Refrigeration, Air Conditioning, Heating, and Ventilation

Wireless Multi-Zone HVAC Control

Courseware Sample

20588-F0

Lab-Volt®

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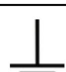
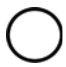
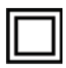
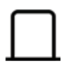
Safety and Common Symbols

The following safety and common symbols may be used in this manual and on the Lab-Volt equipment:

Symbol	Description
DANGER	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
WARNING	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
CAUTION	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger* sign , indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger
	Caution, lifting hazard
	Caution, hand entanglement hazard
	Notice, non-ionizing radiation
	Direct current
	Alternating current
	Both direct and alternating current
	Three-phase alternating current
	Earth (ground) terminal

Safety and Common Symbols

Symbol	Description
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

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Preface

This line of products introduces students to the basic principles of heating, ventilation, and air conditioning (HVAC) systems. It covers all components commonly used in HVAC systems today, and teaches students the skills required to work in the HVAC field. Throughout the activities of the manuals, students develop practical knowledge on how to install, maintain, and troubleshoot HVAC systems, and they become familiar with a large variety of HVAC systems as well as with their different characteristics.

The training systems in this line of products are specially designed for full modularity. This particularity allows them to be used to implement a wide variety of HVAC systems and circuits. The training systems also incorporate actual residential, industrial, and commercial devices in order to give students an experience that is as close as possible to actual work in the HVAC field.

About This Manual

Manual objectives

When you have completed this manual, you will be able to:

- understand how HVAC systems, sub-systems, and components operate.
- wire HVAC control circuits.
- read and understand technical documents such as diagrams.
- identify and document potential malfunctions and correct them if possible.

Safety considerations

Safety symbols that may be used in this manual and on the Lab-Volt equipment are listed in the Safety Symbols table at the beginning of the manual.

Safety procedures related to the tasks that you will be asked to perform are indicated in each exercise.

Make sure that you are wearing appropriate protective equipment when performing the tasks. You should never perform a task if you have any reason to think that a manipulation could be dangerous for you or your teammates.

Reference material

Refer to the textbook titled *Refrigeration and Air Conditioning Technology* written by Bill Whitman, Bill Johnson, John Tomczyk, and Eugene Silberstein.

Additional information can be found on the website of the different component manufacturers.

Prerequisite

Basic electrical knowledge is a prerequisite to this series of manuals. It is assumed that you have a general understanding of these concepts:

- Voltage, current, and power, both in dc and ac circuits
- Basic electrical components (resistor/potentiometer, inductor, capacitor, diode, transistor)
- Ohm's law
- Series and parallel circuits
- Electrical measurement using a digital multimeter (DMM)

Systems of units

Units are expressed using the U.S. customary system of units followed by the units expressed in the SI system of units (between parentheses).

To the Instructor

You will find in this Instructor Guide all the elements included in the Student Manual together with the answers to all questions, results of measurements, graphs, explanations, suggestions, and, in some cases, instructions to help you guide the students through their learning process. All the information that applies to you is placed between markers and appears in blue.

Accuracy of measurements

The numerical results of the hands-on exercises may differ from one student to another. For this reason, the results and answers given in this manual should be considered as a guide. Students who correctly performed the exercises should expect to demonstrate the principles involved and make observations and measurements similar to those given as answers.

Sample Exercise
Extracted from
the Student Manual
and the Instructor Guide

Rooftop Unit Control

EXERCISE OBJECTIVE

In this exercise, you will:

- Connect the RTU controller inputs and outputs to the RTU section of the main module.
- Observe how the RTU controller commands the fan, the heating elements, and the cooling elements.
- Observe how the RTU controller controls the economizer and bypass dampers.
- Learn the difference between occupied and unoccupied modes.
- Troubleshoot the system.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

DISCUSSION

Zoning information

The following figure illustrates the information that the RTU controller exchanges with the zone controllers. In short, the RTU controller informs the zone controllers of the outdoor temperature, the current occupancy mode, and the RTU active mode. For their part, the zone controllers only ask for hot or cool air.

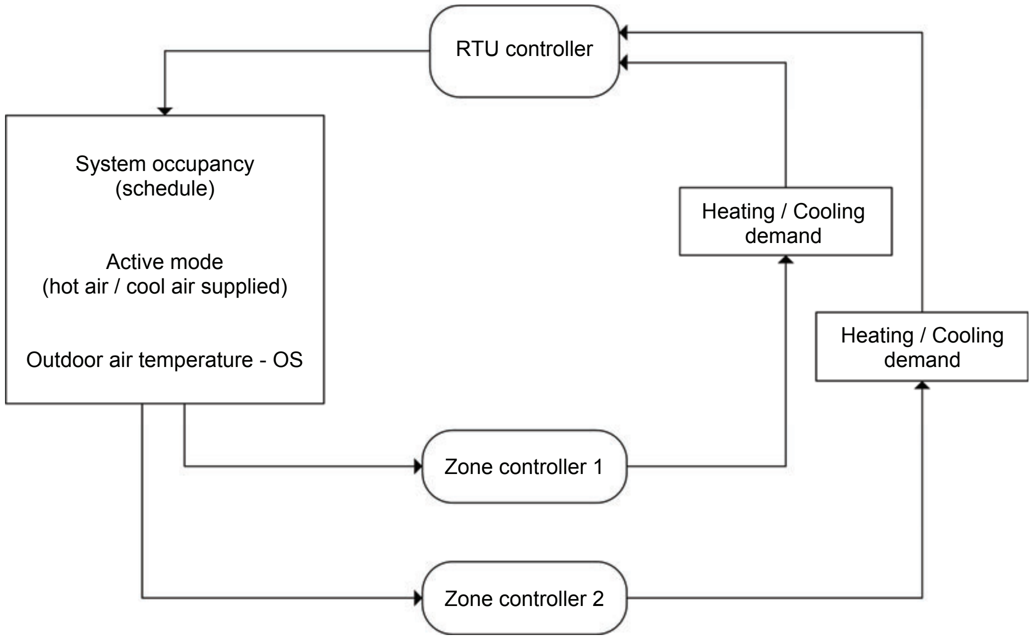

Figure 37. Information exchange between the RTU controller and the zone controllers.

Behavior of the RTU

It is not easy to get a grasp of how the whole RTU operates. Therefore, let us consider some simpler, separate tasks that it accomplishes.

Scheduling

Outside of working hours, having cooler or hotter temperatures than normal does not create discomfort to anyone. Additionally, extending the acceptable temperature range provides for substantial energy savings because the heating and cooling elements can be turned off for longer periods.

Figure 38. The occupied period may correspond to regular office hours.

Scheduling means programming the RTU controller so that it behaves differently when the building is occupied than when it is not. Figure 39 shows how a week can be divided into occupied (green) and unoccupied (light gray) periods. Special events may also be added to account for holidays.

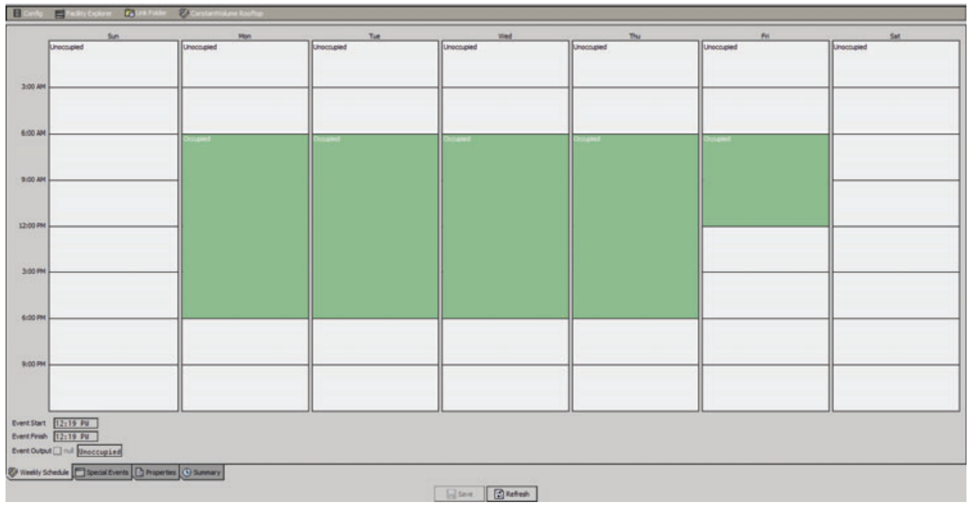

Figure 39. Occupied period (in green) on a supervisory controller.

In occupied mode, the blower is always on to maintain a proper ventilation of the building.

In unoccupied mode, the blower can be turned off if the zone temperatures fall within the unoccupied temperature dead band and the heating and cooling elements are off. However, the blower is turned back on if a zone has a heating or cooling demand to make the conditioned air reach the zone.

The bypass damper opens if the blower is off to avoid overpressure when the blower restarts.

Free cooling with the "economizer"

There are two means by which the RTU provides cool air to the zones:

- using cooling coils through which the supplied air passes, or
- opening a damper that lets some cool air from outside enter as shown in Figure 40.

The latter case is called "**free cooling**" because no energy is used to chill the air. However, this scenario is only possible when the outside air is below a certain temperature set point and the zones require cooling. With the multi-zone system, this means that:

- the outdoor temperature (OS) is below the free cooling set point (Chngstpt) of 55°F (13°C) by default.
- the zone temperature is higher than the current cooling set point (Occ CL or Unocc CL).

Higher supply temperature (DS) accelerates the opening of the economizer damper.

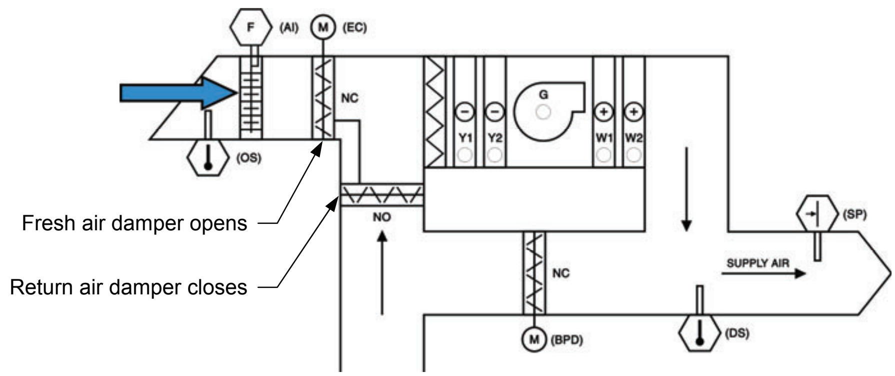

Figure 40. Free cooling.

Static pressure and the role of the bypass damper

In a variable air volume (VAV) system, the flow of air varies depending on the opening and closing of various dampers. When all zone dampers are fully open, maximum airflow is needed. On the other hand, if many zone dampers go to their minimum opening position, the need for air supply decreases. In this case, **static pressure** in the supply duct rises and more air enters the zone for a same damper opening. However, if static pressure somehow remains stable, the air flow rate delivered to the zones can stay relatively constant.

To regulate the supplied air flow and prevent overpressure, the fan speed or the opening of a **bypass damper** is varied according to the reading of a **pressure transmitter**. The multi-zone system shown in Figure 41 is an example where the fan speed remains constant but a bypass damper opens as static pressure increases.

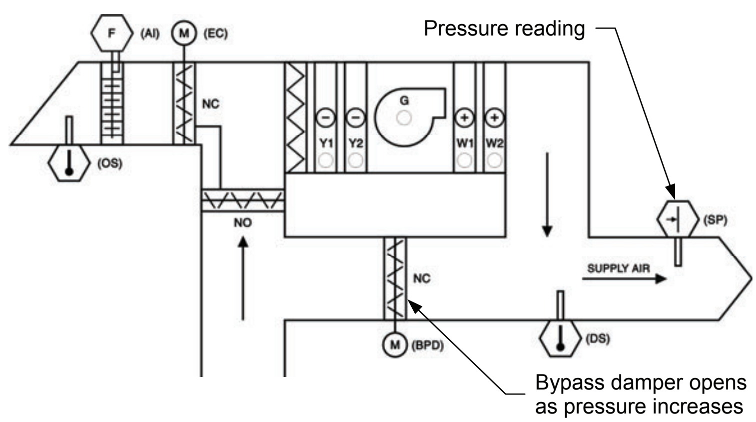

Figure 41. The bypass damper opens when static pressure is high.

Analog control

Electrical signals convey information to and from the controllers. Each controller **analog input** receives a low-level electrical signal (in volts or milliamperes) that corresponds to a real physical value. For example, the static pressure (SP) signal of the RTU controller is a 0-5 V input. Figure 42 shows that 0 V corresponds to 0 inH_2O (0 Pa) and 5 V corresponds to 2 inH_2O (500 Pa). If 2.5 V are received, this means a pressure of 1 inH_2O (250 Pa).

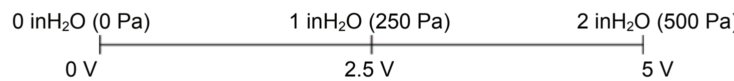

Figure 42. Correspondence between an analog input signal and static pressure.

The same principle applies to **analog outputs**. The multi-zone system dampers operate on 0-10 V signals. If the RTU controller sends 5 V, the damper should open half-way. Note that, in this case, the damper will remain partly open even if no voltage is received to ensure minimal air circulation.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Set up and connections
- User menu of the RTU controller
  Setting the system mode. Setting the schedule for one day. Setting the clock.
- Fan control and cooling
  Free cooling scenario (economizer).
- Static pressure control with the bypass damper
- Heating
- Guided troubleshooting
  Inserting a fault. Observation. Deduction. Measurements. Conclusion.
- End of the exercise

PROCEDURE

Set up and connections

This section shows the recommended setup and wiring to test the RTU controller behavior.

1. Install all the system modules in the workstation as shown in Figure 43.

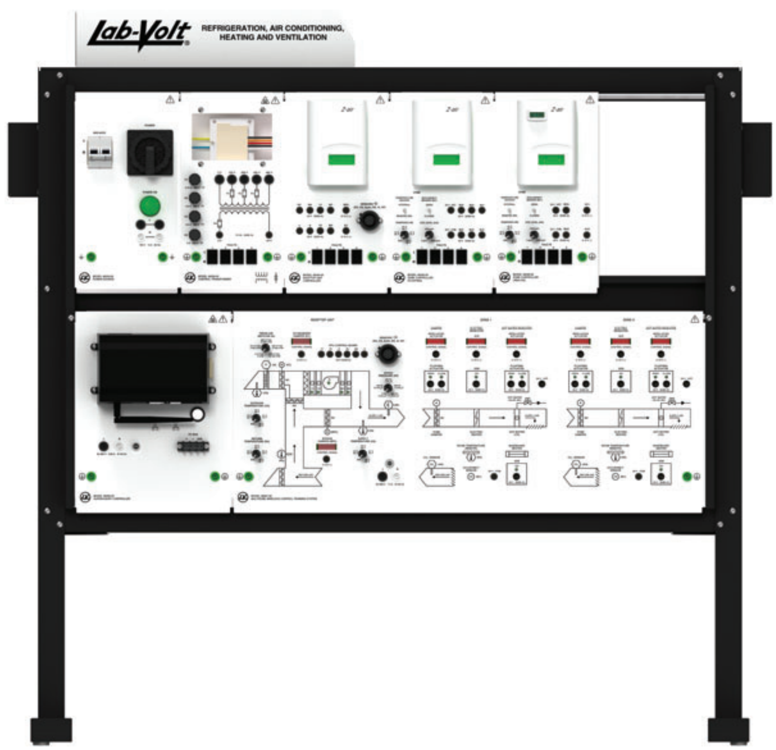

Figure 43. All modules installed on the workstation.

2. Make sure that the main power switch on the power source is set to the O (off) position, and then connect the module to an ac power outlet.

⚠ CAUTION

Always check the power specification of a module before connecting it to the power source.

3. Use the test leads to connect the power source, control transformer, RTU controller, and RTU as shown in Figure 44.

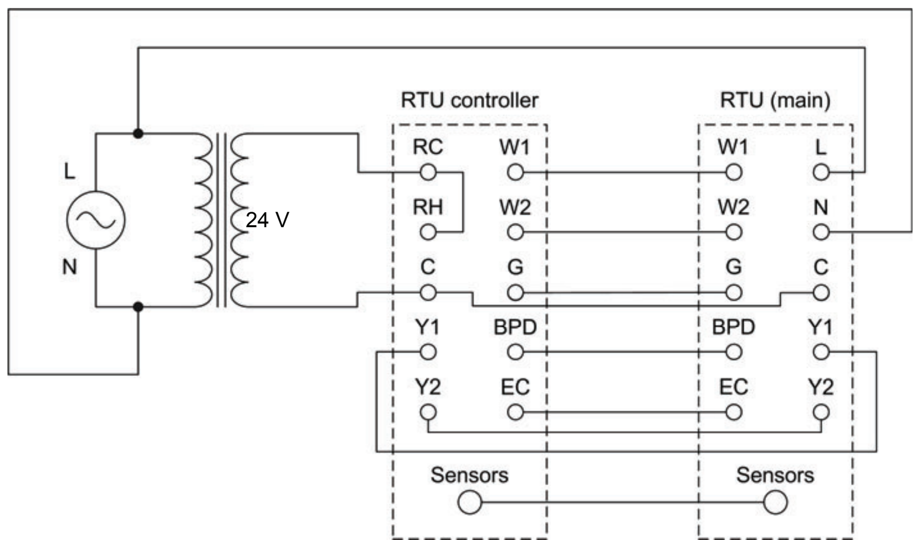

Figure 44. Connecting the RTU.

4. Set the controls of the RTU section according to Table 15.

Table 15. RTU section settings (main module).

Button or switch	Setting
Fresh air flow (AI)	10 000 CFM (283 m^3/min)
Static pressure (SP)	1 inH_2O (250 Pa)
Outdoor temperature (OS)	70°F (21°C)
Return temperature (RS)	70°F (21°C)
Supply temperature (DS)	70°F (21°C)

5. Connect the 24 V - HOT and 24 V - COM terminals of the floating zone controller to the control transformer so that the module can be powered. Set the controls according to Table 16.

Table 16. Floating zone controller settings.

Button or switch	Setting
Temperature sensor	Remote (RS)
Occupancy sensor	Open
Temperature	70°F (21°C)
CO_2 level	0 ppm

6. Ground all modules by connecting them in series to one of the ground terminals of the power source.

7. Once everything is properly connected, turn the power source on. The display of each controller should light up.

8. Make sure the default parameters from Exercise 1 are entered in the RTU controller and in the floating zone controller.

User menu of the RTU controller

Setting the system mode

9. Press the *MENU* button briefly to access the user menu. If you are in unoccupied mode, the controller will ask if you want to override the schedule (Override Sched? Y/N). Press *NO*.

The user menu is different from the configuration menu. You need to press MENU *for several seconds to access the configuration menu.*

If the controller is already in override mode (Cancel Ovrd? Y/N), press *YES* to cancel the override.

10. When asked to set the system mode (Sys mode set? Y/N), press *YES*, select Sys mode auto using the arrows, and press *YES* again to confirm your choice. The auto mode allows the RTU controller to switch between heating and cooling modes.

Setting the schedule for one day

11. The RTU controller follows a schedule to operate according to preset occupied and unoccupied periods. By default, two events are entered each day:

- The time when the occupied period starts (e.g., 8 AM)

- The time when the unoccupied period starts (e.g., 5 PM)

Press *NO* until you obtain the current day (e.g., Tuesday set? Y/N). Then press *YES*.

12. Set the occupied period to start in about 10 minutes from now so we can observe the change of mode. Use the buttons to modify the time, press *YES* to confirm the value, and note the value below.

Occupied start time: ___________________

13. Set the unoccupied period to start after you are done with this exercise. Use the buttons to modify the time and press *YES* again to confirm the value.

Unoccupied start time: __________________

Setting the clock

14. In order to establish a meaningful schedule, we need to set the correct time (Clock Set? Y/N). If necessary, press *YES* and use the buttons to establish the time, day, and time format.

15. Exit the menu.

Fan control and cooling

16. What is the mode indicated on the RTU controller and on the zone controller?

Unoccupied for both

17. What is the state (on/off) of the blower and bypass damper? Why is it so?

The blower is off and the bypass damper is open because we are in unoccupied mode and the zone controller does not call for cooling or heating (the temperature is between 65°F and 80°F).

18. Turn up the zone temperature to a maximum. Describe what happens with the blower and why.

The LEDs under the blower, snowflake, and fire icons on the controllers are good indicators of what is going on with the controllers.

The blower starts within a few seconds because the zone controller asks for cooling. Note that the bypass damper closes at least in part.

19. Wait until the RTU controller switches to occupied mode (see step 12). What is the mode on each controller?

RTU controller: occupied
Zone controller: stand-by

20. Turn the OCCUPANCY SENSOR (BI1) switch to CLOSED as if someone entered the zone at the beginning of the workday. What is the mode on each controller now?

RTU controller: occupied
Zone controller: occupied

Free cooling scenario (economizer)

21. Since it is hot in the zone (zone temperature is maximum), the RTU is in cooling mode with the cooling elements on. Turn down the OUTDOOR TEMPERATURE (OS) to MIN to simulate that the air outside the building is cool. Observe the indicators on the main module and describe how the RTU controller responds to the situation.

The cooling elements turn off and the economizer damper opens. We are in free cooling mode.

22. Return the zone temperature and outdoor temperature to 70°F (21°C) to stabilize the system. Since the cooling demand is dropping, you might be able to see that only one of the two cooling stages remains on.

Static pressure control with the bypass damper

23. Increase the static pressure to the maximum level. Describe what happens with the bypass damper with more pressure in the supply air duct.

The bypass damper opens completely to try to diminish the pressure in the duct.

24. Decrease the static pressure to the minimum level. Describe what happens with the bypass damper.

The bypass damper closes entirely to help build some pressure in the duct.

25. Return the static pressure to 1 inH_2O (250 Pa).

Heating

26. Diminish the zone temperature very slowly. Describe what happens as the temperature goes down.

If the cooling elements were on, they turn off. Then the first stage of heat is activated, followed by the second stage.

27. Return the zone temperature to 70°F (21°C).

Guided troubleshooting

Inserting a fault

28. Actuate fault number four on the RTU controller module. This fault will likely disrupt the way the module operates. The question is how.

Observation

29. Operate the system in cooling, free cooling, and heating modes. Describe what you observe below.

The system operates normally in cooling and in heating modes. However, when the temperature is high in the zone and the outdoor temperature is low, there is something wrong. The cooling stages are turned off for free cooling, but the economizer damper does not open.

Deduction

30. What could be the cause(s) of the trouble?

There seems to be a problem with the economizer damper.

Measurements

31. Because the conditions for free cooling make the RTU controller stop the cooling stages, this is probably a problem with the economizer damper. Use a multimeter to check the economizer output signal on the RTU controller. The multimeter must be in dc voltage mode and the probes connected between the EC and C terminals. Record your reading below.

0 V

Conclusion

32. Clearly, the economizer damper cannot open if it does not get a signal from the controller. Remove the fault. What does the multimeter read?

(close to) 10 V

33. We see that the economizer opens as soon as the fault is removed to act according to the free cooling mode. It was a case of bad wiring between the economizer and RTU controller output.

End of the exercise

34. Make sure that no fault remains on the modules.

35. Turn off the power source.

36. Disconnect all leads and arrange the modules and leads neatly in preparation for the next laboratory exercise.

CONCLUSION

In this exercise, you connected the RTU controller to the main module. You entered a schedule and you observed the behavior of the system when the zone temperature, outdoor temperature, or static pressure changes. You also performed a guided troubleshooting activity.

REVIEW QUESTIONS

1. Why does the RTU have occupied and unoccupied periods?

   The unoccupied periods permit energy savings because the fan can be turned off and the heating and cooling stages are off more often.

2. Which heating set point is the highest: the occupied or unoccupied mode set point? Explain.

   The occupied mode set point is the highest. In other words, the temperature cannot fall as much in occupied mode before heating is triggered.

3. Which cooling set point is the highest: the occupied or unoccupied mode set point? Explain.

   The unoccupied mode set point is the highest. In other words, the temperature can increase more in unoccupied mode before cooling is triggered.

4. What conditions are required for free cooling to happen?

The zone controllers must call for cooling and the outside air must be cool enough (below 55°F (13°C) in our case).

5. What is the purpose of the bypass damper?

The bypass damper helps regulate the static pressure in the air supply duct, and hence, the air flow. The bypass damper is also open when the blower is off to avoid overpressure when the blower restarts.

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