

suitable air-pressure changes by means of an electronic-pneumatic transducer.

TYPES OF CONTROL ACTION

Control action may be divided into five types:

1. **Two-position action**, Fig. 2, is the type in which the controlled device can be positioned only to a maximum or minimum position, or can be either on or off. A thermostat which opens and closes a valve, or starts and stops a burner, is an example.

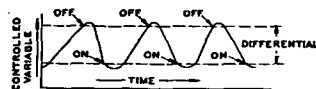


Fig. 2.... Two-Position Control

2. **Timed two-position action** is a common variation of two-position control action in which the time of on periods are prematurely shortened. This type of action usually is employed only in room thermostats, and is accomplished by a heater element in the thermostat which is energized during the on periods. The percentage of time on is varied in proportion to the system load.

Controller differential applying to two-position control action, is the difference between the setting at which the controller operates to one position and the setting at which it operates to the other position. As an example, if a pressure controller starts a pump at 12 psig and stops it at 15 psig, the differential is 3 psi. It is sometimes desirable to have a controller in which the differential can be changed by manual adjustment. This is designated as an adjustable differential.



Fig. 3.... Floating Control Showing Variations in Controlled Variable as Load Changes

3. **Floating action**, Fig. 3, is the type, as with two-position action, where the controller can perform only two operations: moving the controlled device usually at a constant rate either towards its open or its closed position. Generally there is a neutral zone between the two positions which allows the controlled device to stop at any position whenever the controlled variable is within the differential of the controller. When the controlled variable gets outside the differential of the controller, the controller moves the controlled device in the proper direction. An example of floating control is a firebox draft controller positioning a damper in the breeching of a boiler.



Fig. 4.... Proportional Control Showing Variations in Controlled Variable as Load Changes

4. **Proportional action**, Fig. 4, is the type where the controlled device is positioned proportionately in response to slight changes in the controlled variable. It does not run through its complete stroke, as is the case with two-position control, nor does it continue to move until the change in the controlled variable resulting from that movement is felt by

the controller, as is the case with floating control, but it immediately assumes a position in proportion to the system requirement.

An example of proportional control is a thermostat in a fan discharge duct actuating an automatic valve in the steam supply to a coil to regulate the air temperature leaving the coil. This control would be similar to that shown in Fig. 1.

Throttling range is the total amount of change in the controlled variable required for the controller to move the controlled device through its complete stroke, from one extreme to the other. It is often adjustable to meet job requirements.

Set point is the value at which the controller is set and represents the desired value of the controlled variable.

Control point is the actual value of the controlled variable at which the instrument is controlling. It will vary within the throttling range of the controller according to the demand on the system and other variables.

Offset is the difference between the set point and the actual control point under stable conditions. This is sometimes also called *drift*, *deviation*, or *droop*.

5. **Proportional plus automatic reset action**, Fig. 5, combines floating action with proportional action to achieve both the stability of proportional control, with a relatively wide throttling range, and the invariable control point of floating control. The system functions the same as proportional action, the automatic reset serving to shift the control point back to the set point whenever any offset occurs.

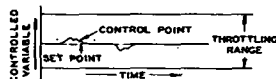


Fig. 5.... Proportional Plus Automatic Reset Control Showing How Control Point is Returned to Set Point after a Load Change

Reset rate is the number of times per minute the proportional action is duplicated by the reset action, and usually is expressed as repeats per minute. The reset rate in most controllers is adjustable and must be carefully matched to the system characteristics to avoid unstable operation. Because automatic reset is necessarily slow-acting, it should be used only when load changes are of reasonably long duration and when the maximum offset resulting from proportional control alone is outside of acceptable limits.

Figs. 4 and 5 show the results of rather abrupt demand changes, which usually result in two or three cycles before stability is restored. More gradual demand changes will result in a smoother curve.

AUTOMATIC CONTROL SYSTEM COMPONENTS

In addition to controllers and controlled devices, many control systems include auxiliary apparatus such as switches and relays of various kinds, clocks or timers, thermometers, gages, pilot lights, and other indicators for observing the operation of the system. Only those more commonly used will be described here.

Controllers

Automatic controllers have both a measuring element and a controlling element.

The **measuring element** measures changes in the controlled variable and produces a proportional effect on the controlling element. This effect usually is a change in position, force, or electrical resistance.

The **controlling element** converts the effect produced by the measuring element into an effect suitable for opera-

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tion of the controlled device. (In self-contained controllers the measuring element produces a force which is directly applied to the controlled device. In pneumatic or electronic controllers the controlling element regulates the application of energy such as compressed air or electricity.)

Types of Measuring Elements

Temperature measuring elements usually consist of (1) a bimetal strip, (2) a rod and tube of dissimilar metals, (3) a sealed bellows, with or without a remote bulb, or (4) an electrical resistance.

1. A **bimetal element** is composed of two thin strips of dissimilar metals fused together. Because the two metals have different coefficients of thermal expansion, the element bends as the temperature varies and produces a change in position. Depending on the space available and the movement required, it may be in the form of a straight strip, U-shaped, or wound into a spiral. This element finds its most common application in room thermostats, but is also used in insertion and immersion thermostats.

2. A **rod-and-tube element** consists of a high-expansion metal tube inside of which is a low-expansion rod with one end attached to the rear of the tube. The tube changes length with changes in temperature, causing the free end of the rod to move. The rod-and-tube element is commonly employed on certain types of insertion and immersion thermostats.

3. A **sealed-bellows element** is either vapor-filled, gas-filled, or liquid-filled, after being evacuated of air. Changes of temperature cause changes in pressure or volume of the gas or liquid, resulting in a change in force or a movement. This element is often employed in room thermostats.

4. A **remote-bulb element** is a sealed bellows or diaphragm to which a bulb or capsule is attached by means of a capillary tube, the entire system being filled with vapor, gas, or liquid. Changes of temperature at the bulb result in changes of pressure or volume which are communicated to the bellows or diaphragm through the capillary tube. The remote-bulb element is useful where the temperature measuring point is remote from the desired thermostat location. It usually is provided with fittings suitable for insertion into a duct or into a pipe or tank.

5. A **resistance element** is made of wire whose electrical resistance changes with temperature changes. It is used with electronic controllers. It is available in forms suitable for measuring room temperature or for insertion into a duct or into a pipe or tank.

Humidity measuring elements are made of (1) hygroscopic organic materials or (2) an electrical resistance.

1. An **organic element** usually is made of human hair, wood, paper, or animal membrane. Changes in relative humidity cause the element to expand and contract.

2. A **resistance element**, for use with electronic controllers, frequently consists of a thin coating of hygroscopic salt on an insulating form. The resistance of the salt varies with the relative humidity.

Pressure measuring elements can be divided into one of two general classes depending upon pressure range.

1. For pressures or vacuums measured in pounds per square inch or inches of mercury, the element usually is a bellows, diaphragm, or Bourdon tube. One side of the element may be open to atmosphere in which case the element responds to pressures above or below atmospheric. A differential-pressure element has connections to both sides so that it will respond to the difference between two pressures.

2. For low ranges of pressure or vacuum which are usually measured in inches of water, such as the static pressure in an air duct, the measuring element may be an inverted bell immersed in oil, a large slack diaphragm, or a large flexible metal bellows. The element usually is of the differential type, and when employed in conjunction with orifices, Pitot tubes, and similar accessories, may be used to measure flow, velocity, or liquid level as well as static pressure.

Measuring elements for other purposes, such as flame detection or for measuring smoke density, specific gravity, CO₂, CO, etc., often are necessary for the complete control of a heating, ventilating, or air-conditioning system.

Types of Controlling Elements

Controlling elements differ because some regulate the application of pneumatic energy while others regulate the application of electrical energy. They also differ according to the type of control action produced.

An **electric controlling element** is used in several of the common types of control action.

For **two-position control** it may simply make and break an electrical contact, to start a burner, motor, etc., or to actuate a spring-return valve or damper operator. Another type makes one contact while breaking another and is used to control unidirectional valve or damper operators. Either type may be used for timed two-position action by the addition of a small resistance heater.

For **floating control** two contacts are employed, but there is a neutral zone between the two contacts where neither is made. This type is commonly used with reversible valve or damper operators.

For **proportional control** a contact is moved across a potentiometer to vary the voltage applied to a relay. The relay controls the operation of a reversible valve or damper operator and is rebalanced as the controlled device is positioned. In another arrangement the controlling element has two contacts and a neutral zone as described for floating control and is rebalanced by a small solenoid which is energized by a variable voltage feedback from the reversible valve or damper operator which it positions.

An **electronic controlling element** consists of an electronic amplifier and an electric relay or relays. The amplifier receives the minute electrical signals from the measuring element and amplifies them sufficiently to actuate the relays. The electronic controlling element may be two-position, floating, or proportional, depending upon the amplifier and relay arrangement.

An **electronic-pneumatic controlling element** consists of an electronic amplifier and an electropneumatic relay. It may be two-position, or proportional, depending upon the amplifier and relay arrangement.

A **pneumatic controlling element** is most often of the proportional action type but may also be used for the other types of control action. It may be classified as nonrelay type and relay type.

A **nonrelay type** of pneumatic controlling element is the simplest form and employs a restricted air supply and a nozzle or control port. The measuring element varies the opening of the nozzle and the resulting variable pressure is applied to the controlled device. This type is limited to applications requiring small volumes of air.

In a **relay-type** pneumatic controlling element the relay contains both a supply and an exhaust valve usually arranged so that the exhaust valve must close before the supply valve opens. Both valves are closed except when the control pressure is required to change. The variable force for operating the valves may be supplied directly by the measuring element or it may be supplied by a diaphragm actuated by air pressure from a very small nozzle and restrictor arrangement, this air pressure being varied by the measuring element. In either case the control pressure, operating on a diaphragm within the relay, produces a force which balances the force produced by the measuring element.

Pneumatic controllers may be either direct or reverse acting.

A **direct-acting controller** increases the control air pressure as the controlled variable increases. For example, a direct-acting thermostat increases the air pressure as the temperature increases.

A **reverse-acting controller** decreases the control air pressure as the controlled variable increases. A reverse-acting