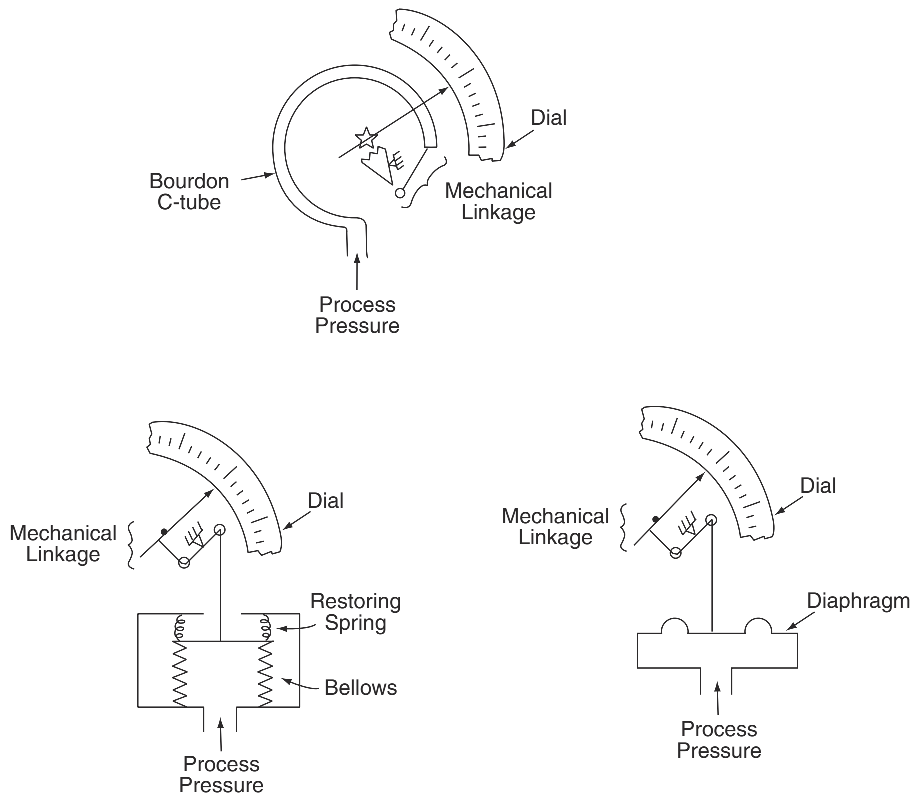

Figure 5-1 Bourdon, bellows, and diaphragm pressure sensors

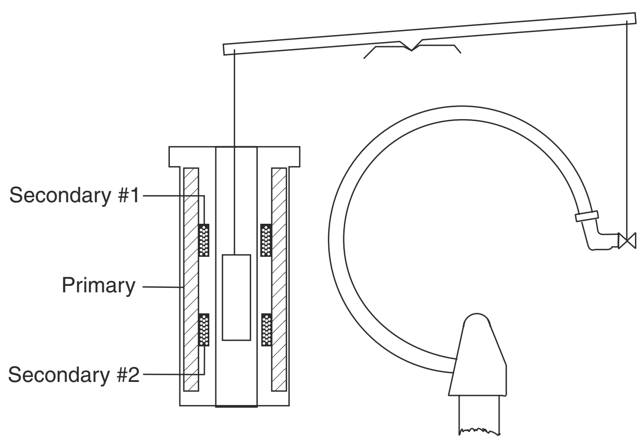

Figure 5-2 Typical LVDT application

The change in pressure in the fluid-filled chamber causes a small displacement of the sensor diaphragm. This change is detected as a change in capacitance between two capacitance plates on either side of the sensing chamber. The change is then converted electronically to a conventional 4–20 mA DC signal.

This type of sensing mechanism can also be used for flow monitoring when used with a differential pressure-producing primary flowmeter, such as a Venturi tube or an orifice plate. In this application, the high- and low-pressure connections of the primary flowmeter device are connected to either side of the sensing chamber. The sensing

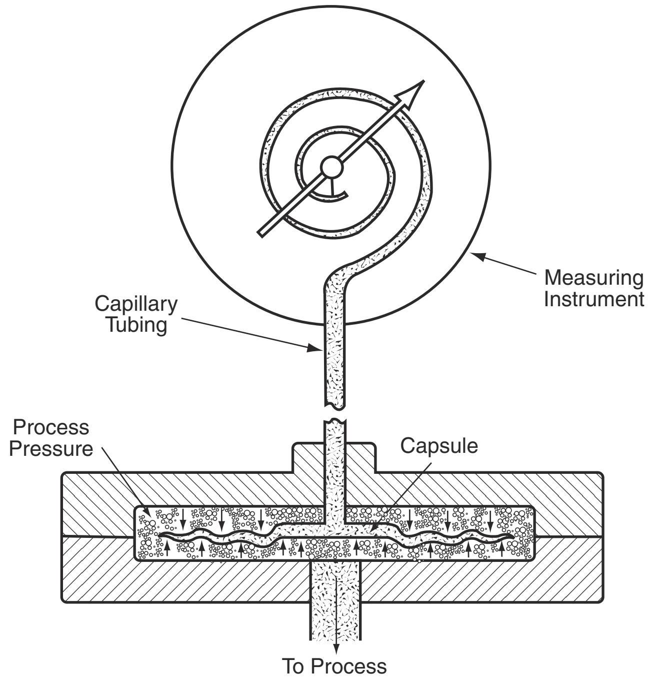

Figure 5-3 Diaphragm seal

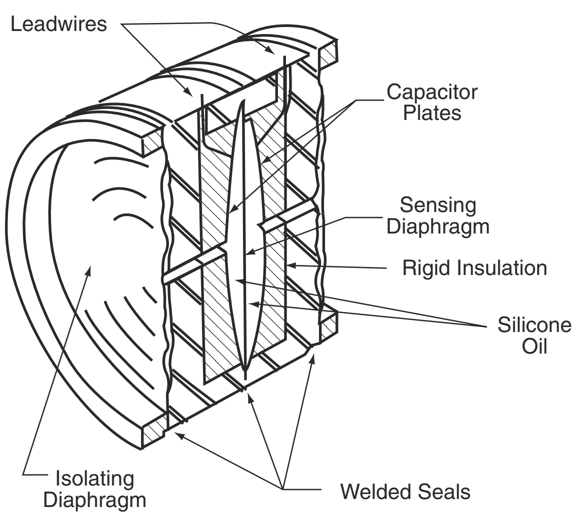

Figure 5-4 Variable capacitance pressure sensor

mechanism then responds to the difference in these two pressures and produces an output signal representative of flow through the primary flowmetering device.

Other concepts used in similar devices include variable reluctance, bonded strain gauges, and vibrating wires. Variable reluctance sensors are similar to the variable capacitor concept except that the electrical quantity is reluctance. In bonded strain gauge sensors, the pressure acts on a semiconductor strain gauge, which causes a change in output voltage. The change corresponds to the pressure acting on the strain gauge assembly. In the vibrating wire concept, pressure changes the tension on a resonant wire. The change in the resonant frequency of the wire is representative of the pressure.

With differential pressure transmitters used for flow measurement, additional electronics in the transmitter circuit extract the square root of the differential pressure measurement. Therefore, the transmitter produces an output signal directly proportional to flow.

Pressure-sensing devices typically have accuracies varying from ±1 percent to less than ±0.25 percent of full-scale measurement. The accuracy depends on the quality of the equipment and care taken in calibration.

Level

Level measurements determine water level in storage tanks or level of liquid chemicals in chemical storage tanks.

Pressure sensors can be readily adapted to level measurement by installing the sensor at the base of a tank. As the level increases in the tank, the pressure reading increases. The reading can be calibrated in feet of liquid. In elevated tanks the level measurement needed is the level in the elevated portion of the tank rather than in the tank and riser. Transmitting mechanisms can be calibrated so that zero represents the bottom or minimum level in the elevated portion of the storage tank.

The float-operated level sensor is another common level-sensing system. Float-operated sensors would normally be used in open reservoirs, particularly when a transmitter cannot be located at the low point of the reservoir. A float-operated transmitter consists of a float resting on the surface of the water. The float usually travels in a stilling well and is attached to a pulley and counterweight with a cable. As the float rises and falls in the stilling well, the pulley system turns and positions an indicating pointer or a transmitting mechanism to indicate water level. An example of a float-type, level-sensing system is shown in Figure 5-5.

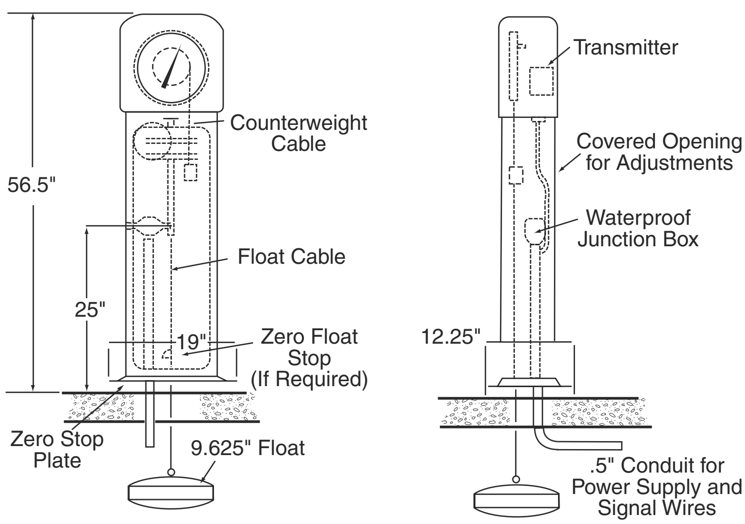

Figure 5-5 Float-type, level-sensing system

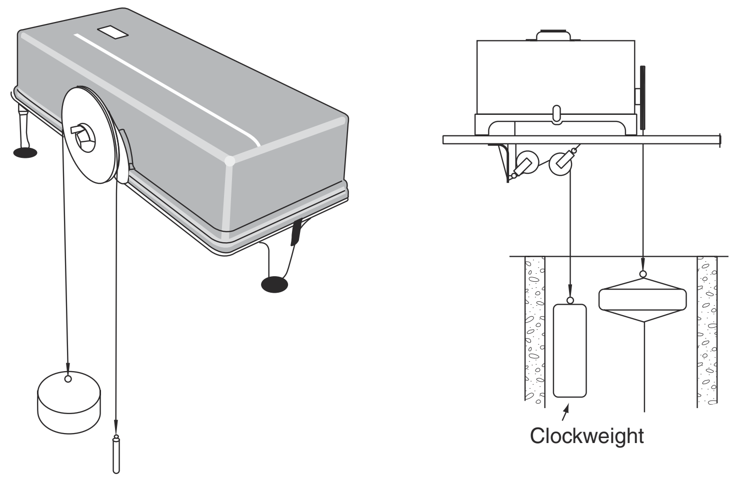

Figure 5-6 Stage recorder

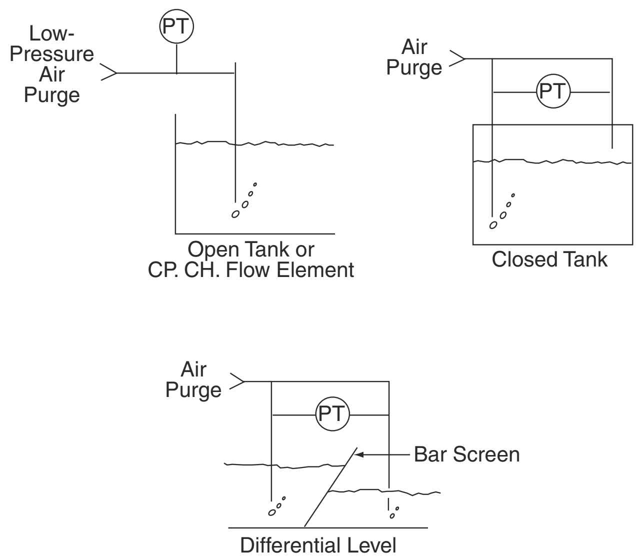

Figure 5-7 Bubbler

Accuracies of conventional float-type level transmitters will normally be ±1 percent of full-scale reading.

Where extreme accuracy in level-sensing systems is required, a special adaptation of a float-type level transmitter has been used. The adaptation is called a stage recorder and uses larger floats and a more precise pulley system to increase positioning accuracy. These devices may also be equipped with a digital sensing system. Levels can be transmitted as binary coded decimal output. Readings are accurate to within ±1⁄8 in. (3 mm) throughout the full measure range. An example of this type of stage recorder is shown in Figure 5-6.

Another type of level sensor quite frequently seen in water system applications is the pneumatic bubbler (Figure 5-7). A small diameter tube is installed in the tank with the tube bottom as near as possible to the tank bottom. A regulated and

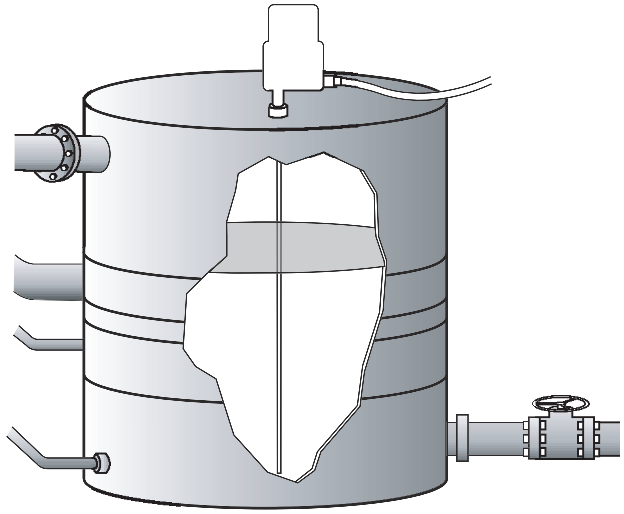

Figure 5-8 Admittance probe

continuous flow of air passes into the tube and slowly bubbles out the bottom end. The air pressure is just enough to overcome the water pressure. A conventional pressure sensor is connected to the bubble tube assembly. The measured air pressure within the bubbler system corresponds to the water depth.

With the bubbler transmitters, a good quality dry air must be used. If the air contains a significant amount of moisture, the bubbler may not operate properly, particularly in freezing temperatures. Accuracies will be ±1 percent of the maximum depth measurement.

In recent years, direct electronic devices have been used for level measurement. Among these are capacitance or admittance probes, variable resistance devices, and ultrasonic systems.

Figure 5-8 is an example of an admittance probe. In this system, an insulated metallic probe is installed in the reservoir. As the water level rises and falls in the reservoir, the capacitance changes between the metallic portion of the probe and the water. This capacitance signal can then be converted to a 4–20 mA DC output representative of level. When the tank is not made of a conducting material, a second electrode will be required. Admittance or capacitance probes can also be used for level measurement of solid or granular material in storage tanks. With some materials, coating may occur on the electrodes that can interfere with proper operation of the admittance probe concept. This possibility needs to be investigated as part of the application of this type of level measurement.

A variable resistance level sensor is shown in Figure 5-9. The sensor consists of a wound resistor inside of a semiflexible envelope. As the level rises, the semiflexible outer portion of the sensor presses against the resistor. A portion of the resistor element is temporarily shorted out, which changes the overall resistance of the sensor itself. The resistance is converted to an output signal representative of level.

In ultrasonic level-sensing systems, an ultrasonic generator is installed above the water level. This generator sends ultrasonic signals toward the water surface. The signals bounce back and are detected by a receiver located with the generator. The time required for this signal to echo is calibrated to produce an output signal representative of water level. An example of an ultrasonic level sensor is shown in Figure 5-10. Air temperature variations must be compensated for because the speed

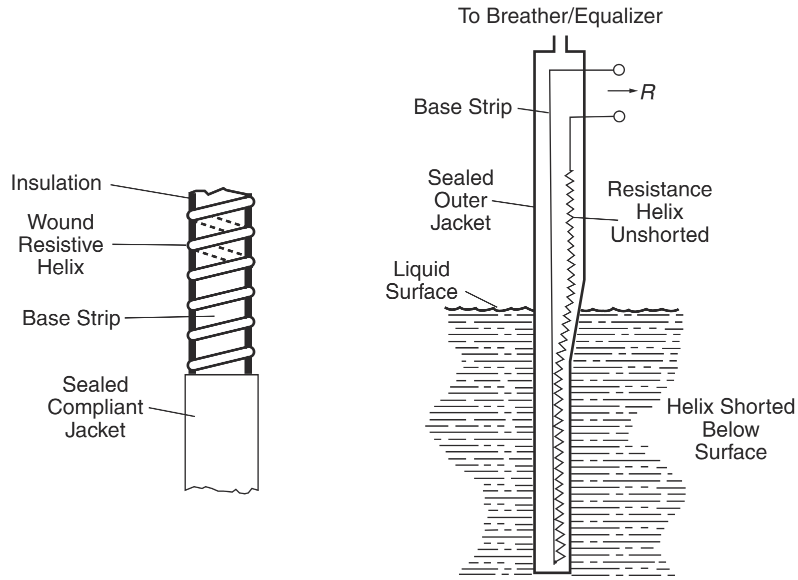

Figure 5-9 Variable resistance level sensor

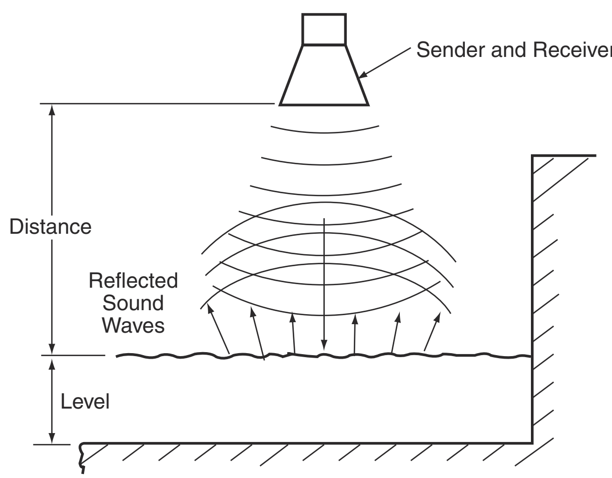

Figure 5-10 Ultrasonic level sensor

of sound in air is a function of temperature. Excessive humidity in the air above the liquid in a stilling well may also significantly interfere with proper operation. Accuracy is ±1 percent of the level measurement.

With the wide selection of level sensors available, the selection of the proper device for a particular application may oftentimes become somewhat confusing. A number of factors must be considered in making this decision. Among others, the factors include the type of material being measured and the physical conditions of the particular installation. Manufacturers' representatives can help in making the choice. Recommendations from those individuals experienced in sensor selection inside or outside the utility are also good sources.

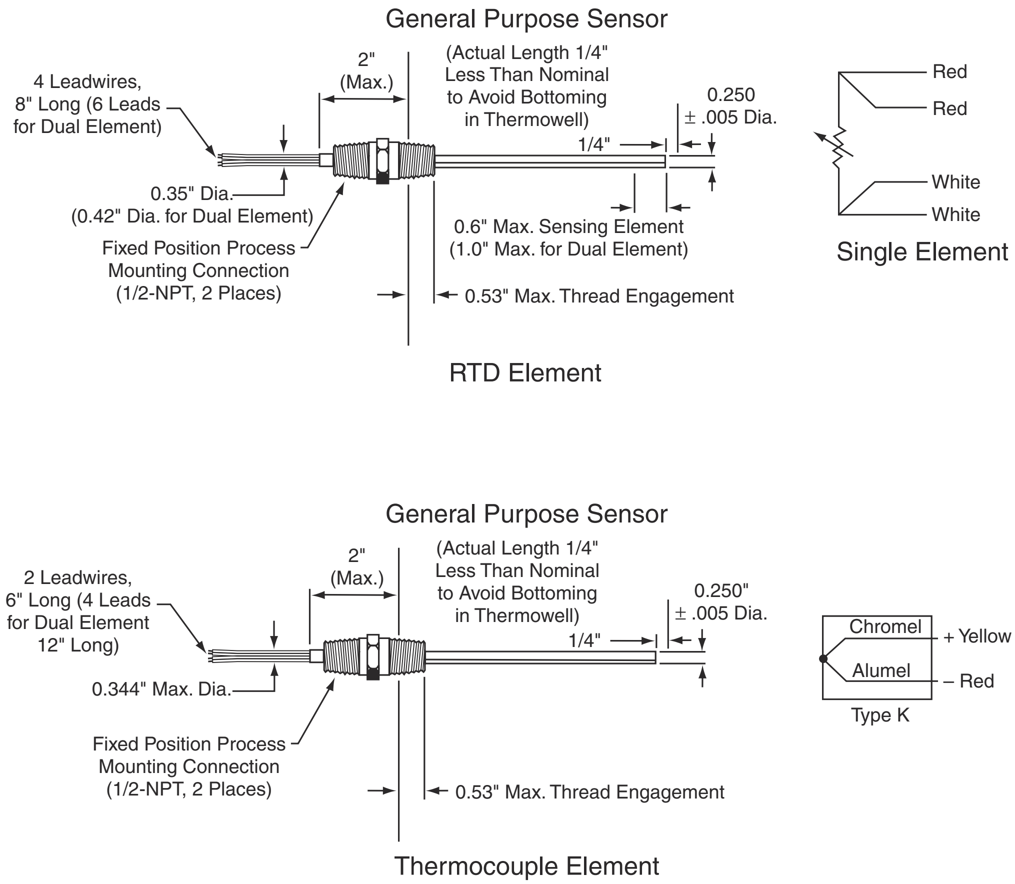

Figure 5-11 Typical temperature elements

Temperature

Temperature sensing is not encountered in water system applications as frequently as level and pressure sensing; however, depending on the specific details of a treatment process, temperature signals may be quite important. Also, temperature measurements often monitor performance of large pumps to detect abnormal operating conditions.

Resistance temperature devices (RTDs) and thermocouples are the two most common temperature sensors. The RTD sensor is a precision-wound metallic element inside a corrosion-resistant sheath. The element is encapsulated in a fill material. Changes in temperature cause a change in the resistance of the metallic element. The change is then calibrated and converted to a conventional output signal for indicating temperature.

A thermocouple is made from the connection of two dissimilar metals. When two thermocouples at different temperatures are connected together, a thermoelectric current proportional to the temperature difference is produced. This low-level signal can be amplified to produce an output signal representative of the temperature difference.

Examples of RTDs and thermocouple temperature sensors are shown in Figure 5-11.

The sensing devices can be installed either directly in the process or device, or in a thermowell. The thermowell is a corrosion-resistant fitting that protects the

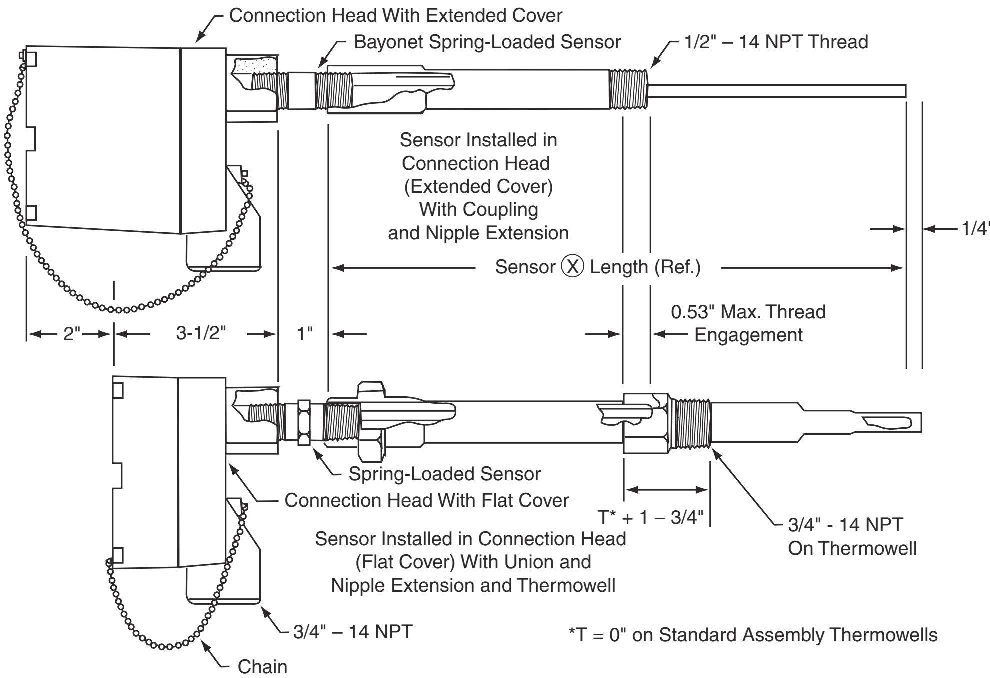

Figure 5-12 Thermowell

temperature-sensing device from direct contact with the process fluid. Figure 5-12 illustrates installation of an RTD- or thermocouple-type temperature sensor with and without a thermowell.

The accuracy of a temperature-sensing system depends on the matching of a sensor and transmitter to meet a particular situation. Generally speaking, sensing accuracies of ±0.5°C can be obtained.

ELECTRIC POWER AND EQUIPMENT STATUS

Not directly related to water or process measurements but equally important are measurements of electric power and equipment status.

Electric Power

With increasing costs for electrical power, the need for monitoring voltage, current, and electric power use is increasing. Expensive, large motors are commonly monitored for voltage and current. Motor voltage and current signals can be converted into 4–20 mA DC process signals for input into the instrumentation system. Figure 5-13 illustrates current transformers that provide output signals proportional to the motor current. A current transformer is mounted on one phase of the motor, and the secondary output of the current transformer is connected to the signal converter. The bottom portion of the illustration in this figure shows a method of scaling that may be useful in matching current transformer output to input requirement of the signal converter. For voltage measurements, similar signal converters are used. The necessary scaling transformer is installed on the input side.

Caution should be observed in providing signal converters for current and voltage monitoring in high-voltage equipment. Particularly in the case of current transformers,

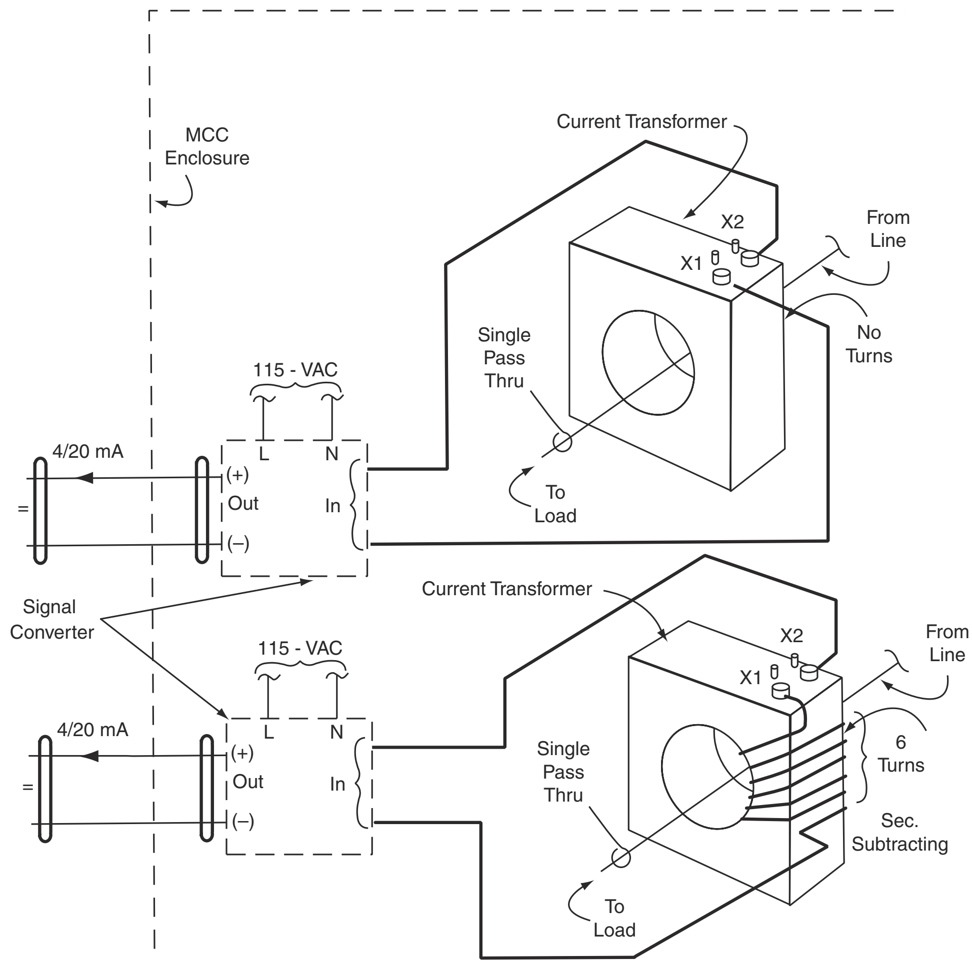

Figure 5-13 Motor current sensor

if the secondary of the transformer is disconnected from the signal converter when current is flowing through the main line, dangerously high voltages can occur on the transformer secondary. For this reason, the signal converters should be mounted within a motor control enclosure. The motor control center must be opened to access the signal converter, and automatic interlocks ensure that power is off.

Current transducers are also available that incorporate an integral transducer to provide a 4–20 mA output without a separate transducer. The transducer portion is loop-powered so that no additional power source is required.

Individual watt transducers can also be provided for individual electric motors to monitor the power being consumed by each device. These transducers monitor both current and voltage and produce an output signal proportional to total power being used by the motor. These devices are suitable for mounting directly in the individual motor control center and incorporate current transducers.

Current and voltage information is primarily used with power and demand monitoring. A more detailed discussion of power monitoring has been included in chapter 2.

Equipment Status Monitoring

A number of operating conditions associated with major equipment should be monitored. Vibration should be monitored in a plant process control system, particularly for large, expensive equipment, such as pumps and blowers. Excessive vibration can quickly cause significant damage to this equipment, particularly when operated at higher speeds (above 1,800 rpm). Vibration sensors are available which, when mechanically attached to the particular piece of equipment, will activate a contact closure when vibration levels exceed a specific acceleration or *g* value. To minimize problems associated with adapting equipment to accommodate these sensors in the field, vibration sensors could be included as part of the specifications. Analog vibration sensors are also available. These devices produce an analog 4–20 mA DC output signal proportional to the magnitude of the vibration within the specified range of the particular sensor.

Position and speed are two other equipment status conditions that can be monitored. Position transmitters normally work with variable resistance devices mechanically linked to equipment. The output of the variable resistance device is then converted to a 4–20 mA DC signal for monitoring. Speed transmitters are usually tachometers driven by equipment being monitored. The tachometers produce a voltage converted to standard current values for monitoring.

With some equipment, particularly clarifier drives, torque is another variable sometimes monitored. Torque sensing is normally used to shut down circuits to prevent damage to the equipment. Torque-sensing equipment can be supplied to produce either a contact closure when torque rises above a preset value or can be supplied with converters that produce a 4–20 mA DC signal proportional to the magnitude of the torque.

Larger pumps and motors incorporate discrete sensors that measure parameters, such as temperature, pressure, and position. These discrete sensors are installed for safety monitoring and sequential control operations.

PROCESS ANALYZERS

With increasingly stringent requirements for water quality, analytical equipment that measures process variables is used more frequently in water systems. No discussion of primary sensors would be complete without some discussion of process analytical devices that may be used for these applications.

Turbidity

Turbidity monitoring is almost mandatory for the effluent from granular media filters. Raw water turbidity is frequently measured as well as settled water and finished water leaving the treatment plant. These measurements show water quality improvement at different stages in the treatment process.

Early turbidity monitoring equipment used a sensor to detect changes in the amount of light transmitted through a sample. This concept of sensing was found to be nonresponsive, particularly when measuring very low turbidity levels. Currently, turbidity sensing devices monitor the intensity of light scattered from turbidity particles when a beam of light is passed through the sample. The most common method measures the amount of light scattered in a direction at 90° to the path of the light beam. This type of turbidity monitoring has found widespread use for filter effluent turbidity. Figure 5-14 illustrates this principle of light scatter for turbidity sensing.

At higher turbidity levels, this concept will not be practical because the scattered light at high levels of turbidity cannot be measured accurately. One successful method