PROCESS CONTROL SYSTEMS

1

LEARNING ACTIVITY PACKET

INTRODUCTION TO PROCESS CONTROL

IST™
AMATROL
INTEGRATED SYSTEMS TECHNOLOGY

B270-XD

INTRODUCTION TO PROCESS CONTROL

INTRODUCTION

Process control systems are used in industrial plants throughout the world to control various aspects of the liquids, gases, and semi-solids used in product manufacturing.

This LAP covers the basic concepts of process control systems. These concepts include common process terminology and process safety. This LAP also introduces the operations of measuring and manually controlling liquid level, which are common in process control applications.

ITEMS NEEDED

Amatrol Supplied
- 1 T5552 Process Control Learning System

School Supplied
- 1 Water Supply (10 gallons)
- 1 Compressed Air Supply

FIRST EDITION, LAP 1, REV. B

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SEGMENT 1

PROCESS CONTROL CONCEPTS

OBJECTIVE 1 DEFINE PROCESS CONTROL

Read This

A process control system provides control of some facet of an industrial process, typically involving either liquids or gases. One example of a process control application is the control of liquid level in a tank, as shown in figure 1. To maintain a constant liquid level, the liquid flow out of the tank is controlled by opening and closing a valve. The control system for this application consists of a liquid level sensor, valve, and controller of some type.

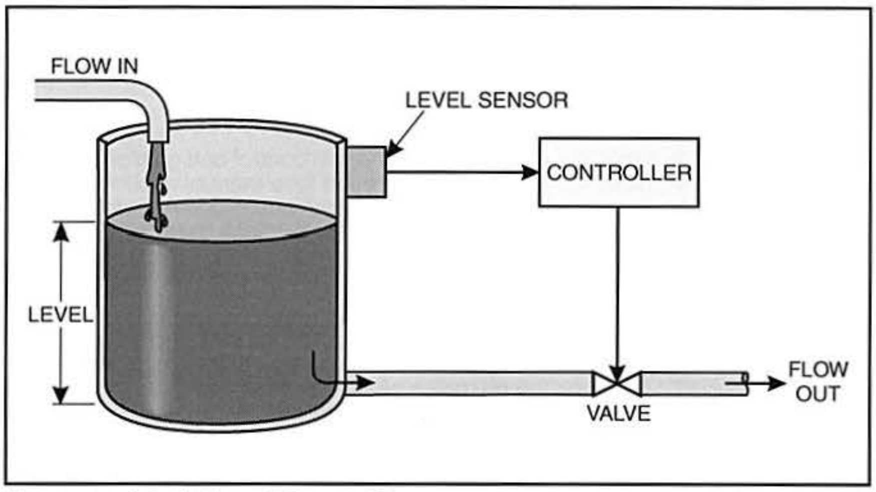

Figure 1. Liquid Level Control System

Process control systems range from very simple systems involving manual control to more complex systems that continuously monitor and adjust the output to maintain the output at a constant level (e.g. a constant liquid level).

OBJECTIVE 2 DESCRIBE THREE COMMON PROCESS CONTROL APPLICATIONS

Process control is used in virtually every industry today. Three common applications are:

- Pharmaceutical Production
- Fuel Refinement
- Chemical Manufacturing

Pharmaceutical Production

The pharmaceutical industry uses process equipment, as shown in figure 2, to precisely control the blending of chemicals used to make drugs.

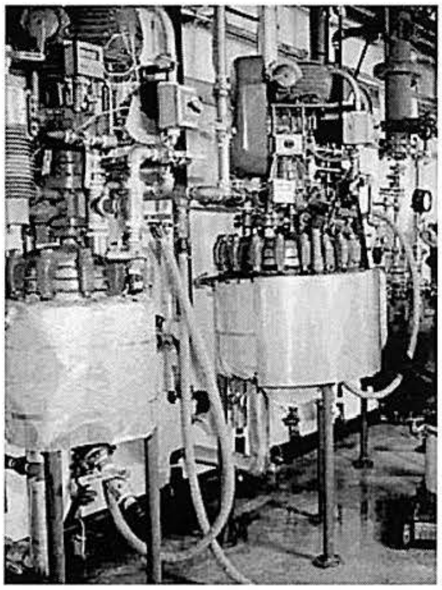

Figure 2. Process Equipment Used in Pharmaceutical Industry

Fuel Refinement

Petrochemical companies use process equipment in refineries like the one in figure 3 to convert crude oil into gasoline and other useful products.

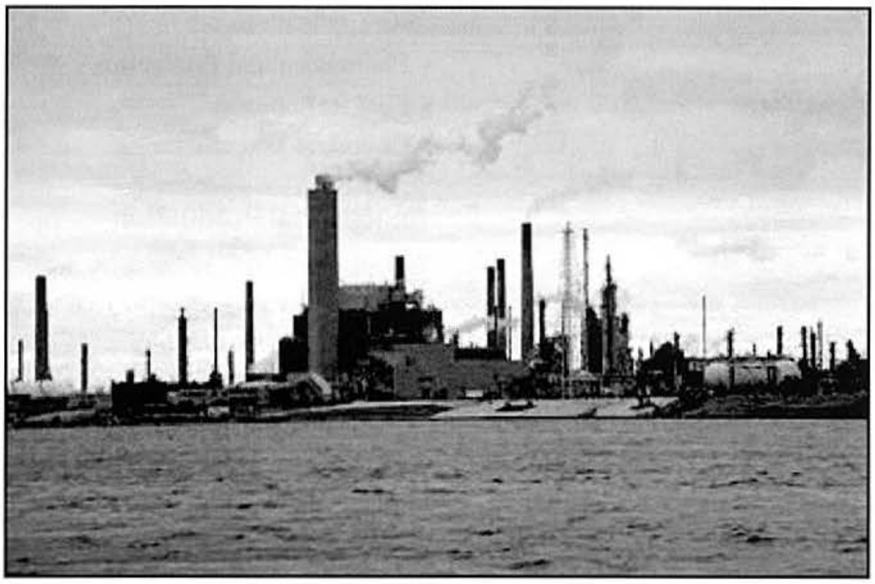

Figure 3. Refinery

Chemical Manufacturing

Chemical manufacturing involves the transformation of organic (chemicals containing carbon and hydrogen) and inorganic raw materials (chemicals made from salts, minerals, metals, and atmosphere) to create products or other chemicals. The precise control of chemicals is essential in manufacturing products like soaps and bleach, plastics materials, pharmaceutical products, dyes, and fuel.

Figure 4. Chemical Mixing Process

OBJECTIVE 3 DEFINE THREE BASIC PROCESS CONTROL TERMS AND EXPLAIN THEIR IMPORTANCE

Read This

To understand the operation of a process control system, it is important to first understand three basic terms that are used to describe their operation:

- Process Variable
- Setpoint
- Error

Process Variable

The process variable is the aspect of the process that is being controlled. It is described as a numerical value and is often abbreviated as "PV".

One example of a PV is liquid level in a tank, as shown in figure 5. In this figure, the actual level of water in the tank is 10 feet. Therefore, the PV is said to be 10 feet.

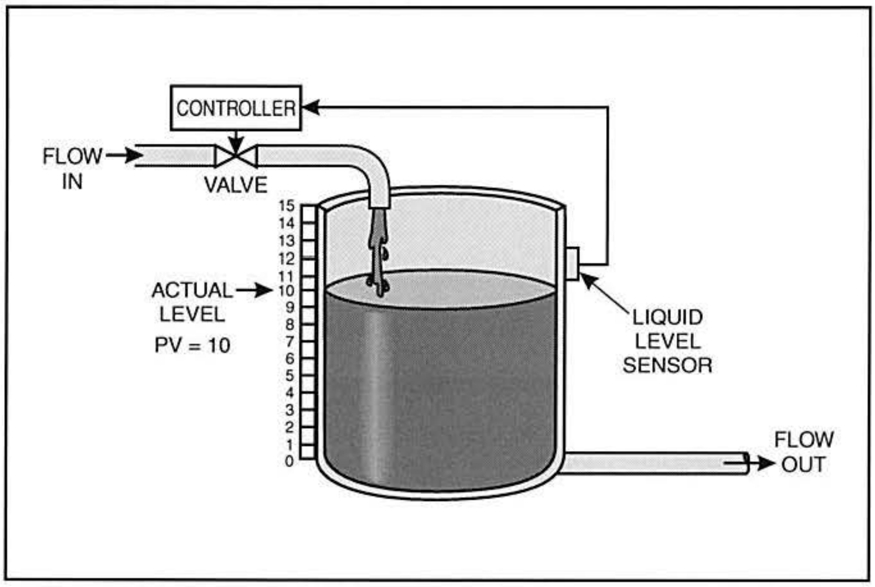

Figure 5. Level in the Tank is Process Variable

Setpoint

The desired value of the process is called the setpoint, or "SP". SP refers to the value at which the PV is to be maintained. For instance, if you want the level in a tank to be 10 feet, the setpoint is 10 feet of water (SP = 10 ft.). However, the actual level in the tank (the PV) may be more or less than the desired SP, as shown in figure 6.

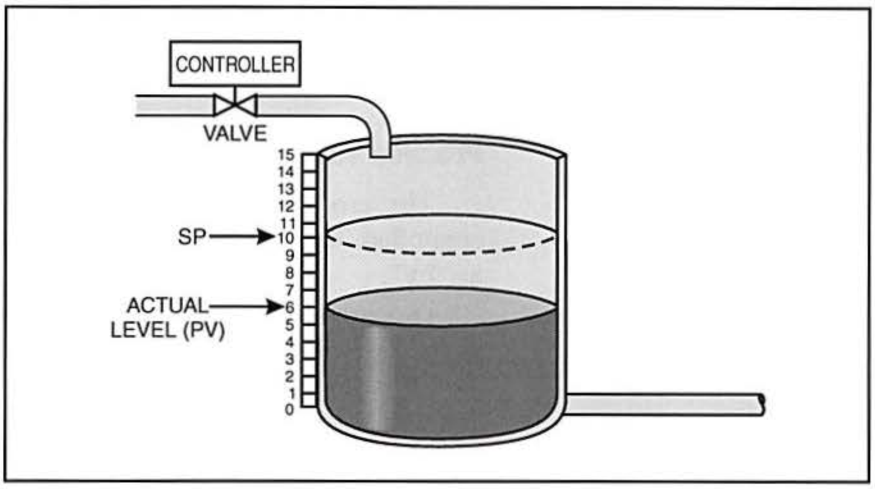

Figure 6. Actual Level Not Equal to SP

Error

The difference between SP and PV at any given point in time is called the "error," as shown in the following formula.

ERROR FORMULA

$$Error = SP - PV$$

Where SP = *Setpoint*
PV = *Process Variable*

For example, if the actual level in a tank (PV) is 6 feet of water and the setpoint (SP) is set at 10 feet, the error would be 4 feet (10 - 6 = 4). Therefore, in order for the PV to reach SP, the level would have to increase by 4 feet of water. This is shown in figure 7.

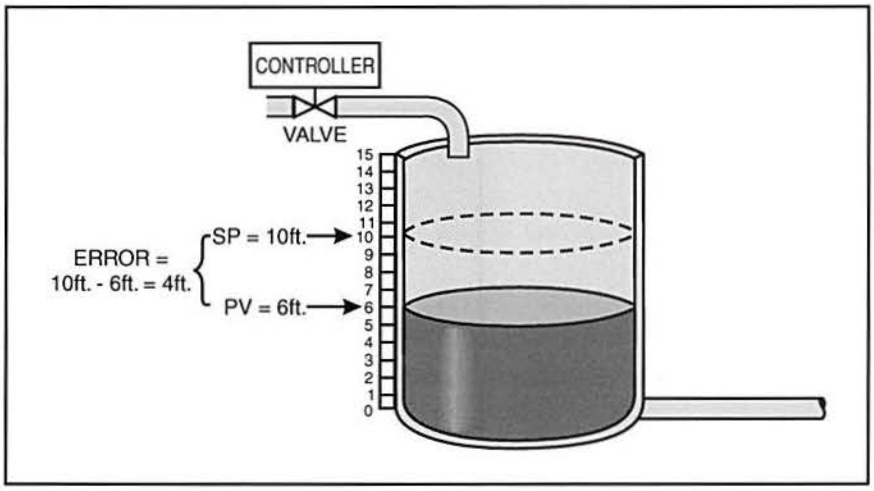

Figure 7. Error in a Process

The error is important because it is the value the controller uses to determine what the output needs to be to cause the process variable (PV) to become equal to the setpoint (SP).

OBJECTIVE 4 DESCRIBE FIVE COMMON PROCESS VARIABLES AND GIVE AN APPLICATION OF EACH

Process control systems can be designed to control many types of process variables. The five most common process variables are:

- Flow
- Level
- Pressure
- Temperature
- Chemical/Analysis

Flow

The precise control of the flow of a liquid or gas is often needed as part of a process. This is accomplished using a valve to restrict the fluid stream. For example, figure 8 shows a flow control application in which the flow of hot water to a heat exchanger is controlled. The heat exchanger transfers some of the heat to the process fluid.

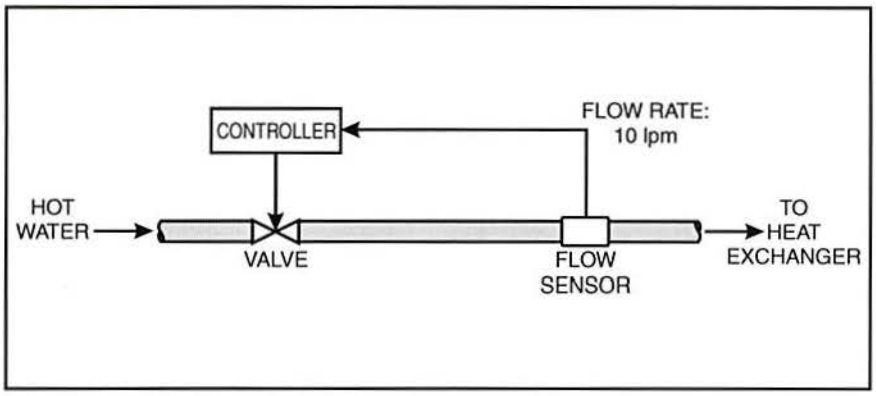

Figure 8. Flow Control to a Heat Exchanger

Applications for flow control include mixing processes (where the flow of materials must be controlled at specific ratios) and gas furnaces (where the flow of gas into the furnace is critical in controlling the temperature).

Level

A level control system controls the height of a column of a substance, usually a liquid, inside a container. Level control is usually accomplished by a valve that restricts the flow of a liquid entering a tank or leaving it, as shown in figure 9.

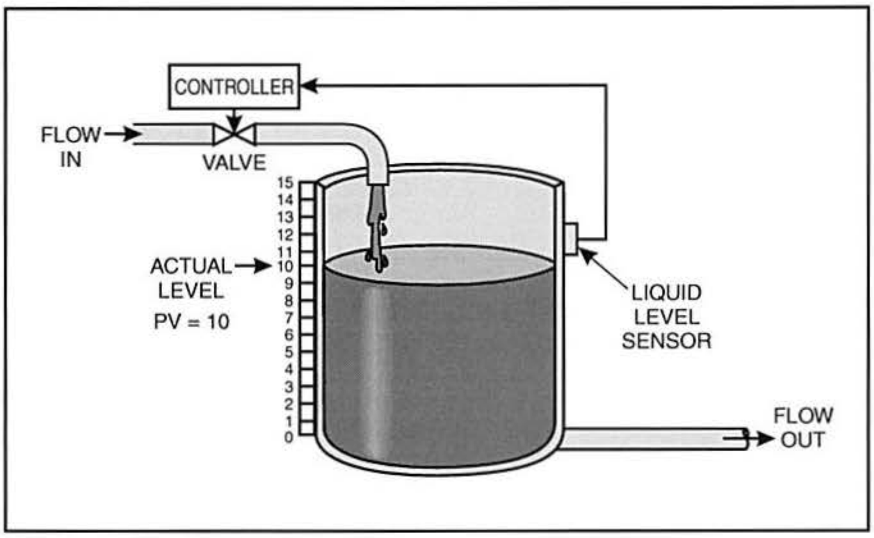

Figure 9. Level Control

Applications for level control include boilers, cooling towers, and chemical reaction tanks.

Pressure

The pressure of a liquid or gas in tanks and pipes is another common variable controlled by process control systems. Figure 10 shows a process that controls the pressure in a tank by controlling the flow of gas out of the tank.

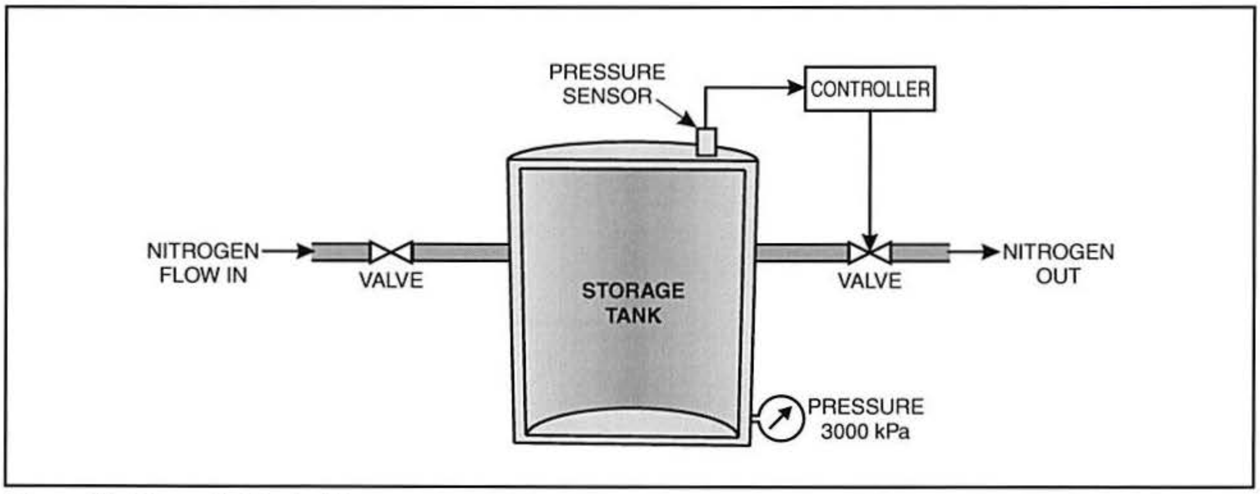

Figure 10. Example Control Loop

Applications for pressure control include boilers and compressors.

Temperature

Temperature control systems control the temperature of a liquid or gas. Temperature control is usually accomplished by routing the process fluid through a heat exchanger of some type, as shown in figure 11.

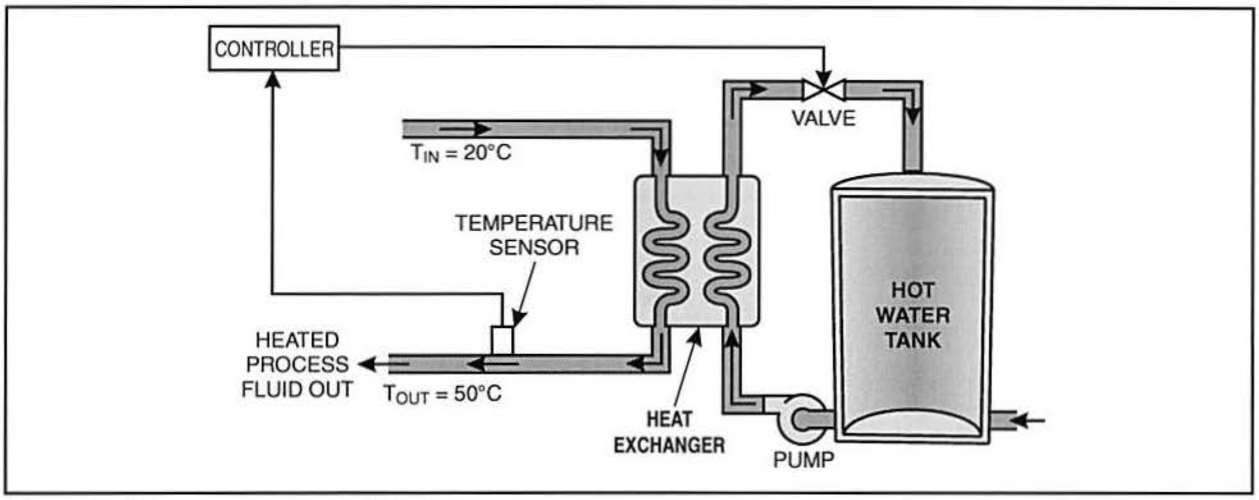

Figure 11. Temperature Control System

Applications for temperature control include furnaces, beverage manufacturing, and chemical manufacturing.

Chemical/Analysis

Chemical process systems, also known as Analysis Control Systems, measure and control the chemical properties of a process fluid. Properties that are commonly measured include humidity, specific gravity, pH, conductivity, and density. Figure 12 shows a process measuring pH. In this process, controlling the flow of two chemicals into the tank allows control over the pH of the resulting mixture.

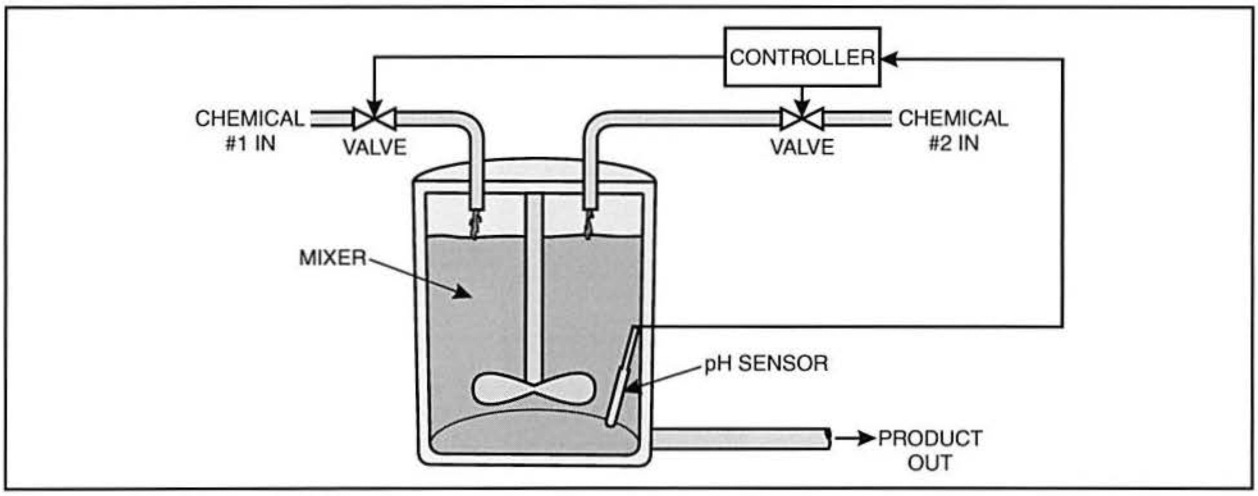

Figure 12. Liquid Density Measurement

Applications for chemical/analytical control include wastewater treatment, pharmaceutical production, and paper manufacturing.

OBJECTIVE 5 DEFINE TWO TYPES OF PROCESS VARIABLES: CONTROLLED AND MANIPULATED

Read This

The controlled variable is the facet of the process that the system is designed to control. However, the variable that actually changes to alter the controlled variable is often a different variable, which is called the manipulated variable.

For example, in a liquid level loop like the one in figure 13, the controlled variable is liquid level. However, the variable that actually changes to control level is the flow rate out of the tank. Flow is therefore the manipulated variable in this process.

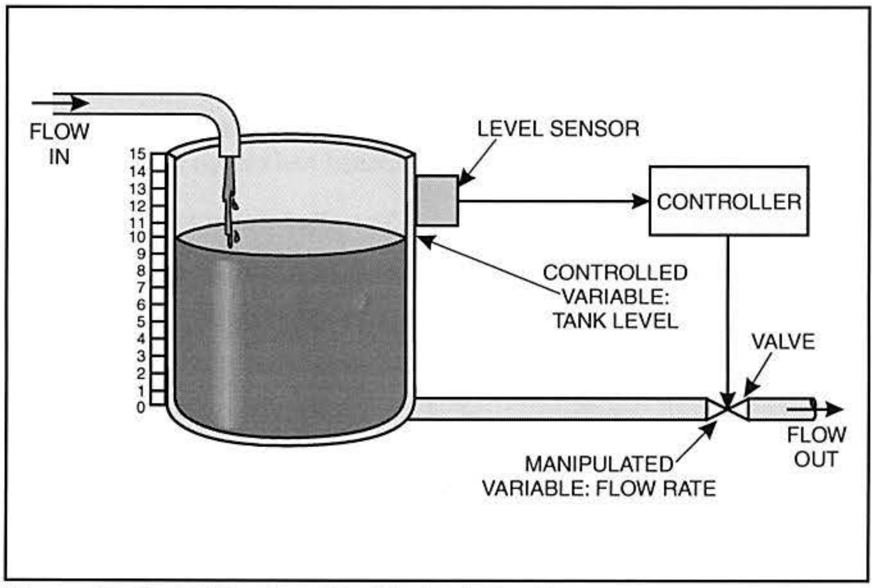

Figure 13. Controlling Level by Manipulating Flow

SKILL 1 DETERMINE THE MANIPULATED AND CONTROLLED VARIABLES GIVEN PROCESS DESCRIPTIONS

Procedure Overview

In this procedure, you will be given various scenarios that describe a control loop. With this information, you will determine the controlled and manipulated variable of that loop. This will allow you to practice identifying the relationships within a process.

☐ 1. Determine the manipulated variable and the controlled variable for the following scenario.

Scenario: You are adjusting the flow into a vessel to prevent the vessel from overflowing. The control system uses a valve that is opened and closed by pneumatic pressure.

Controlled Variable ______________________________

Manipulated Variable ______________________________

In this case, the controlled variable is flow and the manipulated variable is pressure.

☐ 2. Determine the manipulated variable and the controlled variable for the following scenario.

Scenario: You are adjusting the flow out of a water tower in order to keep the water level in the tower at a constant level.

Controlled Variable ______________________________

Manipulated Variable ______________________________

☐ 3. Determine the manipulated variable and the controlled variable for the following scenario.

Scenario: To develop a pressure in a vessel, you are heating the vessel.

Controlled Variable ______________________________

Manipulated Variable ______________________________

☐ 4. Determine the manipulated variable and the controlled variable for the following scenario.

Scenario: To heat a process fluid, you are adjusting the amount of electrical current that is flowing to a heating element.

Controlled Variable ______________________________

Manipulated Variable ______________________________

☐ 5. Determine the manipulated variable and the controlled variable for the following scenario.

Scenario: To maintain a neutral process pH, you are controlling the flow of an alkali into the process fluid.

Controlled Variable ______________________________

Manipulated Variable ______________________________

☐ 6. Examine the control loop in figure 14. Determine the manipulated and controlled variables.

Controlled Variable ______________________________

Manipulated Variable ______________________________

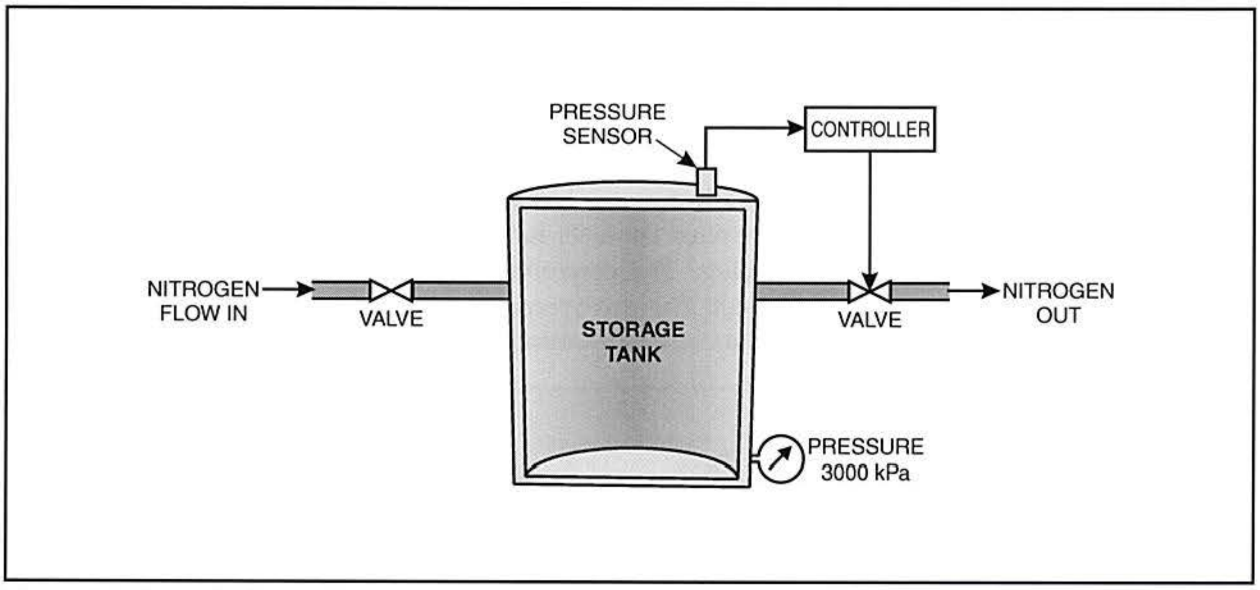

Figure 14. Example Control Loop

OBJECTIVE 6 DEFINE A PROCESS INSTRUMENT AND GIVE AN EXAMPLE

A process instrument is any device that directly or indirectly measures, controls, or manipulates the process variable. When most people hear the term process instrument, they usually associate it with a measurement device. However, process instruments are not limited to measurement devices.

Measurement instruments (e.g. level, flow, temperature, and pressure sensors) determine the existence and magnitude of a process variable. Control instruments (e.g. computers, PLCs, and electronic controllers) work to maintain a process variable at a specific value or within a specified range. Manipulation instruments (e.g. control valves and pumps) act to directly change (manipulate) the process variable. They are commonly referred to as final control elements.

A control loop is a collection of process instruments combined into a system. For example, figure 15 shows a level control loop made up of several process instruments including a level sensor, a controller, and a valve. Each instrument has a different function in the loop. The level sensor measures the level in the tank and supplies this measurement to the controller. The controller determines whether the level is at the desired point. The valve receives a signal from the controller that causes it to open or close as necessary to keep the level at the desired point.

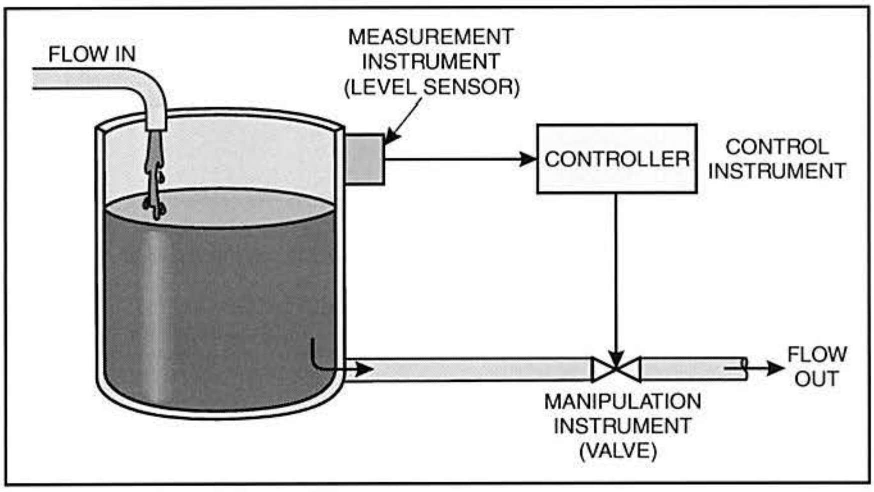

Figure 15. A Level Control Loop

The performance of any control loop depends heavily on the proper operation of each of the process instruments.

OBJECTIVE 7 DEFINE AN OPEN LOOP PROCESS CONTROL SYSTEM AND GIVE AN ADVANTAGE

Read This

The most basic type of control loop is an open loop process control system, which includes only a control instrument and a manipulation instrument, as shown in figure 16.

The open loop control system creates a variable output that is determined by the setpoint. This system does not have any means for sensing (measurement instrument) the actual output value, and is therefore unable to automatically correct for changes in the process.

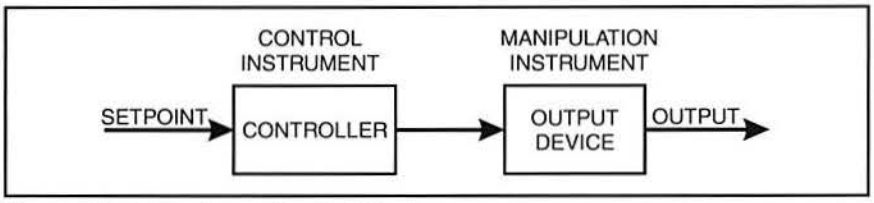

Figure 16. Open Loop Control System

An example of an open loop process control system is the liquid level control system shown in figure 17. This system has a controller that is capable of adjusting the valve to any position, which gives the system the ability to create any desired liquid level by controlling the flow rate out of the tank. Flow out of the tank must match flow into the tank for the level to stabilize.

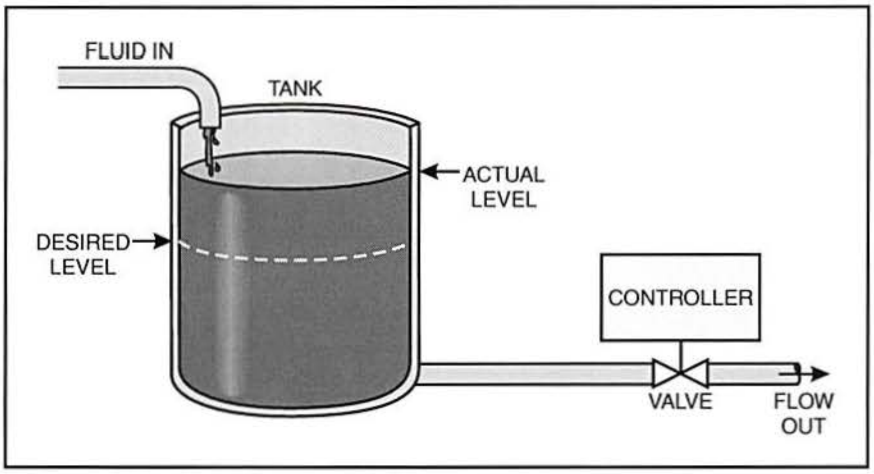

Figure 17. An Open-Loop Level Control System

The advantages of open loop systems are that they are usually simpler and cost less than closed loop systems. The weakness of an open loop system is that it cannot continue to maintain the desired level if conditions change. For example, if the flow rate into the tank in figure 17 increases, the level in the tank begins to rise because the valve position stays constant and, therefore, the output flow stays constant. Open loop systems are used in applications where exact control is not critical and there is not much change in conditions.

OBJECTIVE 8 DEFINE A CLOSED LOOP PROCESS CONTROL SYSTEM AND GIVE AN ADVANTAGE

Read This

A closed loop system, like the one in figure 18, consists of the same instruments used in the open loop system plus a feedback sensor (measurement instrument) that monitors the controlled variable and feeds back the signal to the controller. The controller then compares it to the setpoint and adjusts its output until the feedback signal equals the setpoint.

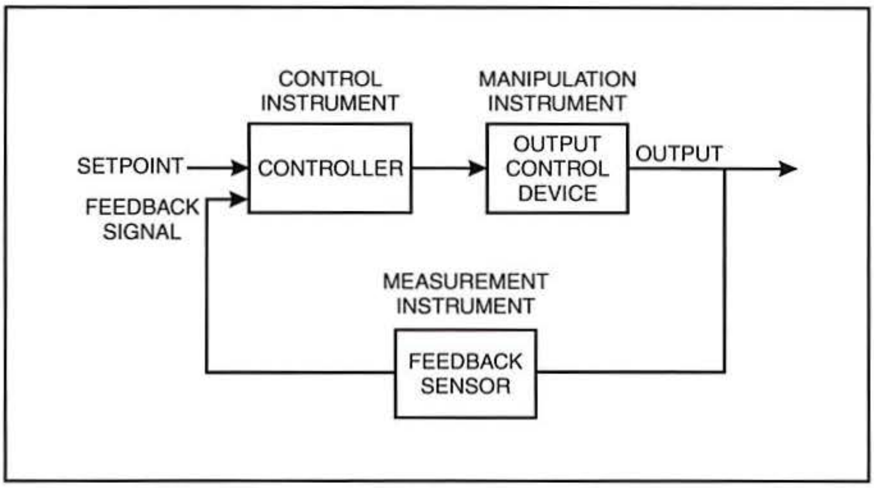

Figure 18. A Closed Loop Level Control System

An example of a closed loop process control system is the liquid level control system shown in figure 19. This system contains the instruments of the open loop system plus a liquid level sensor to measure the level in the tank and feed it back to the controller. The controller adjusts its output signal to the valve based on the feedback from the level sensor. This causes the valve to open or close, thereby increasing or decreasing the output flow to maintain the desired level.

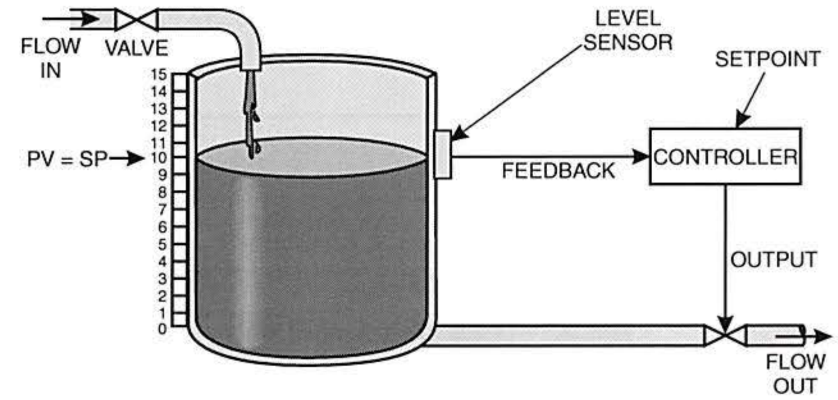

Figure 19. Closed Loop Level Control

Closed loop process control systems are more expensive and complex than open loop systems. However, their ability to maintain a constant output under changing conditions makes them a common choice for a wide range of process control applications.

Activity 1. T5552 System Familiarization

Procedure Overview

In this procedure, you will identify the components of the Amatrol T5552 Process Control System. The T5552 Process Control System is a process simulator capable of controlling fluid flow and level using both open and closed loop control.

❑ 1. Locate the T5552 Process Control System, shown in figure 20.

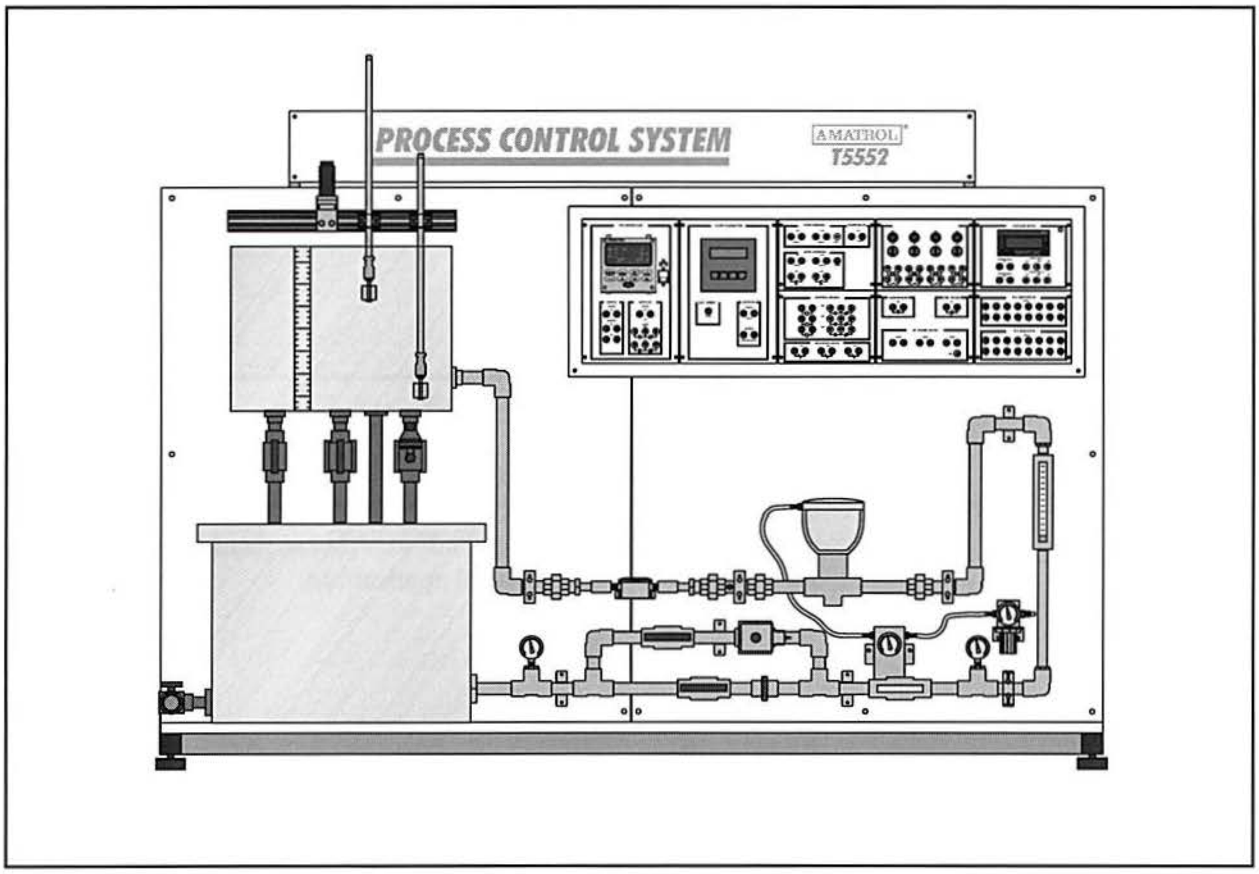

Figure 20. The Amatrol T5552 Process Control System

❑ 2. Locate the five major components on the T5552, as shown in figure 21.

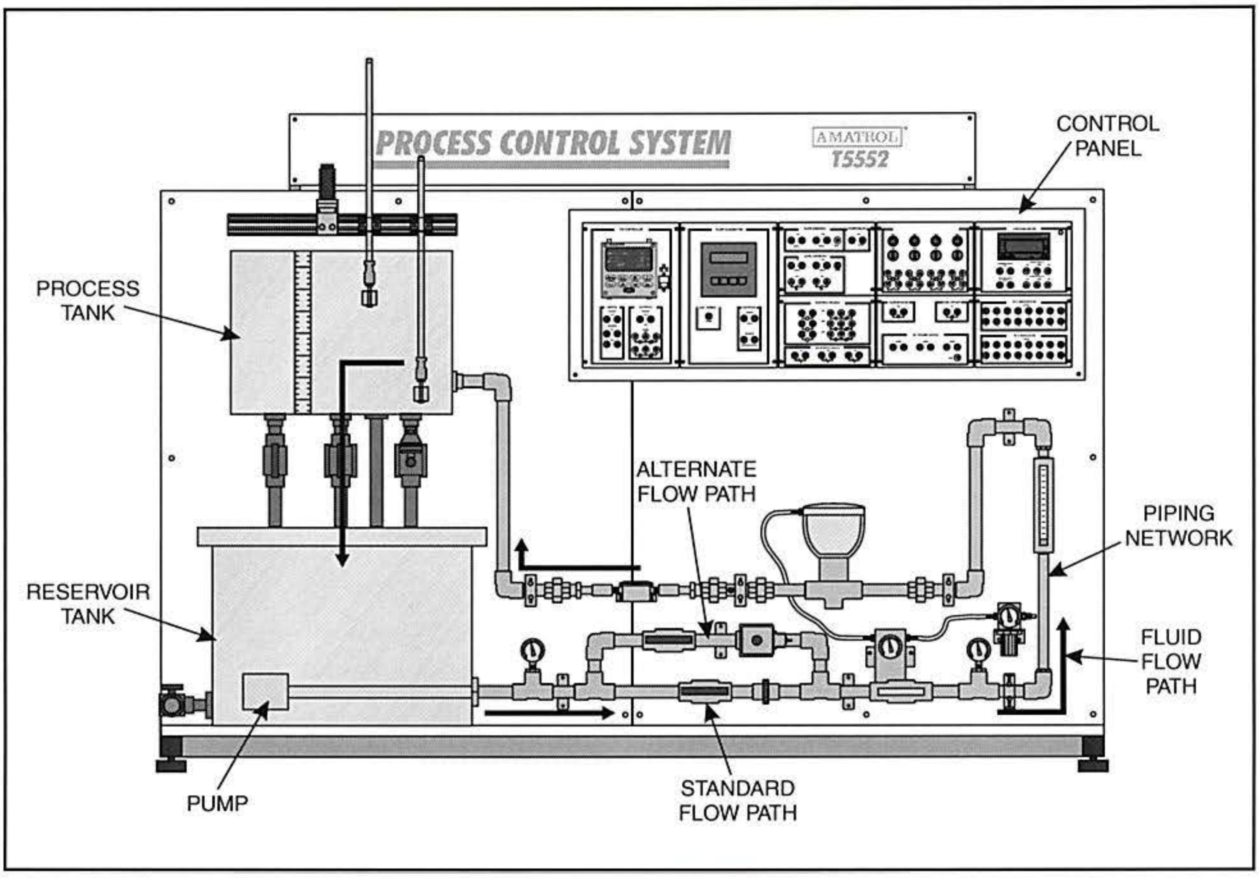

Figure 21. Process Flow Through the T5552

- **Control Panel** - The control panel contains connections to the control components to provide control of flow and liquid level. It also contains instrumentation to display the status of input and output signals.
- **Reservoir Tank** - The fluid process starts at the reservoir tank, where water is stored.

CAUTION

The reservoir tank should be filled with enough water so that the pump remains submerged at all times during use.

- **Pump** - The pump, located inside the reservoir tank, is a centrifugal type. It pumps water from the reservoir tank into the piping network.

  The water helps to cool the pump and prevents the pump from overheating. Failing to keep the pump submerged at all times can result in the pump overheating and being damaged. Figure 22 shows a pump that has cracked as a result of being run dry.

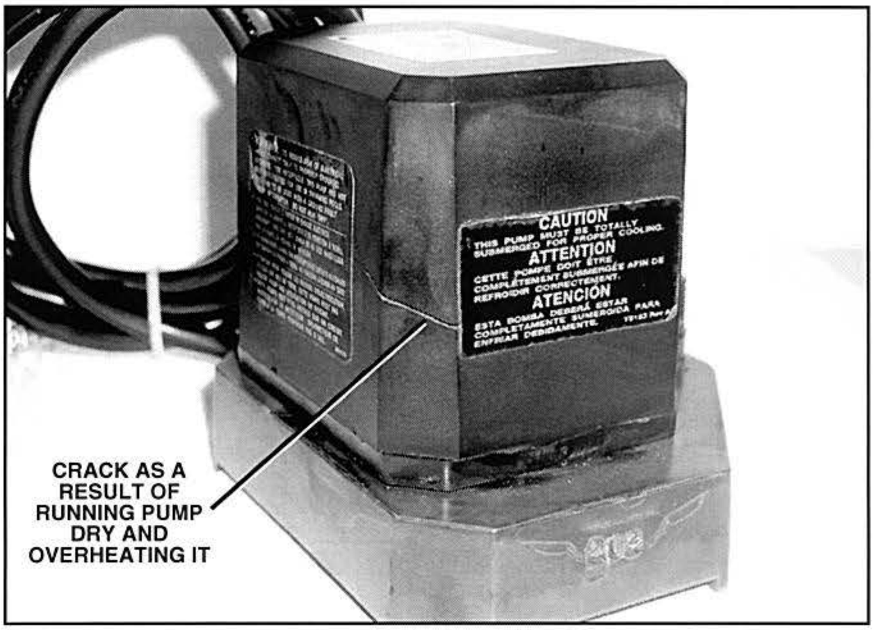

Figure 22. Pump Damage from Overheating

- **Piping Network** - The piping network provides a path through which the water flows from the reservoir tank to the process tank. The flow rate can be sensed and controlled using flow sensors and valves located in the piping network.

  Notice in figure 21 that the flow moves through the piping in a counterclockwise direction. All components in the main piping are connected in series except in one location where a valve can be opened to allow the water to flow through an alternate flow path that contains a solenoid valve. This alternate path can be used when you want to control the flow using the solenoid valve (i.e. ON/OFF control).

- **Process Tank** - The process tank is where the fluid exits the piping network. It is the point where liquid level is monitored using sensors and represents the point where a real world process would take place. The fluid flows back to the reservoir tank by gravity so that the process can operate continuously without refilling.

❑ 3. Locate the following process piping components on the T5552 system, as shown in figure 23.

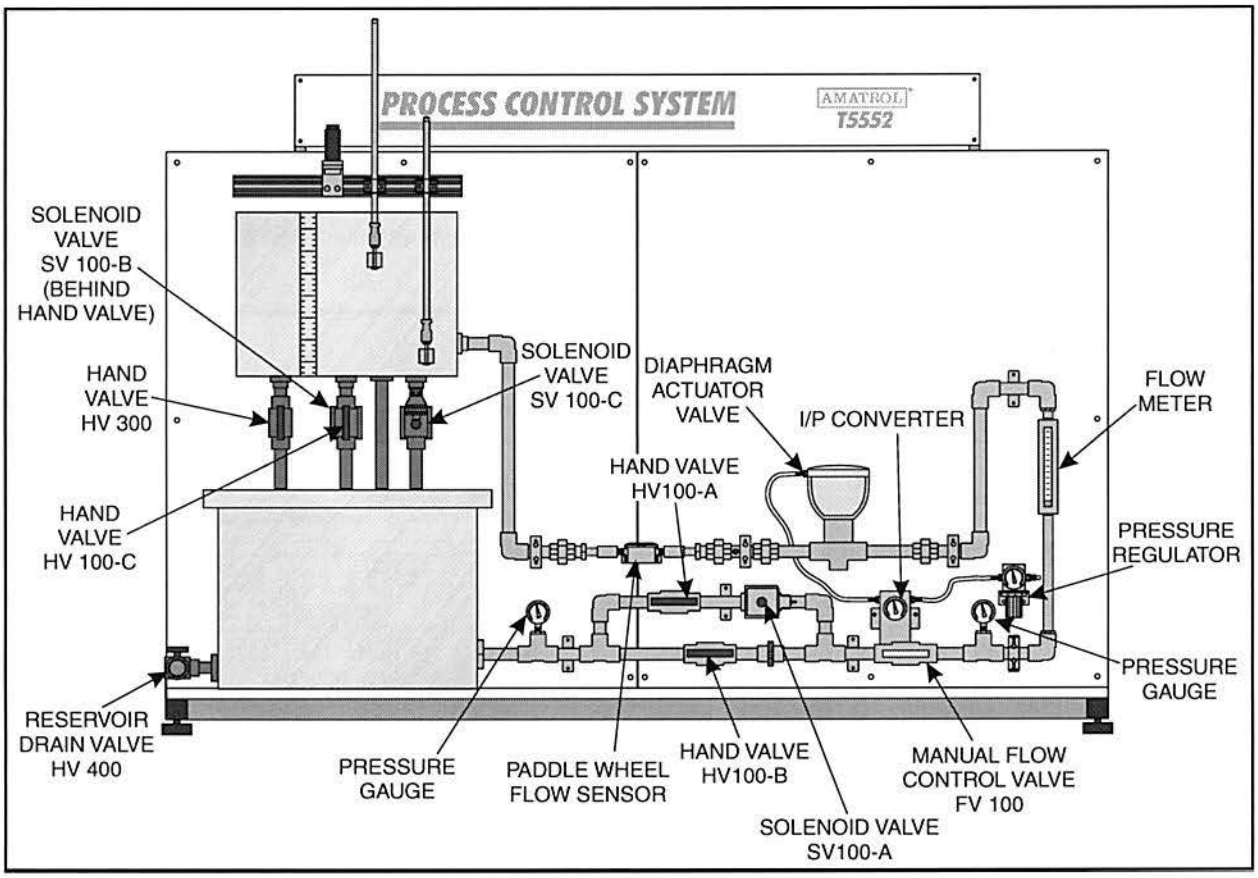

Figure 23. T5552 Process Piping Network Components

- **Hand Valves -** Hand valves HV 100-C and HV 300 drain the process tank. Hand valves HV 100-A and HV 100-B restrict flow through their respective paths. Hand valve HV 400 drains the reservoir tank. Hand valve FV 100 is called the manual flow control valve and is the main hand valve used to set the maximum flow rate through the piping network.
- **Solenoid Valves -** Solenoid valve SV 100-A can be used with a control relay to automatically restrict flow through this path. SV 100-B and SV 100-C are used to drain the process tank. Each solenoid valve is a normally closed (N.C.) valve.
- **Flow Meter -** The flow meter identified is a rotameter. It provides a visual indication of the flow rate of the fluid through the system.
- **Diaphragm Actuator Valve -** The diaphragm actuator valve is an air-to-close proportional valve that can automatically control the amount of flow in the system.
- **I/P Converter -** The current-to-pressure (I/P) converter is a signal conditioner that converts an electrical signal from a controller into a pneumatic signal to control the diaphragm actuator valve.

- **Pressure Regulator** - The pressure regulator controls the amount of supply air that is sent to the I/P converter.
- **Pressure Gauges** - The two pressure gauges on the T5552 indicate the pressure in the piping network.
- **Paddle Wheel Flow Sensor** - The paddle wheel flow sensor is a turbine-type flow sensor that automatically measures the flow rate in the system and sends its frequency output signal to a flow transmitter.

❑ 4. Locate the control components on the T5552, as shown in figure 24.

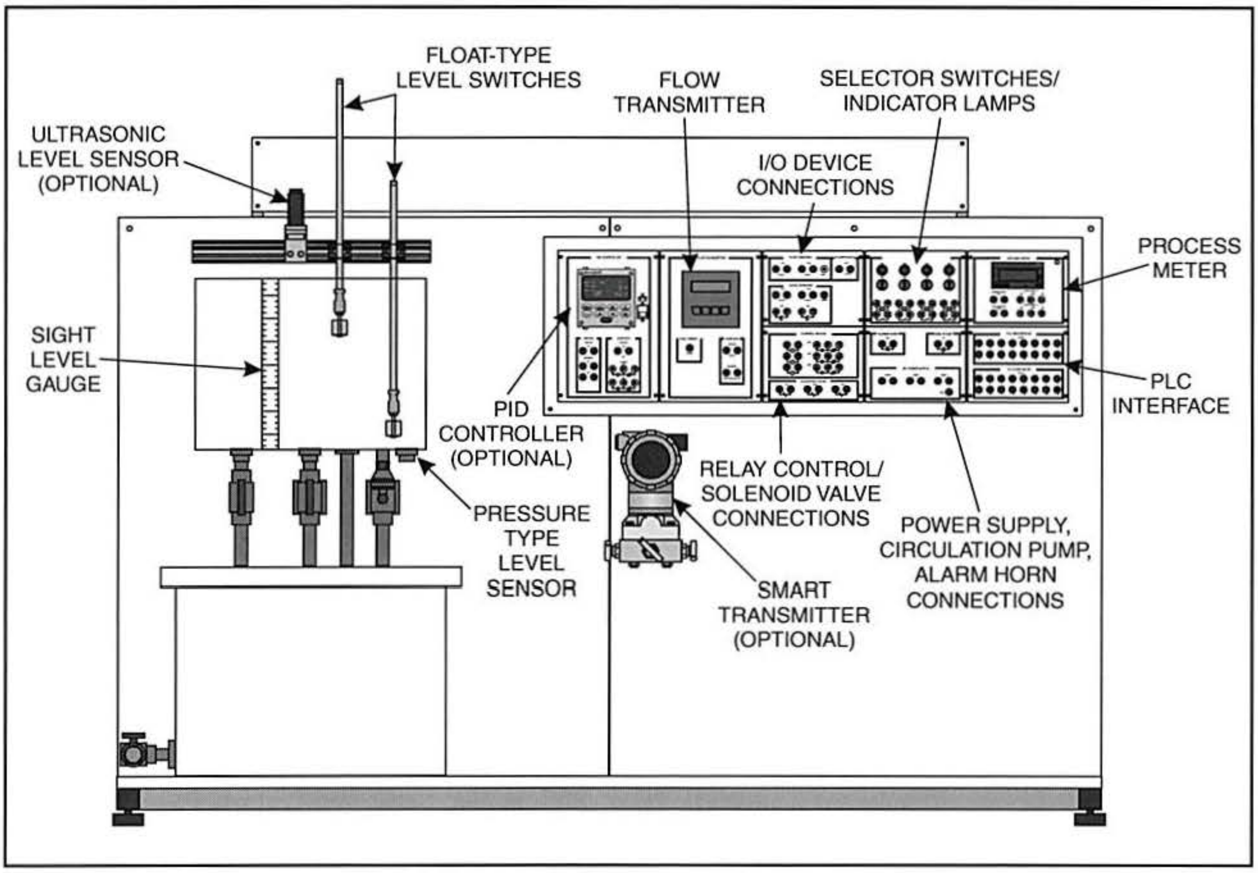

Figure 24. T5552 Control Panel and Process Tank Components

- **PID Controller (Optional)** - The optional PID controller provides automatic control of level or flow in the T5552. The controller has one analog input, two digital inputs, one analog output, and two alarm relays.
- **Flow Transmitter** - The flow transmitter displays the flow rate from the paddle wheel flow sensor. It also provides a feedback signal to the PID controller when required.
- **Relay Control/Solenoid Valve Connections** - The relay control connections include three control relays with normally open and normally closed contacts. Also included are connections for the three solenoid valves.

- **I/O Device Connections** - The input/output (I/O) device connections include connections to the float-type level switches, the pressure-type level sensor, and the I/P converter. Connections for the optional ultrasonic level sensor are also provided.
- **Selector Switches/Indicator Lamps** - This panel consists of contact closure selector switches and indicator lamps that can be used to indicate when a device or alarm is energized. The connections for the switches and lamps are included.
- **Power Supply, Circulation Pump, Alarm Horn Connections** - This panel has connections for the 24VDC power supply, the circulation pump inside the reservoir tank, and the alarm horn on the trainer.
- **Process Meter** - The process meter can be programmed to indicate flow or level in the T5552. The process meter has an analog current input, an analog voltage input, and two SPDT alarm relays.
- **PLC Interface** - The PLC interface provides a way to connect the digital and analog inputs and outputs on the T5552 to a PLC. The connection jacks on the PLC interface panel are wired to the connectors on the right side panel of the control panel enclosure.
- **Float-type Level Switches** - The T5552 has two adjustable (up and down) float-type level switches that extend into the process tank. The level switches are shipped in the normally open configuration but may be reversed to function as normally closed types.
- **Pressure-Type Level Sensor** - The pressure sensor measures the head pressure of the liquid in the process tank to provide a measurement of liquid level in the tank. The output signal can be used as feedback for control of liquid level.
- **Ultrasonic Level Sensor (Optional)** - The optional ultrasonic level sensor is positioned above the process tank and measures the level in the tank using ultrasonic waves.
- **Smart Transmitter (Optional)** - The optional smart transmitter is a differential pressure transmitter that works with a differential pressure sensor to calculate and display the flow rate through the system. Examples of differential pressure sensors that can be used with the smart transmitter include orifice plates, pitot tubes, and venturi tubes. Each of these sensors is also an option for the T5552.

❑ 5. Determine if the following differential pressure sensor options have been provided with your system.

These options are used in later LAPs.

- **Pitot Tube -** The pitot tube, as shown in figure 25, is one type of differential pressure flow sensor. It is used with the optional smart transmitter.

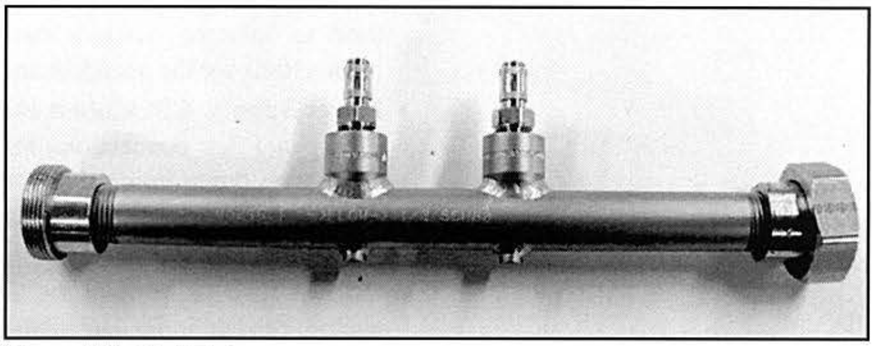

Figure 25. Pitot Tube

- **Venturi Tube -** The venturi tube, as shown in figure 26, is another type of differential pressure flow sensor. It too is used with the optional smart transmitter.

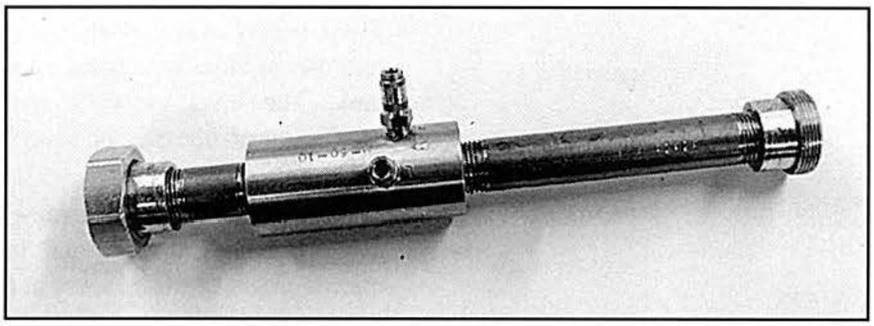

Figure 26. Venturi Tube

- **Orifice Plate -** The orifice plate, as shown in figure 27, is another type of differential pressure flow sensor and is used with the optional smart transmitter.

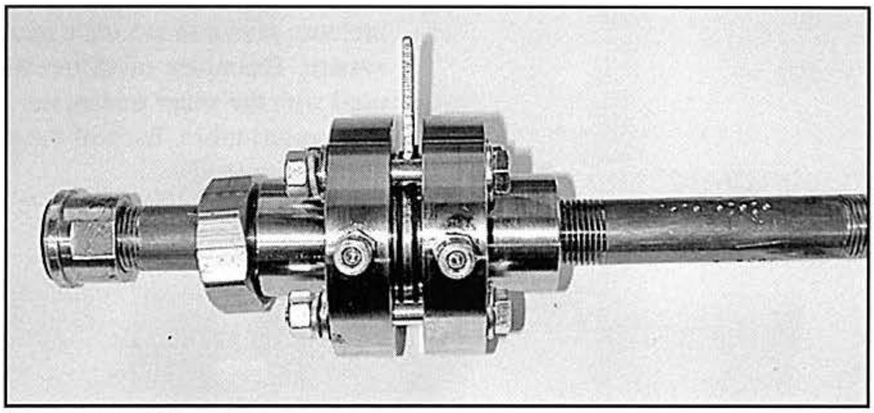

Figure 27. Orifice Plate

SEGMENT 1

SELF REVIEW

1. A process variable is the aspect that can be ___________.

2. The desired value of your process variable is called the ______________.

3. The five most commonly controlled variables in process systems are level, flow, pressure, chemical, and ______________________.

4. The two types of loops in process systems are open loop and ________ loop.

5. _______-loop control is a method that does not provide feedback to the process to correct for disturbances to the process.

6. ____________-loop process control systems are used in applications where the output variable must remain relatively constant even if conditions change.

7. The variable that actually changes to alter the controlled variable is called the _______ variable.

8. A process _______________ is any device that directly or indirectly measures, controls, or manipulates the process variable.

9. A process control system provides control of some _______ of an industrial process.

10. _______ companies use process equipment in refineries to convert crude oil into gasoline and other useful products.

SEGMENT 2

SAFETY

OBJECTIVE 9 DESCRIBE SIX RULES FOR SAFE DRESS WHEN WORKING WITH PROCESS CONTROL EQUIPMENT

Read This

Safety is the highest priority in all modern industrial plants. Companies strive to increase the productivity while at the same time ensuring that no one is injured. Since process equipment deals with nearly all types of energy transmission, an operator or a technician should understand how to prevent accidents when using process control equipment.

The first line of defense against accidents with process equipment is proper dress, as shown in figure 28.

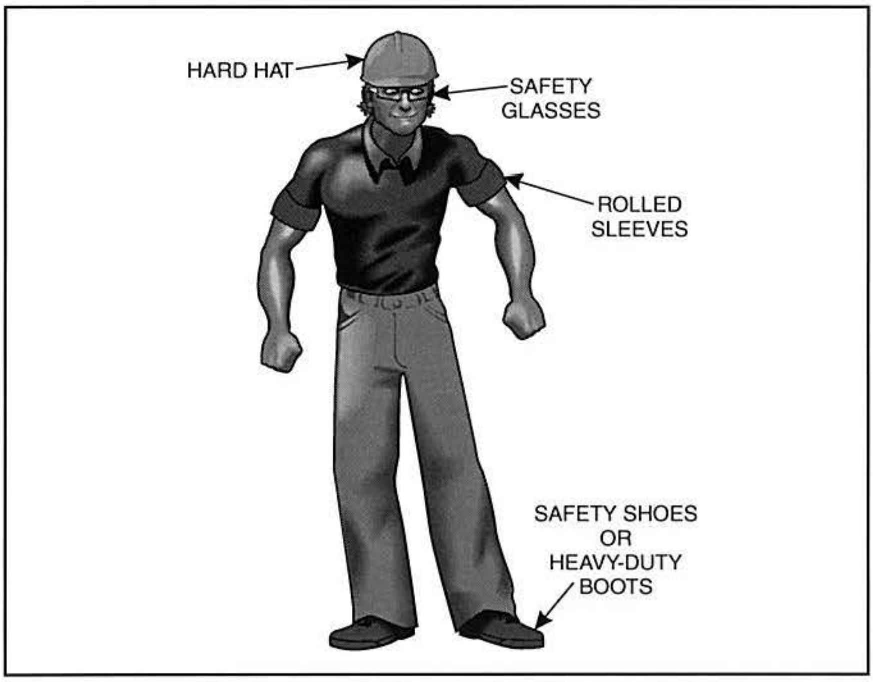

Figure 28. Safety Attire When Working with Running Machinery

The following rules will help to ensure personal safety when working around process equipment.

- Wear safety glasses at all times.
- Avoid wearing loose fitting clothes.
- Remove ties, watches, rings, and other jewelry.
- Tie up long hair, put it under a cap or tuck it in your shirt.
- Wear heavy-duty leather shoes, steel-toed shoes are recommended. Canvas shoes are not acceptable.
- Roll up long sleeves or wear short sleeves.
- Do not wear gloves around machinery when it is running. Gloves can get caught in the moving components and pull your hand into the machine.

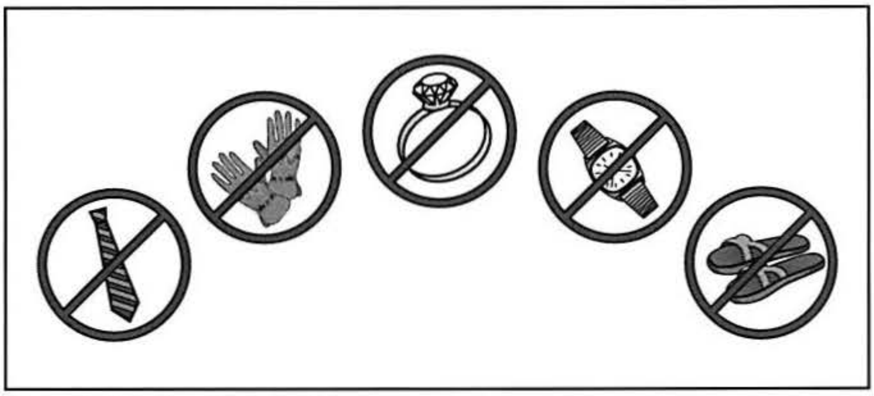

Figure 29. Rules for Safe Dress

OBJECTIVE 10 DESCRIBE 14 BASIC RULES OF PROCESS SAFETY

Read This

In addition to dress rules, there are other rules to follow while working with process equipment. Theses include:

- **Be aware of the conditions before working on a piece of equipment.** Make sure that all power sources to a piece of equipment have been completely shutoff and any stored energy has been released. Devices such as electrical capacitors, springs, and pressurized fluids can store energy.
- **When troubleshooting a system or replacing components, make sure all power sources are locked out.** OSHA requires the use of a lockout/tagout system to help ensure that the power to a circuit or piece of equipment is off.
- **Do not rely on safety devices to protect you.** Circuit protection devices, overload protection devices, and safety interlocks may not be working.
- **Make sure equipment is well grounded.** Never remove the grounding prong on an AC plug. This eliminates the equipment ground and produces a shock hazard.
- **Always keep your tools and test equipment organized.** An unorganized pile of test leads, components, and tools increase the potential of shocks, short circuits, and other accidents. Be organized and systematic when you are working around electrical or mechanical equipment.
- **Do not work on wet floors.** Water decreases the resistance between the body and ground, increasing the possibility of severe shock, as shown in figure 30. It also increases the possibility of slips. Try to work on a rubber mat or an insulated floor when possible, as also shown in figure 30.

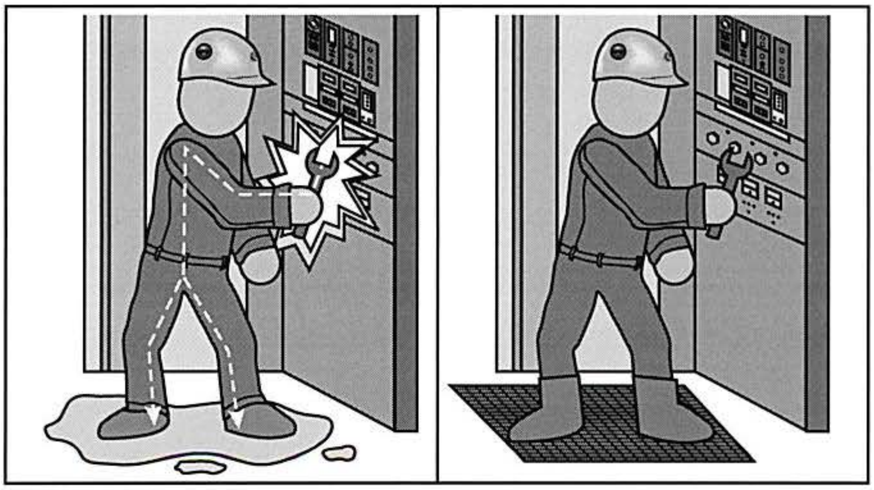

Figure 30. Do Not Work on Wet Floors

- **When possible, work with one hand when working with electrical components.** By working with one hand (put the other behind the back or in a pocket), the possibility of having current pass through the body between the hands is avoided. A current that passes between the hands crosses the heart and can be more dangerous than if the current passes from the hand to the feet.
- **Always move slowly and deliberately.** Rapid or careless movements can lead to an accidental shock or other injury.
- **Do not work alone.** It is a good practice to have someone around who can shut off the power or to call for medical attention if a shock or other accidents occur.
- **Do not let yourself be distracted.** Make sure there are no unauthorized personnel around who could be a distraction or cause a safety hazard. One moment of distraction could have serious consequences.
- **Do not enter a machine's area of operation until the machine is completely stopped.**
- **Understand the basic operation of the system.** This will help to determine if the system is not operating properly.
- **Make sure that all guards are in place and everyone is clear before operating the system.**
- **Always get help when lifting heavy parts.** Valves, piping sections, pumps and motors sometimes have to be moved or replaced. These items can be very heavy. Get help or use the proper devices (e.g. jacks, hydraulic lifts, rigging, etc.) to lift this equipment.

OBJECTIVE 11 DESCRIBE THE FUNCTION OF LOCKOUT/TAGOUT

One of the greatest dangers to a process technician is when someone unknowingly turns on a piece of equipment while they working on it. To avoid this possible danger, most countries require that all power sources (electrical, mechanical, pneumatic, hydraulic, etc.), be locked out for servicing or maintenance. In fact, all companies are required to develop a procedure and must train the employees on that procedure. This procedure is called lockout/tagout.

NOTE

In the United States, the Occupational Health and Safety Administration (OSHA) establishes and enforces all rules concerning health and safety of all workers in the workplace.

What does lockout/tagout mean? It is actually a combination of two processes: lockout and tagout.

Lockout is the process of blocking the energy flow from a power source to a piece of equipment and assuring that it remains blocked. This is accomplished using a lockout device such as a lock, block, or chain at the power source to prevent a piece of equipment from receiving power from the source. For example, in figure 31, the lockout device physically prevents the power switch from being placed in the ON position.

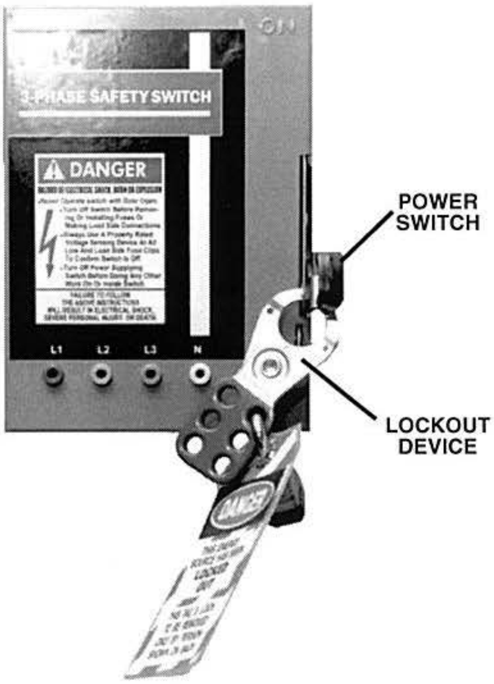

Figure 31. Electrical Lockout Device

Tagout involves placing a tag on the power source that warns others not to restore power, as figure 32 shows. The tags should clearly state: Do not operate or some other similar statement. The tags must be applied by hand. There are special occasions when a tagout can be used without a lockout. However, special care should be taken because a tagout is not a physical restraint like a lockout.

Figure 32. Tagout Device

Anyone who is working on a piece of process equipment should perform a lockout/tagout. The only person who should remove a lockout/ tagout is the person who installed it. In a case where there may be several persons servicing a piece of equipment, a multiple lockout is used so that all have their own lockout. Therefore, the power cannot be restored until everyone has removed their lockout.

OBJECTIVE 12 DESCRIBE HOW TO PERFORM A LOCKOUT/TAGOUT ON A PROCESS CONTROL SYSTEM

Read This

To properly lockout process equipment, the following three actions are performed:

- Shut off all power sources to the process
- Lockout all applicable devices
- Remove stored energy from the system

Shut Off All Power Sources to the Process

This step is accomplished by the opening of electrical disconnects, the closing of valves, or the blocking of mechanical movements.

Lockout All Applicable Devices

Once all power sources to the process are shut off, the appropriate lockout devices must be applied to the equipment, as figure 33 shows. This electrical lockout prevents someone from turning on the power to the system. There are also various lockouts for power cords and pneumatic lines.

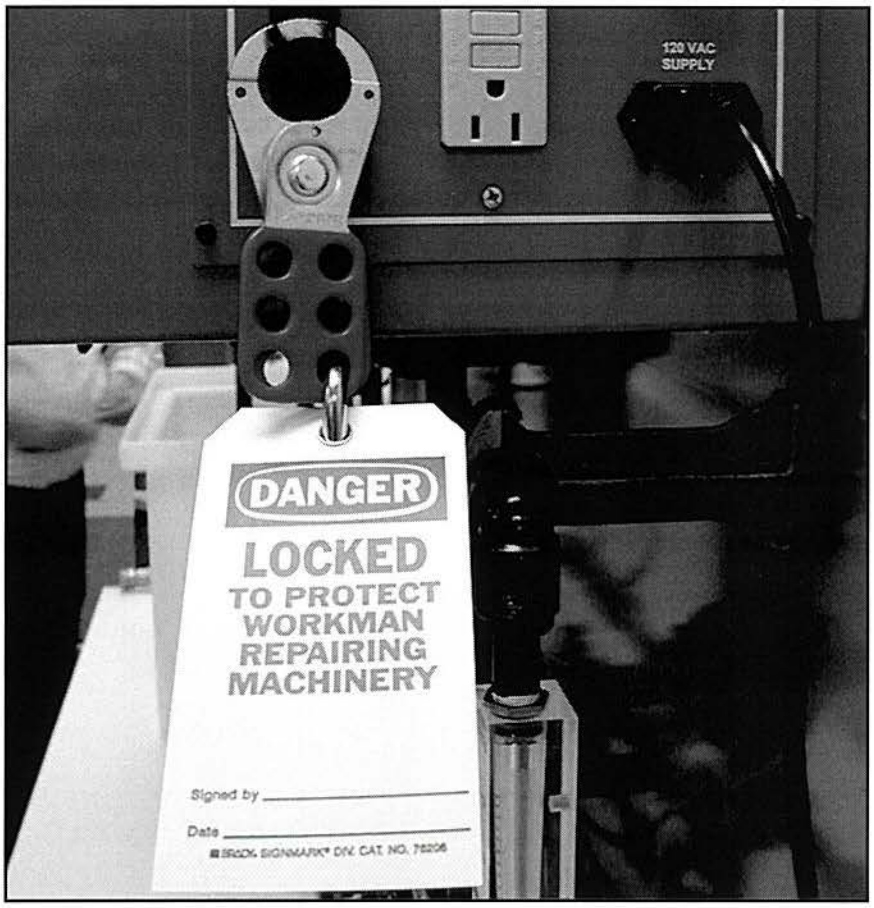

Figure 33. Lockout Device Installed

Remove Stored Energy from the System

Once the power inputs to the system have been shut off and locked out, power that is stored in the system must be released. All types of power systems have different means to store power. To safely work on these systems, make sure to dissipate all stored power.

For example, in electrical systems, capacitors store energy in the form of an electrostatic charge. To dissipate this charge, many electrical power sources include a bleeder resistor across the capacitor, as figure 34 shows. The bleeder resistor provides a quick and safe means to dissipate this charge. If a bleeder resistor is not present, the capacitor must be manually discharged by shorting the leads.

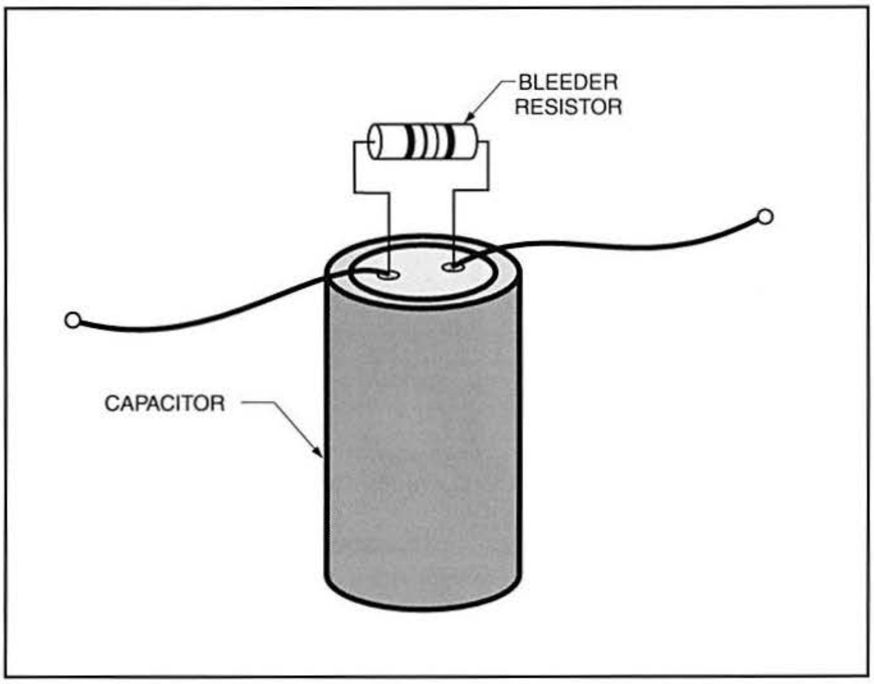

Figure 34. Bleeder Resistor Across a Capacitor

In fluid systems, there can be pressure trapped in the lines or stored in an accumulator even after removing power to the system.

The removal of this stored pressure is necessary to make working with the equipment safe. To accomplish this, trapped pressure is vented to the atmosphere, similar to figure 35, and liquids are drained to a non-pressurized tank.

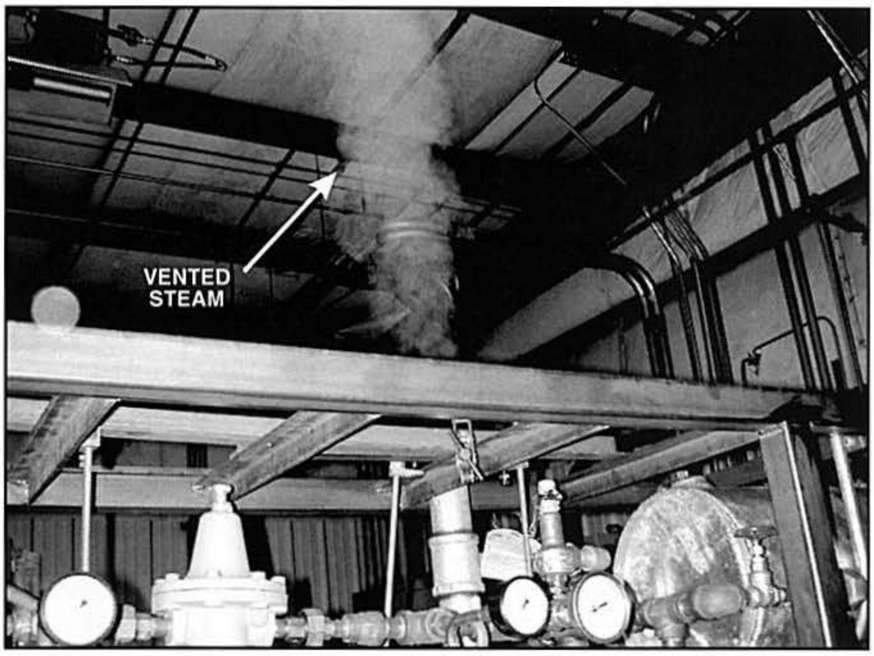

Figure 35. Venting Trapped Pressure

Mechanical energy is often stored in springs. To remove stored mechanical energy, disconnect the springs so there is no pressure applied to them.

SKILL 2 PERFORM A LOCKOUT OF PROCESS CONTROL EQUIPMENT

Procedure Overview

In this procedure, you will perform a lockout/tagout on the electrical supply to the T5552 Process Control System.

❑ 1. Locate the main circuit breaker on the right side of the control panel of the T5552, as figure 36 shows.

The main circuit breaker includes a bracket that allows it to be locked out when turned off.

RIGHT SIDE OF CONTROL PANEL

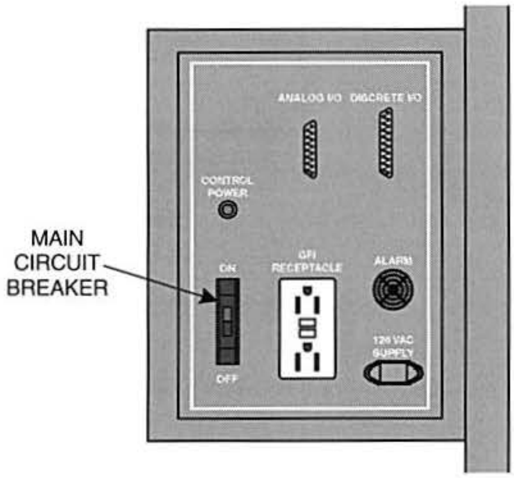

Figure 36. The Main Circuit Breaker

❑ 2. Perform the following substeps to lock out the main circuit breaker of the T5552.

A. Request the lockout/tagout equipment from your instructor.

The equipment includes a tagout tag, a multiple-person lockout device and a padlock, as figure 37 shows. If you are working in teams, each person must have their own padlock.

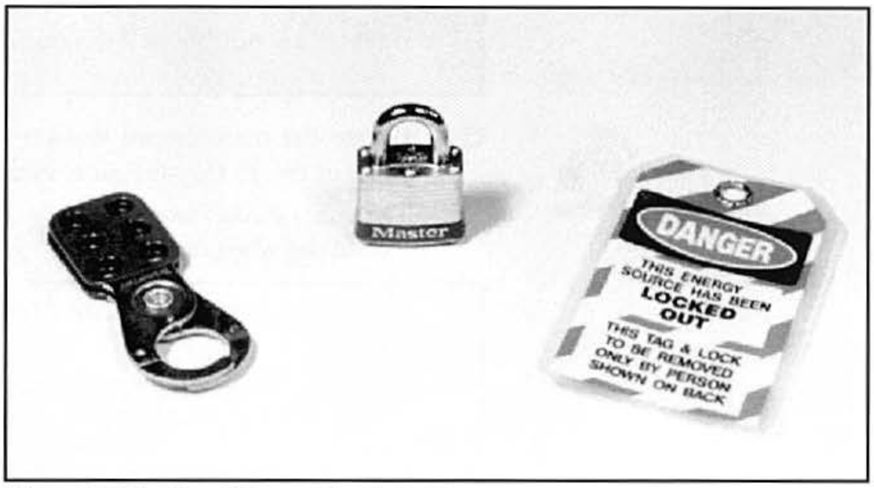

Figure 37. Lockout/Tagout Equipment

B. Make sure the circuit breaker is in the **OFF** or down position, as figure 38 shows.

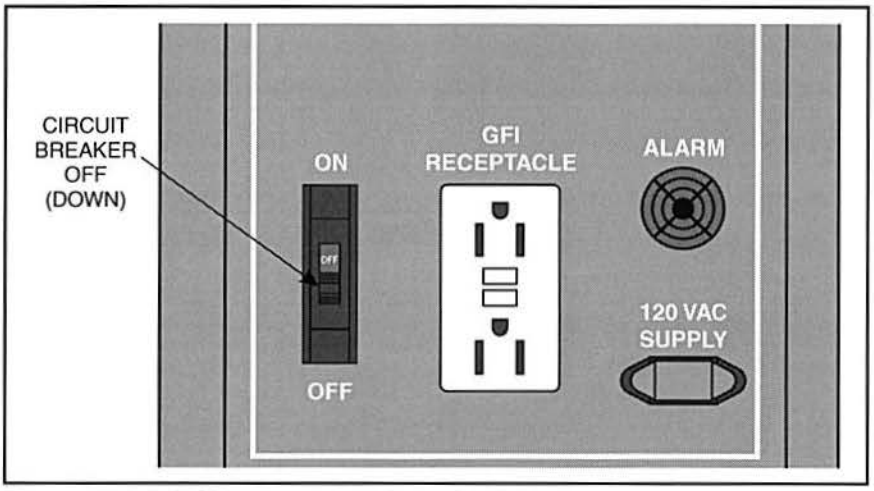

Figure 38. Main Circuit Breaker in the OFF Position

SEGMENT 4

SELF REVIEW

1. The measurement of ____________ in a container is one of the most commonly performed actions in process systems.
2. The __________ is the curvature of liquid that forms at the top of a column when you place liquid in a cylindrical container.
3. The two main functions of level measurement are to monitor and ___________ operations.
4. A(n) ______________________ level gauge is a plastic or glass tube mounted to the outside of the tank.
5. __________ -type sight gauges are commonly used in applications that require an underground tank.
6. When reading a sight glass, if the liquid curvature is concave you take the reading from the __________ of the curve.
7. A sight gauge is a device that gives a _______ indication of the liquid level in a container.

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

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

B. Adjust the manual flow control valve until the flow rate is approximately 1.3 gpm, as measured by the rotameter.

C. Shut off the circulation pump by turning off **SS1**.

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

E. Turn off the main circuit breaker.

F. Disconnect the pump control circuit.

C. Open the lockout device and hook it through holes in the brackets on either side of the circuit breaker, as figure 39 shows.

Figure 39. Lockout Device Hooked Through Hole in Brackets

D. Close the lockout device.

E. Open the padlock and slide the tagout tag onto the hasp, as figure 40 shows.

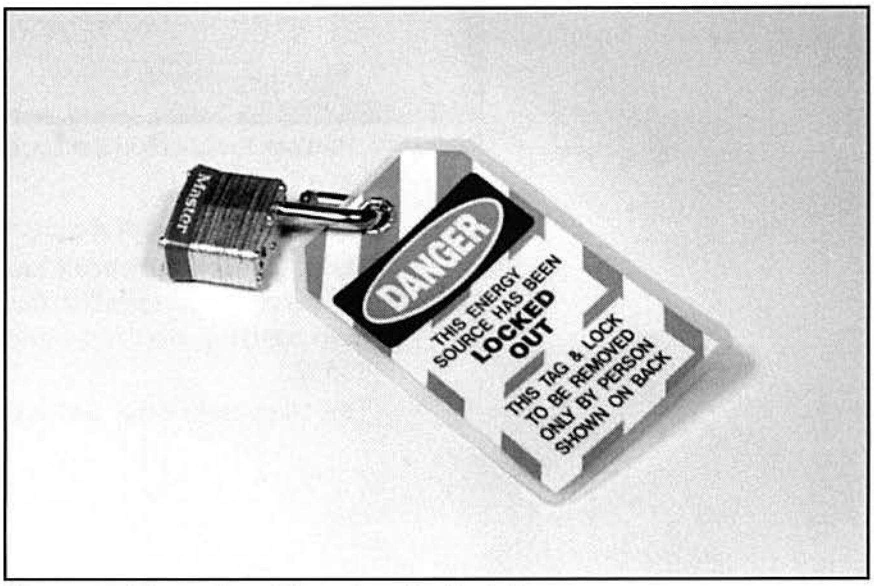

Figure 40. Tagout Tag Placed on Padlock Hasp

F. Install the padlock in one of the open holes in the lockout device and close the padlock, as figure 41 shows.

NOTE

All partners should install their own padlock. This ensures that power is not applied until all persons working on the equipment have removed their locks.

Figure 41. Padlock Installed on the Lockout Device

The lockout/tagout of the electrical supply is now complete.

The lockout on the circuit breaker should only be removed by the person who installed the lockout. This prevents anyone from applying electrical power while you are working on the T5552.

This takes care of the electrical system.

Now that the electrical system is locked out, you can move to the fluid power system, which in this case is pneumatic.

The pneumatic line does not have a shutoff valve. However, you can disconnect the T5552 from the main pneumatic line. In industry, pneumatic lines can be locked out using a lockout device similar to the one shown in figure 42.

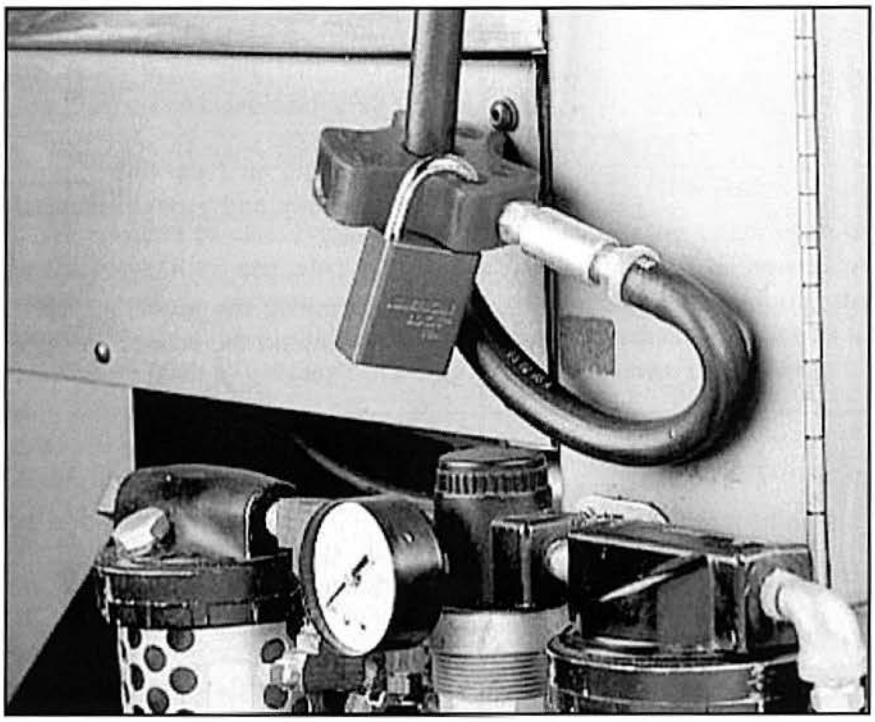

Figure 42. Pneumatic Line Lockout Device

- ❑ 3. Remove the lockout/tagout equipment from the circuit breaker.
- ❑ 4. Return all lockout/tagout equipment to the instructor.
- ❑ 5. Reconnect the pneumatic line to the T5552.

  To do this, pull back on the collar of the female connector and push the female connector onto the male connector. When the connectors engage, release the collar to lock the connection.

OBJECTIVE 14 DESCRIBE THE OPERATION OF OPEN LOOP MANUAL CONTROL AND GIVE AN APPLICATION

An open loop manual system requires the operator to manually adjust the output device so that the controlled variable matches the set point at the beginning of the operation. The output device is then left unadjusted during operation.

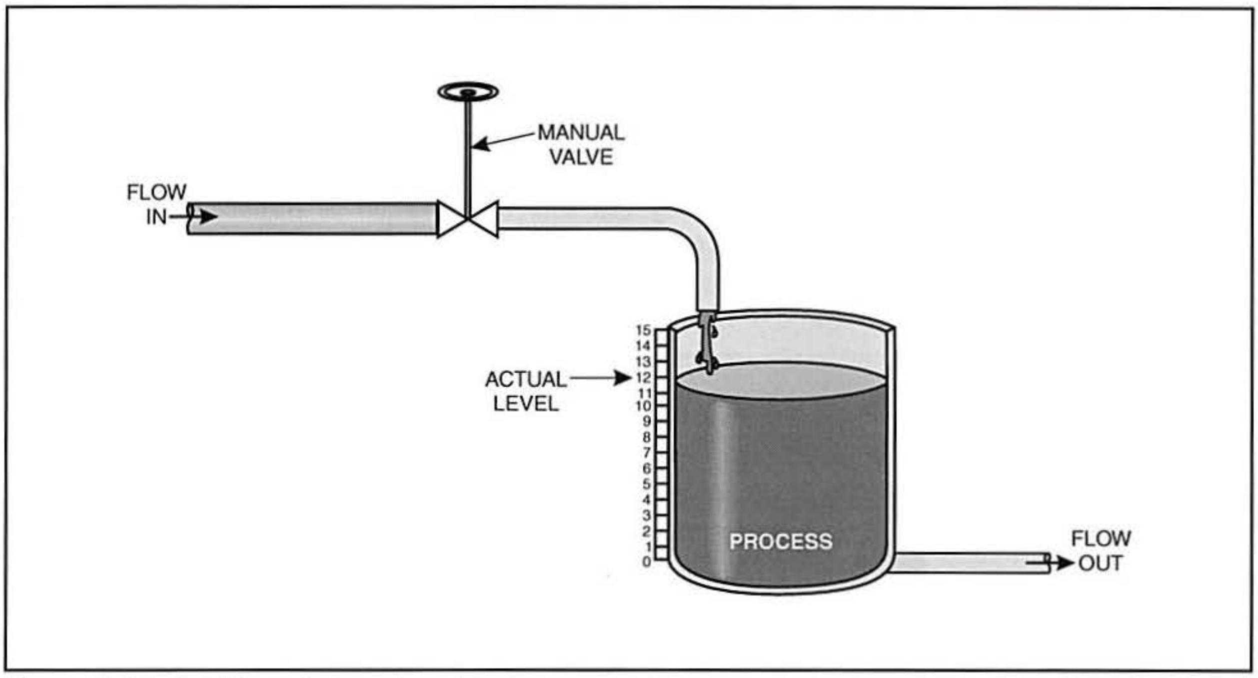

Figure 44. Typical Manual Open Loop System

Manual open loop control systems are used when there is rarely a need to adjust the setting of the valve, either because the application doesn't require a great deal of accuracy or the process conditions rarely change. For example, a manual control system might be used to control the flow of city water into a plant.

OBJECTIVE 15 DESCRIBE THE OPERATION OF CLOSED LOOP MANUAL CONTROL

Read This

A closed loop manual process control system operates in a similar manner to an open loop system except the operator remains present to act as the controller and the feedback sensor. During operation, the operator visually monitors the output and makes adjustments to maintain the process variable at a desired level.

For example, figure 45 shows the same manual level control system but with an operator continuously monitoring the level and adjusting the valve. In this system, the operator must watch the level as it changes. The operator's visual observation of the level is the feedback that closes the loop.

The operator compares the actual level in the tank (the process variable) with the desired level (the setpoint). If the two are the same, the operator makes no changes. However, if there is a difference between the actual level and the desired level, the operator adjusts the valve to make a correction to the tank's input flow so that the level changes to match the setpoint.

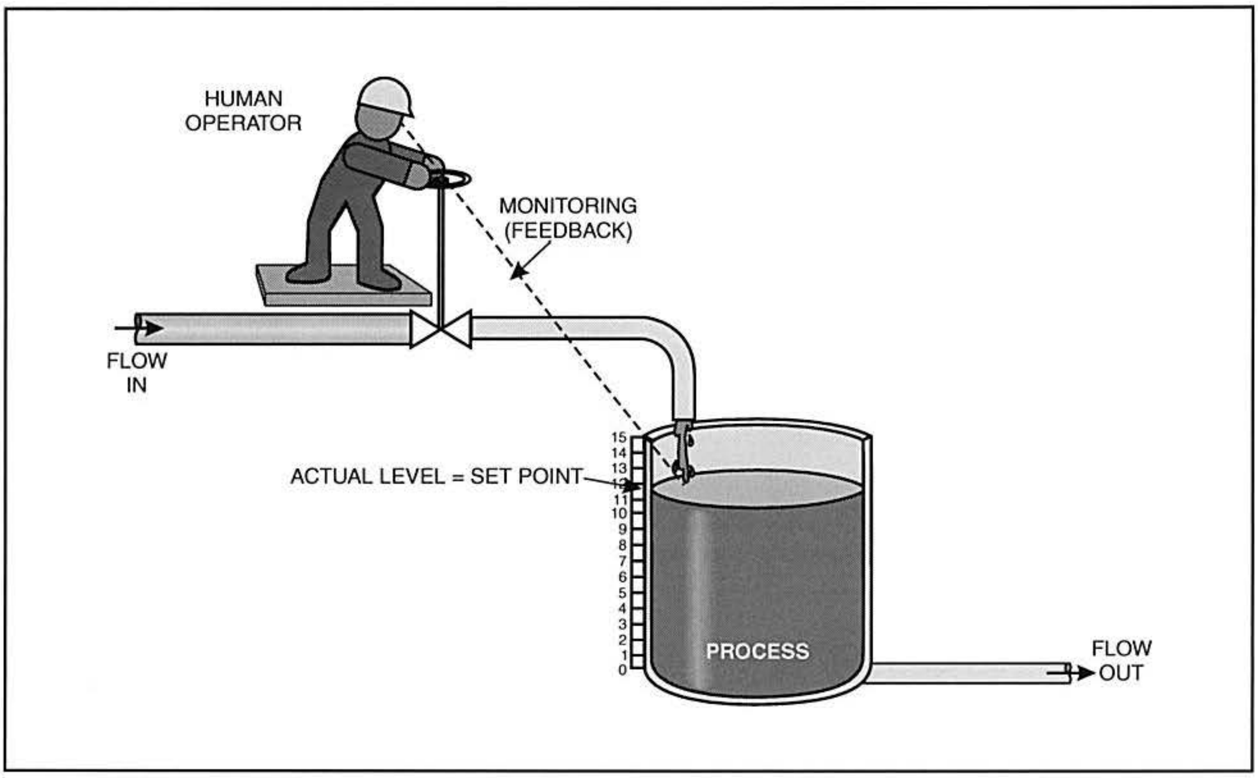

Figure 45. Manual Closed Loop Level Control System

Manual closed loop control systems are uncommon because the cost of an operator is usually more than the cost of automating the process. In addition, an operator would likely have difficulty maintaining precise control. However, open loop manual systems are quite common.

SKILL 3 MANUALLY CONTROL THE LIQUID LEVEL IN A TANK USING OPEN AND CLOSED LOOP METHODS

Procedure Overview

In this procedure, you will control the level in the process tank of the T5552 by manually adjusting a flow control valve. During operation, you will also observe how changes in the process affect the output. This will help you to understand the advantages and disadvantages of manual control.

Do This

- ❑ 1. Perform a lockout/tagout.
- ❑ 2. Check the reservoir tank level to make sure it is above 4 inches from the top of the tank, as figure 46 shows.

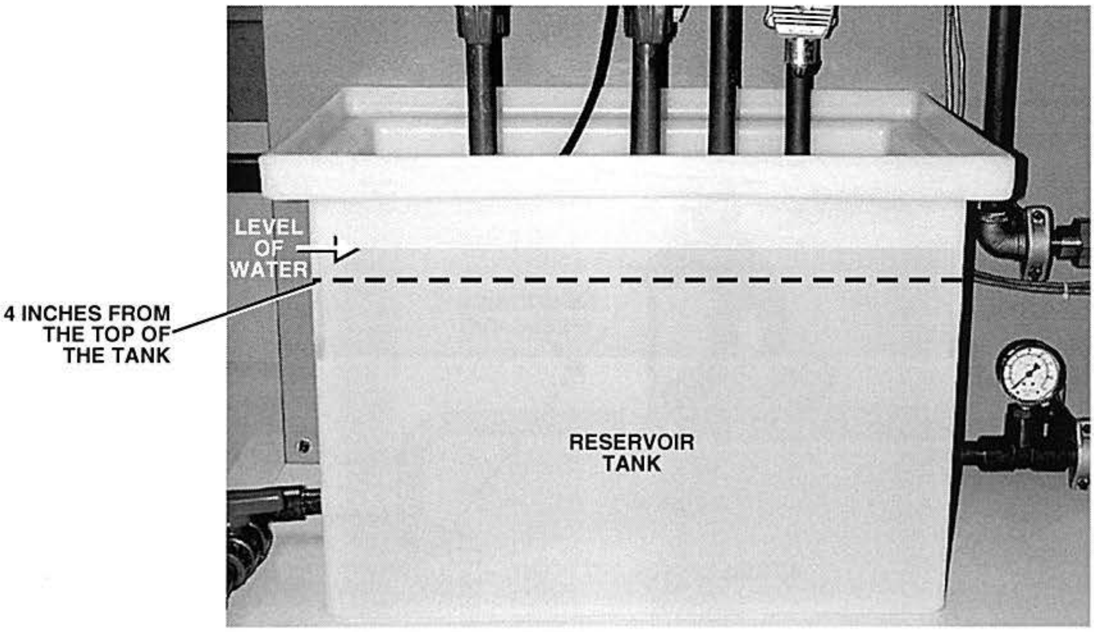

Figure 46. Reservoir Tank Filled

❑ 3. Perform the following substeps to fill the reservoir tank if the tank level is below 4 inches from the top of the tank. If it is above 4 inches from the top of the tank, skip to step 4.

A. Make sure the reservoir drain valve is closed and the drain cap is in place, as shown in figure 47.

This prevents water from escaping from the reservoir.

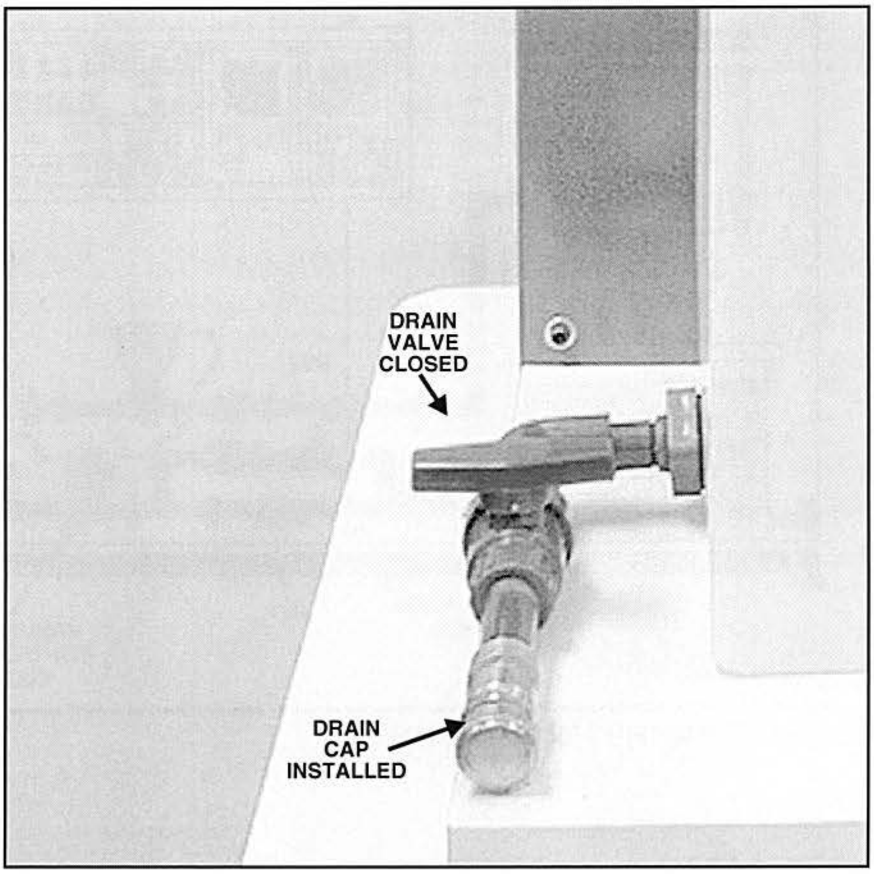

Figure 47. The Drain Valve Closed and the Drain Cap Installed

B. Fill the reservoir tank with water until the level is approximately 4 inches below the top of the tank.

If available, use a faucet and hose to fill the tank. If you do not have a hose, you will need a bucket to get the water from the faucet to the tank.

CAUTION

The reservoir tank should be filled with enough water so that the pump remains submerged at all times during use.

❑ 4. Perform the following substeps to set up the T5552 for manual control, as shown in figure 48.

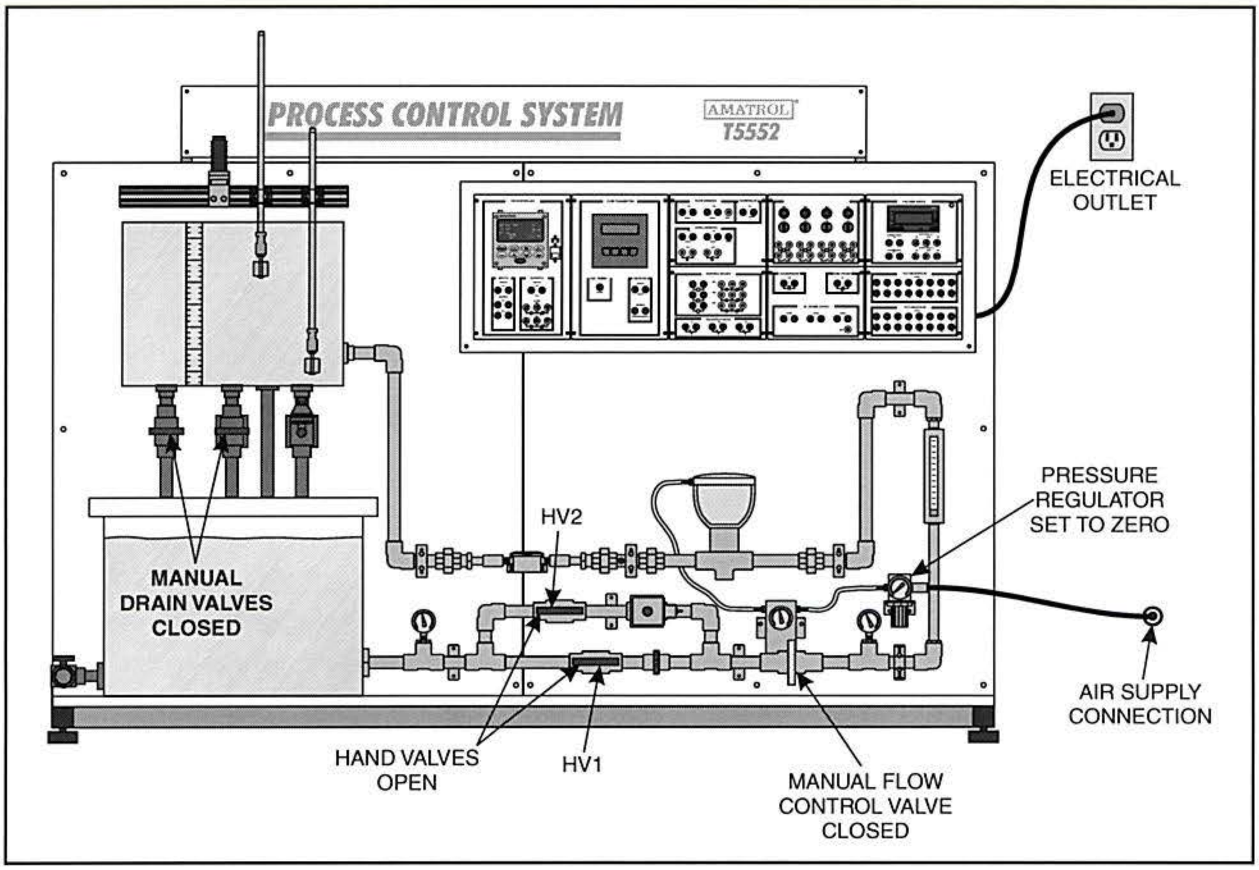

Figure 48. T5552 Setup for Manual Control

A. Determine if the air supply line is connected to the T5552, as shown in figure 49.

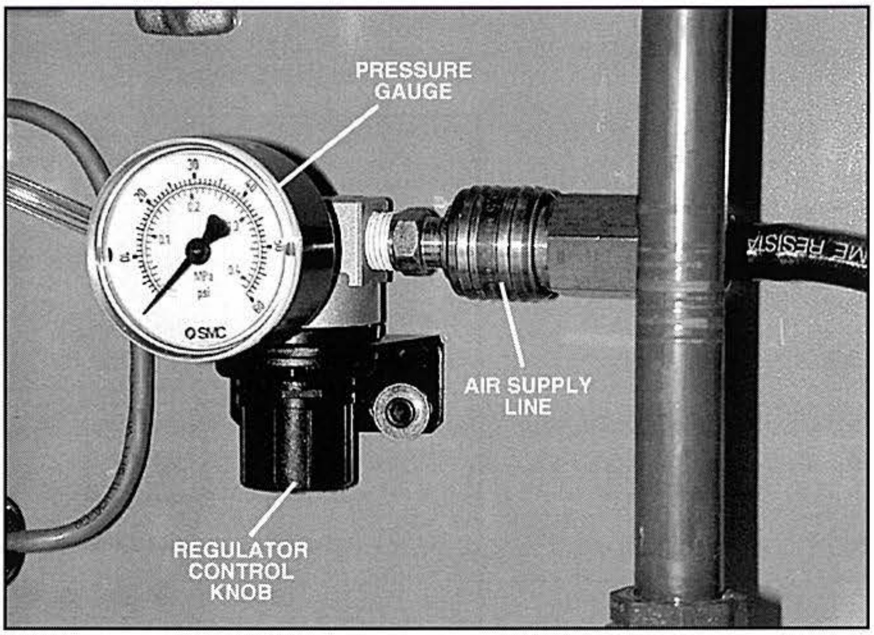

Figure 49. Air Supply Line Connected to the T5552

B. If the air supply line is connected, adjust the pressure to 0 psi. If the air supply line is not connected, do not connect it. You will not need it for this skill.

The diaphragm actuator proportional valve is an air-to-close type, so zero air pressure will cause it to be fully open.

C. Connect the circuit shown in figure 50 to control the circulation pump.

You will use a selector switch to start the circulation pump. There can be no flow through the system unless the circulation pump is running.

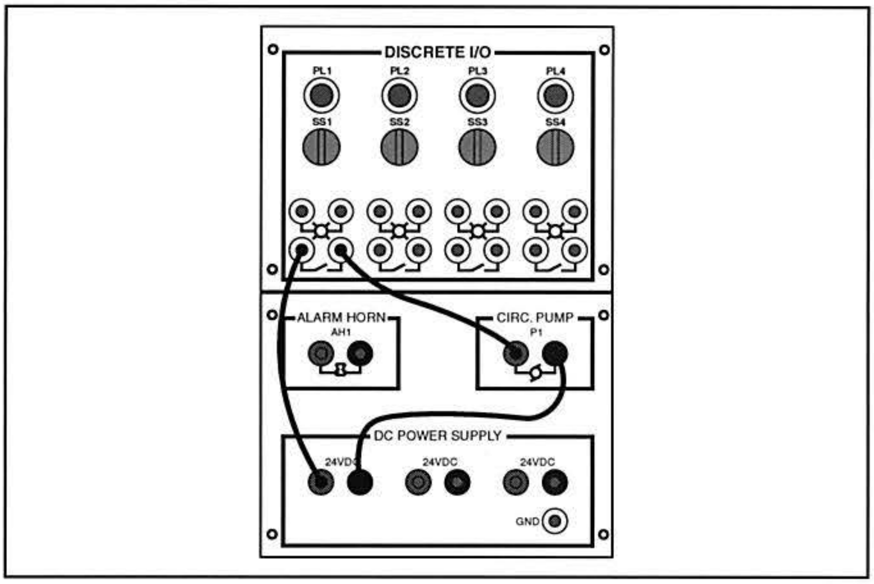

Figure 50. Circuit to Control the Circulation Pump

D. Make sure the selector switch **SS1** is in the **OFF** position (up), as shown in figure 51.

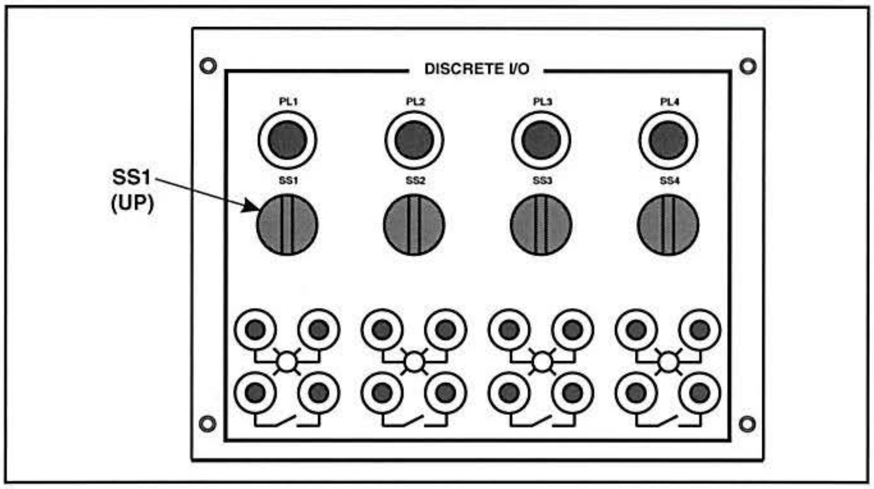

Figure 51. Selector Switch in OFF Position

E. Make sure the hand valves HV1 and HV2 in the process piping use both open (fully counterclockwise).

F. Make sure the two manual process tank drain valves, as shown in figure 52, are closed (turned fully clockwise).

NOTE

The handle on the valves indicate which direction opens or closes the valve.

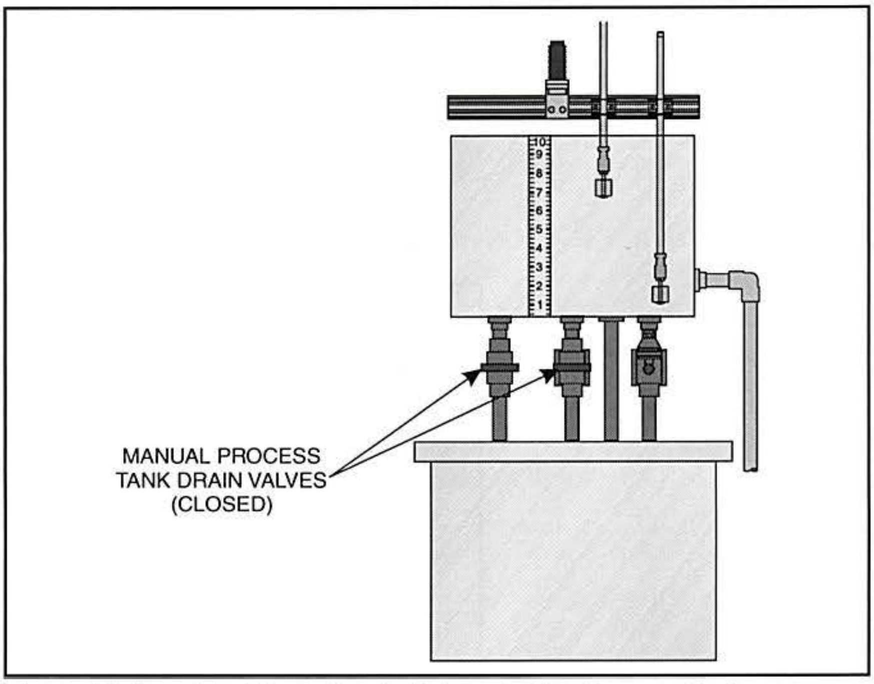

Figure 52. The Two Manual Drain Valves for the Process Tank

G. Make sure the manual flow control valve is completely closed (fully clockwise), as figure 53 shows.

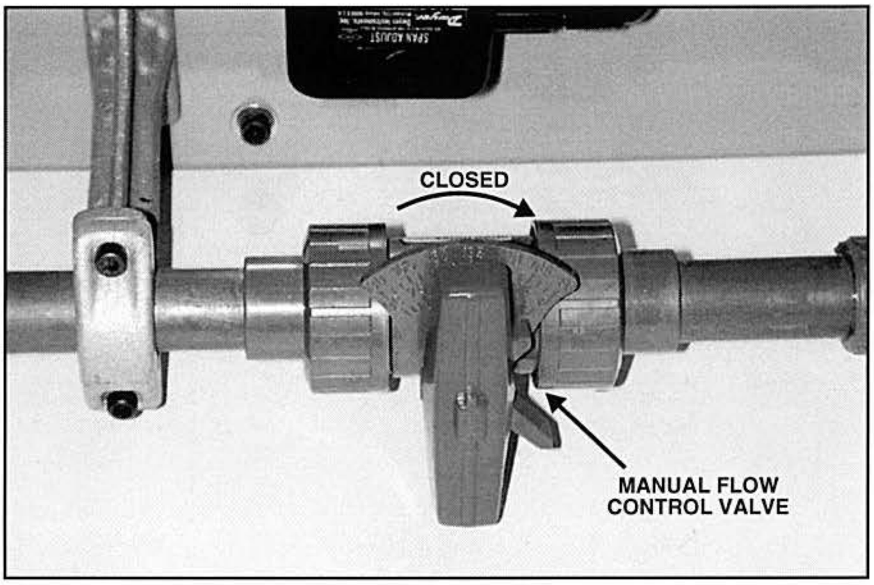

Figure 53. Manual Flow Control Valve Closed

❑ 5. Make sure the T5552 electrical power cord is connected to an electrical outlet.

❑ 6. Remove lockout/tagout.

❑ 7. Perform the following substeps to turn on the pump.

A. Turn on the main circuit breaker.

The control power indicator light above the circuit breaker should be lit, indicating that control power is present. If the indicator light is not lit, check the power cord and make sure it is plugged in.

B. Turn **SS1** clockwise to the **ON** position, as figure 54 shows, to start the circulation pump.

Even though the pump is now running, there should be no flow of water into the process tank because the manual flow control valve is closed.

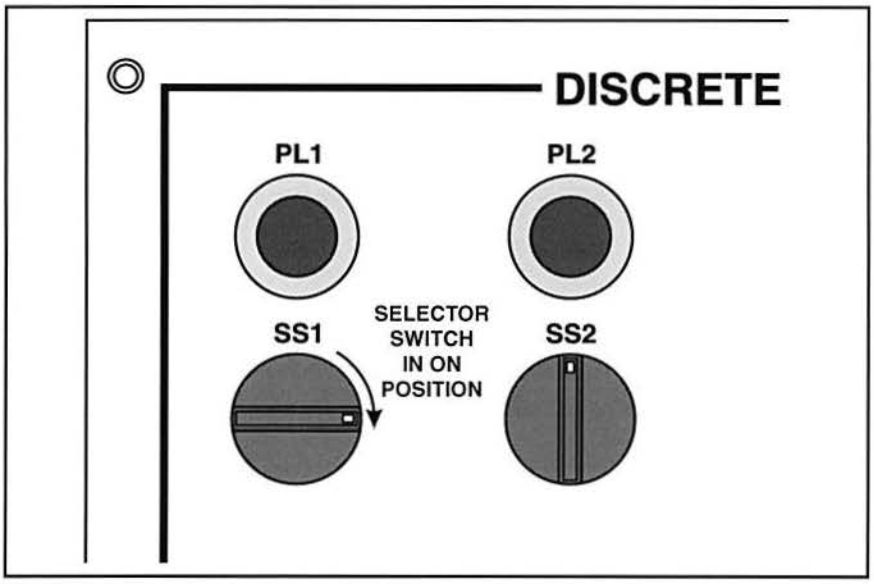

Figure 54. SS1 in the ON Position

❑ 8. Open the manual flow control valve by turning it counterclockwise until the flow rate indicated on the rotameter, as shown in figure 55, is about 1.3 gpm (gallons per minute).

Water should begin to flow into the process tank.

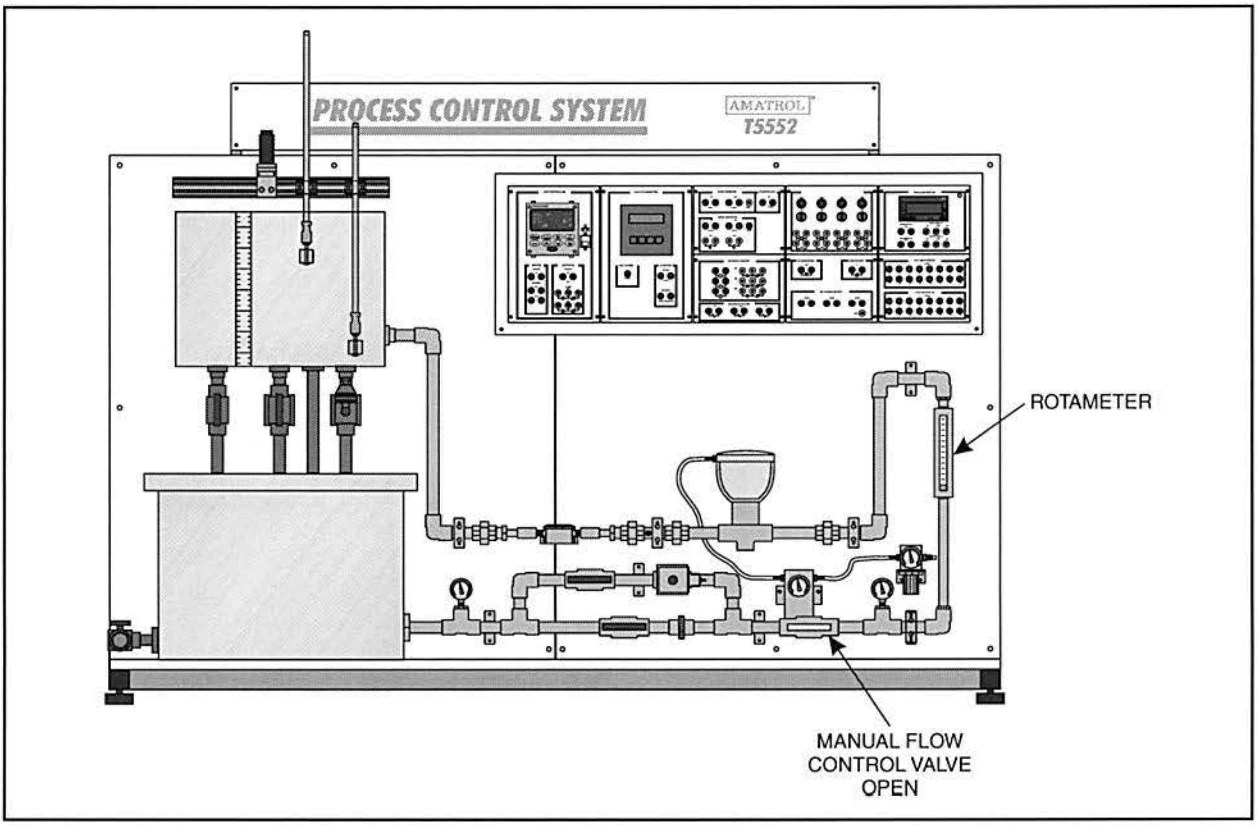

Figure 55. Open Manual Flow Control Valve

The measurement is read at the widest part of the float, as shown in figure 56.

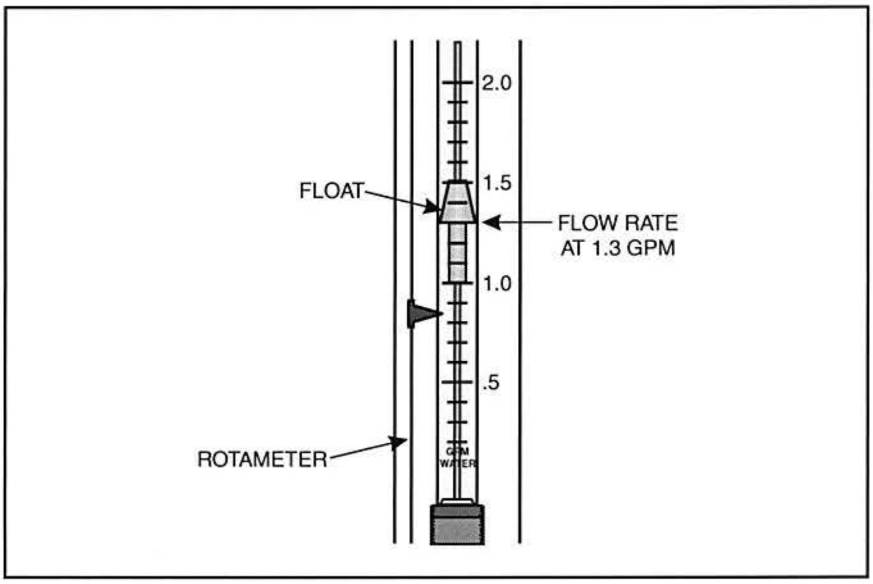

Figure 56. Rotameter Indicates Flow Rate of 1.3 gpm

❑ 9. When the level in the process tank reaches 5 inches, open the right-side hand drain valve of the process tank about halfway, as shown in figure 57.

This allows water from the process tank to drain into the reservoir and causes the level in the process tank to begin to drop because there is now a demand on the system.

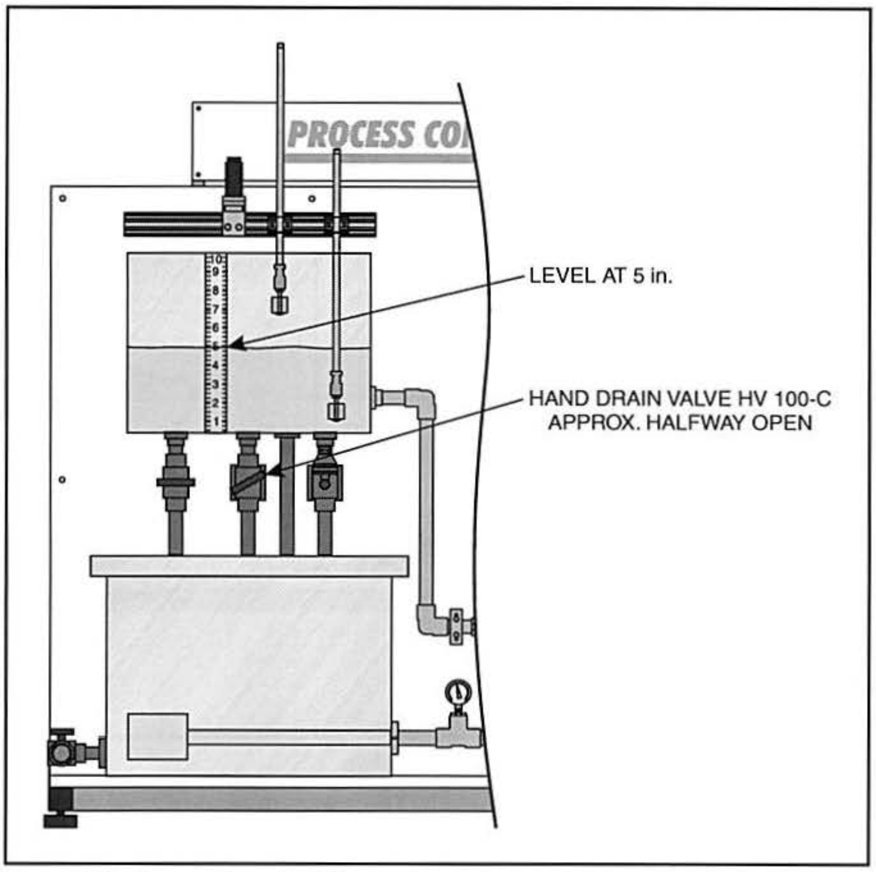

Figure 57. Demand on the Process

❑ 10. Increase the flow into the process tank by adjusting the manual flow control valve until the level returns to and stabilizes at 5 inches.

This demonstrates the ability to control liquid level with open loop control.

❑ 11. Now demonstrate the effect of a disturbance by closing the drain valve slightly (approximately 1/4 turn). Then observe the tank level.

You should observe an increasing level in the tank.

This is an example of manual open loop control. Although the water did stabilize at the desired level in the previous step, there is no component in the process that provides feedback. Therefore, the process does not realize that the liquid is no longer at the desired level. The operator must make a manual adjustment.

❑ 12. Adjust the flow rate using the manual flow control valve so that the level returns to and stabilizes at 5 inches.

By observing that the liquid level had increased above the desired level and adjusting the manual flow control valve, you are acting as the feedback component of the process. With a feedback element added, the process becomes a closed loop system.

As you can see, you have to adjust the flow of water into the tank to control the level of water in the tank. Also notice that you are manipulating one variable (flow) to control another variable (level).

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

A. Close the manual flow control valve by turning it fully clockwise.

B. Turn selector switch **SS1** counterclockwise to the **OFF** position to shut off the circulation pump.

C. Fully open both of the manual process tank drain valves.

Leave the process tank manual drain valves open until all of the water drains from the process tank to the reservoir tank.

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

E. Turn off the main circuit breaker.

As you can see, a manually controlled system requires the operator to adjust the system.

SEGMENT 3

SELF REVIEW

1. Process control systems can be classified as ______ or closed loop.
2. Manual ______ loop process control is used when there is rarely a need to adjust the setting of a value.
3. In manual _________ loop control, an operator performs the controller functions based on visual feedback.
4. In manual open loop control, the ________ device is left unadjusted.
5. In addition to classifying process control systems as either open or closed loop, they can also be classified as _______ or automatic.
6. Manual _______ control systems are uncommon because the cost of an operator is usually more than the cost of automating the process.

SEGMENT 4

SIGHT GAUGES

OBJECTIVE 16 DESCRIBE TWO FUNCTIONS OF LEVEL MEASUREMENT AND GIVE AN APPLICATION

Level measurement describes the action of measuring the height of material in a container using a scale or level sensor. The two major reasons for measuring level are control and monitoring. The measurement of level in a container is one of the most commonly performed actions in process systems.

Figure 58 shows an example of a level control process. In this process, the operator continuously monitors the level and adjusts the input flow control valve to maintain the level at the SP.

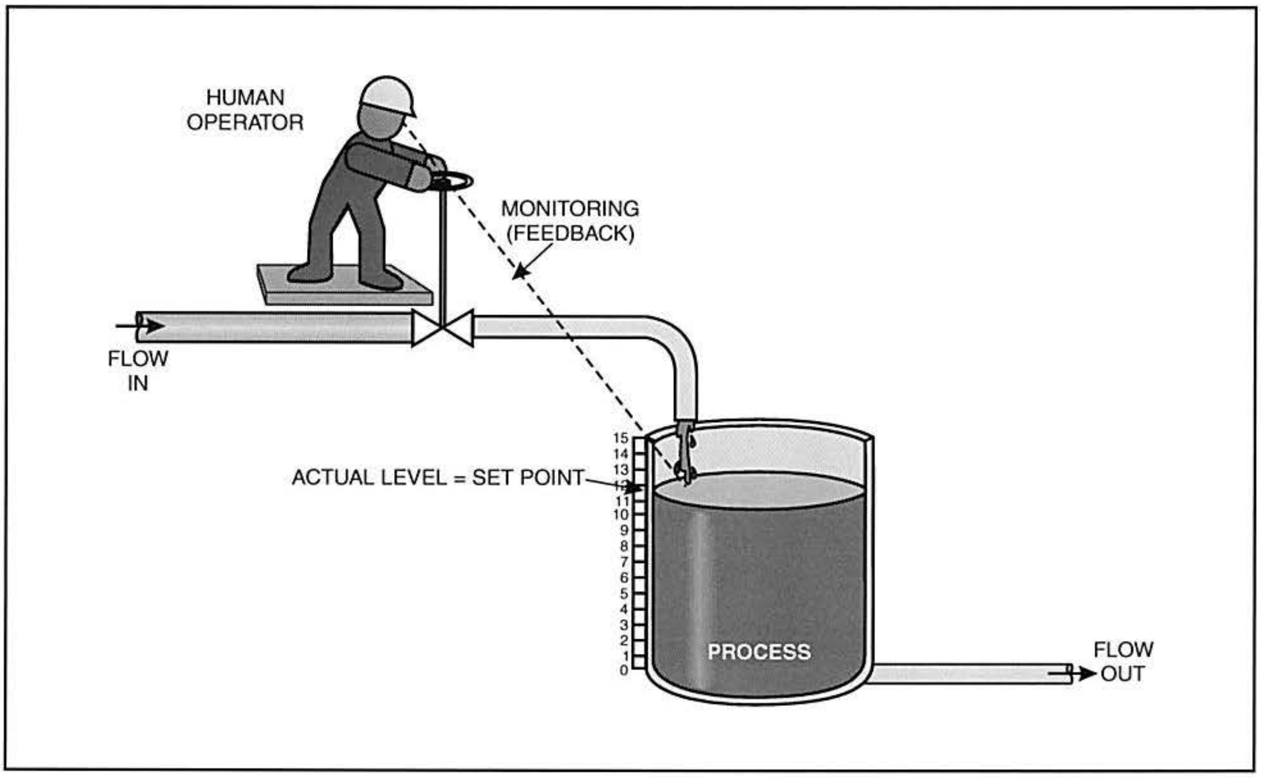

Figure 58. Level Control Process

Figure 59 shows an example of a sight glass level gauge that measures the liquid level in a boiler. In this example, a controller is not used and the level is only being monitored.

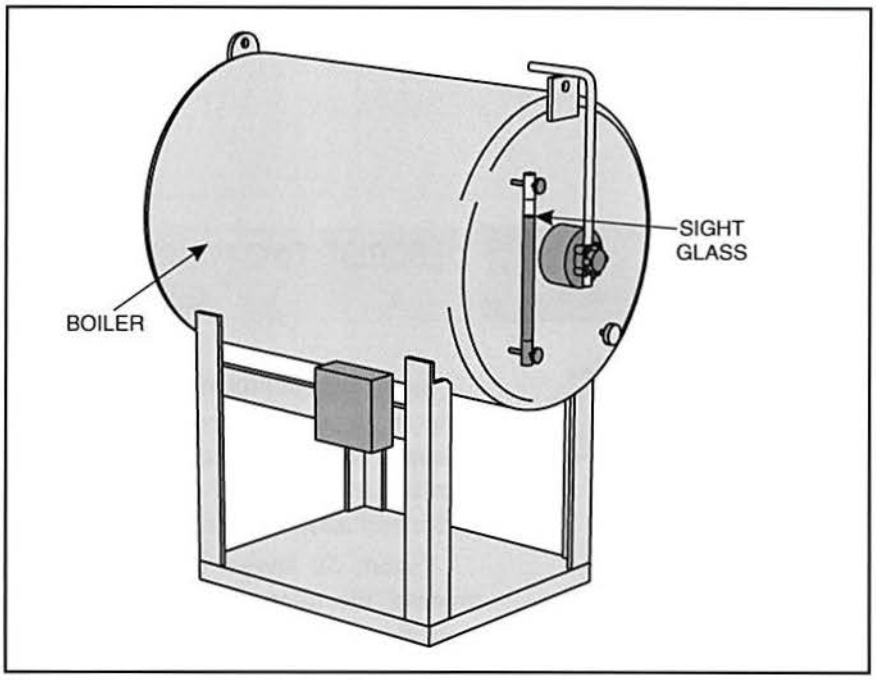

Figure 59. Level Monitoring Process

OBJECTIVE 17 DESCRIBE THE FUNCTION OF A SIGHT GAUGE AND GIVE AN EXAMPLE

Read This

A sight gauge is a device that gives a visual indication of the liquid level in a container. This indication can be provided either by a scale mounted directly on the tank, by an indicator (i.e. a pointer) that moves across a scale as the level changes, by an externally mounted scale, or by a float device.

Figure 60 shows an example of a vertical tank gauge. This type of sight gauge uses a float and a counterweight on a pulley system to indicate the level in the tank. As the level changes, the float rises or lowers, causing the pointer to move. The scale indicates the percent level in the tank.

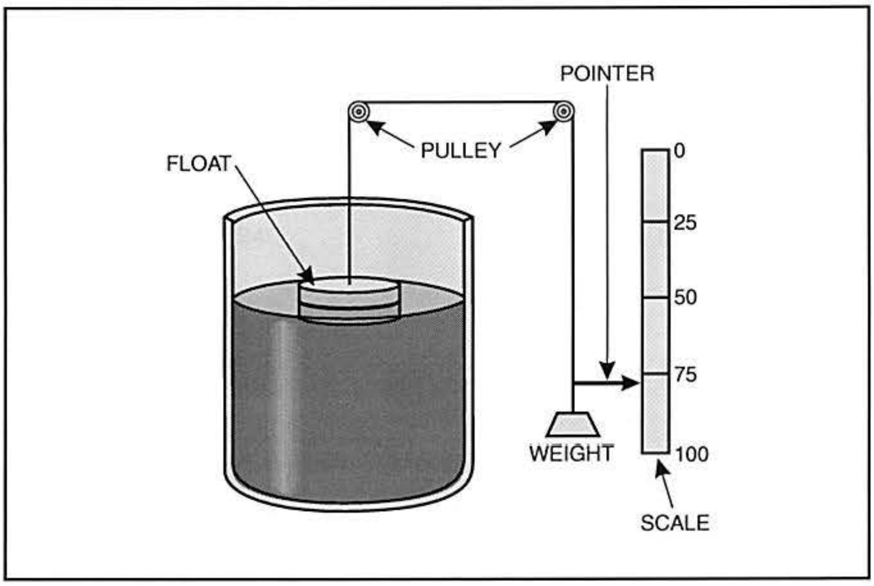

Figure 60. Vertical Tank Gauge

Other types of sight gauges include:

- Float-Type Sight Gauges
- Sight Glasses

OBJECTIVE 18 DESCRIBE THE OPERATION OF A FLOAT-TYPE SIGHT GAUGE AND GIVE AN APPLICATION

Read This

A float-type sight gauge, as shown in figure 61, uses a float that rises and falls with the level in the tank. The gauge consists of a cable with a float on one end and a weight on the other. The cable rests on a pulley that connects to an indicator. As the float moves up and down, the indicator rotates back and forth along a scale, allowing the operator to determine the level in the tank.

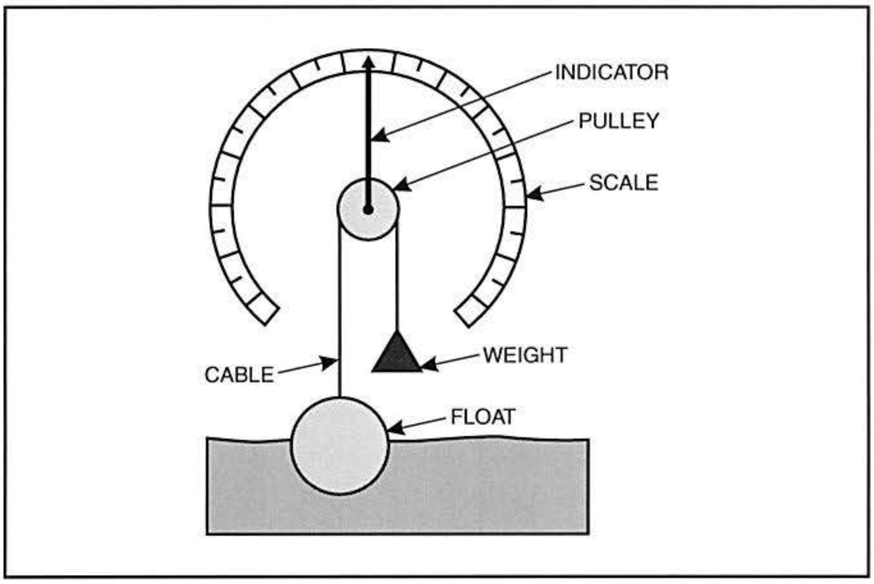

Figure 61. Float-type Sight Gauge

Figure 62 shows another example of a float-type sight gauge. This gauge uses the same principle as the one in figure 61. However, the indicator moves up and down a vertical scale as the level changes.

Float-type sight gauges are used in many applications including the storage of oil and other combustible fluids and wastewater treatment. Applications that use underground tanks, as shown in figure 62, commonly use float-type sight gauges.

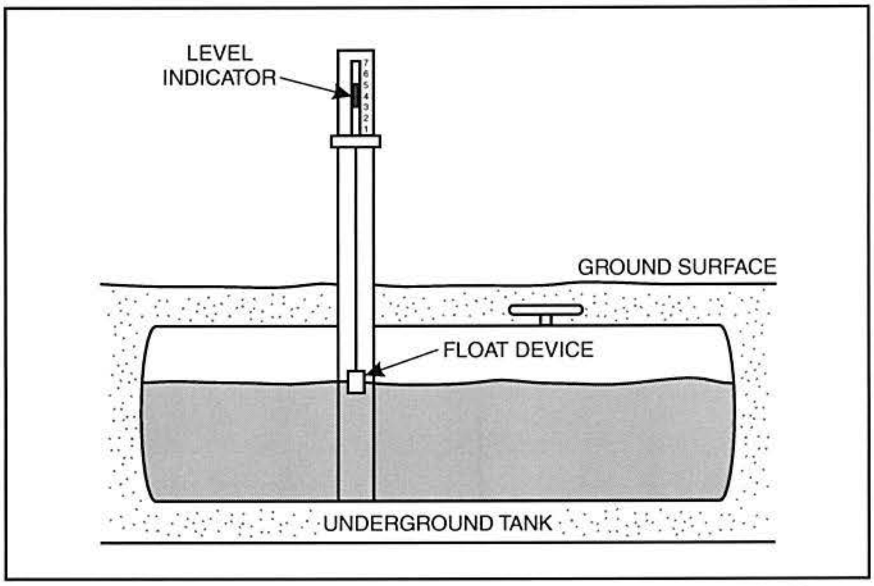

Figure 62. Float-type Sight Gauge Used with an Underground Tank

OBJECTIVE 19 DESCRIBE THE OPERATION OF A SIGHT GLASS AND GIVE AN APPLICATION

Read This

A sight glass level gauge consists of a plastic or glass tube mounted to the outside of a tank, as shown in figure 63. A sight glass uses the principle that liquid maintains a constant level throughout all parts of the container. As the level in the tank rises and falls, so does the level in the tube. The sight glass level gauge has a scale on it, or beside it, to indicate the level in the tube, which is the same as the level in the tank.

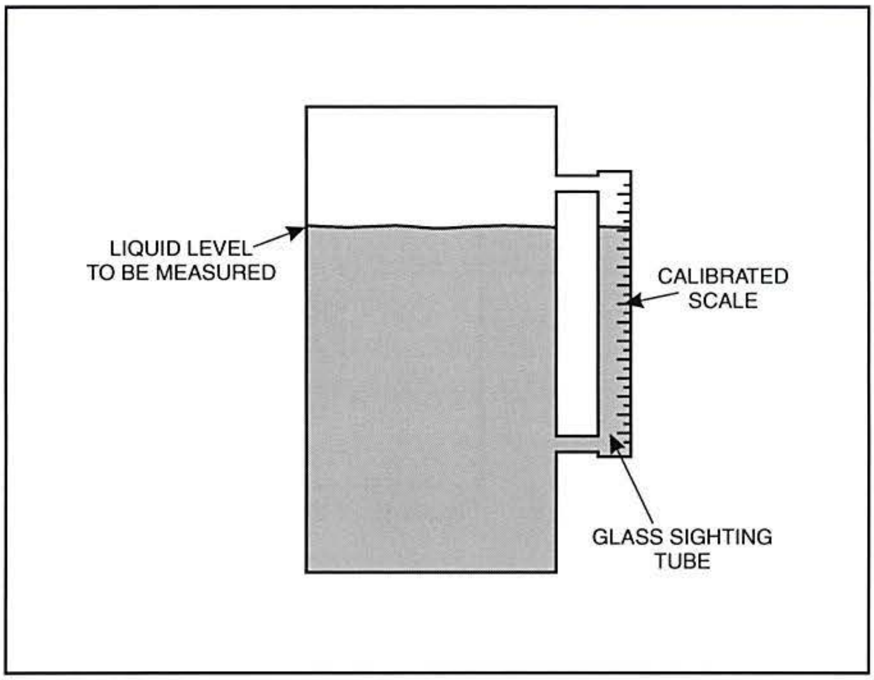

Figure 63. Sight Glass Level Gauge

Sight glass level gauges are a popular choice for measuring the level of all types of fluids because they provide a simple and inexpensive way to measure level. One example is the boiler shown in figure 64.

The sight glass in figure 64 also shows that not all sight glass level gauges have a graduated scale. Some of them only use a high and low level mark.

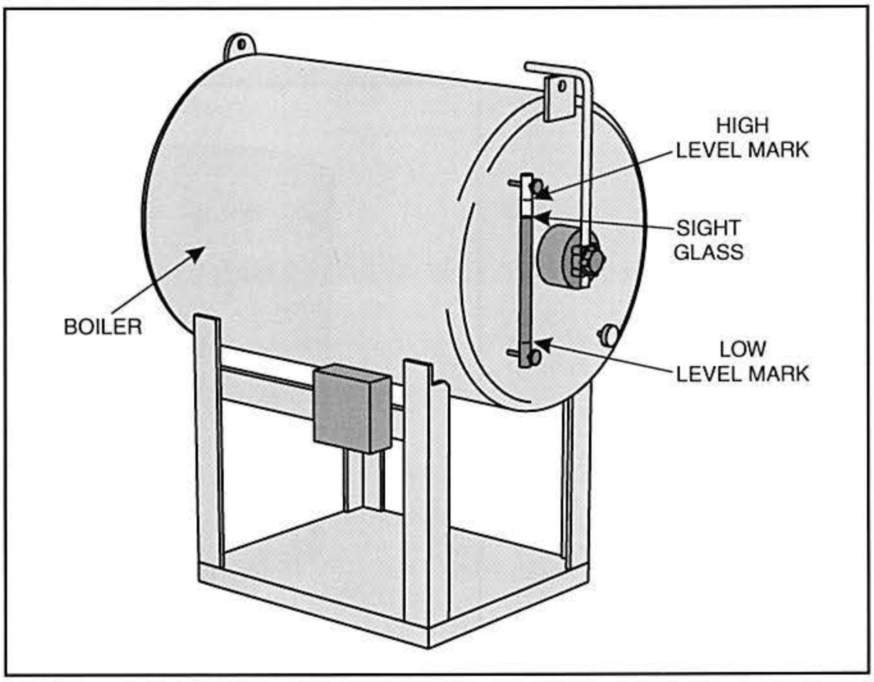

Figure 64. Sight Glass Level Gauge on a Boiler

OBJECTIVE 20 DESCRIBE HOW TO READ A SIGHT GLASS

Most sight glasses have some type of graduations to indicate the height of the liquid in the tank or they simply have a high mark and a low mark, as shown in figure 65. For sight glasses with high and low level marks, the operator only needs to make sure the level stays between these two marks.

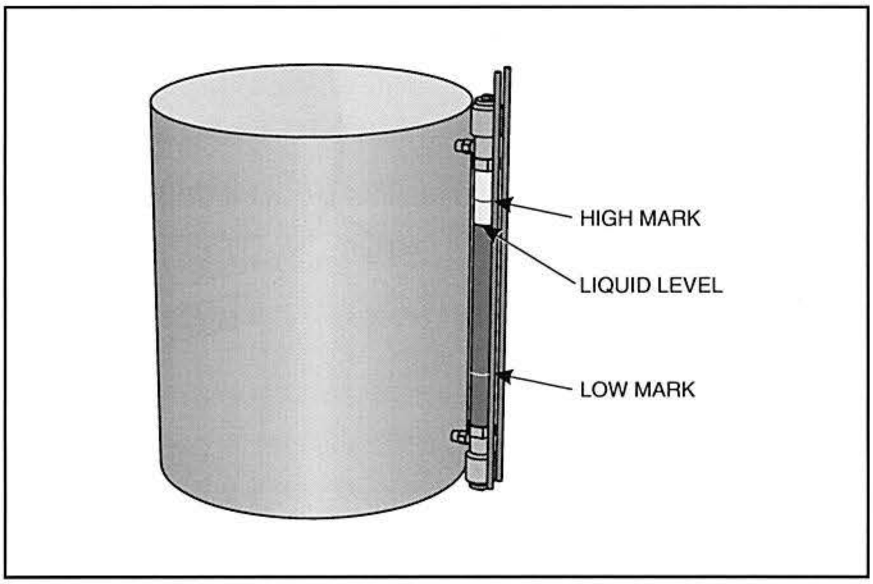

Figure 65. Sight Glass Level Gauge with High and Low Marks

If the sight glass has graduation marks, the operator may need to determine liquid level in terms of units of length. The measurement should always be made to the nearest graduation mark.

If a precise measurement needs to be made, the operator must account for a curvature, called the meniscus, that forms at the top of the column of liquid. The meniscus can either be concave (curves upward) or convex (curves downward), as shown in figure 66. You should read the measurement from the bottom of the meniscus if it is concave and from the top if it is convex.

For example, the level measurement for the sight glass on the left is 8, while the level measurement for the sight glass on the right is 6. The type of liquid and the material from which the container is made determine whether the meniscus is convex or concave.

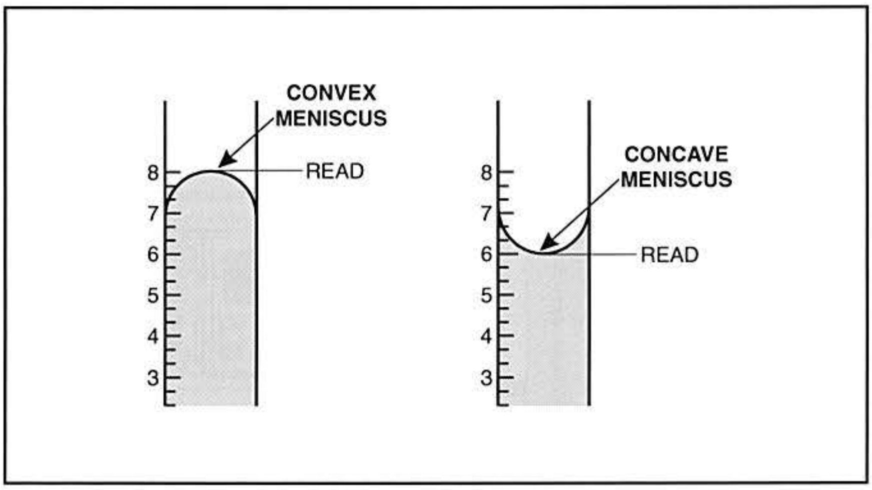

Figure 66. Convex and Concave Menisci

Procedure Overview

In this procedure, you will determine the level of water in the process tank using the sight level scale on the process tank.

Do This

- ❑ 1. Perform a lockout/tagout.
- ❑ 2. Perform the following substeps to set up the T5552, as shown in figure 67.

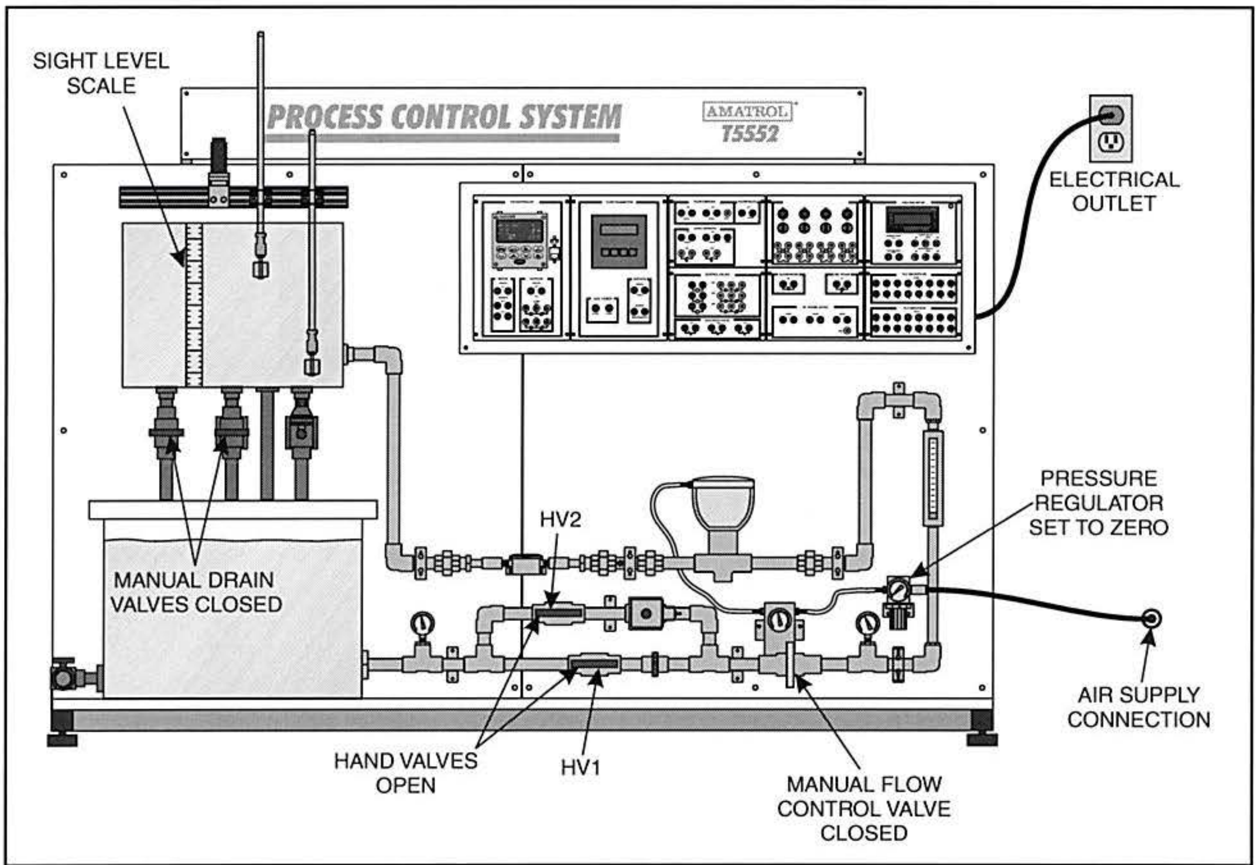

Figure 67. T5552 Setup

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. Make sure the manual flow control valve is fully closed.

F. Make sure the selector switch **SS1** is in the **OFF** (up) position.

G. Connect the circuit shown in figure 68 to control the circulation pump.

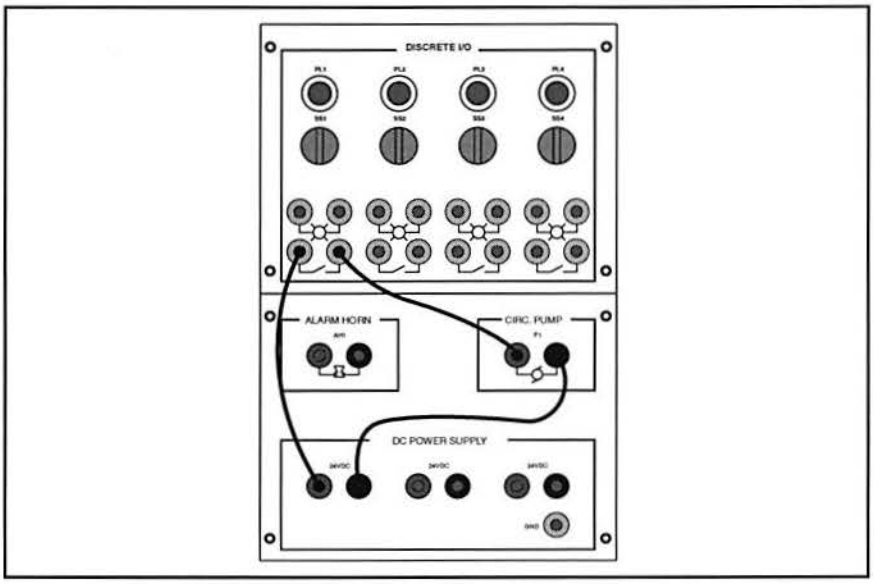

Figure 68. Circuit to Control the Circulation Pump

- ❑ 3. Remove the lockout/tagout.
- ❑ 4. Turn on the main circuit breaker.
- ❑ 5. Start the circulation pump by placing **SS1** in the **ON** position.

  Even though the pump is now running, there should be no flow of water into the process tank because the manual flow control valve is closed.
- ❑ 6. Fully open the manual flow control valve and allow the water to flow into the tank for about 60 seconds.
- ❑ 7. After 60 seconds, close the manual flow control valve.

❑ 8. Determine the level of water in the process tank by observing the sight level scale on the front of the tank.

Each mark on the scale represents 1/4 (0.25) inch, as figure 69 shows. This allows you to read the level to nearest 1/4 inch.

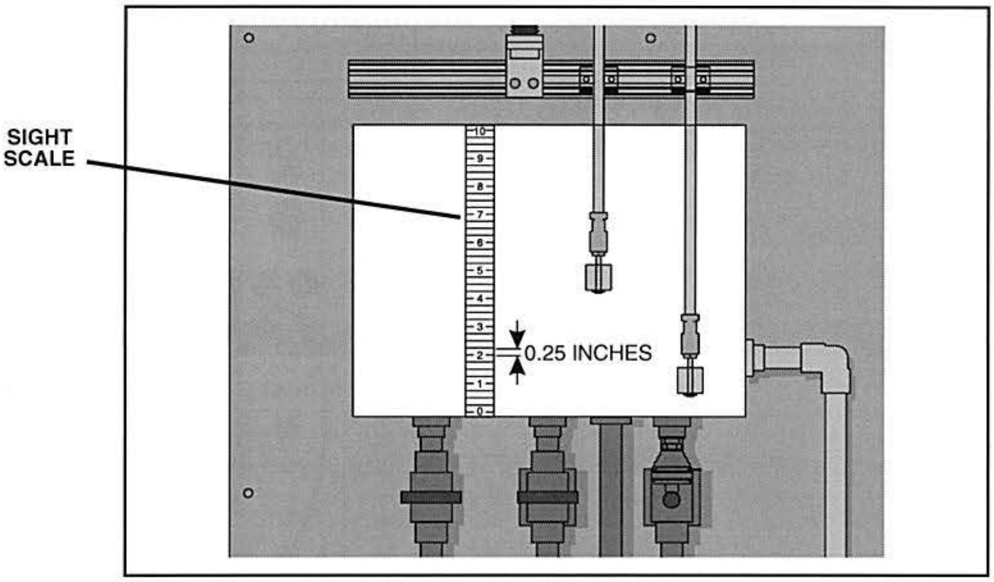

Figure 69. Each Mark Represents 1/4 Inch

❑ 9. Record the current level of water to the nearest 1/4 inch.

Water Level ________________________________ (Inches)

❑ 10. Again, fully open the manual flow control valve and allow the water to flow into the tank for about 30 seconds.

❑ 11. Close the manual flow control valve.

❑ 12. Determine and record the level of water in the tank to the nearest 1/4 inch.

Water Level ________________________________ (Inches)

As you can see, this is not an accurate method of measuring level. The accuracy of the reading is limited by the smallest increment on the scale, in this case 1/4 inch.

In addition, using sight level measurement is subject to human error. When the process requires a high level of accuracy, another method of level measurement is required.

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

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

B. Adjust the manual flow control valve until the flow rate is approximately 1.3 gpm, as measured by the rotameter.

C. Shut off the circulation pump by turning off **SS1**.

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

E. Turn off the main circuit breaker.

F. Disconnect the pump control circuit.

SEGMENT 4

SELF REVIEW

1. The measurement of ____________ in a container is one of the most commonly performed actions in process systems.

2. The __________ is the curvature of liquid that forms at the top of a column when you place liquid in a cylindrical container.

3. The two main functions of level measurement are to monitor and ___________ operations.

4. A(n) ______________________ level gauge is a plastic or glass tube mounted to the outside of the tank.

5. __________ -type sight gauges are commonly used in applications that require an underground tank.

6. When reading a sight glass, if the liquid curvature is concave you take the reading from the __________ of the curve.

7. A sight gauge is a device that gives a _______ indication of the liquid level in a container.