a. Direct-acting controllers increase the output air pressure as the controlled variable increases. For example, a direct-acting thermostat increases output pressure when the sensing element detects a temperature rise.

b. Reverse-acting controllers increase the output air pressure as the controlled variable decreases. A reverse-acting thermostat will increase output pressure when the temperature drops.

Indicating and Recording Features

Controllers may be of the indicating or recording type.

The *nonindicating controller* is most common in heating, ventilating, and air-conditioning work, and includes all types in which the sensing element does not provide a visual indication of the value of the controlled variable. If an indication is desired, a separate thermometer, relative humidity indicator, pressure gage, etc., is required. With room thermostats, for example, a separate thermometer often is attached to the cover.

An *indicating controller* has a pointer added to the sensing element or attached to it by a linkage, so that the value of the controlled variable is indicated on a suitable scale.

A *recording controller* is similar to an indicating controller, except that the indicating pointer is replaced by a recording pen which provides a permanent record on a chart driven by a clock motor.

Proportional band is a term used in connection with indicating and recording controllers and has the same meaning as throttling range. It is usually expressed in percent of the scale or chart range of the controller.

CONTROLS FOR HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS

For convenience, the controls for heating, ventilating, and air-conditioning systems are sub-divided into three groups: (1) controllers, (2) controlled devices, and (3) auxiliary control equipment.

Types of Controllers

Controllers are mainly (1) thermostats, (2) humidistats, and (3) pressure types.

1. Many thermostats are of the simple, single-purpose type, but there are many others for various special purposes. Various types are indicated in paragraphs (*a*) to (*k*), which follow.

a. The *room* type is designed for mounting on a wall and responds to room temperature.

b. The *insertion* type is designed for mounting on a duct, with its sensing element extending into the duct.

c. The *immersion* type is designed for mounting on a pipe or tank. It has a fluid-tight connection to allow the measuring element to extend into the fluid. A separable socket or well is often used with immersion thermostats, to avoid the need for draining the system when removal of the thermostat is required. Since the separable socket will reduce the response rate of the thermostat, the socket should be no heavier than necessary and should fit snugly around the element.

d. The *remote-bulb* type is designed for applications in which the point of temperature measurement is at some distance from the desired thermostat location. It is often used for centralized panel mounting of the controller. The remote-bulb element may be of either the insertion or immersion type.

e. The *surface* type is designed for mounting on and sensing the temperature of a pipe or similar surface.

f. The *day-night*, or *dual* room thermostat controls at a reduced temperature at night. It may be indexed (changed from day to night operation) individually or in groups from a remote point by a manual or time switch. Some electric types have an individual clock and switch built into the thermostat.

g. The *pneumatic day-night* thermostat uses a two-pressure air-supply system, the two pressures often being 13 and 17 psig, or 15 and 20 psig. Changing the pressure at a central point from one value to the other actuates switching devices in the thermostat and indexes them from day to night or vice versa. Supply-air mains are often divided into two or more circuits so that switching can be accomplished in various areas of the building at different times. For example, a school building may have separate circuits for classrooms, offices and administrative areas, auditorium, and gymnasium and locker rooms.

h. The *heating-cooling* or *summer-winter* thermostat can have its action reversed and, if desired, can have its set point changed by the indexing means. It is used to actuate controlled devices, such as valves or dampers, that regulate a heating source at one time and a cooling source at another time. It is often manually indexed in groups by a switch or automatically, by a thermostat sensing the temperature of the control agent, the outdoor temperature, or other suitable variable.

i. The *pneumatic heating-cooling* thermostat uses a two-pressure air-supply system as described for day-night thermostats.

j. A *two-stage* thermostat is arranged to operate in two successive steps.

k. A *submaster* thermostat has its set point raised or lowered over a predetermined range, in accordance with variations in output from a master controller. The master controller can be a thermostat, manual switch, pressure controller, or similar device. For example, a master thermostat measuring outdoor air temperature can be used to readjust a submaster thermostat controlling the water temperature in a heating system. Master-submaster combinations are sometimes designated as *single-cascade action*. When such action is accomplished by a single thermostat having more than one measuring element, it is known as *compensated control*.

2. *Humidistats* are of either the room or insertion type. Submaster humidistats of either type are sometimes used in conjunction with an outdoor master thermostat to reduce the humidity in cold weather and prevent condensation on windows.

A *wet-bulb* thermostat is often used for humidity control in conjunction with proper control of the dry-bulb temperature. A wick, or other means for keeping the bulb wet, and rapid air motion to assure a true wet-bulb measurement are essential.

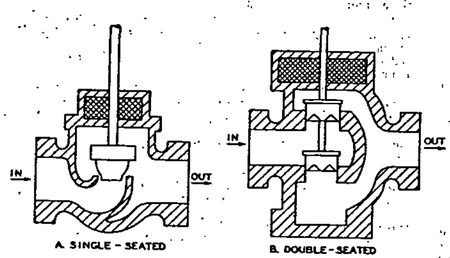

Fig. 6 .... Typical Single- and Double-seated Valves

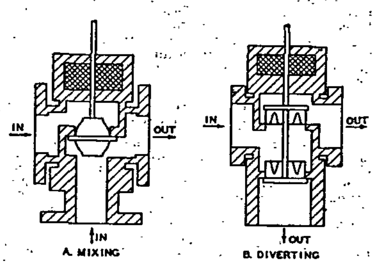

Fig. 7 .... Typical Three-Way Mixing and Diverting Valves

3. A *pressure* or *static-pressure* controller is made for mounting either directly on a pipe, or remotely, on a panel or wall. A small pipe or tube may be used for transmitting the pressure signals to the instrument.

Controlled Devices

Controlled devices may be (1) automatic valves, (2) valve operators, (3) automatic dampers, and (4) damper operators. Other controlled devices include electric heaters, and motors on such equipment as fans, pumps, burners, refrigeration compressors, and similar apparatus.

1. An *automatic valve* is designed to control the flow of steam, water, gas, and other fluids, and may be considered as a variable orifice which is positioned by an electric or pneumatic operator in response to impulses from the controller. It may be equipped with a throttling plug or v-port of special design to provide the desired flow characteristics.

Renewable composition discs are common. They are made of materials best suited to the media handled by the valve, and the operating temperature and pressure. For high pressures or for superheated steam, metal discs are often employed. Internal parts of valves, such as the seat ring, throttling plug or v-port skirt, disc holder, and stem, are sometimes made of stainless steel or other hard and corrosion-resistant metals for use in severe service. Automatic valves should be properly selected and sized for specific applications. See the section on Design Coordination in this chapter for further details.

The functions of various types of automatic valves are as follows:

a. A *single-seated valve* (A, Fig. 6) is designed for tight shut-off. Appropriate disc materials for various pressure ranges and media are used.

b. A *pilot piston valve* utilizes the pressure of the control agent as an aid in operating the valve. It usually is single-seated and is used where large forces are required for valve operation.

c. A *double-seated or balanced valve* (B, Fig. 6) is designed so that the media pressure acting against the valve disc is essentially balanced, thereby reducing the force required of the operator. It is widely used where the fluid pressure is too high to permit a single-seated valve to close. It cannot be used where tight shut-off is required.

d. A *three-way mixing valve* (A, Fig. 7) has two inlet connections and one outlet connection, and a double-faced disc operating between two seats. It is used to mix, as required, two fluids entering through the inlet connections and leaving through the the common outlet.

e. A *three-way diverting valve* (B, Fig. 7) has one inlet connection and two outlet connections, and two separate discs and seats. It is used to divert the flow to either of the outlets or to proportion the flow to both outlets.

f. A *butterfly valve* consists of a heavy ring enclosing a disc which rotates on an axis at or near its center, and, in principle, is similar to a round single-blade damper. The disc usually seats against a ring machined within the body.

2. Valve operators are of three general types:

a. A *solenoid* consists of a magnetic coil operating a movable plunger. It is used for two-position operation. The most common use of a solenoid operated valve is to control the flow of gas, water, air, and refrigerants, and it is generally limited to relatively small sizes.

b. An *electric-motor* operates the valve stem through a gear train and linkage. Electric motor operators are classified in three types: *unidirectional*, *spring-return*, or *reversible*.

(1.) *Unidirectional*, for two-position operation. The valve opens during one-half revolution of the output shaft and closes during the other one-half revolution. Once started, it continues until the half revolution is completed, regardless of subsequent action by the controller. Limit switches built into the operator stop the motor at the end of each stroke. If the controller has been satisfied during this interval, the operator will continue to the other position.

(2.) *Spring-return*, for two-position operation. Electric energy drives the valve to one position and holds it there. When the circuit is broken, the spring returns the valve to its normal position.

(3.) *Reversible*, for floating and proportional operation. The motor can run in either direction and can stop in any position. It is sometimes equipped with a return spring. For proportional control applications, a potentiometer for rebalancing the control circuit is also driven by the motor.

c. A *pneumatic operator* consists of a spring-opposed, flexible diaphragm or bellows attached to the valve stem in such a way that an increase in air pressure moves the valve stem and simultaneously compresses the spring. Springs of various ranges, in terms of air pressure, can be employed to provide sequence operation of two or more devices by proper selection or adjustment of the springs. Springless pneumatic operators, using two opposed diaphragms or two sides of a single diaphragm, are also used; but are generally limited to special applications involving large valves or high pressures. Pneumatic operators are designed primarily for proportional control. Two-position control is accomplished by use of a two-position controller, or a two-position pneumatic relay to apply either full air pressure or no pressure to the valve operator.

Pneumatic valves and valves with spring-return electric operators can be classified as normally open or normally closed.

A *normally open* valve will assume an open position when all operating force is removed.

A *normally closed* valve will assume a closed position when all operating force is removed.

3. *Automatic dampers* are designed to control the flow of air or gases, and function like valves in this respect. Steel blades and frames are most common, but other materials are used for special applications, such as those involving corrosive fumes. Large dampers are often made in two or more sections for strength and convenience in handling, the sections being interconnected so as to operate as a unit. The damper types commonly used are:

a. Single-blade, which is generally restricted to small sizes because of the difficulty of securing proper operation with high-velocity air.

b. Multiblade or *louver* damper (Fig. 8) which has two or more blades linked together. It may be arranged for *parallel operation*, in which all blades rotate in the same direction, or *opposed operation*, in which adjacent blades rotate in opposite directions. See later section, Control of Air Flow, for difference in air flow characteristics.

c. Mixing dampers, composed of two sections interlinked so that one section opens as the other closes.

4. *Damper operators* of the electric type may be unidirectional, spring-return, or reversible, similar to electric-motor valve operators. Pneumatic damper operators are similar to pneumatic valve operators, except that they usually have a longer stroke or the stroke is increased by means of a multiplying lever. Damper operators are mounted on the damper frame and are connected with linkage directly to a damper blade, or are mounted outside the duct and connected to a crank arm attached to a shaft extention of one of the blades.

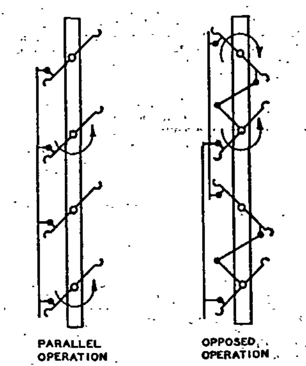

Fig. 8 .... Typical Multiblade Dampers