Chapter 3

Hardware—System Components

There are five basic components that are used in energy management systems. Starting from the equipment being controlled and working back to the operator's console the components are sensors, actuators, microprocessor-based field panels (controllers), communication links, and a central operator station.

Sensors and/or actuators are located at the equipment being controlled. Sensors transmit information that defines a single operating condition, such as temperature or pressure. This information is supplied to the field panels (controllers) for monitoring or decision-making purposes. Actuators are the mechanical interfaces that implement actions initiated by the controllers. The actions can be self-initiated by the controllers. The actions can be self-initiated or initiated as a consequence of information received from the sensors. Field panels centralize the input from the sensors and distribute the output from the controllers to the actuators. The information is then transmitted over the communication links to a central operator station. These links carry information between all system components.

SENSORS

Sensors are electric devices that assess changes in ambient conditions and react by varying electrical voltage, or current. This voltage or current variation is transmitted either as a digital or analog signal to field panels, for subsequent monitoring or analysis by the controller. A digital signal may have one of two predetermined values used to monitor two-position conditions, such as on/off or high/low. The analog signal has a range of values that vary proportionally to the condition being measured and is used for items such as temperature, pressure, flow, and relative humidity. Examples of analog sensors are thermocouples, resistance temperature detectors, and thermistors. Refer to Figure 3-1 for sensor mountings.

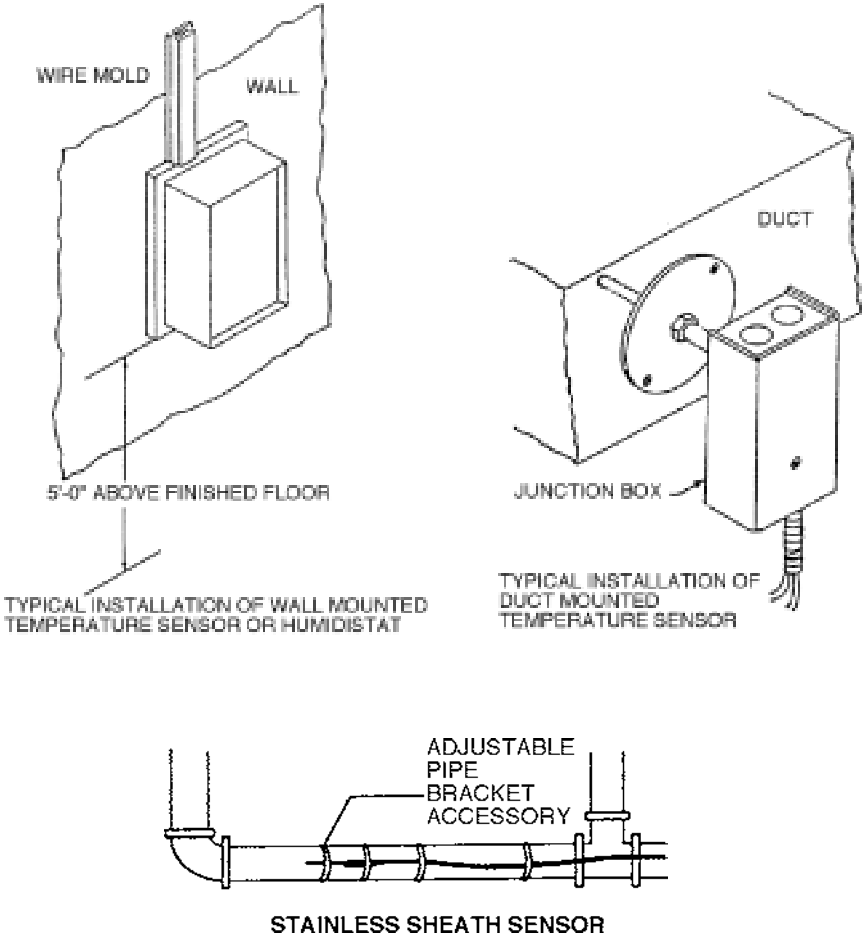


Figure 3-1. Sensor Mountings

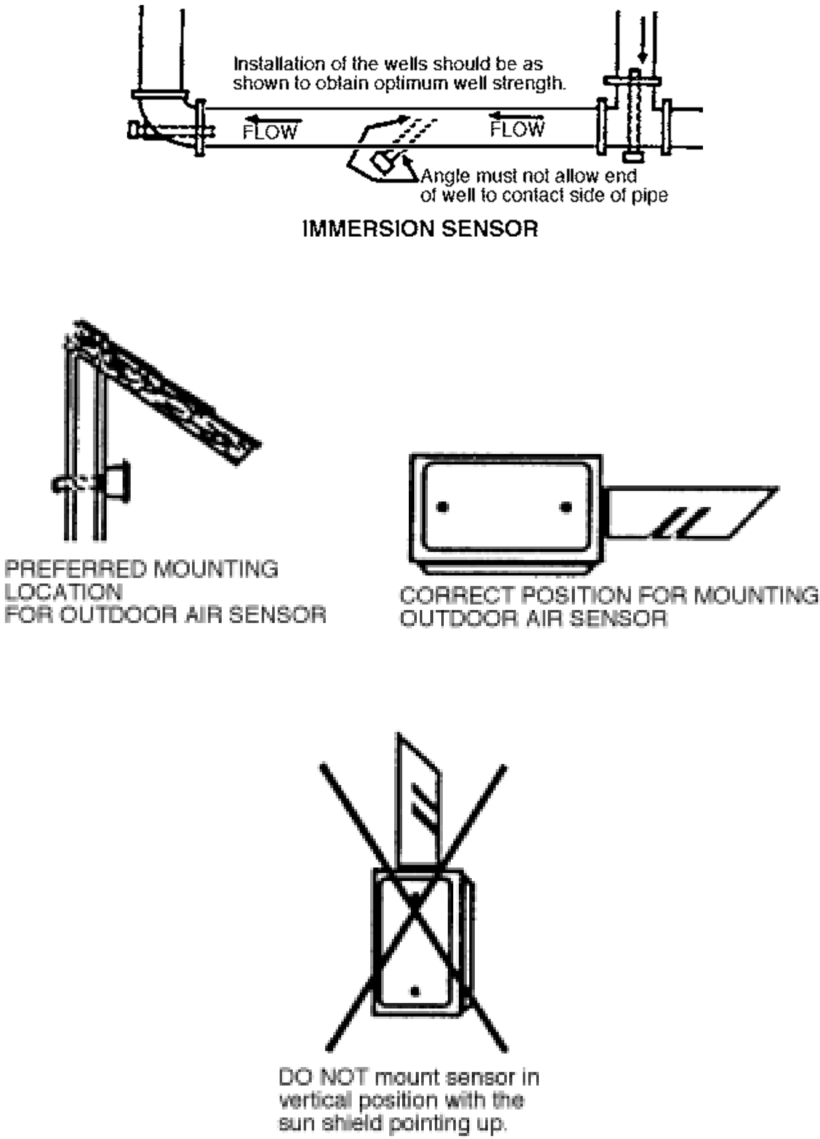


Figure 3-1. Sensor Mountings (*Continued*)

Resistance Temperature Detector (RTD)

The electrical resistance of certain metals varies proportionally with temperature in a precise, consistent, and repeatable manner. RTDs made of these metals provide a measurable resistance that is proportional to temperature.

Thin Film Platinum is considered the optimum sensor because of its' superior characteristics such as operating temperature range, interchangeability, linearity, stability, and reproducibility available through automated manufacturing conditions. These RTDs can be furnished as 2 or 3 wire, 4-20 MA units with an accuracy of ± 0.1% of span and a 1000 ohm @ 0°C reference resistance. The sensing element has a temperature coefficient of 0.00 375 ohm/ohm/°C.

There are other wire wound RTDs available such as Nickel (medium accuracy), Balco (low accuracy), and Nickel-Iron (70%-30%/medium accuracy).

All mounting configurations are available for room, duct, immersion, strap-on, and outside air temperature sensing.

Thermistor

Thermistors are a semiconductor made from combinations of nickel, manganese, copper and other metals. They offer a fast response, are good for small spans, and are a relative low cost sensor.

Disadvantages include very non-linear, poor interchangeability, and not suitable for wide spans. Their accuracy is ± 0.4°F of span.

Thermocouple

Two wires of two dissimilar metals joined to form a junction are seldom, if ever, used with modern EMSs. They can operate over a wide temperature range however their interchangeability and repeatability are poor. They also have a low output sensitivity.

Relative Humidity

The principle of operation of a capacitive relative humidity sensor is a small capacitor consisting of a hygroscopic dielectric material placed between a pair of electrodes. Most capacitive sensors use a plastic or one micron thin polymer as the dielectric material, with a typical dielectric constant ranging from 2 to 15. When no moisture is present in the sensor, both this constant and the sensor geometry determine the value of the capacitance.

By definition, relative humidity is a function of both the ambient temperature and water vapor pressure. Therefore, there is a relationship between relative humidity, the amount of moisture present in the sensor, and sensor capacitance. This relationship is at the base of the operation of a capacitive humidity instrument.

Note: All humidity sensors should be factory calibrated following procedures described in ASTM standard E104-85, Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions.

Pressure

The most common use is a pressure-electric (PE) switch where a fluid pressure activates electrical contacts in the device. Differential PE switches can be used to sense the flow of a fluid in ducts and in pipes. There are also pressure to electric transducers which will produce a proportional output electrical signal change relating to a varying input pressure.

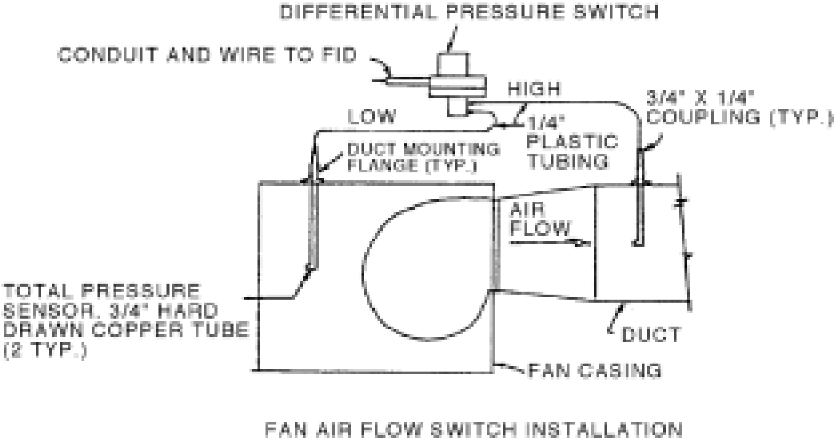
Devices are also used to measure static pressure in systems to control fluid flow. Pressure should never exceed the calibrated range of the instrument.

Flow

These devices measure flowrate, converting kinetic energy to a pressure differential. Measured differential pressure typically varies from a few inches of water to 10 or 20 psi. See Figure 3-2 for flow sensors.

Accuracy or uncertainty is considered to be comprised of two components, that due to the systematize error and that due to the precision or random error. For direct calibration of the overall meter system which includes the differential pressure transmitter system, the upstream and downstream piping and suitable flow straightener, best accuracy is estimated to fall within the approximate range 0.2 to 0.5 percent.

A vortex shedding meter, on the industrial scene since 1970, operates on the principles that the frequency of vortex shedding for fluid flow around a submersed object is proportional to the fluid stream velocity. Flowrate is measured by detecting this frequency. A big advantage for a building EMS application is that accurate measurement of the probe output is a much simpler measurement task than accurate measurement of a differential pressure type meter.



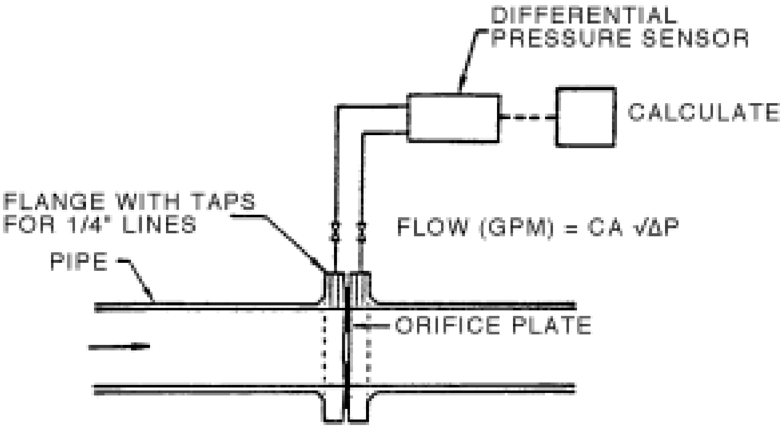


Figure 3-2. Flow Sensors

A turbine meter contains a bladed rotor or turbine which rotates at a velocity proportional to volume rate of flow. Most models employ magnetic pick-offs in which the rotor blades vary the reluctance of a magnetic circuit which generates an AC voltage in the pick-off coil. The frequency is directly proportional to rotor speed. This frequency is sensed as an indication of flow. It can be counted by an electronic

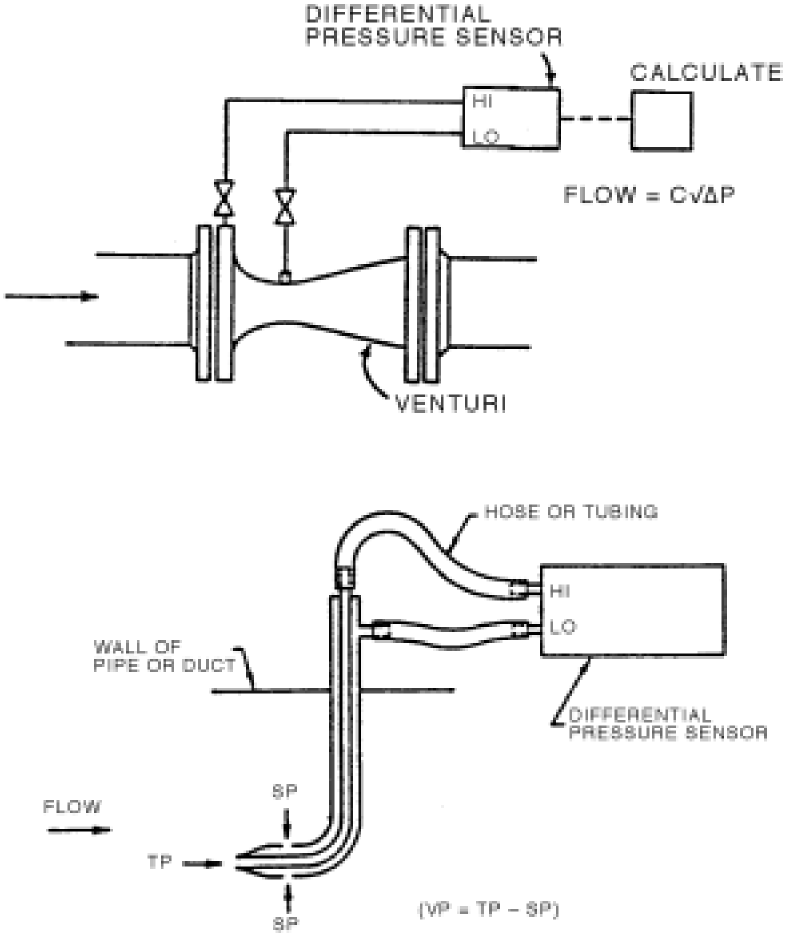


Figure 3-2. Flow Sensors (*Continued*)

counter, or converted to an analog signal using voltage to frequency converter circuits. The calibration factor or meter factor is expressed in electrical pulses generated per unit volume of throughput, e.g. pulses/gallon. The turbine meter has advantages of small size, repeatability, and a type of output which is digital in nature. These make the meter quite suitable for EMS applications.

kW Meters

kW Meters or watt hour meters are used to measure kW and kWh. Input voltage must match the meter rating. Meters can be solid state with non-resettable electromechanical display for local indication of kWh and a contact closure for remote signaling to an EMS. Watt hour transducers are also available which measure true watt-hours and provide a pulse output to drive counters or can signal an EMS.

ACTUATORS

The actuator transforms electric- or pneumatic-coded instructions into mechanical responses. Actuators, which may be pneumatic, electric, electronic, or solid state, position controlled devices such as dampers or heating and cooling valves in response to signals received from the device controlling the actuator. Actuators may be either proportioning or modulating, with two position or snap action control.

Depending on the required control sequence of operation, if either controlling air pressure or electric power is lost, actuators can fail in the normally open or normally closed position. Pneumatic actuators respond to controlling air pressure changes over a range of 3 to 15 psi (pounds per square inch); electric actuators respond to on/off electric signals from the controlling device. Proportioning electric actuators respond to changes in resistance from the controlling devices, generally over a 135 ohm range, or to changes over a 3 to 15 volt dc range for solid state actuators.

1. Electric Relays or contractors are designed for switching electrical loads such as air conditioning, compressors, and resistance heating appliances. Coils and contacts must be rated for the load they are controlling.

2. Damper Operator/Actuators open and close dampers according to an electric, electronic, or pneumatic signal from a controller. Most operators are spring return to normal position. Operators can be installed externally or internally (inside a duct).

3. Valve Operator/Actuators are the part of an automatic valve that moves the stem up and down based on an electric, electronic, or

pneumatic signal from a controller. For butterfly or other rotary valves, the operator rotates the stem. The operator and valve can be two separate devices or together they can be one device.

4. Transducers are electro-mechanical devices that can provide electric or pneumatic outputs which can be changed by the application of a varying electrical signal to its input.

   During the 1970's, such devices were sometimes referred to as an electro-pneumatic motor driven servo. 6 or 24 volt DC power was used as the applied power. Positive voltage applied to the integral motor rotated it in a clockwise direction causing an increase in output pressure (negative voltage = counterclockwise = decrease in output pressure). The magnitude of the pneumatic output change is directly proportional to the duration of the electric input signal. The output is used to reset or reposition pneumatic controlling receivers or controlled devices.

   Modern day transducers are sometimes 100% solid state using a piezoresistive silicon pressure sensor and an electropneumatic converter to provide the desired pneumatic output pressure. These units can be mounted in any orientation and do not require filtered air. They provide reliable, repeatable, and an accurate means of converting any analog signal into pneumatic pressure.

   Transducers are also manufactured to provide a 4 to 20 mA or 0 to 20 mA output proportional to the duration of the pulse input (pulse wave modulation—PWM). Outputs may also be in the form of user selectable 0 to 10 V dc or 0 to 20 V dc depending on the end device requirements.

   See Figure 3-3 for actuator devices.

FIELD PANELS

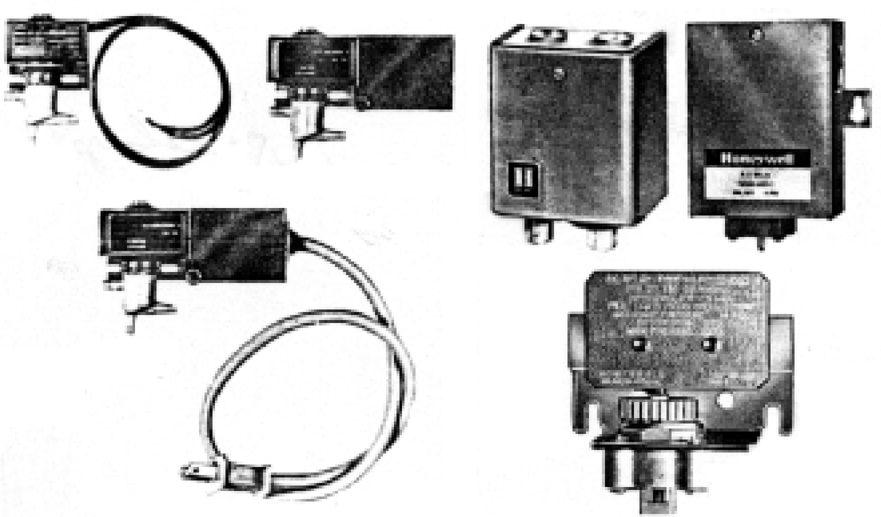
Field panels provide an interface between remote sensors and actuators. Today these are considered to be direct digital controller (DDC) panels. Previously they were simply data gathering panels which relayed information to a central minicomputer.

DDCs serve as a point of consolidation for many sensor and control points. Each sensor or actuator represents one control point.

Uncoded signals from sensors are received, coded, and sent to the DDC microprocessor. Conversely, coded information is received from the DDC, decoded, and sent back to the actuators. The number of control points that can be accommodated by a DDC panel varies from 4 to 200. "Intelligent" or "smart" DDCs have their own microprocessor to process information and respond with instructions.

Many field panels are manufactured with a built-in keyboard and visual display. This is an item that should be specified for (at least) the primary or master panels located throughout a facility. If the panel is not equipped with this feature, maintenance workers will have to rely on a portable operator interface device which are cumbersome and easily "left behind."

Refer to Chapter 5 for additional information on digital controllers.



Pressure-electric relays

Pressure-electric switches

Figure 3-3. Actuator Devices

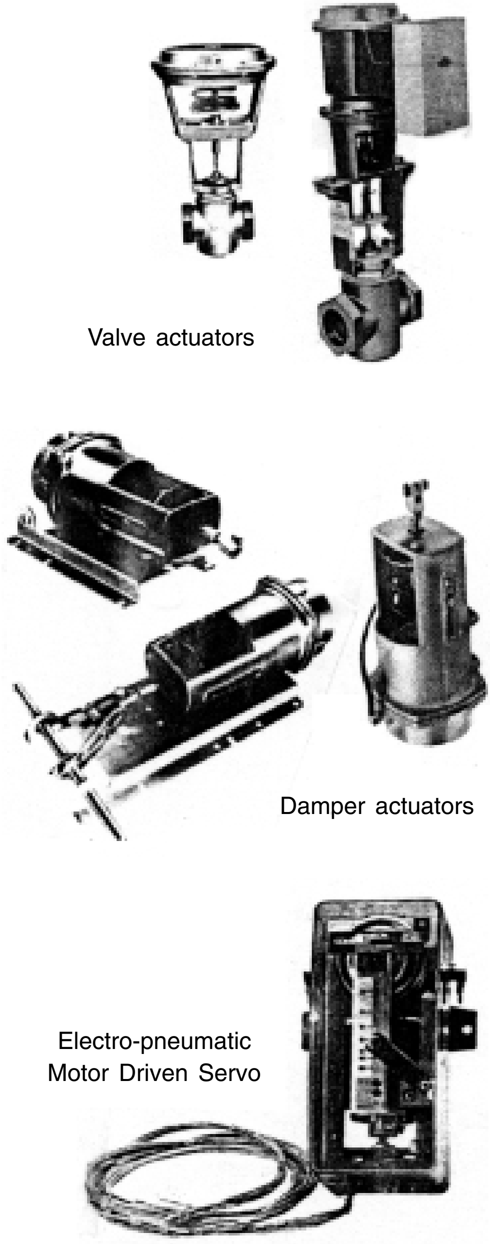
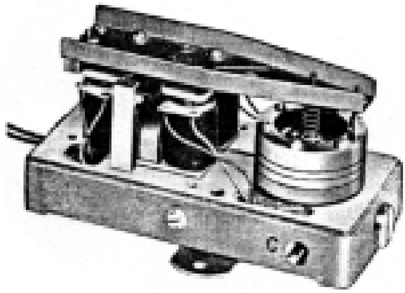
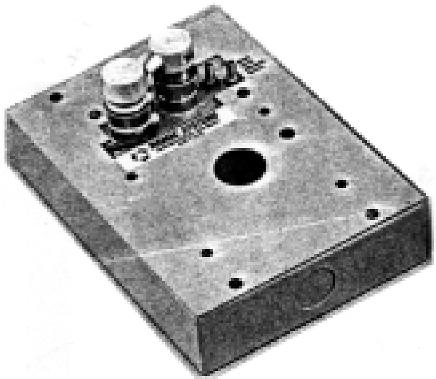


Figure 3-3. Actuator Devices (*Continued*)



Electro-pneumatic Transducer



Solid-state Piezoresistive Silicon
Electropneumatic Converter

Figure 3-3. Actuator Devices (*Continued*)