Chapter 10

Central Plants

Contents of Chapter 10

Instructions

Read the material of Chapter 10. Re-read the parts of the chapter that are emphasized in the summary and memorize important definitions.

Objectives of Chapter 10

In the last chapters we have discussed various air-conditioning systems and the fact that heating and cooling can be provided from a central plant by means of hot water, steam, and chilled water. In this chapter we will consider central plants. We will start with some general considerations about what they produce, their advantages, and their disadvantages. After studying the chapter, you should be able to:

- Discuss some advantages and disadvantages of central plants.
- Identify the main types of boiler and sketch a twin boiler circuit.
- Describe the operation of chillers, and be able to sketch a dual chiller installation with primary only, and primary-secondary chilled water circuits.
- Understand the operation of cooling towers, what affects their performance, and what regular maintenance is required for safe and reliable operation.

10.1 Introduction

For this course, central plants include boilers, producing steam or hot water, and chillers, producing chilled water. These pieces of equipment can satisfy the heating and cooling requirements for a complete building. In a central plant, the boilers and chillers are located in a single space in the building, and their output is piped to all the various air-conditioning units and systems in the building. They are used in all types of larger buildings. Their initial cost is often higher than packaged units and they require installation floor area as well as space through the buildings for distribution pipes. Central plants generally require less maintenance than numerous smaller package systems and the equipment usually has a longer life.

This central plant concept can be extended to provide heating and cooling to many buildings on a campus or part of a town. The equipment for these larger systems is often housed in a separate building which reduces, or avoids, noise and safety issues.

We will be discussing some of the advantages and disadvantages of central plants and then we will go on to consider the main items of equipment found in central plants: boilers, chillers, and cooling towers.

Boilers are pressure vessels and their installation and operation are strictly prescribed by codes. Their general construction, operation, and main safety features will be discussed.

Chillers come in a huge range of sizes and types and we will briefly introduce them. We will discuss their particular requirements for chilled water piping and specialized control.

The job of the chiller is to remove heat from the water and reject it to the condenser. The condensers are often water-cooled. The cooling water is called "**condenser water**." The condenser water flows to a cooling tower, where it is cooled before it returns to the chiller to be heated once again. This will be discussed in detail in Section 10.4.

Cooling towers are devices used to cool water by evaporation. Water is sprayed or dripped over material with a large surface area, while outdoor air is drawn through. Some water evaporates, cooling the bulk of the water before it returns to the chiller.

10.2 Central Plant versus Local Plant in a Building

There is no rule about when a central plant is the right answer or when distributed packages or systems should be used. Circumstances differ from project to project, and location to location. The good designer will assess each project on the merits of that situation and involve the client in making the most suitable choice for the project.

In this section we are going to consider, in a general way, some of the technical issues that can influence the choice. We are not going to consider the internal politics that can have major influences and costs in time and money. In addition to politics, the availability of money for installation versus operating costs can have a major impact on system choices. For minimum installation-cost, the package approach usually wins.

Here are some <u>true</u> statements in favor of central plants. Read them. Can you think of a reason why each one of them might, in some circumstances, be wrong, or irrelevant? Write down your suggested reason.

"*It is easy to have someone watching the plant if it is all in one place.*"
"*The large central plant equipment is always much more efficient than small local plant.*"
"*The endless cost of local plant replacement makes it uneconomic compared to a main central plant.*"

As you know, technology is rapidly changing, and you should think about whether categorical statements or "rules-of-thumb" are correct or relevant in your particular situation. You cannot go against the laws of physics, but every day new ways of doing things are being developed.

Let us consider each of the above statements in turn.

"*It is easy to have someone watching the plant if it is all in one place.*"

This statement is true if visual inspection of the plant is useful. A hundred years ago, the look and sound of the plant were the best, and only, indicators of performance. Operators "knew their plant" and almost intuitively knew when things needed attention. Now, in the 21st century, plant is much more complex and we have excellent monitoring equipment available at a reasonable price. The information from those monitors can be instantly, and remotely, available. So instead of paying someone to physically watch the central plant, the building owner can pay someone to monitor the performance of, not just the central plant, but all the plant, regardless of where it is located in the buildings. Now, using the Internet, many buildings can be monitored from anywhere in the world with fast and reliable Internet service.

The second statement, "*The large central plant equipment is always more efficient than small local plant*," is generally true but not always relevant. For example, an apartment building might have a large central boiler that provides both hot water for heating, and domestic hot water. In winter this is an efficient system. However throughout the summer the boiler will be running sporadically at very low load. It will take a considerable amount of energy to heat up the boiler before it starts to heat the domestic water, and this heat will dissipate to atmosphere before it is called on to heat the water again—very inefficient. The unit has a high efficiency at full load but when its efficiency is averaged over the year, "**seasonal efficiency**," may be surprisingly low.

In this situation, it may be beneficial to install a series of small hot-water heaters for the domestic hot water, although they are not as efficient as the main boiler at full load. Their advantage is that they only run when needed and have low standby losses.

The last statement "*The endless cost of local plant replacement makes it uneconomic compared to a main central plant*," is also true in some cases, but definitely not in other cases. In many organizations, replacement of smaller pieces of equipment is paid for as part of the maintenance operations' budget. On the other hand, major plant replacements are paid for out of a separate "capital" fund. From the point-of-view of the maintenance managers, small, local plant is an endless expense to their maintenance budget, while other budgets fund large, central-plant replacements from the capital account. When it comes to new facilities, the maintenance managers in this situation are likely to be biased against small, packaged-plant equipment, because its replacement costs will all fall on their maintenance budget.

Let us go back to the reasons you wrote down as to why these three statements about central plant might be wrong. Are you still comfortable with them and can you think of others?

This section has deliberately been encouraging you to think about the some of the pros and cons of central plants. Now let us consider three other advantages.

1. "It is so much easier to maintain a high standard of operation and maintenance of a few large units in a single place, instead of lots of little packages all over the site."

   Plant operators know that having complete information about the plant, all the tools in one place, space to work, and protection from the weather, all make central plant maintenance very attractive.
2. "Trying to optimize many package units is really difficult compared to the two identical chillers and boilers in our central plant."

   A few central pieces of equipment can be monitored relatively easily and adjusted by the maintenance staff. When there are many units all over the building, it becomes difficult to remember which one is which and their individual quirks and characteristics.
3. "Heat recovery from central plant chillers and boilers is financially worthwhile."

   Heat recovery is the recovery of heat that would otherwise have gone to waste. For example, the chiller absorbs heat from the chilled water and rejects it through the condenser to atmosphere. In a hospital with substantial hot water loads, some of this waste heat could be used to preheat the domestic hot water and perhaps to heat the air-conditioning reheat coils.

   In a similar way, additional heat can be recovered from boiler flue gases by means of a **recuperator**. This is a device consisting of water sprays in a corrosion resistant section of flue. The water heats to around 50 °C and is pumped through a water-to-water heat exchanger to provide water at about 46 °C. This water can be used in an oversized coil for preheating outdoor air.

   Both the heat-recovery from the chillers and recuperator-heat from the boilers are examples of the improved energy efficiency that is often not economically feasible on the smaller distributed-packaged equipment.

10.3 Boilers

Boilers are pressure vessels used to produce steam or hot water. They are different from **furnaces**, a term usually used to refer to air heaters of any size. Boilers come in a vast range of types and sizes.

The critical design factor is pressure. Boilers are fitted with safety valves that release the steam or water if the pressure rises significantly above the design pressure. The safety-equipment requirement and staff-monitoring requirements are far less stringent for low-pressure boilers, so there is a significant incentive to use low-pressure except where high pressure is needed, or more economic.

A "low-pressure" steam boiler operates at a pressure of no more than 100 kilopascals, 100 kPa, more than the local atmospheric pressure. This means 100 kPa as measured by a **gauge** exposed to the local atmospheric pressure.

In comparison, "low-pressure" hot water boilers are allowed up to 1100 kPa. There is a good reason for the extreme difference in allowable pressure:

> *When a steam boiler fails, the effect can be catastrophic: as the steam expands uncontrollably, it is like a bomb going off. In comparison, when a hot water system bursts, the hot water pours out, but there is no explosive blast like there is with steam. For this reason, "low-pressure" hot water boilers are allowed up to the higher pressure of 1100 kPa.*

Boilers and system components are regulated by codes. These codes are generally written, and updated, by practitioners in their geographic area. The main codes in North America are those issued by the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* while the European Community has their own, and in many areas, much less demanding set of codes. It is therefore critical that a designer or operator knows the local code requirements, since their experience from one place may not be relevant in another jurisdiction.

Boiler Components

Boilers have two sections: the combustion section and the heat transfer section.

The **combustion section** is the space in which the fuel-air mixture burns. *Figure 10-1* shows a commercial boiler with the combustion chamber at the bottom. In this boiler, the base is insulated, but the top and sides of the combustion chamber are heat transfer surfaces. The proportion of air significantly influences the efficiency. If there is excess air, it is heated as it goes through the boiler, carrying heat with it up the chimney. Too little air will cause poor combustion, usually producing noxious combustions products and, in the extreme,

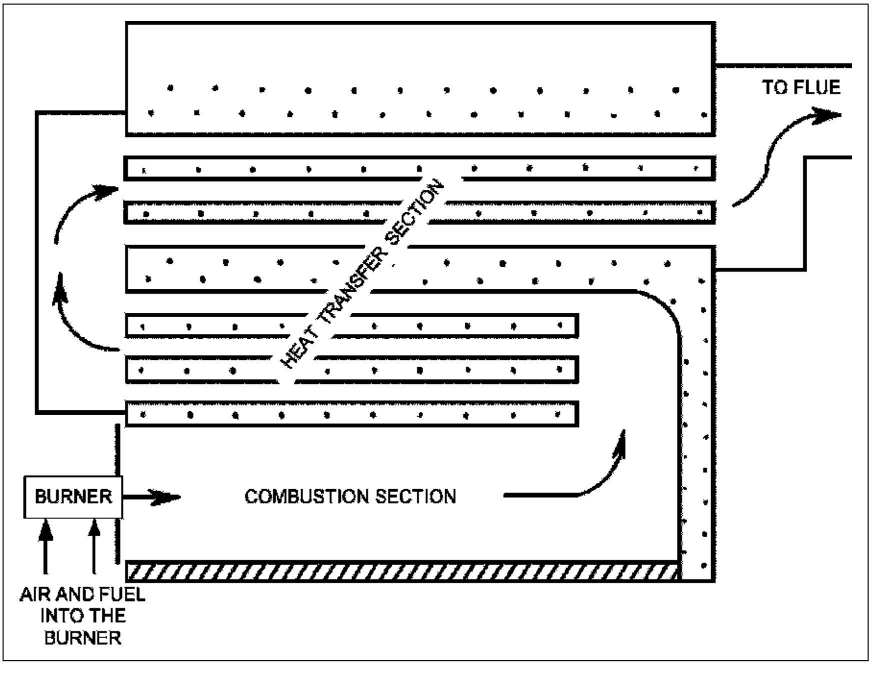

Figure 10-1 Three-Pass Commercial Water Tube Boiler

may cause extra expense by allowing unburnt fuel through the boiler and up the chimney.

The second section of the boiler is the **heat-transfer section**. This section comprises the two upper spaces in *Figure 10-1*, where the hot gases pass right-to-left and then left-to-right, before exiting to go up the flue. In large boilers, the heat transfer section will be fabricated of cast iron sections that are bolted together, or of welded steel plate and tubes. In smaller, particularly domestic, boilers, the heat-transfer section may be fabricated from copper, aluminum, or stainless steel sheet. Boilers can be designed for any fuel: electricity, gas, oil, or coal are the most usual. In this age of recycling and sustainability, there is also an initiative to use urban and manufacturing waste as fuel.

In all boilers, there is a need to modulate, or adjust, the heat input. Gas and oil burners may be cycled "on" and "off." The longer the "on" cycle, the greater the heat input. With the "on-off" cycle, the water temperature or steam output will vary up and down, particularly at low loads. This may not matter, but the efficiency improves and cycling effect is much reduced by having a burner with "high-low-off" cycles.

On larger units, a modulating burner will usually be installed that can adjust the output from 100% down to some minimum output. The burner modulation range is called the "**turn-down ratio**," which is the ratio between full "on" and the lowest continuous operation. A burner that can operate at anywhere from 100% output down to 10% output has a 10:1 turn-down ratio. With a modulating burner, efficiency increases as the output drops. This increase in efficiency is due to the increase in the ratio of heat-exchanger surface-area to heat-input as the output, or **firing rate**, is reduced.

In a coal-fired boiler, the adjustment is achieved by altering the draft of combustion air through the grate. As the air supply increases, the fuel burns faster and hotter, increasing the boiler output.

In general, boiler efficiency drops as the mean temperature of the heated fluid rises. As a result, a hot-water boiler will be more efficient heating water from 65 °C to 75 °C (mean temperature 70 °C) than from 70 °C to 80 °C (mean temperature 75 °C). However, the cooler the mean temperature of the heated fluid, the larger the heat-transfer surfaces must be. Here we have another example of where the designer must consider trading the higher ongoing costs and use of fuel against initial equipment costs.

Because boiler operation is critical for the facility, it is often valuable to have a two-boiler system, so that there is always one available for maintenance back up.

Figure 10-2 shows a hot water system with two boilers.

The boilers, which are connected in parallel so that one can be valved off and serviced or replaced while the other continues to operate.

Two pumps, so that pump failure does not prevent operation.

A pressure tank which maintains system pressure and accommodates the changes in water volume as the system is heated up from cold. The pressure tank often has a membrane in it that separates the water from the air, to prevent absorption of oxygen from the air. If the water level drops too low, more water is pumped into the system; if the pressure needs to be increased, more air is pumped into the top of the tank.

A spring-loaded safety valve, which is provided for each boiler. The valve is set to release at some pre-determined pressure. Then if, for example, the burner controls jammed at full fire, the hot water or steam would be released, protecting the system from bursting.

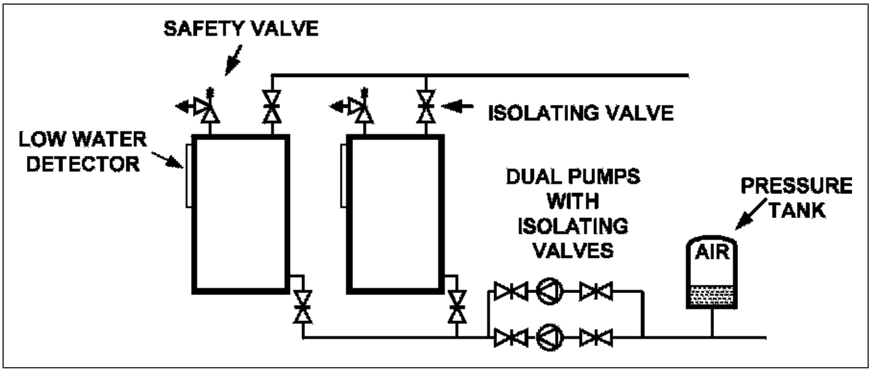

Figure 10-2 Hot Water Heating System with Two Boilers

A low water detector/cutout, which is fitted for each boiler. This safety device prevents the boiler from operating with too little water, and thus overheating, which could easily cause serious damage to the unit.

Dissolved oxygen and other chemicals in normal domestic water can cause severe corrosion and fouling of the heating system, especially with steel pipework. In closed hot water systems, water treatment chemicals may be added as the system is filled. Then, periodically, the system water quality is checked and any needed additional treatment added.

In steam systems, the makeup water must be treated to remove oxygen and dissolved solids before it enters the boiler. This is to prevent the boiler from filling with dissolved solids, since steam (pure water) is continuously boiled off. The steam is very corrosive, so a chemical treatment is included to offset the corrosive characteristics. Thus, there is a need for frequent monitoring, since any failure of treatment can cause problems in the boiler and distribution systems.

With the two boilers in parallel, about half the water will flow through each boiler. If just one boiler is firing, the supply temperature will be based on the average temperature of the return water from the idle boiler and the heated water from the firing boiler. If the supply-temperature requirement equals the temperature that is produced by the operating boiler, then the flow through the idle boiler must be stopped, by closing the inlet valve. For systems with low summer loads, this is ideal since the efficiency is maintained and the idle boiler can be serviced with no interruption of hot-water production.

Note that with steam boilers, if one is running, both will fill with steam to the same pressure. The operating boiler keeps the second boiler hot and ready to fire.

Having considered the heating plant, now let us turn our attention to cooling and consider chillers and cooling towers that, together, provide central chilled water in many buildings.

10.4 Chillers

Chillers are refrigeration machines used to cool water or brine (water containing an antifreeze). The condenser can either be air-cooled or water-cooled. A water-cooled chiller, shown in *Figure 10-3*, is fundamentally the same as the

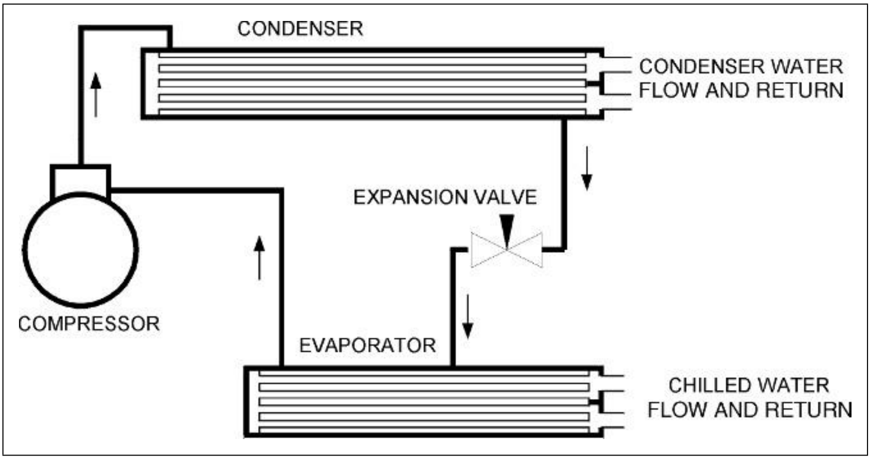

Figure 10-3 Water Chiller with Water Cooled Condenser

basic refrigeration circuit you were introduced to in *Figure 10-3*, Chapter 6, Section 6.3, except that, instead of the evaporator and condenser being air-cooled, they are now water-cooled.

As you can see in the drawing, there are two flows of water, labeled the chilled water and the condenser water. The water that flows through the evaporator coil gives up heat, and becomes cooler. The cooled water is referred to as "**chilled water**." The water that flows through the condenser, called the "**condenser water**," becomes warmer and is piped away to a cooling tower to be cooled before returning to the condenser to be warmed again.

The size of the cooling load determines the requirements for chiller capacity. This requirement can be met by one or more chillers. The standard measure of chiller capacity is the **kilowatt**, a heat absorption capacity of 1000 watts. The historical origin of this unit is from early days of refrigeration, when ice production was the main use. In 24 hours, 12,000 Btu per hour (3.517 kW) produces one ton of ice. Residential air-conditioners are typically two to ten kilowatts; central chillers, delivered as complete, preassembled packages from the factory, can be as large as 8500 kilowatts; and built-up units can go up to 35000 kilowatts.

The main difference between chillers is the type of compressor:

- Smaller compressors are often **reciprocating units**, very much like an automobile engine, with pistons compressing the refrigerant.
- Larger units may have screw or scroll compressors. These compressors are called "**positive-displacement**," since they have an eccentric scroll or screw that traps a quantity of refrigerant and squeezes it into a much smaller volume as the screw or scroll rotates.
- Finally, for 265 kW up to the largest machines, there is the **centrifugal compressor**. It has radial blades spinning at high speed that compress the refrigerant.

The choice of compressors is influenced by efficiency at full and part load, ability to run at excess load, size, and other factors. At times of lower load, the capacity of the reciprocating compressor can be reduced in steps by unloading cylinders. The other types of machine can all have their capacity reduced, to some degree, by using a variable speed drive. In addition, the centrifugal machine has inlet guide vanes that reduce the capacity down to below 50%.

When designing a central plant, it is often worth some additional investment in plant and space to have two 50% capacity chillers instead of a single chiller for the following reasons:

- There is 50% capacity available in case of a chiller failing.
- The starting current is halved, lowering the demands on the electrical system.
- Chiller efficiency is higher, the higher the load on the chiller. When load is lower, the second chiller can be turned off.
- Maintenance work can be carried out during the cooling season during times of low load.
- A variable chilled water flow arrangement is shown in *Figure 10-4*. The chillers are shown with the condensers dotted, since they are not relevant to the chilled water circuit.

As you can see in the diagram, at full load, both chillers and pumps are running, and the valves in the coil circuits are fully open. As the load decreases, the temperature sensors, in front of each coil, start to close their valve, restricting the flow through the coil. The flow sensor, in the chilled-water pipe from the chillers, senses the flow reduction, and restores flow by opening the bypass valve to maintain chiller flow.

When the load drops below 50%, one of the chillers and pumps can switch off, leaving one pump and one chiller to serve the load. The check valve in front of the pump that is "off" closes, to prevent the chilled water from flowing back through it. The output of each chiller is adjusted to maintain the chilled water setpoint temperature. As the cooling load on the two coils drops, the return-water temperature will fall and the chiller will throttle back to avoid over-cooling the chilled water.

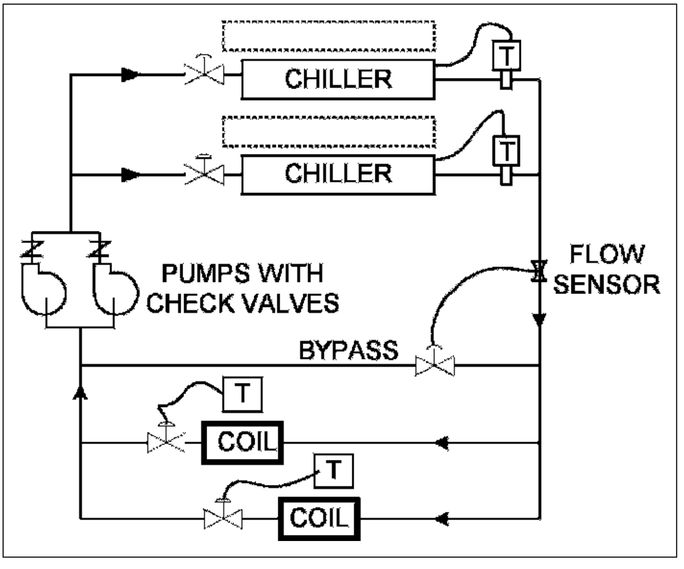

Figure 10-4 Two Chiller Piping with Constant Chiller Flow

Load estimation is quite accurate nowadays, so chillers should be sized to match the estimated load without a "safety" factor. This is particularly important where there is just one chiller, since it has to handle all load requirements, including low load. If the chiller is a little undersized, there will be a few hours more a year when the chilled water temperature will drift up a bit. This is generally far better than over-sizing. Over-sizing costs more in chiller purchase price, larger pumps, and other components. The larger chiller will have a lower operating efficiency, so it will have a higher operating and maintenance cost, as well as more difficulty dealing with low loads.

If failure to meet the load is critical, such as in some manufacturing operations, then the issue of sizing to the load is combined with the issue of having standby capacity for a failed machine. In this case the manufacturing operation should have two units sized to 50% of the load each, with a third 50% unit as standby.

10.5 Cooling Towers

Cooling towers are a particular type of big evaporative cooler.

The following description details the sequence of activity in the natural-draft tower, shown in *Figure 10-5*:

1. Hot water (typically at 35 °C) is sprayed down onto an extended surface "**fill**."

   The fill normally consists of an array of indented plastic sheets, wood boards, or other material with a large surface area.

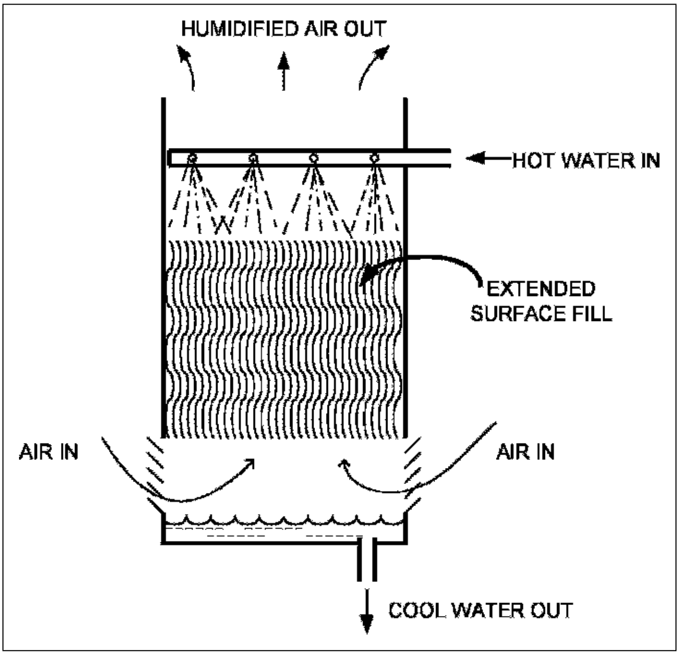

Figure 10-5 Typical Natural-Draft Open Cooling Tower

2. The water coats the fill surface and flows down to drop into the sump at the bottom.
3. At the same time, air is entering near the bottom and rising through the wet fill.
4. Some of the descending water evaporates into the rising air and the almost saturated air rises out of the tower.
5. The latent heat of evaporation, absorbed by the water that does evaporate, cools the remaining water.
6. The cooled water in the sump is then pumped back to the chiller to be reheated.

The cooling performance and consistency of operation under various weather conditions can be greatly improved by using a fan to either drive (forced draft) or draw (induced draft) the air through the cooling tower. The addition of a fan increases the speed of the air flowing through the tower, and smaller water drops may become entrained in the air stream. These drops, if allowed to escape, would be wasted water and could cause wetting of nearby buildings or vehicles. Therefore an array of sheets, called "**drift eliminators**" is included to catch the drops and return the water to the spray area.

In the open cooling tower, the condenser water is exposed, or open, to the air and it will collect dirt from the atmosphere. Strainers will remove the larger particles but some contamination is inevitable. This contamination can be avoided by using a closed-cooling tower, as is shown in *Figure 10-6*. Here, the fluid to be cooled is contained in a coil of pipe in place of the fill. This closed tower is an induced-draft tower (the fan draws the air through the tower) and includes drift eliminators.

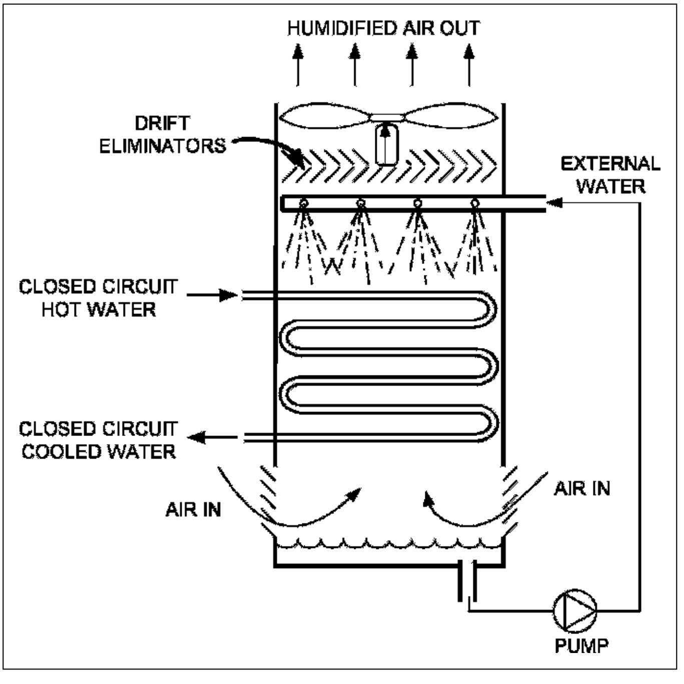

Figure 10-6 Induced Draft, Closed Circuit Cooling Tower

The figure shows water in the closed coil. Alternatively, refrigerant can be passed through the coil and then the refrigerant pipe loop in the tower is the refrigerant circuit condenser.

In a typical cooling tower, at full load, the closed circuit fluid, water or refrigerant, can be cooled 16–20 °C cooler than with an air-cooled coil. This substantially increases the performance of the refrigeration system.

Now that you understand the physical arrangement of the cooling tower, let us consider what is going on inside of the tower. *Figure 10-7* shows the basic operation of the cooling tower. On the left, the warm water is falling and becoming cooler while on the right, air rises through the tower and becomes more saturated with water vapor. The evaporating water absorbs its latent heat of evaporation from the surrounding air and water before it is carried up and out of the tower in the flow of air. In effect, the air is a vehicle for removing the evaporated water.

The cooling performance of the tower is dependent on the enthalpy of the ambient air entering the tower. Remember, the drier and cooler the air, the lower its enthalpy. The lower the enthalpy of the entering air, the greater the evaporation, and therefore, the greater cooling performance.

Surprisingly, the temperature of the air may rise, stay the same, or fall as it passes upwards through the tower.

Look at *Figure 10-8*, and consider these **two scenarios**:

Scenario 1: Air at Condition 1 enters the tower and is heated and humidified as it rises through the tower, to leave the tower virtually saturated at Condition 3. As the water cools, it provides heat to raise the air temperature.

In this first situation, from Condition 1 to Condition 3, the amount of water evaporated to absorb latent heat was equal to the reduction in the water enthalpy less the cooling provided by the cool air being warmed:

Total latent heat of evaporation = Reduction in water enthalpy – air cooling effect

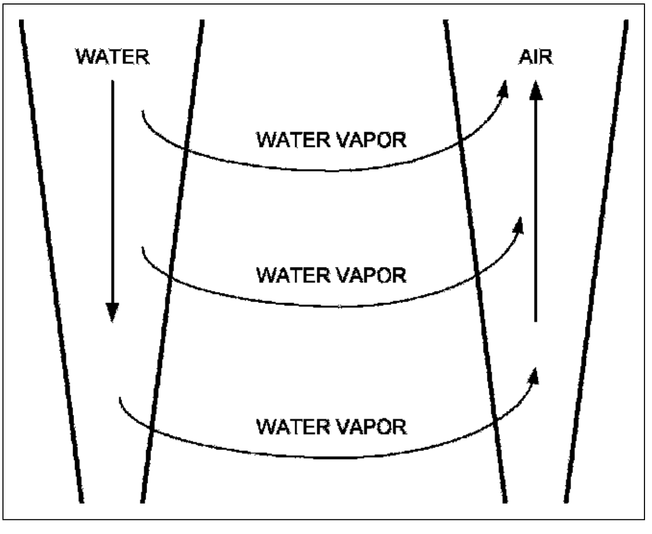

Figure 10-7 Flow of Water, Water Vapor, and Air in a Cooling Tower

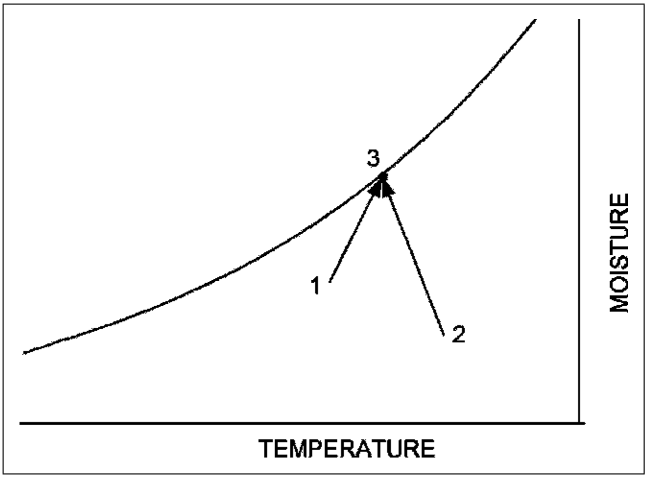

Figure 10-8 Cooling Tower Psychrometric Chart For Air

Scenario 2: In contrast, when warmer air, at roughly the same enthalpy, enters the tower at Condition 2, it will be cooled and humidified as it passes through the tower to leave at Condition 3. The reduction in air temperature is achieved through additional evaporation.

In this situation, from Condition 2 to Condition 3, the amount of water evaporated to absorb latent heat was equal to the reduction in enthalpy of the water plus the heat required to lower the air temperature:

Total latent heat of evaporation = Reduction in water enthalpy + air heating effect

Overall, the tower has approximately the same cooling effect on the water for entering air with the same enthalpy whatever the entering air temperature. However, with the same enthalpy, as the air becomes hotter and dryer more evaporation will take place.

The tower capacity can be reduced in several ways. The fan can be cycled on-and-off, but the frequent starts are very hard on the motor. Better, for both energy conservation and motor life, is to use a two-speed motor and cycle between high, low, and off. For slightly better control and energy savings, a variable speed fan can be used.

The water that is evaporated leaves behind any dissolved chemicals. At full load this can be as much as 1% of flow. In addition, the water cleans the air, removing dust and debris. Since the water is warm and full of nutrients, it is an ideal site for bacterial growth, legionella in particular. It is thus critical that the tower be regularly cleaned and treated to prevent biological growth.

The Next Step

We have considered components, systems, and, in this chapter, central plant. Along the way, equipment has been "controlled" and energy saving has been mentioned. In the next chapter, we will focus on controls and how they work. We will revisit several of the systems you have already studied, and consider their particular control features. Then after controls, we will consider energy conservation in Chapter 12.

Summary

This chapter has been concerned with central plant, specifically with boilers, producing steam or hot water, chillers producing chilled water, and cooling towers that cool the chillers.

10.2 Introduction

Central plants generally require less maintenance than numerous smaller package systems and the equipment usually has a longer life. Other advantages include ease of operation and maintenance in a central location; efficiency; heat recovery options; less maintenance and a longer life. Cons include: cost of installation, space requirements for the equipment and for the distribution pipes. Issues of seasonal efficiency were also raised.

10.3 Central Plant versus Local Plant in a Building

Issues that can influence the choice include installation costs vs. operating costs. For minimum installation cost, the package approach usually wins. However, the central plant has several operational benefits.

10.4 Boilers

Boilers are pressure vessels used to produce steam or hot water. The critical design factor for boilers is pressure. A low-pressure steam boiler operates at a pressure of no more than 100 kPa. Low-pressure hot water boilers are allowed up to 1100 kPa.

Boilers and system components are covered by local code requirements. The safety equipment and staff monitoring requirements are far less stringent for low-pressure boilers so there is a significant incentive to use low-pressure.

Boilers have two sections: The combustion section is the space where the fuel-air mixture burns; the second section of the boiler is the heat transfer section. In all boilers there is a need to modulate the heat input. On smaller units, the efficiency improves and cycling effect is reduced by having a "high-low-off" burner. On larger units, a modulating burner can adjust the output from 100% down to some minimum output. The burner modulation range is called the "turn-down ratio." With a modulating burner, efficiency increases as the output drops and efficiency drops as the mean temperature of the heated fluid rises.

Boilers can run in parallel: With two water boilers, about half the water will flow through each boiler; with steam boilers, if one is running both will fill with steam to the same pressure.

In steam systems, there is a constant loss of water in the condensate return system. To prevent problems with solids build-up in the boiler and distribution pipe corrosion, continuous high quality water treatment is required.

10.5 Chillers

Chillers are refrigeration machines with water, or brine, heating the evaporator. The standard measure of chiller capacity is the kilowatt, a heat absorption capacity of 100 watts. The main difference between chillers is the type of compressor. Smaller compressors are often reciprocating units, larger units may have screw or scroll positive-displacement compressors, and for 250 kilowatts up to the largest machines, there is the centrifugal compressor.

Chillers should be sized to match the estimated load without a 'safety' factor. An oversized chiller will have a lower operating efficiency, so it will have a higher operating and maintenance cost, as well as more difficulty dealing with low loads. When designing a central plant, it is often worth having two 50% capacity chillers instead of a single chiller. If failure to meet the load is mission critical, use two units sized to 50% of the load each, with a third 50% unit as standby.

10.6 Cooling Towers

Cooling towers are a particular type of big evaporative cooler. In the cooling tower, warm water is exposed to a flow of air, causing evaporation, and, therefore, cooling of the water.

The psychrometric chart can be used to illustrate the workings of the cooling tower.

It is often considered worthwhile to over-size the tower to ensure that full chiller capacity will always be available. The tower capacity can be reduced by using a fan that can be cycled on and off; with a two-speed motor that can cycle between high, low, and off; or a variable speed fan can be used.

A danger of cooling towers arises from the warm, nutrient-rich environment that can propagate bacteria growth; therefore, the tower should be regularly cleaned and treated to prevent biological growth. In addition, some water must be bled off to prevent the build-up of dissolved solids.

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