Chapter 5

Zones

Contents of Chapter 5

Instructions

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

Objectives of Chapter 5

We have talked, in a general way, about spaces and zones earlier in Chapter 2, Section 2.4. In this chapter we will go into detail about the reasons for choosing zones, economic considerations, and how zone controls operate. After studying the chapter, you should be able to:

Define a space and give examples of spaces.
Define a zone and give examples of zones.
List a number of reasons for zoning a building and give examples of the reasons.
Make logical choices about where to locate a thermostat.

5.1 Introduction

In Chapter 2, we discussed the fact that spaces have different users and different requirements, and in Chapter 4 we discussed issues of thermal comfort. To maximize thermal comfort, systems can be designed to provide independent control in the different spaces, based on their users and requirements. Each space, or group of spaces, that has an independent control is called a "**zone**."

In this chapter, we consider what constitutes a zone, the factors that influence zone choices, and the issues concerning location of the zone thermostat.

5.2 What is a Zone?

We have introduced and used the words "space" and "zone" in previous chapters.

To recap, a "**space**" is a part of a building that is not necessarily separated by walls and floors. A space can be large, like an aircraft hanger, or small, like a personal office.

A "**zone**" is a part of a building whose HVAC system is controlled by a single sensor. The single sensor is usually, but not always, a thermostat. Either directly or indirectly, a **thermostat** controls the temperature at its location.

A zone may include several spaces, such as a row of offices whose temperature is controlled by one thermostat in one of the offices. On the other hand a zone may be a part of a space, such as the area by the window in a large open area office.

The zone may be supplied by its own, separate HVAC system, or the zone may be supplied from a central system that has a separate control for each zone.

Some examples of spaces and zones are shown in *Figure 5-1*.

Having established the meaning of a zone let us now consider the various reasons for having zones in a building's HVAC system.

5.3 Zoning Design

There are several types of zones. These zones are differentiated based on what is to be controlled, and the variability of what is to be controlled. The most common control parameters are: thermal (temperature), humidity, ventilation, operating periods, freeze protection, pressure, and importance.

The most common reason for needing zones is variation in thermal loads. Consider the simple building floor plan shown in *Figure 5-2*. Let us assume it has the following characteristics:

Well-insulated
A multi-story building, identical plan on every floor
Provided with significant areas of window for all exterior spaces
Low loads due to people and equipment in all spaces
Located in the northern hemisphere.

In this example, we will first consider the perimeter zone requirements on intermediate floors due to changes in thermal loads. These changes can occur because of the movement of the sun around the building during the course of a sunny day. These changes in thermal loads take place because the spaces receive solar heat from the sun, called **solar gain**.

The designer's objective is to use zones to keep all spaces at the setpoint temperature. The **setpoint temperature** is the temperature that the thermostat is set to maintain.

Early in the morning, the sun rises in the east. It shines on the easterly walls and through the east windows into spaces NE and SE. Relative to the rest

Space	Zones	Reason for zones
A theatre used for live performance	1. Audience seating	The audience area requires cooling and high ventilation when the audience is present.
	2. Stage	The stage requires low ventilation and low cooling until all the lights are turned on, and then high cooling is required.
Indoor ice rink	1. Spectators	Spectators need ventilation and warmth.
	2. Ice sheet	The ice sheet needs low air speeds and low temperature to minimize melting.
	3. Space above	The space above the spectators and ice may need moisture removal to prevent fogging.
Deep office	1. By the windows	People by the window may be affected by the heat load from the sun and by the cool window in winter, external factors.
	2. Interior area	The interior zone load will change due to the occupants, lights, and any equipment – a cooling load all year.
Large church or mosque	1. Within 1.8 meters of the floor	The occupied zone is within 1.8 meters of the floor and needs to be comfortably warm or cool for congregation.
	2. Above 1.8 meters	The space above does not need to be conditioned for the congregation.
Airport	1. Lobby 2. Security 3. Retail outlets 4. Check-in	This is a huge space with a variety of uses, and extremely variable occupancy and loads.Each zone requires its own conditions.

Figure 5-1 Examples of Spaces and Zones

of the building, these spaces, NE and SE, need more cooling to stay at the setpoint temperature.

As the morning progresses toward midday, the sun moves around to the south so that the SE, S, and SW spaces receive solar gain. However, the solar heat load for the NE space has dropped, since the sun has moved around the building.

As the afternoon progresses, the sun moves around to the west to provide solar gain to spaces SW and NW.

Zoning Design Considerations

While most of the spaces have been experiencing a period of solar gain, the two N spaces have had no direct solar gain. Thus, the load in the two N spaces is only dependent on the outside temperature and internal loads, like lights.

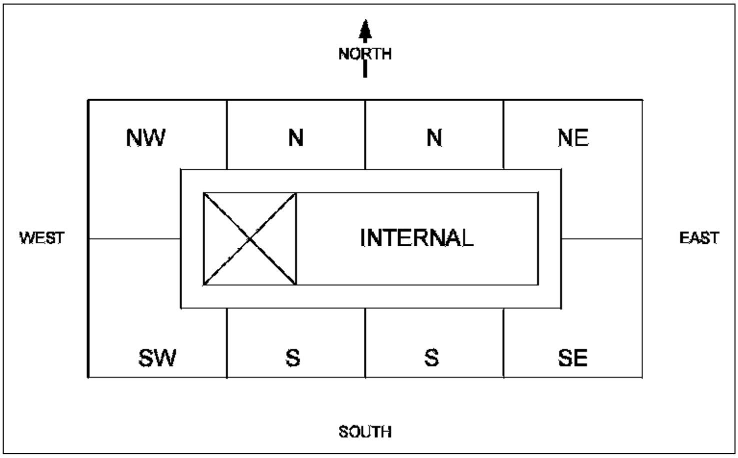

Figure 5-2 Building Plan

These two factors are approximately the same for each space. Therefore these two N spaces could share a common thermostat to control their temperature and it would not matter whether the thermostat was located in one space or the other. These two spaces would then be a single zone, sharing a single thermostat for the temperature control of the two spaces.

The two S spaces have similar thermal conditions with high solar gain through the middle of the day. Both of the two S spaces could also share a thermostat, since they have similar solar and other loads.

The remaining spaces: NE, SE, SW, and NW, all have different solar gains at different times. In order to maintain the setpoint temperature, they would each need their own thermostat.

Thus, if we wanted to deal with the solar gain variability in each of these eight spaces, we would need six zones. Note that this discussion is considering zoning on the basis of only solar loads.

In real life there may not be enough funds allocated for six zones. Thus, the designer might combine the two N spaces with the NE space; on the basis that a little overheating in NE space in the early morning would be acceptable. Then the choice is between N and NE spaces for the thermostat location. Since it is generally better to keep the majority happy, the designer would choose to put the thermostat in an N space. However, if the designer knew that the NE space was going to be allocated to a high-ranking executive, the choice could be to put the thermostat in the NE space!

In a similar way the two S spaces and the SE space could be combined, since they all experience the midday solar gain. Lastly, the SW and NW spaces could be combined, since they both experience the high solar gain of the late afternoon.

In this way, the six zones could be reduced to three. The effect would be to have considerable loss of temperature control performance, but there would also be a coincident reduction in the installation cost.

The balance between performance and cost is a constant challenge for the designer. Too few zones could lead to unacceptable performance and potential liability, while excessive zoning increases costs and maintenance requirements.

Interior and Roof Zones

The discussion so far has ignored both the internal zone and the effect of the roof. The internal zones on intermediate floors are surrounded by conditioned spaces. As a result, they never need heating, are not affected by solar gain and need cooling when occupied all year. In a cool climate this can often create a situation where all exterior zones require heating but the interior zones still require cooling. The different behavior of interior zones can be dealt with by putting them on a separate system.

The top floor perimeter zones are also different from the intermediate floor zones since they have the added summer roof solar gain and the winter heat loss. On the top floor, interior zones are also affected by solar gain and winter heat loss. As a result the top floor design needs special consideration with additional cooling and heating abilities.

Choosing zones is always a cost/benefit trade-off issue. In an ideal world, every occupant would have control of their own part of the space. In practice the cost is generally not warranted. As a result the designer has to go through a selection process, like we did in this example, to decide which spaces in a building can be combined. In our example, we only considered solar gain, but in a real building the designer must consider all relevant factors. Common factors are outlined below:

Thermal Variation

Solar gain. As shown in the example, solar gain through windows can create a significant difference in cooling load, or the need for heating, at varying times of the day according to window orientation.

Wall or roof heat gains or heat losses. The spaces under the roof in a multi-floor building will experience more heat gain in summer, or heat loss in winter, than spaces on the lower floors.

Occupancy. The use of spaces and the importance of maintaining good temperature control will influence how critical zoning is.

Equipment and associated heat loads. Equipment that gives off significant heat may require a separate zone in order to maintain a reasonable temperature for the occupants. For example, a row of private offices may have worked well as a single zone, but the addition of a personal computer and a server in one of those offices would make it very warm compared to the other offices. This office could require separate zone design.

Freeze protection in cold climates. In a cold climate, the perimeter walls and roof lose heat to the outside. Therefore, it is often advantageous to designate the perimeter spaces as separate heating zones from those in the core of the building.

Ventilation with Outside Air

Occupancy by people. In a typical office building, the population density is relatively low. However, conference rooms have a fairly high potential population density, and therefore a variable ventilation load. As a result, conference rooms are often treated as different zones for ventilation *and* for time of operation, compared to the offices in a building.

Exhausts from washrooms. As noted in Chapter 4, washrooms may be treated as a separate zone and provided only with exhaust. The exhausted air may be made up of air from the surrounding spaces.

Exhausts from equipment and fume hoods. Often, equipment is required to operate continuously, although the majority of the building is only occupied during working hours, Monday to Friday. In these cases, it may be advantageous to treat spaces with continuous exhaust as a separate zone or even service them from a separate system.

Time of Operation

Timed. In many buildings, the time of operation of spaces differs. For example, an office building might have several floors occupied by tenants who are happy with full service only during working hours from Monday to Friday. One floor could be occupied by a weather forecasting organization that requires full operation 24 hours a day, seven days a week. In this case it might be advantageous to have the building zoned to only provide service when and where needed.

On demand – manual control or manual start for timed run. In many buildings there are spaces that are only used on occasion. They may be designed as separate zones, which are switched on when needed. The activation can be by means of an occupancy sensor, or by a manual start switch in the space, which runs the zone for a predetermined time. For example a low-use lecture theatre in a university building might be provided with a push button start that would energize the controls to run the space air conditioning for two hours before switching off.

Humidity

Mold protection in hot, humid climates. In hot, humid climates, the moisture can infiltrate into the building through leaks in the walls, doors, and windows. This can cause the building contents to mold unless dehumidification is activated.

Humidity sensors can be installed in individual representative zones that will measure relative humidity. If these sensors detect excess humidity in these zones, they can trigger the system to provide system-wide dehumidification. The control system can be designed to provide dehumidification without ventilation during unoccupied hours.

Museum and art gallery requirements for good humidity control. High quality museums and art galleries have to maintain accurate control of the humidity in the storage and exhibit areas. This humidity control is generally not required in other spaces like offices, restaurants, merchandising, and lobby areas. Therefore museums and art galleries often have at least two systems, to provide the collections with the required humidity control.

Pressure

Air flows from places at a higher pressure to places at a lower pressure.

A difference in pressure can be used to control the movement of airborne contaminants in the building. For example, in a hospital, the tuberculosis (TB) patient rooms can be kept at a negative pressure compared to surrounding areas, to ensure that no TB germs, known as bacilli, migrate into surrounding areas.

In a similar way, kitchens, smoking rooms, and toilets are kept negative to contain the odors by exhausting more air than is supplied to the spaces. Conversely, a photographic processing laboratory is kept at a positive pressure to minimize the entry of dust.

Zoning Problems

One recurring problem with zoning is change in building use after the design has been completed. If there are likely to be significant changes in layout or use, then the designer should choose a system and select zones that will make zone modification as economical and easy as practical.

Having reviewed the reasons for choosing to zone a building, let's consider the control of the zone.

5.4 Controlling the Zone

The most common zone control device is the thermostat. It should be placed where it is most representative of the occupants' thermal experience. A thermostat is usually mounted on the wall. It is designed to keep a constant temperature where it is, but it has no intelligence; it does not know what is going on around it. The following are some of the issues to be aware of when choosing the thermostat location.

- Mounting the thermostat in a location where the sun can shine on it will cause it to overcool the zone when the sun shines on it. The sun provides considerable radiant heat to the thermostat. The thermostat interprets the radiant heat as though the whole location had grown too warm, and it will signal the air conditioning system that it requires a lower air temperature. As a result, the occupants will be cold, and cooling expenses will escalate.
- In many hotels, the thermostat is mounted by the door to the meeting room. If the door is left open, a cold or warm draft from the corridor can significantly, and randomly, influence the thermostat.
- In some conference or assembly rooms, the thermostat is mounted above lighting dimmer switches. These switches produce heat that rises up into the thermostat, signaling that the room is warmer than it actually is. If the dimmers are left alone and their output is constant, the thermostat can be set at a setpoint that allows for the heating from the dimmers. Unfortunately the dimmers heat output changes if the dimmer setting is adjusted, so adjusting the lighting level will alter the thermostat performance.
- Mounting a thermostat on an outside wall can also cause problems. If the wall becomes warm due to the sun shining on it, the thermostat will lower the air temperature to compensate. This offsets the increased radiant temperature of the wall on the occupants, but usually the effect is far too much and the room becomes cool for the occupants. In a similar way, in the winter the wall becomes cool and a cool draft will move down the wall over the thermostat, causing it to raise the air temperature to compensate.
- There are times when heat from equipment can offset the thermostat. A computer mounted on a desk under a thermostat can easily generate enough heat to cause the thermostat to lower the air temperature. If the computer is only turned on periodically, perhaps to drive a printer, this offset will occur at apparently random times, creating a difficult problem for the maintenance staff to resolve.
- If the thermostat is mounted where it is directly affected by the heating or the cooling of the space, it will likely not maintain comfortable conditions. For example, suppose that the air-conditioning system's air supply blows

directly onto the thermostat. In the heating mode, the thermostat will warm up quickly when the hot air stream blows over it. Therefore, it will quickly determine that the room is warm enough and turn off the heat. The result will be rapid cycling of the thermostat and the room will be kept cooler than the setpoint temperature. Conversely, when in the cooling mode, the thermostat will be quickly cooled and will cycle rapidly, keeping the room warmer than the setpoint temperature.

If the system has been adjusted to work satisfactorily during the heating season, then when the system changes over to cooling, the thermostat will keep the zone warmer than it did when in the heating mode. Complaints will result and the thermostat will get adjusted to satisfactory operation in the cooling mode. When the season changes, the shift will reverse and readjustment will be required once more. This is the sort of regular seasonal problem that occurs in many air-conditioning systems.

- Wall-mounted thermostats generally have a cable connecting them to the rest of the control system. The hole, tubing, or conduit can allow air from an adjoining space or the ceiling to blow into the thermostat, giving it a false signal.
- Lastly, mounting a thermostat near an opening window can also cause random air temperature variations as outside air blows, or does not blow, over the thermostat.

Humidity

While this discussion has been all about thermostats and poor temperature control, the issues are very similar for humidity, which is controlled by **humidistats**. The result of failing to consider placement of the humidistat will be poor humidity control. Remember, as we discussed in Chapter 2, Section 2.2, if the temperature rises, then relative humidity drops and conversely, if the temperature falls then the humidity rises.

The Next Step

Having considered the issues around zones, we are now going to consider typical systems that provide zone control. In Chapter 6 we will be considering single zone systems and in Chapter 7, systems with many zones.

Summary

5.2 What is a Zone?

A zone is a section of a building where the HVAC system is controlled by a single sensor. The single sensor is usually, but not always, a thermostat. Either directly or indirectly, a thermostat controls the temperature at its location.

5.3 Zoning Design

Zones are chosen based on what is to be controlled and the variability of what is to be controlled. The most common control parameters include temperature, humidity, ventilation, operating periods, freeze protection, pressure, and organizational position.

5.4 Controlling the Zone

The most common zone control is the thermostat. It should be placed where it is most representative of the occupants' thermal experience. A thermostat does its best to keep a constant temperature where it is. It has no intelligence; it does not know what is going on around it. Therefore, in order to maintain a setpoint for the zone, the thermostat must be located away from sources affecting temperature, like drafts, windows, and equipment.