output achieved through radiation.

Radiant Heating: High temperature, or infrared, units operate at over 150 °C. There are three main types of high temperature units:

- High intensity units are electric lamps operating from 1000–2750 °C.
- Medium intensity units operate in the 650–1000 °C range and are either metal-sheathed electric units or a ceramic matrix heated by a gas burner.
- Low intensity units are gas-fired and use the flue as the radiating element

Important safety and control issues to consider include both heater location and thermostat location.

Radiant Cooling: This is always achieved by using a "large area" panel system. Issues for consideration include: space moisture level, location of insulation on the panels, and the response time of the system.

13.3 Thermal Storage Systems

Thermal storage can be "**active**" or "**passive**."

Passive thermal storage uses some part of the building mass or contents like a thermal flywheel to store heat or cooling and to release it over time to reduce the heating or cooling load.

Active thermal storage takes place when a material is specifically cooled or heated, with the object of using the cooling or heating effect at a later time.

13.4 Chilled Water and Ice Storage

There are two reasons to use chilled water and ice storage: to potentially reduce installation costs and to reduce operating costs.

Chilled-water Storage: Storing chilled water is normally done in a large stratified tank, cold at the bottom and warmer at the top. One economical use of chilled-water storage is in the capacity extension of existing facilities.

Ice Storage: There are four main methods of generating ice for ice storage systems: coils with external melt; coils with internal melt; ice harvesting; and water in numerous plastic containers. Ice storage can result in smaller pipes, ductwork, and fans, when low-temperature supply-air is used. Ice storage requires less space than water for the same storage capacity.

13.5 The Ground as Heat Source and Sink

The ground can be treated as a large heat source or as a heat sink: one can extract heat from the ground or reject heat to the ground. There are three general methods of using the ground as a source or sink, the well, the horizontal field, and the vertical field.

13.6 Occupant-Controlled Windows with HVAC

Many people like to have control of their environment, resulting in a demand for occupant controlled windows, operable windows. Unfortunately, people often are not good at assessing when to have the window open or when to close it.

Actual ventilation depends on orientation, building height, wind direction, and wind speed. In mild climates, with judicious building design and use, operable windows can be used to both ventilate the building and provide overnight pre-cooling.

13.7 Room Air Distribution Systems

There are four main types of room-air distribution: mixing, displacement, underfloor, and task control. Mixing is by far the most popular in North America and task control has yet to gain popularity.

13.8 Decoupled and Dedicated Outdoor Air Systems

There are situations where mixing the outdoor air with return air and conditioning the mixture is not a good choice. Examples include warm, humid climates; or where fumes should not be recirculated with the building air.

Your Next Step

The objective of this course has been to provide an understanding of HVAC in general, and to introduce the more common systems used in the HVAC industry. We have not gone into great detail on any subject but hope to have provided enough knowledge to understand how systems work and for the reader to decide what he or she wants to learn more about.

Fundamentals Series

For further study, the ASHRAE Learning Institute has the following titles in this Fundamentals Series.

- *Fundamentals of Thermodynamics*
- *Fundamentals of Thermodynamics and Psychrometrics*
- *Fundamentals of HVAC Systems (this book)*
- *Fundamentals of Heating and Cooling Loads*
- *Fundamentals of Air System Design*
- *Fundamentals of Water System Design*
- *Fundamentals of Heating Systems*
- *Fundamentals of Electrical Systems and Building Electrical Energy Use*
- *Fundamentals of HVAC Control Systems*
- *Fundamentals of Refrigeration*

ASHRAE Handbooks

The four ASHRAE Handbooks are an excellent source of information on all aspects of heating, ventilating, air conditioning, and refrigeration. Each year, one volume is updated and published, following a four-year cycle. Members receive a copy of the current year's edition each year and copies can be individually purchased. All four handbooks can also be obtained on a CD.

Fundamentals – This volume contains information on the properties and behavior of air, water, and other fluids, and how they flow in ducts and pipes. It includes the theory and practice of calculating heat gains and heat losses through all types of building materials.

Systems and Equipment – This volume includes HVAC systems, air handling and heating equipment, package equipment, and general components such as pumps, cooling towers, duct construction, and fans.

Applications – This volume begins with a section on how to apply systems and equipment to comfort, industrial, and transportation situations. Following this, there is a section on general issues, such as operation and maintenance, and energy management. The Handbook finishes with general applications such as the design of intakes and exhausts, seismic restraint, water treatment, and evaporative cooling.

Refrigeration – This volume provides very detailed information on all aspects of refrigeration equipment and practices, followed by sections on food storage, food freezing, low temperature refrigeration, and industrial applications that include ice rinks.

As a matter of policy, the ASHRAE Handbooks are not commercial, and do not recommend any product.

Manufacturers

Manufacturers put significant effort into training their staff about their products. Do not be shy to ask them about their products. When choosing a product, ask the representative: "What would you suggest?" "Is it suitable?" "Is there something better?" "Is there something less expensive?" "Is there something more efficient?" "Who has one of these in and working and can I call them?" Be sure to ask more than one manufacturer's representative for information, so you can get a different perspective on what is available for your application. Don't hesitate to ask manufacturers for sales materials and read them with an alert mind. Is there something here that could really work well in this situation? Is this too good to be true? If so, why? Be realistic—manufacturers put the best light on their product. The challenge for you is to find the product that will perform well in your situation.

Keep asking, keep learning, and have fun doing it.

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Epilogue

This story is not a part of the text of the book. I have heard and read a number of variations of it over the years. To me, it speaks of the importance of what we are doing, and what we can be doing, as members of this profession:

Long ago a king decided to go out on his own to see his kingdom. He borrowed some merchant's clothes and dressed so that no one would recognize him.

He came to a large building site and went in while the gatekeeper was dealing with a delivery of huge wooden beams. As he walked around the site he came upon a stonemason, who was chiseling at a large piece of stone.

"What are you doing?" the king asked.

"Oh, I'm making this stone to fit that corner over there." said the man, pointing.

"Very good." Said the king, and walked on. The king approached another stonemason and asked, "What are you doing?"

"I'm doing my job. I'm a stonemason. It's great working here, lots of overtime, enough to pay for an extension to the cottage," said the man with a big grin.

"Very good," said the king, and walked on.

The king stood and watched the third stonemason, who was carefully working on a detail, before asking him, "What are you doing?"

The man paused, and looked up, considering his reply. Then he answered, "I am building a cathedral."