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 consist of (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 its 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 sometimes are 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 the 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* 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* 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* 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 the inlet connections and leaving through the common outlet.

e. A *three-way diverting valve* 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 generally it is 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 distinct types. *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. *Spring-return*, for two-position operation. Electric energy drives the value to one position and holds it. When the circuit is broken, the spring returns the valve to its normal position. *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 at the same time 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, also are used but generally are 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 often are made in two or more sections for strength and convenience in handling, the sections being inter-connected 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. *Multi-blade* or *louver* damper which has two or more blades linked together. It may be arranged for (a) *parallel operation*, in which all blades rotate in the same direction or (b) *opposed operation*, in which adjacent blades rotate in opposite directions and provide more linear air flow characteristics than obtained with parallel operation.

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 similarly 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 extension of one of the blades. On large dampers two or more operators may be required, and usually are applied at separate points on the damper. Normally-open or normally-closed operation is obtained according to the method of mounting the operator and connecting the linkage.

Auxiliary Control Equipment

In addition to the conventional controllers and controlled devices described, many control systems require auxiliary devices to perform various functions. Auxiliary controls for electric systems include:

1. *Transformers* to provide current at the required voltage.

2. *Electric relays* for control of electric heaters or to start and stop oil burners, refrigeration compressors, fans, pumps, or other apparatus for which the electrical load is too large to be handled directly by the controller. Other uses include time delay, circuit interlocking safety applications, and similar functions.

3. *Potentiometers* for manual positioning of proportional controlled devices or for remote set point adjustment of electronic controllers.

4. *Manual switches* for manually performing a variety of operations. These may be of two-position or multiple-position type or may be of single or multiple-pole type.

5. *Auxiliary switches* on valve and damper operators for providing a selected sequence of operations.

Auxiliary control equipment for pneumatic systems include:

1. *Air compressors and accessories*, to provide a source of air at the required pressure.

2. *Electro-pneumatic relays*, which are electrically-actuated air valves for operating pneumatic equipment when an electrical circuit is energized or de-energized.