PROCESS CONTROL SYSTEMS

6

LEARNING ACTIVITY PACKET

LEVEL MEASUREMENT

AMATROL

INTEGRATED SYSTEMS TECHNOLOGY

B270-XD

LEARNING ACTIVITY PACKET 6

LEVEL MEASUREMENT

INTRODUCTION

Level is one of the most commonly measured process variables. Some processes require precise measurement and control of level. One example is a chemical process which requires that the level in the reaction tank be maintained at a specific level so the chemicals are properly mixed.

This LAP covers how a number of level sensing devices operate and how to interpret their electrical signals in physical units of the level, such as feet or meters.

The last segment covers how to use a process meter to display the output of a level sensor. Process meters are commonly used to provide a visual indication of the status of a process variable.

ITEMS NEEDED

Amatrol Supplied

1	T5552 Process Control Learning System

School Supplied

1	Water (10 gallons)
1	Compressed Air Supply
1	Digital Multimeter

FIRST EDITION, LAP 6, REV. C

Amatrol,Inc., P.O. Box 2697, Jeffersonville, IN 47131 USA, Ph 812-288-8285, FAX 812-283-1584 www.amatrol.com

TABLE OF CONTENTS

SEGMENT 1

LEVEL SENSOR OPERATION

OBJECTIVE 1 DESCRIBE THE FUNCTIONS OF THE TWO PARTS OF A SENSOR: THE TRANSDUCER AND THE TRANSMITTER

Read This

A sensor is a device that responds to some type of physical input (e.g. pressure, thermal energy, magnetism, motion, etc.) by producing an output signal, usually electrical, as shown in figure 1.

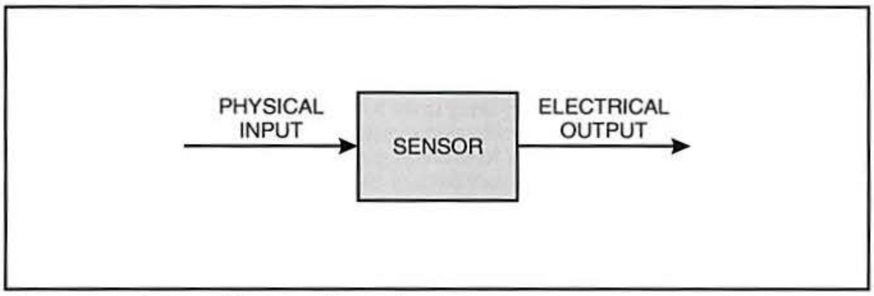

Figure 1. General Sensor Function

The two main parts of a sensor are the transducer and the transmitter, as figure 2 shows. The transducer converts the physical input into a variable electrical measurement (e.g. variable resistance, variable capacitance, etc.). The transmitter then creates an electrical output signal that is sent to a controller or some other device.

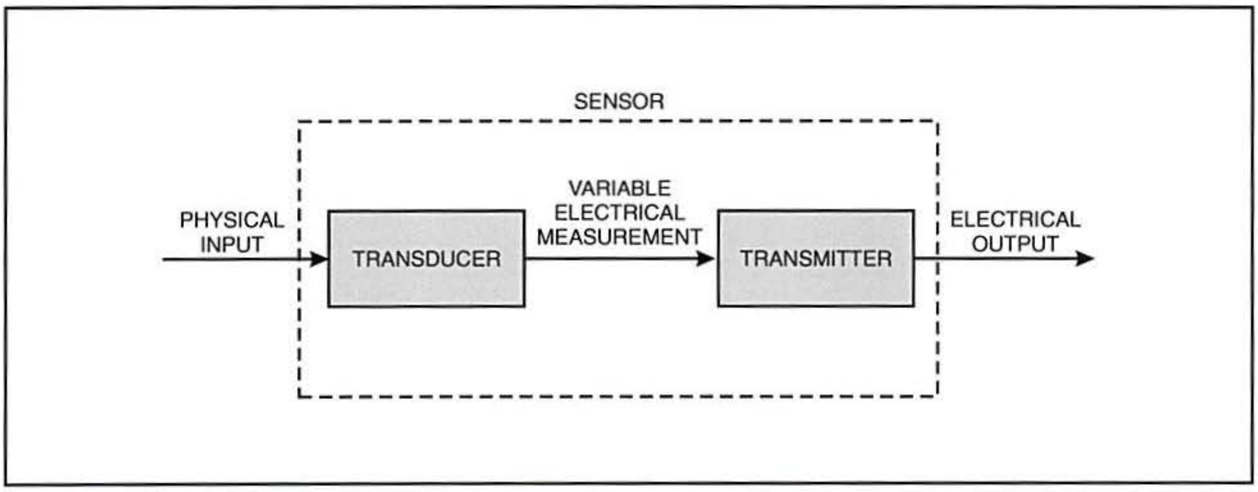

Figure 2. Two Main Parts of a Sensor

Some sensors, like the pressure sensor in figure 3, are made with the transmitter and transducer built into the sensor housing. The sensor receives a pressure input signal and produces an electrical output signal that is proportional to the pressure.

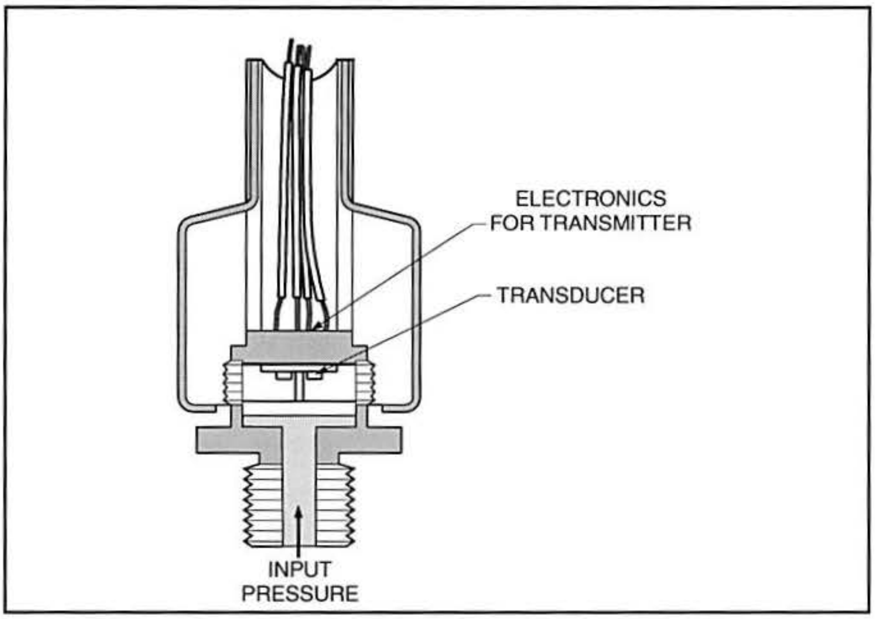

Figure 3. Pressure Sensor with an Internal Transmitter and Transducer

In other cases, the transducer and transmitter are packaged separately. Figure 4 shows an example of a flow transducer with an external transmitter. As liquid flows over the blades, the paddle wheel rotates. This generates a frequency output that is sent to an external transmitter and converted to an analog output.

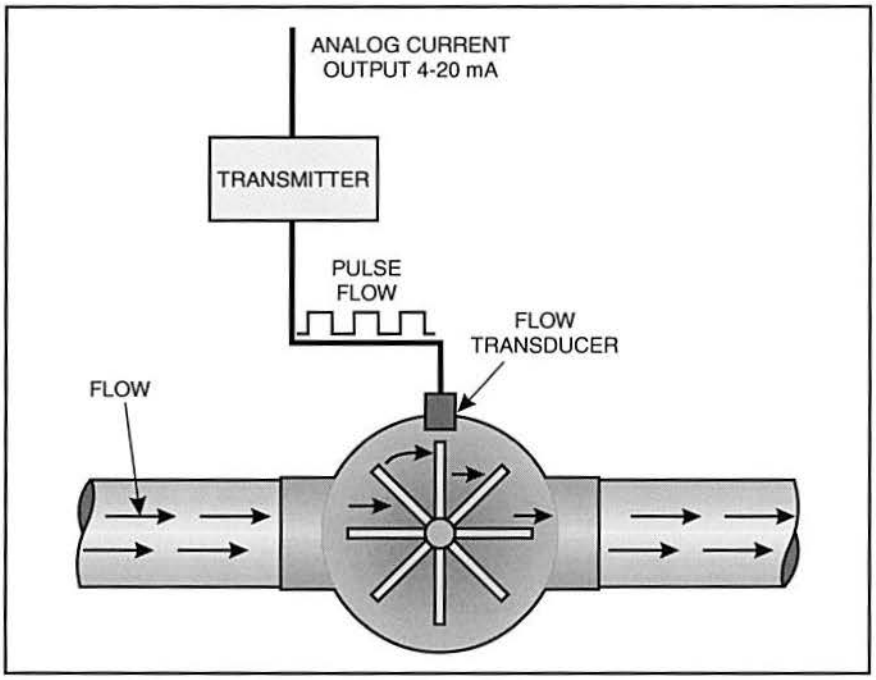

Figure 4. Flow Transducer with External Transmitter

OBJECTIVE 2 DESCRIBE TWO TYPES OF ANALOG TRANSMITTER SIGNAL OUTPUTS

Read This

Transmitters are designed to provide two types of analog signal outputs:

- DC Voltage
- DC Current

Voltage producing transmitters most often produce a 0 volt output when the physical input signal (i.e. pressure, temperature, etc.) is also at zero. As the physical input signal increases, the voltage also increases in a proportional or straight line manner. For example, the graph in figure 5 shows the output of a 0-10 V pressure transmitter. The transmitter produces 0 volts at 0 psi and 10 volts at 1 psi.

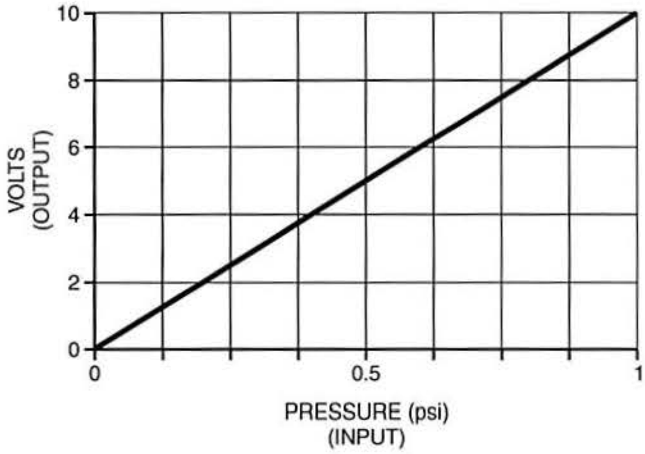

Figure 5. Pressure Input/Voltage Output Chart for a Transmitter

Transmitter outputs can have a minimum value other than zero. The current producing transmitter represented in figure 6 has a range of 4 to 20 milliamps (mA), where an output of 4 mA actually represents a zero physical input signal and 20 mA represents the output at maximum input, or full range. The output graph is still proportional but shifted up, or offset, as shown in figure 6. Manufacturers state the range for a transmitter in their specifications.

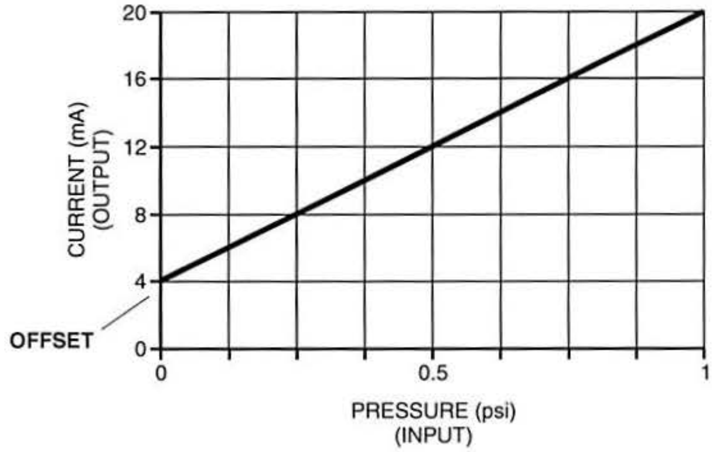

Figure 6. Pressure Input/Current Output Chart for a Transmitter

OBJECTIVE 3

DESCRIBE FOUR METHODS OF SENSING LEVEL AND GIVE AN APPLICATION OF EACH

Read This

There are a variety of sensors used to measure level. The type used depends on the application. Four methods of sensing level are:

- Pressure
- Electrical Resistance
- Electrical Capacitance
- Ultrasonic

Pressure

Pressure-type level sensors measure level by measuring the pressure of the liquid at the bottom of a container. This pressure is then converted to an analog electrical signal that is proportional to the liquid level in the tank. Figure 7 shows an example of a pressure-type level sensor. This type of level sensor has an internal transmitter that produces a 4-20 mA electrical current output.

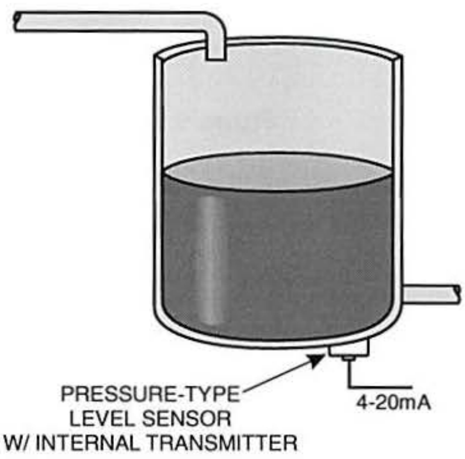

Figure 7. Pressure-Type Level Sensor Application

Pressure-type level sensors are often used in wastewater treatment tanks, chemicals, and fuel manufacturing. Common types of pressure-type level sensors include strain-gage pressure sensors, bubbler systems, and variable capacitance pressure sensors.

Electrical Resistance

A resistance level sensor measures liquid level by changing its resistance as the level changes. This resistance is then converted to an analog electrical signal that is proportional to the liquid level in the tank. An example of this type of sensor is a resistance tape level sensor, as shown in figure 8. It consists of a metal base strip and a wire winding.

When the sensor is placed in a liquid, the pressure causes the winding to contact the base strip. This contact creates a change in the resistance of the wire that is proportional to the change in level. An internal transmitter converts the resistance measurement to a 4-20 mA output.

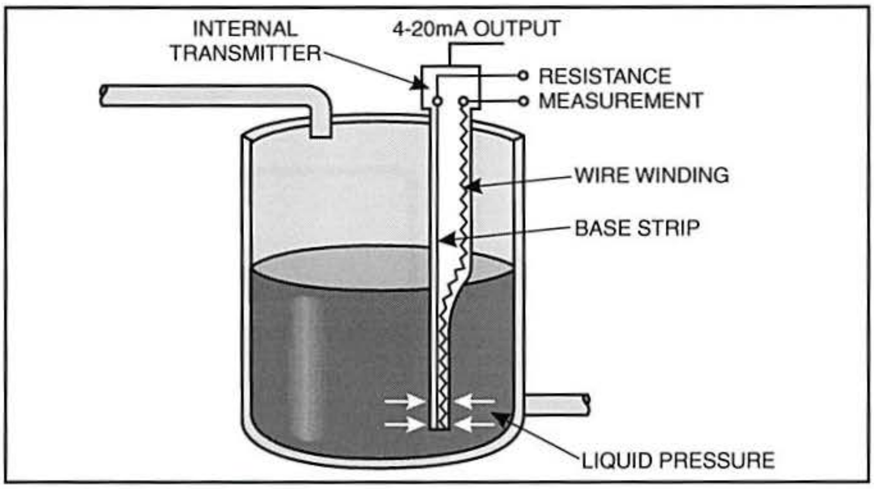

Figure 8. Submersion (Resistance Tape) Level Sensor

Resistance tape level sensors are often used to measure raw sewage, sludge, and gasoline levels.

Electrical Capacitance

A capacitive sensor measures level by measuring the change in capacitance caused by a change in level. This change in capacitance is then converted to an analog electrical signal that is proportional to the material level in the tank.

A capacitive sensor, as shown in figure 9, forms a capacitor using a sensor probe as one of the plates, the vessel wall as the other plate, and the material in the container as the dielectric material. As the material level changes, the capacitance also changes. The sensor contains electronic circuitry that senses the change in capacitance and produces a proportional electrical output that is usually a 4-20 mA current.

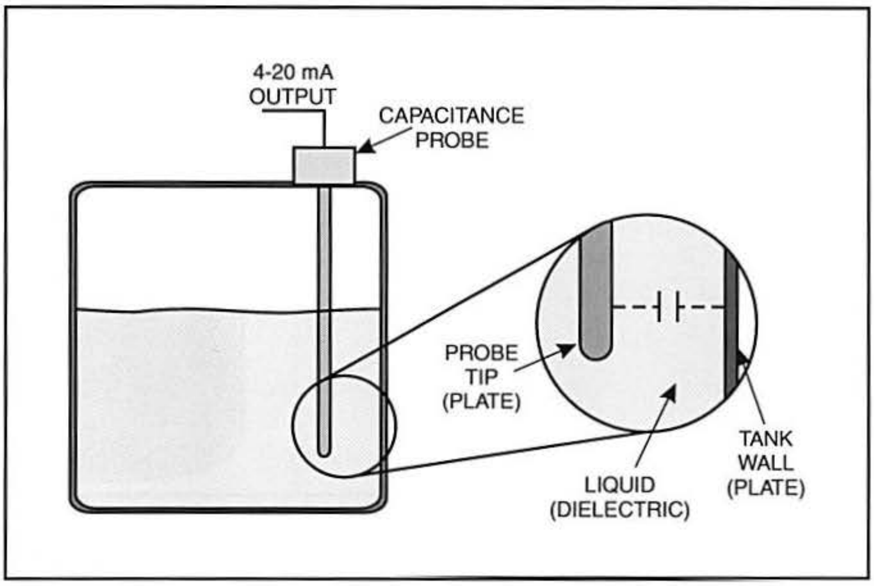

Figure 9. Capacitive Level Sensor

Capacitive sensors are generally used with non-conductive, non-corrosive materials. A common application of capacitive level sensors is to measure refrigerant liquid level.

Ultrasonic

Ultrasonic level sensors measure the level in the tank by transmitting ultrasonic waves and measuring the time it takes for the reflected waves to return to the sensor. The sensor converts this time measurement into an analog electrical signal that is proportional to the liquid level in the tank. An internal transmitter produces a 4-20 mA output, which can be sent to a controller or some other device.

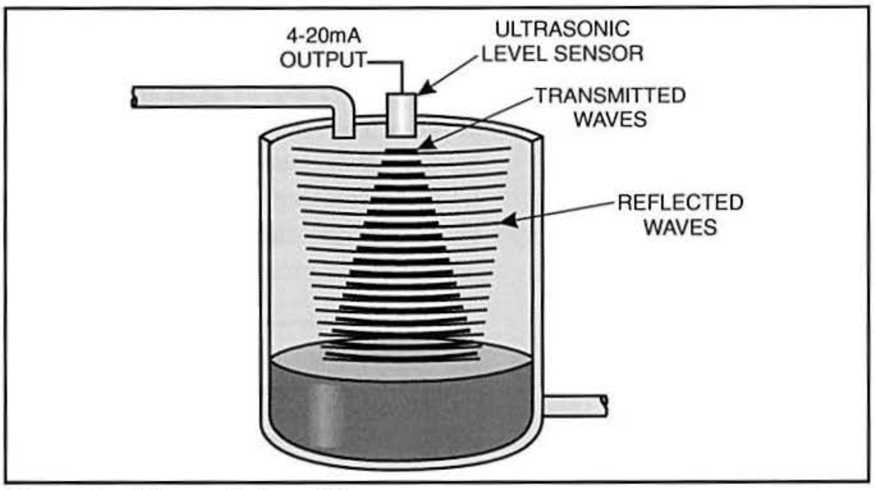

Figure 10. Ultrasonic Level Sensor

Applications for ultrasonic level sensors include measuring the level of chemicals that can become contaminated through any type of contact. Ultrasonic sensors are also used to measure the level of combustible fluids.

OBJECTIVE 4 DESCRIBE HOW TO MEASURE LIQUID LEVEL USING A PRESSURE SENSOR AND GIVE AN APPLICATION

Read This

A volume of liquid in a tank exerts pressure on the bottom of the tank due to its weight. This pressure is referred to as hydrostatic pressure, which is commonly measured in pounds per square inch (psi).

Pressure can also be expressed in terms of the height of the liquid. In this case, it is referred to as hydrostatic head and is measured in feet/inches or meters/centimeters.

Figure 11 shows an example of the pressure on the bottom of a tank expressed in terms of hydrostatic pressure and hydrostatic head. The amount of pressure or head depends on the height and the density of the liquid. Increasing the liquid level in the tank increases the pressure at the bottom of the liquid column. Decreasing the liquid level in the tank decreases the pressure.

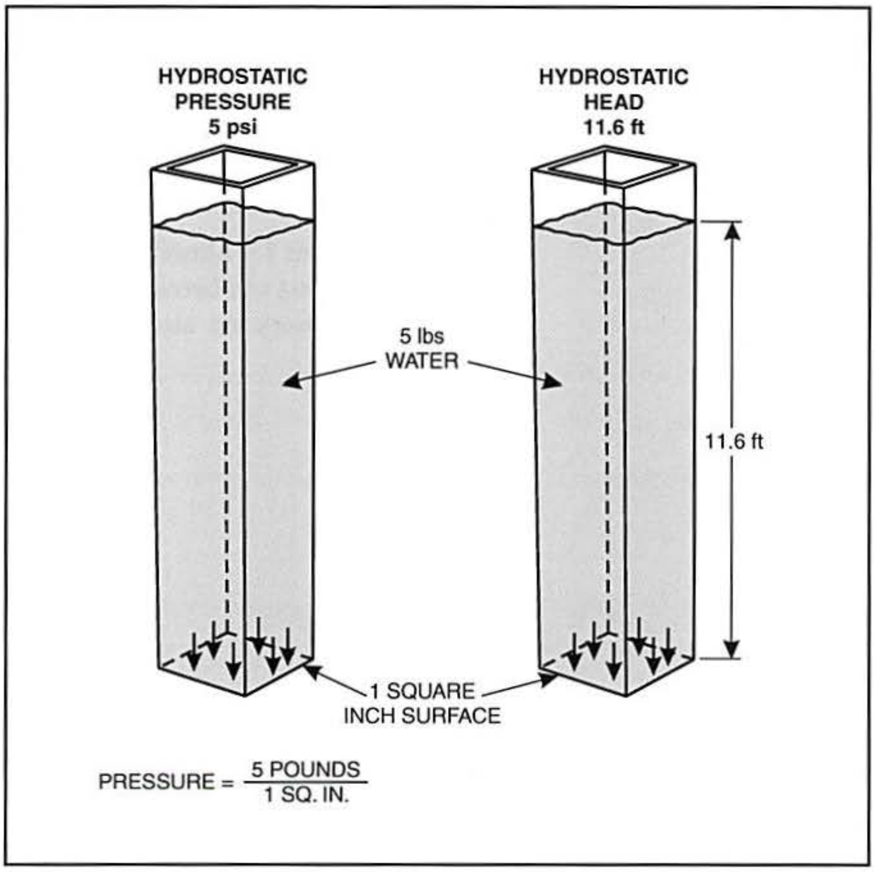

Figure 11. Hydrostatic Pressure Vs. Hydrostatic Head

Level Measurement in an Open Container

Hydrostatic head, or head, can be measured in an open container by placing an analog pressure sensor at the bottom of the tank. Since the pressure at the bottom of the tank is equal to the sum of the atmospheric pressure (P_1) and the hydrostatic pressure, a pressure sensor that measures gage pressure is used. Gauge pressure indicates the amount of pressure above atmospheric pressure. This type of sensor subtracts the effect of the atmospheric pressure (P_{abs}) so that the signal measured is only the hydrostatic pressure.

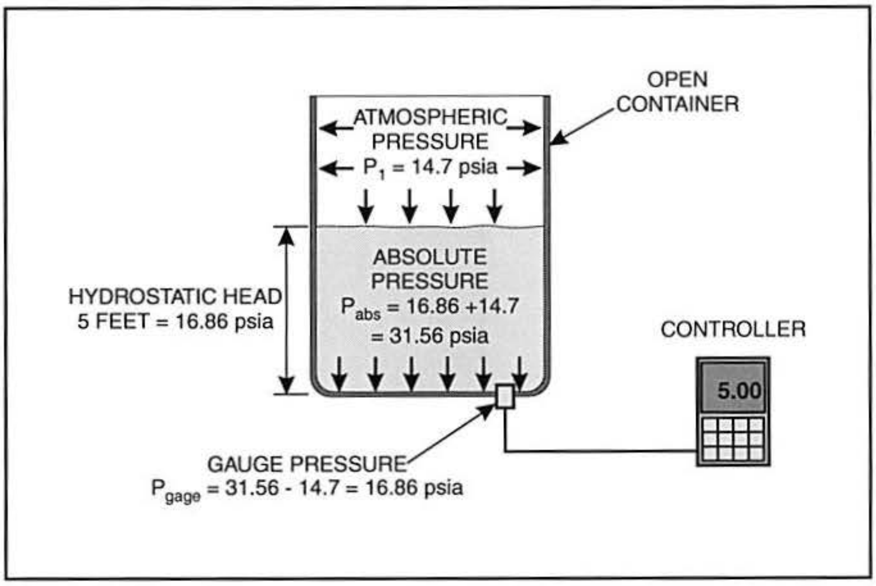

Figure 12. Open Tank Level Measurement Using Pressure-Type Level Sensor

Level Measurement in a Closed Container

If the liquid is held in a pressurized tank, standard head pressure measurement is not accurate because the pressure at the bottom of the tank is greater than the sum of atmospheric pressure and hydrostatic pressure.

For example, in figure 13, the pressure measured by the sensor is 46.86 psia, which is the sum of the air pressure in the tank (30 psia) and the liquid or hydrostatic pressure (16.86 psia). Therefore, the controller indicates a level of 74.44 ft even though the actual liquid level is only 5 ft.

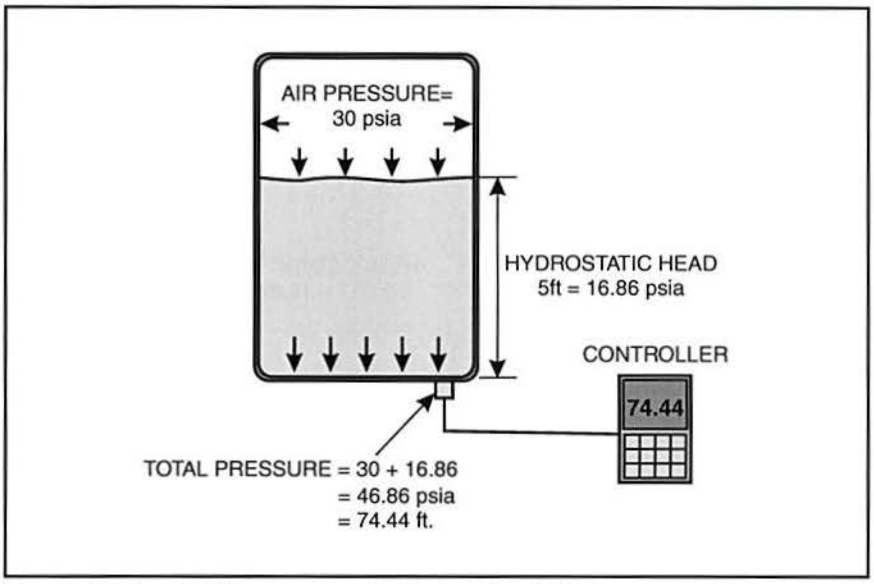

Figure 13. Level Measurement in Pressurized Tank

The solution to this problem is to use a differential pressure sensor to monitor the level in the tank. This method uses two taps in the tank, one at the top and one at the bottom, as figure 14 shows.

The differential pressure transmitter subtracts the air pressure at the top of the tank from the pressure at the bottom, leaving only the differential pressure, which represents the hydrostatic pressure.

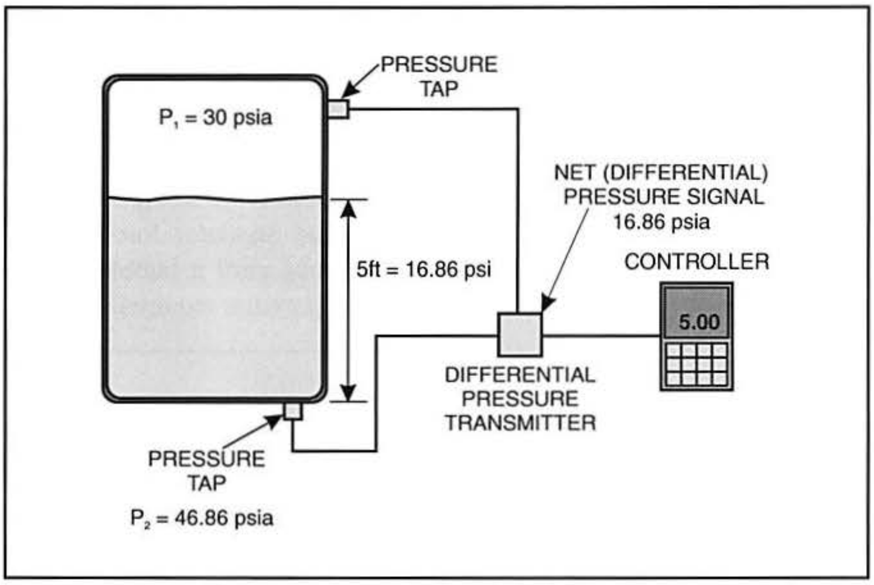

Figure 14. Differential Pressure Measurement

Pressure type level sensors are used in various industries including oil and gas, marine, medical, and space. Differential pressure measurement is commonly used when measuring the level of potentially volatile liquids such as liquid oxygen or hydrogen.

OBJECTIVE 5 DESCRIBE HOW TO MEASURE LIQUID LEVEL USING A BUBBLER AND GIVE AN APPLICATION

Read This

A bubbler system is a type of level measuring device that determines the level of a liquid by measuring the pressure of a gas that is forced out of a tube into the liquid in the tank. This type of system is often used for measurement but seldom for control because its accuracy is not as high as other methods.

Bubbler systems consist of a tube, regulator, gas supply (usually air or nitrogen), and pressure gauge, as shown in figure 15. The tube is placed inside the tank or vessel so that it extends near the bottom of the tank or just below the lowest point of desired level measurement. The gas supply and regulator force a regulated volume of air or nitrogen through the tube until it bubbles out the open end. The pressure gauge measures the pressure required to force the gas out of the tube.

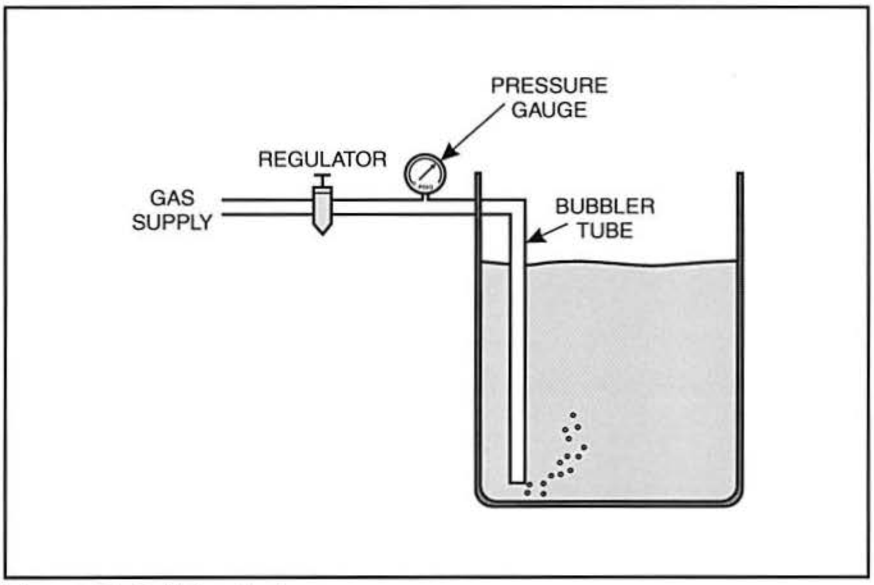

Figure 15. Bubbler System

The pressure required to force the gas out of the tube is approximately equal to the hydrostatic pressure at the bottom of the tank. The hydrostatic pressure can be expressed in terms of height of a liquid column (e.g. inches of water, millimeters of mercury, etc.). Therefore, the operator is able to determine the level. As the level in the tank increases and decreases, the pressure to force the gas out of the tube increases and decreases, respectively.

Bubbler systems are often used in combustible fluid applications. They prevent having an electrical signal in the tank, thereby reducing the risk of fire or an explosion due to a spark. Also, the only wetted part of the bubbler system is the tube, which costs less than a typical pressure sensor. Therefore, the components in a bubbler system should last longer than a system that places a pressure sensor in the bottom of the tank.

Bubbler systems do have some limitations. For instance, a bubbler cannot be used in a sealed tank unless a differential pressure measurement is used or the tank is vented, as figure 16 shows. If the tank is not vented, gas flow stops when the pressure in the open area of the tank equals the hydrostatic pressure. In addition, if the material in the tank has sensitive chemical properties, the introduction of another gas can upset the balance of the materials in the tank.

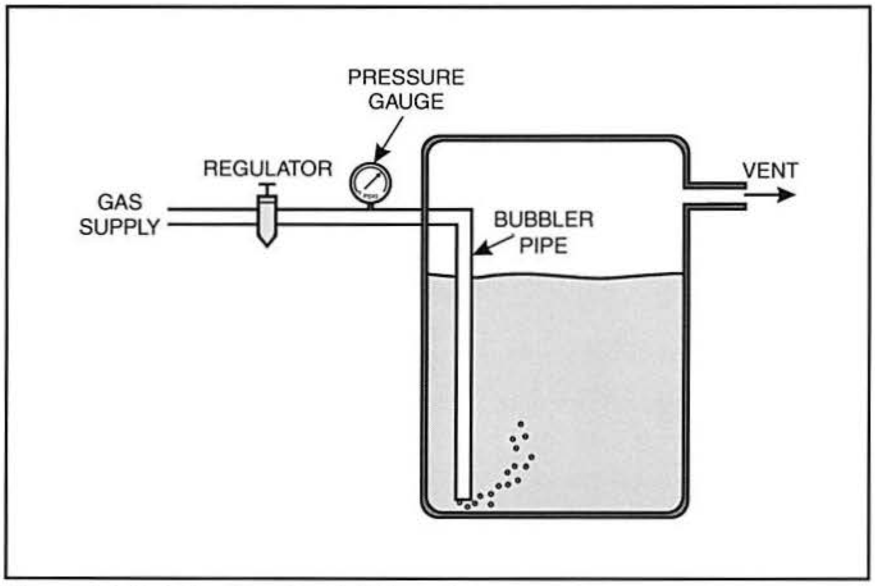

Figure 16. Bubbler in a Sealed Vessel

OBJECTIVE 6 DESCRIBE THE OPERATION OF A VARIABLE CAPACITANCE PRESSURE SENSOR

Read This

One type of electrical pressure sensor is a variable capacitance pressure sensor. This sensor uses a change in capacitance to create an electrical output signal that is proportional to pressure. Figure 17 shows an example of a typical variable capacitance pressure sensor. Common features of variable capacitance pressure sensors include a round or tubular body, a pipe fitting on one end of the sensor, and an electrical connection on the other end of the sensor, as figure 17 also shows.

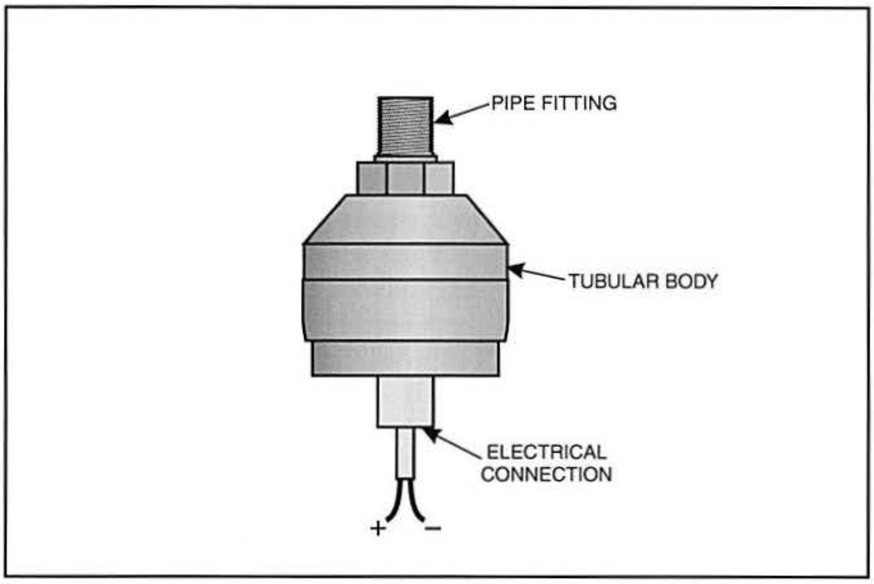

Figure 17. Construction of a Typical Pressure Sensor

Figure 18 shows the internal components of a variable capacitance pressure sensor. It contains a stationary electrode and a flexible diaphragm, usually made of stainless steel. Together they form a capacitor, which is the transducer portion of the sensor. This assembly is connected to electronic circuitry that acts as the transmitter.

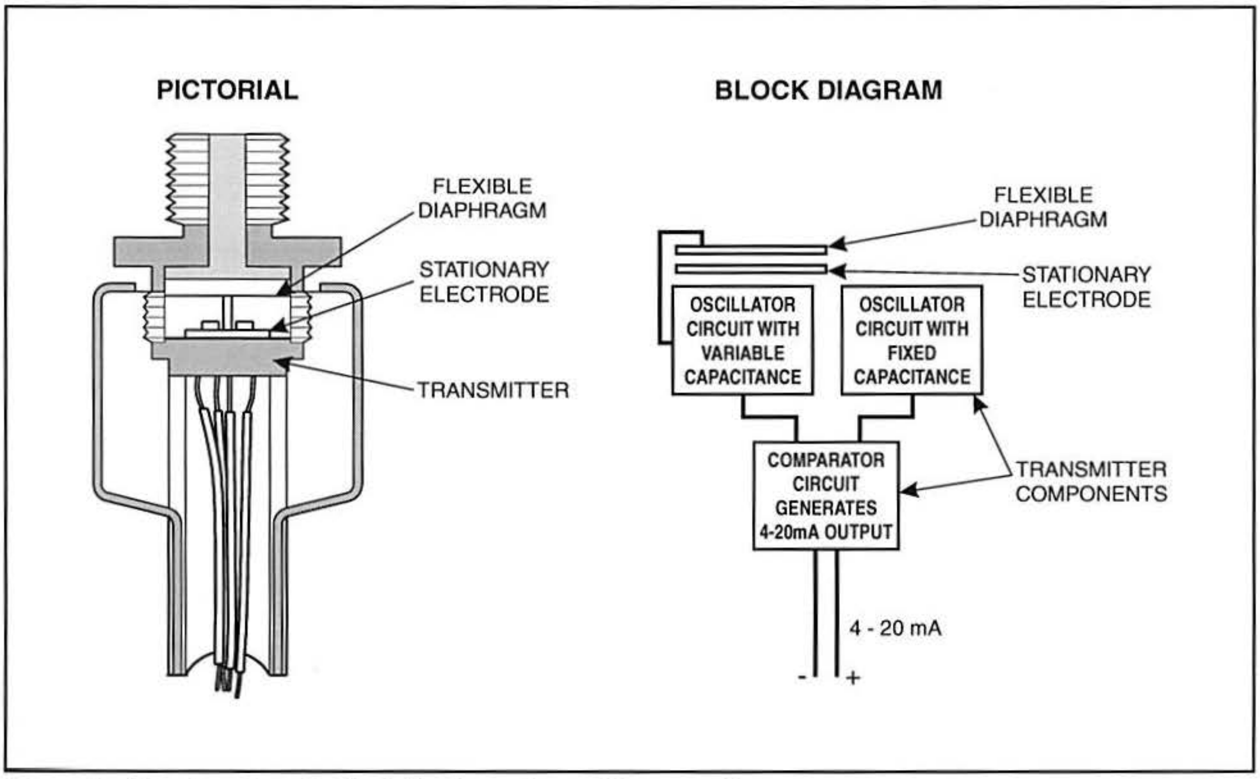

Figure 18. Construction of a Variable Capacitance Pressure Sensor

When fluid pressure acts on the diaphragm, it flexes causing the capacitance to change.

To detect the change in capacitance, this sensor uses two oscillator circuits one connected to a fixed capacitance and the other connected to available capacitance created by the diaphragm. When pressure increases, the frequency of the oscillator circuit connected to the flexible diaphragm changes. A comparator circuit compares the difference in frequency between the oscillator circuit connected to the flexible diaphragm to the frequency of a fixed capacitor oscillation circuit and produces a proportional analog output signal, usually 4-20 mA.

The 4-20 mA analog output signal of a variable capacitance pressure sensor varies linearly with the input pressure, as figure 19 shows.

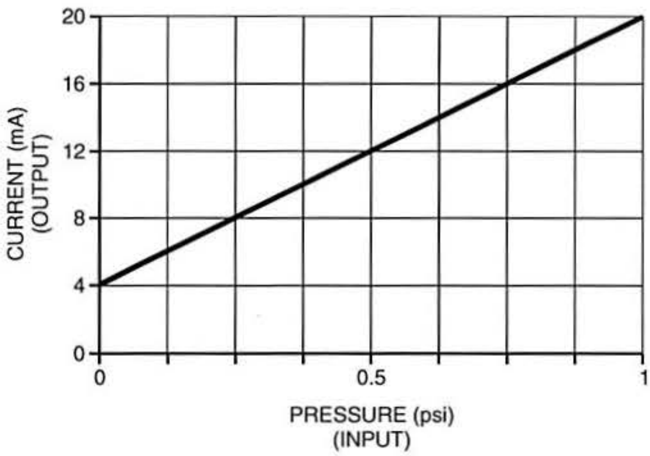

Figure 19. Linear Current Input-Pressure Output Relationship of a Variable Capacitance Pressure Sensor

OBJECTIVE 7 DESCRIBE HOW TO USE A MULTIMETER TO MEASURE ANALOG SENSOR OUTPUT SIGNAL

A sensor's output can be tested by using a multimeter to measure the output signals of both voltage and current-producing sensors.

To measure current from a sensor, the leads of a multimeter are connected in series with the sensor output, as shown in figure 20.

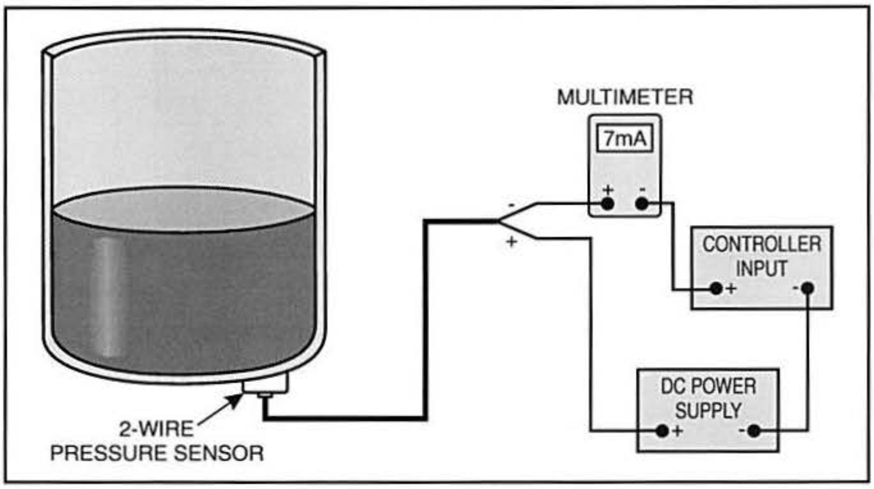

Figure 20. Output from a Pressure Sensor Measured as a Current

The output of a current-producing sensor can also be measured as a voltage by placing a resistor across the input terminals of the controller and connecting the leads of a multimeter across the controller input terminals, as shown in figure 21. This method is also commonly used with digital display meters because they are sometimes designed only to receive voltage input signals.

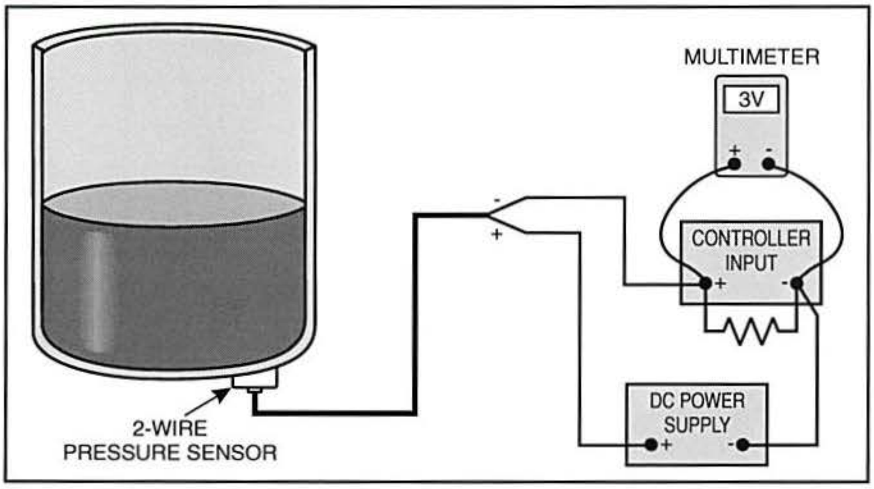

Figure 21. Output from a 2-Wire Pressure Sensor Measured as a Voltage

Many voltage-producing pressure sensors use a 3-wire design. The output voltage can be measured by placing a multimeter across the input terminals of the controller, as shown in figure 22.

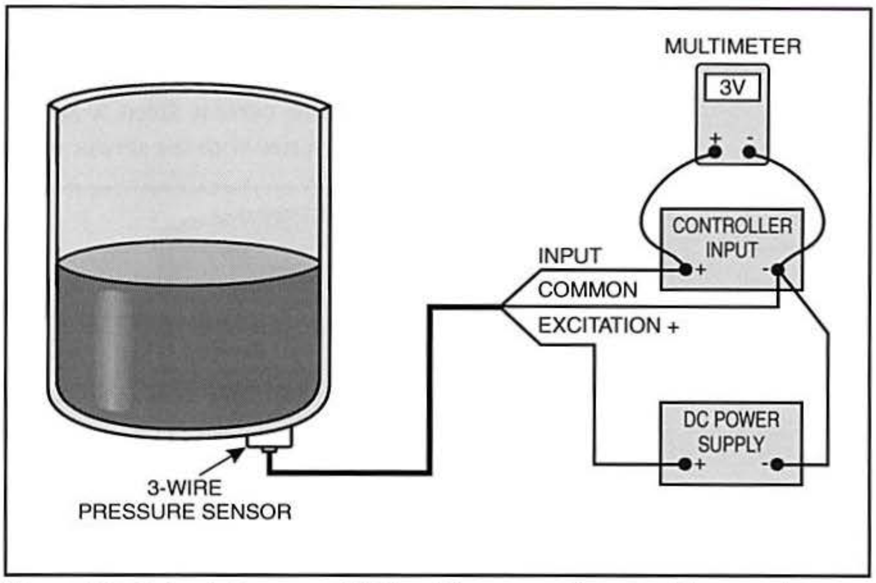

Figure 22. Output from a 3-Wire Pressure Sensor Measured as a Voltage

SKILL 1	CONNECT AND OPERATE A VARIABLE CAPACITANCE PRESSURE SENSOR

Procedure Overview

In this procedure, you will connect a 2-wire variable capacitance pressure sensor to an external power supply on the T5552 process control system. You will then place a digital multimeter (DMM) in the circuit to determine if the sensor produces an output signal.

Do This

❑ 1. Perform a lockout/tagout.

❑ 2. Perform the following substeps to set up the T5552, as shown in figure 23.

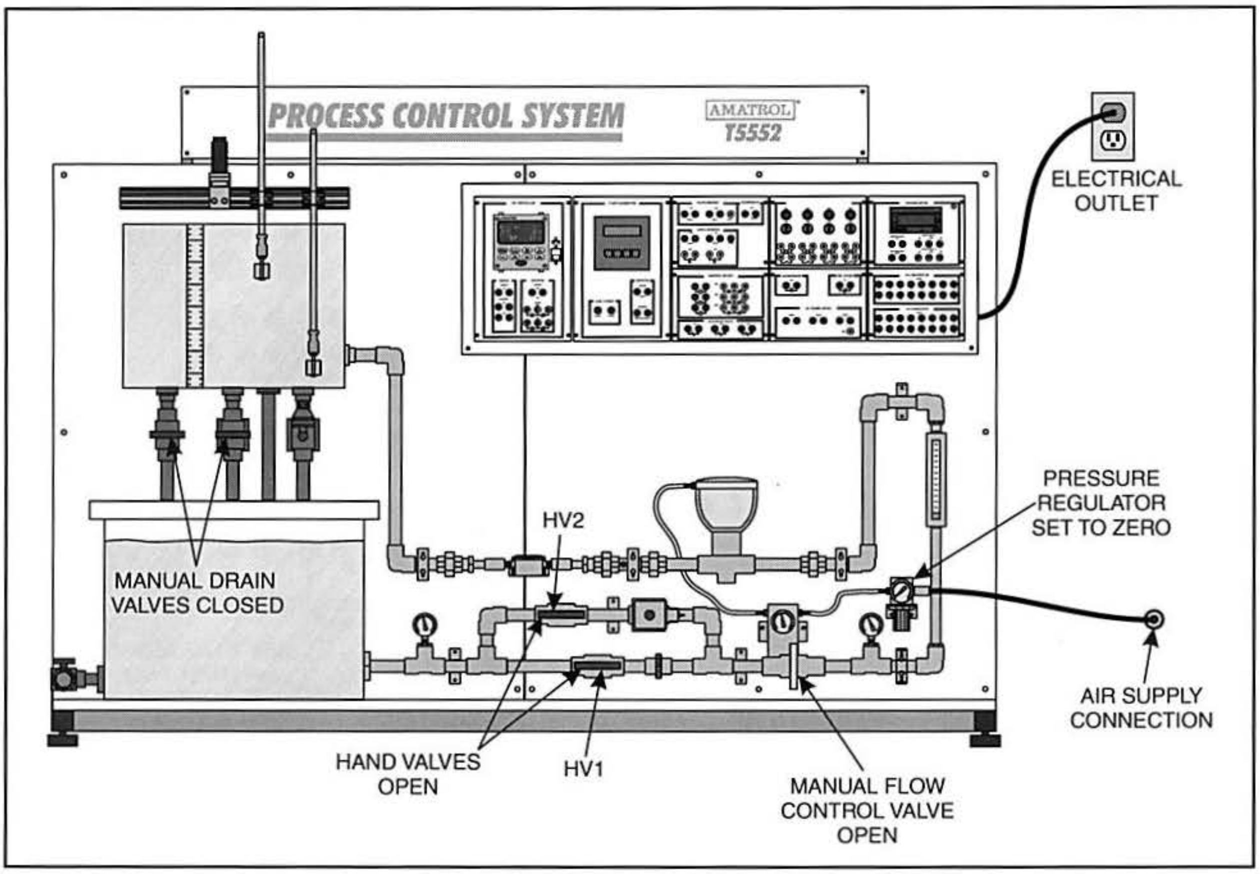

Figure 23. T5552 Setup

A. Connect the air supply line to the T5552.

B. Set the pressure regulator to 0 psi.

You will not control flow with the diaphragm actuator valve in this skill.

C. Fill the reservoir tank with water.

D. Close (turn fully clockwise) the two process tank manual drain valves.

E. Open the manual flow control valve.

F. Locate a digital multimeter (DMM) and set it to measure milliamps (mA).

G. Make sure that the DMM test probes are connected to the appropriate jacks (COM and mA) and the selector switch is set to DC mA.

❑ 3. Locate the pressure sensor attached to the bottom of the tank, as shown in figure 24.

The pressure sensor on the process tank of the T5552 is a variable capacitance type sensor. It has a current producing output with a 4-20 mA range. This sensor's leads are pre-wired to the output jacks on the control panel labeled LT1, as shown in figure 24.

❑ 4. Connect the circuit shown in figure 24.

This circuit allows you to control the flow into the process tank using the hand valves or by turning the pump on and off. It also allows you to measure the output of the pressure sensor (LT1) using the DMM.

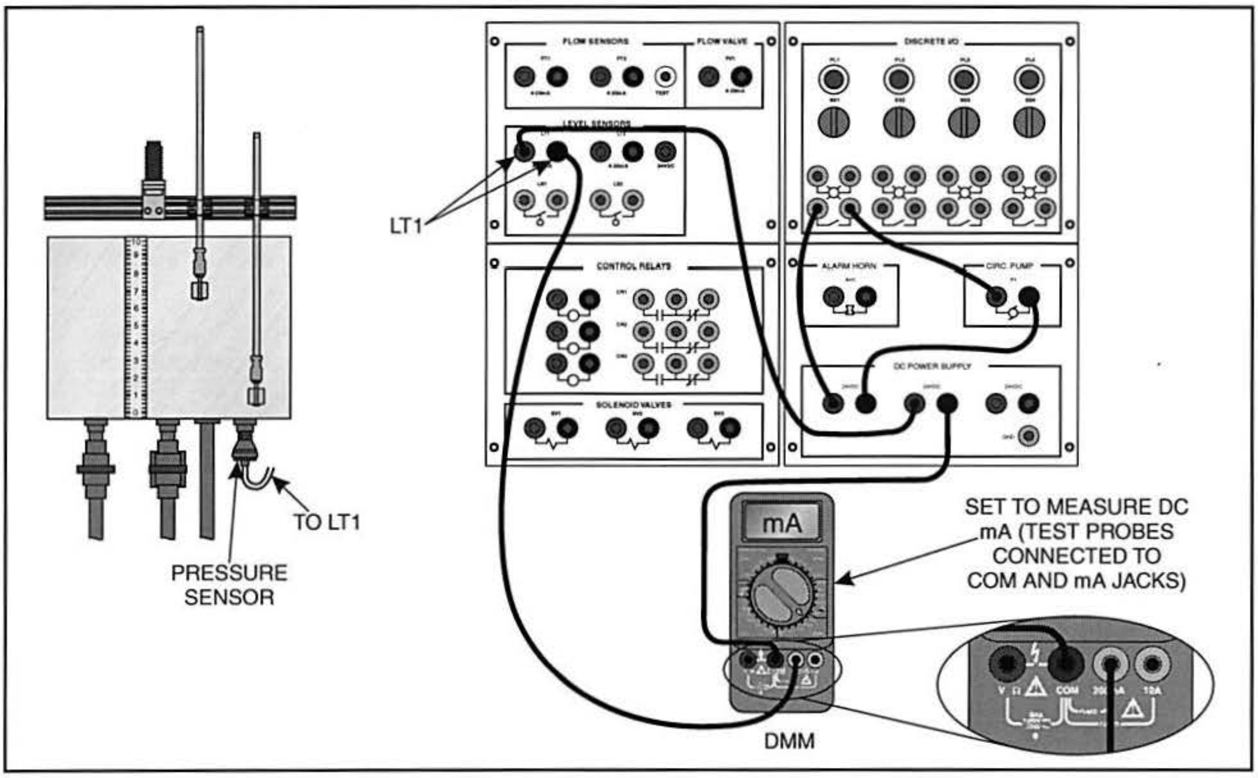

Figure 24. Circuit to Measure Pressure Sensor Output

❑ 5. Remove the lockout/tagout.

❑ 6. Turn on the main circuit breaker.

❑ 7. Perform the following substeps to fill the process tank and determine the effects on the output of the sensor.

A. With the process tank empty, observe the display of the DMM and record the reading.

Pressure Sensor Output ________________________ (mA)

This represents the minimum value of the sensor output for this application.

B. Start the circulation pump by placing selector switch **SS1** in the ON position.

Water should begin to flow into and fill the process tank.

C. Allow the tank to fill for approximately 30 seconds and determine the effect of filling the process tank on the sensor output by watching the DMM display. After 30 seconds, turn off the circulation pump (SS1 off).

Pressure Sensor Output ____________ (Increases/Decreases)

You should find that the sensor output increases as the tank fills because the sensor measures more pressure on the diaphragm.

D. Fully open (counterclockwise) the two process tank manual drain valves and determine the effect of draining the process tank on the sensor output by watching the DMM display.

Pressure Sensor Output ____________ (Increases/Decreases)

You should find that the sensor output decreases as the tank drains because the sensor measures less pressure on the diaphragm.

❑ 8. Perform the following substeps to shut down the T5552.

A. When the process tank is empty, close the manual drain valves by turning them clockwise.

B. Turn off the main circuit breaker.

C. Disconnect the control circuit.

D. Return the DMM to its proper storage location.

SELF REVIEW

1. A ____________ is a device that responds to some type of physical input by producing an output signal.

2. A ____________ converts the input energy of a device to the desired output energy.

3. A ____________ creates and sends the output signal to a controller or some other device.

4. Two types of analog transmitter output signals are DC current and ____________.

5. Four methods of sensing liquid level are electrical capacitance, pressure, ultrasonic, and electrical __________.

6. The pressure that a liquid exerts on the bottom of a tank is called ____________ pressure or head pressure.

7. The pressure exerted on the bottom of a tank depends on the height and __________ of the liquid in the tank.

8. A system that uses a tube through which a gas is forced as a method of sensing pressure is called a ___________.

9. A variable _______________ sensor contains a stationary electrode and a flexible diaphragm.

10. To measure current from a sensor, the leads of a multimeter are connected in _______ with the sensor output.

SEGMENT 2

LEVEL SENSOR SIGNAL MEASUREMENT

OBJECTIVE 8 DEFINE SPECIFIC GRAVITY AND DESCRIBE ITS EFFECT ON LEVEL MEASUREMENT

Read This

Specific Gravity (SG) is the ratio of the weight of a liquid to an equal amount of water. There is no unit of measure for specific gravity because it is a ratio.

The formula below shows how to calculate the specific gravity of a material.

FORMULA: SPECIFIC GRAVITY

$$SG = \frac{M_{material}}{M_{water}}$$

Where:

SG = *Specific Gravity*
$M_{material}$ = *Mass of the material*
M_{water} = *Mass of an equal volume of water*

The specific gravity of a liquid must be known to convert a hydrostatic pressure value into a liquid level. Figure 25 shows that the same level of three liquids with different specific gravities produces a different hydrostatic pressure (in psi).

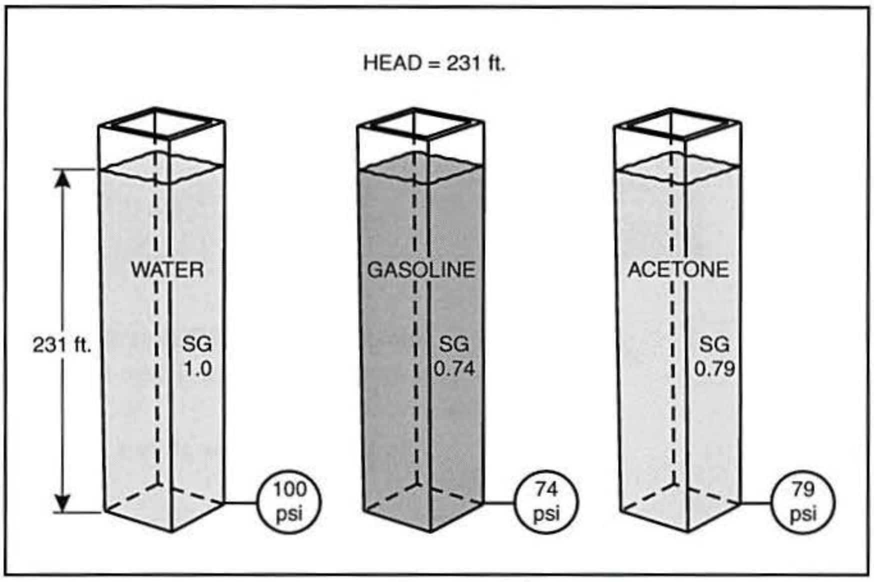

Figure 25. Relationship Between Specific Gravity, Pressure, and Head

The specific gravity of various liquids are shown in figure 26.

LIQUID	SPECIFIC GRAVITY
Acetone	0.79
Corn Oil	0.92
Crude Oil	0.85
Gasoline	0.74
Glucose	1.35 - 1.42
Glycol	101
Molasses	1.45
Soy bean oil	0.93
Tar	1.2
Water (fresh)	1.00
Water (sea)	1.03

Figure 26. Specific Gravity of Various Liquids

A liquid that has a specific gravity greater than 1 (the specific gravity of fresh water) exerts more pressure on the bottom of a tank than water, or any fluid with a specific gravity less than 1.

OBJECTIVE 9 DESCRIBE HOW TO CONVERT LIQUID LEVEL UNITS TO FLUID PRESSURE UNITS

Liquid level units can be converted to fluid pressure units if the level in the tank and the specific gravity of the liquid in the tank are known. Converting liquid level units to pressure units is useful in determining the proper components for the system.

The following formula converts liquid level units to pressure units.

FORMULA: LIQUID LEVEL TO PRESSURE

$$P = L \times SG \times k$$

Where:

P = *Pressure (psi, kPa)*
L = *Level (inches, feet, meters)*
SG = *Specific Gravity*
k = *Conversion Factor* = $0.036\ psi/in$
= $0.432\ psi/ft$
= $9.772\ kPa/m$

Example: Determine the range needed for a pressure sensor for a tank. The maximum level is 25 feet of water, as shown in figure 27.

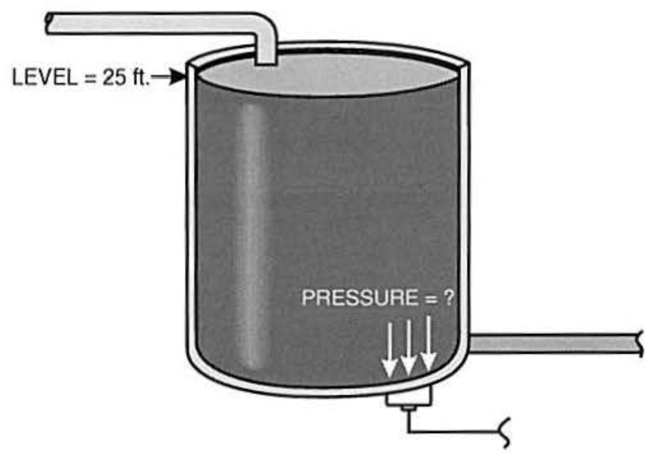

Figure 27. Level Measuring System

The maximum pressure exerted by the water is determined using the level to pressure formula as follows:

$$P = L \times SG \times 0.432$$

$$P = 25 \times 1 \times 0.432$$

$$P = 25 \times 0.432$$

$$P = 10.80\ psi$$

In this case, the pressure sensor must have a wide enough range to handle the 10.8 psi maximum pressure.

SKILL 2 CONVERT LIQUID LEVEL UNITS TO FLUID PRESSURE UNITS

Procedure Overview

In this procedure, you will be given the height of a liquid and asked to calculate the pressure that will be detected by the level sensor. Or, you may be given the pressure and asked to calculate the height of the liquid. This information would then be used to select a level sensor for that application.

Do This

☐ 1. Determine the maximum pressure exerted by a column of liquid given the following scenario.

Scenario: You have a tank that contains glucose at a maximum height of 18.35 ft (5.59 m), as shown in figure 28 and you want to select the proper level sensor for this tank.

Maximum Pressure = ______________________________ (psi/kPa)

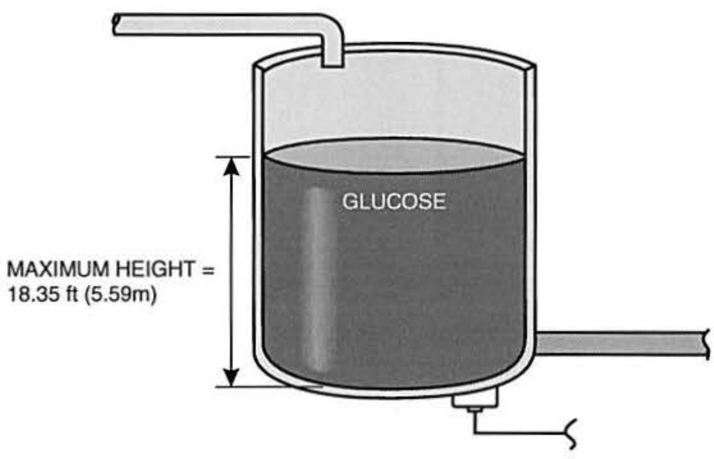

Figure 28. Tank Containing Glucose

Your answer should be 10.70 psi (73.74 kPa) to 11.26 psi (77.57 kPa).

For this application, you would need to select a sensor with an upper range value greater than 11.26 psi (77.57 kPa).

❑ 2. Determine the maximum pressure exerted by a column of liquid given the following scenario.

Scenario: You have a tank that contains tar at a maximum height of 43 ft (13.11 m) and you want to select the proper level sensor for this tank.

Maximum Pressure = ______________________________ (psi/kPa)

You should find that the maximum pressure is 22.29 psi (153.69 kPa).

❑ 3. Determine the maximum pressure exerted by a column of liquid given the following scenario.

Scenario: You have a tank that contains seawater at a maximum height of 98.5 in (2.5 m) and you want to select the proper level sensor for this tank.

Maximum Pressure = ______________________________ (psi/kPa)

You should find that the maximum pressure is 3.65 psi (25.16 kPa).

❑ 4. Determine the height of the column of liquid given the following scenario.

Scenario: You have a tank that contains molasses exerting a pressure of 32.80 psi (226.15 kPa) as shown in figure 29 and you want to determine the column height (level) of the molasses.

Column Height (Level) = ______________________________ (ft/m)

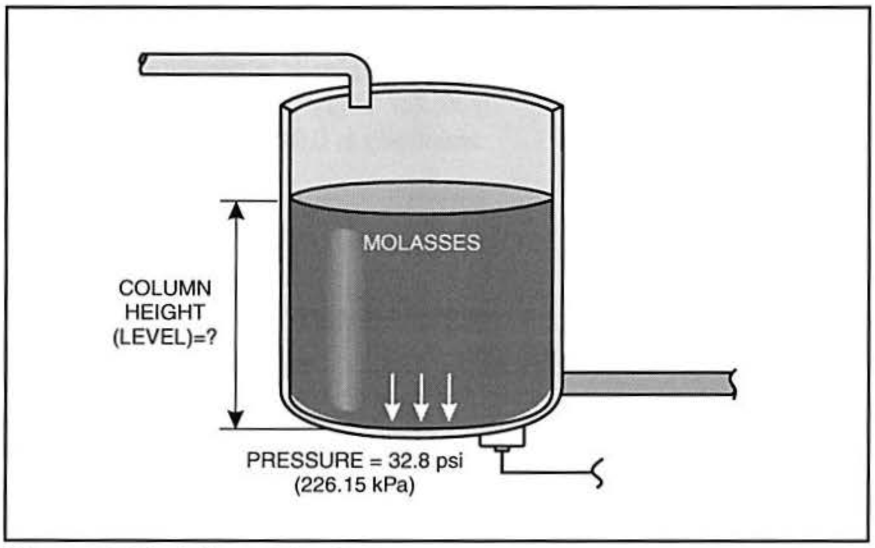

Figure 29. Tank Containing Molasses

You should find that the column height (level) is 52.36 ft (15.96 m).

❑ 5. Determine the height of the column of liquid given the following scenario.

Scenario: You have a tank that contains soybean oil exerting a pressure of 4.82 psi (33.23 kPa) and you want to determine the column height (level) of the soybean oil.

Column Height (Level) = ________________________ (in/m)

You should find that the column height (level) is 144 in (3.66 m).

OBJECTIVE 10 DEFINE SENSITIVITY AND EXPLAIN ITS IMPORTANCE

The sensitivity of a sensor is the amount of change in the electrical signal (output) that occurs for a given amount of change in the physical quantity being sensed (input). This relationship is shown in the following formula:

SENSITIVITY FORMULA

$$S = \frac{\Delta\, O_{Elec}}{\Delta\, I_{Phys}}$$

where

S = *Sensitivity*
Δ = *Amount of Change*
O_{Elec} = *Electrical Output Signal*
I_{Phys} = *Physical Input Signal*

Example: If a pressure sensor increases its electrical signal 0.001 volt for every 1 psi increase in pressure, as shown in figure 30, its sensitivity is 0.001 volts per 1 psi (0.001 volt/1 psi).

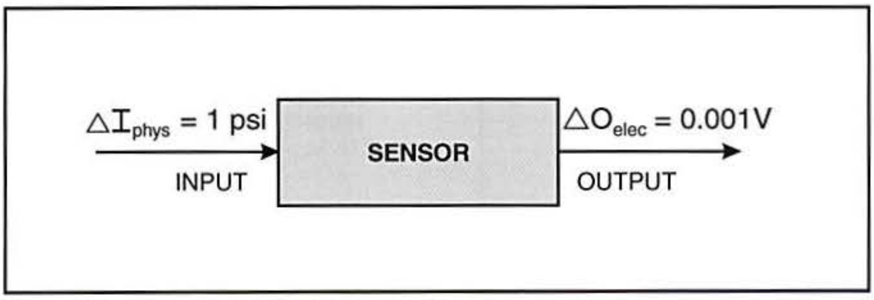

Figure 30. Sensitivity of a Pressure Sensor

Sensitivity is important in process control systems because the end result of the data collection process is not an electrical signal in units of volts or amps but data in units of the quantity being sensed. The sensitivity can be used to calculate the sensor's output in the physical units sensed by the sensor.

OBJECTIVE 11 DESCRIBE HOW TO CONVERT PRESSURE SENSOR OUTPUT SIGNALS TO PRESSURE UNITS

Read This

The sensitivity formula is modified as follows to calculate the signal values in physical units, in this case pressure, for a given current or voltage signal that ranges from zero to some number (e.g. 0-10 V, 0-20 mA).

FORMULA: ELECTRIC SIGNAL TO PRESSURE CONVERSION

(Minimum Output Signal = 0)

$$P_m = \frac{O_m}{S}$$

Where:

P_m = *Measured Pressure*

O_m = *Measured Output Signal Value*

S = *Sensitivity*

Example: Determine the actual pressure exerted on the pressure sensor in figure 31 if the output range of the sensor is 0-5 V and the input range is 0-20 psi.

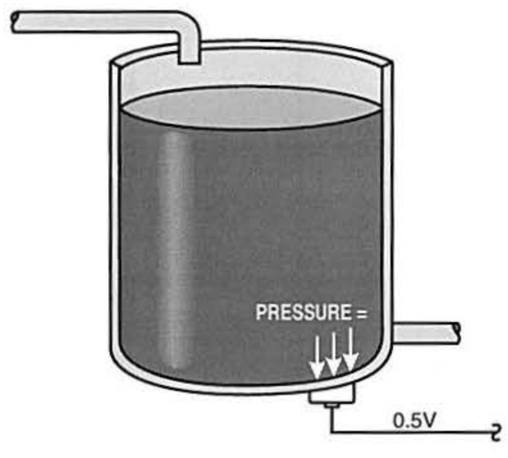

Figure 31. Pressure Sensor Signal to a Electronic Controller

First, determine the sensitivity.

$$S = \frac{5}{20} = 0.25 \ volts\ /\ psi$$

Then, calculate the actual pressure.

$$P_m = \frac{0.5}{0.25} = 2.0 \ psi$$

To calculate signal values for current or voltage producing sensor signals that do not have zero as the minimum output value (i.e. 4-20 mA), the formula must include a deduction for the offset from zero. This is shown as follows:

FORMULA: ELECTRIC SIGNAL TO PRESSURE CONVERSION

(Minimum Output Signal ≠ 0)

$$P_m = \frac{(O_m - O_{min})}{S}$$

Where:

P_m = *Measured Pressure*

O_m = *Measured Output Signal Value*

O_{min} = *Minimum Output Signal Value*

S = *Sensitivity*

Example: Calculate the pressure that the sensor in figure 32 senses using the following information:

Electrical Output Signal Range = 1-5 V

Pressure Input Signal Range = 0-20 psi

Measured Output = 1.5 V

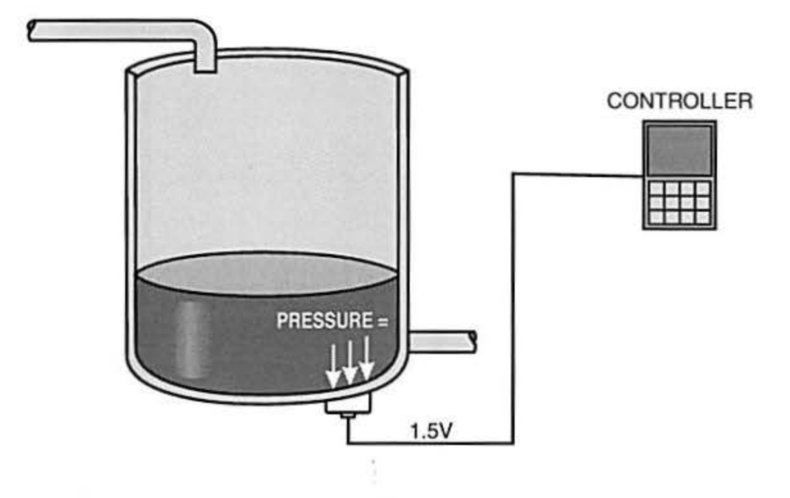

Figure 32. Pressure Sensor with an Output Signal of 1.5 V

To solve the problem, first determine the sensitivity. Then use the sensitivity to determine the measured pressure.

Determine the sensitivity:

$$
\begin{aligned}
S &= \frac{\Delta O_{Elec}}{\Delta I_{Phys}} \\
&= \frac{5V - 1V}{20\ psi - 0\ psi} \\
&= \frac{4\ V}{20\ psi} \\
&= 0.2\ V/psi
\end{aligned}
$$

Determine the measured pressure:

$$
\begin{aligned}
P_m &= \frac{(1.5 - 1)}{0.2} \\
&= \frac{0.5}{0.2} \\
&= 2.5\ psi
\end{aligned}
$$

To calculate the pressure sensor output signal value given the measured pressure input signal value, the previous formula can be rearranged as follows:

FORMULA: PRESSURE TO ELECTRICAL SIGNAL VALUES

$$O_m = (P_m \times S) + O_{min}$$

Where:

O_m = *Measured Output Signal Value*

P_m = *Measured Pressure*

S = *Sensitivity*

O_{min} = *Minimum Output Signal Value*

Example: Determine the value of the measured output signal for the pressure sensor in figure 33 using the following information:

Electrical Output Signal Range = 1-5 V

Pressure Input Signal Range = 0-20 psi

Measured Pressure = 2.5 psi

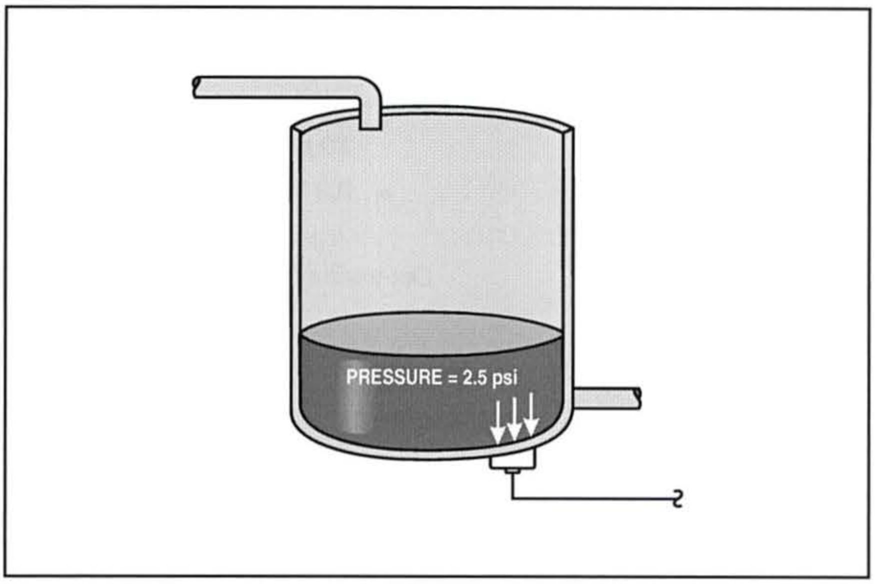

Figure 33. Pressure Sensor Measuring a Pressure of 2.5 PSI

To solve the problem, first determine the sensitivity. Then use the sensitivity to determine the measured output.

Determine the sensitivity:

$$\begin{aligned} S &= \frac{5V - 1V}{20\ psi - 0\ psi} \\ &= \frac{4\ V}{20\ psi} \\ &= 0.2\ V/psi \end{aligned}$$

Determine the measured output:

$O_m = (2.5 \times 0.2) + 1$

$O_m = 0.5 + 1$

$O_m = 1.5V$

SKILL 3 CONVERT PRESSURE SENSOR OUTPUT SIGNALS TO PRESSURE UNITS

Procedure Overview

In this procedure, you will convert pressure sensor output signals to pressure units and vice versa given the pressure and output ranges of the sensor and either the measured output signal or the measured input pressure.

☐ 1. Calculate the pressure sensed by the pressure-type level sensor shown in figure 34. It has a 0-5 psi (0-34.47 kPa) input range and a 4-20 mA output range. The measured output from the sensor is 15 mA.

Pressure ______________________ psi (kPa)

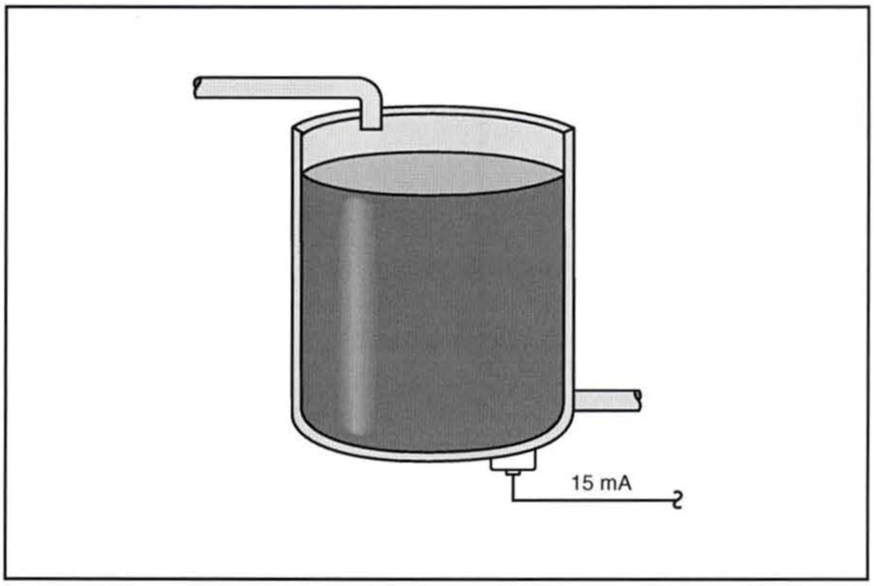

Figure 34. Pressure Sensor with a 15 mA Output

You should find that the pressure is approximately 3.44 psi (23.72 kPa).

☐ 2. Calculate the pressure sensed by a pressure-type level sensor that has a 0-3 psi (0-20.68 kPa) input range and a 1-5 V output range if the measured output is 3.5 V.

Pressure ______________________ psi (kPa)

You should find that the pressure is approximately 1.88 psi (12.96 kPa).

❑ 3. Calculate the pressure sensed by a pressure-type level sensor that has a 0-7 psi (0-48.26 kPa) input range and a 4-20 mA output range if the measured output is 16 mA.

Pressure ________________________ psi (kPa)

You should find that the pressure is approximately 5.25 psi (36.20 kPa).

❑ 4. Calculate the measured output of a pressure-type level sensor shown in figure 35 that has a 0-4 psi (0-27.58 kPa) input range and a 0-20 mA output range if the pressure sensed is 3 psi (20.68 kPa).

Electrical Output ________________________ (mA)

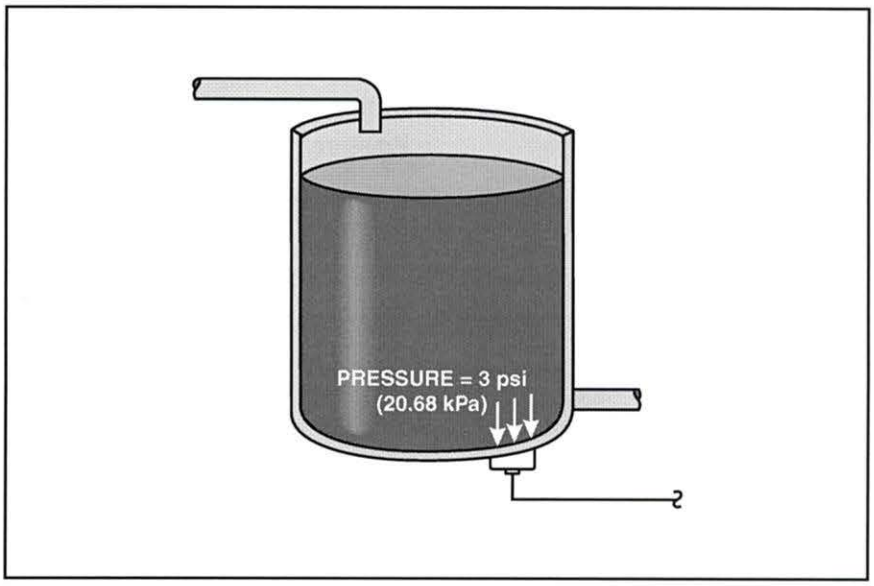

Figure 35. Pressure Sensor Measuring a Pressure of 3 psi

You should find that the electrical output is approximately 15 mA.

❑ 5. Calculate the pressure sensed by the pressure-type level sensor that has a 0-1 psi (0-6.89 kPa) input range and a 1-5 V output range if the measured output is 2 V.

Pressure ________________________ psi (kPa)

You should find that the pressure is 0.25 psi (1.72 kPa).

❑ 6. Calculate the pressure sensed by a pressure-type level sensor that has a 0-15 psi (0-103.42 kPa) input range and a 0-10 V output range if the measured output 8 V.

Pressure ________________________ psi (kPa)

You should find that the pressure is 12 psi (82.74 kPa).

☐ 7. Calculate the measured output of a pressure-type level sensor that has a 0-9 psi (0-62.05 kPa) input range and a 4-20 mA output range if the pressure sensed is 5 psi (34.47 kPa).

Electrical Output ______________________________ (mA)

You should find that the electrical output is approximately 12.9 mA.

☐ 8. Calculate the measured output of a pressure-type level sensor that has a 0-12 psi (0-82.74 kPa) input range and a 1-5 V output range if the pressure sensed is 10 psi (68.95 kPa).

Electrical Output ______________________________ (V)

You should find that the electrical output is approximately 4.33 V.

OBJECTIVE 12 DESCRIBE HOW TO CONVERT LIQUID LEVEL UNITS TO SENSOR OUTPUT SIGNAL UNITS

Read This

Liquid level units are converted to sensor output signal units by first converting the liquid level units to pressure units and then converting the pressure units to sensor output signal units. This calculation is useful in troubleshooting and allows the technician to determine if the pressure sensor is providing the correct output.

Substituting the expression relating liquid level to pressure into the equation that converts pressure units to sensor output signal units gives the following equation:

LIQUID LEVEL TO SENSOR OUTPUT CONVERSION

$$O_m = (S \times L \times SG \times k) + O_{min}$$

Where:

O_m = *Measured Output Signal*
S = *Sensitivity*
L = *Level (inches, feet, meters)*
SG = *Specific Gravity*
O_{min} = *Minimum Output Signal Value*
k = *Conversion Factor*
= $0.036\ psi/in$
= $0.432\ psi/ft$
= $9.772\ kPa/m$

Example: Calculate the measured output of a pressure sensor with a 0-3 psi range and a 1-5 V output signal range if the level of crude oil (SG = 0.85) in the tank is 26 inches. Figure 36 shows this system.

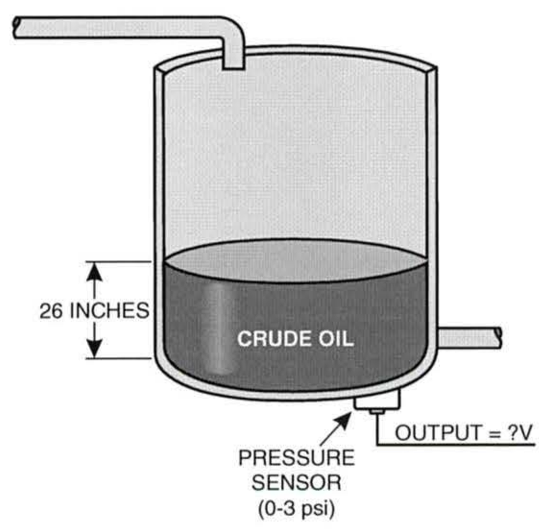

Figure 36. System Measuring Crude Oil Level

Using the equation:

$$O_m = \left(\left(\frac{4}{3}\right) \times 26 \times 0.85 \times 0.036\right) + 1$$

$$O_m = (1.33 \times 26 \times 0.85 \times 0.036) + 1$$

$$O_m = 1.06 + 1$$

$$O_m = 2.06\ V$$

To determine liquid level when given the electrical output, the equation above can be rewritten as follows:

SENSOR OUTPUT SIGNAL TO LIQUID LEVEL CONVERSION

$$L = \frac{(O_m - O_{min})}{(S \times SG \times k)}$$

Where:

L = *Level (inches, feet, meters)*
O_m = *Measured Output Signal*
O_{min} = *Minimum Output Signal Value*
S = *Sensitivity*
SG = *Specific Gravity*
k = *Conversion Factor*
= $0.036\ psi/in$
= $0.432\ psi/ft$
= $9.772\ kPa/m$

Example: Calculate the level (in inches) of soybean oil (SG = 0.93) in a tank if the measured output from a 6 psi sensor with a pressure range of 0-5 psi is 8 mA. The sensor has a 0-20 mA output signal range.

Using the equation:

$$L = \frac{(8 - 0)}{\left(\left(\frac{20}{5}\right) \times 0.93 \times 0.036\right)}$$

$$L = \frac{8}{(4 \times 0.93 \times 0.036)}$$

$$L = \frac{8}{0.134}$$

$$L = 59.74\ inches$$

SKILL 4 CONVERT LIQUID LEVEL UNITS TO SENSOR OUTPUT SIGNAL UNITS

Procedure Overview

In this procedure, you will convert liquid level units to sensor output signal units using the equations to convert liquid level to pressure and pressure to sensor output signal. Refer to Appendix A for the specific gravity of the liquids.

❑ 1. Calculate the current output signal from a pressure-type sensor that has a 0-2 psi (0-13.79 kPa) input signal range if it measures a water level of 21 inches (0.53 m).

The sensor has a 4-20mA output signal range.

Electrical Output Signal ____________________________ (mA)

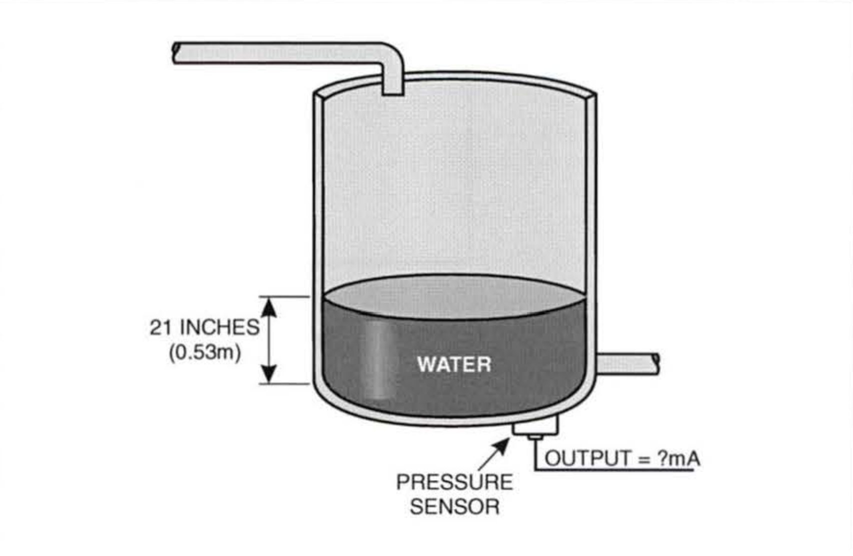

Figure 37. System Measuring Water Level

You should find that the electrical output signal is approximately 10.05 mA.

❑ 2. Calculate the measured output signal from a pressure-type sensor that has a 0-4 psi (0-27.5 kPa) input signal range measuring a water level of 72 inches (1.83 m). The sensor has a 4-20mA output signal range.

Electrical Output Signal ____________________________ (mA)

You should find that the electrical output signal is approximately 14.37 mA.

❑ 3. Calculate the measured output signal from a pressure-type sensor that has a 0-1 psi (0-6.89 kPa) input signal range measuring an acetone level of 18 inches (0.46 m). The sensor has a 1-5 V output signal range.

Electrical Output Signal ______________________________ (V)

You should find that the electrical output signal is approximately 3.05 V.

❑ 4. Calculate the measured output signal from a pressure-type sensor that has a 0-5 psi (0-34.47 kPa) input signal range measuring a crude oil level of 100 inches (2.53 m). The sensor has a 0-20 mA output signal range.

Electrical Output Signal ______________________________ (mA)

You should find that the electrical output signal is approximately 12.24 mA.

❑ 5. Calculate the measured output signal from a pressure-type sensor that has a 0-2 psi (0-13.79 kPa) input signal range measuring a glycol level of 21 inches (0.53 m). The sensor has a 0-10 V output signal range.

Electrical Output Signal ______________________________ (V)

You should find that the electrical output signal approximately 4.16 V.

❑ 6. Calculate the level of tar in a tank if the measured output from a pressure-type sensor that has a 0-3 psi (0-20.68 kPa) input signal range is 7 mA. The sensor has a 4-20 mA output signal range.

Level ______________________________________ in (m)

You should find that the level is approximately 13.02 inches (0.33 m).

❑ 7. Calculate the level of gasoline in a tank if the measured output from a pressure-type sensor that has a 0-7 psi (0-48.26 kPa) is 16 mA. The sensor has a 0-20 mA output signal range.

Level ______________________________________ in (m)

You should find that the level is approximately 210.53 inches (5.38 m).

❑ 8. Calculate the level of tar in a tank if the measured output from a pressure-type sensor that has a 0-3 psi (0-20.68 kPa) input signal range is 7 V. The sensor has a 0-10 V output signal range.

Level ______________________________________ in (m)

You should find that the level is approximately 48.61 inches (1.24 m).

❑ 9. Determine the measured output signal of the pressure sensor shown in figure 38. The sensor has a 0-3 psi (0-20.68 kPa) input signal range and a 4-20 mA output signal range.

Electrical Output ________________________________ (mA)

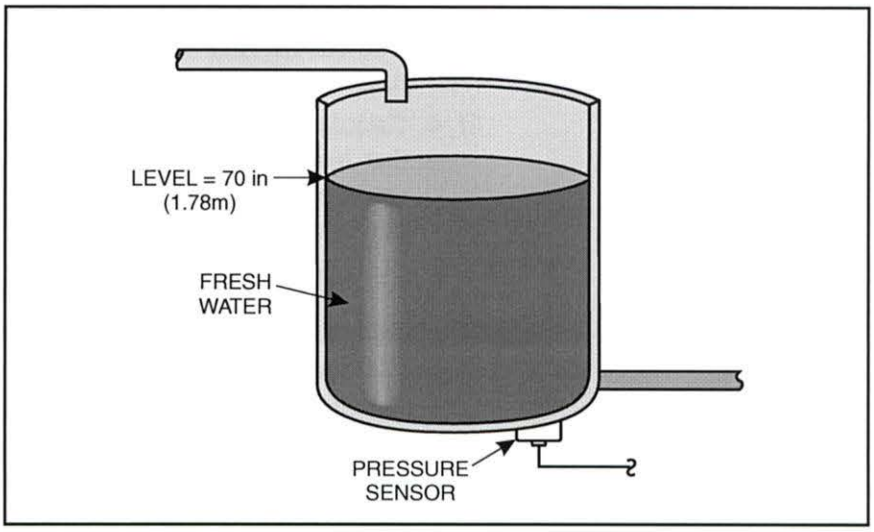

Figure 38. Level System

You should find that the electrical output is 17.44 mA.

❑ 10. Determine the level in the tank shown in figure 39 if the output signal from the pressure sensor is 4.5 V. The sensor has a 0-7 psi (0-48.26 kPa) input signal range and a 1-5 V output signal range.

Level ________________________________ in (m)

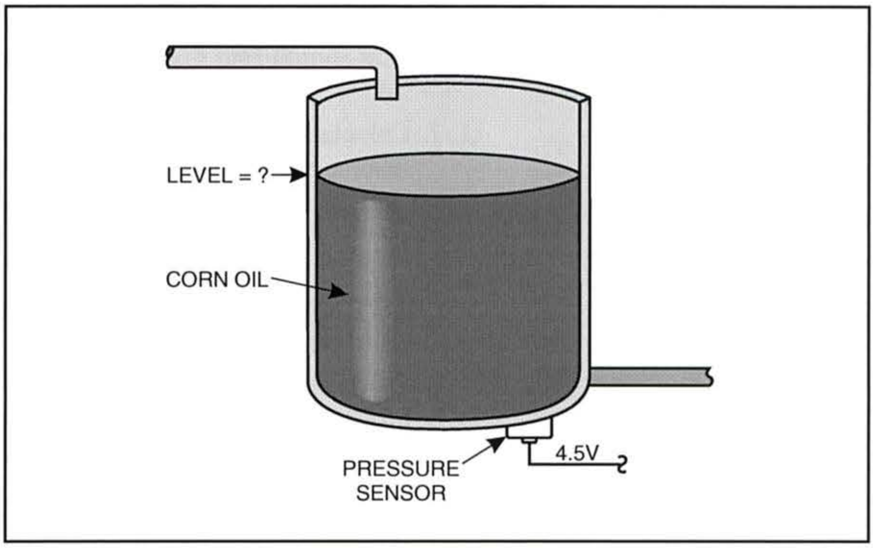

Figure 39. Level System

You should find that the level is approximately 184.93 inches (4.7 m).

SKILL 5 USE A MULTIMETER TO TEST PRESSURE SENSOR OPERATION

Procedure Overview

In this procedure, you will check the output of a pressure sensor using a digital multimeter (DMM). The sensor should produce an analog electrical signal (current) that is proportional to the fluid level in the process tank. As the level in the tank increases, so should the output signal of the sensor. You will verify this relationship in this procedure.

This is a procedure commonly used to troubleshoot a suspected bad sensor.

❑ 1. Perform a lockout/tagout.

❑ 2. Perform the following substeps to set up the T5552, as shown in figure 40.

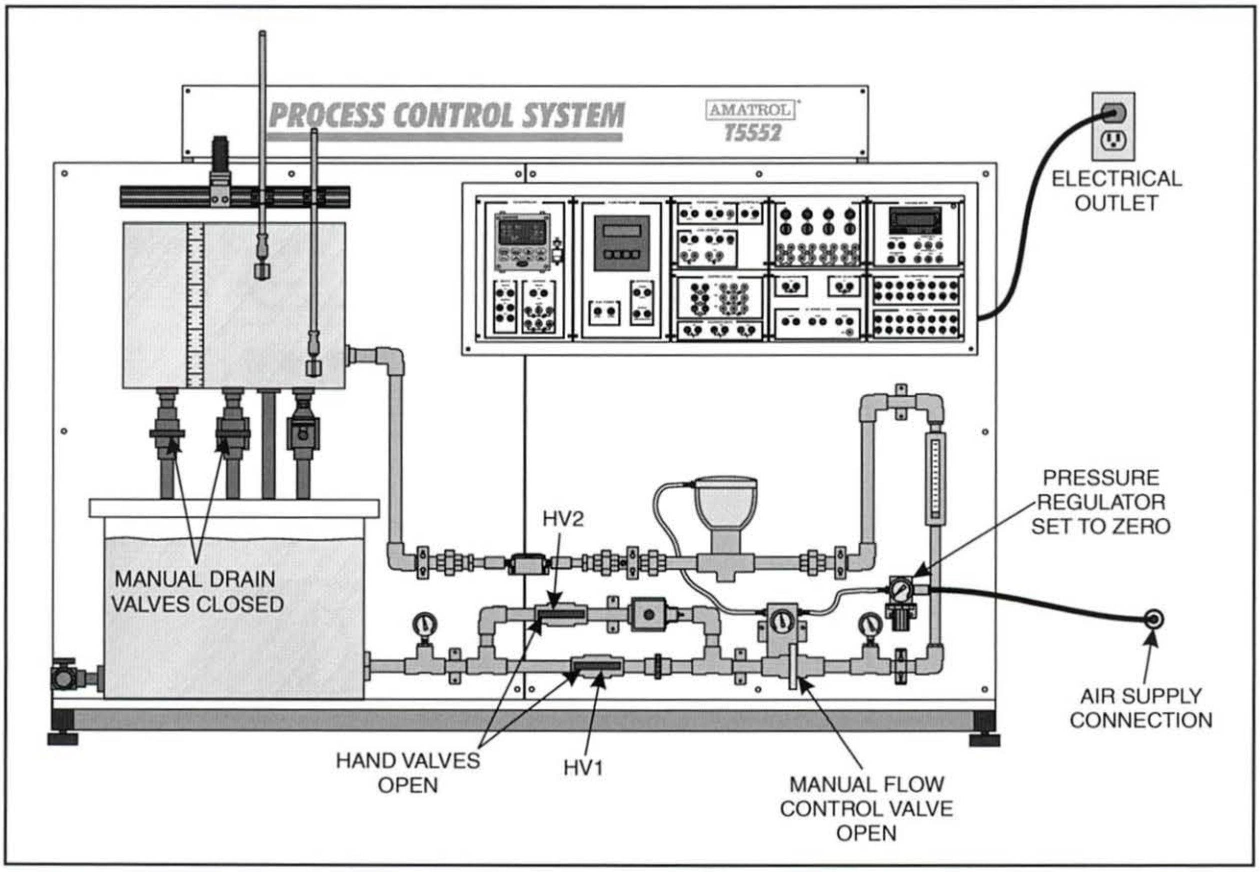

Figure 40. T5552 Setup

A. Connect the air supply line to the T5552.

B. Set the pressure regulator to 0 psi.

You will not be controlling flow with the diaphragm-actuated control valve in this skill.

C. Fill the reservoir tank with water.

D. Close (fully clockwise) the two manual process tank drain valves.

E. Open the manual flow control valve.

F. Locate a digital multimeter (DMM) and set it to measure DC milliamps (mA).

When you measure milliamps with a DMM, make sure that the test probes are connected to the appropriate jacks (COM and mA) of the DMM and the selector switch is set to DC mA.

G. Connect the circuit shown in figure 41.

This circuit allows you to control the flow into the process tank by turning the circulation pump on or off. It also allows you to measure the output of the head pressure sensor (LT1) with the DMM.

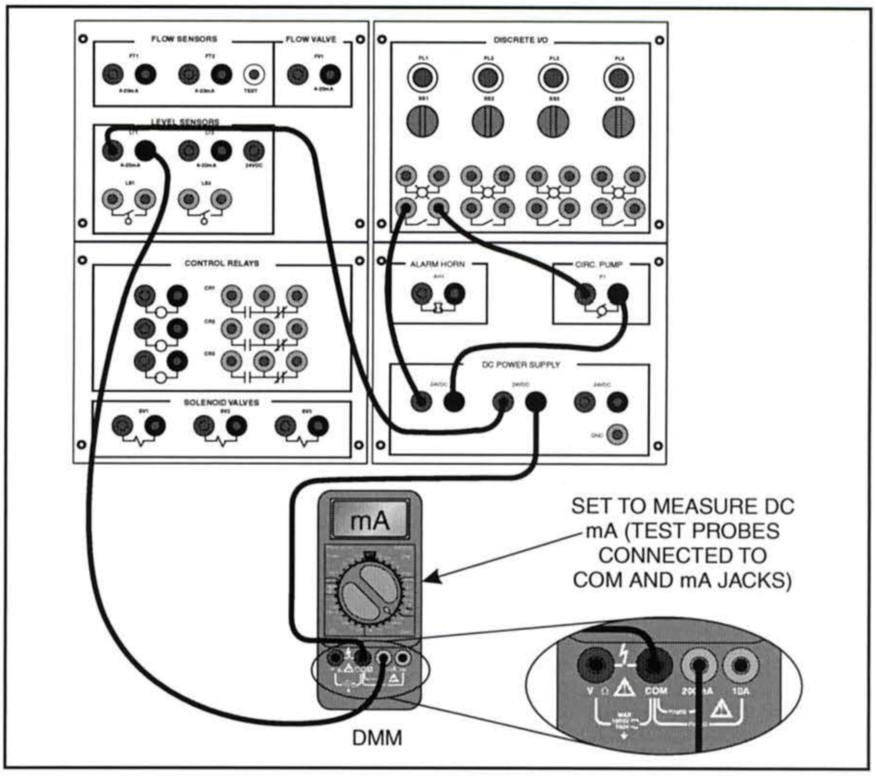

Figure 41. Circuit to Measure Output of Head Pressure Sensor

H. Make sure **SS1** is in the **OFF** (up) position.

The 2-wire variable capacitance pressure sensor on the T5552 has a pressure range of 0-1 psi. Therefore, it can measure levels from zero to 27.7 inches (1/0.036 = 27.7 inches).

The pressure sensor outputs a 4-20 mA analog signal. Theoretically, a signal of 4mA represents zero psi (zero inch). A signal of 20 mA represents 1 psi (27.7 inches). However, the T5552 does not use the full range of the sensor.

The maximum level in the process tank is 10 inches, which is less than half of the maximum level (27.7 inches) the sensor can detect. Therefore, the output of the sensor will never reach the 20 mA maximum.

> **NOTE**
>
> Actual measurements depend on how well the sensor is calibrated.

❑ 3. Remove the lockout/tagout.

❑ 4. Turn on the main circuit breaker.

❑ 5. Perform the following substeps to fill the process tank and observe the output of the pressure sensor as the tank fills.

A. With the process tank empty, observe the display of the DMM and record the reading.

Pressure Sensor Output ____________________________ (mA)

Theoretically, with no (or very little) water in the process tank, the output of the sensor should be near its minimum signal, which is approximately 4 mA.

However, because the sensor diaphragm is actually located almost 1.5 inches beneath the bottom of the tank, there will be some offset to the actual output. You should find that the output of the sensor with the tank level at zero is between 5.3 and 5.5 mA.

B. Start the circulation pump by placing **SS1** in the **ON** position.

This causes water to begin to flow into the process tank, and the tank to fill.

C. When the tank level reads each of the levels listed in the following chart, read and record the corresponding DMM reading.

LEVEL (inches)	SENSOR OUTPUT (mA)
2	
4	
6	
8	
10	

You should find the readings to be close (typically within ± 0.5 mA) of the theoretical values (from the graph in figure 43). If your recorded values vary from theoretical values by more than ±1 mA, inform your instructor. The sensor may be out of calibration.

D. When the level in the tank reaches 10 inches, turn off the circulation pump.

❑ 6. Make a plot of the sensor output versus the level using the data you recorded in substep 5C.

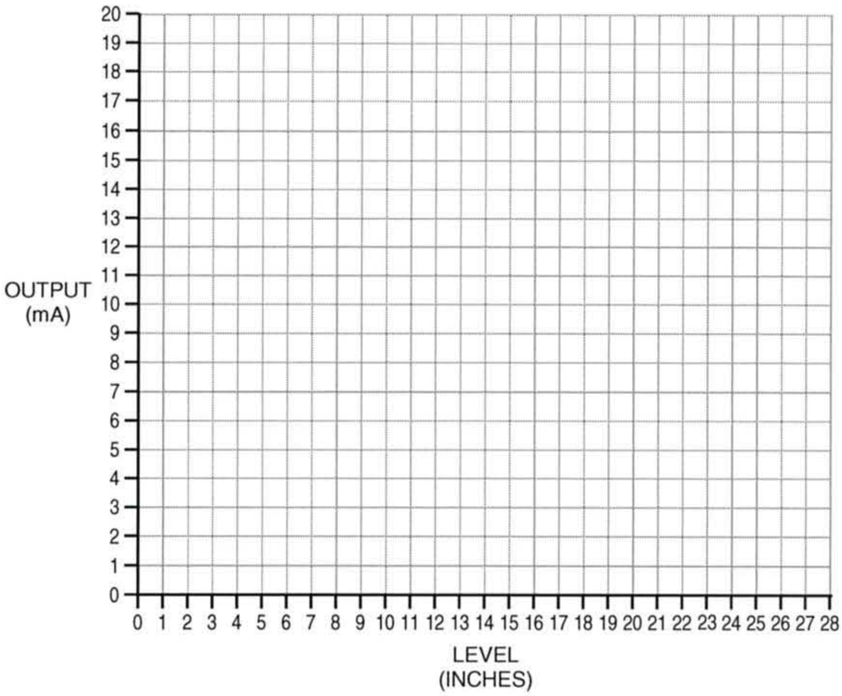

Figure 42. Graph Sheet

You should notice a linear relationship, similar to figure 42.

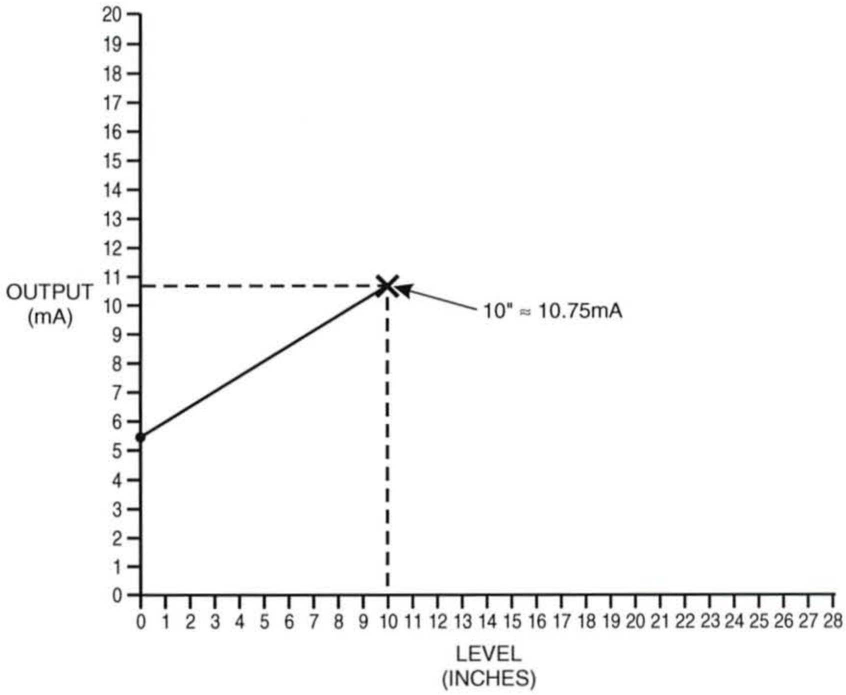

Figure 43. Level Vs. Current Output

❑ 7. Perform the following substeps to shut down the T5552.

A. Open the process tank manual drain valves until all of the water drains from the process tank.

B. When the process tank is empty, close the manual drain valves by turning them clockwise.

C. Turn off the main circuit breaker.

D. Disconnect the control circuit.

E. Return the DMM to its proper storage location.

SEGMENT 2

SELF REVIEW

1. To convert liquid level units to pressure units, you need to know the level and the ________________________ of the fluid.

2. The ratio of the change in electrical output signal to the change in physical input signal is called ________________.

3. The specific gravity of water is _______.

4. To convert sensor output signals to pressure units, you need to know the sensitivity, the minimum output signal, and the ____________ output signal value.

5. Water exerts a pressure of ____________ psi per column inch.

6. When converting liquid level units to sensor output signal units, you should first convert the liquid level units to ___________ units.

SEGMENT 3

DISPLAY SCALING

OBJECTIVE 13 DEFINE DISPLAY SCALING

Display scaling is the process of configuring a display device such as a controller or a process meter to display the output signal from a sensor in measurement units other than the actual units of the sensor's signal. Scaling allows the display to show the sensor's signal in physical units such as liquid level or pressure. For example, figure 44 shows a controller that is receiving a 5 mA input signal from a level sensor. The controller is displaying 2.0 to indicate the actual value of the liquid level in the tank, which is 2 meters.

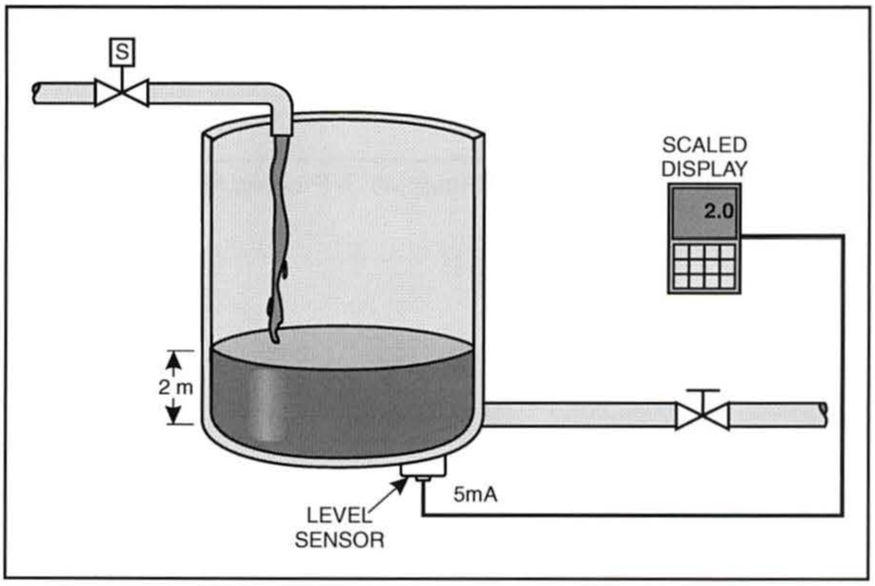

Figure 44. Display Scaled to Show Actual Level Value

In addition to displaying physical units, the sensor signal can be scaled to display the percentage of the total input range. The scale may also be inverted so that the maximum value displayed corresponds to the minimum input value and the minimum display value corresponds to the maximum input value.

Most electronic controllers and some process meters have the ability to scale the input automatically. This is done when the low and high values for the input are entered into the device. The controller compares the programmed range for the display values to the electrical input signal range and calculates the proper scale factor.

OBJECTIVE 14 DESCRIBE THE FUNCTION OF A PROCESS METER AND GIVE AN APPLICATION

Read This

A process meter is a versatile measurement instrument that is widely used in process control applications to provide a visual indication of the value of a process variable (i.e. level, flow, pressure, temperature, and pH).

Figure 45. A Process Meter

Process meters are typically wired directly to sensors that monitor a process variable. Figure 46 shows a system that connects a level sensor to a process meter to indicate the level in the tank.

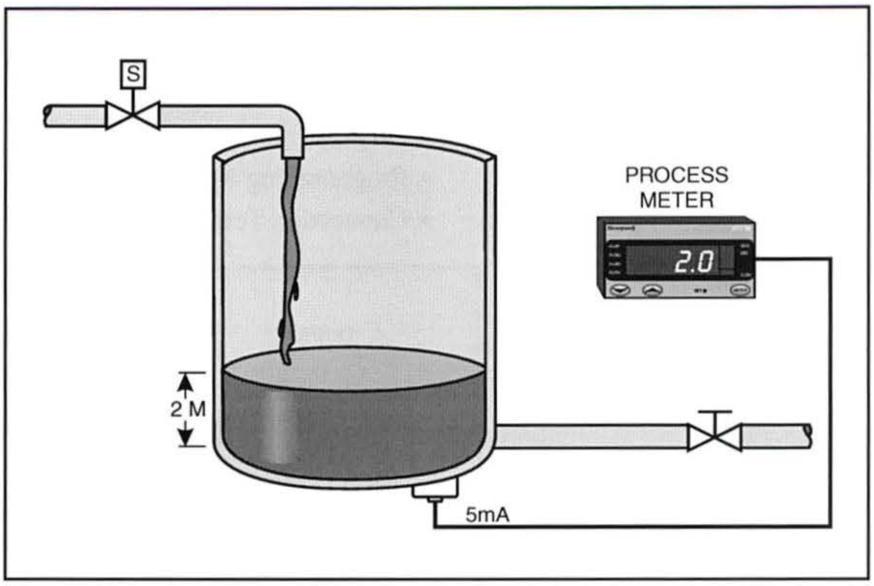

Figure 46. Process Meter Indicating Level

Process meters are often scaled to display the electrical input signal in terms of the physical units (i.e. display scaling). For example, although the process meter in figure 46 receives a 5 mA input signal, it displays 2.0 (the level in meters).

Process meters can be mounted almost anywhere. In some applications, it is necessary to mount the process meter near the actual process. Some applications require the process meter to be installed in a central location such as a control panel or a control room.

OBJECTIVE 15 DESCRIBE THE OPERATION OF A PROCESS METER

Although process meters vary widely in appearance and functionality, most process meters have the same basic components shown in figure 47:

- Display
- Programming Keys
- Connection Terminals

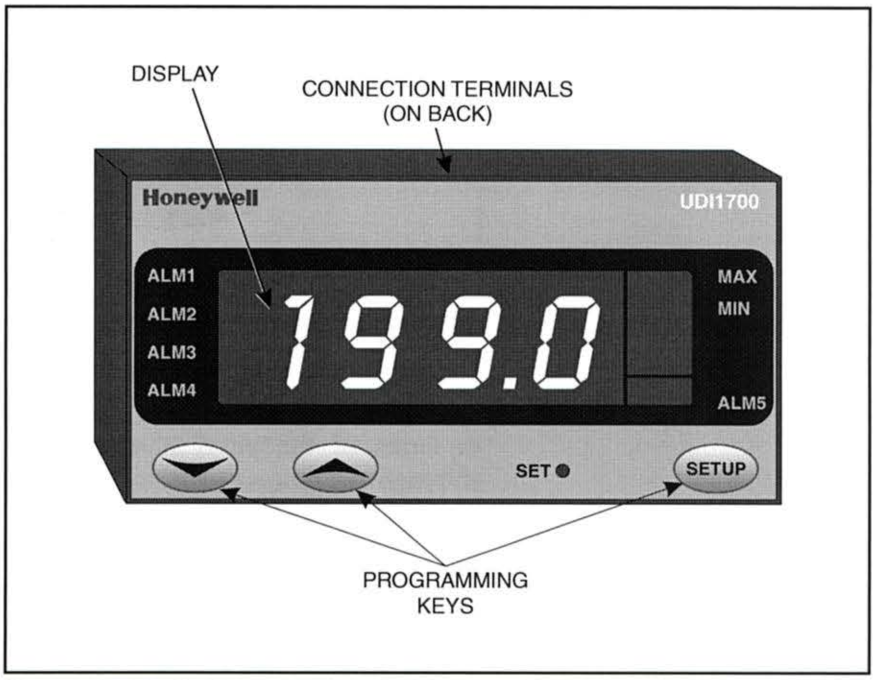

Figure 47. Basic Components of a Process Meter

Display

While some older process meters have an analog display (scale and pointer), most of today's process meters have a digital display, like those in figure 48. The digital display makes it easier to read and understand the data.

Process meters can be programmed to display either the actual value of the input signal, a percentage of the input signal, or most commonly, the physical units of the process variable that the input signal represents. Figure 48 shows three process meters that all receive the same 12 mA input signal. The process meter on the left indicates 12.0, the actual value of the input signal (in mA). The process meter in the center indicates 50.0, the percentage of the input signal range (assuming a 4-20 mA range), and the process meter on the right indicates 5.0, the liquid level measured in feet.

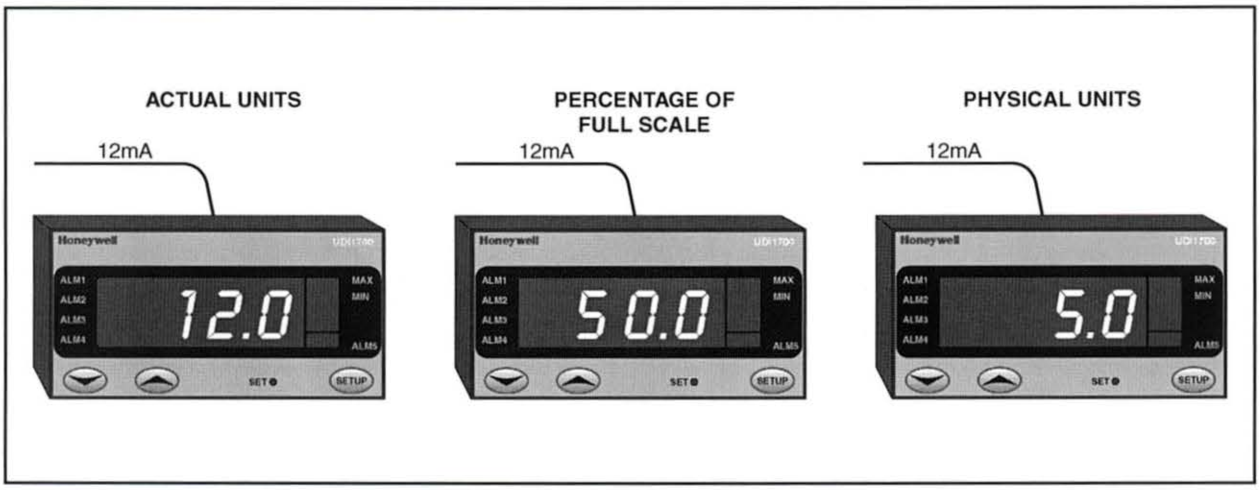

Figure 48. Process Meter Displaying Different Units

Programming Keys

Most of today's process meters are microprocessor-based, making them programmable. Microprocessor-based process meters provide a set of keys that allow the user to program the meter to display the process variable. Typically, this requires changing a number of parameters.

For example, the Honeywell UDI 1700 process meter shown in figure 49 allows the user to select the type of input signal, the range of the input signal, and the high and low display values that correspond to the upper and lower limits of the input signal range. It also allows the user to program relays that can be used as alarms.

The SETUP key is used along with the up arrow ▲ key to place the process meter in the Select Mode. The Select Mode allows the user to select which set of parameters to edit. The up ▲ and down ▼ arrow keys are used to scroll through the different programming menus and to change parameter values. When a programming mode is selected, the SETUP key is used to scroll through the parameters in the selected mode and the up ▲ and down ▼ keys are used to change parameter values.

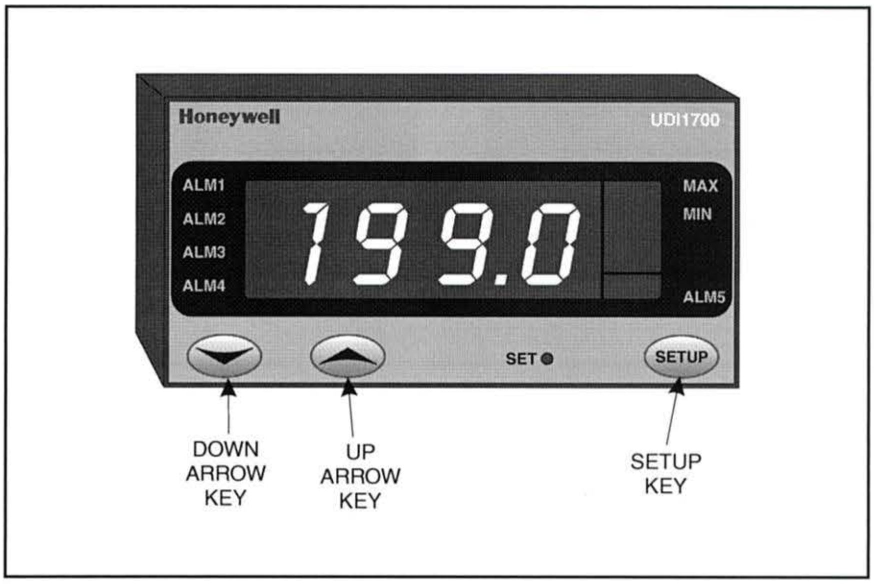

Figure 49. Honeywell UDI1700 Process Meter Programming Keys

Connection Terminals

The connection terminals provide a means to connect the process devices to the process meter. Typically, the connection terminals are located on the back of the process meter, as figure 50 shows, since most process meters are designed to be panel mounted.

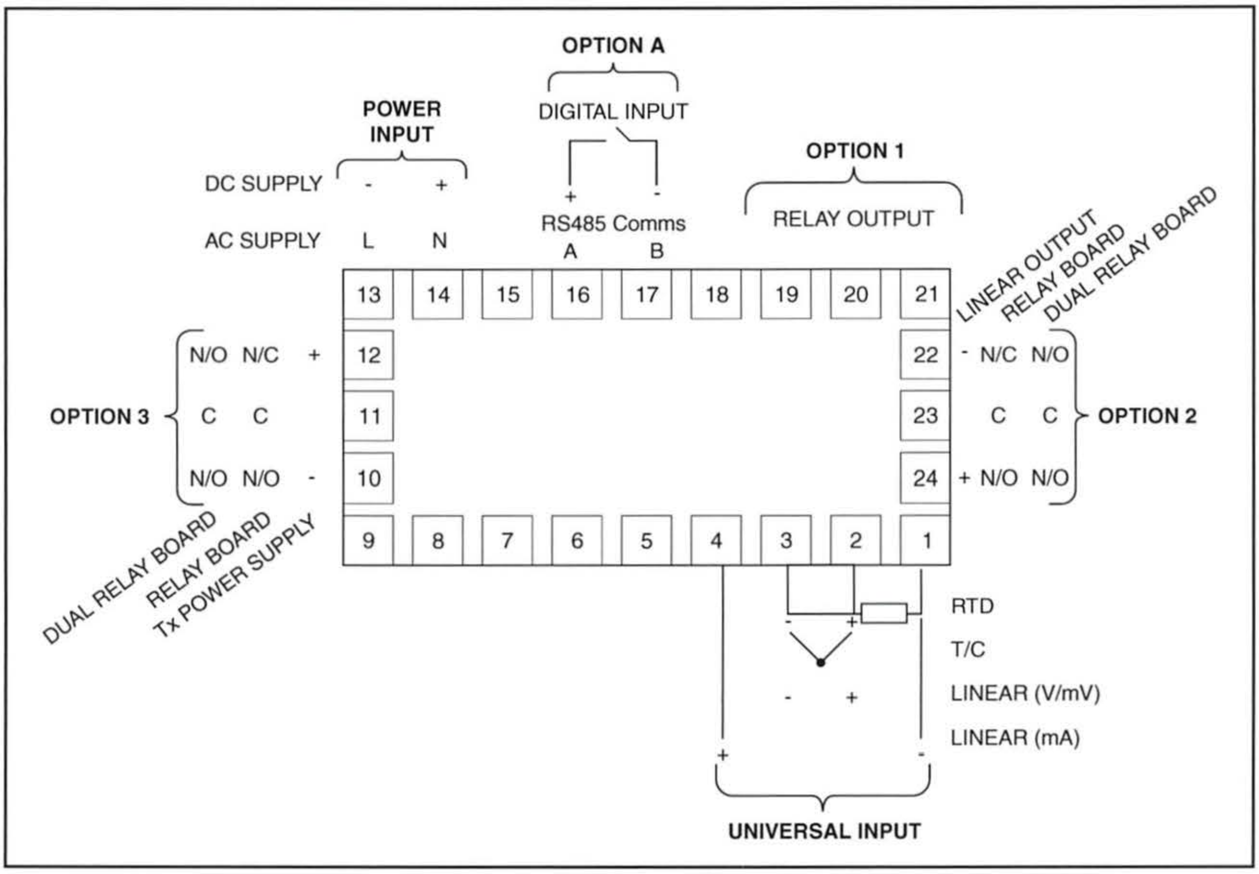

Figure 50. Connection Terminals on a Process Meter

Terminals 1-4 are input terminals. When connecting an RTD (Resistance Temperature Detector), terminals 1-3 are used. When using a thermocouple, terminals 2 and 3 are used. Terminals 2 and 3 are also used if the input signal is a voltage. If the input signal is a current (mA), terminals 1 and 4 are used.

Terminals 5-9 are not typically used. Terminals 10-12 are used for Option 3, if used. Typically, these terminals are used for relays.

Terminals 13 and 14 are connections for the input power. The input power can be AC or DC. Terminal 15 is not used.

Terminals 16 and 17 are used for Option A. Typically they can either be used for a digital (discrete) input or for communications (RS485). Terminal 18 is not used.

Terminals 19-21 are used for Option 1, which is a relay output. Terminal 19 is the NC contact, terminal 20 is the common, and terminal 21 is the NO contact connection.

Terminals 22-24 are used for Option 2. Option 2 can be another relay or terminals 22 and 24 can provide a 4-20mA output.

Figure 51 shows a level sensor wired to the input of a process meter and the output from the process meter wired to a controller in a remote location. The level sensor provides a voltage output. The output from the process meter closes the control loop.

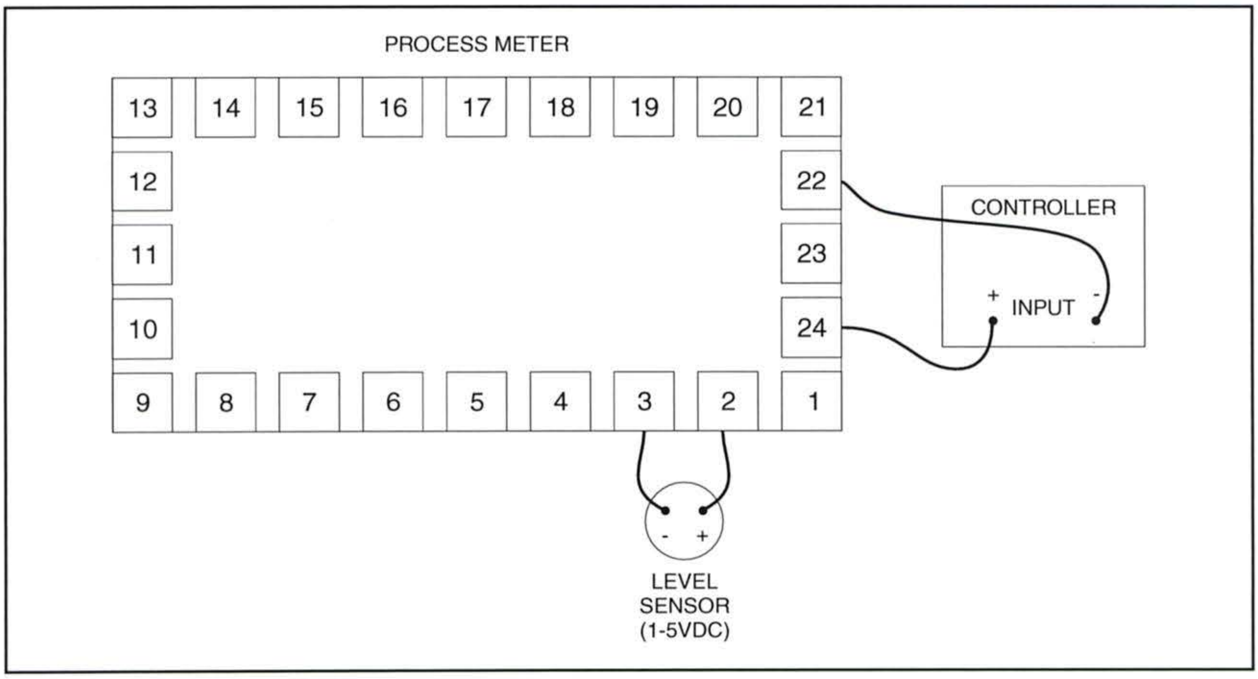

Figure 51. Process Meter Wired to a Level Sensor and Remotely Located Controller

Since the level sensor outputs a 1-5V DC signal, it is connected to terminals 2 and 3. The positive terminal on the level sensor is connected to terminal 2 and the negative terminal on the level sensor is connected to terminal 3.

The process meter is equipped with a 4-20mA output that is connected to the input terminals of the controller. Terminals 22 and 24 provide the output signal.

Display Operation

When a process meter receives an analog input signal, the signal is converted (analog-to-digital) and fed to its microprocessor, as figure 52 shows. The microprocessor adjusts the input based on the parameters entered into the processor's memory and then sends the adjusted data to the display. The microprocessor constantly monitors the input and updates the display so that the data displayed remains accurate.

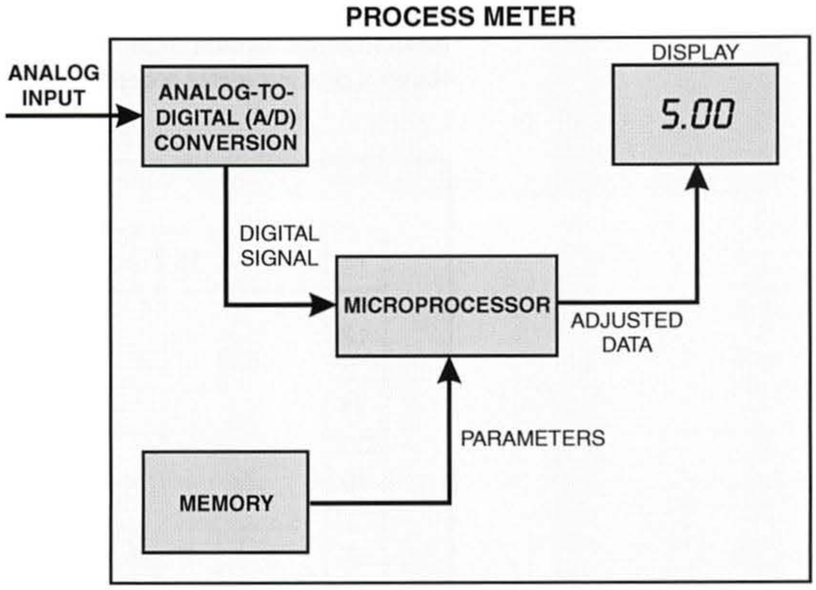

Figure 52. Basic Operation of a Process Meter

OBJECTIVE 16 DESCRIBE HOW TO CONFIGURE A HONEYWELL UDI 1700 PROCESS METER TO DISPLAY A PROCESS VARIABLE

Configuring a process meter involves programming the meter to accurately display the process variable in the desired units. To configure a process meter, the input signal range parameters and the measurement range parameters must be programmed.

The input signal range represents the minimum and maximum values of the electrical input signal. Common analog input signals that process meters accept include 4-20 mA, 0-20 mA, 1-5 V, and 0-10 V. Figure 53 shows a process meter accepting a 4-20 mA signal.

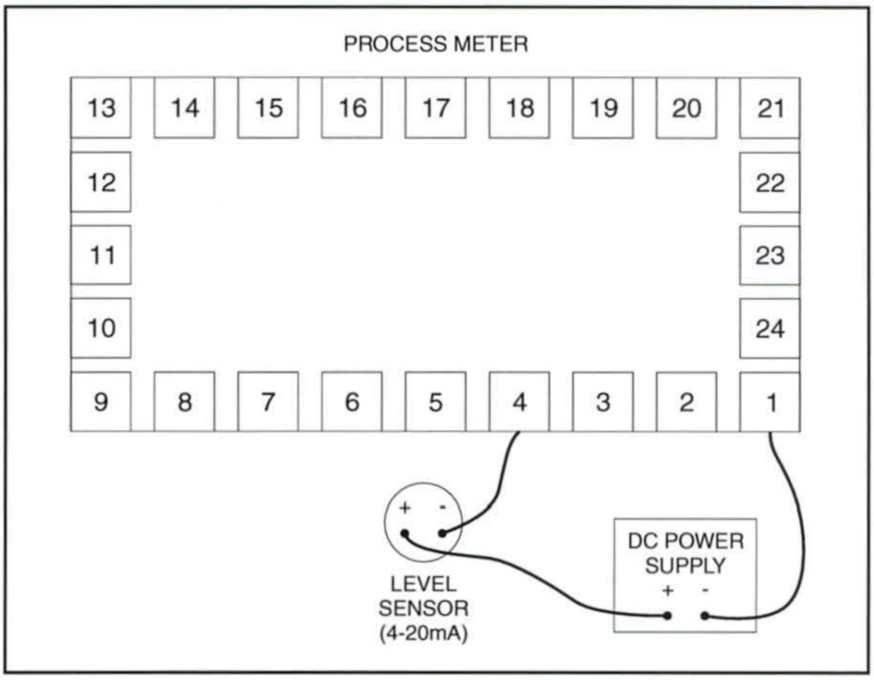

Figure 53. Process Meter Accepts 4-20mA Signal

Program Input Signal and Range

For the Honeywell UDI 1700 process meter, the input type/range parameter (inPt) is located in the Configuration Menu. The selections for this parameter include several types of thermocouples and RTDs. When a thermocouple or RTD is selected, the range is automatically set. If the input is a voltage or current, the desired range is selected (i.e. 4_20 for 4-20mA). The table below shows the various selections for the input (inPt) parameter.

CODE	INPUT TYPE & RANGE	CODE	INPUT TYPE & RANGE	CODE	INPUT TYPE & RANGE
bC	B: 100 - 1824 °C	LC	L: 0.0 - 537.7 °C	P24F	PtRh20% vs 40%:
bF	B: 211 - 3315 °F	LF	L:32.0 - 999.9 °F		32 - 3362 °f
CC	C: 0 -2320 °C	nC	N: 0 - 1399 °C	PtC	Pt100: - 199 - 800 °C
CF	C: 32 - 4208 °F	nF	N: 32 - 2551 °F	PtF	Pt100: -328 - 1472 °F
JC	J: -200 - 1200 °C	rC	R: 0 - 1759 °C	PtC	Pt100: -128.8 -537.7 °C
JF	J:-328 - 2192 °F	rF	R: 32 - 3198°F	PtF	Pt100: -199.9 -999.9 °F
JC	J: -128.8 - 537.7 °C	SC	S: 0 - 1762 °C	0.20	0 - 20 mA DC
JF	J: - 199.9 - 999.9 °F	SF	S: 32 - 3204 °F	4.20	4 - 20 mA DC
KC	K: -240 - 1373 °C	tC	T: - 240 - 400 °C	0.50	0 - 50 mV DC
KF	K: -400 - 2503 °F	tF	T: -400 - 752 °F	10.50	10 - 50 mV DC
KC	K: -128.8 - 537.7 °C	tC	T: -128.8 - 400.0 °C	0.5	0 - 5V DC
KF	K: - 199.9 - 999.9 °F	tF	T: -199.9 - 752.0 °	1.5	1 - 5 V DC
LC	L: 0 - 762 °C	P24C	PtRh20% vs. 40%	0.10	0 - 10 V DC
LF	L: 32 - 1403 °F		0 - 1850 °C	2.10	2 - 10 V DC
Note: Decimal point shown in table indicates temperature resolution of 0.1°					

Figure 54 shows the input parameter is set for a 4-20mA signal.

Figure 54. Input Parameter set to 4-20mA

Program Scale Range Parameters

The scale range represents the minimum and maximum display values that correspond to the minimum and maximum values of the input signal range. The scale range is programmed into the meter so that the display indicates the value of the process variable in the desired units.

For example, if a process is measuring the level in a tank from 0-10 ft, the scale range for the meter is 0-10 even though the input signal may be 4-20mA. Entering the scale range enables the meter to scale the display.

The scale range parameters for the Honeywell UDI 1700 process meter are:

- **ruL** – Scale Range Upper Limit that corresponds to the maximum value of the input signal.
- **rLL** – Scale Range Lower Limit That corresponds to the minimum value of the input signal.

Figure 55 shows the Scale Range Upper Limit parameter on the Honeywell UDI 1700 set to 10.0

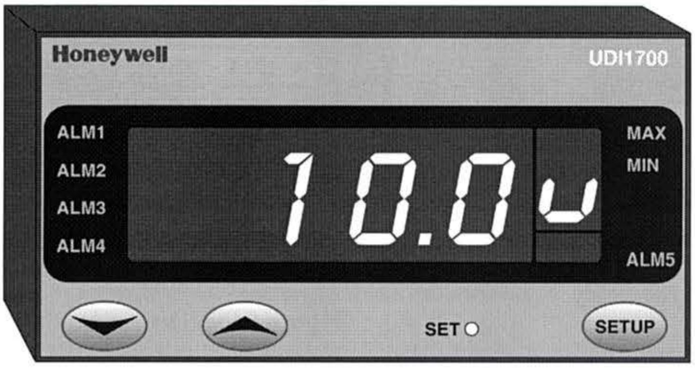

Figure 55. Scale Range Upper Limit Parameter Set to 10

The following steps describe how to program a Honeywell UDI 1700 process meter to display a process variable:

Step 1: Enter the Select Mode – Pressing and holding the SETUP key and pressing the up arrow ▲ key enters the select mode.

Step 2: Scroll to the Configuration Menu Selection – Scroll through the menu selections using the up ▲ and down ▼ arrow keys until ConF (Configuration Menu) is displayed. The Configuration Menu is used to select the input type/range and the scale range.

Step 3: Enter the Configuration Menu – Pressing the SETUP key enters the Configuration Menu.

Step 4: Enter the Unlock Code – The unlock code for the Configuration Menu is 20. The value is set using the up ▲ and down ▼ arrow keys. When 20 is displayed, pressing the SETUP key accepts the value and opens the Configuration Menu.

Step 5: Select the Input Type/Range – If the input (inPt) parameter is not currently displayed, scroll to the input parameter by pressing the SETUP key until "inPt" appears on the display, as figure 56 shows. After one second, the current input value should appear. Using the up ▲ and down ▼ arrow keys, scroll until the desired value appears (i.e. 4-20mA). When the desired value appears, press the SETUP key. This causes the Yes (YES?) prompt to appear. Accept the new value by pressing the up ▲ arrow key.

Figure 56. Input Parameter

Step 6: Set the Scale Range Upper Limit – Using the SETUP key, scroll to the Scale Range Upper Limit (ruL) parameter. After a second, the current value of the parameter is displayed. Change the value using the up ▲ and down ▼ arrow keys. The longer a key is held, the faster the value changes in the display. When the desired value appears, select it by pressing the SETUP key. This causes the Yes (YES?) prompt to appear. Accept the new value by pressing the up ▲ arrow key.

Step 7: Set the Scale Range Lower Limit – Using the SETUP key, scroll to the Scale Range Lower Limit (rLL) parameter. After a second, the current value of the parameter is displayed. Change the value using the up ▲ and down ▼ arrow keys. When the desired value appears, select it by pressing the SETUP key. This causes the Yes (YES?) prompt to appear. Accept the new value by pressing the up ▲ arrow key.

Step 8: Exit the Configuration Menu – Pressing and holding the SETUP key and pressing the up ▲ arrow key exits the Configuration Menu and returns to the Select Mode.

Step 9: Exit the Select Mode – Scroll the display using the up arrow key until "OPtr" appears. Then, return to the Operating Mode (OPtr) by pressing the SETUP key. The display momentarily displays "Proc" and then returns to the Operating Mode, displaying the current scaled value of the input.

SKILL 6 CONFIGURE A HONEYWELL UDI 1700 PROCESS METER TO DISPLAY A PROCESS VARIABLE

Procedure Overview

In this procedure, you will connect and configure the process meter on the T5552 to measure the level of water in the process tank. To do this, you must first determine the output of the level sensor/transmitter for a level of zero inches and a level of 10 inches. You will then use this information to configure the meter.

Do This

❑ 1. Perform a lockout/tagout.

❑ 2. Perform the following substeps to set up the T5552, as shown in figure 57.

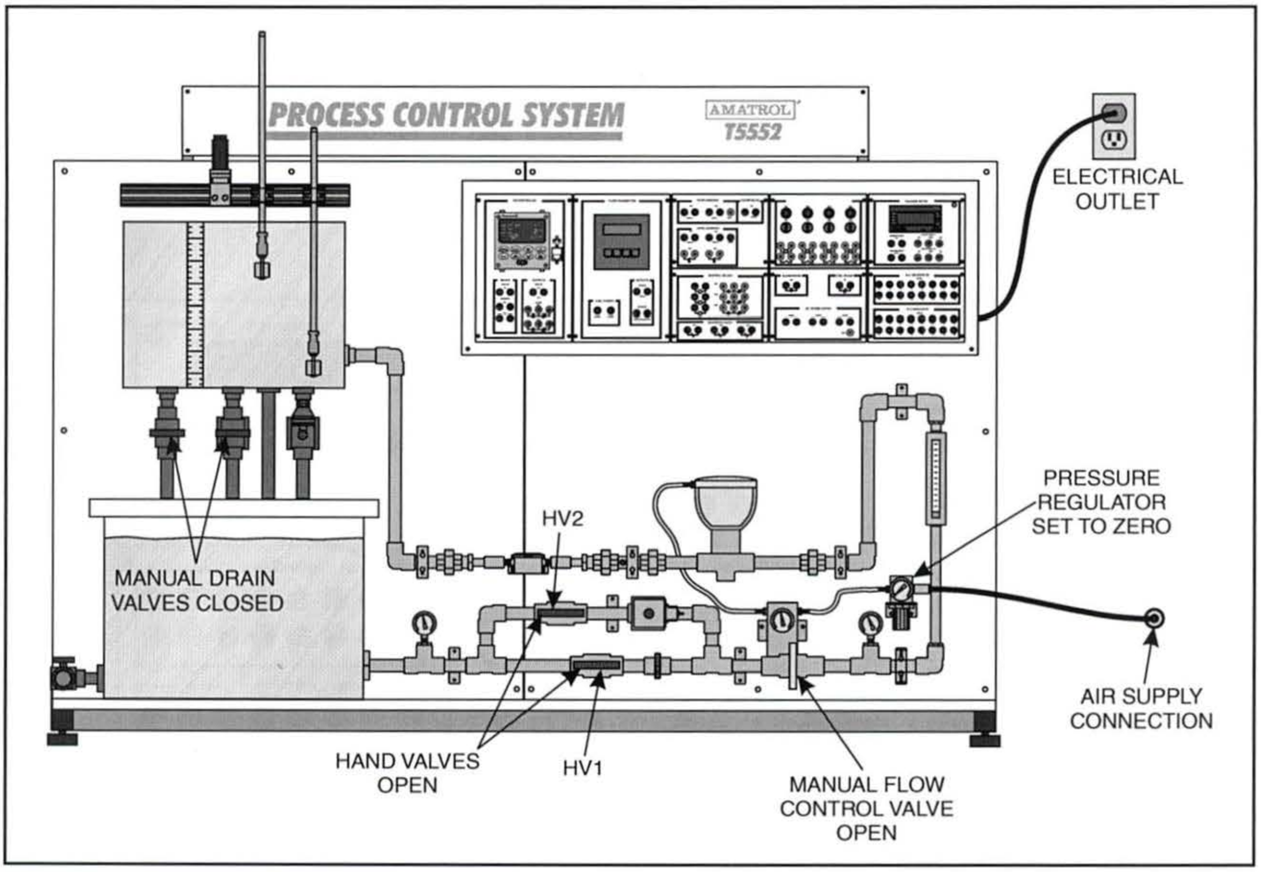

Figure 57. T5552 Setup

A. Connect the air supply line to the T5552.

B. Set the pressure regulator to 0 psi.

You will not be controlling flow with the diaphragm-actuated control valve in this skill.

C. Fill the reservoir tank with water.

D. Close (fully clockwise) the two manual process tank drain valves.

E. Open the manual flow control valve.

❑ 3. Remove the lockout/tagout.

NOTE

You must set several parameters to properly configure the process meter on the T5552. The relevant parameters will be explained as you progress through the remaining steps.

❑ 4. Perform the following substeps to set up the process meter on the T5552 for configuration.

A. Connect the circuit shown in figure 58.

Make sure the current input terminals are used.

This circuit allows you to measure the level of water in the process tank with the process meter.

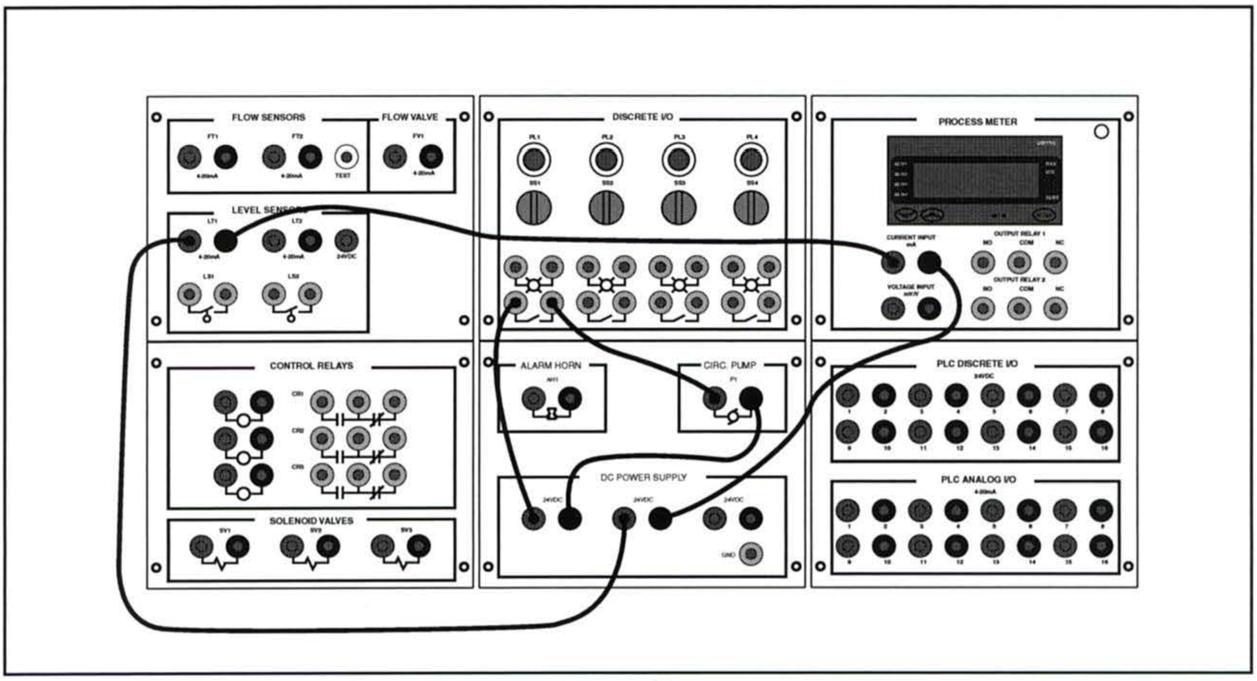

Figure 58. Circuit to Measure Level Using the Process Meter

Figure 59 shows the wiring diagram for the level circuit.

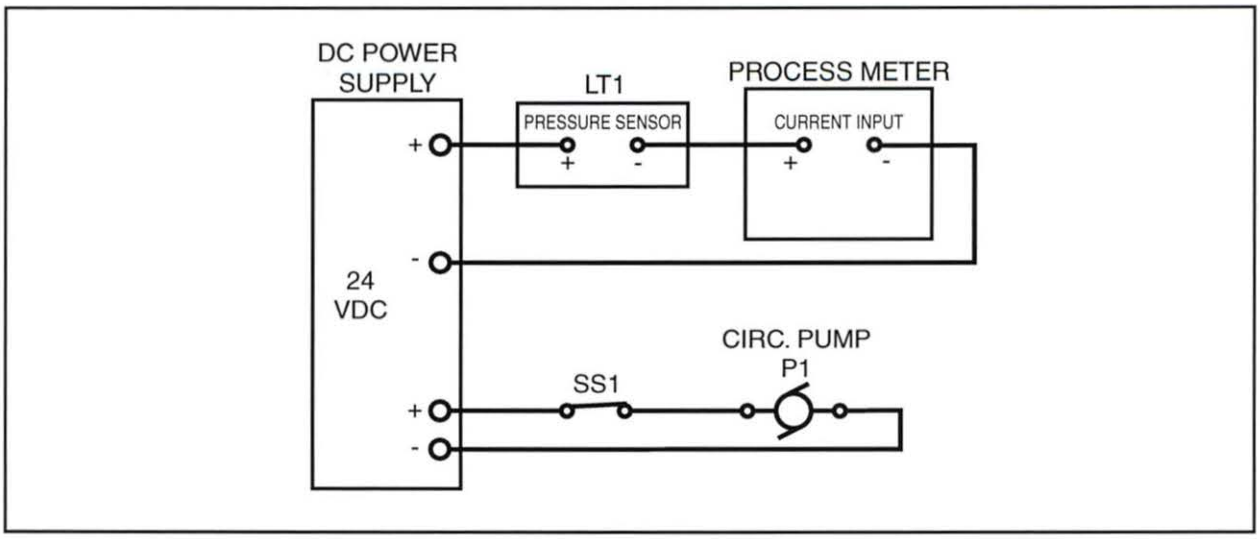

Figure 59. Wiring Diagram for Level Sensor Connected to the Process Meter

B. Turn on the main circuit breaker.

❑ 5. Perform the following substeps to enter the Configuration Menu on the Honeywell UDI 1700 process meter.

A. Press and hold the **SETUP** key and then press the up ▲ arrow key.

This places the meter in the Select Mode. The letters "SLCt" should appear on the display briefly, indicating that the meter is now in the Select Mode. Then, the last selected menu will appear on the display.

From the Select Mode, you can select from the four available menus, as listed in the table in figure 60. Two of the menus, Set Up and Configuration, require codes to unlock them. The unlock codes are also listed in the table.

You will be using the Configuration Menu for this skill.

SELECTION MODE MENUS			
MENU	**DISPLAY**	**DESCRIPTION**	**UNLOCK CODE**
Operator	Optr	Normal operation - Allows user to view process variable or other data	None
Set Up	SetP	Allows user to customize settings for specific application. Includes adding an offset for the PV, adding a filter for the input, and setting scaling breakpoints.	10
Configuration	ConF	Allows user to configure the meter settings including inputs, alarms, and outputs.	20
Product Information	InFo	Displays product information for meter including options, firmware information, manufacture date, and serial number.	None

Figure 60. Selection Mode Menus

B. Use the up ▲ and down ▼ arrow keys to scroll through the menus until the Configuration Menu (ConF) appears on the display.

"ConF" should now appear on the display.

C. Press the **SETUP** key to open the Configuration Menu.

Since the Configuration Menu is locked, "ULoc" appears on the display briefly, followed by 0. The unlock code must be entered before you can continue.

D. Use the up ▲ and down ▼ arrow keys to change the displayed value to **20**, which is the unlock code for the Configuration Menu.

E. When **20** is displayed, press the **SETUP** key to enter the unlock code.

The Configuration Menu should now be unlocked and the first parameter in the menu should be displayed. The first parameter is the input (inPt) parameter. The display should briefly show "inPt", followed by the current setting for the input parameter, similar to figure 61.

You should also notice that the SET indicator, shown in figure 61, is flashing to indicate that the meter is in the Configuration Menu. It continues to flash until the Configuration Menu is closed. When the Set Up Menu is opened, the SET indicator remains on constantly until the menu is closed.

Figure 61. Example of Current Input Parameter Value

❑ 6. Perform the following substeps to select the desired input type.

The output from the level sensor (LT1) is a current with a 4-20mA range.

A. If 4-20mA is not currently displayed, as shown in figure 61, use the up ▲ and down ▼ arrow keys to scroll through the input selections until it appears on the display.

NOTE

The longer you hold a key, either up or down, the faster the value scrolls.

If 4_20 mA is currently displayed, skip to Step 7.

B. When the correct input is displayed, press the **SETUP** key.

This causes the Yes prompt to appear on the display, as shown in figure 62. This prompt appears any time you change a value in the Configuration Menu.

Figure 62. Yes Prompt

C. Press the up ▲ arrow key to accept the new value for the input parameter.

NOTE

If you do not press the up ▲ arrow key in response to a Yes prompt, the value of the selected parameter reverts to the previous setting.

With the correct input selected, the next step is to set the scale range limits for the process variable.

❑ 7. Perform the following substeps to set the scale range limit parameters.

NOTE

In order to scroll through the parameters using the SETUP key, the name of a parameter (i.e. inPt) must appear on the display. If a value is displayed (i.e. 4_20), pressing the SETUP key displays the parameter name. The parameter name will appear for about one second before returning to the value. You can only scroll with the SETUP key when a parameter name is displayed.

The scale range limit parameters are also located in the Configuration Menu.

A. Using the **SETUP** key, scroll to the Scale Range Upper Limit (ruL) parameter. When "ruL" appears on the display, stop scrolling.

   After a second, the current value of the parameter should appear.

B. Use the up ▲ and down ▼ arrow keys to change the value to **27.7**.

   The measurement range for the level sensor is 0 to 27.7 inches.

C. When the correct value is displayed, press the **SETUP** key.

   The Yes prompt again appears on the display.

D. Press the up ▲ arrow key to accept the new value for the parameter.

E. Using the **SETUP** key, scroll to the Scale Range Lower Limit (rLL) parameter. When "rLL" appears on the display, stop scrolling.

   After a second, the current value of the parameter should appear.

F. Use the up ▲ and down ▼ arrow keys to change the value to **0.0**.

G. When the correct value is displayed, press the **SETUP** key.

   The Yes prompt again appears on the display.

H. Press the up ▲ arrow key to accept the new value for the parameter.

I. Using the **SETUP** key, scroll to the to the Decimal Point Position (dPoS) parameter. When "dPoS" appears on the display, stop scrolling.

   After a second, the current value of the parameter should appear.

J. Use the up ▲ and down ▼ arrow keys to change the value to **1**, if necessary.

   A setting of 1 for this parameter indicates that there is one position after the decimal point (XXX.X). Other settings for this parameter are 0 (XXXX), 2 (XX.XX), and 3 (X.XXX).

K. When the correct value is displayed, press the **SETUP** key.

   The Yes prompt again appears on the display.

L. Press the up ▲ arrow key to accept the new value for the parameter.

   That completes the parameter settings in the Configuration Menu. You can now exit the Configuration Menu and the Select Mode.

❑ 8. Perform the following substeps to exit the Configuration Menu and the Select Mode.

A. Press and hold the **SETUP** key and press the up ▲ arrow key to return to the Select Mode.

B. Use the up ▲ arrow key to scroll to the Operator Menu (OPtr). Stop when the display shows "OPtr".

C. Press the **SETUP** key to exit the Select Mode and return the process meter to normal operation.

"Proc" should appear briefly on the display followed by the process variable value. You should notice that the value shows a level of approximately 1.6, even though the actual level (according to the sight scale) is zero.

The reason for this difference is that the level sensor is mounted to the bottom of the tank, causing the actual sensing element to be below the zero mark in the process tank. In fact, the sensing element is approximately 1.6 inches below the zero mark in the tank.

In order to compensate for this difference, you need to set the Process Variable Offset (OFFS) parameter in the Set Up Menu.

❑ 9. Perform the following substeps to set the Process Variable Offset parameter in the Set Up Menu.

A. Press and hold the **SETUP** key and then press the up ▲ arrow key to enter the Select Mode.

B. Use the up ▲ and down ▼ arrow keys to scroll through the menus until the Set Up Menu (SEtP) appears on the display.

"SEtP" should now appear on the display.

C. Press the **SETUP** key to open the Set Up Menu.

Since the Set Up Menu is locked, "ULoc" appears on the display briefly, followed by 0. The unlock code must be entered before you can continue.

D. Use the up ▲ and down ▼ arrow keys to change the displayed value to **10**, which is the unlock code for the Set Up Menu.

E. When **10** is displayed, press the **SETUP** key to enter the unlock code.

The Set Up Menu should now be unlocked and the first parameter in the menu should be displayed. The first parameter is the Input Filter Time Constant (FiLT) parameter.

F. Using the **SETUP** key, scroll to the Process Variable Offset (OFFS) parameter. Stop scrolling when "OFFS" appears on the display.

Remember, the name of a parameter (i.e. FiLT) must be displayed before you can scroll using the SETUP key.

After a second, the current value of the parameter should appear.

G. Use the up ▲ and down ▼ arrow keys to change the value to **–1.6**.

Setting the Process Variable Offset (OFFS) parameter to –1.6 compensates for the difference between the sensing element location and the actual zero mark in the process tank.

H. Press the **SETUP** key to accept the new value.

I. Press and hold the **SETUP** key and press the up ▲ arrow key to return to the Select Mode.

J. Use the up ▲ arrow key to scroll to the Operator Menu (OPtr). Stop when the display shows "OPtr".

K. Press the **SETUP** key again to exit the Select Mode and return the process meter to normal operation.

The process value on the display should now be 0.0. If it is not 0.0, you can go back to the Process Variable Offset parameter and adjust the value until the meter displays 0.0 when the water level is at the zero mark on the process tank.

❑ 10. Perform the following substeps to fill the process tank and measure the level using the process meter.

A. Observe the process meter while the process tank is empty.

You should observe that the process meter display shows 0.0.

B. Start the circulation pump by placing **SS1** in the **ON** position.

The process meter should display the level of water in the tank (in inches) as it continues to increase.

C. Continue to allow the tank to fill and observe the process meter as the level increases.

You should find that the indicated level on the process meter continues to increase as the actual level in the process tank increases.

D. When the process meter indicates **10.0** (10 inches), turn off the circulation pump.

E. Check the level of water in the tank using the sight level scale on the front of the process tank.

Is the level close to 10 inches? __________________ (Yes/No)

You should find that the level according to the sight level scale is close to 10 inches. If not, you may need to reconfigure the process meter.

F. Open the right side process tank manual drain valve and drain the process tank to the 5-inch mark.

G. When the level reaches the 5-inch mark, close the tank drain valve.

H. Check the level indicated on the process meter.

You should find that the displayed value indicates approximately 5.0 inches.

As you can see, when a process meter is properly configured, it can provide the operator or technician with valuable data concerning the process. You can determine whether a process is in control (PV = SP) without physically observing the process.

❑ 11. Perform the following substeps to shut down the T5552.

A. Open the process tank manual drain valves until all of the water drains from the process tank.

B. When the process tank is empty, close the manual drain valves by turning them clockwise.

C. Turn off the main circuit breaker.

D. Disconnect the control circuit.

SEGMENT 3

SELF REVIEW

1. Display _______________ is the process of configuring a device to display the output signal from a sensor in measurement units other than the actual units of the sensor's signal.

2. Most newer process meters have a(n) _______________ display.

3. When a process meter receives an analog input signal, the signal is converted (analog-to-digital) and sent to its _______________.

4. Process meters can be programmed to display the actual value of the input signal, a percentage of the input signal, or the ___________ units of the process variable.

5. To configure a process meter, you must program the input signal range and the _______________ range parameters.

6. Process meters are typically wired directly to _______ that monitor a process variable.

APPENDIX A

SPECIFIC GRAVITY OF VARIOUS LIQUIDS

LIQUID	SPECIFIC GRAVITY
Acetone	0.79
Corn Oil	0.92
Crude Oil	0.85
Gasoline	0.74
Glucose	1.35-1.42
Glycol	1.01
Molasses	1.45
Soy bean oil	0.93
Tar	1.2
Water (fresh)	1.00
Water (sea)	1.03