BUILDING ENVIRONMENTAL CONTROL SYSTEMS OPERATION

1. GENERAL

1.01 This section provides the description of environmental control systems operation.

1.02 Whenever this section is reissued, the reason(s) for reissue will be stated in this paragraph.

1.03 For detailed information concerning a specific system, refer to the manufacturer's as-built operating and maintenance instructions and control diagram.

1.04 For calibration instructions and operation of a particular thermostat or control device, refer to the manufacturer's data sheet.

1.05 SW 760-550-901, Engineering Guide for Environmental Controls, provides additional design-based information concerning environmental control systems.

2. TYPES OF ENVIRONMENTAL CONTROL SYSTEMS

2.01 Local environmental control systems may be classified into the following three types:

(a) Pneumatic systems which use compressed air, usually at a pressure of 15 to 35 psi gage, as a source of energy. This is supplied to the controller, which in turn regulates the pressure supplied to the controlled device.

(b) Electric/electronic systems which utilize electric energy, either low or line voltage as the energy source. Those systems which include electronic sensing and amplification of micro-computer based direct digital control systems are classified as electronic.

(c) Combination systems which are combinations of the above and use multiple power sources such as electric and pneumatic, and transmit the signals to derive the benefits of both types.

3. COMPONENTS OF AUTOMATIC CONTROL SYSTEMS

3.01 For convenience, the controls for HVAC (heating, ventilating, and air conditioning) systems are subdivided into four groups: (a) sensing elements, (b) controllers, (c) controlled devices, and (d) auxiliary control equipment 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.

3.02 Sensing Elements

A sensing element is a device which measures changes in the controlled variable and produces a proportional effect for use by the controller.

(a) Temperature sensing elements usually consist of: (1) a bimetal element, (2) a rod-and-tube element, (3) a sealed bellows element with or without a remote bulb, or (4) a resistance element.

(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 most common application in room thermostats, but is also used with 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 used on certain types of insertion and immersion thermostats.

(3) A sealed bellows element is either vapor-, gas-, or liquid-filled, after the air has been evacuated. Changes in temperature cause changes in pressure or volume of gas or liquid, resulting in a change in force or a movement. This element is often used 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 is filled with vapor, gas, or liquid. Changes in temperature at the bulb result in changes in 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, 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 semiconductor 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 change. These various elements are available in forms suitable for measuring room temperature or for insertion into a duct, pipe, or tank.

(b) Humidity Sensing Elements.

(1) Hygroscopic elements change in size or form to cause a mechanical deflection (organic materials such as hair, wood, paper, or animal membrane, and manufactured elements such as nylon).

(2) Electrical elements cause a change in characteristics (resistance of capacitance) due to the hygroscopic nature of the element.

(c) Pressure sensing elements can be divided into two general classes, depending on pressure range.

(1) For pressures or vacuums 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 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 connection with orifices. Pitot tubes and similar accessories may be used to measure flow, velocity, or liquid level as well as static pressure.

(d) Water flow sensing elements may use a variety of basic sensing principles and devices as follows: orifice plate, Pitot tube, venturi, flow nozzles, turbine meter, magnetic flow meter, and vortex shedding flow meter.

(e) Other Sensing Elements.

Sensing elements for other purposes, such as for 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.

3.03 The sensing element configurations are listed below:

(a) Room (designed for mounting on a wall and responding to space temperature).

(b) Insertion (designed for mounting on a duct, with its sensing element extending into the duct).

(c) Immersion (designed for mounting in the wall of 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) Remote bulb (designed for applications in which the point of temperature measurement is at some distance from the desired thermostat location). Used for centralized panel mounting of the controller, the remote-bulb element may be of either the insertion or immersion type.

(e) Surface (designed for mounting on and sensing the temperature of a pipe or similar surface).

3.04 Controllers

Controllers take the sensor effect, compare it with the desired control condition, and regulate an output signal to cause various types of control action.

(a) Electric/Electronic Controllers.

(1) For two-position control, the controller output 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 control a three-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.

(2) For floating control, the controller output is a SPDT switching circuit with a neutral zone where neither contact is made. This type of control is used with reversible motor operators.

(3) Proportional control gives continuous or incremental changes in output signal to position an electrical actuator or control device.

(b) Indicating or Recording Controllers.

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

(c) Pneumatic Controllers.

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

(1) 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.

(2) 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.

(d) Transducers.

Combination systems consisting of combinations of electric and pneumatic control devices may be required. For these applications, devices commonly called transducers are used to convert electric signals to pneumatic output or vice versa. Transducers may convert proportional input to either proportional or two-position output.

(e) Thermostats.

Many thermostats are of the simple, single-purpose type, but others serve various special purposes.

(1) 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.

The pneumatic day-night thermostat uses a two-pressure air supply system. 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.

(2) The heating-cooling or summer-winter thermostat can have its action reversed and, if desired, can have its set point changed by 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. 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 another suitable variable.

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

(3) Multistage thermostats are arranged to operate two or more successive steps in sequence.

(4) 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.

(5) A wet-bulb thermostat is often used for humidity control 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.

(6) A dew point thermostat is a device designed to control from dew point temperatures.

3.05 The controller configurations are listed below:

(a) Thermostats and humidistats are those controllers which have the sensing elements and controller functions in one device.

(b) Sensor (or transmitter)-receiver controller systems utilize a sensing element (sensor) remote from the controller function.

3.06 Controlled Devices

Controlled devices may be (a) automatic valves, (b) valve operators, (c) automatic dampers, and (d) damper operators. Other controlled devices include electric heaters, relays, and motors on such equipment as fans, pumps, burners, refrigeration compressors, and similar apparatus.

(a) 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. The functions of various types of automatic valves are:

(1) A single-seated valve is designed for tight shut-off. Appropriate disc materials for various pressures and media are used.

(2) A pilot piston valve uses 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.

(3) 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 when tight shutoff is required.

(4) A three-way mixing valve has two inlet connections, 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 connection and leaving through the common outlet.

(5) A three-way diverting valve has one inlet connection, 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.

(6) 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 seats against a ring machined within the body or a resilient liner in the body.

(b) Valve operators are of three general types:

(1) Solenoid -- consists of a magnetic coil operating a movable plunger. The majority of solenoid valves are for two-position operation, but modulating solenoid halves are available utilizing a pressure equalization bellows or piston to achieve very high resolution. Solenoid valves are generally limited to relatively small sizes [up to 100 mm (4 inches)].

(2) 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.

(a) 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.

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

(c) 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.

(3) 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 used 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.

(An electric-hydraulic actuator is similar to a pneumatic one, except it uses an incompressible fluid which is circulated by an associated electric pump.)

(c) 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:

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

(2) Multiblade or louver damper, 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.

(3) Mixing dampers, which are composed of two sections interlinked so that one section opens as the other closes.

(d) Damper operators of the electric type may be unidirectional, spring-return, or reversible, similar to electric-motor valve operators.

3.07 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 control systems include:

(a) Transformers to provide current at the required voltage.

(b) 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, etc.

(c) Potentiometers for manual positioning of proportional control devices or for remote set point adjustment of electronic controllers.

(d) Manual switches for manually performing a variety of operations. These may be of two-position or multiple-position type with single or multiple poles.

(e) Auxiliary switches on valve and damper operators for providing a selected sequence of operations.

Auxiliary control equipment for pneumatic systems include:

(a) Air compressors and accessories, including driers and filters, to provide a source of clean, dry air at the required pressure.

(b) Electropneumatic relays, which are electrically actuated air valves for operating pneumatic equipment in accordance with variations in electrical input to the relay.

(c) Pneumatic-electric relays, which are actuated by air pressure to make or break an electrical circuit.

(d) Pneumatic relays, which are actuated by the pressure from a controller to perform numerous functions. They may be divided into two groups:

(1) Two-position relays, which permit a controller actuating a proportional device to also actuate one or more two-position devices. They are also used in various automatic switching operations.

(2) Proportional relays, which are used to reverse the action of a proportional controller, select the higher or lower of two pressures, average two or more pressures, respond to the difference between two pressures, add or subtract pressures, amplify or retard pressure changes, and perform other similar functions.

(e) Positioning relays, which are devices for assuring accurate positioning of a valve or damper operator in response to changes in pressure from a controller. They are affected by the position of the operator and the pressure from the controller. Whenever the two are out of balance, these relays will change the pressure applied to the operator until balance is restored.

(f) Switching relays, which are pneumatically operated air valves for diverting air from one circuit to another or for opening and closing air circuits.

(g) Pneumatic switches, which are manually operated devices for diverting air from one circuit to another or for opening and closing air circuits. They may be of the two-position or multiple-position type.

(h) Gradual switches, which are proportional devices for manually varying the air pressure in a circuit.

Auxiliary control devices common to both electric and pneumatic systems include:

(a) Step controllers for operating a number of electric switches in sequence by means of a proportional electric or pneumatic operator. They are commonly used for controlling a number of steps of refrigeration capacity and may be arranged to prevent simultaneous starting of compressors and to alternate the sequence to equalize wear. They may also be used for wide band sequence operation of heating and cooling equipment in response to the demands of a proportional controller.

(b) Clocks or timers for turning apparatus on and off at predetermined times for switching control systems from day to night operation and for other time sequence functions.