Chapter 2

Mechanical Systems and Equipment Overview

Before we begin taking a look at the various types of systems and the equipment that makes up these systems, now is probably a good time to draw the distinction between "**packaged**" equipment, and equipment that must be "**built up**." A packaged piece of equipment is one that is furnished with some amount of factory mounted and installed controls devices. These controls may partially or even completely allow the equipment to operate, without any other added controls. In our examples from the previous chapter, the hot water boilers are "packaged" pieces of equipment. Each boiler can operate via its factory installed control system, with virtually no other controls required. Just hook up the gas, water, and power, connect it to the piping/pumping system, and let it fire!

The exhaust fan from our first example is typical of a piece of equipment that must be "built up." The fan itself comes with no controls at all, and must be equipped with controls upon installation. An air handling unit that comes from the factory as nothing more than a fan, a hot water coil, and a mixing box, is another example of a piece of equipment that needs to be "built up." Controls required to make this air handling unit operate include, but are not limited to, a fan controller, a control valve for the hot water coil, a damper actuator for the mixing box, and some kind of a temperature controller.

It's interesting to note that just because a piece of equipment comes with factory controls, it doesn't mean that it can't be it can't be part of a built up "system." Either of the two boilers from our hot water system example have the ability to operate completely via their own factory installed controls. Yet in the example they are additionally controlled by a central boiler controller. A "hierarchy of control" exists here, and will be explored more deeply in the chapters to come.

With the distinction made between packaged equipment and built up equipment, let us now begin our discussion on the various types of mechanical systems. We can break down these systems into three major types: airside, waterside, and "miscellaneous." We'll talk about the airside first...

Airside Systems and Equipment

The topic of airside systems encompasses those systems and types of equipment that are primarily dealing with the movement and conditioning of air. As such, we will be taking a look at fan systems and air handling equipment, as well as zoning equipment. What follows is a brief description of some typical air systems and associated equipment.

Rooftop Units

Rooftop units, in the purest sense, are packaged air handlers designed to provide single zone heating and cooling. Heating is typically gas-fired, though it could be electric, and cooling is done by refrigeration, with the entire "refrigeration cycle" integral to the unit. They are packaged in the sense that virtually every control device required for unit operation, less a space thermostat, is factory furnished and mounted. Although fundamentally designed for single zone applications, they can be adapted for use in multizone applications as well.

Make-up Air Units

Make up air units, as the name implies, are air handling units designed to replace, or "make up" air that's being exhausted by some exhaust system. Typically designed for 100 percent outside air, they primarily operate to maintain a constant discharge air temperature. They can be bought as packaged units with gas-fired heating, or they can be built up systems with electric or steam heating coils. Although cooling isn't a concern in many make-up air applications, it can be added. The packaged make-up air unit manufacturer may be able to offer cooling as part of the "package." If not, a separate cooling coil would need to be added. This being the case, and for a built up unit requiring cooling as well, the cooling coil can be a chilled water coil, or a DX coil with a remote condensing unit.

Chapter 5

End Devices

End devices are devices that play a critical part in the control of mechanical systems. The controllers in the previous section measure and process a sensed variable, make a decision as to what type of action should be implemented, and act upon this decision by producing an appropriate output, or command. If nothing is around to receive the commands, though, then no actions are taken, and nothing happens. The controllers need something to receive their commands, and to carry them out. This section explores the various end devices that we encounter in every day life in the HVAC biz.

Relays and Contactors

A relay is basically an electrically operated switch. Rated for a specific coil voltage, the relay's switch, or "contacts" change state when the proper voltage is applied to the "coil" of the relay. So a relay typically consists of contacts and a coil. The coil is capable of accepting a voltage, and the contacts change state when the voltage is applied. A relay with a single switch or set of contacts is referred to as a single pole relay. A relay with two independent sets of contacts is referred to as a double pole or two-pole relay. Three and four-pole relays are also commonly available. Figure 5-1 illustrates a simple single pole relay.

With a relay, we have the ability to switch an electrical circuit in and out, remotely, via another, completely isolated electrical circuit. Without getting "too much" into the construction of a relay and its functions and applications, consider the following example: a remote bulb temperature controller monitors outside air temperature, and makes when the temperature drops below 40 degrees. Upon this, an electrical circuit is completed to the coil of a relay. The relay has four isolated contacts (four-pole relay). Now, four separate circuits of electric radiant baseboard heating are required to be enabled whenever the outside air

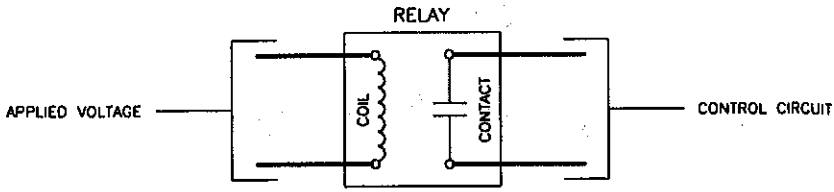

Figure 5-1. Conceptual diagram of a relay. Voltage applied to the coil of the relay causes a "change of state" of the contact. The normally open contact closes upon energizing the coil. The closed contact completes a separate circuit, by allowing current to flow.

temperature is below the setting of the outside air temperature controller. The controller can't do this on its own, because the four heating circuits are independent of each other and must remain isolated. However, the relay can do it, with its four separate switches, each switch handling a circuit of electric heating. The temperature controller, with one switch, controls the relay, with four switches, which in turn takes control of the four electric heating circuits.

Relays are normally rated for low power "pilot duty" applications, and are used more so as a "building block" in the implementation of control "logic" circuits. Relay logic, or ladder logic, is a method of using relays to accomplish some function or arrive at some outcome, given certain required conditions. By connecting contacts of different relays in series and in parallel, in some meaningful manner, and controlling the coils of the relays as a function of some condition, we can perform "operational logic." With the result of this logic, we can control some other end devices in their intended manner. Ladder logic is a tool in the controls designer's tool belt, and has been since the beginning. Yet nowadays many applications requiring any extent of logic can be implemented with a programmable digital controller with inputs and outputs, the ladder logic being replaced by programming. Nevertheless, relays and relay logic will continue to be a simple, cost-effective means of control in the modern world.

Contactors are essentially relays whose contacts can handle much more power. The previous example of the four-pole relay operating the electric baseboard heating would more likely be done with a contactor. For the sake of putting forth some order of magnitude here, let's briefly discuss something called "current rating." Current is "electrical flow." When a switch is closed to complete an electrical circuit, current flows

Chapter 15

Exhaust Fans and Systems

Exhaust fans are a fundamental component of most HVAC systems. Exhaust requirements of a typical office building range from bathroom, kitchen, and conference room exhaust to equipment and telecomm room exhaust. Industrial exhaust applications encompass fume hood exhaust systems and general warehouse exhaust systems. Applications that call for the movement of air from an interior space to the outdoors are those requiring the removal of odors, fumes, smoke, heat, contaminants, or just "stagnant air" from the spaces served. Ventilation requirements for most commercial and industrial facilities mandate the continuous introduction of outside air via the main fan systems that are conditioning the building. As such, in addition to all of the above-mentioned needs for exhaust systems, additional exhaust may be required simply to balance out the amount of outside air being brought in.

The mechanical designer often has his hands full with trying to 1) account for all of the required exhaust for a building, 2) determine how to handle all of the various exhaust requirements, 3) strike a balance between supply and exhaust requirements in the building, and 4) select exhaust fans and systems in accordance with his design. Needless to say, the issue of exhaust in a typical HVAC system is of substantial concern, and must be considered not only fan by fan, but also on a building-wide level. In general, as a whole, the entire ventilation system (the "V" in HVAC) must operate to maintain the building at a fairly constant, fairly neutral building static pressure. The mechanical designer must be mindful of this, and must address this issue up front, with at least a minimal amount of foresight into how (and when) the various exhaust systems will operate, what effects they have on the overall balance of the building pressure, and what can be done to counteract the effects in order to maintain an acceptable pressure in the building.

Hopefully the last two paragraphs demonstrated the importance of exhaust and ventilation in buildings requiring HVAC systems. While this chapter is not meant to explore the design concepts behind ventilating systems, it should at least be known that it is an important and crucial part of the overall mechanical design process of an HVAC system. It's not as simple as saying, "Hey, this room needs exhaust, put a fan in there!", without being aware of the effect that this exhaust system has on the overall building-wide ventilation requirements. With all of this said, we'll move on and leave all of that fun stuff to the mechanical systems designer!

Exhaust fans take on various shapes and styles. **Roof mounted exhaust fans** are, yep, usually up there on the roof. They are ducted from the fan, through an opening in the roof, down to the spaces that they serve to exhaust. Roof fans are the popular choice for most general exhaust applications (see Figure 15-1). **Sidewall exhausters** poke through the side of a wall. Depending on the setup, they may or may not be ducted. This is the type of fan that you would commonly find in a warehouse, there to provide general warehouse ventilation. **Ceiling fans** are ducted fans that reside in the ceiling space and typically serve bathrooms and other such spaces. The fan itself sits in the ceiling, and is ducted from there to the outdoors. **In-line fans** are fans that are ducted to and from, the fan being "in line" with the duct system. An alternative to roof and sidewall fans, in-line fans have their place in HVAC applications.

Before we talk about the different methods of controlling exhaust fans, it might behoove us to cover a few of the electrical aspects of exhaust fans, as they do impact the methods of controlling them. Exhaust fan motors (or any motors, for that matter) will be either single-phase or three-phase, this basically being a function of the required size of the motor. When we use the term size, we refer not to the physical size of the motor, but to its strength, or "horsepower" (HP). Small motors with less than 1 HP are commonly referred to as fractional horsepower motors. There is a practiced cutoff point between single-phase motors and three-phase motors, that typically occurs in that fractional horsepower range. Specifically, the amp draw of a motor gets to a point to where the use of a single-phase motor is simply not economical, and a three-phase motor must be used. For instance, a 3/4 HP fan motor, at 120 volts single-phase, draws close to 15 amps of current. The same size motor at 460 volts three-phase draws only a couple of amps. The reduction in current trans-