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.

Controller differential, applying to two-position control action, is the difference between a setting at which the controller operates to one position, and a setting at which it operates to the other position. The differential usually referred to in a thermostat rating is that differential in degrees which will become apparent by raising and lowering the dial setting. This differential is usually referred to as the *manual differential* of the thermostat. When the same thermostat is applied to an operating system, the total change in temperature that occurs between a call for more heat and a call for less heat is usually greater than the manual differential due to thermostat lag. The differential encountered on the job under control is referred to as *operating differential*. For example, a thermostat having a 2 deg differential when raising and lowering the dial setting may actually produce temperature variations of 3 deg between system *on* and system *off*.

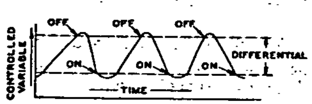

Fig. 2 .... Two-Position Control

2. *Timed two-position action* is a common variation of straight two-position action often employed in room thermostats to reduce operating differential. In heating thermostats, a heater element is energized during the *on* periods, prematurely shortening the *on* time as the heater falsely warms the thermostat (heat anticipation). The same anticipating action can be obtained in cooling thermostats by energizing a heater during thermostat *off* periods. In either case, the percentage of *on* time is varied in proportion to the system load, while the total cycle time remains relatively constant.

3. *Floating action*, Fig. 3, is the type, as is two-position action, in which the controller can perform only two operations, moving the controlled device, usually at a constant rate, either toward its open or 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 static pressure controller positioning a damper or inlet vanes to maintain static pressure in the discharge duct.

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

4. *Proportional action*, Fig. 4, is the type in which 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. Instead, 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.

Throtting 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*.

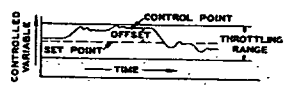

Fig. 4 .... Proportional Control Showing Variations in Controlled Variable as Load Changes

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.

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.

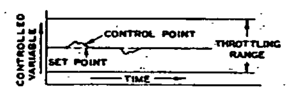

Fig. 5 .... Proportional Plus Automatic Reset Control Showing How Control Point is Returned to Set Point after a Load Change

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 sensing element and a transducer.

The *sensing element* measures changes in the controlled variable and produces a proportional effect on the transducer.

This effect may be a change in force, position, or electrical resistance, depending on the type of sensing element used.

The *transducer* converts the effect produced by the sensing element into an effect suitable for operation of the controlled device. In pneumatic systems, a mechanical transducer regulates the pressure of a compressed air energy source applied to the controlled device; in electric or electronic systems, the transducer regulates the flow of electrical energy.

Types of Sensing Elements

Temperature sensing 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.

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.

4. A *resistance element* is made of wire with electrical resistance that changes with temperature changes. A *thermistor* is a special kind of semi-conductor in which electrical resistance changes with temperature changes. A *thermocouple* is a union of two dissimilar metals joined at the ends, having generated voltage that varies as a function of temperature changes. These various elements are available in forms suitable for measuring room temperature or for insertion into a duct, pipe, or tank.

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

1. An *organic element* is usually made of human hair, wood, paper, or animal membrane. Changes in relative humidity cause the element to expand or 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 sensing elements can be divided into two general classes, depending upon pressure range.

1. For pressures or vacuums measured in pounds per square inch or inches of mercury, the element is usually a bellows, diaphragm, or Bourdon tube. One side of the element may be open to the 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 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.

Sensing elements for other purposes, such as flame detection, or for measuring smoke density, specific gravity, current, CO_2, CO, etc., are often necessary for the complete control of a heating, ventilating, or air-conditioning system.

Types of Transducers

Transducers differ widely; 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. Five types are in common use:

1. *Electric transducers* are normally combined with sensing elements having a force or position type output to obtain various control modes.

a. For *two-position control*, the transducer may be a simple electrical contact which starts a burner, pump, etc., or which actuates a spring-return valve or damper operator. SPDT switching circuits are used to control a 3-wire unidirectional motor operator. SPDT circuits also are used for heating-cooling applications. Either SPST or SPDT circuits may be modified to obtain timed *two-position* action.

b. For *floating control*, the transducer output is a SPDT switching circuit with a neutral zone where neither contact is made. This type of control is normally used with reversible motor operators.

c. For *proportional control*, two types of transducer systems are in common use.

(1.) The sensing element moves a wiper arm across a potentiometer to vary the voltage applied to a balancing relay. The relay controls the operation of a reversible motor operator, and is rebalanced by a variable voltage feedback signal from a second potentiometer in the motor operator.

(2.) The sensing element positions a floating type switching circuit with a neutral zone, which controls the operation of a reversible motor operator. The control is rebalanced by a small solenoid, energized by a variable voltage feedback signal from a potentiometer in the motor operator.

2. An *electronic transducer* uses an electronic amplifier to detect the small voltage changes generated by the sensing elements. Two types of systems with different transducer outputs are in common use.

a. In one system the amplifier output actuates an electric relay or relays. The control mode may be two-position, floating, or proportional, depending upon the amplifier and relay arrangement. For proportional control, relays control the operation of a reversible motor operator, and rebalance is obtained by a variable voltage feedback signal impressed on the amplifier from a potentiometer in the motor operator.

b. Another system uses the amplifier output to actuate an electrohydraulic relay which in turn varies the position of a hydraulic operator. The control mode is proportional, and rebalance is provided by a spring in the operator.

3. *Electronic-pneumatic transducers* use the output of an electronic amplifier to actuate an electropneumatic relay, resulting in a variable air pressure applied to the controlled device. The control mode may be two-position or proportional, depending upon the amplifier and relay arrangement.

4. *Pneumatic transducers* are normally combined with sensing elements having a force or position output to obtain a variable air pressure output. The control mode is usually proportional, but other modes may be used. They are generally classified as nonrelay type and relay type.

a. The *nonrelay type* of pneumatic transducer is the simplest form. It uses a restrictor in the air supply and a bleed nozzle. The sensing element positions a flapper which varies the nozzle opening, resulting in a variable air pressure output applied to the controlled device, usually a small pneumatic operator. The nonrelay type is limited to applications requiring small volumes of air.

b. In a *relay type* pneumatic transducer, the variable force produced by the sensing element either directly, or indirectly through a restrictor, nozzle, and flapper arrangement, actuates a relay of substantial air handling capacity. The force produced by the output pressure change is rebalanced against the force produced by the sensing element.

Pneumatic transducers are further classified by construction as direct- or reverse-acting.