Commercial Comfort System (CCS) Changeover Bypass (COBP) Zoning System Design

Application Note

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Introduction

This document describes general layout considerations and procedures when designing a Commercial Comfort System (CCS) Changeover Bypass (COBP) Zoning System. This document does not describe how to wire, install, set up or troubleshoot your CCS. For information on these topics, refer to the *Related Documentation* section.

Note: The procedures in this document are not intended to replace local codes and regulations in place by Authorities Having Jurisdiction (AHJ).

Related Documentation

Table 1 lists documentation related to the Commercial Comfort System (CCS).

Table 1: CCS COBP Zoning System Related Documentation

For Information On	See Document	LIT or Product No.
Features, Benefits, and Applications of the CCS	*Commercial Comfort System (CCS) Product Bulletin*	*LIT-12011347*
	Application and Installation of Controls for Commercial Comfort Systems Training CD-ROM *http://www.johnsoncontrols.com/publish/us/en/products/building_efficiency/resources/johnson_controls_institute0/packaged_learning.html*	*Product No. C-3100-EN*
Configuring Settings and Parameters within the CCS	*Commercial Comfort System (CCS) System Manager and Zone Coordinator User's Guide*	*LIT-12011444*
Operating Modes and Strategies of the CCS	*Commercial Comfort System (CCS) Operation Overview Technical Bulletin*	*LIT-12011617*
Installation and Specifications of a Controller or Component of the CCS Changeover Bypass (COBP) Zoning System	*CCS System Manager and Zone Coordinator Installation Instructions*	*LIT-12011644*
	CCS Single-Zone (SZ) and Change-Over Bypass (COBP) Single Packaged Unit (SPU) Controllers Installation Instructions	*LIT-12011544*
	CCS Zone and Bypass Damper Controllers Installation Instructions	*LIT-12011545*

Key Concepts

COBP Zoning System Overview

In a COBP zoning system, the Rooftop Unit (RTU) uses a constant volume fan. Air volume control is achieved by bypassing air from the RTU supply duct back into the RTU return air duct on the RTU. This bypass air is controlled based on a static pressure sensor located in the supply air duct downstream of the unit supply air discharge. The bypass damper modulates open and closed based on the static pressure in the duct. The discharge air temperature at the RTU varies in relation to the demand from the zones. Figure 1 provides an overview of the COBP Zoning System.

Typically, the RTUs used for the COBP zoning system have both heating and cooling capabilities. The fan supplies a constant volume of cold or hot air to the duct system, which is then fed to the individual zones by modulating zone dampers. Each zone controller sends its heating or cooling needs to the Zone Coordinator. The Zone Coordinator determines the RTU mode of operation (heating, cooling, or fan only) depending on the needs from the zones. The Zone Coordinator uses a voting system to determine the correct mode of operation (see *Zone Voting Logic*).

Each zone controller determines whether to use the air supplied by the RTU based on its heating and cooling setpoints. For example, if one of the zones calls for cooling when the temperature in the duct is above the zone's cooling setpoint, then the zone moves to its minimum cooling position to minimize warm air from entering the space. The zone dampers within the COBP zoning system are usually pressure dependent. However, pressure independent zone boxes can also be used.

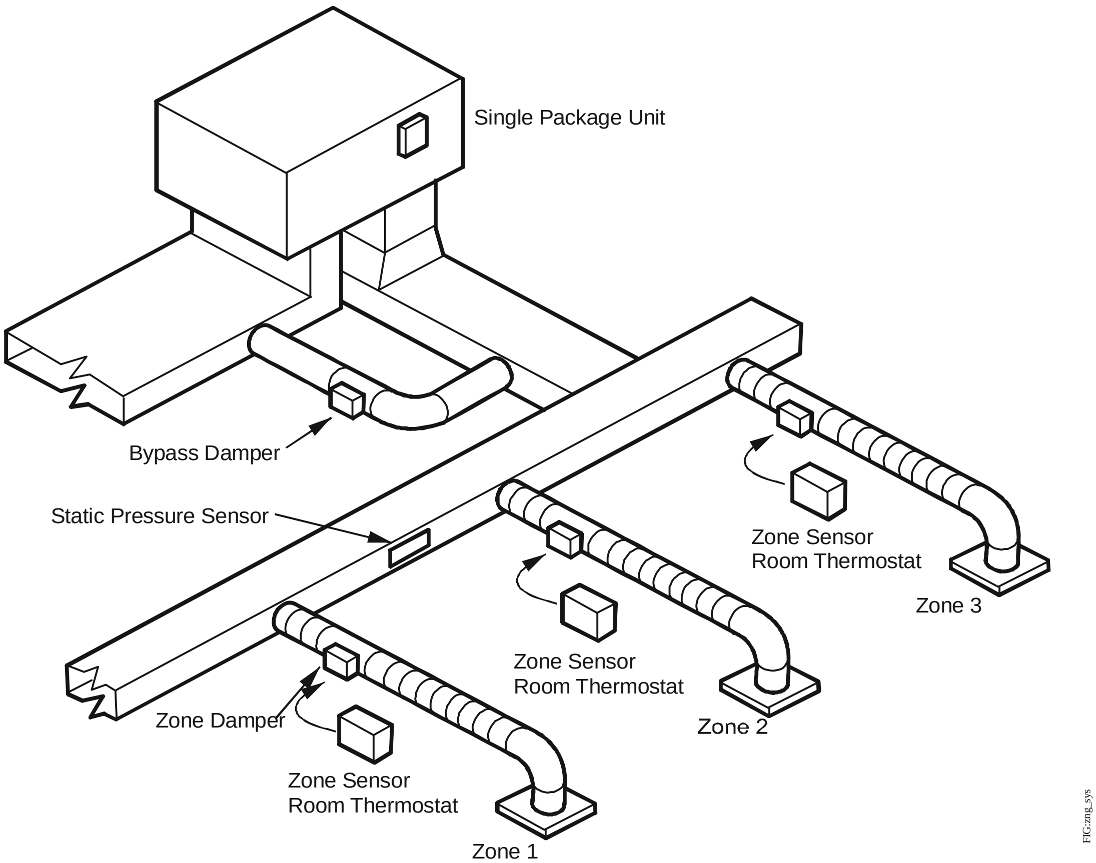

Figure 1: COBP Zoning System

Zone Voting Logic

In the zone voting logic used by the COBP zoning system, the Zone Coordinator monitors the status of the individual zones. These zones vote for either heating or cooling based on how the current zone temperature deviates from the current zone temperature setpoint. The zone coordinator processes the votes, determines whether the RTU should provide heating or cooling to the zones, and commands the RTU to the appropriate mode based on this decision. The Zone Coordinator continues to monitor the zones and change the operating mode of the RTU as needed to accommodate the zone needs.

COBP Zoning System Guidelines

COBP zoning system design requires you consider the following guidelines when designing your zoning system and layout:

- group zones with similar load profiles on the same RTU
- keep perimeter zones separate from interior zones on the same RTU
- ensure each zoned RTU has a minimum of 3 to 4 zones
- ensure each zoned RTU supports a maximum of 24 voting zones
- size the bypass dampers for the remaining airflow volume when all zones are at minimum airflow (Bypass Airflow [cfm] = Unit Airflow [cfm] – All Zones Minimum Airflow [cfm])

Design Considerations

Design considerations include load diversity and partial load conditions for both heating and cooling.

Load Diversity

When creating your COBP Zoning System design, be sure not to mix interior zones that require cooling all year with exterior zones that may only require constant heating during the winter months. Group similar loads on an individual RTU and use more than one zoning system if necessary. Special loads can be handled by using separate constant volume RTUs.

Partial Load Conditions

Cooling

Consider the following factors when applying a COBP zoning system for hot weather operation:

- Low Ambient Temperature Lockout - During cold weather months, it is common for mechanical systems to have low temperature lockouts that protect equipment from damage if operated under these conditions.

  If the rooftop unit services interior zones with thermal loads that require cooling when outside temperatures are below the safe operating limits for your equipment, you must use an economizer and/or low ambient mechanical cooling provisions to prevent damage to the equipment. The CCS control system is designed to integrate these safeguards into zoning system operation. Economizers lower utility costs and provide comfort under conditions when it is not possible to operate the mechanical cooling system.

- Low Supply Air Temperatures - Under lightly loaded conditions, you can bypass much of the supply air back into the return air side of the RTU. Bypassing the supply air lowers the supply air temperature and increases the risk of reaching the low temperature safety limit. If the supply air low temperature safety limit is exceeded, the control system cuts off the mechanical cooling to protect it from damage. Excessive cycling of the mechanical system may occur if this condition persists. Comfort may also suffer if the system cannot run long enough to satisfy cooling demands. To avoid excessive cycling of the mechanical system, implement the following operational and design changes:

  Operational Changes:

  - Increase cooling minimum airflow or damper position settings to allow more airflow during cooling operation. Be careful to avoid minimum settings that are too high and cause overcooling.
  - Increase the static pressure setpoint to reduce the amount of air being bypassed. Be aware of increased noise levels and operating costs if you use excessive static pressures. This technique may cause overcooling of the spaces due to increased airflow at minimum positions.

  Design Changes:

  - Avoid oversizing the unit by carefully calculating loads. Oversizing the unit is a common cause of excessive low supply air temperature cycling.
  - Use an economizer to improve operation and ventilation during cool weather when cooling loads are minimal.
  - Bypass the air into the ceiling plenum instead of into the return air intake. Use precaution with this method since you may get dumping of cold air from the return air grills. This method works best with plenum returns, but cannot be used with ducted returns.

Heating

Consider the following factors when applying a COBP zoning system for cold weather operation:

- High Supply Air Temperatures - Under lightly loaded conditions, you can bypass much of the supply air back into the return air side of the RTU. Bypassing the supply air raises the supply air temperature and increases the risk of reaching the high temperature safety limit. If the supply air high temperature safety limit is exceeded, the control system cuts off the mechanical heating to protect it from damage. Excessive cycling of the mechanical system may occur if this condition persists. Comfort may also suffer if the system cannot run long enough to satisfy heating demands. To avoid excessive cycling of the mechanical system, implement the following operational and design changes:

Operational Changes:

- Increase heating minimum airflow or damper position settings to allow more airflow during heating operation. Be careful to avoid minimum settings that are too high and cause overheating.
- Increase the static pressure setpoint to reduce the amount of air being bypassed. Be aware of increased noise levels and operating costs if you use excessive static pressures. This technique may cause overcooling of the spaces due to increased airflow at minimum positions.

Design Changes:

- Avoid oversizing the unit by carefully calculating loads. Oversizing the unit is a common cause of excessive low supply air temperature cycling.
- Bypass the air into the ceiling plenum instead of into the return air intake. Use precaution with this method since you may get dumping of cold air from the return air grills. This method works best with plenum returns, but cannot be used with ducted returns.

Override Conditions

After-hours overrides can produce aggravated partial load conditions in both the heating and cooling modes. A single zone being overridden for after-hours use most commonly causes the problem. This usage causes the rooftop equipment to operate for only one zone. CCS allows you to use a global override to trigger a group of zones. This method allows the system to operate with sufficient load to reduce cycling caused by light load conditions.

Building Pressurization

Building pressurization problems may reduce economizer effectiveness due to doors remaining open during economizer operation. To avoid these problems, use power exhaust functions. For systems with ducted returns, use power exhaust fans. The return duct pressure drop causes most barometric relief dampers to function poorly or not at all. The RTU has the ability to control power exhaust whenever the economizer is operating.

Detailed Procedures

General Zoning Design Overview

Designing a COBP zoning system requires seven basic steps:

1. Determining the number and location of zones
2. Sizing zone dampers
3. Sizing the central unit
4. Planning the duct system design
5. Selecting air diffusers
6. Sizing bypass dampers
7. Locating the static pressure sensor and probe

Determining the Number and Location of Zones

A single air handler unit can have no more than 24 zones and no fewer than three zones. The primary precaution when applying the COBP zoning system is selecting the zoning, ensuring no zone is at the maximum (design) heating or cooling load when another zone requires the opposite temperature air to satisfy its load.

For example, depending on the wall, ceiling, and floor material and location within the building (top or middle floor), a typical floor of a building usually has several distinct temperature or control zones uniquely affected by the outdoor load. These zones are depicted in Figure 2.

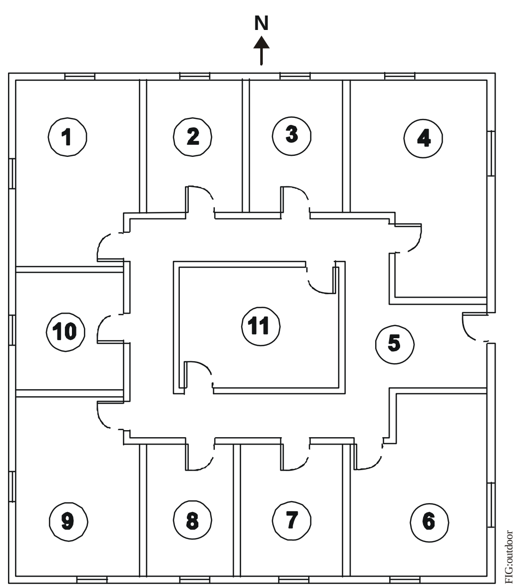

Figure 2: Outdoor Load Locations and Zones

Depending on the size of the building and partition layout, some of the zones may overlap or may not require zoning. In Figure 2, Zone 11 could be multiple conference or computer rooms where additional zoning would be required, and Zone 5 could be a corridor where no zoning is required. Similarly, Zones 7 and 8 could have no external windows and no partitions between them and comprise a single zone. Some zones could be divided into multiple offices with full partitions between them, thus requiring separate damper assemblies because of different internal loads, but the same external load.

Generally, the greater the number of individual zones, the greater the comfort. The designer has to evaluate the specific building, balancing the costs of multiple zones to match the building requirements.

It is important to recognize purely internal zones, such as Zone 11 in Figure 2, which may contain separate offices, conference, and computer rooms. The internal zones could easily have high cooling requirements, whereas external zones (1, 2, 3) could be at or near design heating load. Applying a single zoning system to this arrangement of zones may result in poor zoning system performance and problems meeting the desired comfort levels of the occupants.

The interior zones with cooling only loads should be served by a separate RTU (that could be zoned between multiple rooms with a similar load profile). System performance may be compromised, and frequent change-over from the heating to the cooling mode occurs during the heating season if internal zones are combined on the same air conditioning unit serving perimeter zones. The exposure to the sun has a large effect on the loading of the building. With the building zoned as shown in the following section, Zones 6, 7, 8, 9, and 10 should be put on one RTU and Zones 1, 2, 3, 4 and 5 on another RTU (for the best control). Zone 11 should be on a separate single zone constant volume RTU.

See *Appendix: Example Zoning Designs* for multiple building layout scenarios and zoning recommendations.

Sizing the Zone Dampers

Sizing the zone dampers depends upon multiple factors within your zone. Refer to guidelines found in the American National Standards Institute (ANSI)/American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 62.1-2010 *Ventilation for Acceptable Indoor Air Quality* for information on properly sizing zone dampers.

See Table 2 and Table 3 for zone damper sizes based upon airflow.

Table 2: Round Zone Damper Assemblies

Air Velocity through Damper (FPM)	Damper Size, in. (Area - Sq. Ft)					
	6 in. (0.188)	8 in. (0.338)	10 in. (0.532)	12 in. (0.769)	14 in. (1.050)	16 in. (1.375)
	Airflow (cfm)					
750 FPM - Zone	141	254	399	577	788	1,031
1000 FPM - Zone	188	338	532	769	1,050	1,375
1250 FPM - Zone	235	423	665	961	1,313	1,718

Table 3: Rectangular Zone Damper Assemblies

Air Velocity through Damper (FPM)	Damper Size, W x H in. (Area - Sq. Ft)					
	8 x 12 in. (0.42)	8 x 14 in. (0.5)	8 x 16 in. (0.58)	10 x 16 in. (0.77)	10 x 20 in. (1.00)	14 x 18 in. (1.33)
	Airflow (cfm)					
750 FPM - Zone	315	375	435	578	750	998
1000 FPM - Zone	420	500	580	770	1,000	1,330
1250 FPM - Zone	525	625	725	963	1,250	1,663

Sizing the Central Unit

When sizing the central unit, use a dependable load estimating program to calculate the individual zone loads. Because of load diversity, the central unit should be selected for the instantaneous peak load, not the sum of the peak loads, as would be done with a constant volume single zone system. Consider the following when sizing the central unit:

- Size the peak cooling load based on the month, day, and hour of the greatest total building system load.
- Size the heating load for the lowest design temperature with an additional margin for morning pickup. This margin is generally recommended to be 20 to 25% of base design.

Note: In addition to unit size, consider that RTUs with multiple heating stages tend to provide better temperature control than single-stage RTUs.

Planning the Duct System Design

The CCS system uses a low pressure duct design. To reduce noise problems, duct pressures should not exceed 1 in. Water Column (W.C.).

Avoid undersizing primary trunk ducts, especially for pressure dependent systems. Pressure dependent systems are zone damper assemblies without the airflow sensor. With larger trunk ducts, it is easier to assure relatively constant pressure to each zone. Duct runs should be as short as possible, and the trunk duct system kept as symmetrical as possible to facilitate system balancing. Wherever possible, run the trunk ducts above corridors and locate the zone dampers above corridors to reduce the noise in the space and facilitate service of the units. Trunk ducts should be sized for no more than 0.1 in. W.C. drop per 100 feet, and a maximum duct velocity of 2,000 feet per minute (FPM).

Selecting Air Diffusers

Air motion directly contributes to occupant comfort. Selecting air diffusers for a COBP zoning system requires more care than a constant volume system due to varying airflow into the zones. We recommend slot diffusers due to their superior performance at low airflows. Because the zone airflow is variable volume, lower cost round or rectangular diffusers that were satisfactory for constant volume may prove unsatisfactory with a COBP zoning system. These diffusers may result in dumping cold air at low flows in the cooling mode, and insufficient room air motion at low airflows in the heating mode. Although high air motion in the heating mode can be undesirable, a slot diffuser with a high induction ratio generally helps to reduce room air stratification when the heating comes from a ceiling diffuser. Linear slot diffusers should be properly selected for the airflow and throw suited to the specific installation or zone.

Sound level and throw at design flow are additional factors to consider in diffuser selection. Generally, multiple diffusers results in lower sound levels in the space, but this must be balanced with the additional hardware and installation costs. We recommend that slot diffusers be located near the perimeter or outside wall with the airflow directed into the room. Consult your diffuser supplier for proper diffuser sizing and location.

Sizing the Bypass Dampers

Bypass dampers modulate on a signal from a duct static pressure sensor to bypass air from the supply duct back into the return air duct. If the duct static pressure exceeds the adjustable setpoint, then the damper opens to bypass more air; and if the static pressure drops below the setpoint, it closes to bypass less air.

Size the bypass dampers for the remaining airflow volume when all zones are at minimum airflow. You can use the following equation to help size bypass dampers for the correct airflow: Bypass Airflow (cfm) = Unit Airflow (cfm) – All Zones Minimum Airflow (cfm).

To size the damper, select a damper based on calculated bypass cfm and a maximum velocity between 1,750 and 2,250 FPM. When determining the bypass duct size, be sure to consider any transition fittings and associated pressure drops. See Table 4 and Table 5 for bypass damper selections.

Whenever possible, use a single bypass damper and round duct for the bypass. If space limitations or total airflow requires it, use a rectangular damper.

Locating the Static Pressure Sensor and Probe

For proper control of the bypass damper, the static pressure sensor must be properly located. Figure 3 shows proper sensor location.

In addition, the duct static pressure probe must be located in an area where supply plenum pressure is stable. Be sure to observe the following guidelines when locating the probe:

- locate at least 10 ft (3.05 m) downstream from the Air Handling Unit (AHU)
- locate at least 5 ft (1.52 m) downstream from the first turn off of the supply plenum trunk
- avoid locating excessively far from the supply plenum trunk or past multiple zone taps

For a supply plenum tee, locate two probes at least 5 ft (3.05 m) downstream from the main supply trunk on opposing supply plenum branches. Connect the probes with a tee fitting to average the duct static pressure readings from the two supply plenum branches (Figure 3).

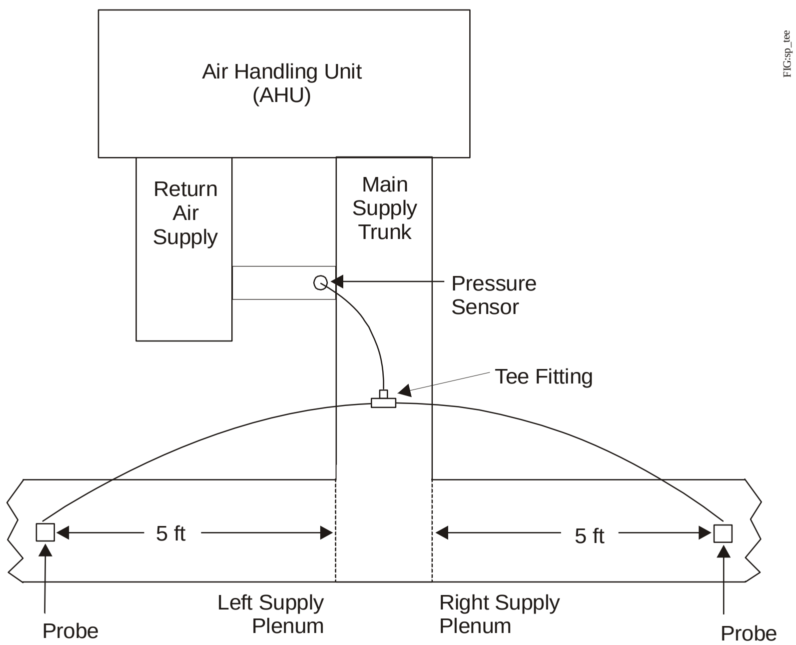

Figure 3: Locating Pressure Sensor and Probe in a Supply Plenum Tee

Table 4: Round Bypass Damper Assemblies

Air Velocity through Damper (FPM)	Damper Size, in. (Area - Sq. Ft)					
	6 in. (0.188)	8 in. (0.338)	10 in. (0.532)	12 in. (0.769)	14 in. (1.050)	16 in. (1.375)
	Airflow (cfm)					
1500 FPM - Bypass only	282	507	798	1,154	1,575	2,062
1750 FPM - Bypass only	329	592	931	1,346	1,838	2,405
2000 FPM - Bypass only	376	676	1,064	1,538	2,100	2,749
2250 FPM - Bypass only	423	761	1,197	1,730	2,363	3,094

Table 5: Rectangular Bypass Damper Assemblies

Air Velocity through Damper (FPM)	Damper Size, W x H in. (Area - Sq. Ft)			
	14 x 12 in. (0.83)	16 x 16 in. (1.36)	20 x 20 in. (2.25)	30 x 30 in. (5.44)
	Airflow (cfm)			
1500 FPM - Bypass only	1,245	2,040	3,375	8,160
1750 FPM - Bypass only	1,453	2,380	3,938	9,520
2000 FPM - Bypass only	1,660	2,720	4,500	10,880
2250 FPM - Bypass only	1,868	3,060	5,063	12,240

Special Considerations for Large Units (30 Tons and Over)

Due to the large airflow capacities of larger units, careful consideration is essential when designing an effective zoning system. Consider the following factors when designing a COBP zoning system with a larger RTU:

- Use constant volume units in your zoning system design.
- Size the bypass dampers for the remaining airflow volume when all zones are at minimum airflow: Bypass Airflow (cfm) = Unit Airflow (cfm) – All Zones Minimum Airflow (cfm)
- Use rectangular dampers instead of round dampers due to the larger air volume. (See Table 3 for rectangular damper sizes and cfm ratings.)
- Locate bypass dampers towards the **end** of the main supply duct run to prevent bypassing large amounts of conditioned air.
- Always have a minimum of six zones on large units due to the high airflow capacities.
- Set zone damper total minimum airflow settings equal to or preferably greater than 30% of the unit's rated cfm to prevent excessive noise in the system.
- Install a high duct static safety switch (such as Johnson Controls® P32 Series Sensitive Pressure Switch or similar) to prevent over-pressurization of the duct work.

Appendix: Example Zoning Designs

Figure 4 shows a building layout with seven zones. Three zones have an eastern exposure (5, 6, 7), four zones have a western exposure (1, 2, 3, 4), two zones have a northern exposure (4, 5) and two zones have a southern exposure (1, 7). This building can be controlled from a single constant volume air handler because all the zones have the same exterior exposure. The layout lacks entirely internal zones making similar load requirements for each zone.

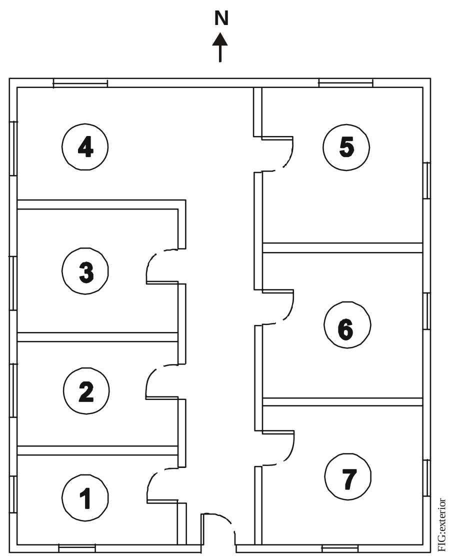

Figure 4: Zone Layout with External Zones Only

Figure 5 shows a building with seven zones. Four of the zones have a northern exposure (1, 2, 3, 4) and the other three zones have a southern exposure (5, 6, 7). We recommend installing two separate zoned RTUs because northern and southern exposures have different effects on a building. The solar load is larger on the southern exposure than the northern exposure.

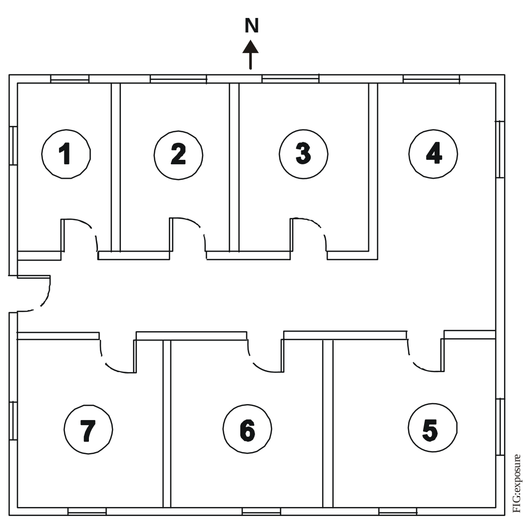

Figure 5: Zones with Northern and Southern Exposures

Figure 6 shows a combination manufacturing facility and office area. The space temperature in the individual zones, numbered 1 through 7, are controlled by two RTUs. Zones 2, 3, and 4 are considered interior zones and are controlled by one RTU. Zones 1, 5, 6, and 7 are considered exterior zones and controlled by another RTU. A single constant volume RTU is used for each of the Zones 8 through 12.

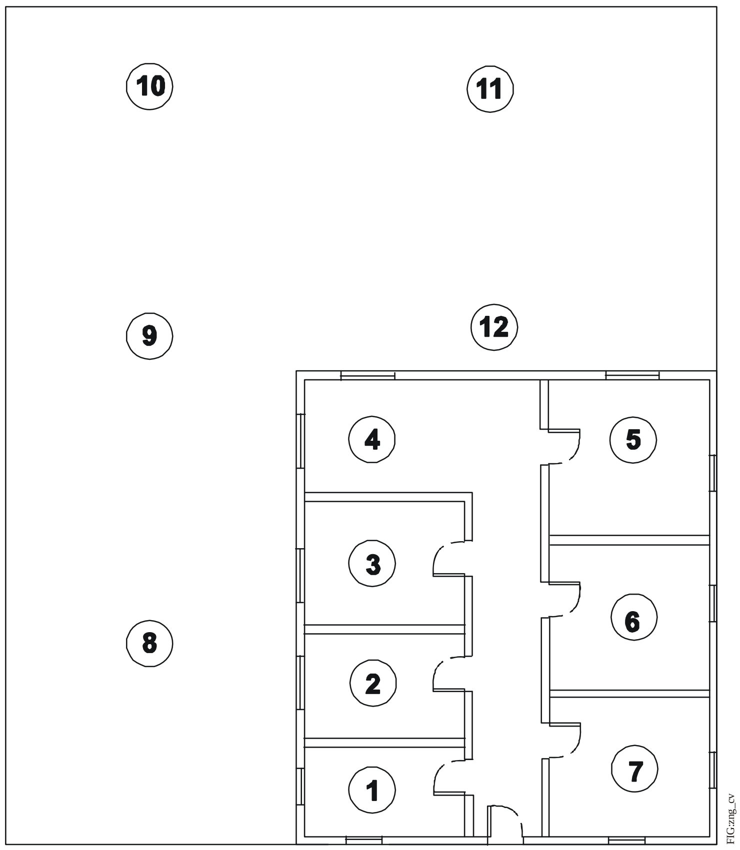

Figure 6: Zoning and Constant Volume Units

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507 E. Michigan Street, Milwaukee, WI 53202