Pneumatic Control Fundamentals

Contents

INTRODUCTION

This section provides basic information on pneumatic control systems and components commonly used to control equipment in commercial heating and air conditioning applications. The information in this section is of a general nature in order to explain the fundamentals of pneumatic control. Some terms and references may vary between manufacturers (e.g., switch port numbers).

Pneumatic control systems use compressed air to operate actuators, sensors, relays, and other control equipment. Pneumatic controls differ from other control systems in several ways with some distinct advantages:
- Pneumatic equipment is inherently proportional but can provide two-position control when required.
- Many control sequences and combinations are possible with relatively simple equipment.
- Pneumatic equipment is suitable where explosion hazards exist.
- The installed cost of pneumatic controls and materials may be lower, especially where codes require that low-voltage electrical wiring for similar electric controls be run in conduit.
- Quality, properly installed pneumatic equipment is reliable. However, if a pneumatic control system requires troubleshooting or service, most building-maintenance people have the necessary mechanical knowledge.

DEFINITIONS

Actuator: A mechanical device that operates a final control element (e.g., valve, damper).

Authority (Reset Authority or Compensation Authority): A setting that indicates the relative effect a compensation sensor input has on the main setpoint (expressed in percent).

Branch line: The air line from a controller to the controlled device.

Branchline pressure (BLP): A varying air pressure signal from a controller to an actuator carried by the branch line. Can go from atmospheric to full main line pressure.

Compensation changeover: The point at which the compensation effect is reversed in action and changes from summer to winter or vice versa. The percent of compensation effect (authority) may also be changed at the same time.

Compensation control: A process of automatically adjusting the control point of a given controller to compensate for changes in a second measured variable such as outdoor air temperature. For example, the hot deck control point is reset upward as the outdoor air temperature decreases. Also know as “reset control”.

Compensation sensor: The system element which senses a variable other than the controlled variable and resets the main sensor control point. The amount of this effect is established by the authority setting.

Control point: The actual value of the controlled variable (setpoint plus or minus offset).

Controlled variable: The quantity or condition that is measured and controlled (e.g., temperature, relative humidity, pressure).

Controller: A device that senses the controlled variable or receives an input signal from a remote sensing element, compares the signal with the setpoint, and outputs a control signal (branchline pressure) to an actuator.

Differential: A term that applies to two-position devices. The range through which the controlled variable must pass in order to move the final control element from one to the other of its two possible positions. The difference between cut-in and cut-out temperatures, pressures, etc.

Direct acting (DA): A direct-acting thermostat or controller increases the branchline pressure on an increase in the measured variable and decreases the branchline pressure on a decrease in the variable. A direct-acting actuator extends the shaft on an increase in branchline pressure and retracts the shaft on a decrease in pressure.

Discharge air: Conditioned air that has passed through a coil. Also, air discharged from a supply duct outlet into a space. See Supply air.

Final control element: A device such as a valve or damper that acts to change the value of the manipulated variable. Positioned by an actuator.

Main line: The air line from the air supply system to controllers and other devices. Usually plastic or copper tubing.

Manipulated variable: Media or energy controlled to achieve a desired controlled variable condition.

Measuring element: Same as sensing element.

Mixed air: Typically a mixture of outdoor air and return air from the space.

Modulating: Varying or adjusting by small increments. Also called "proportional".

Offset: A sustained deviation between the actual system control point and its controller setpoint under stable operating conditions. Usually applies to proportional (modulating) control.

Proportional band: As applied to pneumatic control systems, the change in the controlled variable required to change the controller output pressure from 3 to 13 psi. Usually expressed as a percentage of sensor span.

Reset control: See compensation control.

Restrictor: A device in an air line that limits the flow of air.

Return air: Air entering an air handling system from the occupied space.

Reverse acting (RA): A reverse-acting thermostat or controller decreases the branchline pressure on an increase in the measured variable and increases the branchline pressure on a decrease in the variable. A reverse-acting valve actuator retracts the shaft on an increase in branchline pressure and extends the shaft on a decrease in pressure.

Sensing element: A device that detects and measures the controlled variable (e.g., temperature, humidity).

Sensor: A device placed in a medium to be measured or controlled that has a change in output signal related to a change in the sensed medium.

Sensor Span: The variation in the sensed media that causes the sensor output to vary between 3 and 15 psi.

Setpoint: The value on the controller scale at which the controller is set (e.g., the desired room temperature set on a thermostat). The desired control point.

Supply air: Air leaving an air handling system.

Thermostat: A device that responds to changes in temperature and outputs a control signal (branchline pressure). Usually mounted on a wall in the controlled space.

Throttling range: Related to proportional band, and expressed in values of the controlled variable (e.g., degrees, percent relative humidity, pounds per square inch) rather than in percent.

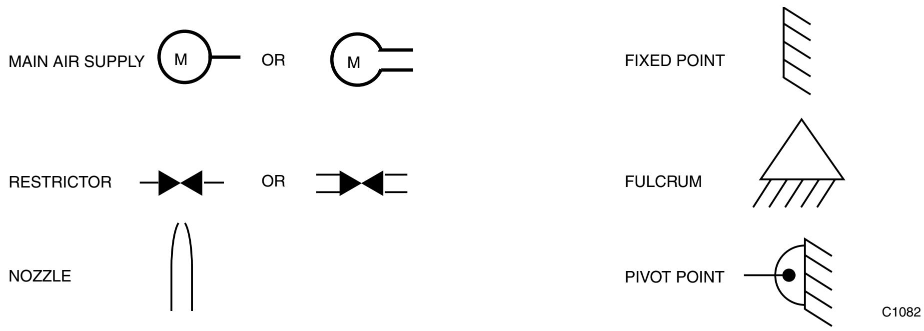
ABBREVIATIONS

The following port abbreviations are used in drawings of relays and controllers:

B	—	Branch
C	—	Common
E	—	Exhaust
M	—	Main
O	—	Normally connected*
X	—	Normally disconnected*
P	—	Pilot (P_1 and P_2 for dual-pilot relays)
S	—	Sensor (S_1 and S_2 for dual-input controllers)
N.C.	—	Normally closed
N.O.	—	Normally open

* The normally connected and common ports are connected on a fall in pilot pressure below the relay setpoint, and the normally disconnected port is blocked. On a rise in pilot pressure above the relay setpoint, the normally disconnected and common ports are connected and the normally connected port is blocked. Refer to Figure 37 in RELAYS AND SWITCHES.

SYMBOLS



BASIC PNEUMATIC CONTROL SYSTEM

GENERAL

A pneumatic control system is made up of the following elements:

— Compressed air supply system
— Main line distribution system
— Branch lines
— Sensors
— Controllers
— Actuators
— Final control elements (e.g., valves, dampers)

A basic pneumatic control system consists of an air supply, a controller such as a thermostat, and an actuator positioning a valve or damper (Fig. 1).

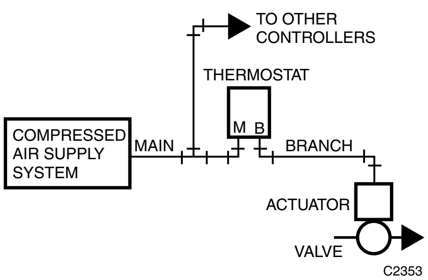


Fig. 1. Basic Pneumatic Control System.

The controller receives air from the main line and regulates its output pressure (branchline pressure) as a function of the temperature, pressure, humidity, or other variable. The branchline pressure from the controller can vary from zero to full mainline pressure. The regulated branchline pressure energizes the actuator, which then assumes a position proportional to the branchline pressure applied. The actuator usually goes through its full stroke as the branchline pressure changes from 3 psi to 13 psi. Other pressure ranges are available.

In a typical control system, the final control element (a valve or a damper) is selected first because it must produce the desired control results. For example, a system designed to control the flow of water through a coil requires a control valve. The type of valve, however, depends on whether the water is intended for heating or cooling, the water pressure, and the control and flow characteristics required. An actuator is then selected to operate the final control element. A controller and relays complete the system. When all control systems for a building are designed, the air supply system can be sized and designed.

AIR SUPPLY AND OPERATION

The main line air supply is provided by an electrically driven compressor pumping air into a storage tank at high pressure (Fig. 2). A pressure switch turns the compressor on and off to maintain the storage tank pressure between fixed limits. The tank stores the air until it is needed by control equipment. The air dryer removes moisture from the air, and the filter removes oil and other impurities. The pressure reducing valve (PRV) typically reduces the pressure to 18 to 22 psi. For two-pressure (day/night) systems and for systems designed to change from direct to reverse acting (heating/cooling), the PRV switches between two pressures, such as 13 and 18 psi. The maximum safe air pressure for most pneumatic controls is 25 psi.

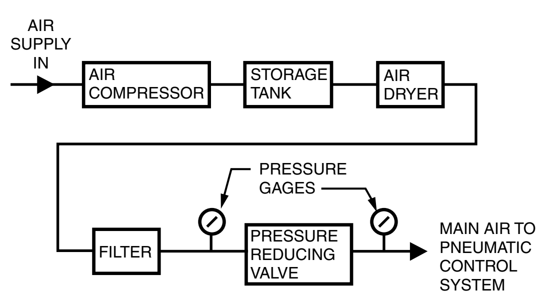


Fig. 2. Compressed Air Supply System.

From the PRV, the air flows through the main line to the controller (in Figure 1, a thermostat) and to other controllers or relays in other parts of the system. The controller positions the actuator. The controller receives air from the main line at a constant pressure and modulates that pressure to provide branchline air at a pressure that varies according to changes in the controlled variable, as measured by the sensing element. The controller signal (branchline pressure) is transmitted via the branch line to the controlled device (in Figure 1, a valve actuator). The actuator drives the final control element (valve) to a position proportional to the pressure supplied by the controller.

When the proportional controller changes the air pressure to the actuator, the actuator moves in a direction and distance proportional to the direction and magnitude of the change at the sensing element.

RESTRICTOR

The restrictor is a basic component of a pneumatic control system and is used in all controllers. A restrictor is usually a disc with a small hole inserted into an air line to restrict the amount of airflow. The size of the restrictor varies with the application, but can have a hole as small as 0.003 inches.

NOZZLE-FLAPPER ASSEMBLY

The nozzle-flapper assembly (Fig. 3) is the basic mechanism for controlling air pressure to the branch line. Air supplied to the nozzle escapes between the nozzle opening and the flapper. At a given air supply pressure, the amount of air escaping is determined by how tightly the flapper is held against the nozzle by a sensing element, such as a bimetal. Thus, controlling the tension on the spring also controls the amount of air escaping. Very little air can escape when the flapper is held tightly against the nozzle.

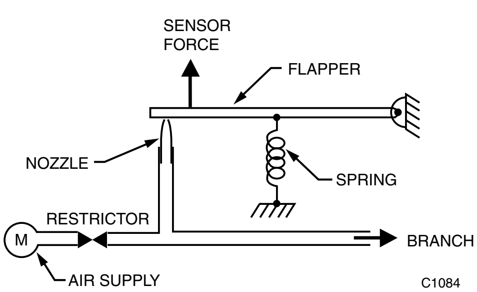


Fig. 3. Nozzle-Flapper Assembly with Restrictor.

To create a branchline pressure, a restrictor (Fig. 3) is required. The restrictor and nozzle are sized so that the nozzle can exhaust more air than can be supplied through the restrictor when the flapper is off the nozzle. In that situation, the branchline pressure is near zero. As the spring tension increases to hold the flapper tighter against the nozzle, reducing the air escaping, the branchline pressure increases proportionally. When the spring tension prevents all airflow from the nozzle, the branchline pressure becomes the same as the mainline pressure (assuming no air is flowing in the branch line). This type of control is called a “bleed” control because air “bleeds” continuously from the nozzle.

With this basic mechanism, all that is necessary to create a controller is to add a sensing element to move the flapper as the measured variable (e.g., temperature, humidity, pressure) changes. Sensing elements are discussed later.

PILOT BLEED SYSTEM

The pilot bleed system is a means of increasing air capacity as well as reducing system air consumption. The restrictor and nozzle are smaller in a pilot bleed system than in a nozzle-flapper system because in a pilot bleed system they supply air only to a capacity amplifier that produces the branchline pressure (Fig. 4). The capacity amplifier is a pilot bleed component that maintains the branchline pressure in proportion to the pilot pressure but provides greater airflow capacity.

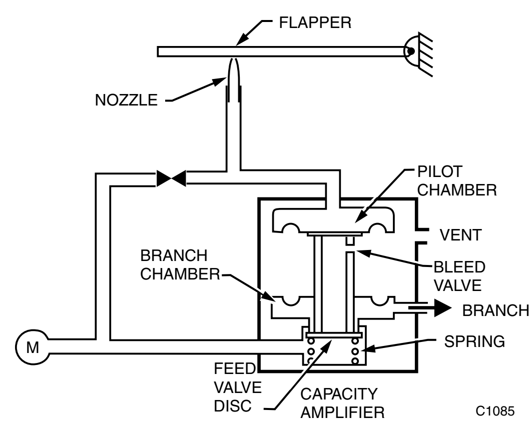


Fig. 4. Pilot Bleed System with Amplifier Relay.

The pilot pressure from the nozzle enters the pilot chamber of the capacity amplifier. In the state shown in Figure 4, no air enters or leaves the branch chamber. If the pilot pressure from the nozzle is greater than the spring force, the pilot chamber diaphragm is forced down, which opens the feed valve and allows main air into the branch chamber. When the pilot pressure decreases, the pilot chamber diaphragm rises, closing the feed valve. If the pilot chamber diaphragm rises enough, it lifts the bleed valve off the feed valve disc, allowing air to escape from the branch chamber through the vent, thus decreasing the branchline pressure. Main air is used only when branchline pressure must be increased and to supply the very small amount exhausted through the nozzle.

SIGNAL AMPLIFIER

In addition to the capacity amplifier, pneumatic systems also use a signal amplifier. Generally, modern amplifiers use diaphragms for control logic instead of levers, bellows, and linkages.

A signal amplifier increases the level of the input signal and provides increased flow. This amplifier is used primarily in sensor-controller systems where a small signal change from a sensor must be amplified to provide a proportional branchline pressure. The signal amplifier must be very sensitive and accurate, because the input signal from the sensor may change as little as 0.06 psi per degree Fahrenheit.

Another use for a signal amplifier is to multiply a signal by two to four times so a signal from one controller can operate several actuators in sequence.

FEED AND BLEED SYSTEM

The “feed and bleed” (sometimes called “non bleed”) system of controlling branchline pressure is more complicated than the nozzle-flapper assembly but theoretically uses less air. The nozzle-flapper system exhausts some air through the nozzle continually, whereas the feed and bleed system exhausts air only when the branchline pressure is being reduced. Since modern nozzle-flapper devices consume little air, feed and bleed systems are no longer popular.

The feed and bleed system consists of a feed valve that supplies main air to the branch line and a bleed valve that exhausts air from the branch line (Fig. 5). Each valve consists of a ball nested on top of a tube. Some pneumatic controllers use pressure balance diaphragm devices in lieu of springs and valves. A spring in the tube continually tries to force the ball up. The lever holds the ball down to form a tight seal at the end of the tube. The feed and bleed valves cannot be open at the same time.

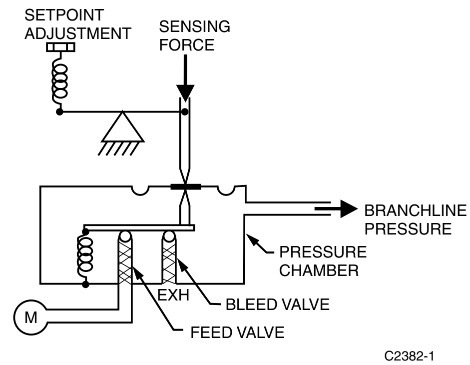


Fig. 5. Feed and Bleed System.

A force applied by the sensing element at the sensor input point is opposed by the setpoint adjustment spring and lever. When the sensing element pushes down on the lever, the lever pivots on the bleed ball and allows the feed ball to rise, which allows main air into the chamber. If the sensing element reduces its force, the other end of the lever rises and pivots on the feed ball, and the bleed ball rises to exhaust air from the system. The sensor can be any sensing element having enough force to operate the system.

SENSING ELEMENTS

BIMETAL

A bimetal sensing element is often used in a temperature controller to move the flapper. A bimetal consists of two strips of different metals welded together as shown in Figure 6A. As the bimetal is heated, the metal with the higher coefficient of expansion expands more than the other metal, and the bimetal warps toward the lower-coefficient metal (Fig. 6B). As the temperature falls, the bimetal warps in the other direction (Fig. 6C).

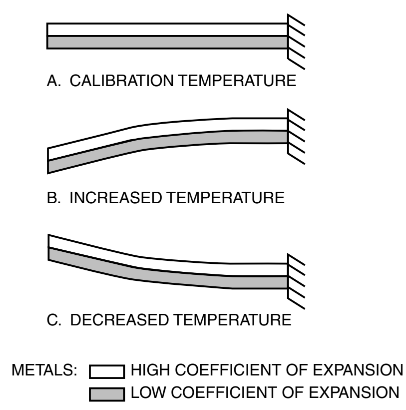


Fig. 6. Bimetal Sensing Element.

A temperature controller consists of a bimetal element linked to a flapper so that a change in temperature changes the position of the flapper. Figure 7 shows a direct-acting thermostat (branchline pressure increases as temperature increases) in which the branchline pressure change is proportional to the temperature change. An adjustment screw on the spring adjusts the temperature at which the controller operates. If the tension is increased, the temperature must be higher for the bimetal to develop the force necessary to oppose the spring, lift the flapper, and reduce the branch pressure.

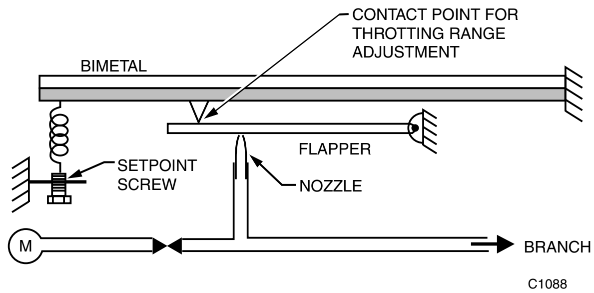


Fig. 7. Temperature Controller with Bimetal Sensing Element.

ROD AND TUBE

The rod-and-tube sensing element consists of a brass tube and an Invar rod, as shown in Figure 8. The tube expands and contracts in response to temperature changes more than the rod. The construction of the sensor causes the tube to move the rod as the tube responds to temperature changes. One end of the rod connects to the tube and the other end connects to the flapper spring to change the force on the flapper.

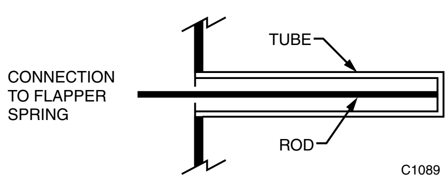


Fig. 8. Rod-and-Tube Insertion Sensor.

On a rise in temperature, the brass tube expands and draws the rod with it. The rod pulls on the flapper spring which pulls the flapper closed to the nozzle. The flapper movement decreases the air-bleed rate, which increases branchline pressure.

REMOTE BULB

The remote-bulb sensing element has as measuring element made up of a capillary and bulb filled with a liquid or vapor (Fig. 9). On and increase in temperature at the bulb, the liquid or vapor expands through the capillary tubing into the diaphragm chamber. The expansion causes the diaphragm pad to push the pin toward the lever, which moves the flapper to change the branchline pressure.

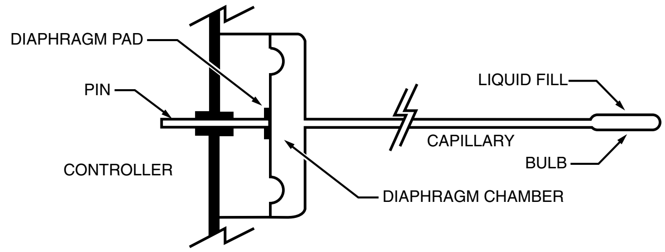


Fig. 9. Remote-Bulb Temperature Sensor. C1090-1

Remote-bulb temperature sensors are used in bleed-type controllers. Capillary length of up to 2.5 meters are normally used for inserting the bulb in duct, tank, or pipe.

AVERAGING ELEMENT

The averaging-element sensor is similar to the remote-bulb sensor except that it has no bulb and the whole capillary is the measuring element. The long, flexible capillary has a slightly wider bore to accommodate the equivalent liquid fill that is found in a remote-bulb sensor. The averaging-element sensor averages temperatures along its entire length and is typically used to measure temperatures across the cross section of a duct in which two air streams may not mix completely. Averaging element sensors are used to provide an input signal to a controller.

THROTTLING RANGE ADJUSTMENT

A controller must always have some means to adjust the throttling range (proportional band). In a pneumatic controller, the throttling range is the change at the sensor required to change the branchline pressure 10 psi. The setpoint is usually at the center of the throttling range. For example, if the throttling range of a temperature controller is 4F and the setpoint is 72F, the branchline pressure is 3 psi at 70F, 8 psi at 72F, and 13 psi at 74F for a direct acting controller.

In all pneumatic systems except the sensor-controller system, the throttling range is adjusted by changing the effective length of a lever arm. In Figure 7, the throttling range is changed by moving the contact point between the bimetal and the flapper. (For information on adjusting the throttling range in a sensor-controller system, see SENSOR-CONTROLLER SYSTEMS.)

RELAYS AND SWITCHES

Relays are used in control circuits between controllers and controlled devices to perform a function beyond the capacity of the controllers. Relays typically have diaphragm logic construction (Fig. 10) and are used to amplify, reverse, average, select, and switch controller outputs before being sent to valve and damper actuators.

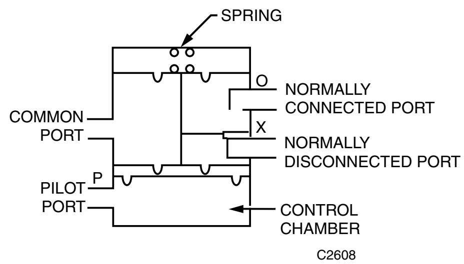


Fig. 10. Typical Switching Relay.

The controlling pressure is connected at the pilot port (P), and pressures to be switched are connected at the normally connected port (O) or the normally disconnected port (X). The operating point of the relay is set by adjusting the spring pressure at the top of the relay.

When the pressure at the pilot port reaches the relay operating point, it pushes up on the diaphragm in the control chamber and connects pressure on the normally disconnected port (X) to the common port as shown. If the pilot pressure falls below the relay setpoint, the diaphragm moves down, blocks the normally disconnected (X) port, and connects the normally connected port (O) to the common port.

AIR SUPPLY EQUIPMENT

GENERAL

A pneumatic control system requires a supply of clean, dry, compressed air. The air source must be continuous because many pneumatic sensors, controllers, relays, and other devices bleed air. A typical air supply system includes a compressor, an air dryer, an air filter, a pressure reducing valve, and air tubing to the control system (Fig. 11).

The following paragraphs describe the compressor, filter, pressure reducing valves, and air drying techniques. For information on determining the moisture content of compressed air, refer to the General Engineering Data section.

AIR COMPRESSOR

The air compressor provides the power needed to operate all control devices in the system. The compressor maintains pressure in the storage tank well above the maximum required in the control system. When the tank pressure goes below a minimum setting (usually 70 to 90 psi), a pressure switch starts the compressor motor. When the tank pressure reaches a high-limit setting, the pressure switch stops the motor. A standard tank is typically large enough so that the motor and compressor operate no more than 50 percent of the time, with up to twelve motor starts per hour.

Some applications require two compressors or a dual compressor. In a dual compressor, two compressors operate

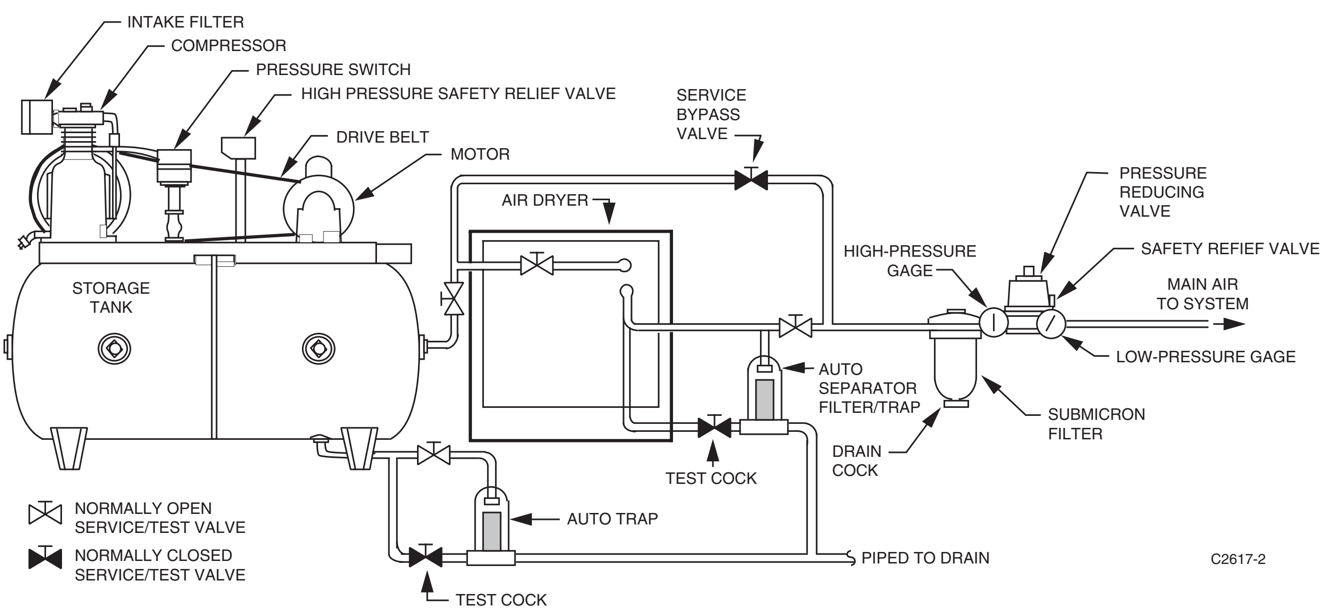


Fig. 11. Typical Air Supply.

alternately, so wear is spread over both machines, each capable of supplying the average requirements of the system without operating more than half the time. In the event of failure of one compressor, the other assumes the full load.

Contamination in the atmosphere requires a compressor intake filter to remove particles that would damage the compressor pump. The filter is essential on oil-less compressors because a contaminated inlet air can cause excessive wear on piston rings. The intake filter is usually located in the equipment room with the compressor, but it may be located outdoors if clean outdoor air is available. After the air is compressed, cooling and settling actions in the tank condense some of the excess moisture and allow fallout of the larger oil droplets generated by the compressor pump.

A high pressure safety relief valve which opens on excessively high tank pressures is also required. A hand valve or automatic trap periodically blows off any accumulated moisture, oil residue, or other impurities that collect in the bottom of the tank.

AIR DRYING TECHNIQUES

GENERAL

Air should be dry enough to prevent condensation. Condensation causes corrosion that can block orifices and valve mechanisms. In addition, dry air improves the ability of filters to remove oil and dirt.

Moisture in compressed air is removed by increasing pressure, decreasing temperature, or both. When air is compressed and cooled below its saturation point, moisture condenses. Draining the condensate from the storage tank causes some drying of the air supply, but an air dryer is often required.

An air dryer is selected according to the amount of moisture in the air and the lowest temperature to which an air line will be exposed. For a chart showing temperature and moisture content relationships at various air pressures, refer to the General Engineering Data section.

DRY AIR REQUIREMENT

The coldest ambient temperature to which tubing is exposed is the criterion for required dryness, or dew point. Dew point is the temperature at which moisture starts to condense out of the air.

The coldest winter exposure is normally a function of outdoor air temperature. Summer exposure is normally a function of temperature in cold air ducts or air conditioned space. The typical coldest winter application is an air line and control device (e.g., damper actuator) mounted on a rooftop air handling unit and exposed to outdoor air temperatures (Fig. 12). The second coldest winter exposure is an air line run in a furred ceiling or outside wall.

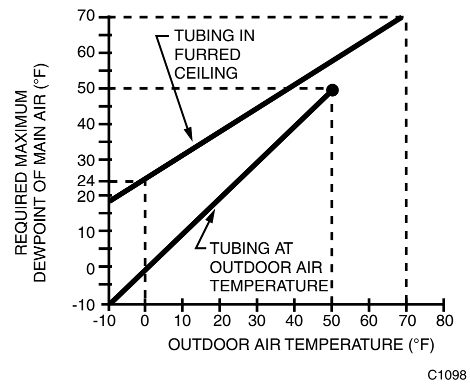


Fig. 12. Winter Dew Point Requirement.

A typical summer minimum dew point application is a cold air plenum. Figure 13 shows a 50F plenum application along with winter requirements for a year-round composite.

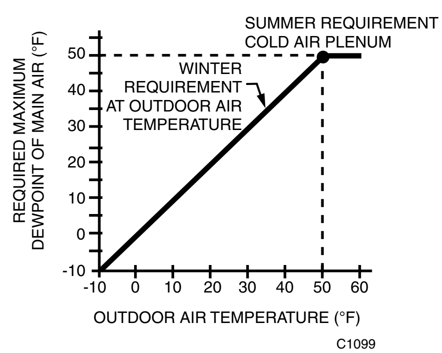


Fig. 13. Twelve-Month Composite Dew Point Requirement.

CONDENSING DRYING

The two methods of condensing drying are high-pressure drying and refrigerant drying.

High-Pressure Drying

High-pressure drying may be used when main air piping is kept away from outside walls and chilling equipment. During compression and cooling to ambient temperatures, air gives up moisture which then collects in the bottom of the storage tank. The higher the tank pressure, the greater the amount of moisture that condenses. Maintaining a high pressure removes the maximum amount of moisture. The compressor should have a higher operating pressure than is required for air supply purposes only. However, higher air pressure requires more energy to run the compressor. The tank must include a manual drain valve or an automatic trap to continually drain off accumulated moisture. With tank pressures of 70 to 90 psi, a dew point of approximately 70F at 20 psi can be obtained.

Refrigerant Drying

Lowering air temperature reduces the ability of air to hold water. The refrigerated dryer (Fig. 14) is the most common means of obtaining dry, compressed air and is available in several capacities. It provides the greatest system reliability and requires minimal maintenance.

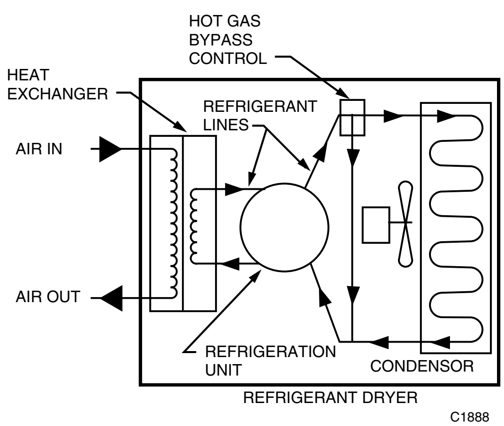


Fig. 14. Typical Refrigerant Dryer Airflow Diagram.

The refrigerant dryer uses a non cycling operation with a hot gas bypass control on the refrigerant flow to provide a constant dew point of approximately 35F at the tank pressure. The refrigeration circuit is hermetically sealed to prevent loss of refrigerant and lubricant and to protect against dirt.

The heat exchanger reduces the temperature of the compressed air passing through it. A separator/filter condenses both water and oil from the air and ejects the condensate through a drain. A temperature-sensing element controls the operation of the refrigeration system to maintain the temperature in the exchanger.

With a dew point of 35F and an average compressor tank pressure of 80 psi, air is dried to a dew point of 12F at 20 psi. Under severe winter conditions and where piping and devices are exposed to outside temperatures, the 12F dew point may not be low enough.

DESICCANT DRYING

A desiccant is a chemical that removes moisture from air. A desiccant dryer is installed between the compressor and the PRV. Dew points below –100F are possible with a desiccant dryer. The desiccant requires about one-third of the process air to regenerate itself, or it may be heated. To regenerate, desiccant dryers may require a larger compressor to produce the needed airflow to supply the control system and the dryer.

It may be necessary to install a desiccant dryer after the refrigerant dryer in applications where the 12F dew point at 20 psi mainline pressure does not prevent condensation in air lines (e.g., a roof-top unit exposed to severe winters).

The desiccant dryer most applicable to control systems uses the adsorbent principle of operation in which porous materials attract water vapor. The water vapor is condensed and held as a liquid in the pores of the material. The drying action continues until the desiccant is saturated. The desiccant is regenerated by removing the moisture from the pores of the desiccant material. The most common adsorbent desiccant material is silica gel, which adsorbs over 40 percent of its own weight in water and is totally inert. Another type of adsorbent desiccant is the molecular sieve.

A desiccant is regenerated either by heating the desiccant material and removing the resulting water vapor from the desiccant chamber or by flushing the desiccant chamber with air at a lower vapor pressure for heatless regeneration. To provide a continuous supply of dry air, a desiccant dryer has two desiccant chambers (Fig. 15). While one chamber is being regenerated, the other supplies dry air to the system. The cycling is accomplished by two solenoid valves and an electric timer. During one cycle, air passes from the compressor into the left desiccant chamber (A). The air is dried, passes through the check valve (B), and flows out to the PRV in the control system.

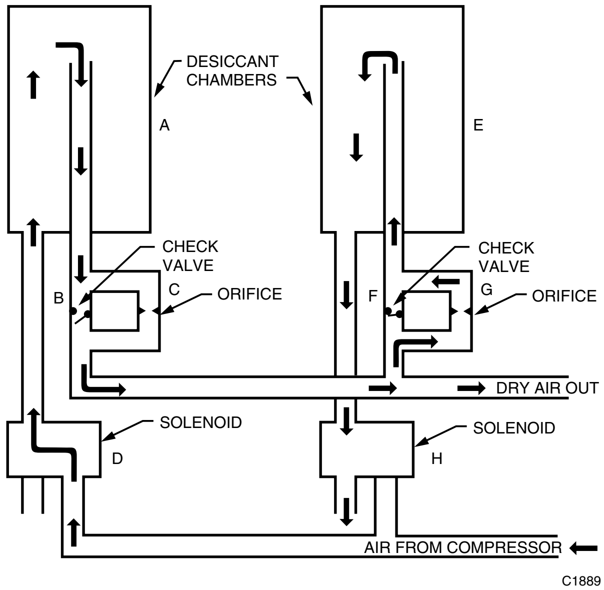


Fig. 15. Typical Heatless Desiccant Dryer Airflow Diagram.

Simultaneously, some of the dried air passes through the orifice (G) to the right desiccant chamber (E). The air is dry and the desiccant chamber is open to the atmosphere, which reduces the chamber pressure to near atmospheric pressure. Reducing the air pressure lowers the vapor pressure of the air below that of the desiccant, which allows the moisture to transfer from the desiccant to the air. The timer controls the cycle, which lasts approximately 30 minutes.

During the cycle, the desiccant in the left chamber (A) becomes saturated, and the desiccant in the right chamber (E) becomes dry. The timer then reverses the flow by switching both of the solenoid valves (D and H). The desiccant in the right chamber (E) then becomes the drying agent connected to the compressor while the desiccant in the left chamber (A) is dried.

The process provides dry air to the control system continually and requires no heat to drive moisture from the desiccant. A fine filter should be used after the desiccant dryer to filter out any desiccant discharged into the air supply.

PRESSURE REDUCING VALVE STATION

The pressure reducing valve station is typically furnished with an air filter. The filter, high-pressure gage, high pressure relief valve, pressure reducing valve (PRV), and low-pressure gage are usually located together at one point in the system and may be mounted directly on the compressor. The most important elements are the air filter and the PRV.

AIR FILTER

The air filter (Fig. 16) removes solid particulate matter and oil aerosols or mist from the control air.

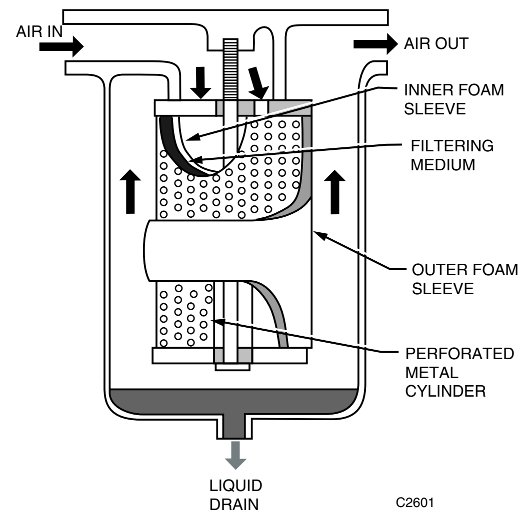


Fig. 16. Typical Air Filter.

Oil contamination in compressed air appears as a gas or an aerosol. Gaseous oil usually remains in a vapor state throughout the system and does not interfere with operation of the controls. Aerosols, however, can coalesce while flowing through the system, and turbulence can cause particles to collect in device filters, orifices, and small passages.

Many filters are available to remove solids from the air. However, only an oil-coalescing filter can remove oil aerosols from control air. An oil coalescing filter uses a bonded fibrous material to combine the small particles of oil mist into larger droplets. The coalesced liquids and solids gravitate to the bottom of the outer surface of the filter material, drop off into a sump, and are automatically discharged or manually drained.

The oil coalescing filter continues to coalesce and drain off accumulated oil until solid particles plug the filter. An increase in pressure drop across the filter (to approximately 10 psi) indicates that the filter element needs replacement. For very dirty air, a 5-micron prefilter filters out large particles and increases the life of the final filter element.

PRESSURE REDUCING VALVES

A pressure reducing valve station can have a single-pressure reducing valve or a two-pressure reducing valve, depending on the requirements of the system it is supplying.

Single-Pressure Reducing Valve

After it passes though the filter, air enters the PRV (Fig. 11). Inlet pressure ranges from 60 to 150 psi, depending on tank pressures maintained by the compressor. Outlet pressure is adjustable from 0 to 25 psi, depending on the control air requirements. The normal setting is 20 psi.

A safety relief valve is built into some PRV assemblies to protect control system devices if the PRV malfunctions. The valve is typically set to relieve downstream pressures above 24 psi.

Two-Pressure Reducing Valve

A two-pressure reducing valve is typically set to pass 13 or 18 psi to the control system, as switched by a pilot pressure. The two-pressure reducing valve is the same as the single-pressure reducing valve with the addition of a switchover diaphragm and switchover inlet to accept the switchover pressure signal. Switchover to the higher setting occurs when the inlet admits main air into the switchover chamber. Exhausting the switchover chamber returns the valve to the lower setting.

The switchover signal is typically provided by an E/P relay or a two-position diverting switch. An automatic time clock can operate an E/P relay to switch the main pressure for a day/night control system. A diverting switch is often used to manually switch a heating/cooling system.

In many applications requiring two-pressure reducing valves, a single-pressure reducing valve is also required to supply single-pressure controllers which do not perform well at low pressures. Higher dual pressure systems operating at 20 and 25 psi are sometimes used to eliminate the need and expense of the second PRV.

THERMOSTATS

Thermostats are of four basic types:

— A low-capacity, single-temperature thermostat is the basic nozzle-flapper bleed-type control described earlier. It is a bleed, one-pipe, proportional thermostat that is either direct or reverse acting.

— A high-capacity, single-temperature thermostat is a low-capacity thermostat with a capacity amplifier added. It is a pilot-bleed, two-pipe, proportioning thermostat that is either direct or reverse acting.

— A dual-temperature thermostat typically provides occupied/unoccupied control. It is essentially two thermostats in one housing, each having its own bimetal sensing element and setpoint adjustment. A valve unit controlled by mainline pressure switches between the occupied and unoccupied mode. A manual override lever allows an occupant to change the thermostat operation from unoccupied operation to occupied operation.

— A dual-acting (heating/cooling) thermostat is another two-pipe, proportioning thermostat that has two bimetal sensing elements. One element is direct acting for heating control, and the other, reverse acting for cooling control. Switchover is the same as for the dual-temperature thermostat but without manual override.

Other thermostats are available for specific uses. Energy conservation thermostats limit setpoint adjustments to reasonable minimums and maximums. Zero energy band thermostats provide an adjustable deadband between heating and cooling operations.

The thermostat provides a branchline air pressure that is a function of the ambient temperature of the controlled space and the setpoint and throttling range settings. The throttling range setting and the setpoint determine the span and operating range of the thermostat. The nozzle-flapper-bimetal assembly maintains a fixed branchline pressure for each temperature within the throttling range (Fig. 17). The forces within the nozzle-flapper-bimetal assembly always seek a balanced condition against the nozzle pressure. If the setpoint is changed, the forces in the lever system are unbalanced and the room ambient temperature must change in a direction to cause the bimetal to rebalance the lever system.

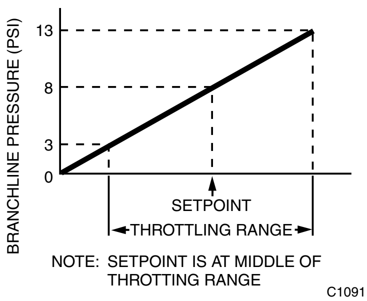


Fig. 17. Relationship between Setpoint, Branchline Pressure, and Throttling Range.

For example, if the setpoint of a direct acting thermostat is increased, the bimetal reduces the force applied to the flapper and raises the flapper off the nozzle. This movement causes the branchline pressure to bleed down and a heating valve to open. Heat enters the space until the temperature at the thermostat increases and the force of the bimetal is again in equilibrium with the opposing force of the pressure at the nozzle. Decreasing the setpoint causes the reverse to occur.

The throttling range adjustment provides the means for changing the effective length of the cantilever bimetal in the lever system. When the throttling range adjustment is positioned directly over the nozzle, the force of the bimetal increases and a narrow throttling range or very high sensitivity results. For example, a change in temperature of 1 degree F could result in a branchline pressure change of 5 psi.

When the throttling range adjustment is moved toward the end of the bimetal and away from the nozzle, the force of the bimetal is reduced. This reduction requires a greater temperature change at the bimetal to throttle the flapper over the nozzle. The result is a wider throttling range or very low sensitivity. For example, a temperature change of 1 degree F could result in a branchline pressure change of only 1 psi.

CONTROLLERS

GENERAL

A controller is the same as a thermostat except that it may have a remote sensing element. A controller typically measures and controls temperature, humidity, airflow, or pressure. Controllers can be reverse or direct acting, proportional or two-position, single or two pressure, and bleed, feed and bleed, or pilot bleed.

A two-position controller changes branchline pressure rapidly from minimum to maximum (or from maximum to minimum) in response to changes in the measured condition, thus providing ON/OFF operation of the controlled device.

A proportional controller changes branchline pressure incrementally in response to a change in the measured condition, thus providing modulating operation of the controlled device.

A proportional-integral (PI) controller adds to the proportional controller a component that takes offset into account. The integral component eliminates the control point offset from the setpoint.

Bleed-type controllers can be used in one-pipe or two-pipe configurations. In a one-pipe system (Fig. 18), the main air goes through a restrictor to the controller and actuator in the most expeditious routing. In a two-pipe system (Fig. 19), the main air goes into the controller, through an internal restrictor in the controller, and out of the controller through a branch line to the actuator. All pilot-bleed and feed-and-bleed controllers are two pipe.

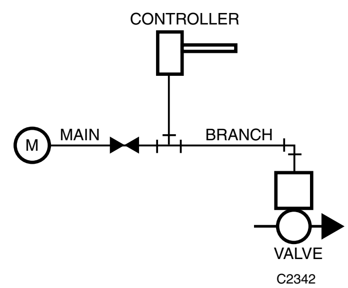


Fig. 18. One-Pipe Controller System.

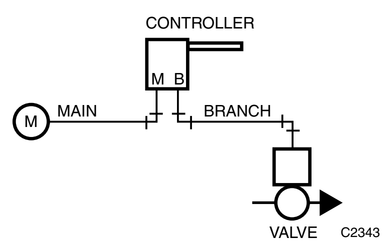


Fig. 19. Two-Pipe Controller System.

Controllers may also be classified as single-pressure or two-pressure controllers. Single-pressure controllers use a constant main air pressure. Two-pressure controllers use a main air pressure that is alternately switched between two pressures, such as 13 and 18 psi. For example, occupied/unoccupied controllers automatically change setpoint from a occupied setting at a mainline pressure of 13 psi to a lowered unoccupied setting at 18 psi. Heating/cooling controllers change from reverse acting at mainline air pressure of 13 psi for cooling to direct acting at 18 psi for heating.

TEMPERATURE CONTROLLERS

Temperature controllers can be one- or two-pipe. The sensing element is typically bimetal, liquid filled remote bulb, or liquid filled averaging capillary tube. Dimensional change of the element with temperature change results in flapper position change and therefore, pilot and branch pressure change.

HUMIDITY CONTROLLERS

Principles that apply to temperature controllers also apply to humidity controllers. The primary difference between temperature and humidity controllers is in the type of sensing element. The sensing element in a humidistat is usually a band of moisture-sensitive nylon. The nylon expands and contracts with changes in the relative humidity of the air.

The humidistat can be used in a one-pipe or two-pipe configuration and is available as either a bleed-type humidistat or a two-pipe capacity humidistat using a capacity amplifier. The humidistat may be direct or reverse acting. The high-capacity humidistat has a capacity amplifier.

PRESSURE CONTROLLERS

Pressure controllers can be divided into two classes according to the pressure range of the measured variable. High-pressure controllers measure and control high pressures or vacuums measured in pounds per square inch or in inches of mercury (e.g., steam or water pressures in an air conditioning system). Low-pressure controllers measure and control low pressures and vacuums measured in inches of water (e.g., pressure in an air duct).

High- and low-pressure controllers have different size diaphragms. In both types, one side of the diaphragm is connected to the pressure to be controlled, and the other side is connected to a reference pressure. Pressures can be measured in respect to atmospheric pressure or another pressure source. The low-pressure controller is available in both bleed-type and pilot-bleed designs.

Figure 20 shows a schematic of a bleed-type, low-pressure controller. The direct-acting pressure sensor measures static pressure from a pressure pickup located in a duct. A reference pressure, from a pickup located outside the duct, is applied to the other side of the diaphragm.

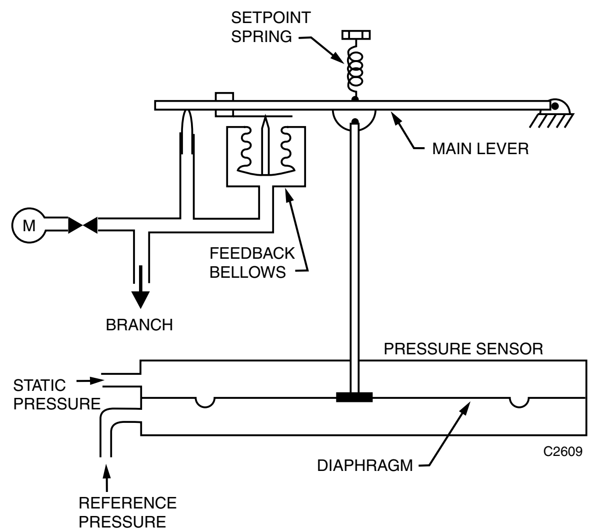


Fig. 20. Bleed-Type Static Pressure Controller.

On an increase in static pressure, the increased force on the diaphragm exceeds the force of the setpoint spring, pulling the main lever downward. A setpoint adjustment screw determines the tension of the setpoint spring. As the main lever is pulled downward, it moves closer to the nozzle, restricts the airflow through the nozzle, and increases the pressure in the branch. The action continues until the pressure on the feedback bellows balances the static pressure on the diaphragm.

On a decrease in static pressure, or if the static pressure sensor is piped for reverse action (high- and low-pressure pickups reversed), the diaphragm moves upward to move the main lever away from the nozzle and reduce the pressure in the branch.

For differential pressure sensing, the two pressure pickup lines connect to opposite sides of the pressure sensor diaphragm.

SENSOR-CONTROLLER SYSTEMS

A sensor-controller system is made up of a pneumatic controller, remote pneumatic sensors, and a final control element. The controller provides proportional or proportional-integral control of temperature, humidity, dew point, or pressure in HVAC systems. Sensors do not have a setpoint adjustment and provide a linear 3 to 15 psi signal to the controller over a fixed sensor range. The controller compares the sensor input signal with the setpoint signal. The difference is the pilot input to a signal amplifier, which provides a branchline pressure to the controlled device. Thus the controller acts as a general-purpose pneumatic amplifier.

PNEUMATIC CONTROLLERS

Controllers generally use diaphragm logic, which allows flexible system application, provides more accurate control, and simplifies setup and adjustment for the needs of each system. Controllers may be proportional only or proportional-integral (PI). The integral function is also called “automatic reset”. Proportional and PI controllers are available with single-sensor input or dual-sensor input for resetting the primary sensor setpoint from a second sensor. They are also available with integral or remote setpoint adjustment.

The single-input controller consists of a signal amplifier feeding a capacity amplifier. The capacity amplifier is discussed under PILOT BLEED SYSTEM. A dual-input controller has inputs from a primary temperature sensor and a reset temperature sensor. The reset sensor resets controller setpoint. Reset can be negative or positive.

Figure 21 depicts a single-input controller as it would appear in a simple application. Figure 22 depicts a dual-input controller with manual remote setpoint control. In Figures 21 and 22 the sensors are fed restricted main air from the controllers. Where sensors are located extremely remote from the controller, a remote restrictor may be required.

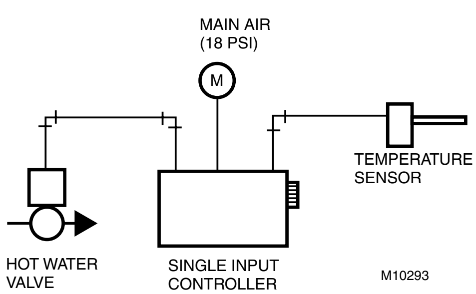


Fig. 21. Single-Input Controller.

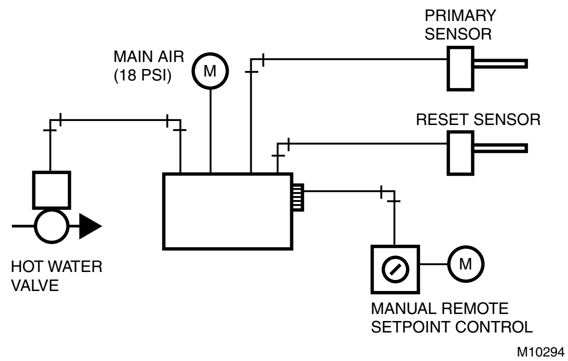


Fig. 22. Dual-Input Controller with Manual Remote Setpoint.

PROPORTIONAL-INTEGRAL (PI) CONTROLLERS

Variations of single-input and dual-input controllers can provide proportional-integral (PI) control. PI controllers are used in critical applications that require closer control than a proportional controller. A PI controller provides close control by eliminating the deviation from setpoint (offset) that occurs in a proportional controller system. PI controllers are similar to the controllers in Figures 21 and 22 and have an additional knob for adjusting the integral reset time.

CONTROLLER ADJUSTMENTS

Controller operation is adjusted in the following ways:
— Adjusting the setpoint
— Changing between direct and reverse control action
— Adjusting the proportional band (throttling range)
— Adjusting the reset authority
— Adjusting the integral control reset time

The setpoint can be manually adjusted with a dial on the controller. Remote setpoint adjustment is available for all controllers. Control action may be direct or reverse, and is field adjustable. The proportional band setting is typically adjustable from 2.5 to 50 percent of the primary sensor span and is usually set for the minimum value that results in stable control. In a sensor with a span of 200 degrees F, for example, the minimum setting of 2.5 percent results in a throttling range of 5 degrees F (0.025 x 200 = 5 degrees F). A change of 5 degrees F is then required at the sensor to proportionally vary the controller branchline pressure from 3 to 13 psi. A maximum setting of 50 percent provides a throttling range of 100 degrees F (0.50 x 200 = 100 degrees F).

Reset authority, also called "reset ratio", is the ratio of the effect of the reset sensor compared to the primary sensor. Figure 23 shows the effect of authority on a typical reset schedule. The authority can be set from 10 to 300 percent.

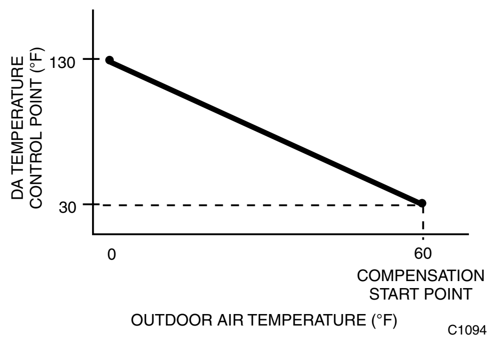


Fig. 23. Typical Reset Schedule for Discharge Air Control.

The integral control reset time determines how quickly the PI controller responds to a change in the controlled variable. Proportional correction occurs as soon as the controlled variable changes. The integral function is timed with the reset time adjustment. The reset time adjustment is calibrated from 30 seconds to 20 minutes. The proper setting depends on system response time characteristics.

PNEUMATIC SENSORS

Pneumatic sensors typically provide a direct acting 3 to 15 psi pneumatic output signal that is proportional to the measured variable. Any change in the measured variable is reflected as a change in the sensor output. Commonly sensed variables are temperature, humidity, and differential pressure. The sensors use the same sensing elements and principles as the sensors in the controllers described earlier, but do not include setpoint and throttling range adjustments. Their throttling range is the same as their span.

A gage connected to the sensor output can be used to indicate the temperature, humidity, or pressure being sensed. The gage scale is calibrated to the sensor span.

Temperature sensors may be vapor-filled, liquid-filled, averaging capillary, or rod-and-tube. The controller usually provides restricted air to the sensor.

Humidity sensors measure the relative humidity of the air in a room (wall-mounted element) or a duct (insertion element). Nylon is typically used as the sensing element. Humidity sensors include temperature compensation and operate on a force-balance principle similar to a wall thermostat.

The low-pressure sensor measures duct static pressure and differential pressure. When the duct static pressure or the pressure differential increases, branchline pressure increases.

VELOCITY SENSOR-CONTROLLER

The velocity sensor-controller combines a highly sensitive air velocity sensor with a pneumatic controller to detect and control airflow regardless of system static pressure. It is used in air terminal units and other air handling systems. Reverse- and direct-acting models are available for normally closed and normally open dampers.

The velocity sensor measures actual velocity and does not require the conversion of velocity pressure to velocity. Although the sensor is typically used in duct air velocity applications, it can accurately sense velocities as low as 100 feet per minute. Flow-limiting orifices inserted into the sensor sampling tube can measure velocity ranges up to 3,500 feet per minute.

Figure 24 shows the operation of a velocity sensor. A restrictor supplies compressed air to the emitter tube located in the air stream to be measured. When no air is flowing in the duct, the jet of air from the emitter tube impinges directly on the collector tube and maximum pressure is sensed. Air flowing in the duct blows the air jet downstream and reduces the pressure on the collector tube. As the duct air velocity increases, less and less of the jet enters the collector tube. The collector tube is connected to a pressure amplifier to produce a usable output pressure and provide direct or reverse action.

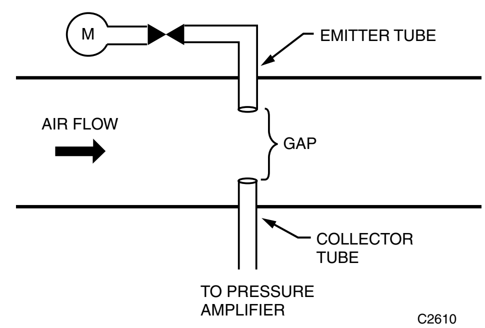


Fig. 24. Velocity Sensor Operation.

A controller connected to the pressure amplifier includes setpoints for maximum and minimum dual air velocity limits. This allows the air volume to be controlled between the limits by a thermostat or another controller.

Two models of the controller are available. One model operates with a one-pipe, bleed-type thermostat, and the other with a two-pipe thermostat. The two-pipe model also allows sequencing for reheat applications.

Figure 25 shows a typical application of a thermostat and velocity controller on a Variable Air Volume (VAV) terminal unit with hot water reheat. The thermostat senses a change in room temperature and resets the velocity setpoint of the velocity controller. The controller repositions the VAV damper to increase or decrease airflow accordingly. If a change in duct static pressure modifies the flow, the controller repositions the actuator to maintain the correct flow. The reheat valve operates only when the thermostat has reset the velocity setpoint down to minimum airflow and the thermostat calls for heating.

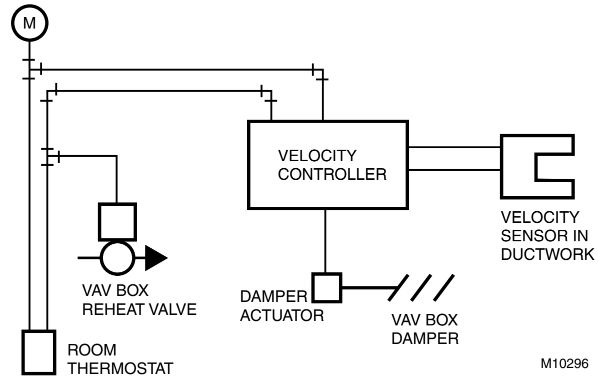


Fig. 25. VAV Box Velocity Controller Control System.

ACTUATORS AND FINAL CONTROL ELEMENTS

A pneumatic actuator and final control element such as a valve (Fig. 26) or damper (Fig. 27) work together to vary the flow of the medium passing through the valve or damper. In the actuator, a diaphragm and return spring move the damper push rod or valve stem in response to changes in branchline pressure.

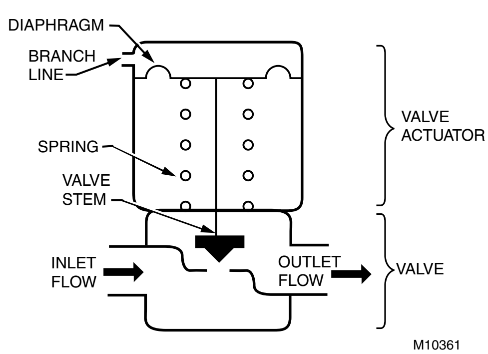


Fig. 26. Pneumatic Actuator and Valve.

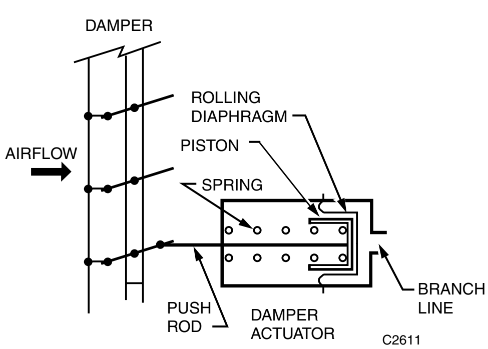


Fig. 27. Pneumatic Actuator and Damper.

ACTUATORS

GENERAL

Pneumatic actuators position damper blades and valve stems. A damper actuator typically mounts on ductwork or on the damper frame and uses a push rod and crank arm to position the damper blades (rotary action). A valve actuator mounts on the valve body and positions the valve stem directly (linear action) for a globe valve or rotary action via linkage for a butterfly valve. Valve actuator strokes typically are between one-quarter and one and one-half inch. Damper actuator strokes range from one to four inches (longer in special applications). In commercial pneumatic actuators, air pressure positions the actuator in one direction and a spring returns it the other direction.

Valve actuators are direct or reverse acting. Damper actuators are direct acting only. A direct-acting actuator extends on an increase in branchline pressure and retracts on a decrease in pressure. A reverse-acting actuator retracts on an increase in branchline pressure and extends on a decrease in pressure.

Pneumatic valve and damper actuator assemblies are termed “normally open” or “normally closed.” The normal position is the one assumed upon zero actuator air pressure. Three-way valves have both normally open (N.O.) and normally closed (N.C.) ports.

SPRING RANGES

Springs used in valve and damper actuators determine the start pressure and pressure change required for full movement of the actuator from open to closed, or from closed to open. Actuators designed for special applications can move through the full range, open to closed or closed to open, on a limited change in pressure from the controller. Such actuators can provide a simple form of sequence control (e.g., operating heating and cooling valves from a single thermostat). Typical spring pressure ranges are 2-7 psi, 8-12 psi, and 3-13 psi.

CONTROL VALVES

Single-seated globe valves (Fig. 28) are used where tight close-off is required. The valve body can be either direct acting or reverse acting. A direct-acting valve body allows flow with the stem up, while a reverse-acting valve body shuts off flow with the stem up. The combination of valve body and actuator (called the valve assembly) determines the normal valve stem position.

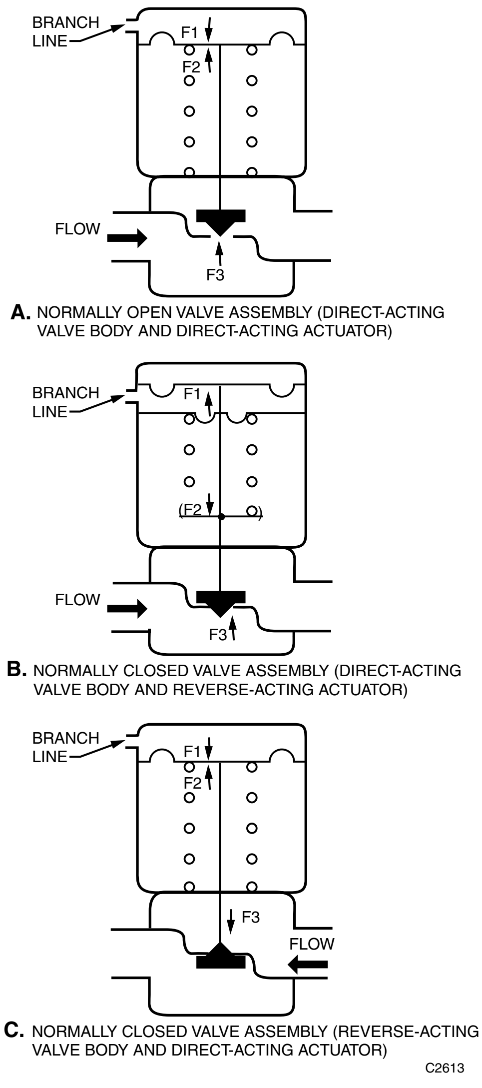


Fig. 28. Single-Seated Valves.

The position maintained by the valve stem depends on the balance of forces acting on it:
— Force F1 from the air pressure on the diaphragm
— Opposing force F2 from the actuator spring
— Controlled-medium force F3 acting on the valve disc and plug due to the difference between inlet and outlet pressures

An increase in controller branchline pressure increases force F1, (Fig. 28A), moving the diaphragm down and positions the valve stem toward closed until it has moved far enough that the sum of the spring force F2 and the controlled-medium force F3 increases balance the increased force F1 on the diaphragm. Conversely, a decrease in controller branchline air pressure in the diaphragm chamber of a direct-acting actuator decreases force F1, allowing forces F2 and F3 to push the diaphragm upward and move the valve stem toward the open position.

In Figure 28B, branchline pressure is applied on the bottom surface of the diaphragm. An increase in air pressure in the diaphragm chamber increases force F1 causing the actuator diaphragm to move upward and open the valve. Motion continues until the increase in pressure on the diaphragm plus the controlled-medium force F3 is balanced by the increase in spring compression (force F2). On a decrease in air pressure in the diaphragm chamber, the compressed spring moves the diaphragm down toward its normal position and the valve stem toward closed. A normally closed valve assembly usually has a lower close-off rating against the pressure of the controlled medium than a normally open valve because the spring force F2 is the only force available to close the valve.

In Figure 28C, an increase in branchline pressure in the actuator increases force F1 causing the diaphragm to move downward and open the valve. Motion continues until the increase in pressure on the diaphragm (force F1) plus the controlled-medium force F3 is balanced by the increase in spring compression (force F2). On a decrease in air pressure in the diaphragm chamber, the compressed-spring pressure moves the diaphragm up and the valve stem moves toward the closed position.

In a double-seated valve (Fig. 29), the controlled agent flows between the two seats. This placement balances the inlet pressures between the two discs of the plug assembly and reduces the actuator force needed to position the plug assembly. Double-seated valves generally do not provide tight close-off because one disc may seat before the other and prevent the other disc from seating tightly.

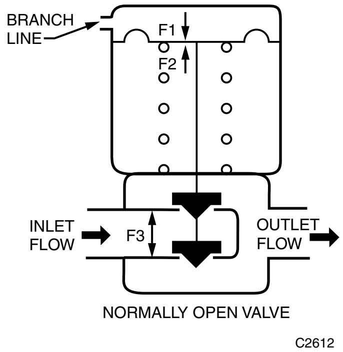


Fig. 29. Double-Seated Valve.

Figure 30 shows three-way globe valve assemblies. The mixing valve has two inlets and a common outlet. The diverting valve has a common inlet and two outlets.

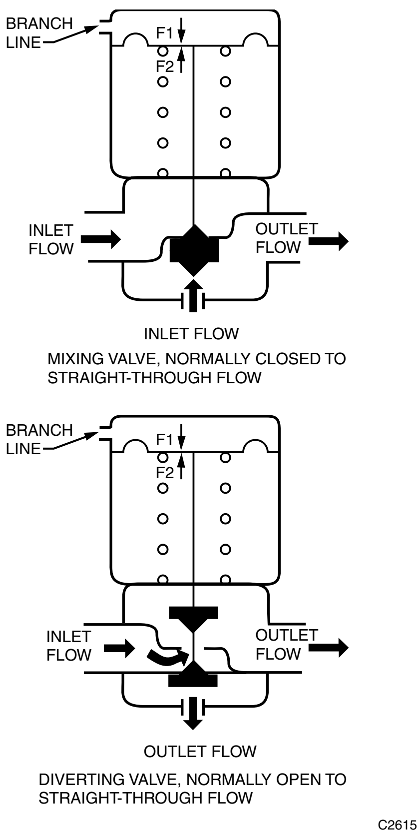


Fig. 30. Three-Way Valve Assemblies.

Three-way valves may be piped to be normally open or normally closed to the heating or cooling load. If a three-way valve has linear characteristics and the pressure differentials are equal, constant total flow is maintained through the common inlet or outlet port.

Two- and three-way butterfly valves can be operated by long stroke pneumatic actuators and appropriate linkage (Fig. 31).

One or two low pressure actuators powered directly by branchline pressure can operate butterfly valves up to about 12 inches, depending on the differential close-off rating of the valve. For other applications high pressure pneumatic cylinders can be used to provide the force required by the valve. A pneumatic positioner provides an appropriate high pressure signal to the cylinder based on a 3 to 15 psi input signal.

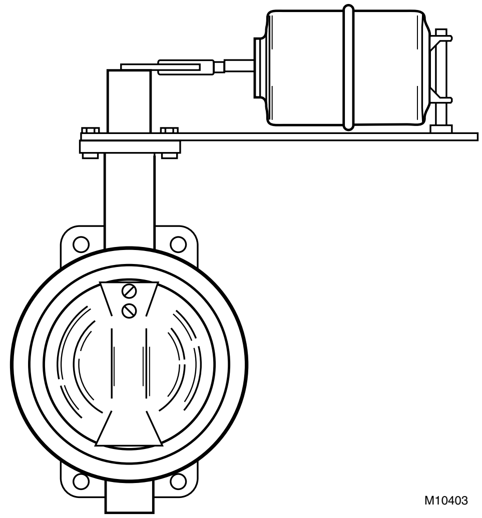


Fig. 31. Butterfly Valve Assembly.

For a more detailed discussion of valves, see the Valve Selection And Sizing section.

DAMPERS

Dampers control the flow of air in air-handling systems. The most common type of damper, a multiblade louver damper, can have parallel or opposed blades (Fig. 32).

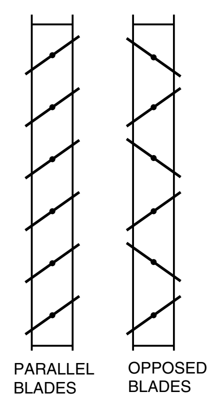


Fig. 32. Parallel- and Opposed-Blade Dampers.

Figure 33 shows normally open and normally closed parallel-blade dampers. A normally open damper returns to the open position with low air pressure in the actuator diaphragm chamber. An increase in branchline pressure forces the rolling diaphragm piston to move against the spring, and a decrease allows the compressed spring to force the piston and diaphragm back to the normal position. As with valve actuators, intermediate positions depend on a balance between the force of the control air pressure on the diaphragm and the opposing force of the actuator spring.

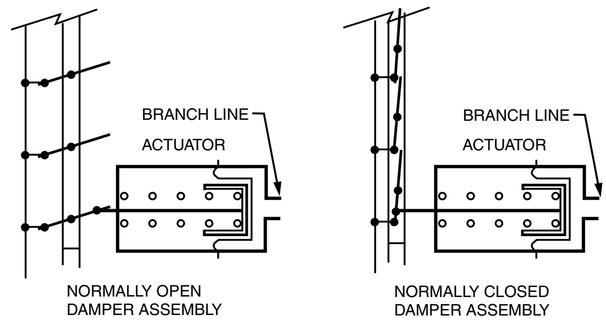


Fig. 33. Normally Open and Normally Closed Dampers.

A normally closed damper returns to the closed position with low air pressure in the actuator diaphragm chamber. The way the damper blades, crank arm, and push rod are oriented during installation determines the normal (open or closed) position of the damper blades.

For a more detailed discussion of dampers, see the Damper Selection and Sizing section.

RELAYS AND SWITCHES

In the following illustrations, common (C) and the normally connected port (O) are connected on a fall in pilot pressure (P) below the relay setpoint, and the normally disconnected port (X) is blocked (Fig. 34). On a rise in pilot pressure above the relay setpoint, C and X are connected and O is blocked.

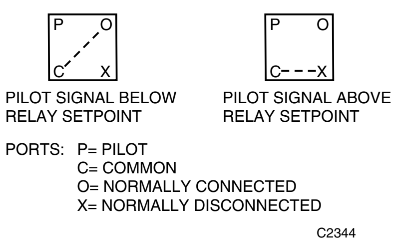


Fig. 34. Relay Port Connections.

SWITCHING RELAY

A switching relay requires a two-position pilot signal and is available with either single-pole, double-throw (spdt) or double-pole, double-throw (dpdt) switching action. Pneumatic heating and cooling control systems use relays to switch a valve or damper actuator from one circuit to another or to positively open or close a device. Both spdt and dpdt switching relays are available with a variety of switching pressures.

Figure 35 shows a typical spdt switching relay application for heating/cooling operation in which the thermostat controls the heating/cooling coil valve. Seasonal mainline pressure changes cause the action of the thermostat to be reversed. A discharge low-limit control is switched into the control circuit for heating and out of the circuit for cooling. The switching is done from mainline pressure connected to the pilot port (P).

During the heating cycle, the 18 psi mainline pressure is above the preset switching pressure. The common port (C) connects to the normally disconnected port (X), connecting the low-limit controller to the thermostat branchline to prevent discharge temperatures below the controller setting. The normally connected port (O) is blocked.

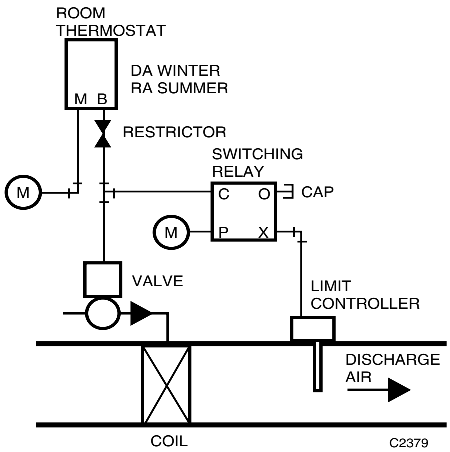


Fig. 35. Typical Switching Relay for Application.

During the cooling cycle, the 13 psi mainline pressure at the pilot port (P) is below the minimum switching pressure of the preset limits. The common port (C) connects to the normally connected port (O), which is capped. The normally disconnected port (X) is closed and removes the low-limit controller from the system.

In a dpdt model, the common, normally connected, and normally disconnected ports are duplicated in the second switch section.

SNAP ACTING RELAY

The snap acting relay is a spdt switch that provides two-position switching action from a modulating signal and has an adjustable switching point. The switching differential is less than 1.0 psi. The switching pressure is manually adjustable for 3 to 15 psi operation.

Figure 36 shows a snap acting relay application. Operation is similar to the switching relay. When the branchline pressure from the outdoor air thermostat equals or exceeds the preset switchover pressure, the relay connects the normally disconnected port (X) and blocks the normally connected port (O) to deliver main air to the normally open heating valve and provide positive close off. When the outdoor air thermostat pressure drops below the relay setpoint, the normally disconnected port (X) is blocked and the normally connected port (O) connects to the common port (C) to connect the valve actuator to the room thermostat.

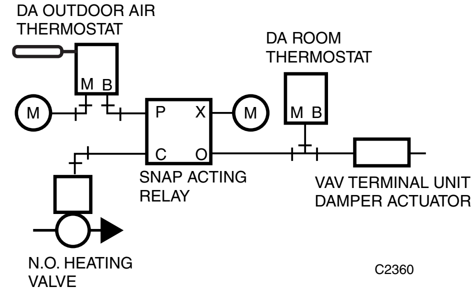


Fig. 36. Typical Application for Snap Acting Relay.

LOCKOUT RELAY

The lockout relay is a three-port relay that closes off one pressure signal when a second signal is higher. Figure 37 shows a typical application in which mixed air control becomes disabled when outdoor air temperature is higher than return air temperature. To prevent air from being trapped in the line between the lockout relay and the snap acting relay, a small bleed must be present either in the pilot chamber of the snap acting relay or in the line.

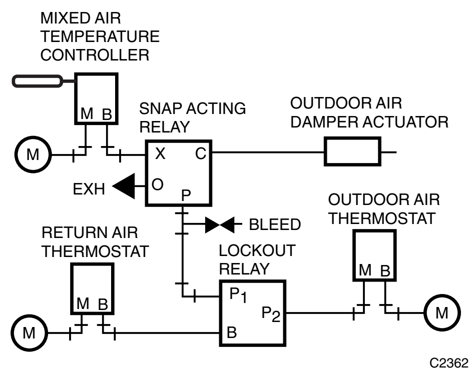


Fig. 37. Lockout Relay in Economizer Cycle.

Figure 38 shows the lockout relay used as a repeater. This application provides circuit isolation by repeating the pilot signal with a second air source.

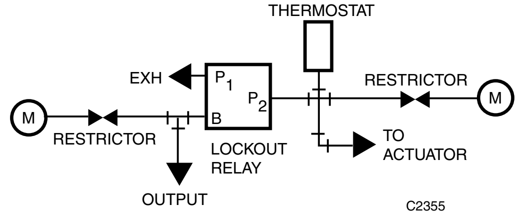


Fig. 38. Lockout Relay as Repeater.

HIGH-PRESSURE SELECTOR RELAY

The high-pressure selector relay is a three-port relay that transmits the higher of two input signals to the output branch. The high sensitivity of the relay allows it to be used in sensor lines with an accuracy of 2 to 3 degrees F.

The application shown in Figure 39 uses pressures from two zones and a high-pressure selector relay to determine control. A separate thermostat controls each zone damper. The thermostat that calls for the most cooling (highest branchline pressure) controls the cooling valve through the high-pressure selector relay.

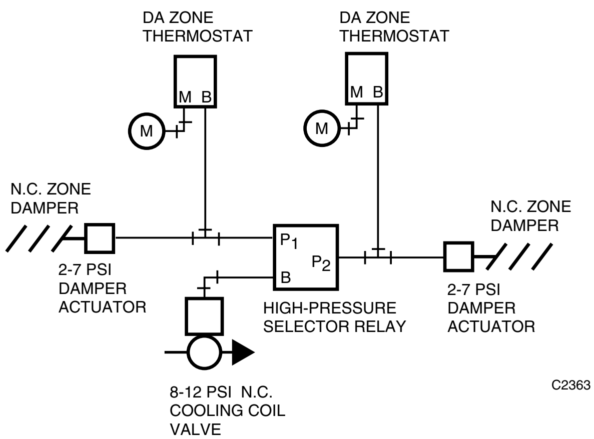


Fig. 39. Typical Application for High-Pressure Selector Relay.

LOW-PRESSURE SELECTOR RELAY

The low-pressure selector relay is a three-port relay that selects the lower of two input pressure signals and acts as a repeater for the lower of the two inputs. The relay requires an external restrictor on the input to the branch port. Figure 40 shows a low-pressure selector relay controlling the heating coil valve from the thermostat that calls for the most heat.

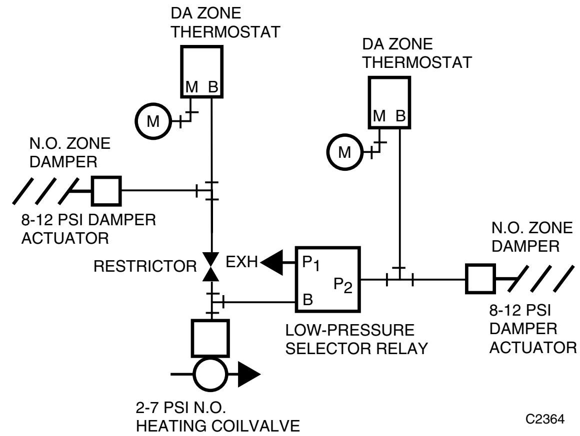


Fig. 40. Typical Application for Low-Pressure Selector Relay.

LOAD ANALYZER RELAY

The load analyzer relay is a bleed-type, diaphragm-logic pressure selector. The relay selects the highest and lowest branch pressure from multiple inputs to operate final control elements (Fig. 41). The relay contains multiple diaphragms and control nozzles. Each input pressure connects to two diaphragms.

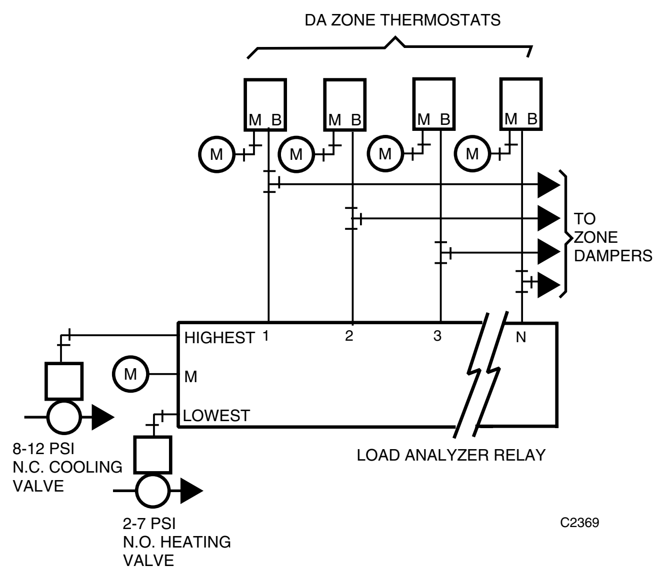


Fig. 41. Load Analyzer Relay in Multizone Air Unit Application.

In Figure 41, the load analyzer relay selects the lowest pressure signal from the thermostat in the coldest zone and transmits that signal to a normally open heating valve. The relay transmits the highest pressure signal from the thermostat in the warmest zone to a normally closed cooling valve.

CAPACITY RELAY

The capacity relay is a direct-acting relay that isolates an input and repeats the input pressure with a higher capacity output. Figure 42 shows a capacity relay enabling a single bleed-type thermostat to operate multiple damper actuators quickly by increasing the output capacity of the thermostat.

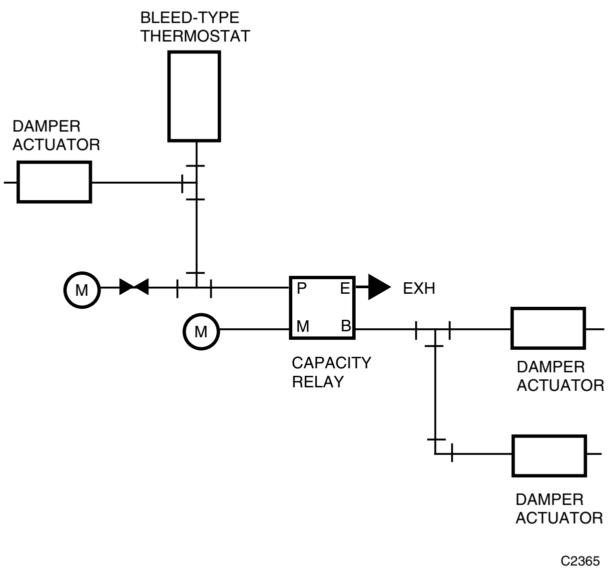


Fig. 42. Typical Capacity Relay Application.

REVERSING RELAY

The reversing relay is a modulating relay with an output that decreases at a one-to-one ratio as the input signal increases. Figure 43 shows a reversing relay application. A falling temperature at the direct-acting thermostat causes the branchline pressure to decrease. The reversing relay branch pressure increases and opens the normally closed heating valve.

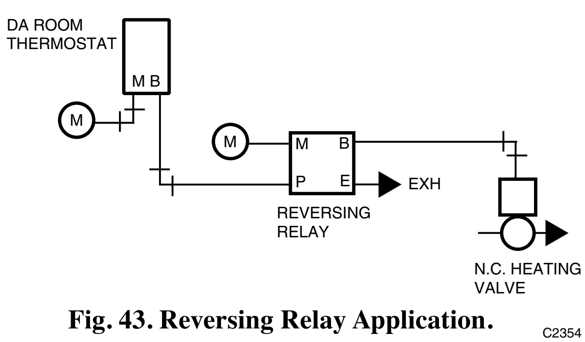


Fig. 43. Reversing Relay Application.

POSITIVE-POSITIONING RELAY

The positive-positioning relay (Fig. 44) mounts directly on a valve or damper actuator. The relay positions the valve or damper precisely according to the branchline pressure from a thermostat or other controller, regardless of the load variations affecting the valve stem or damper shaft. The relay is typically used for large actuators for sequencing, or in applications requiring precise control.

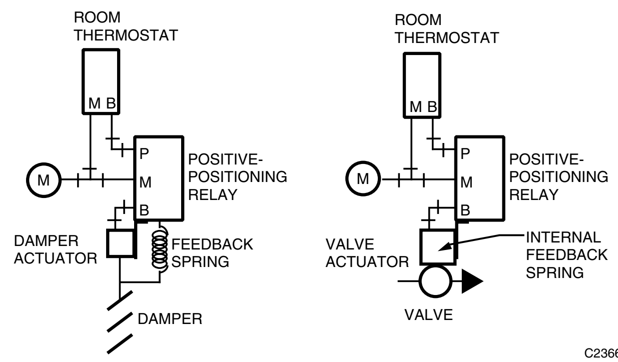


Fig. 44. Positive-Positioning Relay with Damper and Valve Actuators.

When the relay is connected to an actuator, the feedback spring produces a force proportional to the actual valve or damper position. The relay positions the actuator in proportion to the branchline input. If the connected load attempts to unbalance the required valve stem position, the relay either exhausts or applies main pressure to the actuator to correct the condition. If the valve or damper sticks or the load prevents proper positioning, the relay can apply the pressure required (up to full main pressure) or down to zero to correct the condition.

The positive-positioning relay also permits sequenced operation of multiple control valves or dampers from a single thermostat or controller. For example, a normally open heating valve and a normally closed outdoor air damper could be controlled from a single thermostat piloting relays on two actuators. Relays typically have a 3, 5, or 10 psi input pressure span and an adjustable start pressure. As the space temperature rises into the low end of the thermostat throttling range, the heating valve positioner starts to close the valve.

AVERAGING RELAY

The averaging relay is a direct-acting, three-port relay used in applications that require the average of two input pressures to supply a controller input or to operate a controlled device directly.

Figure 45 shows an averaging relay in a typical application with two thermostat signals as inputs. The average of the thermostat signals controls a valve or damper actuator.

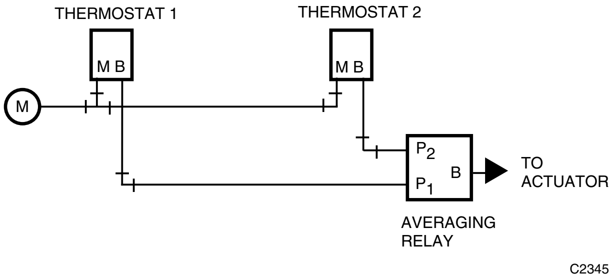


Fig. 45. Averaging Relay Application.

RATIO RELAY

The ratio relay is a four-port, non bleed relay that produces a modulating pressure output proportional to the thermostat or controller branchline output. Ratio relays can be used to control two or three pneumatic valves or damper actuators in sequence from a single thermostat. The ratio relay has a fixed input pressure range of either 3 or 5 psi for a 10 psi output range and an adjustable start point. For example, in a ratio relay with a 5 psi range set for a 7 psi start, as the input pressure varies from 7 to 12 psi (start point plus range), the output pressure will vary from 3 to 13 psi.

In Figure 46, three 3 psi span ratio relays are set for 3 to 6, 6 to 9, and 9 to 12 psi inputs, respectively. The thermostat signal through the relays proportions in sequence the three valves or actuators that have identical 3 to 13 psi springs.

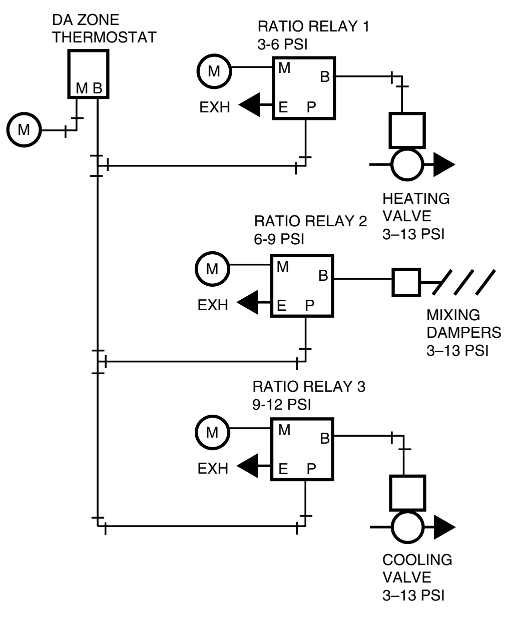


Fig. 46. Ratio Relays in Sequencing Control Application.

PNEUMATIC POTENTIOMETER

The pneumatic potentiometer is a three-port, adjustable linear restrictor used in control systems to sum two input signal values, average two input pressures, or as an adjustable flow restriction. The potentiometer is a linear, restricted air passage between two input ports. The pressure at the adjustable output port is a value based on the inputs at the two end connections and the location of the wiper between them.

Figure 47 shows a pneumatic potentiometer providing an average of two input signals. The wiper is set at mid-scale for averaging or off-center for a weighted average. It can be used this way to average two air velocity transmitter signals from ducts with different areas by positioning the wiper according to the ratio of the duct areas. This outputs a signal proportional to the airflow.

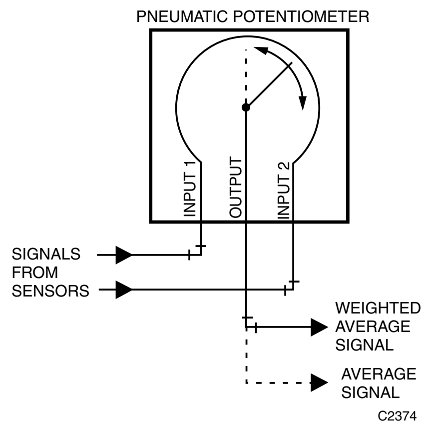
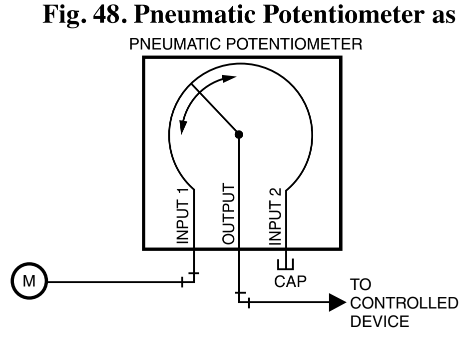


Fig. 47. Pneumatic Potentiometer as Averaging Relay.

Figure 48 shows a pneumatic potentiometer as an adjustable airflow restrictor.

Fig. 48. Pneumatic Potentiometer as



Adjustable Airflow Restrictor.

HESITATION RELAY

The hesitation relay is used with a pneumatic actuator in unit ventilator applications. The output pressure goes to minimum whenever the input pressure is below the minimum setting. Figure 49 shows a graph of the output of a hesitation relay as controlled by the relay knob settings (piloted from the thermostat).

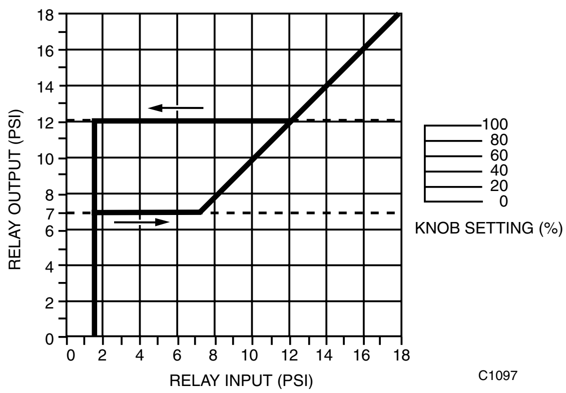


Fig. 49. Hesitation Relay Output Pressure as a Function of Knob Setting.

The hesitation relay has an internal restrictor. Figure 50 shows a typical application of a hesitation relay and a pneumatic damper actuator. When the thermostat branchline pressure reaches 1.5 psi, the relay output goes to its preset minimum pressure. When the branchline pressure of the thermostat reaches the setting of the hesitation relay, the thermostat controls the damper actuator. When the thermostat branchline pressure drops below the hesitation relay setting, the relay holds the damper actuator at the minimum position until the thermostat branchline pressure drops below 1.5 psi. At that point, the hesitation relay output falls to zero.

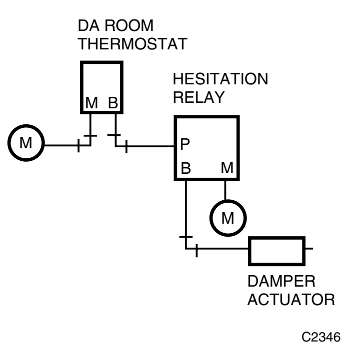


Fig. 50. Typical Hesitation Relay Application.

ELECTRICAL INTERLOCKING RELAYS

Electrical interlocking relays bridge electric and pneumatic circuits. The electric-pneumatic relay uses electric power to actuate an air valve in an associated pneumatic circuit. The pneumatic-electric relay uses control air pressure to make or break an associated electrical circuit.

ELECTRIC-PNEUMATIC RELAY

The electric-pneumatic (E/P) relay is a two-position, three-way air valve. Depending on the piping connections to the ports, the relay performs the same functions as a simple diverting relay. A common application for the E/P relay is to exhaust and close an outdoor air damper in a fan system when the fan motor is turned off, as shown in Figure 51.

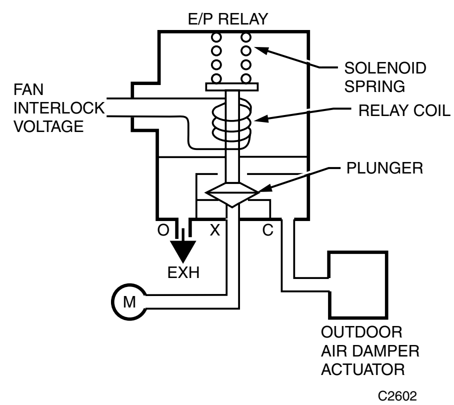


Fig. 51. E/P Relay Application.

When the relay coil is de-energized, the solenoid spring seats the plunger. The normally disconnected port (X) is blocked and the normally connected port (O) connects to the common port (C). The connection exhausts the damper actuator which closes the damper. When the relay coil is energized, the plunger lifts against the tension of the spring and blocks the normally connected port (O). Main air at the normally disconnected port (X) connects to the common port (C) and opens the damper.

PNEUMATIC-ELECTRIC RELAY

Figure 52 shows a simplified pneumatic-electric (P/E) relay with a spdt switch. The P/E relay makes the normally closed contact on a fall in pilot pressure below the setpoint, and makes the normally open contact on a rise above a value equal to the setpoint plus the differential. For example, with a setpoint adjustment of 3 psi and a differential of 2 psi, the pump is energized at pilot pressures below 3 psi and turns off at pilot pressures above 5 psi.

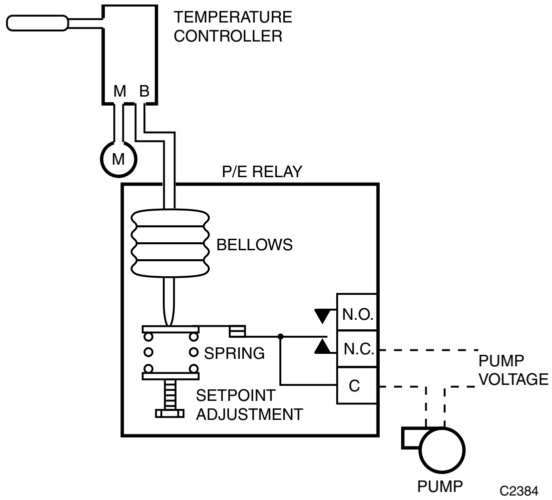


Fig. 52. P/E Relay Application.

ELECTRONIC-PNEUMATIC TRANSDUCER

The electronic-pneumatic transducer is a proportional relay that varies the branch air pressure linearly 3 to 15 psi in response to changes in an electrical input of 2 to 10 volts or 4 to 20 ma. Electronic-pneumatic transducers are used as the interface between electronic, digital, or computer-based control systems and pneumatic output devices (e.g., actuators).

Figure 53 shows discharge air temperature control of a heating coil using digital control for sensing and control. The output of the transducer positions the valve on a heating coil.

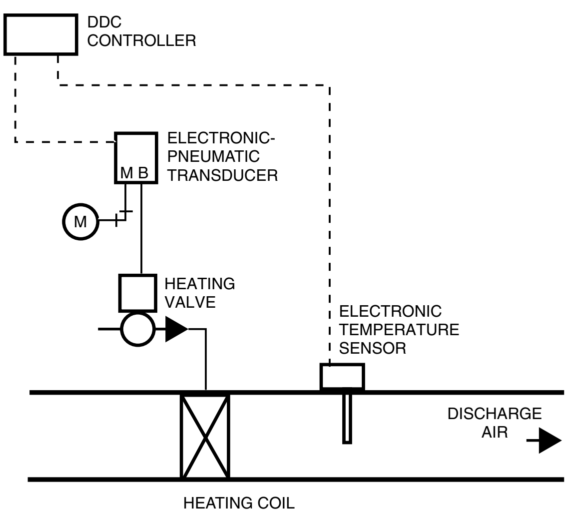


Fig. 53. Typical Electronic-Pneumatic Transducer Application.

A resistance-type temperature sensor in the discharge air duct is the input to the controller, which provides all of the system adjustments and logic requirements for control. The controller output of 2 to 10 volts dc is input to the electronic-pneumatic transducer, which converts the signal to a 3 to 15 psi output to position the heating valve.

PNEUMATIC SWITCH

The pneumatic switch is available in two- or three-position models (Fig. 54). Rotating the switch knob causes the ports to align in one of two ways in a two-position switch, and in one of three ways in a three-position switch. The two-position switch is used for circuit interchange. The three-position switch sequentially switches the common port (Port 2) to the other ports and blocks the disconnected ports.

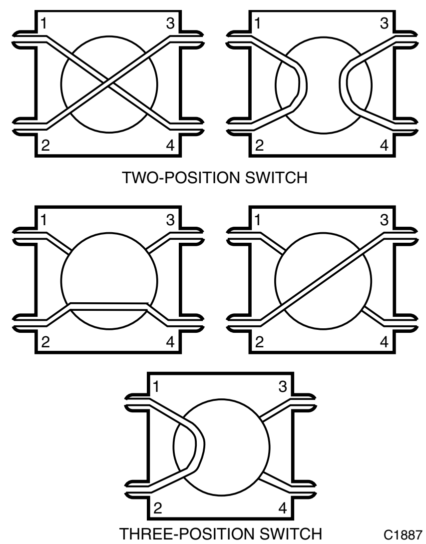


Fig. 54. Pneumatic Switches.

Figure 55 shows a typical application for sequential switching. In the OPEN position, the valve actuator exhausts through Port 4 and the valve opens. In the AUTO position, the actuator connects to the thermostat and the valve is in the automatic mode. In the CLOSED position, the actuator connects to main air and the valve closes.

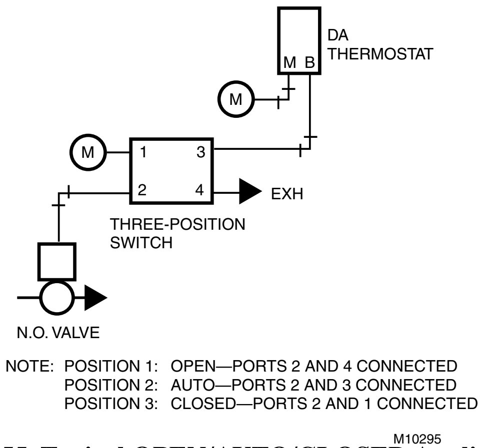


Fig. 55. Typical OPEN/AUTO/CLOSED Application.

MANUAL POSITIONING SWITCH

A manual positioning switch is used to position a remote valve or damper or change the setpoint of a controller. The switch takes input air from a controller and passes a preset, constant, minimum air pressure to the branch regardless of the controller output (e.g., to provide an adjustable minimum position of an outdoor air damper). Branchline pressure from the controller to other devices connected to the controller is not affected.

Figure 56 shows the switch functioning as a minimum positioning switch. The damper will not close beyond the minimum setting of the positioning switch. As the controller signal increases above the switch setting, the switch positions the damper according to the controller signal.

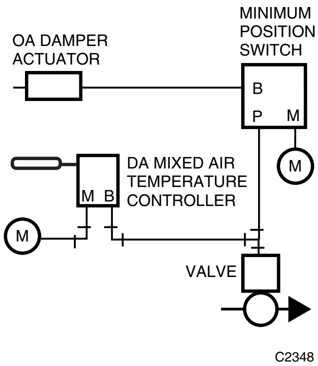


Fig. 56. Typical Three-Port Minimum Position Switch Application.

Manual switches are generally panel mounted with a dial plate or nameplate on the front of the panel which shows the switch position. Gages are sometimes furnished to indicate the main and branch pressures to the switch.

PNEUMATIC CONTROL COMBINATIONS

GENERAL

A complete control system requires combinations of several controls. Figure 57 shows a basic control combination of a thermostat and one or more control valves. A normally open control valve assembly is selected when the valve must open if the air supply fails. A normally open control valve requires a direct-acting thermostat in the heating application shown in Figure 56. Cooling applications may use normally closed valves and a direct-acting thermostat. The thermostat in Figure 56 has a 5 degree throttling range (output varies from 3 to 13 psi of the 5 degree range) and the valves have an 8 to 12 psi spring range, then the valve will modulate from open to closed on a 2 degree rise in temperature at the thermostat.

$$\frac{4 \text{ psi}}{10 \text{ psi}} \text{ X } 5F° = 2F°$$

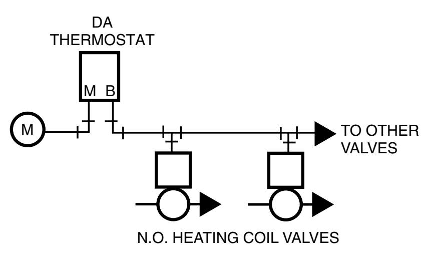


Fig. 57. Thermostat and One or More Normally Open Valves.

A normally open or a normally closed valve may be combined with a direct-acting or a reverse-acting thermostat, depending on the requirements and the conditions in the controlled space. Applications that require several valves controlled in unison (e.g., multiple hot water radiation units in a large open area) have two constraints:

— All valves that perform the same function must be of the same normal position (all normally open or all normally closed).

— The controller must be located where the condition it measures is uniformly affected by changes in position of the multiple valves. If not, the application requires more than one controller.

A direct- or reverse-acting signal to a three-way mixing or diverting valve must be selected carefully. Figure 58 shows that the piping configuration determines the signal required.

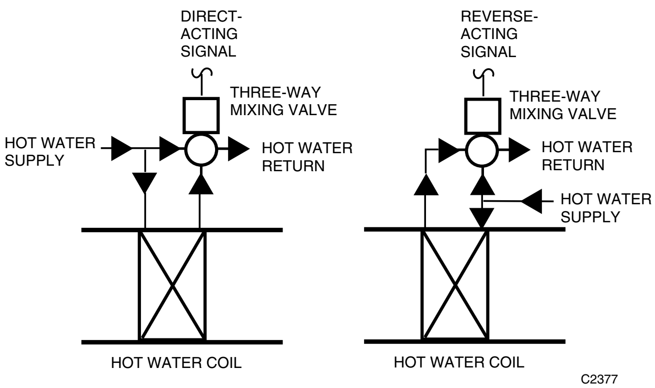


Fig. 58. Three-Way Mixing Valve Piping with Direct Actuators.

SEQUENCE CONTROL

In pneumatic control systems, one controller can operate several dampers or valves or several groups of dampers or valves. For example, year-round air conditioning systems sometimes require heating in the morning and evening and cooling in the afternoon. Figure 59 shows a system in which a single controller controls a normally open heating valve and normally closed cooling valve. The cooling valve is set for an 8 to 13 psi range and the heating valve, for a 2 to 7 psi range. The controller operates the two valves in sequence to hold the temperature at the desired level continually.

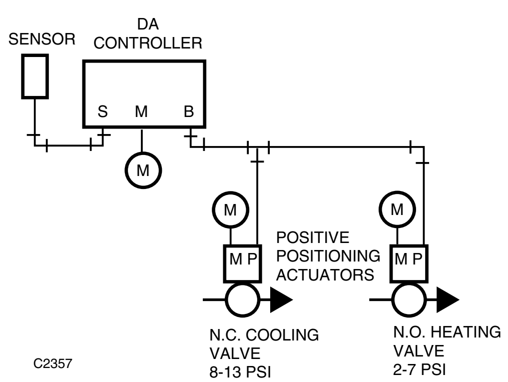


Fig. 59. Pneumatic Sequencing of Two Valves with Positive Positioning Actuators.

When the temperature is so low that the controller calls for full heat, the branchline pressure is less than 3 psi. The normally open heating valve is open and the normally closed cooling valve is closed. As the temperature rises, the branchline pressure increases and the heating valve starts to close. At 7 psi branchline pressure, the heating valve is fully closed. If the temperature continues to rise, the branchline pressure increases until the cooling valve starts to open at 8 psi. The temperature must rise enough to increase the branchline pressure to 13 psi before the cooling valve will be full open. On a drop in temperature, the sequence is reversed.

Valves with positive positioners ensure tight close-off of the heating valve at 7 psi branchline pressure, and delay opening of the cooling valve until 8 psi branchline pressure is reached. Positive positioners prevent overlapping caused by a variation in medium pressure, a binding valve or damper, or a variation in spring tension when using spring ranges for sequencing.

A greater deadband can be set on the positioners to provide a larger span when no energy is consumed. For example, if the positioners are set for 2 to 7 psi on heating and 13 to 18 psi on cooling, no energy is used when the controller branchline pressure is between 7 and 13 psi. The positioners can also be set to overlap (e.g., 4 to 9 and 7 to 12 psi) if required.

Valve and damper actuators without positioners have various spring ranges. To perform the sequencing application in Figure 59 without positioners, select a heating valve actuator that has a 2 to 7 psi spring range and a cooling valve actuator that has an 8 to 13 psi spring range. Although this method lessens precise positioning, it is usually acceptable in systems with lower pressure differentials across the valve or damper and on smaller valves and dampers .

LIMIT CONTROL

Figure 60 shows a sensor-controller combination for space temperature control with discharge low limit. The discharge low limit controller on a heating system prevents the discharge air temperature from dropping below a desired minimum.

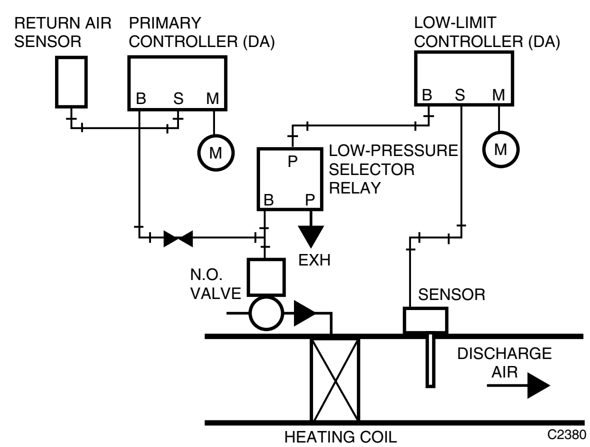


Fig. 60. Low-Limit Control (Heating Application).

Low-limit control applications typically use a direct-acting primary controller and a normally open control valve. The direct-acting, low-limit controller can lower the branchline pressure regardless of the demands of the room controller, thus opening the valve to prevent the discharge air temperature from dropping below the limit controller setpoint. Whenever the low-limit discharge air sensor takes control, however, the return air sensor will not control. When the low-limit discharge air sensor takes control, the space temperature increases and the return air sensor will be unable to control it.

A similar combination can be used for a high-limit heating control system without the selector relay in Figure 61. The limit controller output is piped into the exhaust port of the primary controller, which allows the limit controller to limit the bleed-down of the primary controller branch line.

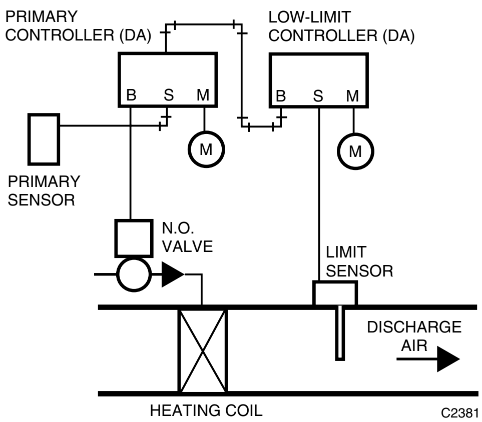


Fig. 61. High-Limit Control (Heating Application).

Bleed-type, low-limit controllers can be used with pilot-bleed thermostats (Fig. 62). A restrictor installed between the thermostat and the low-limit controller, allows the low limit controller to bleed the branch line and open the valve. The restrictor allows the limit controller to bleed air from the valve actuator faster than the thermostat can supply it, thus overriding the thermostat.

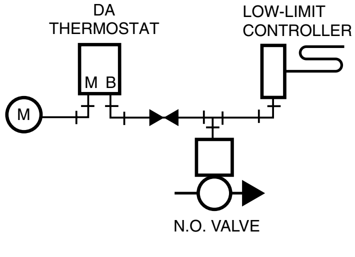


Fig. 62. Bleed-Type, Low-Limit Control System.

MANUAL SWITCH CONTROL

Common applications for a diverting switch include on/off/automatic control for a heating or a cooling valve, open/closed control for a damper, and changeover control for a two-pressure air supply system. Typical applications for a proportional switch include manual positioning, remote control point adjustment, and minimum damper positioning.

Figure 63 shows an application for the two-position manual switch. In Position 1, the switch places the thermostat in control of Valve 1 and opens Valve 2 by bleeding Valve 2 to zero through Port 1. When turned to Position 2, the switch places the thermostat in control of Valve 2 and Valve 1 opens.

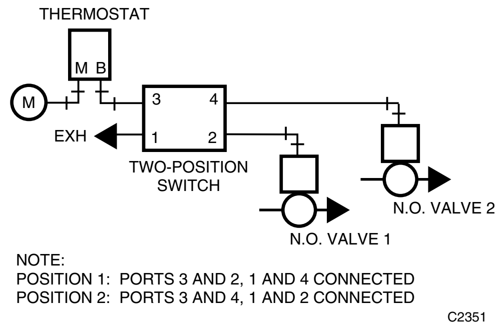


Fig. 63. Application for Two-Position Manual Switch.

Figure 64 shows an application of the three-position switch and a proportioning manual positioning switch.

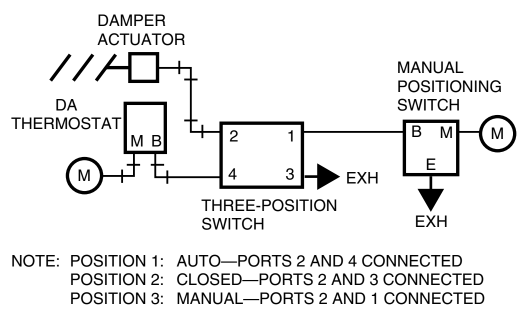


Fig. 64. Application for Three-Position Switch and Manual Positioning Switch.

In Position 1, the three-position switch places the thermostat in control of the damper. Position 2 closes the damper by bleeding air pressure to zero through Port 3. Position 3 allows the manual positioning switch to control the damper.

CHANGEOVER CONTROL FOR TWO-PRESSURE SUPPLY SYSTEM

Figure 65 shows a manual switch used for changeover from 13 to 18 psi in the mains. Either heating/cooling or day/night control systems can use this arrangement. In Position 1, the switch supplies main pressure to the pilot chamber in the PRV. The PRV then provides 18 psi (night or heating) main air pressure to the control system.

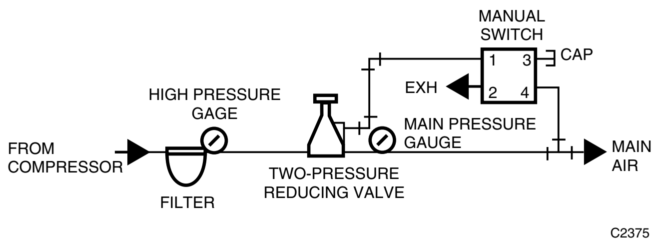


Fig. 65. Two-Pressure Main Supply System with Manual Changeover.

In Position 2, the manual switch exhausts the pilot chamber in the PRV. The PRV then provides 13 psi (day or cooling) to the system.

Figure 66 shows a two-pressure system with automatic changeover commonly used in day/night control. A switch in a seven-day time clock and an E/P relay provide the changeover. When the E/P relay energizes (day cycle), the pilot chamber in the PRV exhausts and controls at 13 psi. When the electric-pneumatic relay de-energizes, the pilot chamber receives full main pressure and the PRV provides 18 psi air.

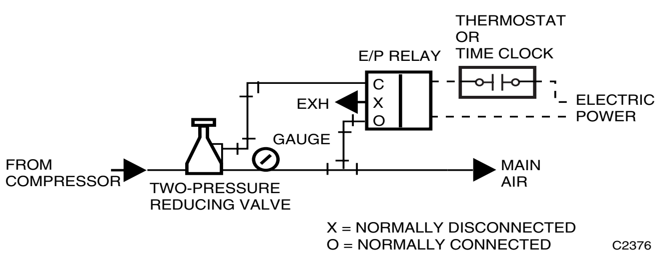


Fig. 66. Two-Pressure Main Supply System with Automatic Changeover.

COMPENSATED CONTROL SYSTEM

In a typical compensated control system (Fig. 67), a dual-input controller increases or decreases the temperature of the supply water as the outdoor temperature varies. In this application, the dual-input controller resets the water temperature setpoint as a function of the outdoor temperature according to a preset schedule. The system then provides the scheduled water temperature to the convectors, fan-coil units, or other heat exchangers in the system.

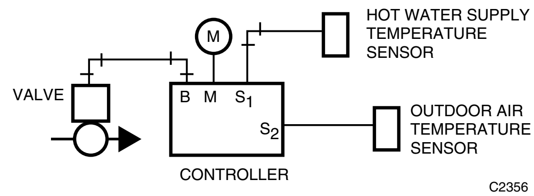


Fig. 67. Compensated Supply Water System Using Dual-Input Controller.

ELECTRIC-PNEUMATIC RELAY CONTROL

Figure 68 shows one use of an E/P relay in a pneumatic control circuit. The E/P relay connects to a fan circuit and energizes when the fan is running and de-energizes when the fan turns off, allowing the outdoor air damper to close automatically when the fan turns off. The relay closes off the controller branch line, exhausts the branch line going to the damper actuator, and allows the damper to go to its normal (closed) position. Figure 69 shows an E/P relay application that shuts down an entire control system.

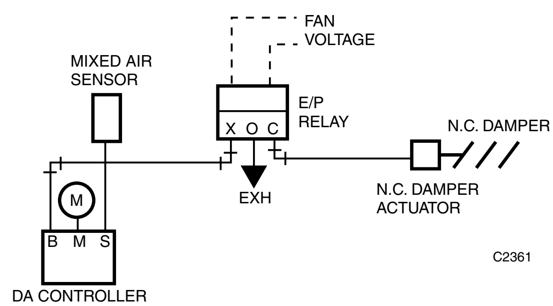


Fig. 68. Simple E/P Relay Combination.

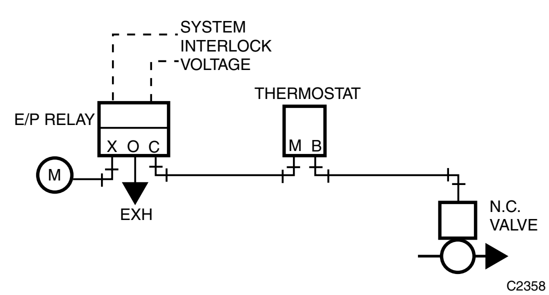


Fig. 69. E/P Relay Combination for System Shutdown.

PNEUMATIC-ELECTRIC RELAY CONTROL

A P/E relay provides the interlock when a pneumatic controller actuates electric equipment. The relays can be set for any desired pressure. Figure 70 shows two P/E relays sequenced to start two fans, one at a time, as the fans are needed.

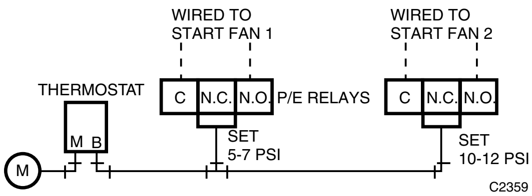


Fig. 70. P/E Relays Controlling Fans in Sequence.

On a rise in temperature, Relay 1 puts Fan 1 in operation as the thermostat branchline pressure reaches 7 psi. Relay 2 starts Fan 2 when the controller branchline pressure reaches 12 psi. On a decrease in branchline pressure, Relay 2 stops Fan 2 at 10 psi branchline pressure, and Relay 1 stops Fan 1 at 5 psi branchline pressure.

Figure 71 shows two spdt P/E relays starting and stopping a two-speed fan to control condenser water temperature.

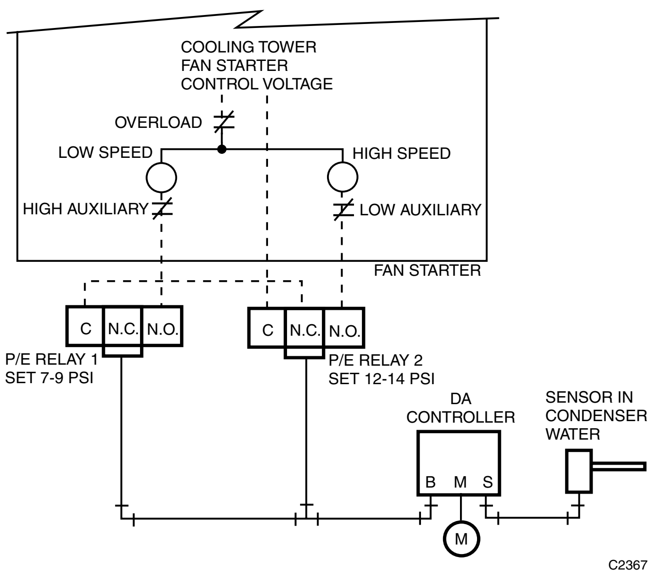


Fig. 71. Two-Speed Fan Operated by P/E Relays.

Voltage is applied to the common contact of Relay 1 from the normally closed contact of Relay 2. When the controller branchline pressure rises to 9 psi, the cooling tower fan is started on low speed by Relay 1 which makes common to normally open. As a further rise in temperature increases the branchline pressure to 14 psi, Relay 2 breaks the normally closed circuit and makes the normally open circuit, removing voltage from Relay 1, shutting down the low speed, and energizing the high speed. On a decrease in temperature, the sequence reverses and the changes occur at 12 and 7 psi respectively.

PNEUMATIC RECYCLING CONTROL

E/P and P/E relays can combine to perform a variety of logic functions. On a circuit with multiple electrically operated devices, recycling control can start the devices in sequence to prevent the circuit from being overloaded. If power fails, recycling the system from its starting point prevents the circuit overload that could occur if all electric equipment restarts simultaneously when power resumes.

Figure 72 shows a pneumatic-electric system that recycles equipment when power fails.

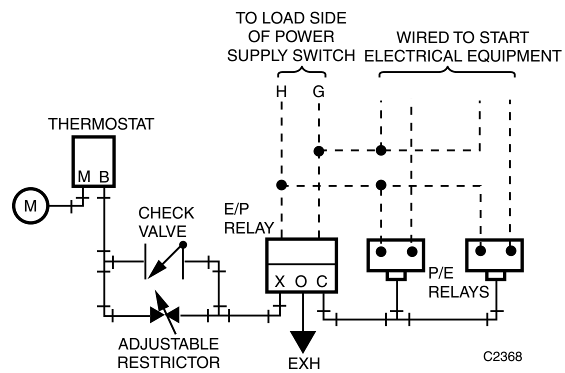


Fig. 72. Recycling System for Power Failure.

When power is applied, the E/P relay operates to close the exhaust and connect the thermostat through an adjustable restrictor to the P/E relays. The electrical equipment starts in sequence determined by the P/E relay settings, the adjustable restrictor, and the branchline pressure from the thermostat. The adjustable restrictor provides a gradual buildup of branchline pressure to the P/E relays for an adjustable delay between startups. On power failure, the E/P relay cuts off the thermostat branch line to the two P/E relays and bleeds them off through its exhaust port, shutting down the electrical equipment. The check valve allows the thermostat to shed the controlled loads as rapidly as needed (without the delay imposed by the restrictor).

PNEUMATIC CENTRALIZATION

Building environmental systems may be pneumatically automated to any degree desired. Figure 73 provides an example of the front of a pneumatic automation panel. This panel contains pneumatic controls and may be local to the controlled HVAC system, or it may be located centrally in a more convenient location.

In this example, the on-off toggle switch starts and stops the fan. The toggle switch may be electric, or pneumatic with a Pneumatic-Electric (P/E) relay.

Two pneumatic "target" gauges are shown for the outside air damper and the supply fan. The ON/OFF Supply Fan Gauge is fed from a fan proof-of-flow relay, and the OPEN/CLOSED Damper Gauge is fed from the damper control line.

The Discharge Air Temperature Indicator is fed from the pneumatic discharge air temperature sensor and the Three-Way Valve Gauge is fed from the valve control line.

When pneumatic automation panels are located local to the HVAC system, they are usually connected with 1/4 inch plastic tubing. When there are many lines at extended lengths, smaller diameter plastic tubing may be preferable to save space and maintain responsiveness. When the panel devices are remote, the air supply should be sourced remotely to avoid pressure losses due to long flow lines. The switching air may be from the automation panel or it may be fed via a remote restrictor and piped in an exhaust configuration.

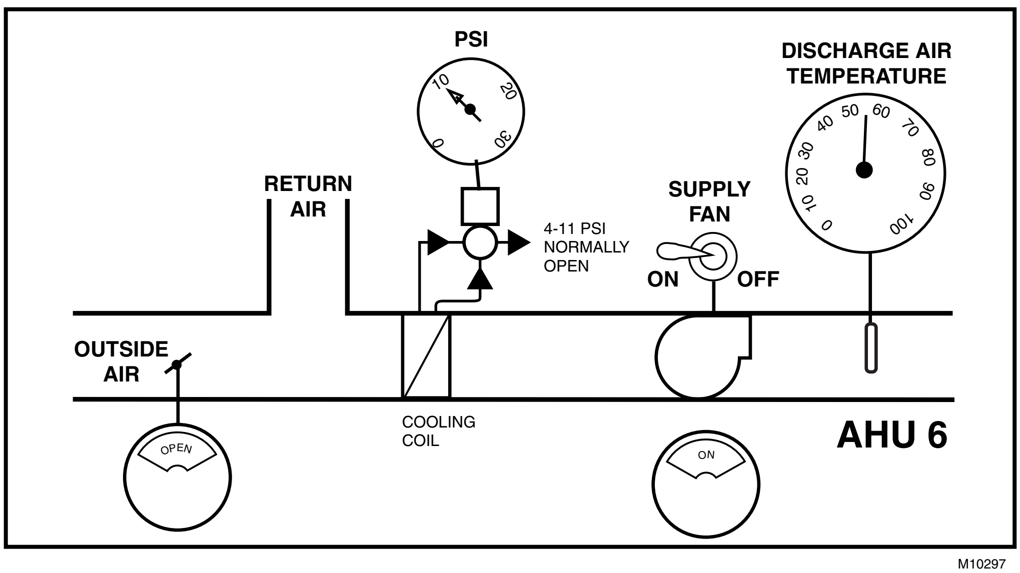


Fig. 73. Pneumatic Centralization

PNEUMATIC CONTROL SYSTEM EXAMPLE

The following is an example of a typical air handling system (Fig. 74) with a pneumatic control system. The control system is presented in the following seven control sequences (Fig. 75 through 79):
— Start-Stop Control Sequence.
— Supply Fan Control Sequence.
— Return Fan Control Sequence.
— Warm-Up/Heating Coil Control Sequence.
— Mixing Damper Control Sequence.
— Discharge Air Temperature Control Sequence.
— Off/Failure Mode Control Sequence.

Controls are based upon the following system information and control requirements:

System Information:
— VAV air handling system.
— Return fan.
— 35,000 cfm.
— 4,000 cfm outside air.
— 3,000 cfm exhaust air.
— Variable speed drives.
— Hot water coil for morning warm-up and to prevent discharge air from getting too cold in winter .
— Chilled water coil.
— Fan powered perimeter VAV boxes with hot water reheat.
— Interior VAV boxes.
— Water-side economizer.
— 8:00 A.M to 5:00 P.M. normal occupancy.
— Some after-hour operation.

Control Requirements:
— Maintain design outside air airflow during all levels of supply fan loading during occupied periods.
— Use normally open two-way valves so system can heat or cool upon compressed air failure by manually running pumps and adjusting water temperatures.
— Provide exhaust/ventilation during after-hour occupied periods.
— Return fan sized for 35,000 cfm.

START-STOP CONTROL SEQUENCE

Fans 1M through 3M (Fig. 75) operate automatically subject to starter-mounted Hand-Off-Automatic Switches.

The Supply Fan 1M is started and controls are energized by Electric-Pneumatic Relay 2EP at 0645 by one of the following:
— An Early Start Time Clock 1TC
— A drop in perimeter space temperature to 65F at Night Thermostat TN
— An after-hour occupant setting the Spring-Wound Interval Timer for 0 to 60 minutes.

The Supply Fan 1M operation is subject to manually reset safety devices including Supply and Return Air Smoke Detectors; a heating coil, leaving air, Low Temperature Thermostat; and a supply fan discharge, duct High Static Pressure Cut-Out.

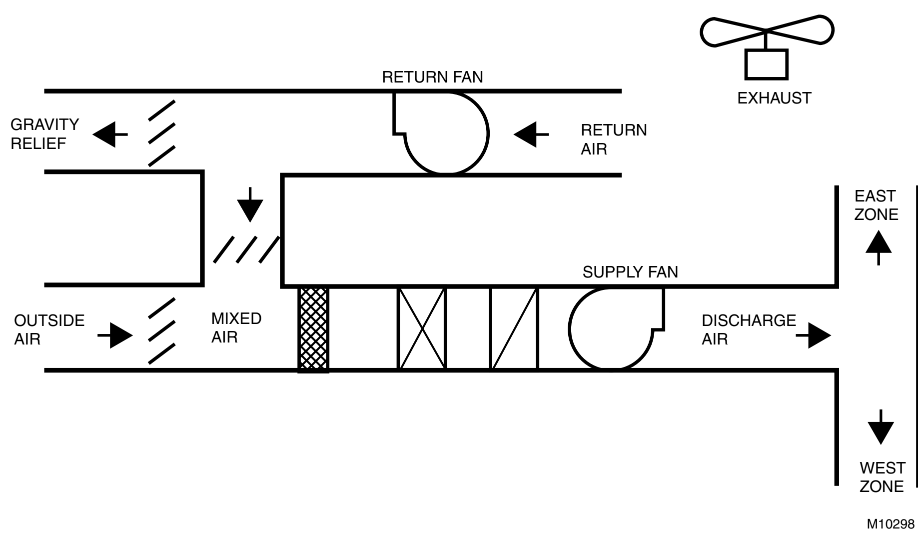


Fig. 74. Typical Air Handling System.

Any time the Supply Fan 1M runs, the Return Fan 2M runs.

Any time the Return Fan 2M runs, the Exhaust Fan 3M and the ventilation controls are energized by the After-Hours Interval Timer or by the Occupancy Schedule Time Clock 2TC set for 0750.

Both Clocks 1TC and 2TC are set to shut the system down at 1700.

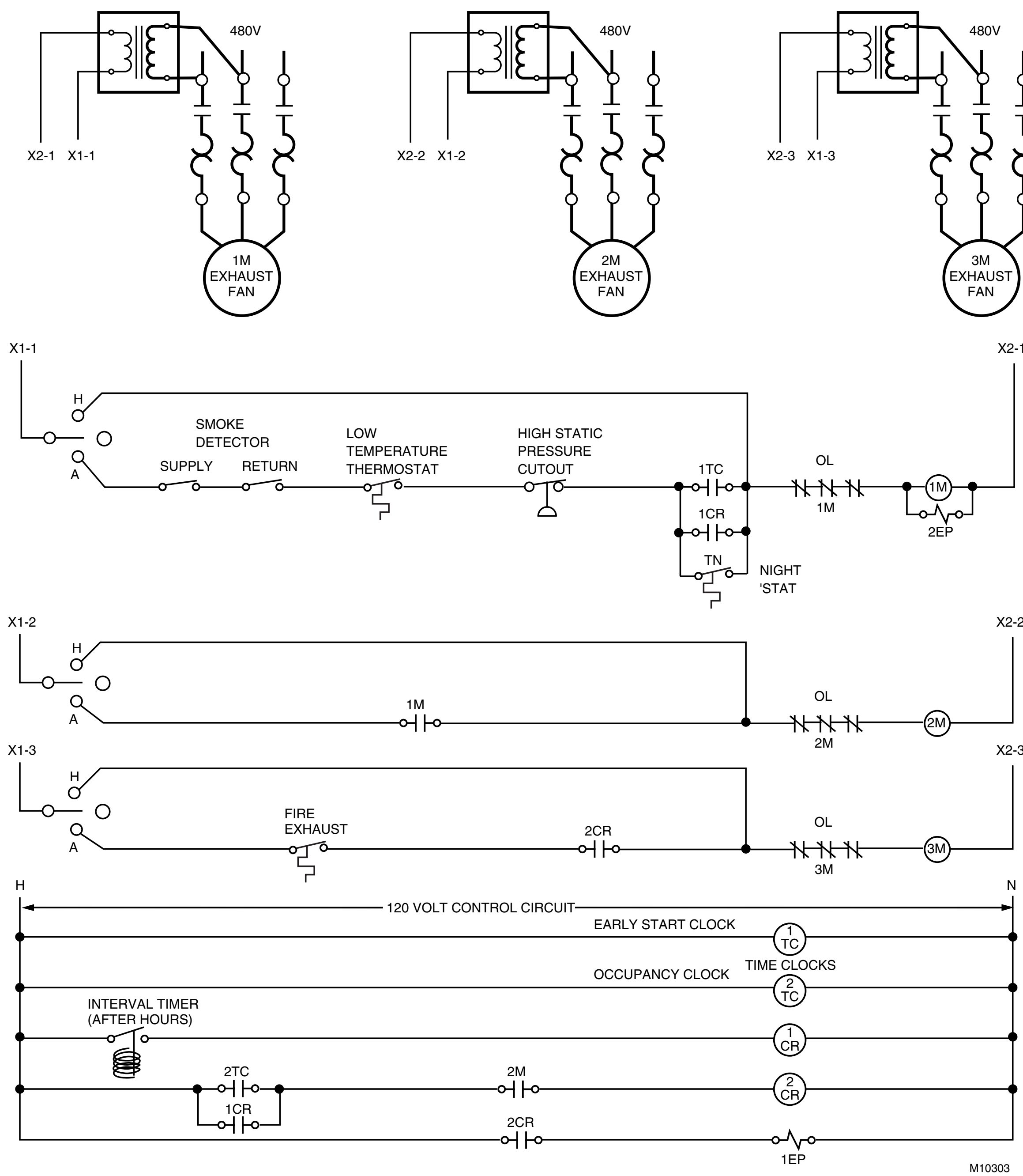


Fig. 75. Start-Stop Control.

SUPPLY FAN CONTROL SEQUENCE

Any time the Supply Fan (Fig. 76) runs, the pressure controller with the greatest demand, Static Pressure Controller PC_1 or PC_2, operates the Electronic-Pressure Transducer PT. The controller used is determined by High Pressure Selector Relay HSR. Transducer PT controls the Supply Fan Variable Speed Drive (VSD) to maintain duct static pressure. The pick-up probes for Static Pressure Controllers PC_1 and PC_2 are located at the end of the east and west zone ducts.

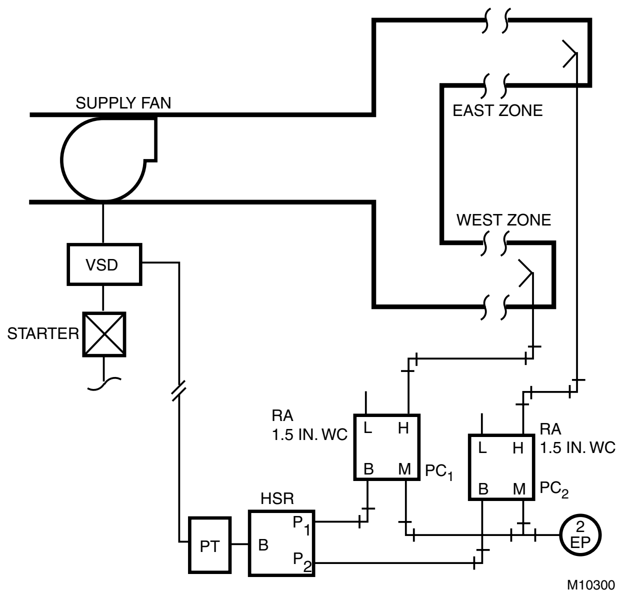


Fig. 76. Supply Fan Load Control.

RETURN FAN CONTROL SEQUENCE

Static Pressure Controller PC (Fig. 77) controls the return fan variable speed drive to maintain space static pressure. The pick-up probe is located in the space

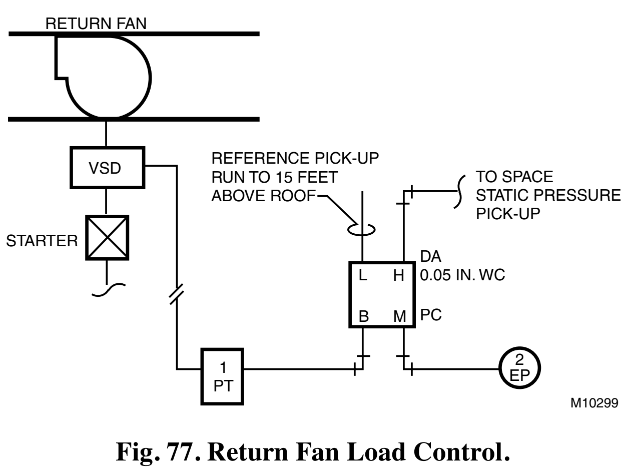


Fig. 77. Return Fan Load Control.

NOTE:
1. Because of varying exhaust between occupied and warm-up modes, space static pressure control of the return fan is selected. Return fan tracking from supply fan airflow is acceptable but is complex if varying exhaust is worked into the control scheme.
2. Exercise care in selecting location of the inside pick-up and in selection of the pressure controller. Location of the reference pick-up above the roof is recommended by ASHRAE.
3. To prevent unnecessary hunting by the return fan at start-up, the supply fan control signal should be slow loading such that the supply fan goes from zero or a minimum to maximum load over three minutes. Shut down should not be restricted.

WARM-UP/HEATING COIL CONTROL SEQUENCE

Any time the Supply Fan (Fig. 78) runs and the return air temperature is below 69F, Temperature Controller TC-1 trips Snap-Acting Relay SA-1 to position Switching Relays SR-1 and SR-2 to initialize warm-up control. Relay SA-1 also positions Switching Relay SR-4 to disable cooling controls. Switching Relay SR-2 opens all interior VAV box dampers and starts the hot water pump. Relay SR-1 switches the hot water valve from normal control to warm-up control via Controller TC-2 and modulates the hot water valve to maintain a discharge air temperature setpoint of 90F.

NOTE: Fan powered perimeter VAV boxes are cool in this mode and operate with the fans on and at the minimum airflow (warm air) setpoints. Reheat valves at each box operate as needed. This allows the warm-up cycle to operate the air handling unit (AHU) fans at a reduced and low cost power range.

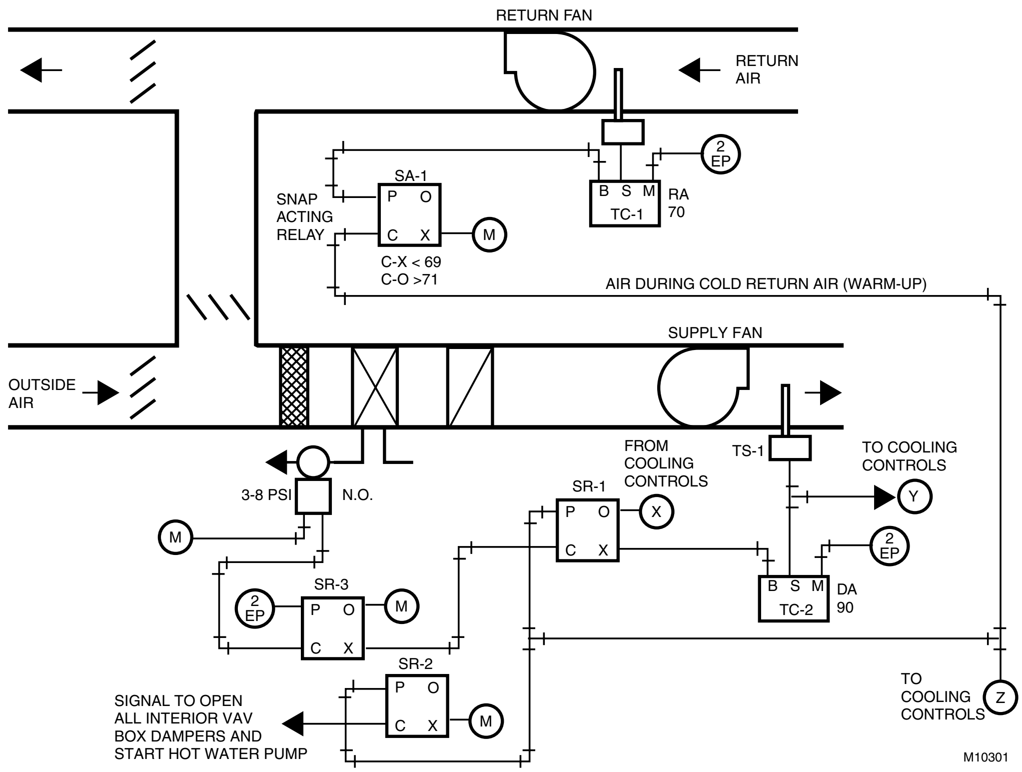


Fig. 78. Heating Coil Control.

MIXING DAMPER CONTROL SEQUENCE

Any time the AHU (Fig. 79) runs in the occupied mode with Electric-Pneumatic Relay 1EP energized, Outside Air airflow Controller P-F modulates the outside air damper toward open and the return air damper toward closed (or vice versa) in unison to maintain design outside air at 4000 cfm.

NOTE: These dampers can control in sequence also, but unison control positions the damper blades better for mixing which is helpful during freezing periods. If the outside air is provided from an outside air shaft with an outside air fan, an outside air filter is helpful to keep the flow sensing element/pick-up clean and effective. Electric-Pneumatic Relay 1EP starts the outside air system.

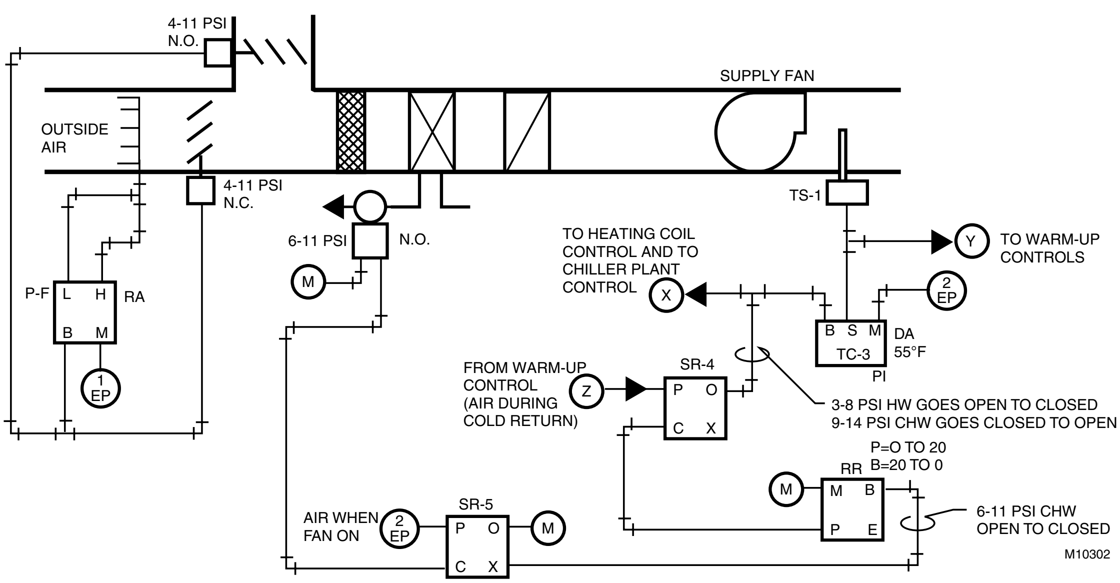


Fig. 79. Mixing Damper and Discharge Air Temperature Control.

DISCHARGE AIR TEMPERATURE CONTROL SEQUENCE

Any time the AHU (Fig. 79) operates in the non-warm-up mode, Switching Relay SR-4 operates to allow the normal Discharge Air Temperature Controller TC-3 to modulate the hot water valve closed (through Switching Relay SR-1, Fig. 77) and the chilled water valve open in sequence, on a rising cooling load, to maintain the Temperature Controller TC-3 setpoint. Controller TC-3 is a PI (proportional plus integral) controller.

NOTE: In this constant 4000 cfm outside air system, if the return air is 72F and the outside air is -5F, the mixed air temperature will drop below 55F if the AHU airflow drops below 52 percent of the design airflow.

OFF/FAILURE MODE CONTROL SEQUENCE

If compressed air fails, both control valves open, the outside air damper closes, and the return air damper opens.

When the fan is off, Switching Relay SR-3 (Fig. 78) positions to close the hot water valve, Switching Relay SR-5 (Fig. 79) positions to close the chilled water valve, the outside air damper closes, and the return air damper opens.