HVAC CONTROLS INTRODUCTION

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Preface

Purpose of this Document

This document serves as an introduction to how a Heating, Ventilating, and Air-Conditioning (HVAC) Control system is used to operate a building's mechanical equipment so as to maintain the desired environmental conditions.

Appendix A – Supporting Documents for TAC Products

A variety of documents are available to support TAC products. Two samples of these are featured in Appendix A. The first sample shows pages from the TAC Catalog, supporting the CP-8511 Transducer. The second sample shows pages from a General Instructions sheet that supports the VM Series Erie Pop-Top™ Modulating Spring-Return Valves. These are meant only as samples and do not represent the entire scope of TAC product support. For complete information on TAC products, consult your local office or wholesale distributor.

Glossary

The Glossary contains a list of abbreviations and alphabetically lists and defines terms used in this document.

Examples Used in this Document

This document contains examples of HVAC equipment and applications. Many of these applications include temperatures, setpoints, throttling ranges, and other examples of conditions found in the HVAC world. When reading this document, keep in mind that these are examples only. Many factors, including equipment, climate, building codes, and local practices vary and can have a major impact on methods, procedures, and sequences used to control buildings.

This document cites examples of products manufactured by TAC. These products represent only a small portion of the TAC product offering, and the applications, features and benefits of TAC controls used in this text represent only their basic functions. TAC has a complete line of products for today's modern building, offering security, lighting, sophisticated energy management solutions, Internet-accessible reporting and many other products to support the needs of a "smart" building.

Conventions Used in this Document

The following conventions apply throughout the HVAC Controls Introduction:

- Terms that are *italic and underlined* are defined in the glossary of this document. Additionally, in the online version of this document, these terms appear in *blue*, to aid in their visibility.
- Key terms in some paragraphs are bolded. Other terms needing emphasis appear in italics.

Introduction

Function of HVAC controls

A Heating, Ventilating, and Air-Conditioning (HVAC) Control system operates the mechanical equipment (boilers, chillers, pumps, fans, etc.) to maintain the proper environment in a cost-effective manner. A proper environment is described with four variables: temperature, humidity, pressure and ventilation.

Temperature — The *comfort zone* for temperature is between 68°F (20°C) and 75°F (25°C). Temperatures less than 68°F (20°C) may cause some people to feel too cool. Temperatures greater than 78°F (25°C) may cause some people to feel too warm. Of course, these values vary between people, regions and countries.

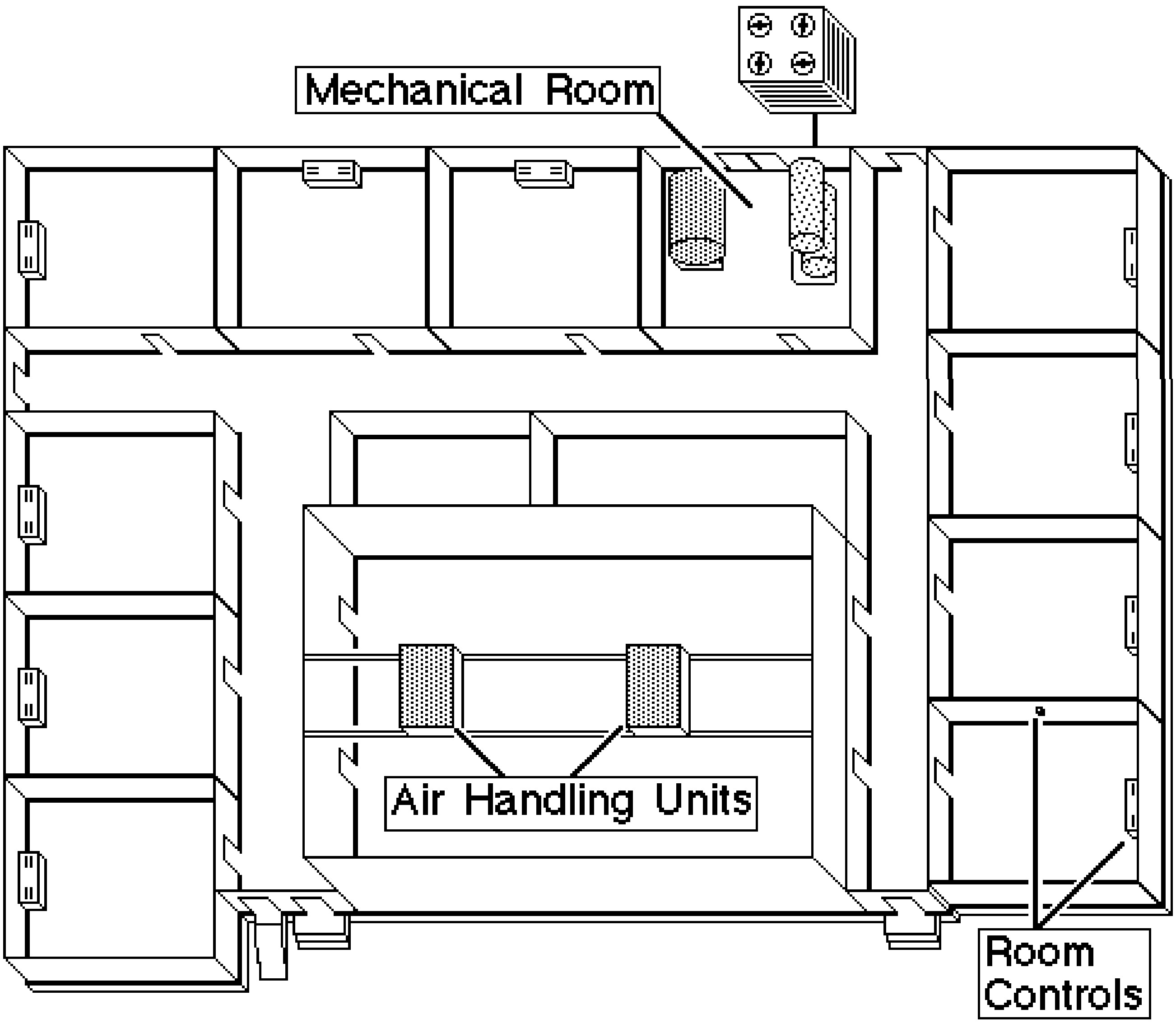
Humidity — The comfort zone for humidity is between 30% *relative humidity* (RH) and 60% RH. Humidity less than 30% RH causes the room to be too dry, which has an adverse effect on health, computers, printers, and many other areas. Humidity greater than 60% RH causes the room to be muggy and increases the likelihood of mildew problems.

Pressure — The rooms and buildings typically have a slightly positive pressure to reduce outside air infiltration. This helps in keeping the building clean.

Ventilation — Rooms typically have several complete air changes per hour. *Indoor Air Quality* (IAQ) is an important issue. The distribution pattern of the air entering room must keep people comfortable without feeling any drafts, and this is important as well.

Location of Equipment

Three areas in a building work together to maintain the proper environment. The HVAC equipment and their controls include the *mechanical room*, the *Air Handling Units (AHUs)* and the individual *room controls*.



Mechanical Room: Boilers, chillers, pumps, heat exchangers, and other associated equipment are found inside the mechanical room. This area is sometimes called the main equipment room.

Air Handling Units (AHUs): AHUs may be found on the roof, in the main equipment room, or in their own equipment room, which is referred to as the secondary equipment room. AHUs may heat, cool, humidify, dehumidify, ventilate, or filter the air to condition it, then distribute that air to a section of the building. (AHU overview on page 9)

Room Controls: Individual room controls regulate the air coming from the AHU to serve a room or a part of a larger area called a *zone*. Devices such as wall *thermostats* and *Variable Air Volume (VAV)* boxes provide local temperature control.

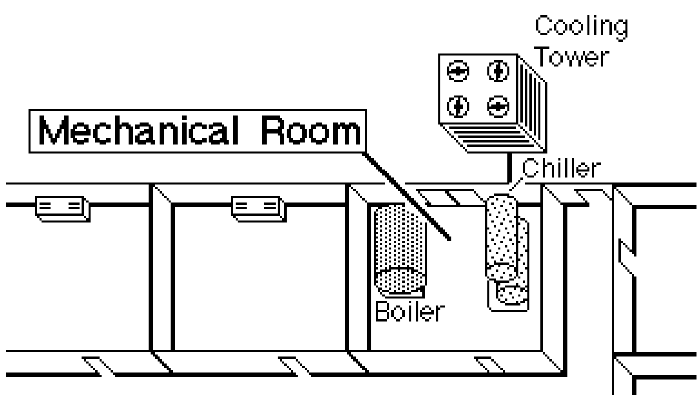
There are also room controls not associated with an AHU. These may directly control mechanical equipment that only serve one room or zone (*zone control*). These room controls are installed on equipment such as *unit ventilators, fan coil units,* and *heat pumps*.

Unit Ventilator

Fan Coil Unit

Photos provide by McQuay International

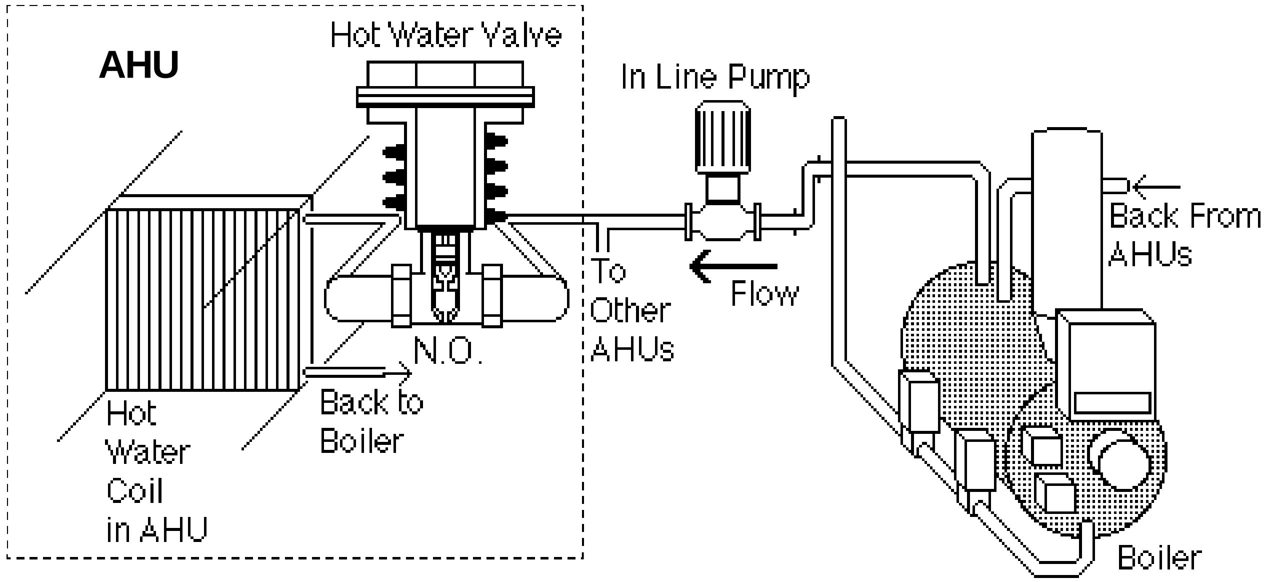
Mechanical Room



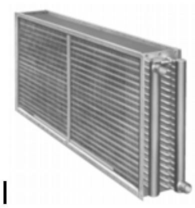
Heating

The mechanical room may contain a *boiler* or a group of boilers. The boilers provide heat for the building. In cooler climates, boilers are large or consist of a number of smaller modular boilers. In warmer climates, boilers are small or even absent from the mechanical room. When enabled, boilers supply a source of hot water that is used by coils throughout the building. The temperature of this hot water may be varied based on the outside temperature. Note: Hot Water Supply (HWS) temperatures may vary because of the application or the HVAC equipment.

Boiler photo provided by Clever-Brooks

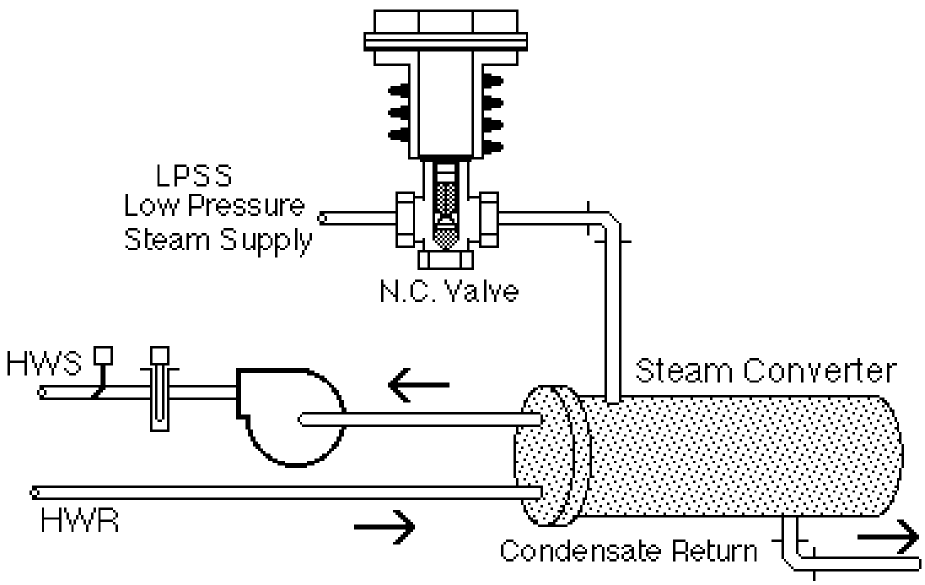

AHU
Hot Water Valve
In Line Pump
Back From AHUs
To Other AHUs
Flow
N.O.
Back to Boiler
Hot Water Coil in AHU
Boiler

Most boilers produce hot water, but there are also boilers that produce steam. Boilers develop their heat through gas, coal, oil burners, or electric coils. The previous picture shows a hot water gas-fired boiler. The hot water developed by the boiler is used by hot water coils found inside the air handling units.



Coil

Some heating applications may have coil or heat exchanger located around the outside walls (perimeter fin-tubes) of the building. In the preceding example, a pump forces water from the boiler to the coils, then back to the boiler. In cold climates, a *normally open (N.O.)* valve is installed to control the volume of water flow through the coil. The amount of flow is expressed in *gallons per minute (GPM)* or, in metric units, in liters per second (L/s). The valve is described as normally open because when no power or control signal is received, the valve goes to 100% open.



Where a steam boiler is used, a **steam converter** is commonly incorporated into the design. A steam converter is a type of heat exchanger. Steam provided from the boiler is used to heat water inside the converter. In turn, the hot water developed by the converter is used in the same way as the hot water is used from a hot water boiler. In the example above, a *normally closed (N.C.)* valve is used to control the amount of steam going to the heat steam converter. When no power or signal is received at this type of valve, it closes. Different types of heat exchangers may be used for other applications, including cooling.

(photos provided by **Bell & Gossett)**

Water Pumps

Pumps move the water thought the system. Basic examples are forcing the water from the boiler to the hot water coils or from the chiller to the chilled water coils. In HVAC applications, it is common to use a centrifugal pump (shown above). A pump is controlled by an output signal from the controller. A pump may be commanded on/off or vary the pump output by use of an adjustable frequency drive.

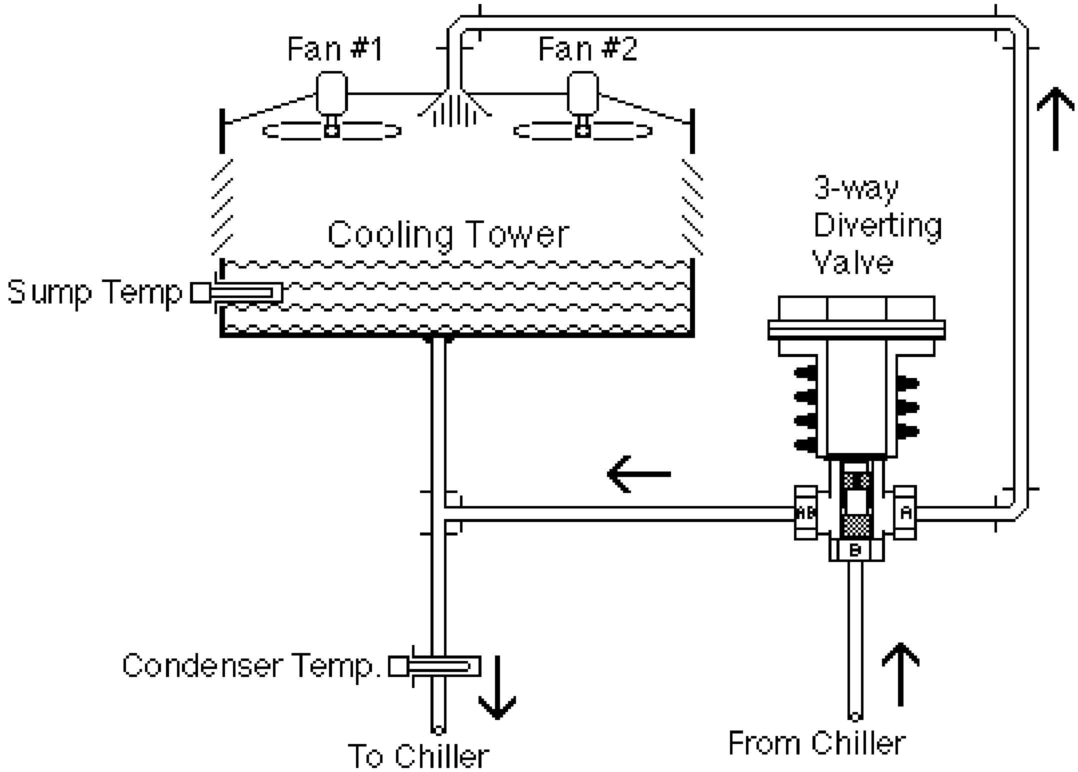
Some applications may require two pumps, a standby pump is ready in case something happens to the operating pump. The operating pump is referred to as the lead or primary pump, and the standby pump is the lag or secondary pump.

Chiller photo provide by McQuay International

Cooling

The *Chiller* is the source of cooling for many buildings. There are a variety of chiller types. A chiller produces cool water, for example 42°F (5°C), which is pumped to the chilled water coils inside the air handling units. In this example, heat is being removed at the Air Handling Unit and being rejected to the outdoors at the cooling tower. There are three basic steps to the heat transferring process:

1) The *chilled water supply (CHWS)* is pumped to the cooling coils in the AHUs, then the cooled return water, at 52°F (example only), is circulated back to the chiller (*chilled water return, or CHWR*). At the *cooling coil*, the heat for the space is transferred to the chilled water and the water carries the heat back to the chiller.
2) In the chiller, the heat is transferred to a *refrigerant*, which in turn transfers the heat to the water going to a *cooling tower*.

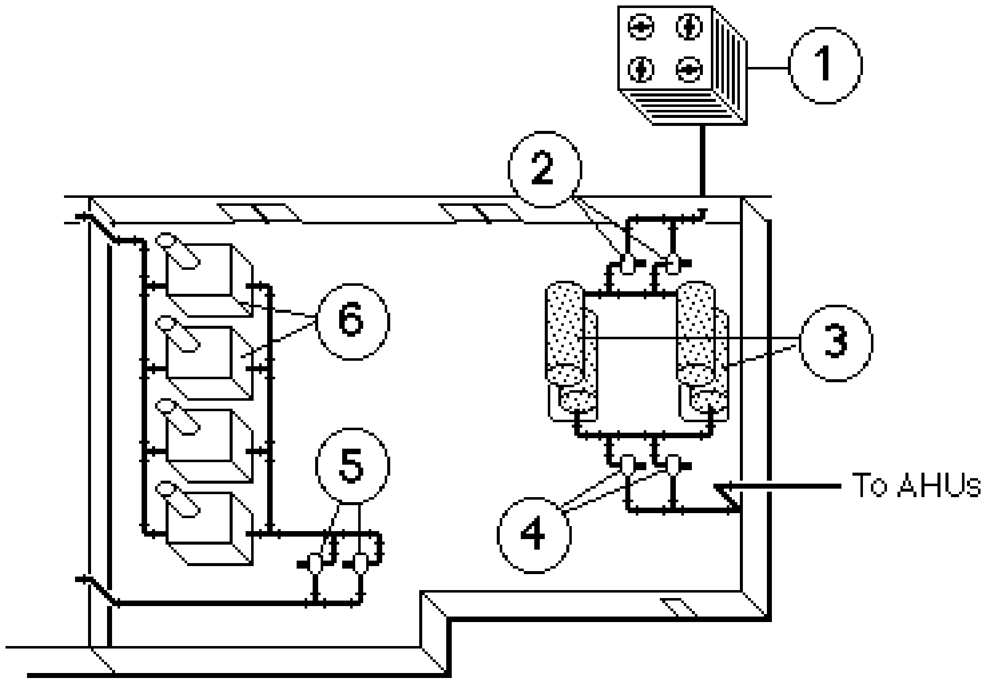


3) The **Cooling Tower** expels the heat to the outside air. The cooling tower is a container that is open to the atmosphere (*Open System*), through which water is passed. When heated water comes from the chiller, it is forced upward to the top of the cooling tower, then sprayed down into the container. Evaporation causes the water to lose some of its heat. To increase the heat loss, fans may be turned on, causing more evaporation. Once the water is cooled to around 85°F (30°C), the water settles in the sump and is sent back to the chiller.

Evaporation is a cooling process that causes some of the water to be lost to the atmosphere. As a result, make up water or fill is needed to maintain the proper water level. Therefore, water in a cooling tower requires water treatment supervision.

There are other ways to cool the condenser water, including *cooling ponds* or *air-cooled condensers*.

Review



Mechanical Room

Match the identification number of the mechanical equipment with its name.

Matching

1.______ A) Boilers

2.______ B) Hot Water Pumps

3.______ C) Chillers

4.______ D) Cooling Tower

5.______ E) Chilled Water Pumps

6.______ F) Condenser Water Pumps

Answers to Review

1. D) Cooling Tower

2. F) Condenser Water Pumps

3. C) Chillers

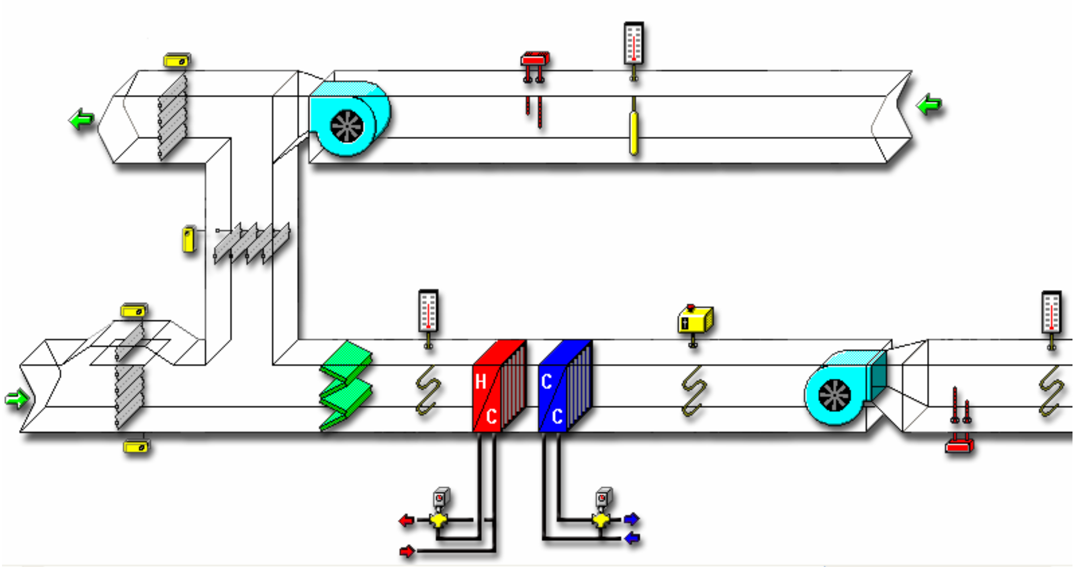
4. E) Chilled Water Pumps

5. B) Hot Water Pumps

6. A) Boilers

Air Handling Units (AHUs)

Air Handling Units (AHUs) supply conditioned air to a particular part of a building. AHUs can supply different sized areas, whether it is a part of a room, a zone, or an entire group of rooms. In the diagram above, two AHUs supply air to a school auditorium. This AHU contains a *mixed air chamber*, a *filter*, a *chilled water coil* (commonly called a cooling coil), a *hot water coil* (commonly called a heating coil), a *fan*, and a *humidifier*. The parts of an AHU are often referred to as the "water side," composed of those parts that pass water through the AHU, and the "air side," which is composed of the devices that direct the air within the AHU.



Mixed Air refers to the mixing of outside air with the air returning from inside the building. This is accomplished by *dampers* controlling airflow in a way similar to venetian blinds controlling sunlight. In the diagram above, there are dampers for the outside air and the *return air*. It is important that these *dampers work together*. As outside air dampers open, the return air dampers must close. An *actuator* (sometimes referred to as a motor or operator) and *linkage* are set up so that this operation occurs.

Ventilation requirements determine the *minimum position* of the outside air dampers. In the winter, when the chiller is shut down, the outside air dampers may open beyond the minimum position to provide cooling. Using outside air for cooling rather than mechanical cooling is referred to as an *economizer mode*. During the summer, when the outside air is too warm to use for cooling, the outside air dampers are set to the ventilation requirement, which is the minimum position. *Exhaust air dampers* allow air to leave the building in proportion to the amount of outside air that enters.

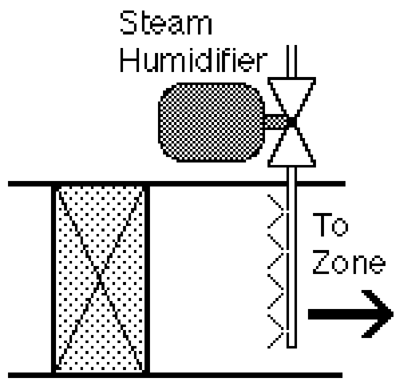
Filters remove dirt particles from the mixed air. It is essential that these filters be replaced periodically. A *mixed air sensor* is typically located after the filter. This sensor averages the mixed air temperature throughout the cross-section of the duct. This is important because in mixed air, *stratification*, which is the layering of the warm and cold air inside the duct, can occur, possibly resulting in control or comfort problems.

The **Supply Fan** moves the air through the air-handling unit and out into the rooms. The amount of air going through the fan may be controlled by the use of *inlet vane* dampers (blades that cover the inlet of the fan), or by the use of a *variable frequency drive (VFD)* that controls the speed of the fan motor by varying the cycles of electricity. The fan may be positioned after the coils as shown below (draw-through fan) or before the coils (blow-through fan).

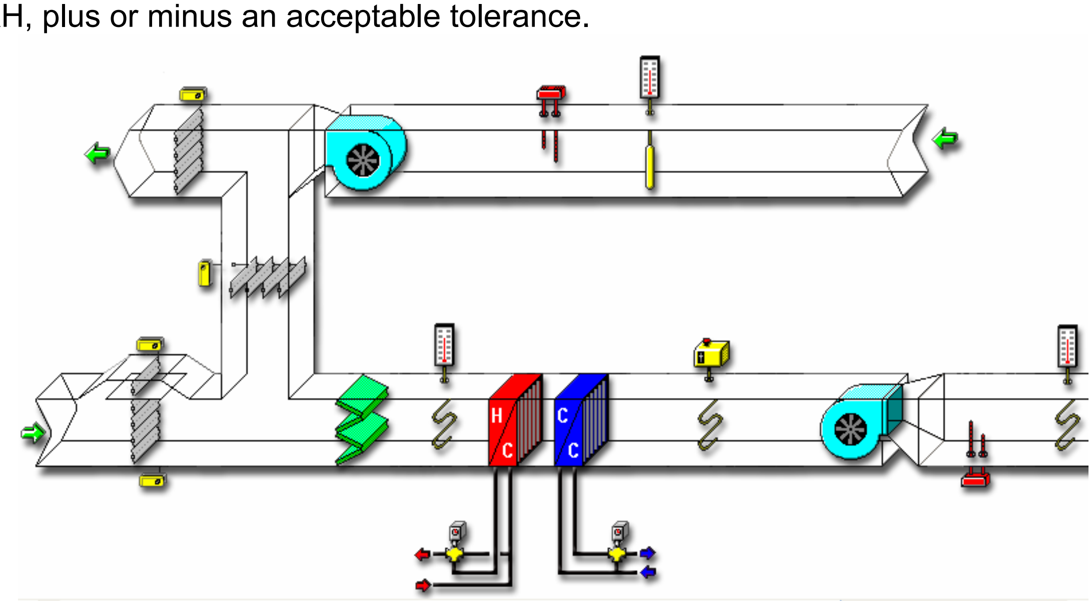
Photo provided by McQuay International

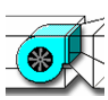
The **Hot Water Coil** heats the air as it passes over the coil. It may be necessary to heat the air even when providing cooling to a building. This concept may be confusing at first. To help understand this application, it is important to remember that the core of a large building may require cooling year-round, regardless of the outside air temperature. Typically, air used for cooling is delivered to the space at 55°F. If the mixed air temperature is below 55°F, it may be necessary to heat the air to 55°F for a cooling application. In the drawing above, the discharge air sensor modulates a two-way *normally open (N.O.)* valve to maintain the 55°F (13°C) *discharge air* temperature. With the removal of the input signal, this valve goes completely open, putting as much hot water into the coil as possible. This reduces the chance of the water freezing, which may destroy a coil.

The **Chilled Water Coil** operates during the summer to drop the discharge air temperature to 55°F (13°C). As shown in the preceding drawing, chilled water is modulated through the coil by the use of a three-way *mixing valve*. The valve forces the chilled water through the coil or bypasses the water around the coil. The Chilled Water coil may also be used for dehumidification of the air, provided the temperature of the cooling coil surface is below the *dew point* of the air passing over the coil. The humidity levels are controlled from a sensor in the rooms being served by this AHU, or by a sensor in the return air duct.



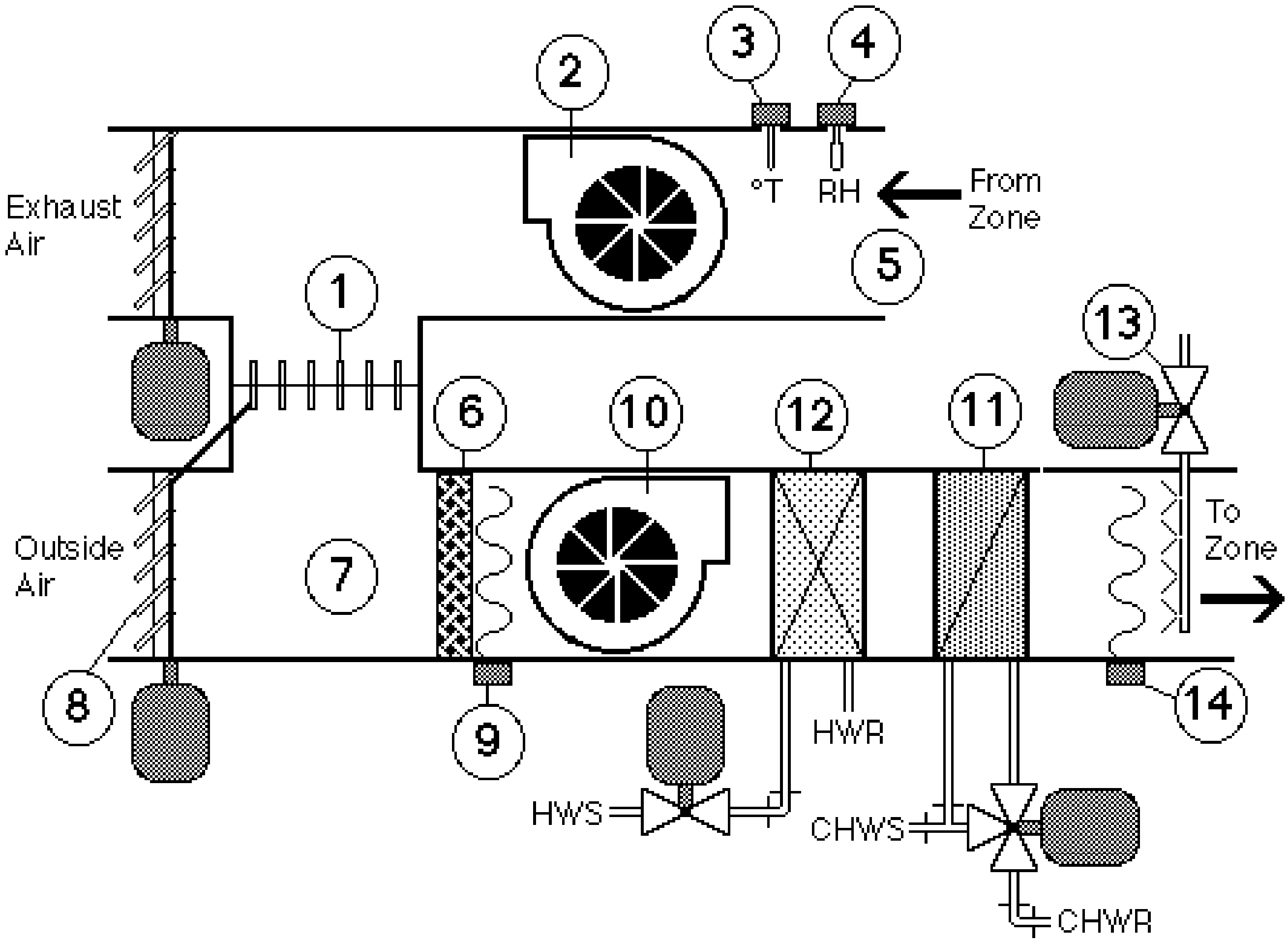
A steam **Humidifier,** or some other form of humidifier, is placed inside an AHU to add moisture to the air when needed. Humidity levels, sensed in the return air, are set at 35% RH, for example. The two-way normally closed (N.C.) valve is modulated to maintain 35% RH, plus or minus an acceptable tolerance.



The **Supply Fan**  distributes the air into the rooms or zones. After the air has gone through the zones, it comes back to the **Return Fan** , which routes the return air back to the return air dampers or the exhaust air dampers.

Review

Observe the Air Handling Unit, below.



Review

Referring to the drawing on the previous page, match the identification number of the equipment with the correct letter.

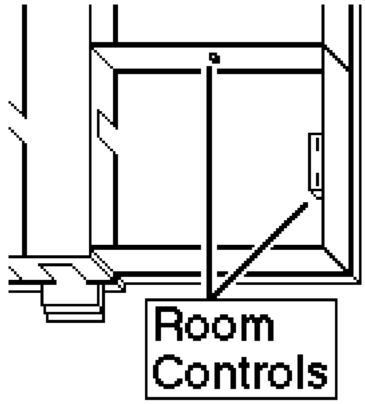
Matching

1.___________	A. Supply Fan
2.___________	B. Filter
3.___________	C. Outside Air Dampers
4.___________	D. Return Air Temperature Sensor
5.___________	E. Hot Water Coil
6.___________	F. Mixed Air
7.___________	G. Return Air Dampers
8.___________	H. Return Air Humidity Sensor
9.___________	I. Discharge Air Temp. Sensor
10.___________	J. Return Fan
11.___________	K. Return Air
12.___________	L. Mixed Air Temperature Sensor
13.___________	M. Steam Humidifier
14.___________	N. Chilled Water Coil

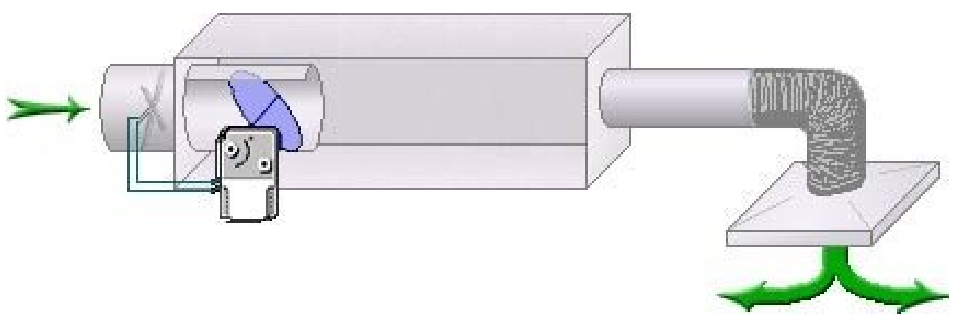
Answers to the Review

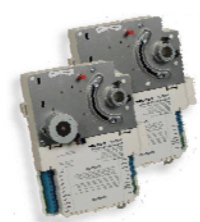
1.	G.	Return Air Dampers
2.	J.	Return Fan
3.	D.	Return Air Temperature Sensor
4.	H.	Return Air Humidity Sensor
5.	K.	Return Air
6.	B.	Filter
7.	F.	Mixed Air
8.	C.	Outside Air Dampers
9.	L.	Mixed Air Temperature Sensor
10.	A.	Supply Fan
11.	N.	Chilled Water Coil
12.	E.	Hot Water Coil
13.	M.	Steam Humidifier
14.	I.	Discharge Air Temp. Sensor

Room Controls



One way to control the temperature in a room is with a **Wall Thermostat** (stat) that sends a signal to an actuator that positions a damper to modulate the airflow in a *variable air volume* (VAV) box. These VAV boxes are installed in the space between the ceiling tile and the structural ceiling. This space is sometimes used as a return air *plenum,* as part of the *building air distribution system*.

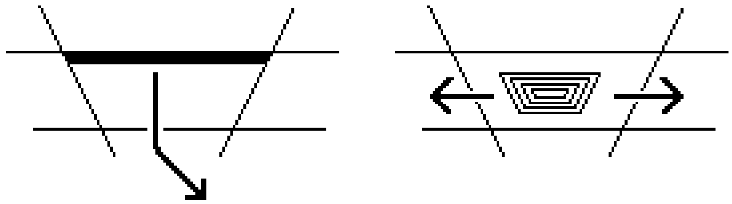




The VAV box has a **Damper** that modulates to maintain the space temperature by increasing or decreasing the volume of air being delivered to the space. The airflow is measured in *cubic feet per minute (CFM)* or *liters per second (L/s)*. If the space is too warm, the damper is adjusted to allow more 55°F (13°C) air into the space. If the space is too cool, less air is delivered to the space.

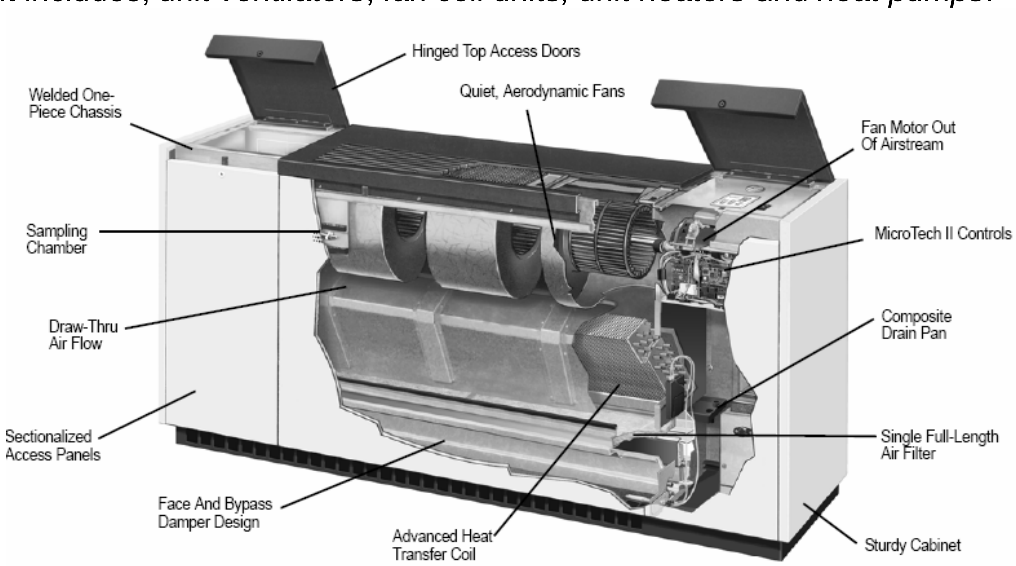
It is also important that these boxes *filter the noise* that is developed by the AHU. The picture above shows a *cooling-only* VAV box with a picture of control/actuator on the right. There are numerous other types of boxes, including *electric heaters*, *separate fans*, or *hot water coils*.

The airflow regulated by the VAV box is distributed into the space by **Air Diffusers**. The airflow patterns in a zone or space should not cause people to feel a draft. Two types of diffusers are shown below, but there are numerous other types of diffusers. Air leaving the room passes through return air *grilles,* to the return air fan in the AHU.



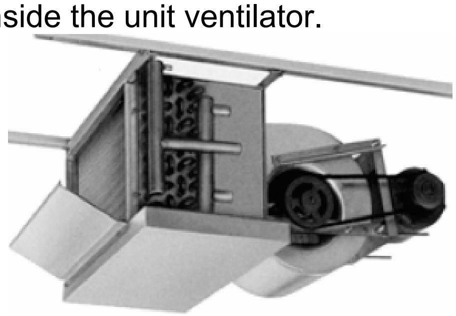
Air Diffusers

Room controls can also control equipment independent from an AHU. This type of equipment includes, *unit ventilators*, *fan coil units, unit heaters* and *heat pumps*.



Unit Ventilator photo provided by McQuay

A **Unit Ventilator**, common in schools, is shown above. It serves as the local air-handling unit and has dampers for the outside and return air, a fan, and a hot water coil. The hot water comes from the boiler. The diffusers are on the top of the unit. A space thermostat controls the valve and dampers in this unit. A switch on the base of the thermostat starts the fan inside the unit ventilator.



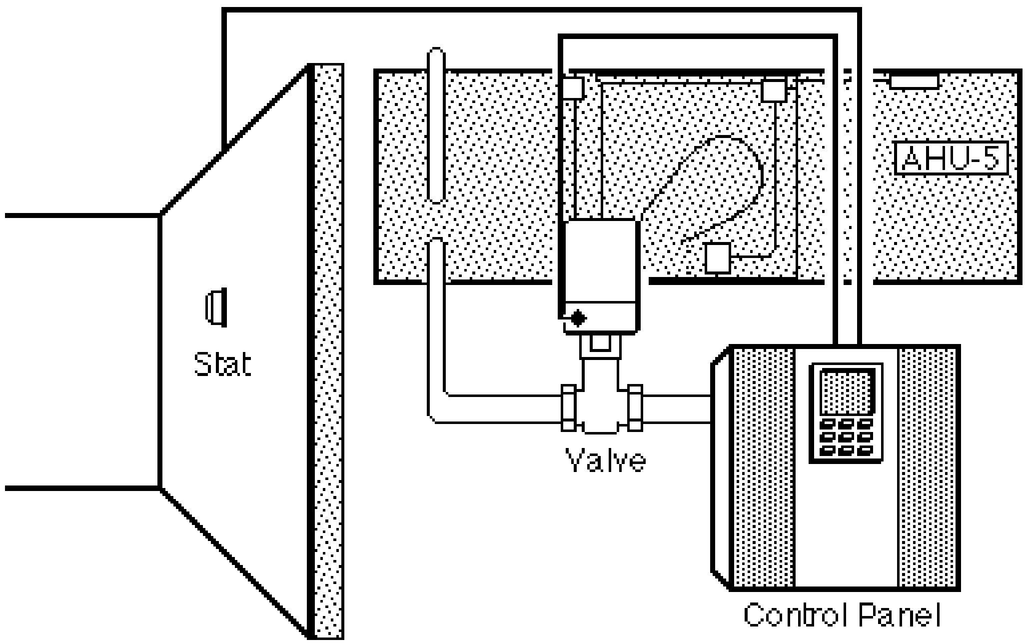
Fan Coil Units differ from unit ventilators in that they have no dampers. Fan coils are typically installed above ceilings or as console units in a room.

INTRODUCTION

There are many different ways to control the environment of a building. This has only been an overview of some of the equipment that may be encountered.

Basic Control System

An important part of the mechanical equipment is the **Control System**. Control systems are the "brains" of HVAC equipment. Pictured below is an AHU that serves only one zone. This type of AHU is called a *single zone AHU*. In the example, a temperature sensor (stat) sends a signal to a control panel, which sends a signal to a valve. These controls make up a *Basic Control System*.



A. Sensor
B. Controller
C. Controlled Devices
    1. Actuators
    2. Valves
    3. Transducers
    4. Dampers

BASIC CONTROL SYSTEM

Every control system, from the simplest room thermostat to the most complicated computerized control, has three basic elements. The next page a diagram shows an example of a basic control system. A Basic Control System always has these parts.

1. A **Sensor** monitors and measures a variable. In the example, the variable is temperature. The sensor provides information to the controller.

2. A **Controller** receives information from a sensor, selects a portion of that input for control, and then produces an intelligent output signal. While there may be several other functions performed by controller, all controllers provide *setpoint*, sensitivity (*differential* or *throttling range*) and *action*. Details of these terms are cover in the next few pages.

3. A *Controlled Device* acts upon the signal from the *controller*. In the example, the valve is the controlled device, modulating hot water to maintain the proper temperature in the room.

A power supply or source of energy is needed to power the control system. Control systems are assumed to be powered and drawings may not show power supplies. Control systems use either a *pneumatic* or electric power supply.

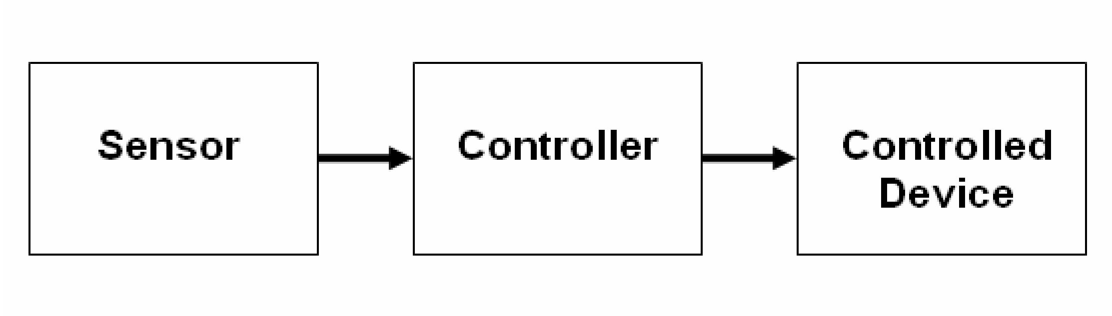
Pneumatic controls use a compressed gas as a source of energy, typically compressed air. Care should be taken to ensure the air supply is clean, dry, and oil-free. Most HVAC pneumatic controls are powered with 15 to 22 *psig*.

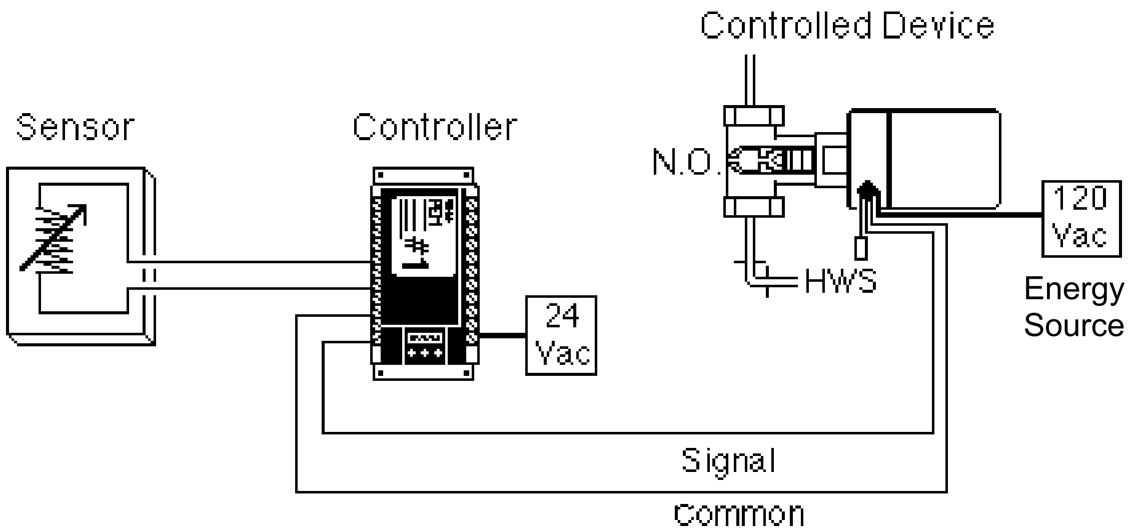
Electric and *electronic controls* could be powered by a variety of electrical power supplies of either Alternating Current (AC) or Direct Current (DC). In the United States of America, the electrical power supplies could be at 20, 24, and 120 volts, 60 Hz. In many parts of Europe, 230 volts, 50 Hz is common.

These three (senor, controller, controlled device) parts are needed in any control system, however, two of these parts may be combined under the same cover, as in the case of some thermostats. While there are occasions when the sensor and controller are combined into one physical device, their basic function remains the same. The sensor, controller, and controlled device are needed for any control system, however an installed system may have additional parts beyond the basics.

The example on the next page shows an electronic-*DDC (Direct Digital Control)* system. In this, a type of resistor senses the temperature. The controller in the control panel receives the sensor information and sends an output signal to the valve. The valve/actuator, which is the controlled device, receives the signal from the controller and adjusts to the correct position. Here, electricity is the source of energy. Sensor, Controller and Controlled Device are explained in detail on the following pages.

BASIC CONTROL SYSTEM





Sensor

A sensor monitors and measures a variable. The HVAC variables are temperature, humidity, and pressure. Different types of signals are produced by different types of sensors.

Electric Controls ON / OFF signals complete or break (close or open) the control signal.

Pneumatic Controls Transmitters sense the variable and produce a 3 psig to 15 psig (pound per square inch, gauge), [20 kPa (kiloPascals) -105 kPa] signal over a particular transmitter's *range*.

Electronic Controls Types of electronic sensors are:

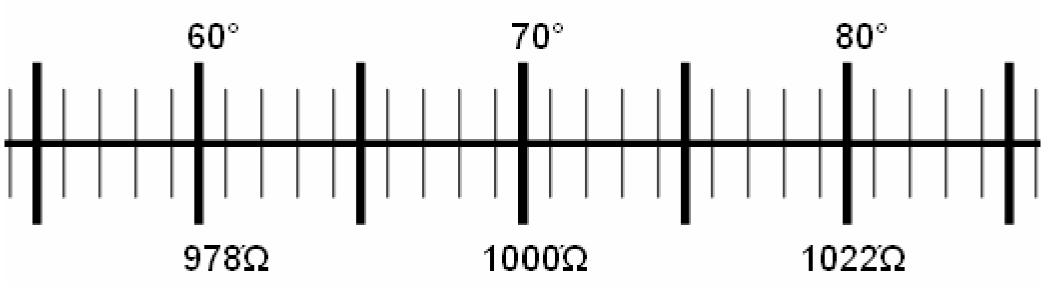
Resistance sensors are *Resistance Temperature Devices (RTDs)*, and are used in measuring temperature. Examples are Balco elements, Copper, Platinum, 10K Thermistors, and 30K Thermistors.

Voltage sensors could be used for temperature, humidity and pressure. Typical ranges are 0 to 5 Vdc (Volts direct current), 1 to 11 Vdc, and 0 to 10 Vdc.

Current sensors could be used for temperature, humidity, and pressure. The typical current range is 4 to 20 mA (milliamps).

Examples of sensors are shown below. While it may appear to be a thermostat, it is a remote sensor with a remote setpoint dial. The controller is in another location.

The resistance outputs of a Balco sensor follow the diagrams below:



Electronic Sensor (Balco)

When 1000 ohms is measured across the Balco element, the temperature is approximately 70°F (21°C). As the temperature increases, the resistance changes 2.2 ohms per 1°F (3.96 ohms per 1°C). This is called a Temperature Coefficient of Resistance Curve (TCR Curve). In a Balco, as the temperature increases, the resistance increases proportionally.

Controller

The controller receives the signal from the sensor and produces an output signal with setpoint, sensitivity (differential or throttling range), and action. Types of signals from these devices are as follows:

Electric Controls The majority of electric controls contain the sensor and controller as one piece. Electric controls use ON / OFF signals.

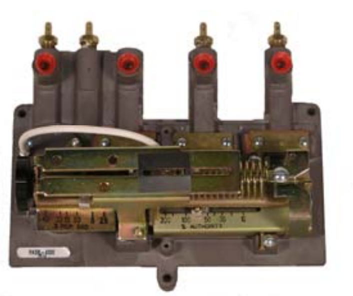
Pneumatic Controls Controller outputs are 3 to 15 psi (21 to 105 kPa).

Electronic Controls There are basically two types of electronic signals.

Voltage outputs may be 0 to 10 Vdc, 2 to 15 Vdc, or other ranges depending on the controller. Voltage outputs have the disadvantage, when compared to current signals, that voltage signals are more susceptible to distortion over long wire distances.

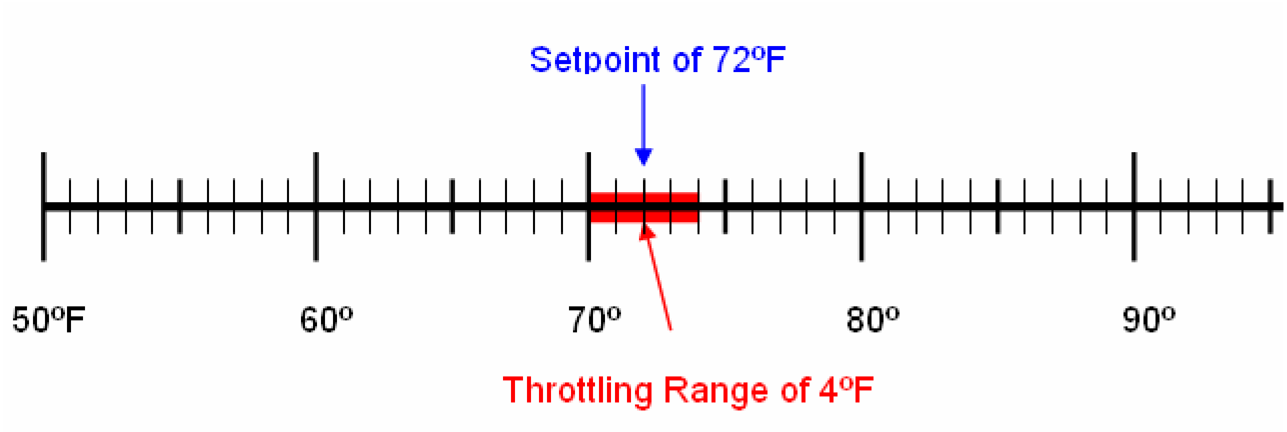
Current outputs modulate from 4 to 20 mA. They have the advantage of producing little signal distortion over long wire distances.

Examples of controllers are shown below:



Many controllers are housed inside a control panel. In the case of the DDC electronic controls, the controller itself may be the control panel.

The operation of these controllers is similar. Review the diagram below.



A signal from the sensor is sent to the controller. In this example, 72°F is the setpoint or desired temperature for a room.

The electronic controller has an output of 0 Vdc at 70°F, and an output of 10 Vdc at 74°F. This throttling range of 4°F is used to identify the voltage change to temperature change. In this example, a 4°F change in temperature produces a 10 Vdc change in the controller output. The output is then sent to the controlled device.

Controlled Device

A controlled device acts upon a signal from the controller. There are a variety of controlled devices. Some examples are;

Electronic Controlled Devices can be either proportional (sometimes referred to as modulating) or two-position (ON/OFF). For example, *hydraulic actuators* are designed to accept a voltage (Vdc) or current (mA) signal, while electronic relays are used for two-position outputs.

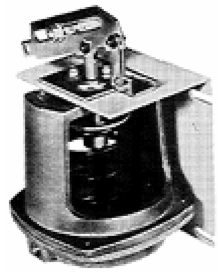
Electric Controlled Devices are ON / OFF or two-position devices used to control electric heat, DX cooling, and two-position dampers or valves.

Pneumatic Controlled Devices are proportional. Pneumatic actuators are described in terms of their spring range. Common spring ranges are 3 to 8 psig (21 to 56 kPa), 5 to 10 psig (35 to 70 kPa), and 8 to 13 psig (56 to 91 kPa).

Combinations of controlled devices are possible. For example, electronic controllers can modulate a pneumatic actuator. Also, proportional electronic signals can be sent to a *transducer*, which converts these signals into proportional air pressure signals used by the pneumatic actuators. These are known as electronic-to-pneumatic (E-P) transducers.

Electric motors with solid state adapters can accept electronic signals. Pneumatic controllers can provide an output to pressure-to-electric (P-E) switches (on-off or two position control).

An example of a pneumatic actuator is shown below:



This actuator operates with either a pneumatic controller or with an electronic controller which sends its signal through a *transducer*.

Actuators

Actuators are devices that operate valves and dampers. There are several different types of actuators, and four are covered here: pneumatic, hydraulic, gear-train, and direct-coupled.

Pneumatic Actuators

Pneumatics Actuator, Positive Posistioner, Valve Assembly

Pneumatic actuators are common controlled devices in the United States. These actuators use compressed air to operate valves and dampers. Pneumatic actuators are easy to repair and can be very cost effective. Specific spring ranges are used for different applications. Spring ranges are selected to provide the most force at close off or to perform a specific sequence of operations. On a normally open valve, the spring range of 3 to 8 psig would be common. On a normally closed valve, the range is typically 8 to13 psig. An additional device, a *positive positioner*, is used on some actuators to them to perform as if they have a different range, or to provide precise position control. It may also adjust the actuator's start point, and possibly provide additional force at the close off of a valve or damper.

Hydraulic Actuators

Hydraulic actuators and valve assemblies are another type of controlled device. They can be used on linear stoked valves or dampers. Hydraulic actuators use hydraulic fluid to extend the shaft of the actuator. An internal spring is used to retract the actuator.

Don’t be confused if the TAC hydraulic actuator is referred to as the “beer can” actuator. The term “beer can” has been a slang term used by many IBS offices and customers for years. It is helpful to understand the hydraulic alphanumeric model number system.

TAC Hydraulic Actuators used on both valves and dampers:

MA is for Two–Position Control
MA-5200 series is used for electric *two-position* control of valves and dampers.

MF is for Floating Control
MF-5500 series are floating actuators used in *floating control* applications

MP is for Proportional Control
MP-5200 series takes a signal of 6 to 9 Vdc and strokes between 6 and 9 Vdc
MP-5400 series comes from the factory set up to stroke between 6 and 9 Vdc and has an adjustable start point and a positive positioning feature
MP-5500 series are compatible with a 0 to 10 Vdc signal

Gear Train Actuators

Gear train actuators are electric controlled devices along with the appropriate linkage may be used on valves and dampers. The gear train actuator can operate in a clockwise or counterclockwise direction. These actuators develop a large amount of torque and caution should be taken to ensure, on spring-return applications, the spring has the necessary power to return the actuator to the fail-safe position.

TAC Gear Train Actuators are MP-300s, MP-400s, MP-2000s, and MP-3000. There are a great variety of features within this product line. The gear train actuators may be used for proportional, floating, and two-position applications. (See the *close-off* ratings in the parts catalog.)

Direct-Coupled Actuators

When used on dampers, direct-coupled EconoDrive™ and DuraDrive™ actuators require minimal or no external linkage, making installation easy to perform. Some EconoDrive and DuraDrive actuators may also be used with ball and globe valves, and are also available as complete actuator and valve assemblies. They are manufactured in a variety of models, including *spring-return*, non-spring return, two-position, proportional, and floating control.

Valves

Valves are an integral part of a building's operation. Two-way and three-way valves are common. "Two-way" describes the number of ports found on a valve, not the different ways the valve can be piped into a system. Water only flows in one direction through a two-way valve. Two-way valves come in two types, *Normally Open (N.O.)* and *Normally Closed (N.C.).* The term "normally" refers to the position at which the valve is set whenever power or the control signal is lost.
HVAC control valves generally fall into three different types, zone valves, ball valves and globe valves.

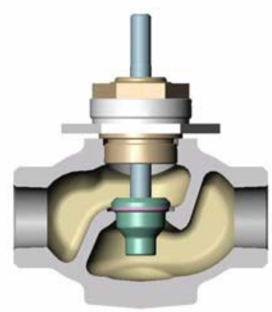
First, we will review globe valves. While TAC globe valves are used as examples, other manufacture's globe valves operate in a similar fashion as TAC valves. However, there are differences in engineering approaches to valve construction. Check the manufacture's product guides for details.

½ inch to 2 inch line size Globe Valves (Bronze)

Note: Explained using TAC VB-7000 series valves. With TAC globe valves, the "normal" or failed position is based on stem-up.

Normally Open (N.O.)

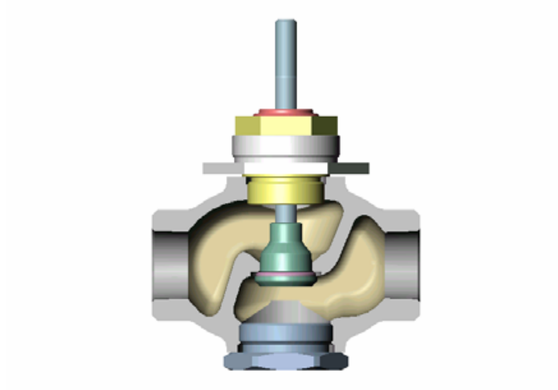
Normally open valves are typically used on hot water coils in an air handling unit. When the control signal is lost, the valve goes to the fail-safe position, completely open, allowing the available hot water to flow through the coil. Note: Some applications may require the control system to use Normally Closed (N.C.) valves in heating applications.



VB-721x Stem Up Normally Open Valve (Shown stem down)

Normally Closed (N.C.)

Normally closed valves are typically used on chilled water systems. When the controller signal is lost, the valve goes to the fail-safe position, fully closed, stopping all water flow to the coil. In very mild climates, where the threat of freezing is not a major consideration, normally closed valves may be used for both heating and cooling.

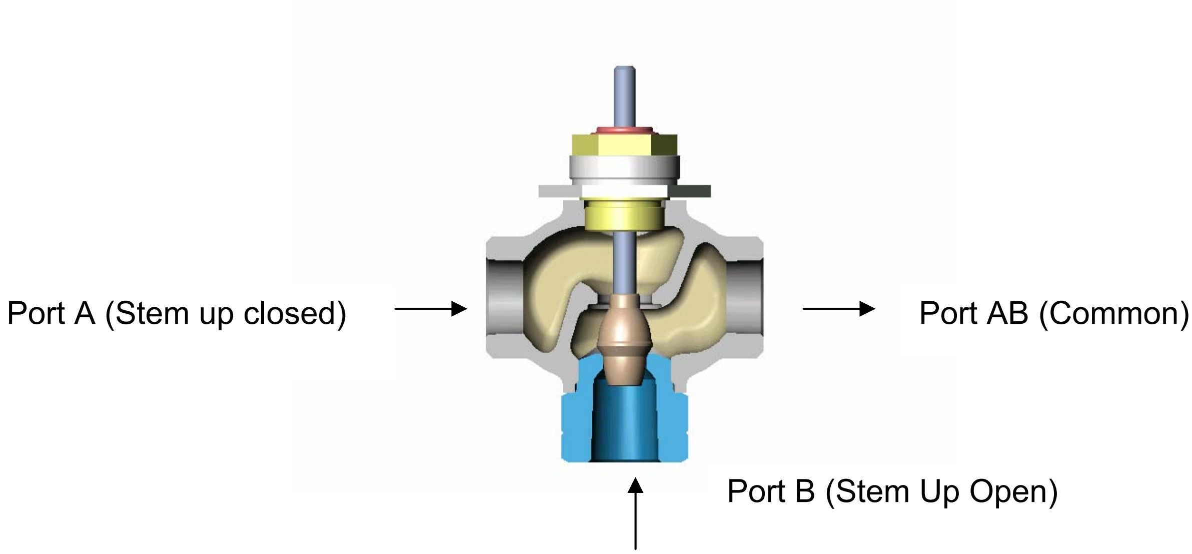


VB-722x Stem up Normally Closed Valve (Shown stem up)

Three-Way valves

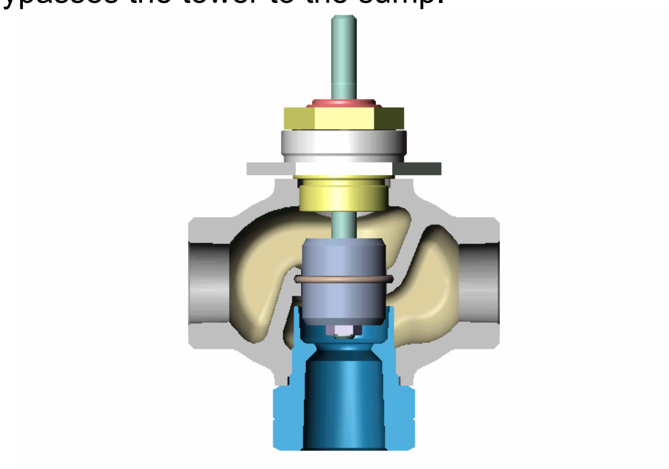
Three-way valves are another type of valve, so named because of their three ports. Three-way valves come in two types: mixing and diverting.

Mixing valves are used more extensively than diverting valves, due to cost considerations. A mixing valve is defined as a valve with two inputs and one output. This valve may be used on chilled water coils to divert water through the coil or bypass around it. The use of mixing valves prevents the buildup of water pressure found with two-way valves.



VB-732x Mixing Valve (Shown in the stem down position)

A diverting valve is defined as a valve with one input and two outputs. A common use of a diverting valve is with a cooling tower, where the valve diverts water to the top of the cooling tower or bypasses the tower to the sump.



Diverting Valve

2½ inch to 6 inch line size Globe Valves (Cast Iron)

Note: Explained using Invensys VB-8000 series valves. With all Invensys globe valves, the “normal” or failed position is based on stem-up. VB-8000 valves use balanced plug technology that provided high closes off with exceptional rangeabilty for superior control while using a smaller actuators than traditions valves.

½ to 3 inch ball valves

Erie Valves and Actuators

<u>What Valve to Use?</u>

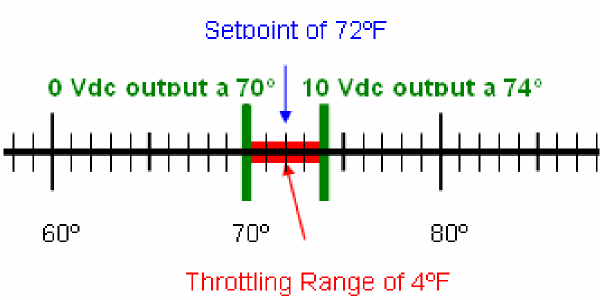
- **GOOD-** ***Erie Valves*** are used for water applications where low pricing or small footprints are the prime considerations.
- **BETTER-** ***Ball Valves*** are an “all around” solution for water applications (no steam). They are more durable than Erie and more cost effective than a globe valve. Ball valves are an excellent choice in hard water environments or sites that do not have great water treatment.
- **BEST-** ***Globe Valves*** are the top of the line solution. For steam or pneumatic applications, they are the best solution. Globe valves can also be field serviced.

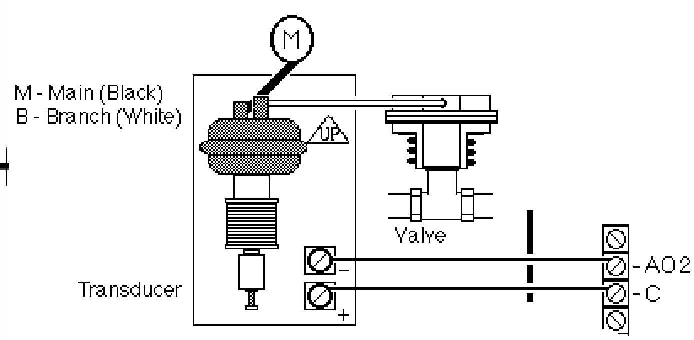
Transducers

Transducers allow electronic controllers to use pneumatic actuators. Transducers convert one type of proportional energy into another. An electronic-to-pneumatic (E-P) transducer converts a voltage or current input into a pneumatic (psig) output.

An E-P transducer converts a proportional electrical signal to a proportional pneumatic signal. Setup is required to modify the voltage signal to match the desired pneumatic output signal.

As an example of an electronic controller connected to a transducer, 0 Vdc is converted into 3 psig, causing the valve to be open. At 10 Vdc, the output from a transducer is 13 psig, completely closing the valve. With a pneumatic controller, 3 psig is sent to the actuator, completely opening the valve. When the controller sends a 13-psig signal to the actuator, the valve strokes to the closed position.

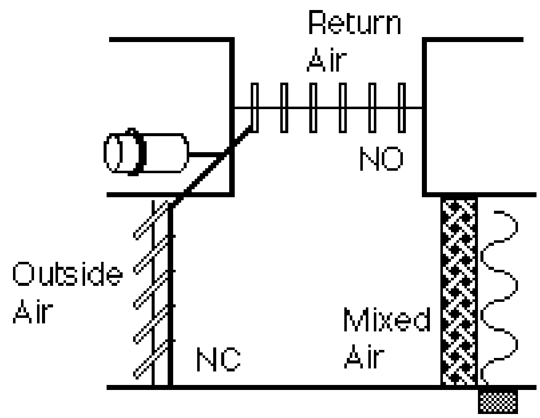




Dampers

The proper damper operation is important to a building. The common types of dampers are parallel blade and opposed blade.

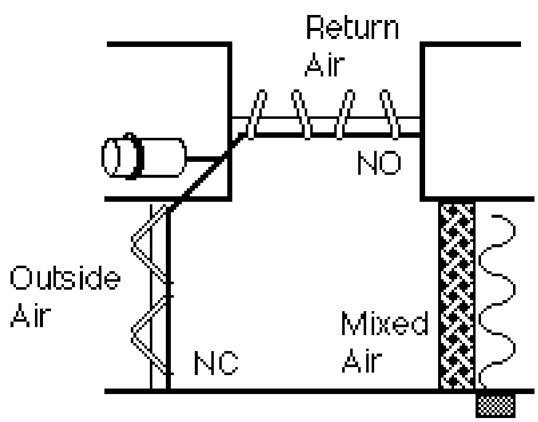
Parallel Blade Dampers



Parallel Blade Dampers

Parallel blade dampers are pictured above. Note that the blades of the damper are parallel to each other. Outside air dampers are linked normally closed, so that if any problem occurs, such as a *low limit* alarm, the outside air dampers go closed. In this example, the return air dampers are linked normally open.

Opposed Blade Dampers

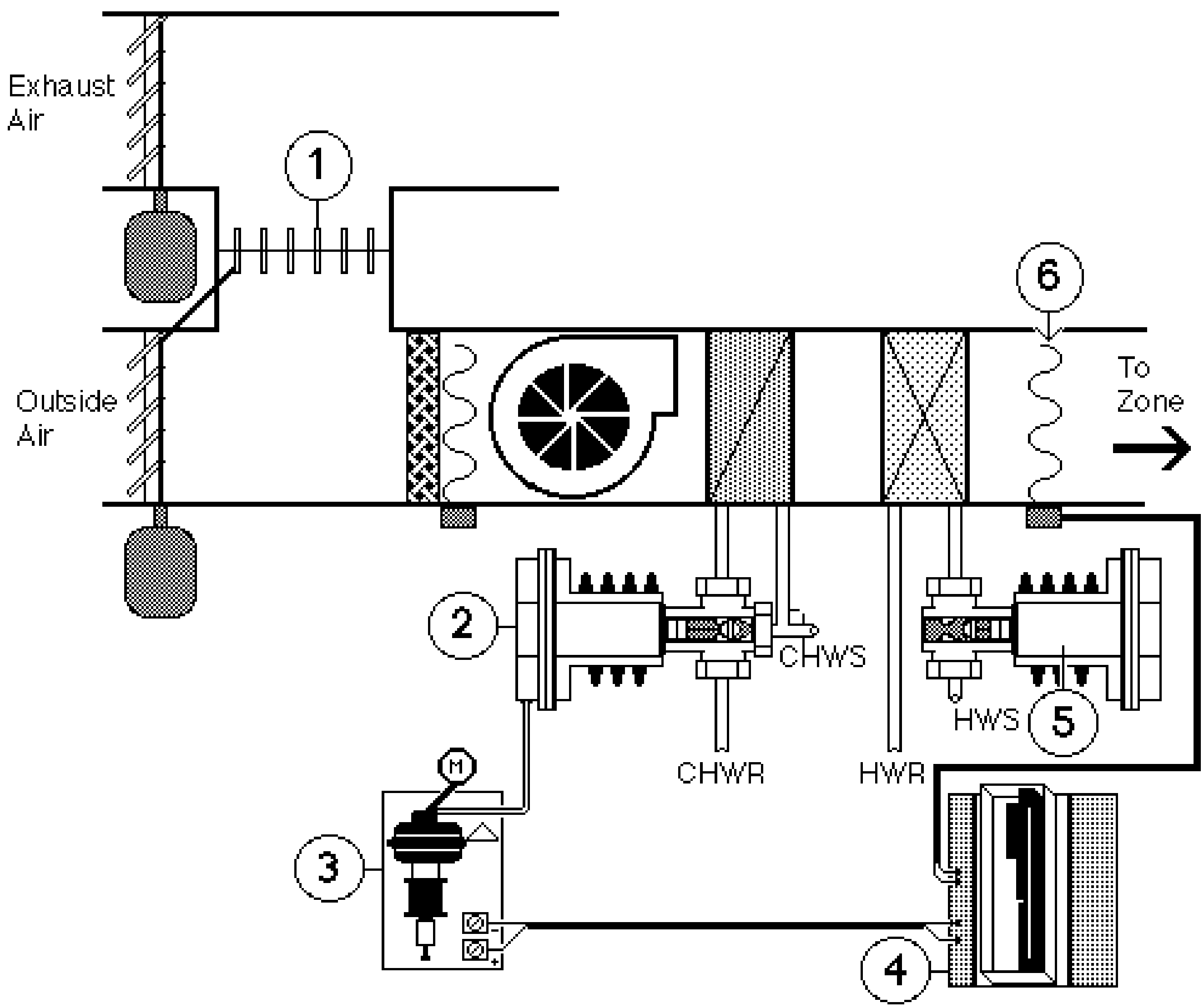


Opposed Blade Dampers

The diagram above shows *opposed blade dampers* in which the adjoining blades of the damper are positioned in opposite directions. It is important that outside air dampers and return air dampers work together. As one damper closes, the other damper opens. If these two dampers fail to work properly and both become closed, the supply fan will continue to pull in air, which could result in the ductwork collapsing.

Review

Review the following diagram and answer the questions on the next page.



Review the previous page and answer the following questions.

Answer questions 1 through 3 by filling in the identification number of the device.

Fill in the Blank

1. Which numbered device is a sensor? __________

2. Which numbered device is a controller? __________

3. Which two devices are controlled devices for *water*? _______ ______

Fill in the Blank

4. Device #1 shows _______________ blade dampers.

5. These dampers control ____________ air.

6. These dampers are linked normally _______________.

7. Device #3 is a __________________.

8. Device #3 converts an ___________ signal into a ____________ signal.

9. Device #2 is a three-way _______________ valve.

10. Device #5 is a two-way ______________________ valve.

Answers to the review

1. 6.
2. 4.
3. 2 and 5
4. Parallel
5. Return
6. Open
7. Transducer
8. Electronic signal into a Pneumatic signal
9. Mixing
10. Normally Open

Control Theory Terminology

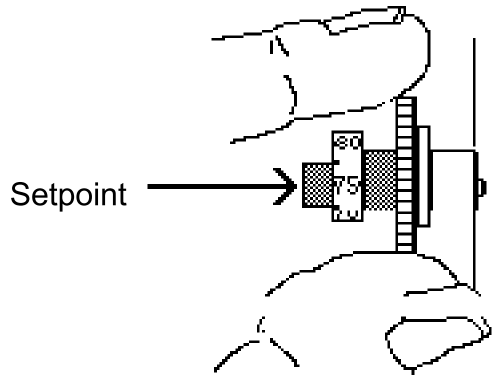
This section covers the following terms:

- Setpoint, Control Point, Offset
- Controller Action
- Reset
- Proportional Control
    - Throttling Range
    - Proportional with Integral (P.I.) Control
- ON/OFF control
    - Differential
    - Floating Control

Setpoint, Control Point, Offset

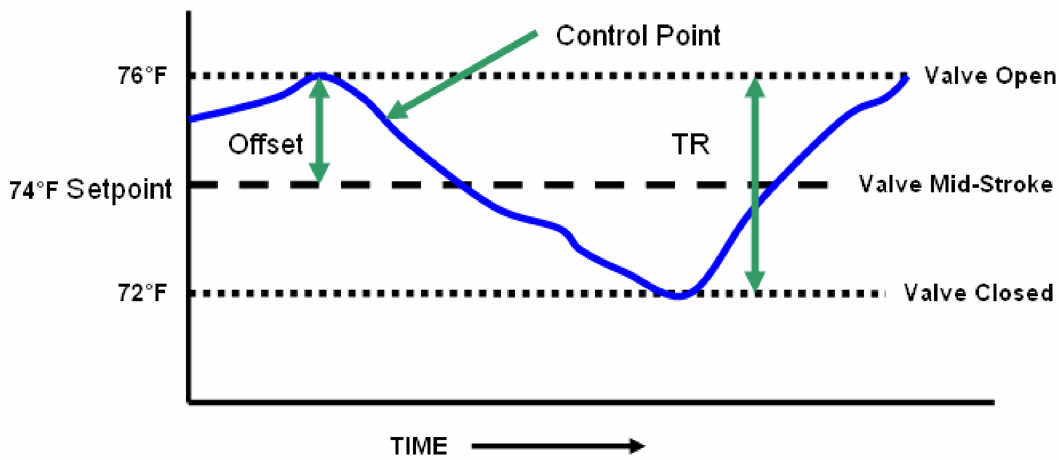
Setpoint

Setpoint is the desired condition of a variable that is to be maintained, such as temperature. A room that needs relative humidity to be at 50% RH, or an air handler duct pressure that is to be 2.0 *in. w.c. (inches of water column)* (500 Pa) are examples of setpoints. In the example below, 75°F (24°C) is the room temperature setpoint.



Control Point

The *Control Point* is the actual temperature being sensed. The Control Point (temperature) may not be on the setpoint, but instead may be above or below it. Systems operate to maintain the setpoint, plus or minus some acceptable limits called differential (two-position or on/off control) or *throttling range* (*proportional control*). Simply stated, setpoint is what you want, while control point is what you get. In the example below, the setpoint is 74°F (23°C), and the control point is shown in blue.

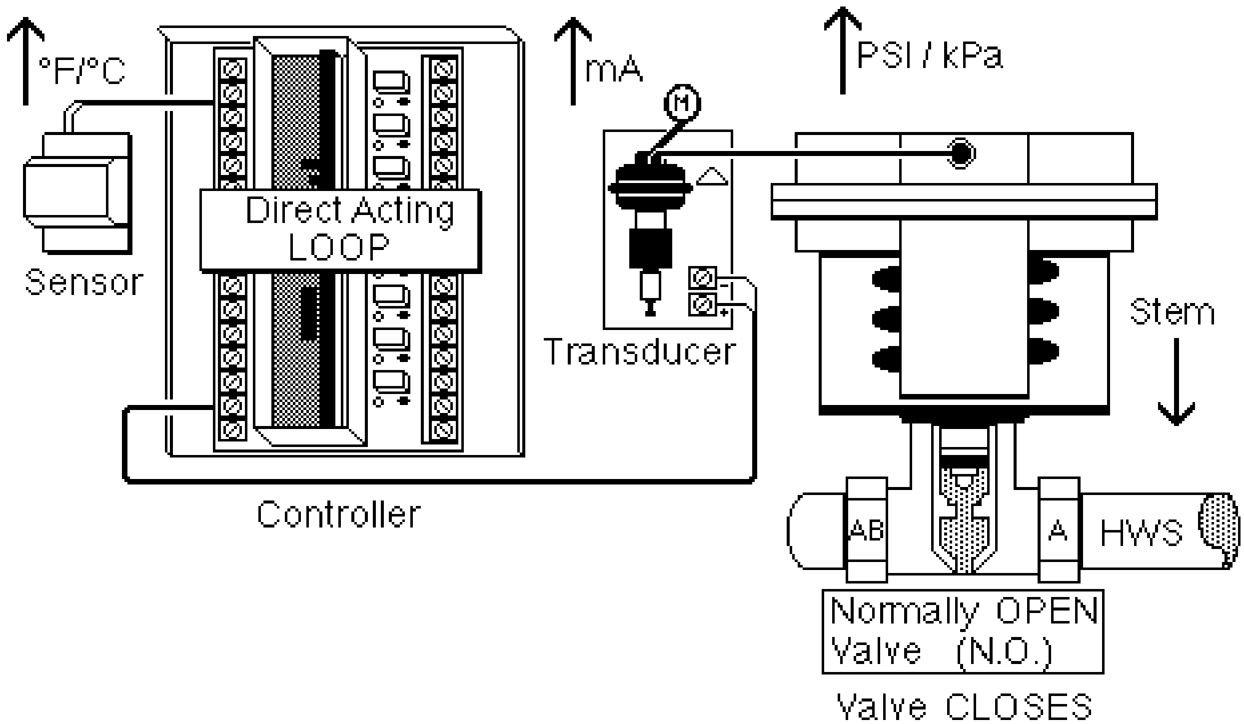


Offset is the amount away from setpoint or the difference between the Setpoint and the Control Point. In the example above, the offset is approximately 4°F.

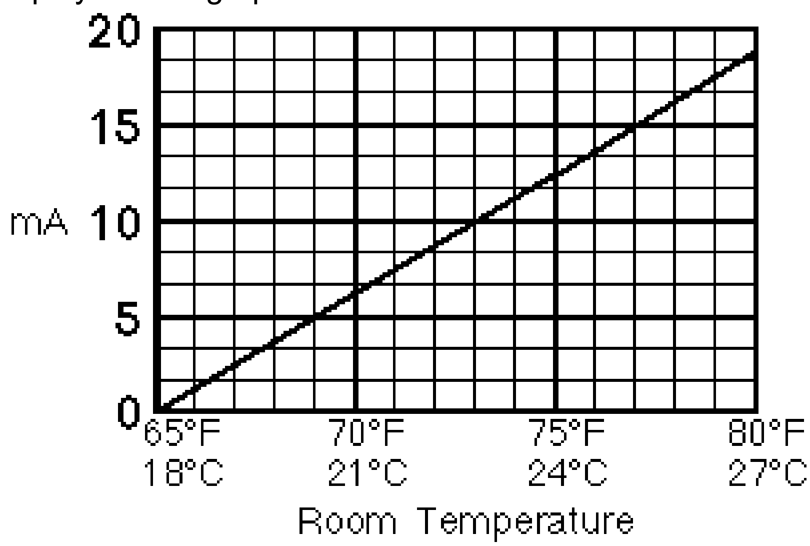
Controller Action

All controllers, from pneumatic to DDC electronic, have an action. They are either *Direct Acting* or *Reverse Acting* (although other terms may be used).

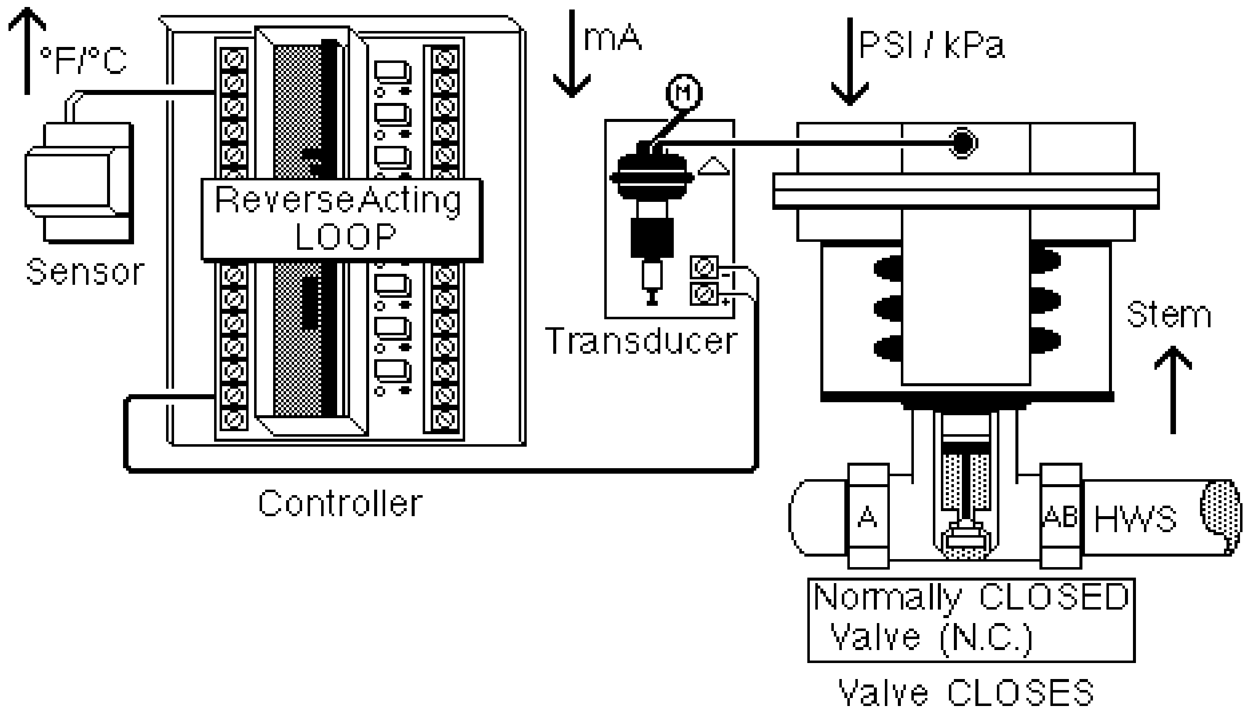
Direct Action means that the controller's output increases as the sensor's input increases. For example, as room temperature (the variable) changes from 70°F (21°C) to 71°F (21.5°), the controller changes its output from 10 to 12 mA. Shown below, as the sensor reads an increasing input (temperature), the controller responds by increasing its output (pressure) to the valve, closing the normally open valve and reducing the hot water flow.



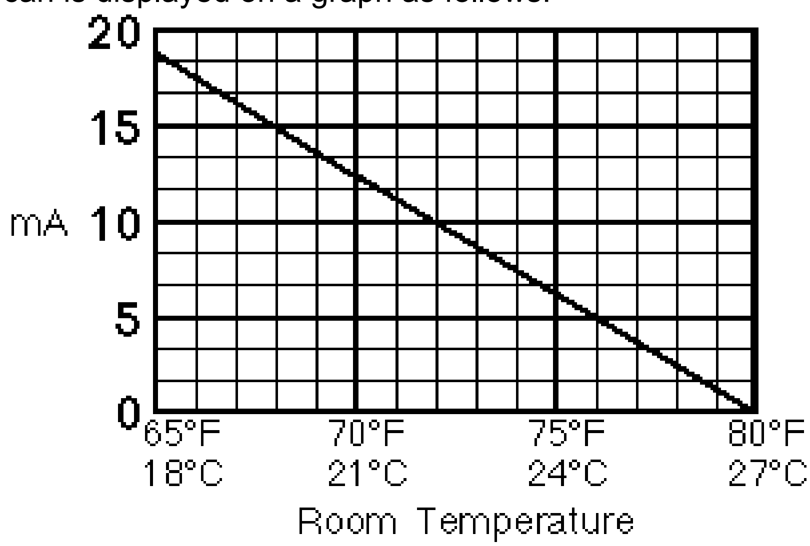
This relationship between the input to a controller (temperature) and its output (current) can be displayed on a graph as follows:



Reverse Action means that as the variable (for example, temperature) increases, the controller's output decreases. For example, as room temperature rises from 70 to 71°F, the controller output decreases from 8.1 to 7.3 mA. In the example below, as the sensor reads an increasing temperature, the controller responds by decreasing its output (pressure) to the valve, closing the normally closed valve and reducing the amount of heating.



This relationship can is displayed on a graph as follows:



The action of the controller must match the proper HVAC application. Normally open heating valves always use direct acting controllers. If a reverse acting controller were to be placed on a normally open heating valve, the heating valve would open as temperature rises. A reverse acting controller never properly controls a normally open heating valve.

The table below was developed to help determine the correct controller action for different applications. To use the table, first pick the correct application: for temperature, select heating or cooling; for humidity, select humidification or dehumidification; for pressure, select whether the sensor is downstream or upstream from the controlled device.

The second step is to determine how the application fails. Example, does the heat fail to full ON or full OFF? Once these questions are answered, follow the column down and follow the row across to the intersection to find the correct action for that application.

Controller Action ***Instructions:*** 1. Pick system application 2. Pick fail safe condition 3. Intersection shows action	***Heating*** ***Humidification*** ***Pressure*** (sensed downstream from C/D)	***Cooling*** ***Dehumidification*** ***Pressure*** (sensed upstream from C/D)
System Fails to ON • Normally open ports, valves, or dampers • Normally closed electric contacts	D.A.	R.A.
System Fails to OFF • Normally closed ports, valves, or dampers • Normally open electric contacts	R.A.	D.A.

Example: In Florida, you are controlling a normally open chilled water valve. In this example, the cooling column is used. In much of Florida, cooling is far more important than heating. Since the valve is normally open, the "Fails to ON" row is used. The column and the row intersect at R.A. or Reverse Acting. As the temperature increases, the signal drops, allowing the chilled water valve to go to its normal open position. As the temperature decreases, the signal increases, closing the normally open chilled water valve.

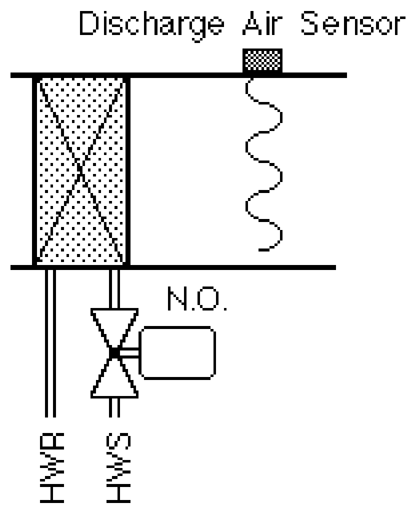
Controller action is very important. Review the examples on the next page and determine if the controller should be D.A. (Direct Acting) or R.A. (Reverse Acting).

REVIEW

Circle the correct answer.

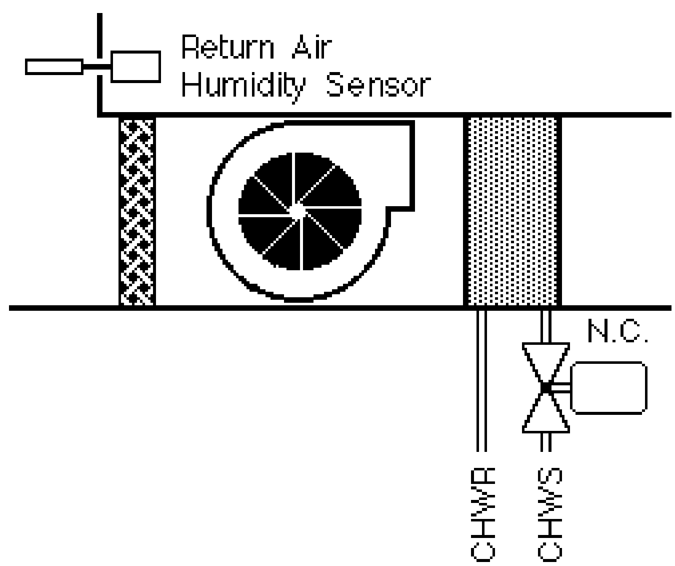
1. A discharge air sensor modulates a normally open hot water valve. What action is needed for the controller?

Circle the correct answer. D.A. or R.A.



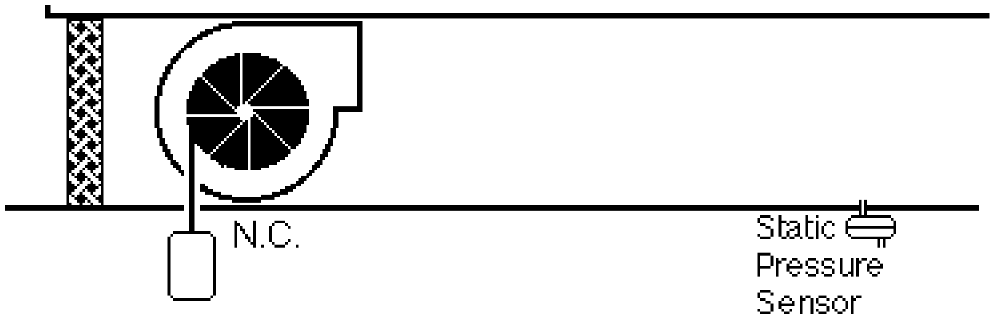
2. A return air humidity sensor modulates a normally closed chilled water valve for dehumidification. What action is needed for the controller?

Circle the correct answer. D.A. or R.A.



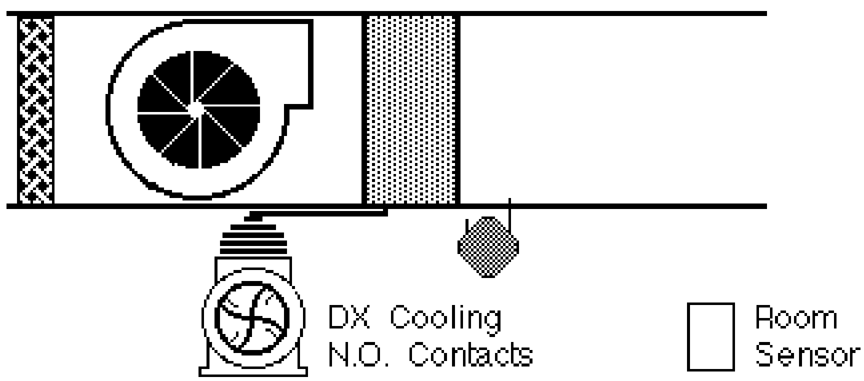
3. A static pressure sensor modulates normally closed inlet vane dampers to maintain 2.0" w.c. (500 Pa). What action is needed for the controller?

Circle the correct answer. D.A. or R.A.



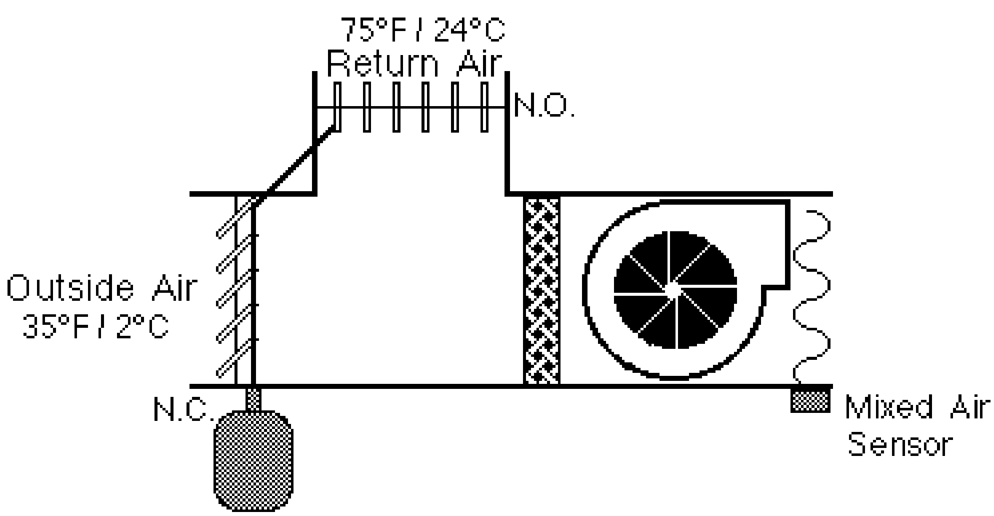
4. A room sensor cycles DX cooling to maintain a room temperature of 75°F (24°C). The DX Cooling has normally open electrical contacts. What action is needed for the controller?

Circle the correct answer. D.A. or R.A.



5. The mixed air sensor modulates the normally closed outside air dampers and the normally open return air dampers to maintain a temperature of 55°F (13°C). What action is needed for the controller?

Circle the correct answer. D.A. or R.A.

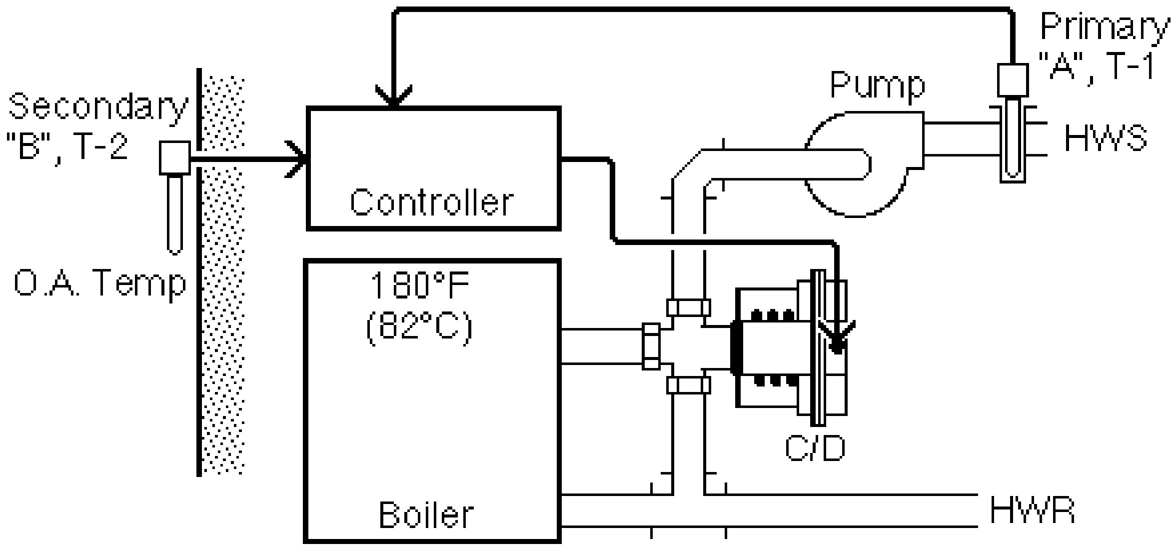


Answers to the Review

1. Direct Acting
2. Direct Acting
3. Reverse Acting
4. Direct Acting
5. Direct Acting

Reset

The word *reset* has different meanings in HVAC. Reset in this instance is the automatic resetting of a setpoint based on a secondary signal. Reset of a setpoint is used for comfort reasons, for better control, or to save energy. A common example of reset is called hot water reset. Hot water reset automatically decreases the hot water temperature setpoint as the outside air temperature rises. If the outside air temperature is 0°F (-18°C), the building requires 180°F (82°C) water. If the outside air temperature is 70°F (21°C), the building requires 90°F (32°C) water. As the outside temperature increases, the hot water setpoint drops.



In every reset application there are at least two sensors. In the example above, the two sensors are outside air temperature (O.A. Temp) and hot water supply temperature (HWS). It is important to know which sensor is the primary sensor and which is the secondary sensor. To determine which is the **primary sensor**, ask, "What are the controls trying to control?" In this example, there is one sensor in outside air and one in hot water. Of these two, the hot water is being controlled, therefore the hot water sensor is the primary sensor. The outside air temperature sensor is the **secondary sensor**. The function of the secondary sensor is to reset, or automatically change, the setpoint of the controller.

Each reset application uses a reset schedule. This schedule is determined by the mechanical engineer or the application engineer. A hot water reset schedule is shown on the next page.

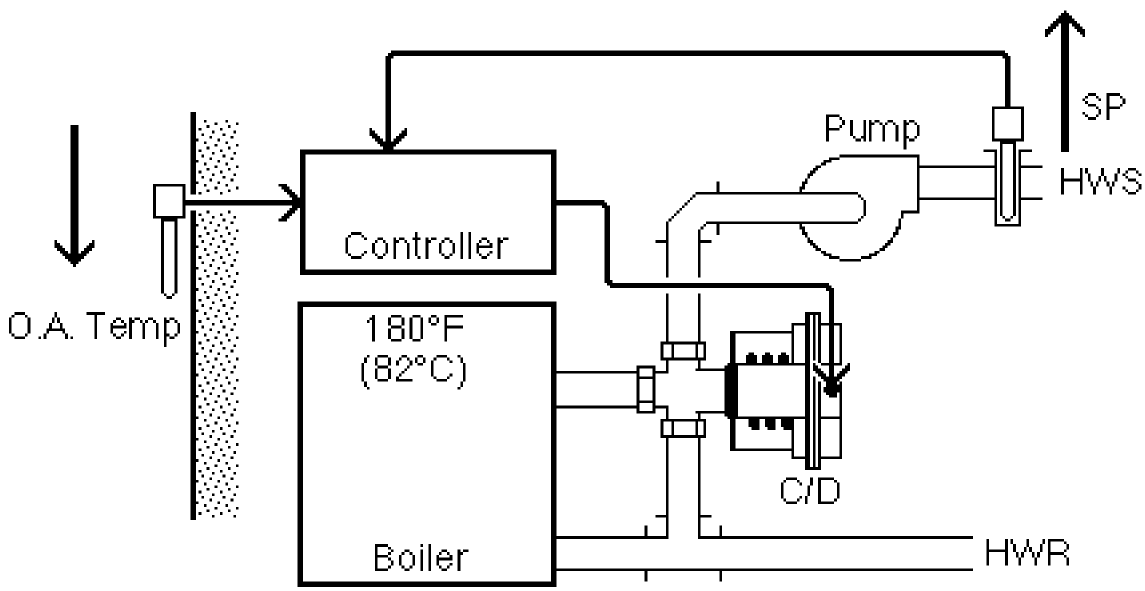
RESET Schedule

O. A. Temp	HWS Setpoint
0°F / -18°C	180°F / 82°C
70°F / 21°C	90°F / 32°C

Just as the term "action" is defined as reverse and direct, "reset" is also defined as reverse and direct. The hot water reset, above, is an example of *reverse reset*.

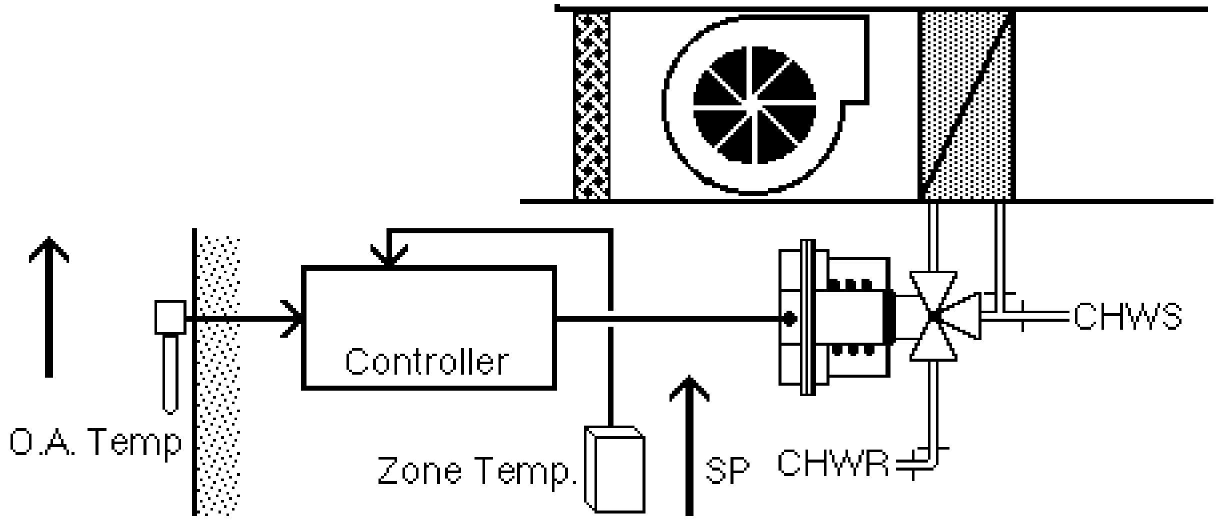
Reverse Reset

The more common of the two types of reset is reverse reset. Reverse reset means that as the signal from the secondary sensor drops, the setpoint of the controller increases. In the example above, as the outside air temperature drops, the hot water setpoint rises.



Direct Reset

With *direct reset*, as the signal for the secondary input increases, the setpoint increases. Direct reset is less common than reverse reset. An example of direct reset is an application called "summer compensation", shown below.



Summer Compensation

When cooling (air conditioning) was first introduced, shopping malls advertised their stores as being a comfortable 72°F (22°C) year round. This was fine until the summer became very hot. People who were outside in 100°F (38°C) weather, dressed for hot weather, would walk into a shopping mall and feel cold. Some people did not stay long in the stores because it felt too cool. Summer compensation is used to counteract this problem. Summer compensation raises the zone setpoint as the outside air temperature increases. The secondary signal and the setpoint go in the same direction. A typical reset schedule for this application may look like the following:

Summer Compensation Reset Schedule

O. A. Temp	Zone Setpoint
72°F / 22°C	72°F / 22°C
105°F / 40°C	78°F / 26°C

This application is used in any building where a large number of people are entering and leaving all day, such as a shopping mall or bank. If this application is used, it may be important to ensure that the air is dehumidified for proper comfort.

Identifying Reverse or Direct Reset.

Identification of an application as reverse reset or direct reset is possible by looking at the reset schedule and noting the relationship between the secondary signal and the setpoint. If the secondary signal increases as the setpoint decreases, then the application is reverse reset. If the secondary signal increases as the setpoint increases, then it is direct reset.

Secondary Signal and Setpoint go in **Opposite** directions = **Reverse Reset**

Secondary Signal and Setpoint go in the **Same** direction = **Direct Reset**

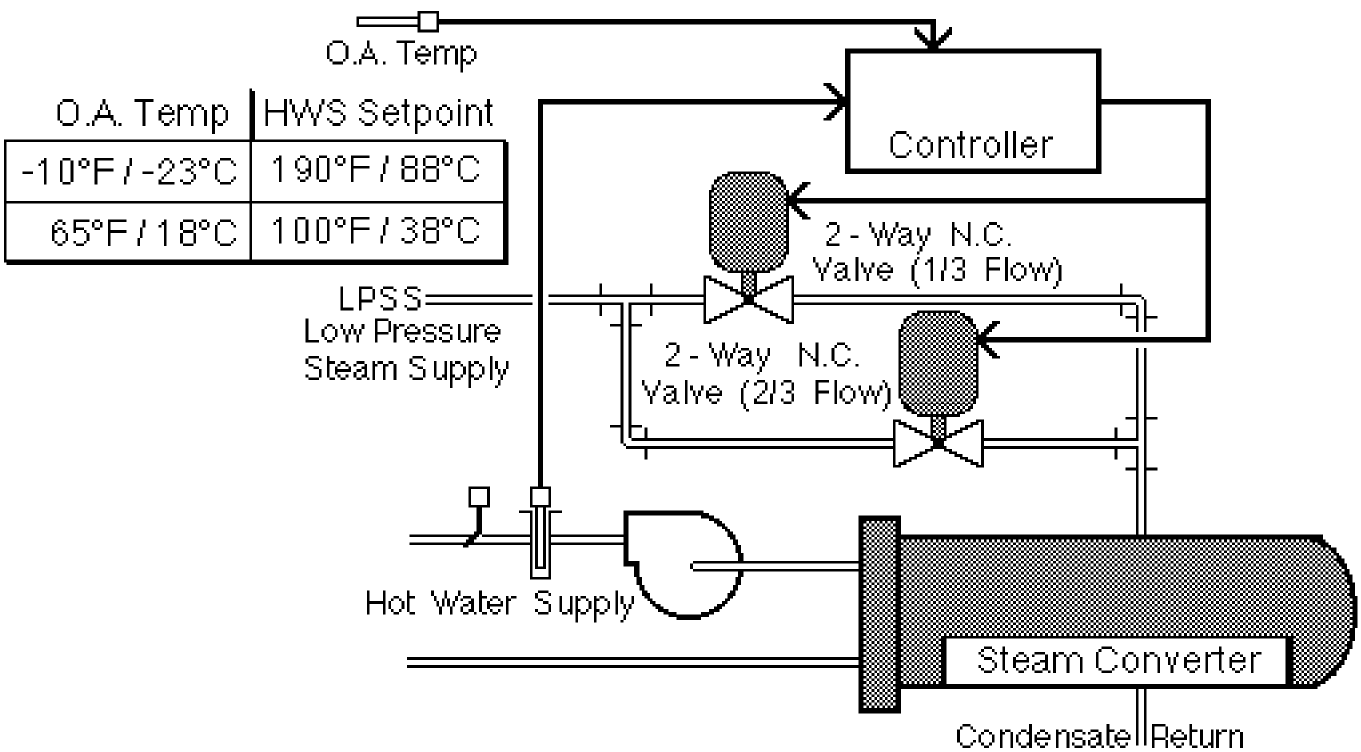
Review

Review the following applications and answer the questions.

Application #1

The hot water supply is maintained by modulating two normally closed steam valves supplying the steam converter.

Hot Water Reset using a Steam Converter



(Circle the correct answer)

1. Which is the primary sensor? — Hot Water Supply (HWS) or Outside Air Temperature (OAT)

2. What type of reset is this? — Direct Reset or Reverse Reset

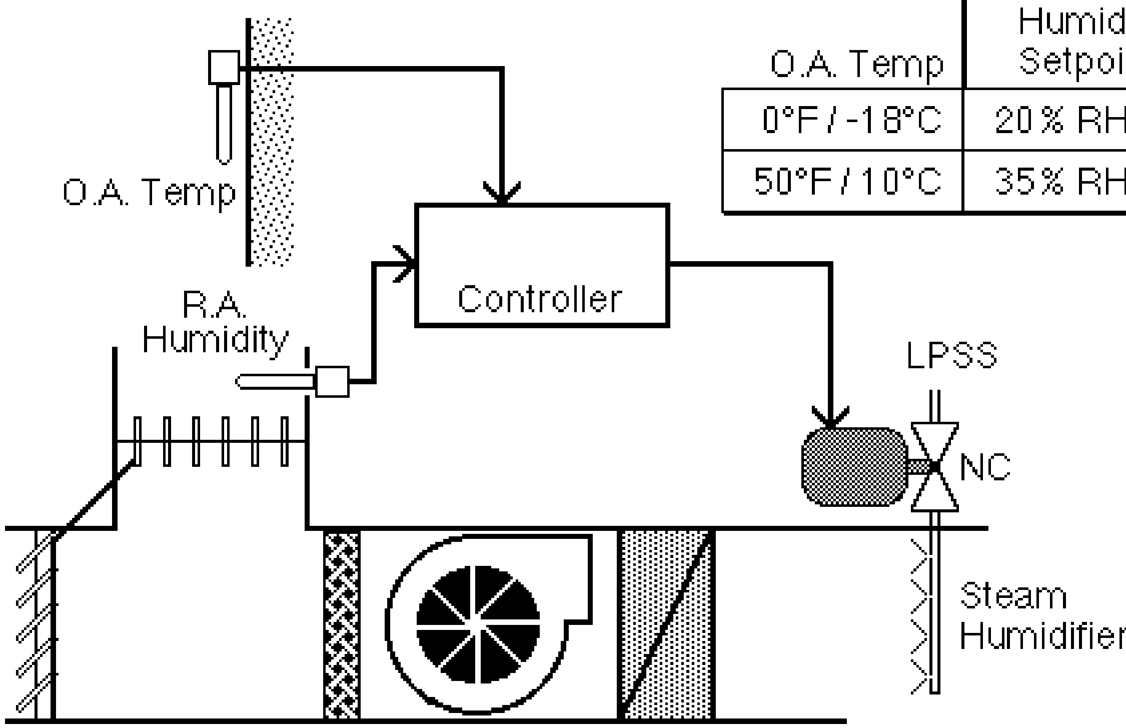
3. What action is needed at the controller? — Direct Action or Reverse Action

Answers follow application #3.

Application #2

The return air humidity sensor controls the normally closed valve on the steam humidifier according to a reset schedule.

Humidity Reset



O.A. Temp	R.A. Humidity Setpoint
0°F / -18°C	20% RH
50°F / 10°C	35% RH

4. Which is the primary sensor? — Return Air Humidity or O.A. Temperature

5. What type of reset is this? — Direct Reset or Reverse Reset

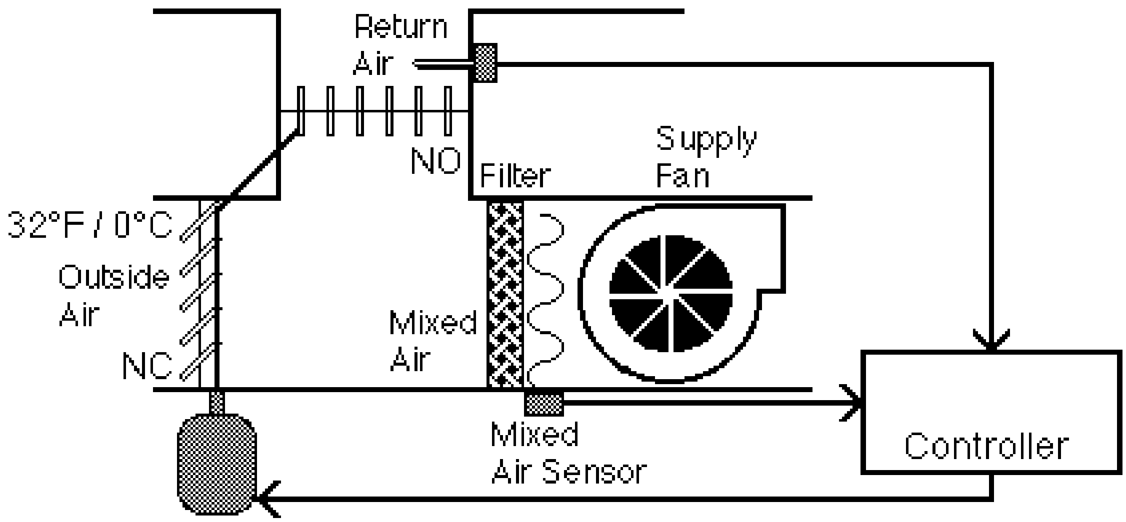
6. What action is needed at the controller? — Direct Action or Reverse Action

Application #3

The mixed air temperature sensor controls the normally closed outside air dampers and the return air dampers. The mixed air temperature setpoint is reset by the return air temperature, according to the following reset schedule.

Mixed Air Reset

Return Air Temp	Mixed Air SP
74°F / 23°C	55°F / 13°C
68°F / 20°C	65°F / 18°C



7. Which is the primary sensor?
   Return Air Temperature
   or
   Mixed Air Temperature

8. What type of reset is this?
   Direct Reset
   or
   Reverse Reset

9. What action is needed at the controller?
   Direct Action
   or
   Reverse Action

Answers to the Review

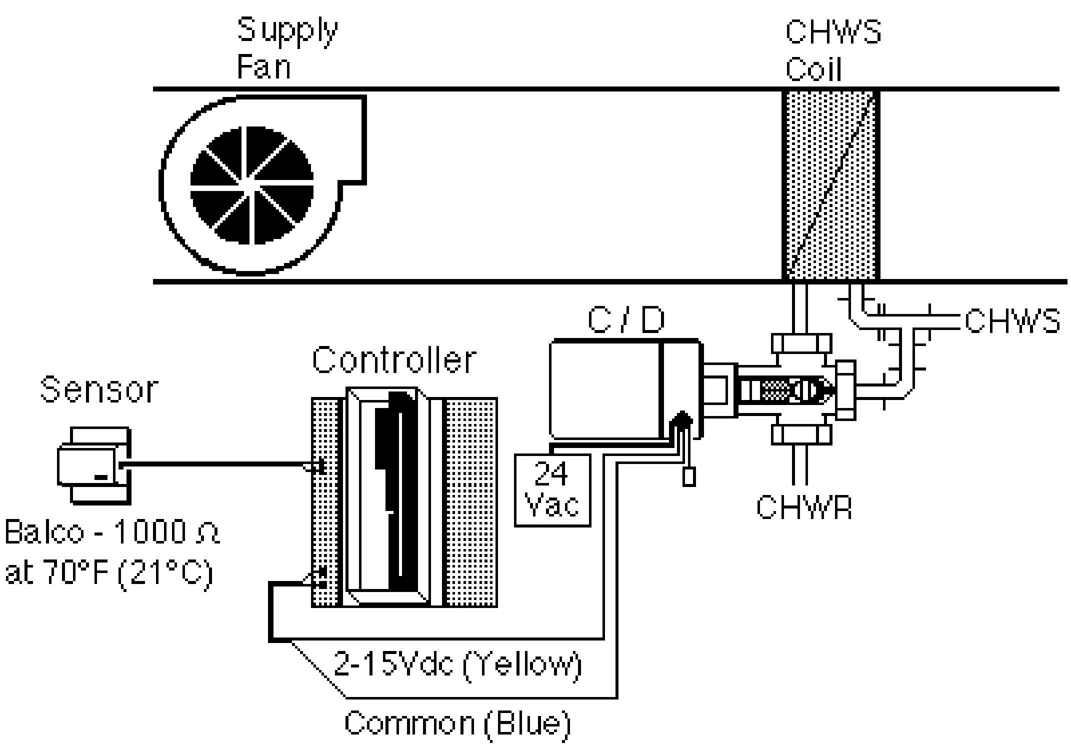
1. Hot Water Supply
2. Reverse Reset
3. Reverse Action
4. Return Air Humidity
5. Direct Reset
6. Reverse Action
7. Mixed Air Temperature
8. Reverse Reset
9. Direct Action

Proportional Control

There are a number of control systems that are proportional by their nature, including pneumatics, electronic *analog* controls, and electronic *digital* controls.

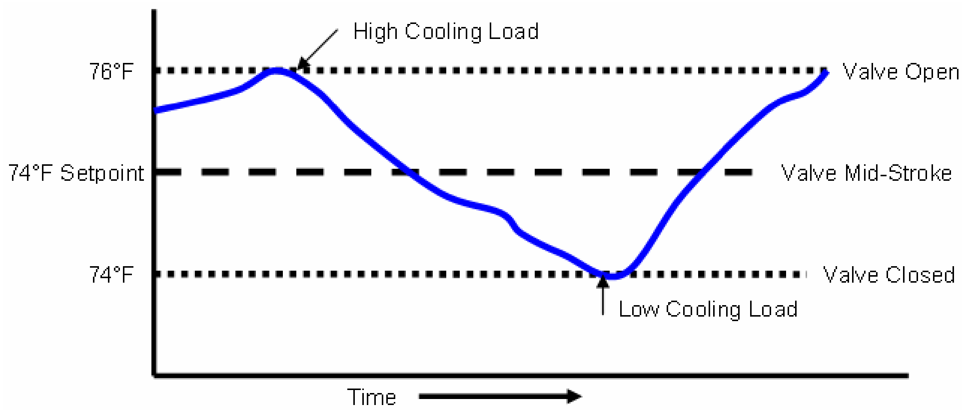
Electronic Direct Digital Control System

Electronic Direct Digital Controls, better known as Direct Digital Controls (DDC), were introduced to the market in the early 1980s. These controls are electronic and microprocessors based, and require programming to operate correctly. These devices run their programs over and over again. Each time a controller completes its program, it scans (reads) the inputs. A DDC controller may scan as fast as several times each second. With each scan, adjustments are made to the outputs. In the example below, a DDC controller modulates a three-way mixing chilled water valve to maintain a room setpoint of 74°F (23°C).



A Balco element may be used as the sensor, although numerous other sensor inputs can be used, including platinum, copper, or 10K thermistors. These are referred to as RTDs (resistance temperature devices). Other inputs might be voltage, from 1 to 5 Vdc, or current of 4 to 20 mA (milliamps). The controller amplifies the signal and provides a setpoint, an action, and a throttling range. The controller might optimize the output, coordinate the output with other controllers, or trend the input and output. Information can be shared with other controllers. The output from the controller goes to the actuator via the yellow wire and varies from 0 to 12 Vdc or from 4 to 20 mA.

Proportional control is a common form of control. Proportional control maintains a setpoint with variations above and below that temperature. A graph of proportional control used with room cooling is shown below.



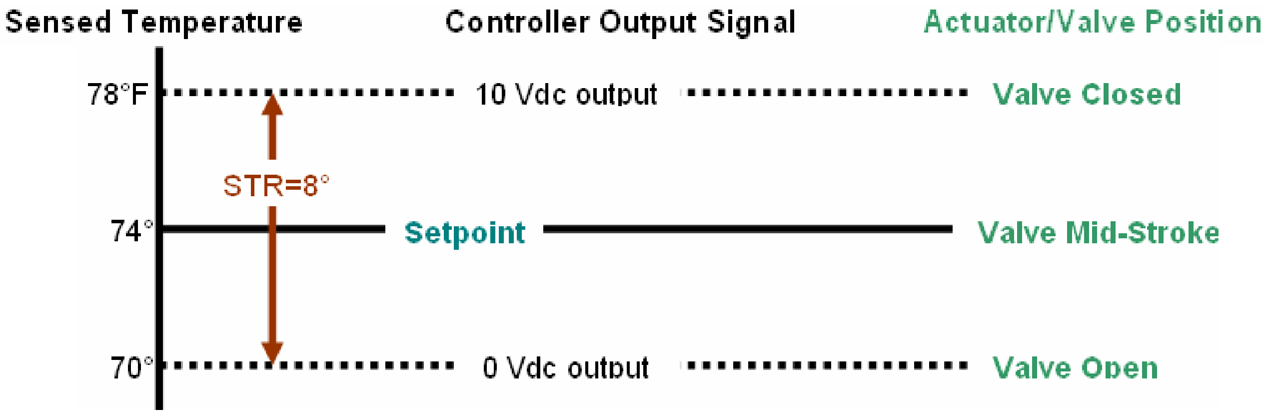
The DDC system on the previous page controls a room with a setpoint of 74°F (23°C). At setpoint, the valve is at midstroke, representing 50% cooling output from the coil*. If there is a large influx of people into the room, the increased heat causes the room temperature to rise. The controller responds by increasing the signal, driving the actuator/valve assembly to the "open" providing additional cooling. Based on the throttling range and the setpoint, each temperature value represents a corresponding actuator position. For example, midstroke is reached at 74°F (23°C). The heavy cooling load resulting from the large number of people entering the space causes the temperature to climb to 76°F (24°C) and the valve strokes to its fully open position. Next, suppose most of the people leave the space, causing a reduction of cooling load. The temperature drops and the actuator retracts, driving the valve to the "close". When the space temperature reaches 72°F (22°C) the valve is full closed. The preceding two examples show that the temperature can swing anywhere within the 4°F (2°C) throttling range, based on the system's cooling load.** It is only when the load is at 50% of its maximum that the space temperature matches the setpoint exactly. Excursions temperature swings of 4° are not noticeable to most people.

*HVAC systems are non-linear. A valve or damper that is 50% open, or at mid-stoke, does not typically equate to 50% flow.

**If the requirement for cooling is beyond the limits of the cooling equipment, the controls may be working properly even though the room temperature is outside the throttling range. For example, if there is a meeting in a room was designed for a maximum capacity of twenty people but forty people actually attend, the heat generated by the additional people will cause the room to become warmer than the controller setpoint plus the throttling range.

Throttling Range

System Throttling Range (STR) is the *change* in the measured variable (i.e. temperature) that causes the controlled device to travel from one end of its stroke to the other. In the example below, the controller's output signal is 0 to 10 Vdc over a change in temperature from 70°F to 78°. It takes a STR of 8°F (4°C) to cause the actuator to travel from the open position to the closed position.



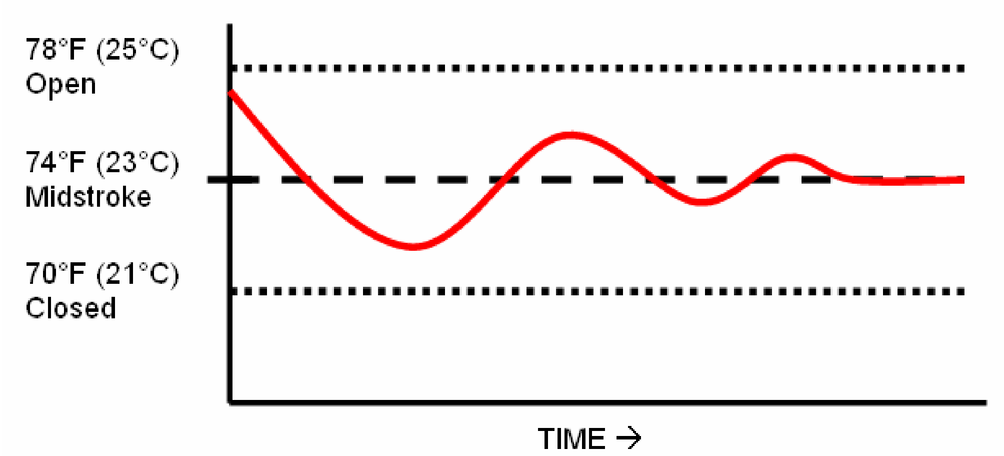
Throttling range is sometimes referred to as "sensitivity". Typical throttling ranges are 6° to 10°F for mechanical controls such as mixed air control and the control of hot water supply. In contrast, room controls must be much tighter, with a throttling range between 2° and 4°F (1° to 2°C)

If the throttling range becomes too narrow, it causes the actuator to go into a mode called *hunting*. In this mode, the actuator continually searches (or "hunts") for the proper controlled position — full open, then full closed; then full open, then full closed, etc. A control system that is hunting, is not in control. It may be possible to eliminate hunting by increase the throttling range so that the controller is less sensitive.

Proportional with Integral (P.I.) Control

Assume that the room that is being controlled has an oversized valve. While there is no substitute for a properly sized valve, *Integral control* can make this condition less objectionable. To stop the actuator/valve assembly from hunting, a wide throttling range 8°F (4°C) may be set. However, room temperature swings of 8°F (4°C) are typically unacceptable and complaints may become common place. A way to correct this situation may be to use proportional plus integral, or P.I., control. Electronic digital controls use this mode of control effectively. Electronic-analog and pneumatic controls can also be set up for P.I. control, but may require considerable time and effort to do so.

Below is a graph of proportional with integral control.

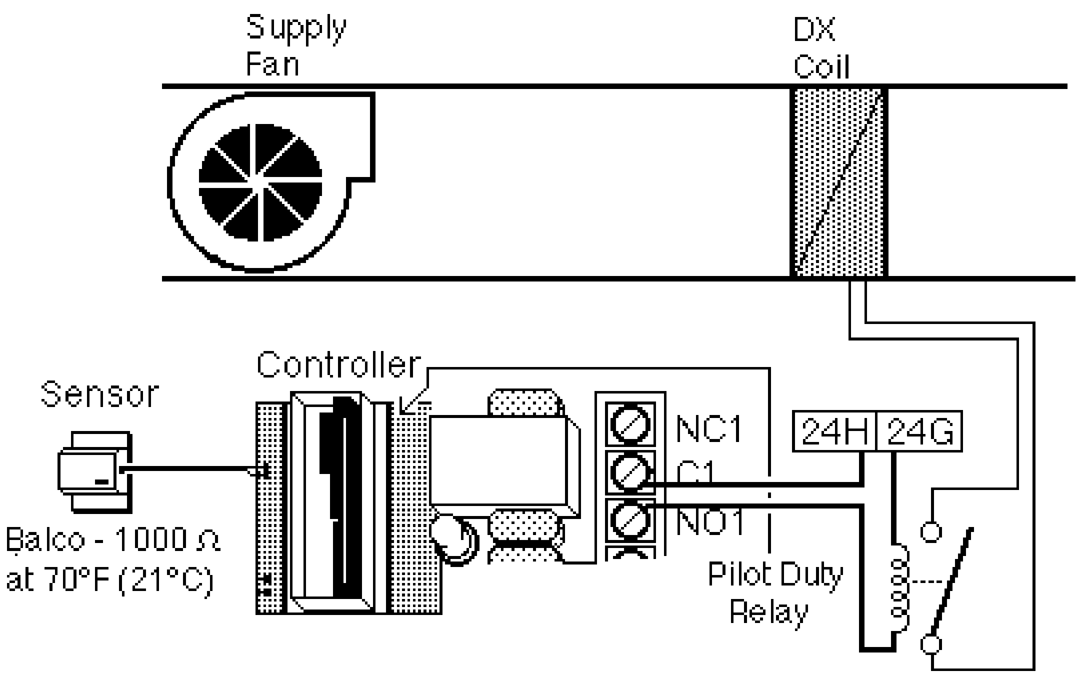


Refer to the graph, above, for an example of how P.I. control works. Note that starting at the left, the temperature matches the setpoint, and the output from the controller is 50%. Then the load changes and there is an offset from the setpoint. The output from the controller starts to compensate, first at 55%, then 60%, then 65% and so forth, until the temperature returns to setpoint. This may cause some oscillation on the part of the controller, but its output eventually stabilizes. In this example the output, at 65%, took three minutes to stabilize and achieve the 74°F (23°C) setpoint. In other words, every time the load changes, the controller attempts to make the setpoint and the control point the same.

Since any temperature changes are amplified, it is important to make sure the system does not hunt before adding integral control. This means the throttling range may need to be increased, or even doubled, to ensure that the system is stable for P.I. control.

ON / OFF Control

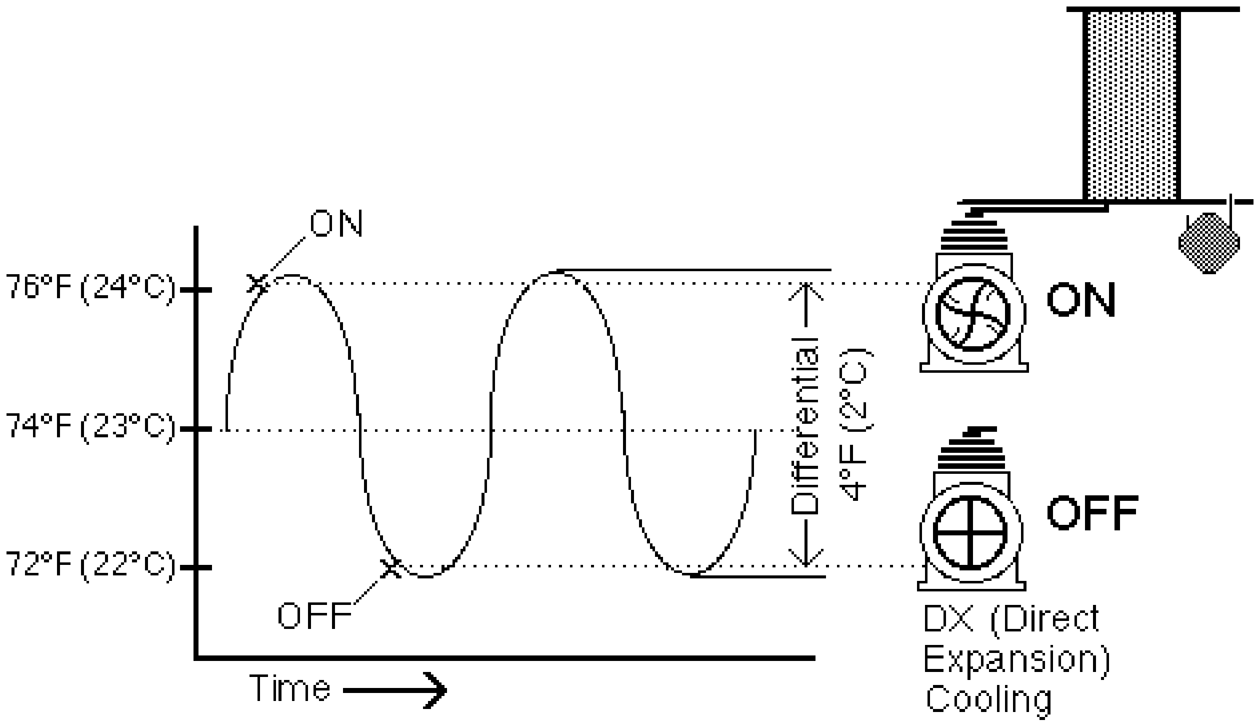
A type of control system where the output is either 0% or 100% is sometimes referred to as "two-position control" or "ON / OFF control". Mechanical equipment such as fans, pumps, chillers, boilers, electric heaters and *D*irect e*X*pansion (DX) cooling may be controlled by a two- position control system. In the diagram below, a room sensor monitors the temperature. The controller uses this sensor information to operate a relay output, by using an appropriate program, the correct action, a setpoint, and a differential. Some controller outputs cannot be used directly to control the large amperage of equipment. In that case, a pilot duty relay is used, as shown below.



In the above example, when the room temperature rises, the controller sends a signal to close the pilot duty relay. The normally open contact is then made to common. This completes the circuit and starts the DX cooling. When the temperature drops, the controller returns the relay output to its open (normal) position, thereby turning OFF the DX cooling.

Differential

A diagram of two-position control as it relates to time and temperature, appears below.



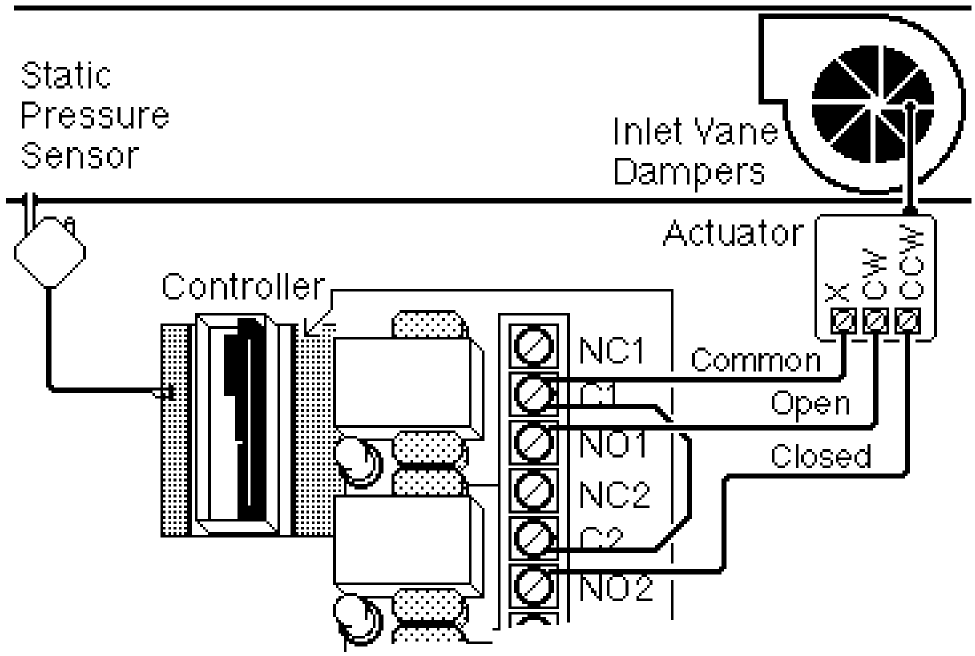
When the temperature reaches 76°F (24°C), the controller turns the DX cooling ON, causing the space to cool. When the temperature has cooled to 72°F (22°C), the controller turns the DX Cooling OFF, causing the space temperature to rise. This 4°F (2°C) swing in temperature is not noticeable to most people. The difference between the temperatures at which the controller turns ON or OFF, is called the **Differential**. The differential is similar to throttling range except that the output is two-position, not proportional. The differential must be wide enough to prevent *short-cycling*, which can cause mechanical equipment to break down prematurely.

The differential is the *change* in the measured variable (i.e. temperature) required to cause the controlled device to go from ON to OFF. The example used in the discussion of throttling range applies here also, with the exception that DX Cooling is cycled from ON to OFF. A 4°F (2°C) differential exists between the temperatures at which DX Cooling comes ON and goes OFF.

There are actually two differentials. **Mechanical Differential** is the difference in the temperatures at which the equipment is turned ON or OFF. The other type is the **Thermal Differential**, which is the swing that occurs in the *actual* room temperature. The thermal differential is wider than the mechanical differential because the cooling or rising of the actual room temperature always lags behind the equipment turning ON or OFF.

Floating Control

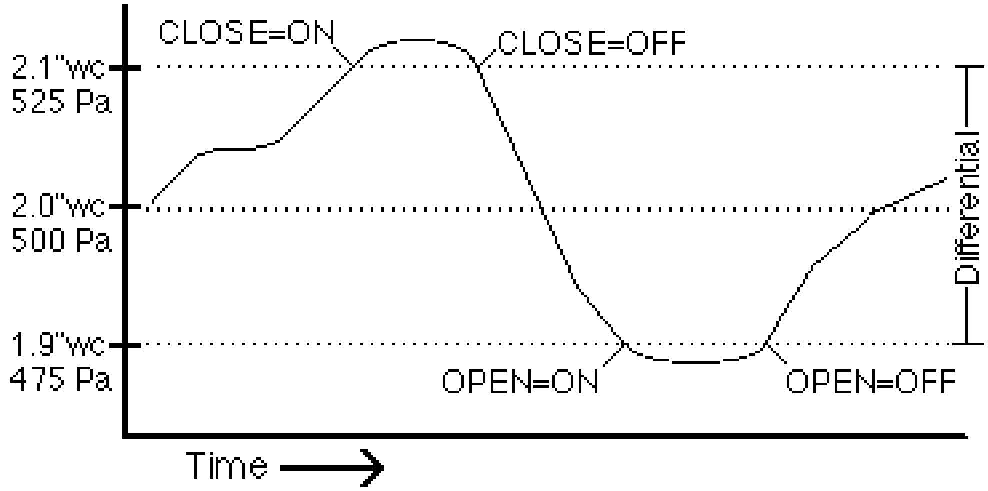
Another variation of ON / OFF Control is Floating Control. Below is an example of this application, in which an electric actuator is used to maintain static pressure inside a supply air duct in a VAV air-handling unit.



The DDC controller in this example is controlling an actuator that positions normally closed inlet vane dampers on a supply fan. At start-up, the inlet vanes are closed and the duct static pressure is low. Because the controller is set up to maintain the duct static pressure at 2 in. w.c. (500 Pa), it completes the OPEN circuit. This in turn drives the electric actuator clockwise, causing the dampers to open, thus allowing more air to enter the duct. This does not necessarily mean the dampers are opened fully. Instead, the system opens the dampers just enough to raise the static pressure to the setpoint, inside the differential. Once this pressure is reached, the controller breaks the OPEN circuit.

If the static pressure is too great, the controller completes the CLOSE circuit. This causes the actuator to drive counterclockwise (anti-clockwise), closing the dampers and reducing the airflow, thus lowering the static pressure. Once the static pressure is within the differential, the controller breaks the CLOSE circuit. At setpoint, neither the OPEN nor CLOSE circuits are made, and the actuator "floats" at its last position.

The diagram of static pressure controlled with floating control, is shown below.



At the left of the graph, when duct pressure is 2 in. w.c. (500 Pa), the controller does not respond. As the demand for cooling drops and several VAV boxes begin to close down, the static pressure inside the supply duct rises. It is only the static pressure reaches 2.1 in. w.c. (525 Pa), that the controller responds. At that point, the controller completes the CLOSE circuit and the actuator slowly drives the inlet vane dampers further closed. If the CLOSE contacts stay closed for only 6 seconds, and it takes 120 seconds for the actuator to travel from one end of its stroke to the other, this would mean than the actuator closed the dampers 5%.

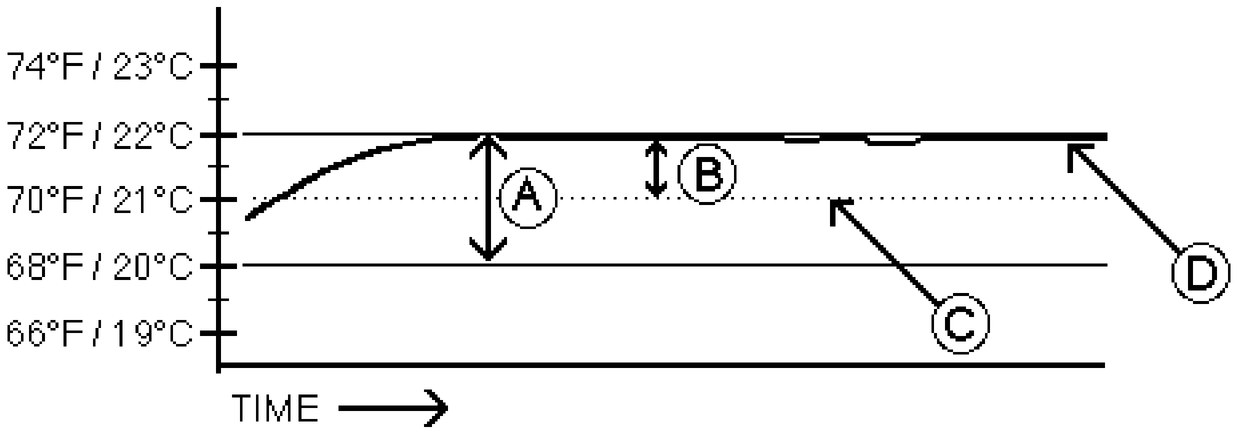
When the demand for cooling increases, some VAV boxes open, and static pressure begins to drop. When the pressure reaches 1.9 in. w.c. (475 Pa), the OPEN contacts are made for 12 seconds, so that the dampers are opened by 10%.

Pulsed Width Modulation

A variation of floating control, which is used in DDC controls, is called Pulsed Width Modulation. This type of control pulses the OPEN or CLOSE contact for a certain number of seconds, then waits for the variable (i.e. temperature) to respond. This type of arrangement has had some success with temperature control.

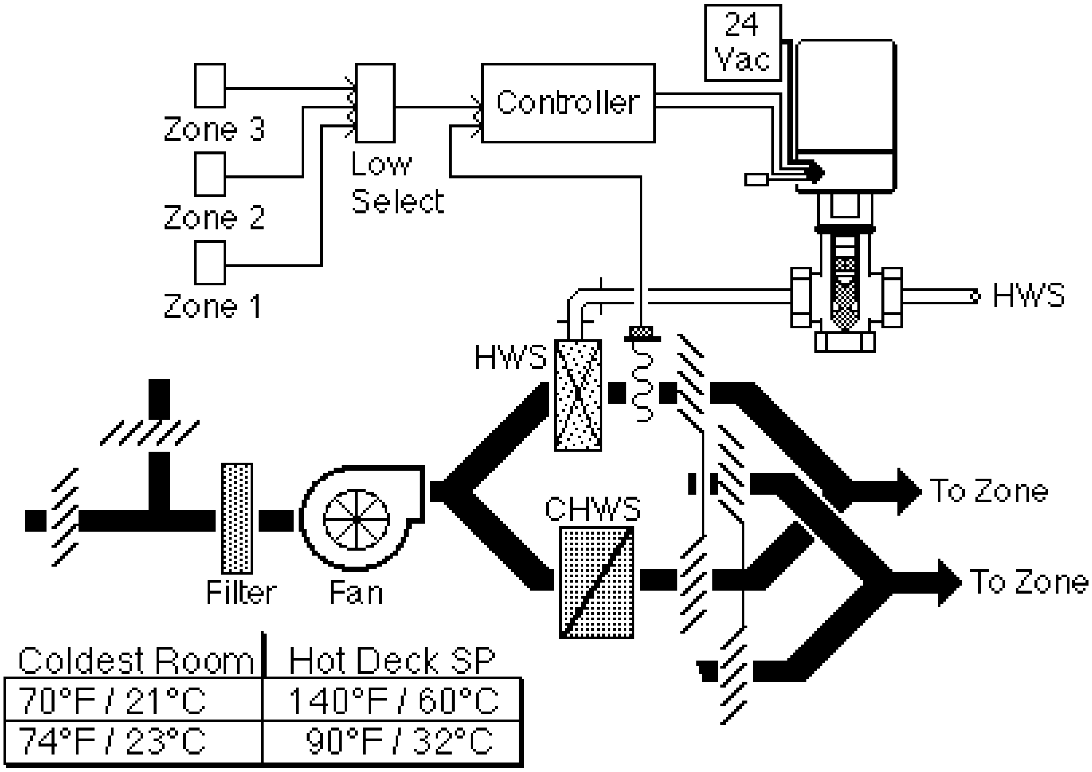
Review

1. Assume that you are using proportional control. Identify each of the lettered items in the graph, with one of the terms discussed in this section, then give its present numerical value either in °F or °C.



	Term Name	Present Value
A.	____________	______________
B.	____________	______________
C.	____________	______________
D.	____________	______________

2. Review the multizone application below, then answer the questions that follow.



Coldest Room	Hot Deck SP
70°F / 21°C	140°F / 60°C
74°F / 23°C	90°F / 32°C

(Circle the correct answer)

A. Which is the primary sensor?

Hot Deck Temperature
or
Low Temperature Select

B. What type of reset is this?

Direct Reset
or
Reverse Reset

C. What type of valve is this?

Normally Open
or
Normally Closed

D. What type of control is this?

Proportional
or
Two-position

E. What action is needed at the controller?

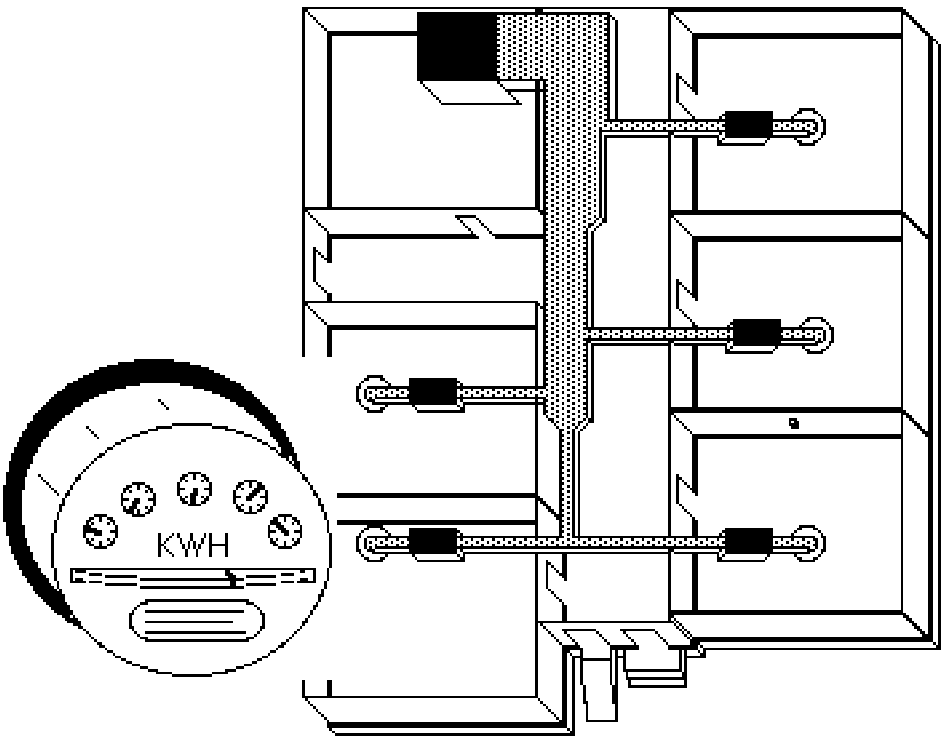
Direct Action
or
Reverse Action

Answers to the Review

1. A. Throttling Range 4°F (2°C)
   (the output is modulating, not two-position, therefore it is not *differential*)
   B. Offset 2°F (1°C)
   C. Setpoint 70°F (21°C)
   D. Control Point 72°F (22°C)

2. A. Hot Deck Temp
   B. Reverse Reset
   C. Normally Open
   D. Proportional
   E. Direct Action

Energy Management Techniques

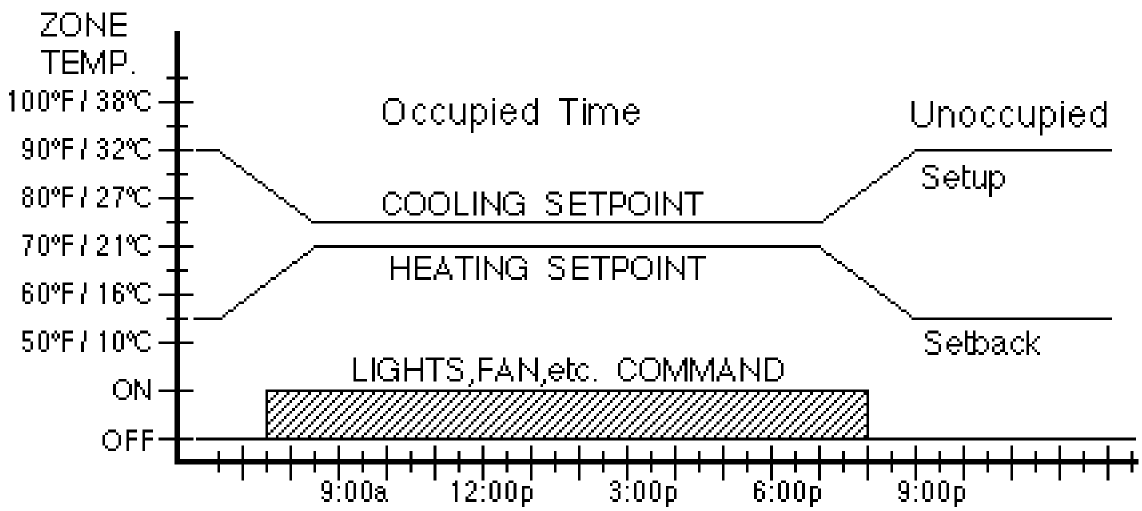


This section covers a number of different strategies used to save energy:

- Timed Programmed Commands
- Duty Cycle
- Optimum Start / Stop
- Electric Demand Limiting
- Enthalpy Optimization
- Degree Day Calculations
- Night Purge Cycle

Before *energy management* is discussed, it is important to remember that there may be a trade-off with comfort. When a building operator attempts to save energy, some comfort may be compromised.

Time-Programmed Commands

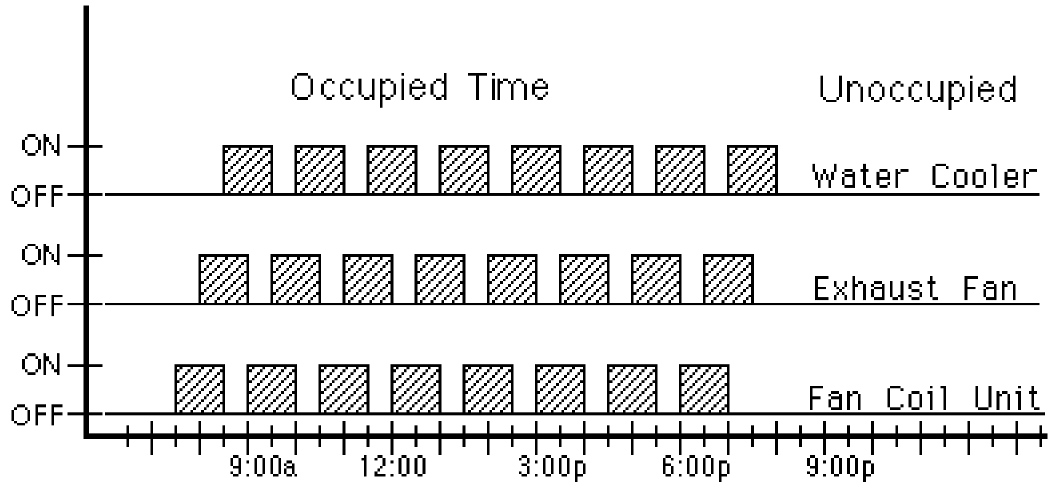


Time-Programmed Commands are an excellent way to save energy. However, this strategy is only effective if a building, or a large portion of a building, has an unoccupied time. During unoccupied time, typically at night, the heating setpoint shifts to 55°F (13°C) (*night setback*); the cooling setpoint shifts to 90°F (32°C) (*night setup*); and lights, fans, chillers, and other mechanical equipment are turned OFF.

Just before occupied time arrives, the heating setpoint shifts to 70°F (21°C) or the cooling setpoint shifts to 75°F (24°C), and the lights, fans, and chillers are turned ON. These temperature setpoints are merely suggestions and may vary. Also, certain types of mechanical equipment, such as a boiler, typically stay ON during winter.

This strategy results in a loss of comfort for those individuals that enter the space during the unoccupied times. If there are individuals who come in after hours, some type of override is required to turn the lights and mechanical equipment back to an *occupied mode*.

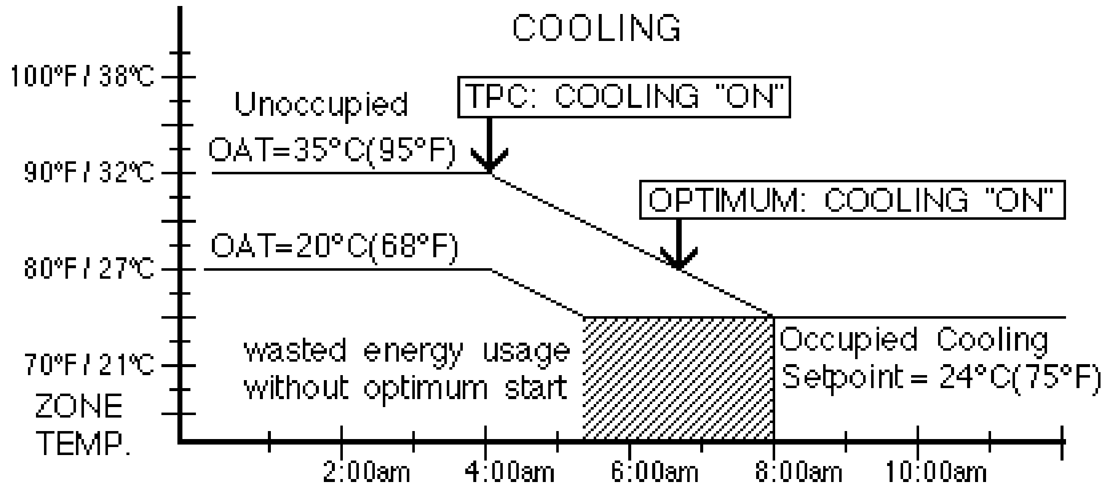
Duty Cycling



Duty cycling is a strategy that cycles certain loads, such as small exhaust fans, ON and OFF. For example, exhaust fans may be cycled ON for 20 minutes, then shut OFF for 10 minutes, continuously throughout the occupied time. This is referred to as a *fixed* duty cycle. At the end of the day, the OFF time may amount to a large portion of the time. While this strategy may look good on paper, in practice it may not be cost effective. For example, if this strategy is used on large fan motors of 15 hp or greater, there may be no energy savings. That is because the money that is saved during the OFF time could be offset by the large current draw required for starting up the large fan, and the ON and OFF cycles can require more maintenance on the motor belts and other equipment.

A modification of this strategy is called the **Temperature Compensated Duty Cycle**. This strategy is used with electric baseboard heaters. If the temperature in the space is 70°F (21°C), the heaters are ON for 1 minute and OFF for 14 minutes. If the space temperature drops to 68°F (20°C), then the heaters are ON for 7 minutes and OFF for 8 minutes. If the space temperatures continue to drop to 66°F (19°C), then the heaters are ON continuously and are not shut OFF until the temperature in the space reaches the setpoint.

Optimum Start / Stop



Optimum Start can be a valuable strategy for saving energy if there are unoccupied times in a building. The optimum start program computes the best, or optimum, time to start the heating or cooling equipment so that at the precise beginning of occupied time, the zone is at the desired temperature. Significant amounts of energy may be saved if the occupied setpoint is achieved as close to occupied time as possible.

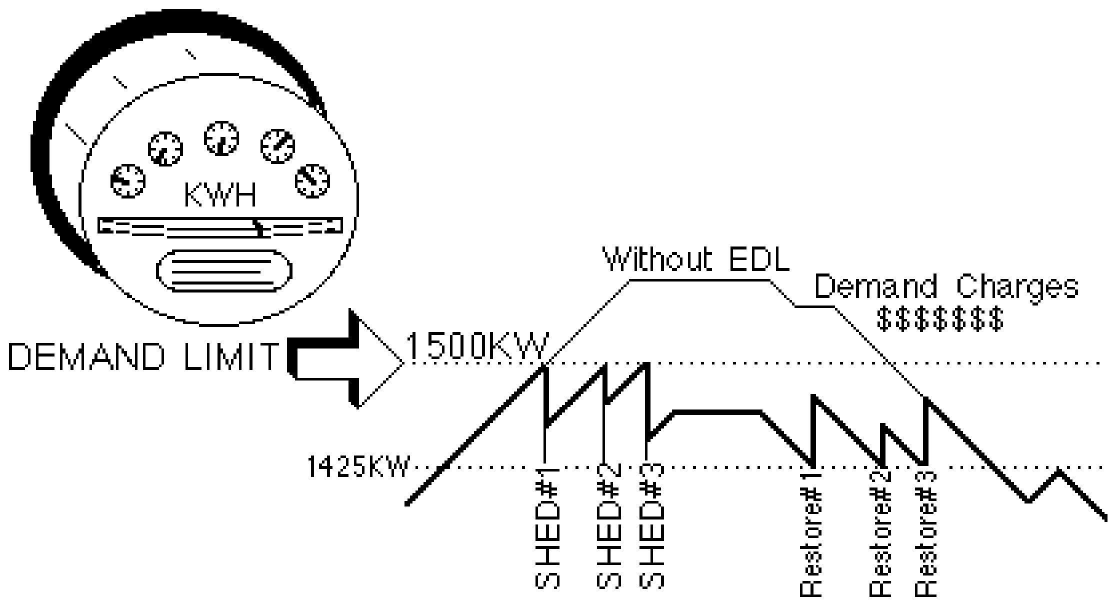
Note the example in the chart above. Using only Timed Program Commands (TPC), and identifying the worst possible conditions in which to start cooling, it has been decided that the cooling must be started at 4:00 a.m., 4 hours before occupied time, when it is 95°F (35°C) outside and the zone temperature is 90°F (32°C). This may be a good strategy if these worst-case conditions always exist. However, if the outside air and zone temperatures are lower, the setpoint will be reached in a shorter time than necessary, wasting energy. As the chart shows, if the outside air is 68°F (20°C) and the zone temperature is 80°F (27°C), the cooling equipment would achieve the occupied setpoint *2-1/2 hours before* occupied time, which is much earlier than necessary. Instead, when optimum start is used under these cooler conditions, the occupied cooling is started *1-1/4 hours* before occupied time. This is much more efficient than the *4 hours* chosen in the earlier strategy.

Optimum start is used in the same way for heating. If heat is required in the morning to raise the temperature to the occupied setpoint, the program would automatically calculate the start time so that setpoint is achieved just before occupied time begins. That means that on warmer mornings, the heating equipment is started at a later time than it is on cooler mornings.

The **Optimum Stop** program calculates a stop time that allows the temperature of the space to “coast” from the occupied setpoint towards the unoccupied setpoint, while maintaining an allowable comfort level with the least amount of energy usage. For example, the program would monitor the end of the occupied day and begin turning heating and cooling equipment OFF as people leave the building, to “coast” to the unoccupied setpoints.

Electric Demand Limiting

Power Demand Limiting is also referred to as EDL.



ELECTRIC DEMAND LIMITING (EDL),

Controlling energy costs is a major concern for today's building owners. Trying to manage the consumption of electricity is a concern for the utility provider, as well. One strategy that electric companies have instituted to hold down electricity usage is to impose **demand charges**, in which the utilities set a demand limit for a facility's electric usage. If this limit is exceeded, the facility pays a penalty, or demand, charge. These demand charges could comprise 30% to 70% of the electric energy bill. An additional problem is that even one excursion beyond the demand limit could increase the utility bill for as long as an entire year. Of course, utility companies and areas vary in the approach taken with consumer utility management, therefore it is suggested that you consult with your providers to ensure your programs are set up correctly.

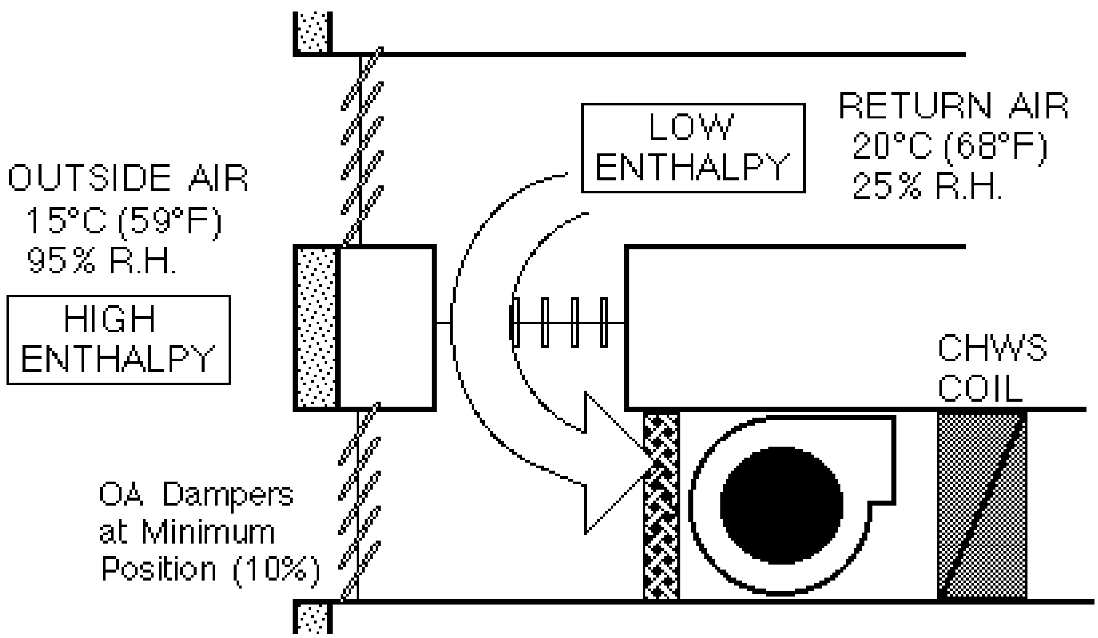
An effective way to manage demand and limit the number of excursions is to use an Electric Demand Limiting (EDL) program. In this strategy, automation equipment, using EDL, monitors all the demand circuits. Through a technique known as sliding-window data, EDL predicts (forecasts) an expected demand level before it occurs. The forecasted demand level is then compared to the pre-established demand limit. If the forecasted value exceeds this demand limit, the program computes the magnitude of the expected excursion and automatically sheds sufficient loads (*load shedding*) to prevent the excursion from occurring. Once the demand drops below the limit, those previously shed loads are brought back on line.

Looking at the example above, the demand limit is 1500 KW, which is calculated over a 15 minute window. As the kilowatt usage approaches the limit, non-essential loads are shed, or turned OFF, to avoid exceeding the limit. This may occur, for example, when there is a large demand for cooling. When the usage level drops to 1425 KW, these loads are restored, or turned back ON.

A difficult part of using the EDL program is the determination of non-essential loads. For instance, if air handling units are turned OFF, people may become uncomfortable. In response to this, some EDL programs offer the option of choosing different methods of shedding loads. An example of this is **Linear Mode**, which puts loads in priority so that the least important areas are shed first. This is also described as First OFF, Last ON. Another option is called **Rotate**, which places all the loads on an equal basis but rotates the selection of which load will be shed first. In other words, one area is shed first this time but another area is shed first the next time. This option is also described as First OFF, First ON.

Note; Demand charges and energy management programs used by utility companies differ greatly. Be sure to investigate the programs that are available in your area.

Enthalpy Optimization

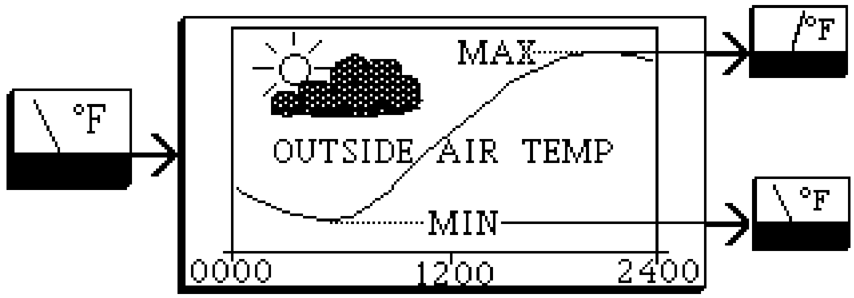


During the cooling season, additional energy savings may be realized by choosing the air source, either *return air* or *outside air*, that contains the least amount of total heat (*Enthalpy*). Enthalpy is determined by a combination of temperature and relative humidity. There are energy savings if the cooling coil is presented with the air having the lower enthalpy, whether this is return air or outside air.

In the example shown above, the outside air is 9°F (5°C) cooler than the return air. However, the relative humidity of the outside air is 95%, fully 70% higher than the return air. This combination of temperature and humidity means that the outside air has more enthalpy than the return air. It would require more energy for the cooling coil to remove the moisture from the outside air than the return air. Therefore, the Enthalpy Optimization program selects the return air as the better choice for cooling.

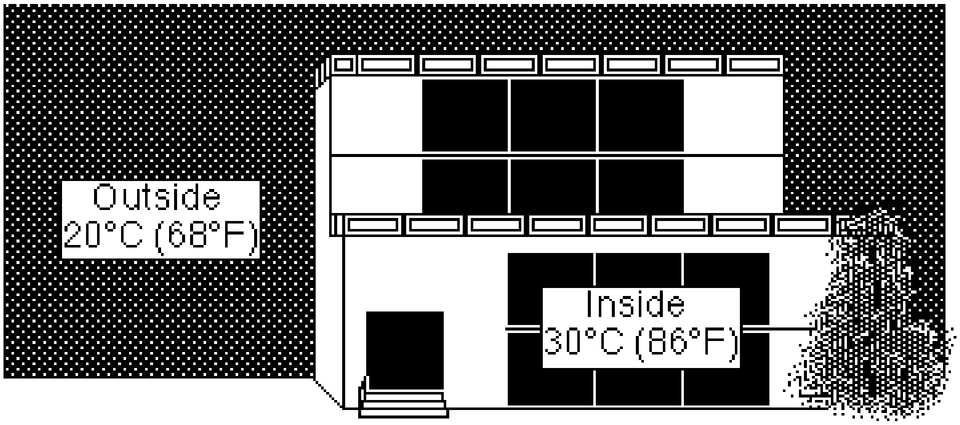
Degree Day Calculations

Degree day calculations do not directly save energy but are designed, instead, to share information. Degree day calculations keep track of outside air conditions and calculate the demand for heating and cooling.



One method of tracking the outside air and the need for heating is the calculation of heating degree day units, used by the National Weather Service. This is a unit, based upon temperature and time, used in estimating fuel consumption and specifying nominal heating load of a building in winter. One heating degree day is given for each degree that the daily mean temperature is below 65°F (18°C), the temperature below which heating is enabled. For example, if yesterday's high for outside air temperature was 60°F (15.5°C), and the low was 40°F (4.5°C), then the average outside air temperature was 50°F (10°C). Since the average outside air temperature is 15°F (8°C) below the heating enable point, 15 heating degree day units (8 heating units for metric) are calculated for that day. Programs in DDC controllers follow the heating and cooling demands, providing the operator a useful tool for energy discussions with the building managers or owners.

Night Purge Cycle



During the cooling season, if the inside temperature is considerably greater than the outside air temperature, then the air handling units may be turned ON during the night, to purge the warm air out of the building. This is called a Night Purge Cycle.

In the example shown above, the inside air temperature is 18°F (10°C) warmer than the outside air temperature, which has cooled during the night. To correct this, the air handling units are turned ON until only a 5.5°F (3°C) difference is present. This type of free cooling reduces the amount of mechanical cooling that has to take place the following morning. However, caution should be taken concerning the humidity of the outside air. To address this concern, an enthalpy optimization program could be established to ensure that only the lowest enthalpy air is used to cool the building at night. Whether or not to use the night purge cycle is determined by comparing the cost of running the air handling units at night versus the cost of running the mechanical cooling in the morning.

REVIEW

1. Which two energy management strategies are dependent upon the facility having Unoccupied Times?
   (Circle the *two* best answers)
   A. Timed Program Commands
   B. Duty Cycle
   C. Optimum Start
   D. Electric Demand Limiting
   E. Enthalpy Optimization
   F. Degree Day Calculations
   G. Night Purge Cycle

2. Of the following energy management strategies, name the two that have had the *least* success.
   (Circle the *two* best answers)
   A. Timed Program Commands
   B. Duty Cycle
   C. Optimum Start
   D. Electric Demand Limiting
   E. Enthalpy Optimization
   F. Degree Day Calculations
   G. Night Purge Cycle

3. Of the following energy management strategies, name the two that deal *only with cooling* and *do not* deal with heating applications.
   (Circle the *two* best answers)
   A. Timed Program Commands
   B. Duty Cycle
   C. Optimum Start
   D. Electric Demand Limiting
   E. Enthalpy Optimization
   F. Degree Day Calculations
   G. Night Purge Cycle

4. Which of the following requires loads to be placed in a priority of importance, from non-essential loads to essential loads?
   (Circle the best answer)
   A. Timed Program Commands
   B. Duty Cycle
   C. Optimum Start
   D. Electric Demand Limiting
   E. Enthalpy Optimization
   F. Degree Day Calculations
   G. Night Purge Cycle

5. Which of the following allows yearly and monthly comparisons of the demands for heating and cooling?
(Circle the best answer)
A. Timed Program Commands
B. Duty Cycle
C. Optimum Start
D. Electric Demand Limiting
E. Enthalpy Optimization
F. Degree Day Calculations
G. Night Purge Cycle

6. Which one of the following programs uses setup and setback?
(Circle the best answer)
A. Timed Program Commands
B. Duty Cycle
C. Optimum Start
D. Electric Demand Limiting
E. Enthalpy Optimization
F. Degree Day Calculations
G. Night Purge Cycle

Answers to the Review

1. A. Timed Program Commands
   C. Optimum Start

2. B. Duty Cycle
   E. Enthalpy Optimization

3. E. Enthalpy Optimization
   G. Night Purge Cycle

4. D. Electric Demand Limiting

5. F. Degree Day Calculations

6. A. Time Programmed Commands

DDC Terminology

This section covers the following terms:

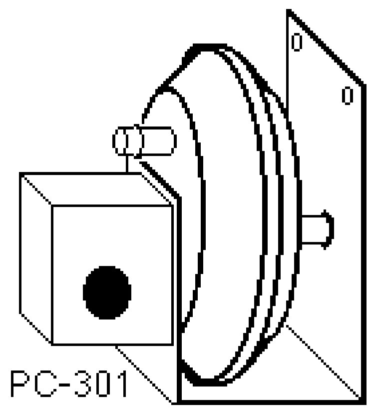
- Points
  - Digital Input (DI)
  - Digital Output (DO)
  - Analog Input (AI)
  - Analog Output (AO)
- Universal Points
- Pulse Input
- Type of DDC Systems
  - Manufacture Specific (Proprietary)
  - Open Protocol

Points

Points are the communications connections between a DDC Controller, sensors and controlled devices. There are four different types of points: Digital Inputs (DI), Digital Outputs (DO), Analog Inputs (AI), and Analog Outputs (AO). Points may have names other than these. For example, a digital input may be called a Contact Input (CI), instead. For consistency, we will refer to points as digital inputs, digital outputs, analog inputs, and analog outputs.

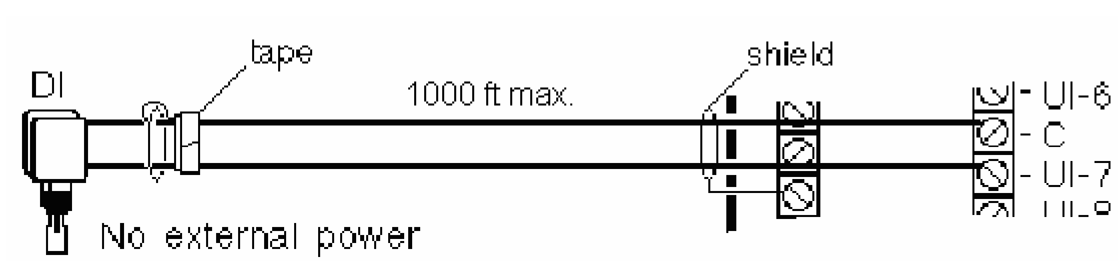
Digital Inputs

Digital means that a piece of equipment can be either ON or OFF. *Input* refers to information being sent *to* the DDC Controller. Therefore, a digital input is an ON/OFF signal sent *to* the controller. Other names for digital are contact, two-position, binary, discrete, or logical. Examples of digital inputs are occupied/unoccupied switches, flow switches, and static pressure switches (pictured below).



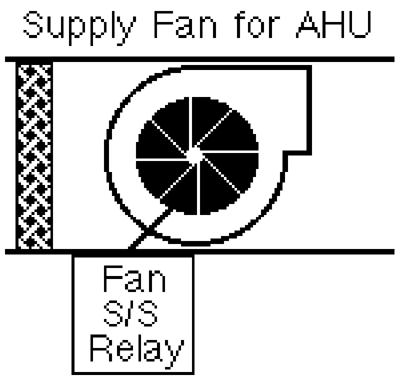
Static Pressure Switch

Shown below is a flow switch, a type of DI, wired to a DDC controller. The terminals labeled on the controller are UI-7 and C. UI-7 is the controller's seventh UI terminal; UI stands for Universal Input, which is explained later. The terminal designation "C" stands for common. *No external power* is applied to this sensor.

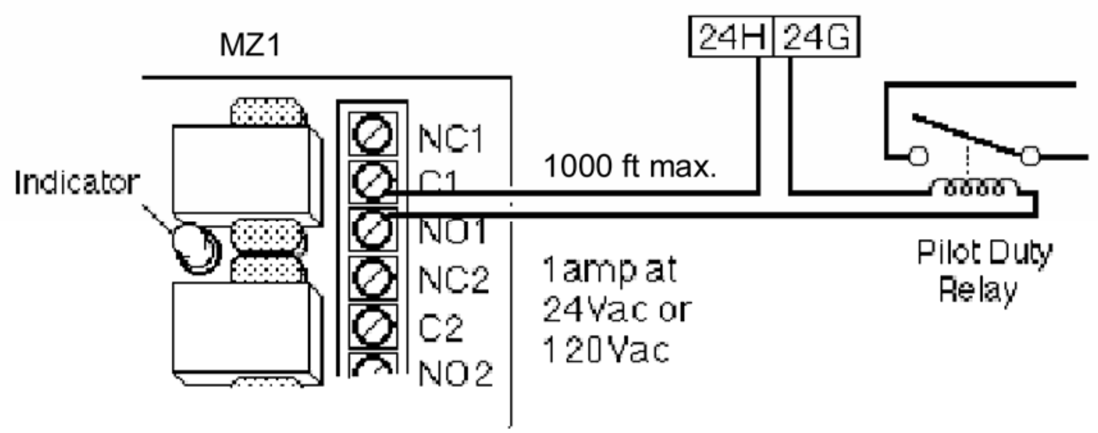


Digital Outputs

A Digital Output (DO) is an ON/OFF signal *sent out from* the controller. Examples of DOs are electric heaters, DX cooling, supply fans (pictured below), boiler enable, and chiller enable.



Below is an example of a DO wired to a DDC controller (the MZ1). These particular outputs are for pilot duty only, which means they cannot handle a large current. In this example, the DO can handle only 1 amp, at either 24 or 120 Vac. Here, the pilot duty relay is an electromagnetically activated switch that actually turns the electric heat or DX cooling ON or OFF. Note that the DDC controller's terminals for this output are labeled NC1 (normally closed output #1), C1 (common for output #1), and NO1 (normally open #1). An indicator is provided to show the status of this DO.



Contact types

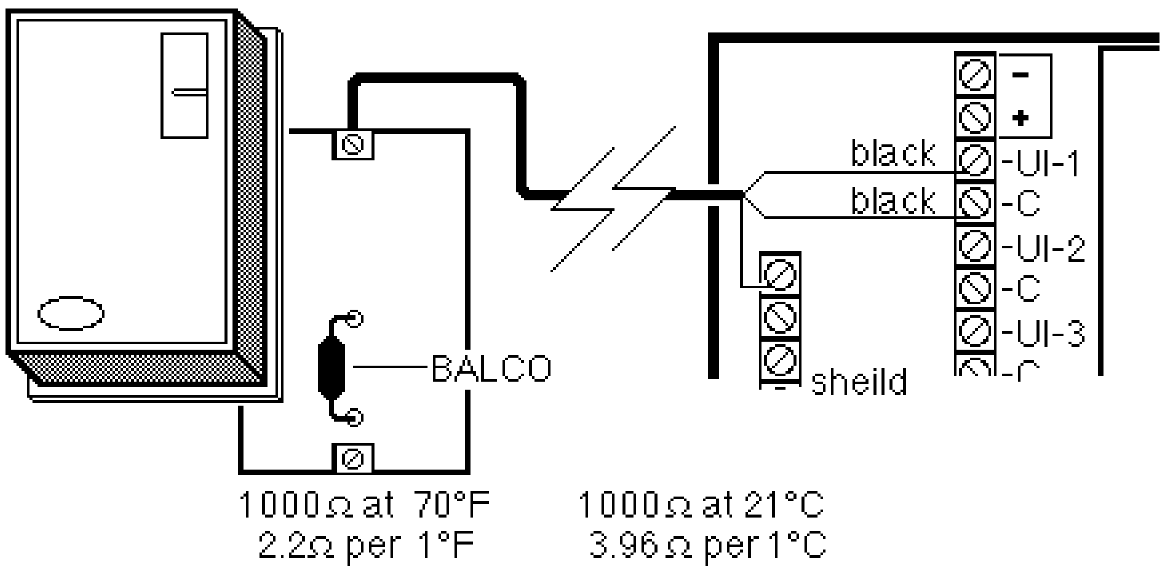
If a controller has dry contacts, power must be added to make the relay work, as pictured above.

If a controller has *powered contacts*, then there is already power at the contacts and external power is not wired to those terminals. *Triacs* are a very common type of powered contacts.

Analog Inputs

Analog Inputs (AIs) are another type of points. In contrast to digital signals, which are either ON or OFF, analog signals can place the equipment in a range of positions. As before, input refers to information being *sent to* the controller. Therefore, an analog input is a *varying, or modulating,* signal that is *sent to* the controller. Other names for analog are proportional, numerical, or modulating. Examples of AIs are hot water temperature, room temperature, outside air temperature, zone humidity, and building static pressure.

The example, below, shows a room temperature sensor wired to a DDC controller. The terminals for this input are labeled UI-1 (Universal Input #1) and C (Common). This sensor is an RTD, a Resistance Temperature Device. These devices can have Balco, Platinum, Copper or Thermistor elements, each of which features a different relationship between temperature and resistance.



RTDs

Balco

Resistance = 1000 ohms at 70°F (1000 ohms at 21°C)
Range = -40° to 240°F (-40° to 115°C)
Ohms to Temp = Direct Relationship

IBS products using Balco resistors include the TS-8000 and TS-80000 series room sensors, solar sensors, *immersion sensors*, *averaging element* sensors, outdoor air sensors, and strap-on sensors.

Copper

Resistance= 1000 ohms at 70°F (1000 ohms at 21°C)
Range = -40° to 240°F (-40° to 115°C)
Ohms to Temp = Direct Relationship

IBS products using copper include the TS-5900 series sensors

Platinum

Resistance = 1000 ohms at 32°F (1000 ohms at 0°C)
Range = -40° to 240°F (-40° to 115°C)
Ohms to Temp = Direct Relationship

An example of an IBS product using a platinum element is the TSMN-58001 Room Sensor

10K Thermistor

Resistance = 10K ohms at 77°F (10K ohms at 25°C)
Range = 40° to 104°F (4 ° to 40°C)
Ohms to Temp = Reverse Relationship

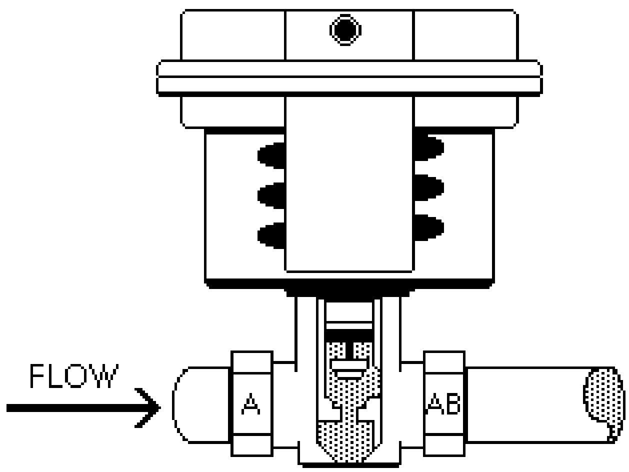
An example of an IBS product using a thermistor element is the TSMN-57001-850 Room Sensor

Voltage and Current Inputs

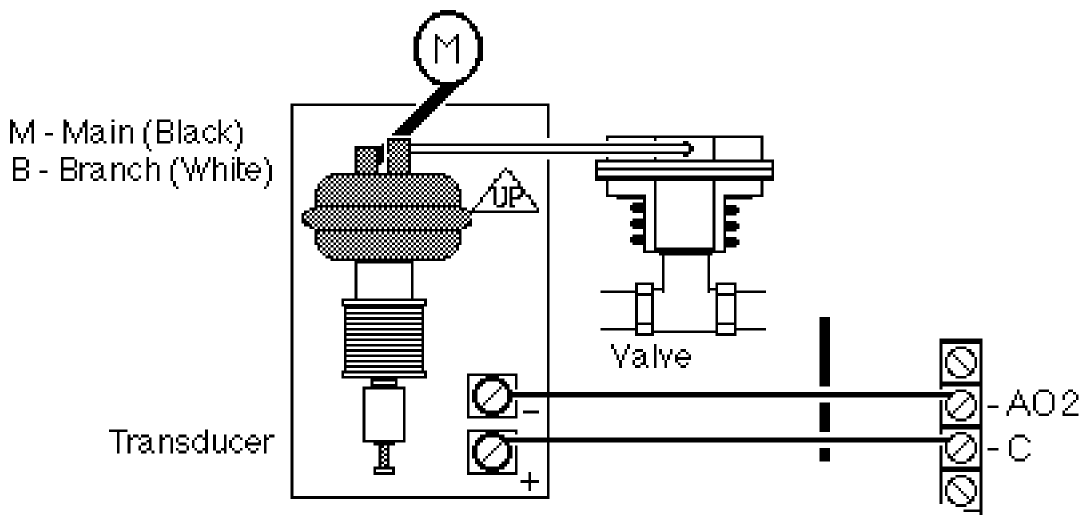
Voltage Inputs are normally 1 to 5 Vdc. Current Inputs are usually 4 to 20 mA, and are sometimes used for humidity or pressure sensors.

Analog Outputs

An Analog Output (AO) is a *varying*, or *modulating*, signal sent *from* the controller. Examples of AOs are hot water valves (shown below), outside air dampers, and variable frequency drives.

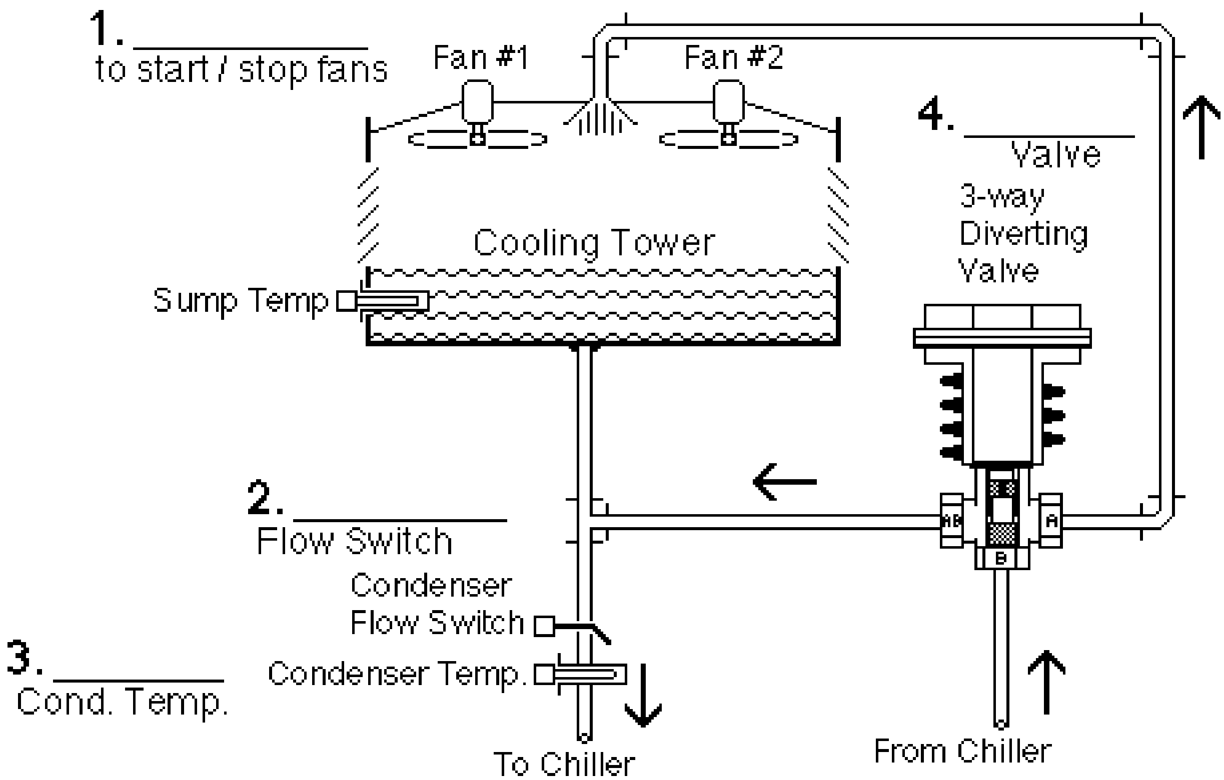


The example shown below is an AO from a DDC controller. The terminals are labeled AO2 (Analog Output #2) and C (Common). A transducer converts the 4 to 20 mA signal to a 3 to15 psig pneumatic signal. This application is frequently used to retrofit buildings with existing pneumatic actuators.

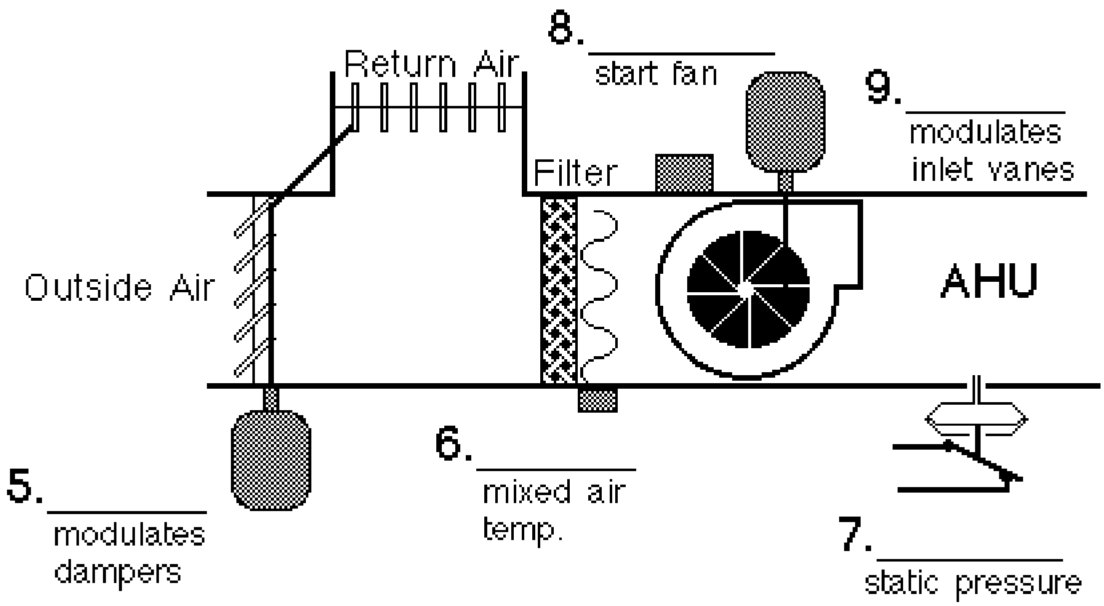


Review

Study the drawing below and identify the numbered points as either: **AI**, **DI**, **AO**, or **DO**



Identify the numbered points in the following diagram as either: **AI**, **DI**, **AO**, or **DO**



Answers to the review

1. DO
2. DI
3. AI
4. AO
5. AO
6. AI
7. DI
8. DO
9. AO

Universal Points

In reviewing a Local Control Unit, it is important to determine how many connections (points) can be made to sensors and controlled devices. Each controller has a maximum number of each point type. Some points have a fixed configuration, while other points have universal, or adaptable, arrangements.

Fixed Point Configuration

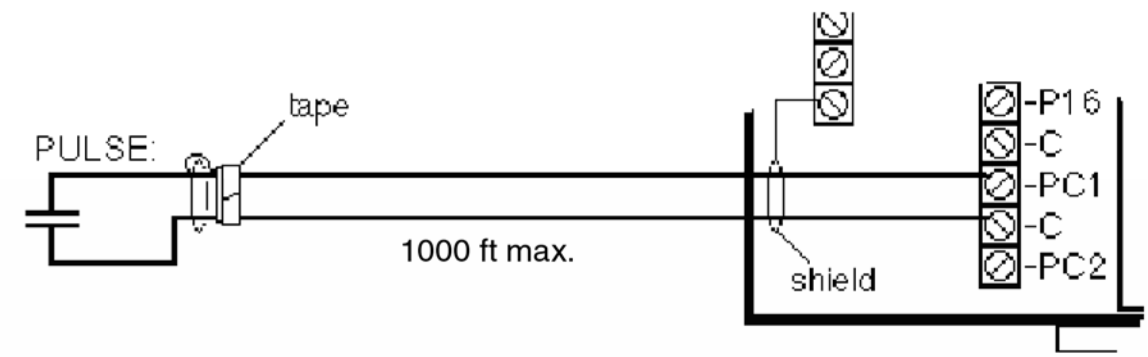
Fixed points are those that are dedicated to be a specific type and cannot be changed. For example, a controller may have four AIs. These AIs may not have to be used, but they are AIs only and cannot be changed to another point type.

Universal Point Arrangement

To address the problem of having fixed points that go unused, some points may be programmed as any of the four different types, that is, AI, AO, DI, or DO. These are referred to as **Universal Points**. For example, if an additional temperature sensor (an AI) is desired, and all that is available in a fixed configuration controller is a digital input, another controller would be required to accommodate the sensor. By using a universal point configuration, any point on the controller can be programmed as an AI after it has been wired. This flexibility can be an advantage over a fixed point configuration.

Pulse Inputs

A Pulse Input point type allows a controller to monitor the power consumption of a device such as a chiller, a fan, or an air hander. Pulse inputs are used to monitor the power consumption of a whole building. Some electric companies offer a pulse input from an electric meter, with each pulse representing a certain number of KW (kilowatts). In the example below, the pulse input comes into terminals PC1 (Pulse Count #1) and C. The controller in this example can sense a maximum of 8 pulses per second.



Current transformers and transducers can also monitor kilowatt usage, but they use a 4 to 20 mA signal, so an AI point would be required.

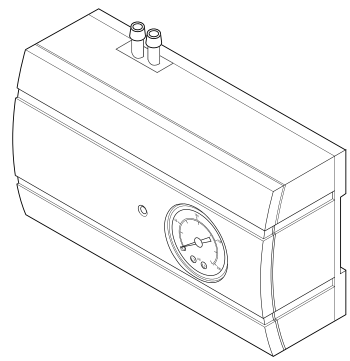
Appendix A

This appendix contains examples of two documents that support IBS products. The first sample consists of pages from the IBS Catalog, describing the CP-8511 Transducer. The second sample contains pages from the General Instructions sheet that supports the VM Series Erie Pop-Top™ Modulating Spring-Return Valves. These are meant only as samples and do not represent the entire scope of IBS product support. For complete information on IBS products, consult your local office or wholesale distributor.

CP-8511-XXX Series

Electronic to Pneumatic Transducer

The CP-8511 transducer receives a variable electronic input signal and produces a 3 to 15 psig (21 to 103 kPa) pneumatic output signal to position pneumatic damper and valve actuators in HVAC systems.



Features:

- Durable enclosure with easily accessible wiring terminations.
- Panel or DIN rail mounting for quick, snap-on installation.
- High accuracy with low hysteresis.
- Long-term driftless operation with high repeatability.
- Low air consumption and large air flow capacity.
- Field selectable input ranges.
- Integral +20 Vdc power output for auxiliary components.
- Factory installed branch pressure gauge
- Integral auto/manual override feature with indication.
- BAS indication of auto/manual override.

Model Chart

Model No.[a]	Field Selectable Input Range	Input Impedance	Output Range	Field Selectable Action[b]	Power Requirements
CP-8511-024	4 to 20 mA[c]	250 Ω	3 to 15 psig[d] (21 to 103 kPa)	D.A. or R.A.	20 to 30 Vac, 24 to 30 Vdc, 3.8 W
	1 to 5 mA	1000 Ω			
	6 to 9 V	> 10,000 Ω			
	1 to 5 V				
	0 to 10 V				
	1 to 11 V				
	2 to 10 V				

[a] CAUTION: This product contains a half-wave rectifier power supply and must not be powered off transformers used to power other devices utilizing non-isolated full-wave rectifier power supplies.

[b] D.A. = Direct acting, branch pressure rises as input increases.
R.A. = Reverse acting, branch pressure falls as input increases.

[c] Factory configured as 4 to 20 mAdc.

[d] A maximum of 18 psig output is available when the zero potentiometer is increased to 6 psig.

Specifications

Inputs	Refer to Model Chart.
Adjustments	
Calibration	Potentiometer for adjusting mid-range branch pressure.
Action	By pin selection, refer to Model Chart.
Power requirements	Refer to Model Chart.
Power supply	Requires 20 to 30 Vac, 50/60 hZ, or 24 to 30 Vdc power supply, 3.8 watts maximum.
Air supply required	20 psig (138 kPa) nominal, 30 psig (207 kPa) maximum. Clean, dry, oil free air required (reference EN-123, F-22516).
Air consumption for sizing air compressor	Maximum 0.012 scfm (5.66 ml/s).

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Document Samples -TAC Catalog Page (1 of 2)

CP-8511-XXX Series

Air capacity for sizing air mains	550 scim (150.24 ml/s).
Air connections	Male barbed fittings for flexible 1/4” O.D. pneumatic tubing.
Wiring connections	Screw terminals for use with 16 to 22 AWG wire.

Specifications (Continued)

Outputs	3 to 15 psig (21 to 103 kPa).
Maximum pneumatic output	1 to 18 psig (7 to 124 kPa).
Action	Refer to Model Chart.
Output air capacity & pressure	515 scim (141 ml/s) with a 20 psig (138 kPa) supply.
Operating characteristics	
Linearity	±1% of span @ 75°F (24°C).
Hysteresis	0.75% of span @ 75°F (24°C).
Adjustments	Field adjustable zero potentiometer.
Auxiliary power supply	+20 Vdc @ 50 mA (maximum).
Auto/manual feedback	Isolated open collector output transistor.
Auto/manual status	Green LED.
Pressure gauge accuracy	Within 2% of total scale range in middle portion of scale and 3% elsewhere (ANSI Class B).
Environment	
Ambient temperature limits	Shipping and storage: -40 to 160°F (-40 to 71°C). Operating: 32 to 140°F (0 to 60°C).
Humidity	5 to 95% RH, non-condensing.
Locations	NEMA Type 1.
Mounting	Upright position. Unit is provided with section of plastic track for panel mounting. AD-8912 enclosure can be ordered separately for remote installations.
Dimensions	4-1/4 H x 5 W x 2-5/32 D in. (108 x 127 x 55 mm).

Accessories

Model No.	Description
K-335	In-line air filter.
M-636	4 in. (102 mm) T and B wire tie.
P-610	35 mm DIN rail (1-3/8 W x 36 L x 3/10 H in).

Typical Applications

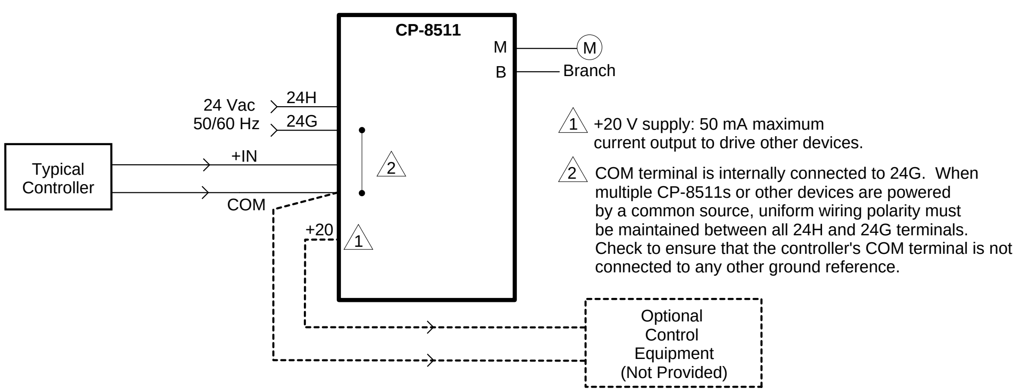

Figure 1 Typical CP-8511 Wiring with Optional +20 Vdc Supply.

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VM Series

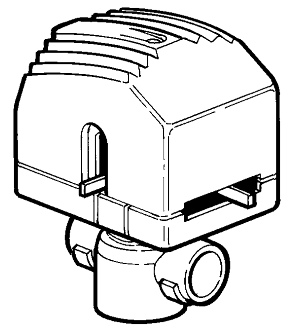
Invensys Building Systems
1354 Clifford Avenue (Zip 61111)
P.O. Box 2940
Loves Park, IL 61132-2940
United States of America

Erie PopTop™
Modulating Spring-Return Valves
General Instructions

Application

The VM series Modulating Spring-Return PopTop valve assemblies are designed for closed hydronic heating and cooling systems. They are used to control fluid flow in fan coil units, VAV reheat, unit ventilators, AHUs, and radiant applications.

PopTop valve assemblies allow the actuator to be easily snapped onto, or off from, the valve body with one hand. The actuator can be mounted quickly and easily after the valve body has been installed into the system, without the need for linkages or calibration. Both two-way and three-way valves are available, and the two-way valves are provided in either normally open or normally closed configurations.



Features

- Models available for hot water and chilled water applications
- 300 psia proof static pressure forged brass valve body
- PopTop feature allows easy installation and removal of the actuator from the valve body
- Magnetic clutch extends motor and gear train life
- Manual operating lever (position indicator) facilitates field setup
- Spring-return to normal position occurs when power to the actuator is lost for more than 2 seconds.

Three-Wire Floating "T" Type

- Compatible with virtually any 24 Vac, three-wire signal
- Standard time-out circuitry extends motor life

Proportional "P" Type

- Compatible with virtually any 0 to 10 Vdc or 4 to 20 mA signal
- Jumper-selectable operating range and action

Applicable Literature

- EN-205 Water and Steam System Guidelines, F-26080

Printed in U.S.A. 12-00 (1-61-123) F-26801

Document Samples - TAC General Instructions Sheet Sample Page (1 of 3)

Piping

Refer to the piping diagrams in Figure-1 and Figure-2 for two-way valves. For three-way valves, refer to Figure-3 and Figure-4.

Caution:

- The valve should be used in a closed loop system.
- All valves must be piped so that the plug closes against the direction of flow. For two-way valves, flow is from port B to port A. For normally closed three-way valves, B is the service port and A is the bypass port. For normally open three-way valves, A is the service port and B is the bypass port.
- Three-way valves must be piped in a mixing configuration, not diverting.

Sweat End Valves

1. Slowly position the actuator's manual operating lever (on the front of the actuator) to the middle position, to manually open the valve so that the plug is not in contact with the valve body.

Caution:

- The plug inside the valve is made of a plastic material. It may be damaged by heat conducted through the valve body if it remains seated against its port during soldering. Be sure to manually open the valve before soldering, to prevent damage.
- If the manual operating lever does not move freely for manual positioning, the solenoid may have latched during shipping. Do not force the lever. Instead, first unlatch the solenoid by placing the red manual solenoid latch lever (on the side of the actuator) in the "up" position, then placing the manual operating lever in the middle position.

2. With the valve in mid-position, latch the solenoid by placing the manual solenoid latch lever in the "up" position. Then, detach the actuator by depressing the release button and pulling it away from the valve body (Figure-6).

Caution:

- Be sure to remove the actuator from the valve body before soldering, to avoid damage to the actuator and to ease the soldering process.
- Use only lead or tin based solder with a melting point below 600°F (315°C).

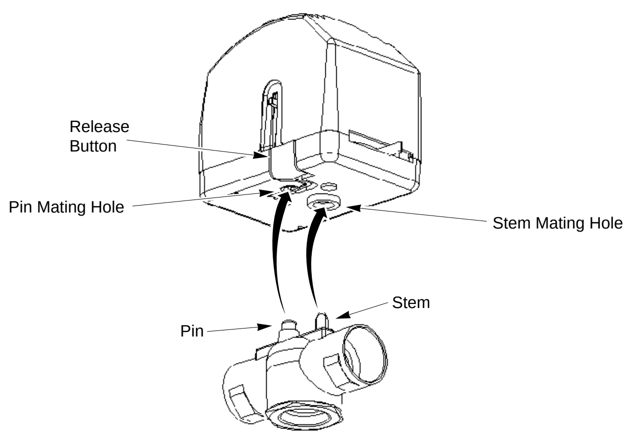


Figure-6 Removal and Installation of Actuator on Valve Body.

3. Thoroughly clean the ends of the water supply tubing for a minimum distance of 1 inch from the end, so that a good joint can be made in the shortest time and without an excessively large flame.
4. Solder the valve body in place, directing the flame tip away from the valve and taking care not to overheat the joint area. When finished, cool the valve quickly with a wet cloth.

5

Document Samples - TAC General Instructions Sheet Sample Page (2 of 3)

ADJUSTMENTS

None.

MAINTENANCE

The valve requires no maintenance. Regular maintenance of the total system is recommended to assure sustained, optimum performance.

FIELD REPAIR

None. Replace an inoperative valve, actuator, or assembly with a functional unit (see Part Numbering System on page 3).

DIMENSIONAL DATA

Table-1 Valve Mounting Dimensions (Figure-9).

Valve Size	Dimensions in inches (mm)		
	A	B (2-Way)	C (3-Way)
1/2" Sweat	1-5/16 (33)	15/16 (23)	1-5/16 (33)
3/4" Sweat	1-3/8 (35)	15/16 (23)	1-11/16 (43)
1" Sweat	1-11/16 (43)	15/16 (23)	1-11/16 (43)
1-1/4" Sweat	1-7/8 (47)	1 (25)	1-13/16 (47)
1/2" NPT, BSP	1-3/8 (35)	15/16 (23)	1-5/16 (33)
3/4" NPT, BSP	1-11/16 (43)	15/16 (23)	1-7/16 (37)
1" NPT, BSP	1-7/8 (47)	1 (25)	1-11/16 (43)
1/2" SAE Flare	2-1/4 (57)	5/16 (8)	2-1/4 (57)

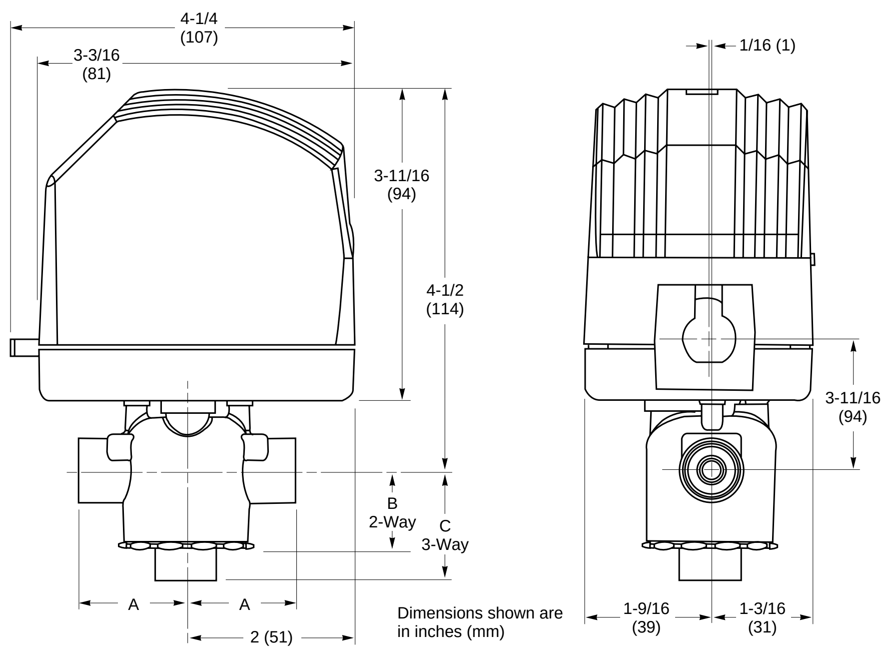


Figure-9 VM Series Spring-Return Modulating PopTop Valve Mounting Dimensions.

All specifications are nominal and may change as design improvements are introduced. Invensys Building Systems shall not be liable for damages resulting from misapplication or misuse of its products.

PopTop is a trademark of Invensys plc and its subsidiaries and affiliates.

U.S. Patents: 5,397,098; DES. 400,967; other U.S. and foreign patents pending

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Document Samples - TAC General Instructions Sheet Sample Page (3 of 3)

Glossary

Abbreviations

AHU:	Air Handling Unit
BTU:	British Thermal Unit
C:	Common
CCW:	Counter Clockwise
CFM:	Cubic Feet per Minute
CR:	Condensate Return
CW:	Clockwise
CWR:	Chilled Water Return
CWS:	Chilled Water Supply
DDC:	Direct Digital Control
D.A.:	Discharge Air, Direct Action, Direct Acting
DIFF:	Differential
EA:	Exhaust Air
EMS:	Energy Management System
EP:	Electric-Pneumatic Switch
GPM:	Gallons Per Minute
h:	Enthalpy
HVAC:	Heating, Ventilating, and Air Conditioning
HWR:	Hot Water Return
HWS:	Hot Water Supply
in. wc:	inches of water column
mA:	Milliamps
M.A.:	Mixed Air
N.C.:	Normally Closed
N.O.:	Normally Open
O.A.:	Outdoor Air
PE:	Pneumatic-Electric switch
PPM:	Parts Per Million
PSI:	Pounds per Square Inch
R.A.:	Return Air, Reverse Action, Reverse Acting
RH:	Relative Humidity
SP:	Setpoint
SPDT:	Single-Pole, Double-Throw
SPST:	Single-Pole, Single-Throw
SS:	Steam Supply
TR:	Throttling Range
Vac:	Volts Alternating Current
VAV:	Variable Air Volume
Vdc:	Volts Direct Current
VFD:	Variable Frequency Drive

Definitions

Absolute Pressure (psia): The sum of both atmospheric pressure (14.7) and gauge pressure (psig). Example: If a pneumatic gauge indicates 8 psig, the absolute pressure will 22.7 psia (8+14.7).

Action: The direction of magnitude change of the output of a controller with respect to the change in the variable that is being sensed. Example: Direct Action (D.A.): Variable increases, output increases. Reverse Action (R.A.): Variable increases, output decreases.

Actuator: A device which is mechanically linked to a damper and positions the damper to regulate the flow of air; or is mounted on a valve and repositions the valve to regulate the flow of steam or water. Actuators are sometimes referred to as operators or motors.

Air Handling Unit (AHU): A mechanical system usually consisting of an enclosure housing a supply-air fan (or fans), heating and/or cooling coils, filters, and outdoor air and return air dampers. May include return air fan(s) and relief air damper(s). May deliver air to a single space, to a number of zones, or to numerous constant-volume or variable-volume air terminal units.

Analog: A proportional type of signal whose level varies smoothly and continuously in amplitude or frequency.

Averaging Element: A sensing device that can extend across the entire duct and sense the average temperature.

Boiler: A closed vessel in which fuel is burned to generate steam or to heat water.

Branch Lines (Pneumatic): The tubing in a pneumatic control system which carries the output signal from controller to auxiliary devices or actuators.

Btu (British thermal unit): The energy or heat required to raise the temperature of one pound of water ı°F under standard pressure.

Butterfly Valve: A cylindrical flanged-end body with an internal, rotatable disc serving as a fluid flow regulating device.

Chiller: A machine, usually centrifugal or reciprocating, that chills the water used to cool a building. Heat removed from the water is rejected to a remote air-cooled condensing unit, or to a water-cooled condenser that is usually an integral part of the chiller.

Close-Off: The maximum allowable pressure drop to which a valve may be subjected while fully closed.

Comfort Zone: The range of temperatures and humidities over which the majority of people feel comfortable. Generally, between 60°F and 70°F and 20% to 60% relative humidity.

Control Point: The actual value of the controlled variable which the controller operates to maintain (under any fixed set of conditions).

Controlled Device (C/D): An apparatus that receives the signal from a controller and positions the damper or valve to match the capacity to the load. Example: Motorized damper or valve.

Controller: A device that monitors a controlled variable and changes the position of final control devices (such as valves, dampers, or contacts) to maintain the value of the controlled variable at or near the controller’s setpoint.

Cubic Feet Per Minute (cfm): A rate of air volume delivery. Standard measure for HVAC ducted systems.

Damper: A valve used to regulate the flow of air or some other gas.

Degree Day, Heating: A unit, based upon temperature and time, used in estimating fuel consumption and specifying nominal heating load of a building in winter. One heating degree day is given for each degree that the daily mean temperature is below 65°F (18°C). Stated another way: A unit measuring the extent to which the daily outdoor average temperature falls below an assumed basis, usually 65° F for heating. One degree-day is counted for each degree falling below (for heating) the assumed base for each calendar day.

Dew Point: The temperature at which a given mixture of air and water vapor is saturated.

Digital: An On/Off or two-position signal.

DIP Switch (Dual Inline Package Switch): A ganged array of switches on a circuit board. Each switch can be set to one of two positions.

Direct Acting (D.A.): An increase in the sensed media causes an increase in the controller output (and vice versa).

Direct Digital Control (DDC): Microprocessor-based control systems that provide direct control of the individual components of an HVAC system without the use of conventional control devices such as thermostats.

Direct Reset: On multiple (typically two) input applications, when a decrease at the second (open loop) sensor causes the controller setpoint to decrease.

Diverting Valve: A three-way valve which has one inlet, two outlets, and can direct full flow to either outlet or proportion the flow between the two outlets.

Dry Contact: A contact closure that does not impose an electronic signal from an outside source. A direct short of normally open contacts.

Duty Cycling: An energy management function that reduces consumption by periodically turning off electrical equipment for short intervals during normal operating hours.

Economizer Mode: A control mode in which outside return and relief dampers are controlled by air temperature to provide the most economical heating and cooling.

Electric-Pneumatic Switch (EP): An electrically operated air flow switch with normally closed and normally opened inputs which lead to a common output. Also known as solenoid air valve.

Electronic Controls: Using very low voltages (20V or less) and currents for sensing and transmitting.

Energy Management: A number of techniques for reducing a building's energy consumption, while maximizing operating efficiency, all without drastic degradation of comfort.

Engineering Units: The units that a medium is measured in, represented by an abbreviation. Examples include degrees Fahrenheit (DEGF), kilowatts (KW), and feet per minute (FPM).

Enthalpy: For most HVAC applications, a measure of total heat (sensible plus latent) of air, measured above an arbitrary datum. The specific enthalpy of dry air is assigned a value of zero at 0 [degrees] F and U.S. standard atmospheric pressure (29.92 in. mercury), and is measured in Btu per pound of dry air.

Exhaust Air Damper: A damper usually associated with an air handling unit. Usually modulates open as the outdoor air damper opens and the return air damper closes. Also called a relief damper.

Feet Per Minute (fpm): A unit of measure to quantify the velocity of air flow.

Floating Control/Action: While definitions vary, floating control is essentially two position control in which the controlled device (i.e., MF-XXXX Actuators) can stop at any point in its stroke at loss of control signal. The controlled device will hold this position until the controller senses another signal to reposition the controlled device.

Flow Coefficient (Cv): The flow of water in gallons per minute (at 6̃°F) that causes a pressure drop of 1 psi across a fully open valve.

Gallons per Minute (gpm): A unit of measure to quantify water flow.

Gauge Pressure (psig): The amount of pressure above atmospheric pressure, usually measured in pounds per square inch, gauge (psig).

Gear Train Actuator: A controlled device that operates dampers or valves by producing a rotary motion as a result of an induction motor driving the output shaft through a series of gears. The motor is driven in either direction and can be stopped at any position so as to obtain proportional control. The electronic actuator drive is necessary to interface the DC signal of the controller and the induction motor.

Heat Pump: A refrigeration machine which is arranged to either heat or cool a building by using heat from the condenser section or by using cooling from the evaporator section..

Hunting: The action of a controller which causes the controlled device to continuously travel from one end of its stroke to the other. Normally associated with proportional control. Hunting is an undesirable condition.

Hydraulic Actuator: A controlled device that operates dampers or valves by producing a linear motion as a result of the fluid pressure developed from a running motor pumping hydraulic fluid through a transducer. As the control signal increases the fluid pressure increases and as the control signal decreases the fluid pressure decreases allowing the spring to retract the output shaft.

Hydronics: The science dealing with the control of and use of water as a heat transfer medium in air conditioning systems.

Immersion Sensor: A device with an extended element, which can be inserted into a well in order to sense the temperature in liquid lines and tanks.

Inches of Water Column (in. w.c.): A unit of pressure measurement used to measure and control low differential pressures. These pressures include duct static pressure relative to space static pressure, space statue pressure relative to that of other spaces or outside atmospheric pressure, and the velocity pressure of air flowing in ducts.

Inlet Vane: An attachment to a centrifugal fan that restricts the flow of air into the fan housing. Also used on centrifugal chillers to restrict refrigerant flow.

Integral Control (PI): A mode of control designed to reduce offset in proportional control.

Kilowatt (kW) - A unit of electrical power equal to 1000 watts or 1.341 horsepower

Kilowatt Hour (kWh) - One kilowatt of power applied for one hour. A kilowatt hour measures the quantity of electricity generated or consumed in one hour.

Load Shedding: The turning off of electrical loads to limit peak electrical demand.

Low Limit: A control/application to prevent a sensed variable from falling below a dangerous or undesirable condition.

Low Temperature Thermostat: A duct thermostat with a capillary-type, vapor-filled sensing element installed across a duct. When any given section of the element (usually one foot) falls below setpoint, the thermostat is actuated, usually to stop the supply fan of an air handling unit and close the outdoor air and relief dampers. Available with manual or automatic reset.

Minimum Position: A control sequence in which the controlled device is prevented from moving to the fully closed position even though the signal from the controller is at a value that would cause the controlled device to be fully closed. However, at a total loss of power or signal from the minimum position, the controlled device will typically go to a fail safe position. i.e. Minimum Position of the outside air damper, for purposes of ventilation, may require that a minimum of X% of outside air be introduced to the building when occupied. However, if there is a loss of power or a low limit that could freeze the coil, the outside dampers will close fully.

Mixing Valve: The three-way valve which has two inlets, one outlet, and can direct full flow from either inlet or proportion the flow from the two inlets.

Night Setback (Heating): An application by which the setpoint is shifted to a lower value during unoccupied hours during the heating season.

Night Setup (Cooling): An application by which the setpoint is shifted to a higher value during unoccupied hours during cooling season.

Normally Closed (N.C.): Applies to the condition of a controlled device which closes when all operating force (control pressure or electric energy) is removed. i.e., power failure.

Normally Open (N.O.): Applies to the condition of a controlled device which is open when all operating force is removed.

Parts Per Million The number of "parts" by weight of a substance per million parts of water. This unit is commonly used to represent pollutant concentrations. Large concentrations are expressed in percentages.

Occupied Mode: A control mode used to heat or cool a building when it is occupied.

Offset: The amount of difference between control point and setpoint in a proportional control system.

Packaged Equipment: Off-the-shelf HVAC equipment.

Pneumatic: Controls powered by low-pressure compressed gas.

Pneumatic-Electric Switch (PE): An air pressure operated switch in which the contacts are made or broken in order to operate electrical devices in a pneumatic control system.

Positive Positioner: Used where accurate positioning of the controlled device is required. Example: Pneumatic positive positioners provide up to full main air to the actuator for any change in position required by the controller. Positive positioners may also be referred to as pilot positioners.

Pressure Independent VAV: A control technique in which the flow of air (usually through a VAV terminal unit) is maintained essentially at the setpoint of a flow controller regardless of variations (reasonably controlled) in supply duct static pressure.

Proportional Control: A mode of control in which the controlled device may assume any position from fully closed to fully open, depending on the load at any given point in time.

Range: (1) The minimum to maximum setpoint capability of a controller, (2) the minimum to maximum sensing capability of a transmitter, or (3) the start point to finish point of an actuator. Examples:
Controller, 55 to 80°F
Transmitter, 40 to 24̃°F
Actuator, 5 to 10 psig

Relative Humidity: The ratio of the amount of moisture that is present in the air to the amount that can be in the air at that temperature.

Reset: Making use of a second (open loop) sensor whose function is to change the effective/desired setpoint of a controller automatically according to changes in the open loop conditions. Not to be confused with Automatic Reset.

Resistance Temperature Device (RTD): An electronic device that senses temperature. As the sensed temperature changes, the resistance changes. Example: Balco.

Return Air: Air returning to the heater or conditioner from the heated or conditioned space.

Reverse Acting (R.A.): A decrease in the sensed media causes an increase in controller output (and vice-versa).

Reverse Reset: On multiple (typically two) input applications, when a decrease at the second (open loop) sensor causes the controller setpoint to be increased..

Rooftop Unit: Packaged heating/cooling or heating/ cooling/ventilating unit designed to be mounted on the roof of a building. May be a small, single-zone unit; a large, complex unite supplying air to many VAV terminals; or anything in between.

Run Time: For HVAC equipment, the total hours of actual running time since installation, the last maintenance, or a specified date.

Setpoint: The desired value assigned to a controller. Example: The setpoint dial on a thermostat indicates the desired occupied condition.

Short-Cycling: When equipment is turned on and off at frequent intervals. Normally associated with two-position control. (Short-cycling is an undesirable condition.)

Single-Pole, Double-Throw (SPDT): An electromechanical switch, which makes one circuit immediately upon breaking the other.

Single-Pole, Single-Throw (SPST): An electromechanical switch, which makes or breaks one circuit.

Span: The difference between the start and finish point of range. Examples:
Transmitter range 50° to 100° = span of 50°
Voltage Range 6 to 9 Volts = span of 3 volts
Spring Range of three to 8 psig = span of 5 psi

Spring-Return: The movement of an actuator as a result of a decreasing voltage signal and therefore the force is supplied by a coiled or compressed spring. Upon a power interruption the spring will drive the actuator to a known position.

Staged Heating/Cooling: A temperature control technique in which heating or cooling is turned in stages. For example, the farther away the temperature is from the setpoint, the more stages of heating or cooling are turned on.

Staging: A method of control in which the total capacity of a two-position mode of control application is divided into several levels of capacity so as to match the capacity to the load more evenly.

Stand-Alone: A device, such as a controller or computer, that does not require support from another device or system.

Stand-Alone Operation: Performance independent of direction of any other component in the system.

Strap-On Thermostat: A Controller designed for mounting on and sensing the temperature of a surface. Example: the surface of a pipe.

Stratification: Layers of air at different temperatures of different velocities flowing through a duct or plenum.

Summer/Winter: A combination of a direct acting and a reverse acting thermostat. The term heating/cooling is synonymous.

Supply or Main Pressure (Pneumatic): The force per unit area (psig) of the compressed air supplied to a controller. It is usually constant at 15 to 20 psig, but may have some other value in special cases.

Therm: 100,000 Btu Approximately 100 cubic feet of gas.

Thermistor: A semiconductor whose resistance is extremely temperature sensitive. Like carbon, thermistors have negative temperature coefficients; that is, their resistance increases as temperature decreases. They are used to compensate for temperature variations in other parts of a circuit and are also used as transducers.

Thermostat: An instrument which measures temperature and controls device(s) for maintaining a desired temperature. Throttling Range (Controller): Throttling range is the change in measured variable (temperature, pressure, liquid level, etc.) required to cause the controller output to vary a pre-defined range. In System 8000™ this range is 6 to 9 volts. In Pneumatics, this range may be three to 13 psig or three to 15 psig.

Throttling Range (Controller): Throttling range is the change in the measured variable (temperature, pressure, liquid level, etc.) required to cause the controller output to vary a predefined range. In System 8000 this range is 6 to 9 volts. In Pneumatics, this range may be 3 to 13 psig or 3 to 15 psig.

Throttling Range (System): The amount of change of the variable necessary for the controller to drive the actuator(s) through their complete stroke(s).

Transducer: A device which converts one form of energy into another form of energy.

Tubeaxial Fan: An airfoil (propeller) fan within a cylinder and including driving mechanism supports for belt drive or direct connection.

Two-Position Control: A method of control in which the control device is either 100% open or closed; therefore, the controlled medium is flowing at these respective rates. Also called On-Off control..

Variable Air Volume (VAV): A system that controls space temperature by varying the quantity of supply air rather than by varying the temperature of the supply air.

Variable Frequency Drive: A device that varies the voltage to an electric motor to vary the speed of the motor (also called a speed drive.)

Zone: A space or group of spaces within a building with heating and/or cooling requirements sufficiently similar so that comfort conditions can be maintained throughout by a single controlling device.

Zone Control: A control process in which a building is divided into different areas (zones). Each zone can be controlled independently.

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