ANALYTICAL PROCESS CONTROL

1

LEARNING ACTIVITY PACKET

INTRODUCTION TO PROCESS CONTROL

AMATROL®

B33303-AB01AEN

LEARNING ACTIVITY PACKET 1

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 flow, which are common in process control applications.

ITEMS NEEDED

Amatrol Supplied

- 1 T5554 Analytical Process Control Learning System
- 1 Bottle of Sodium Bisulfate (Acid)
- 1 Bottle of Sodium Carbonate (Base)

School Supplied

- 1 Municipal Water Supply
- 1 120VAC Electrical Supply

FIRST EDITION, LAP 1, REV. A

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PROCESS CONTROL CONCEPTS

OBJECTIVE 1 DEFINE PROCESS CONTROL

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.

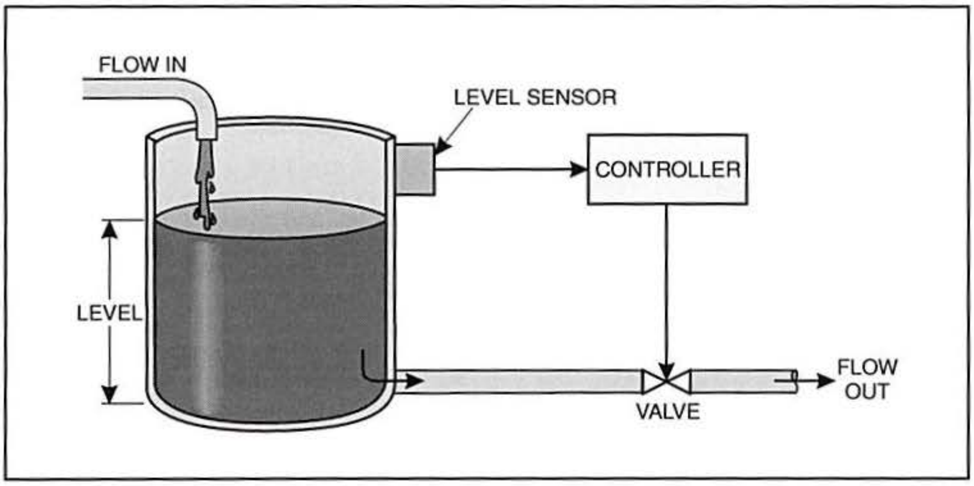

Figure 1. Liquid Level Control System

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

Read This

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.

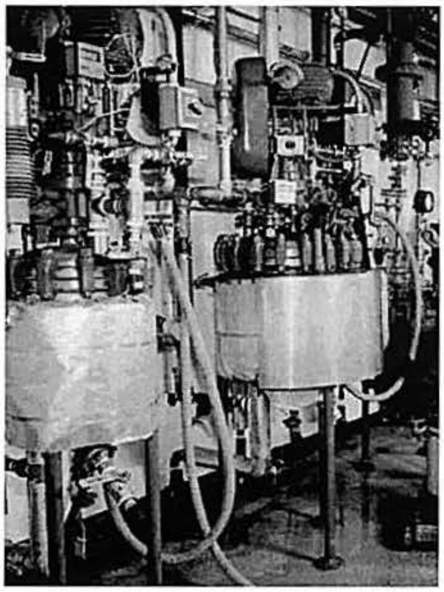

Figure 2. Process Equipment Used in Pharmaceutical Industry

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.

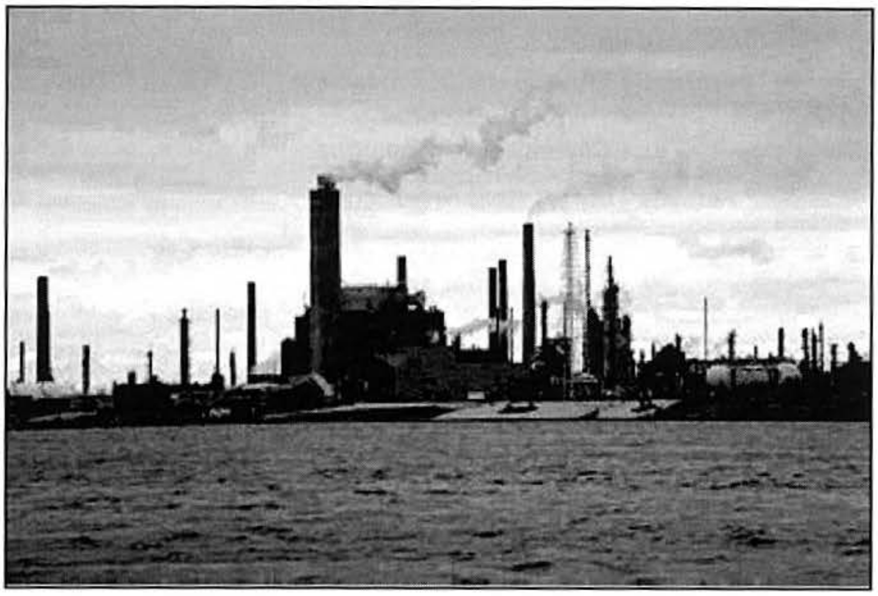

Figure 3. Refinery

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.

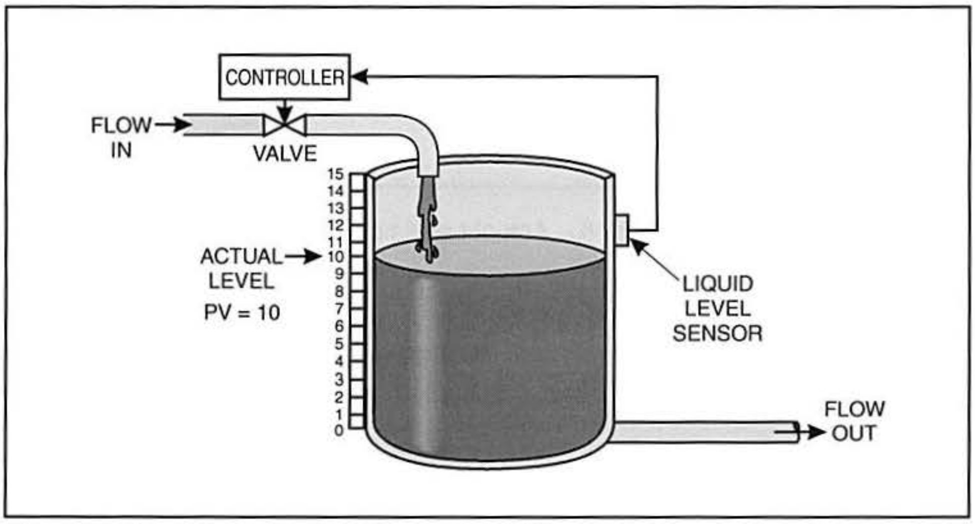

Figure 5. Level in the Tank is Process Variable

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 of water, the set point 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 setpoint, as shown in figure 6.

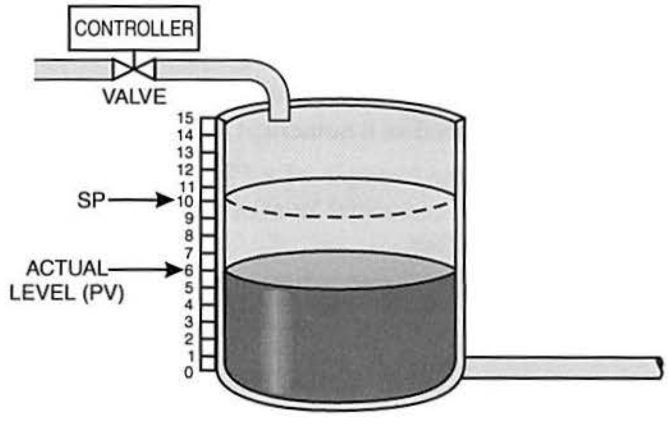

Figure 6. Actual Level Not Equal to SP

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, as shown in figure 7.

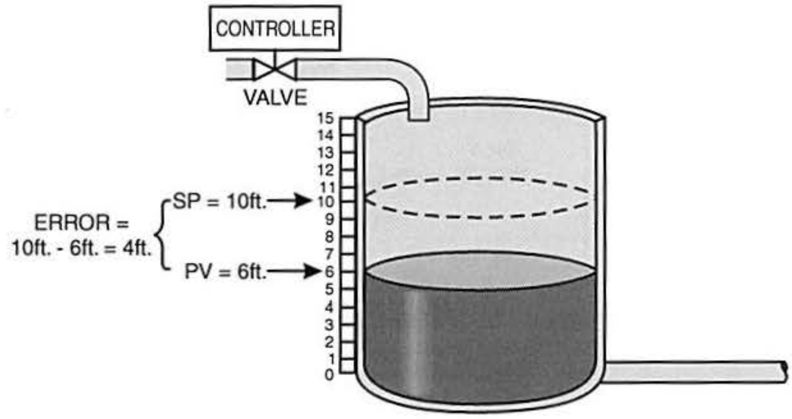

Figure 7. Error in a Process

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

Read This

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.

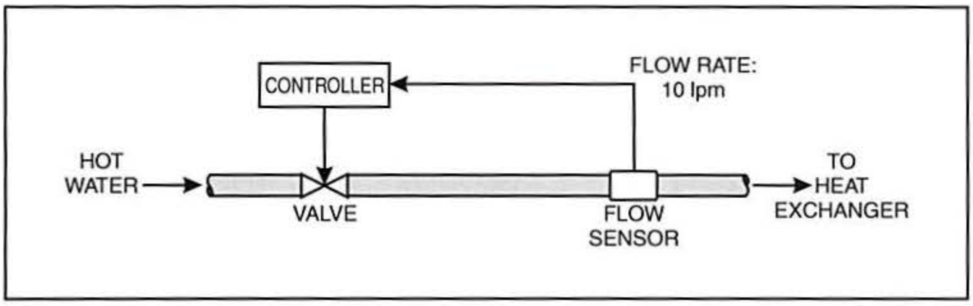

Figure 8. Flow Control to a Heat Exchanger

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.

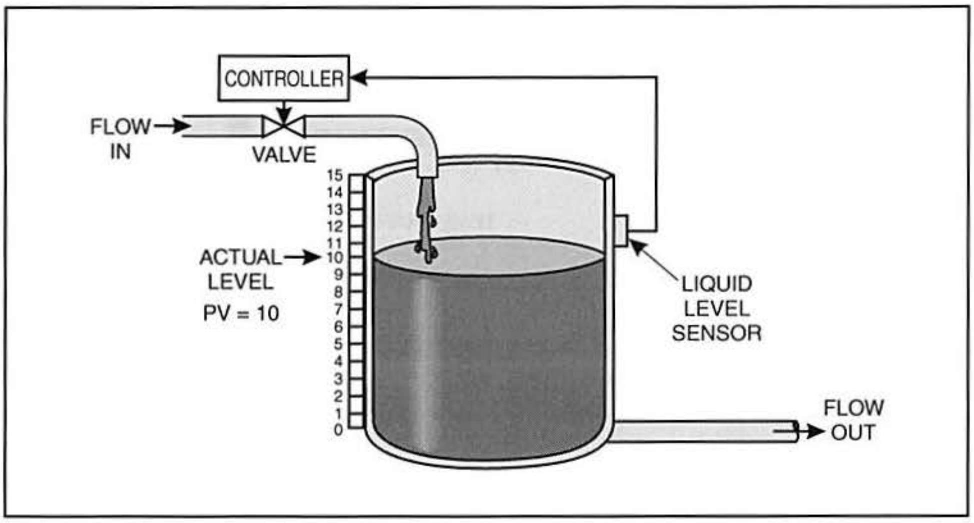

Figure 9 Level Control

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.

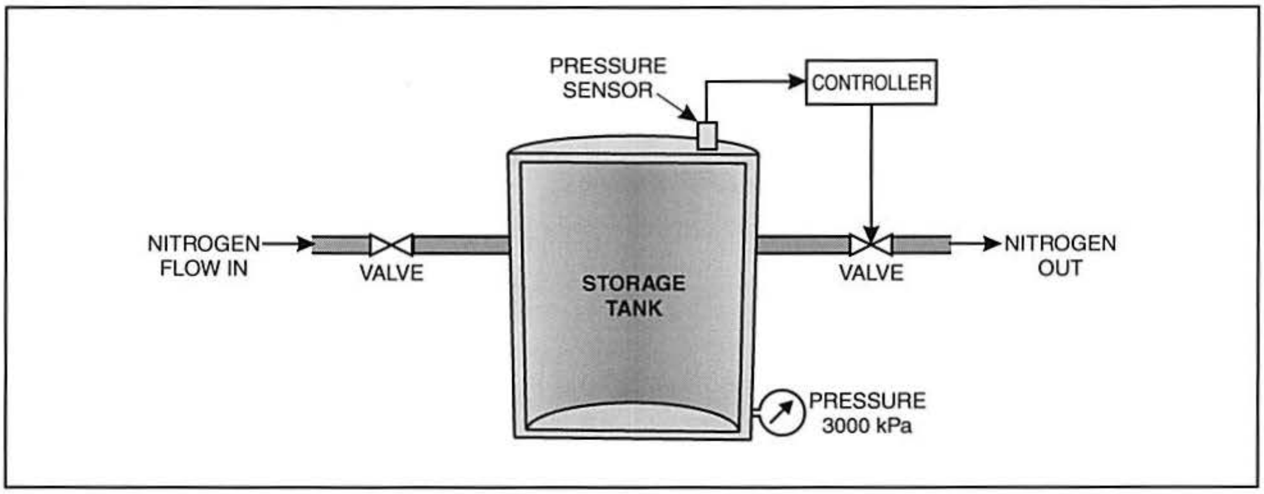

Figure 10. Example Control Loop

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.

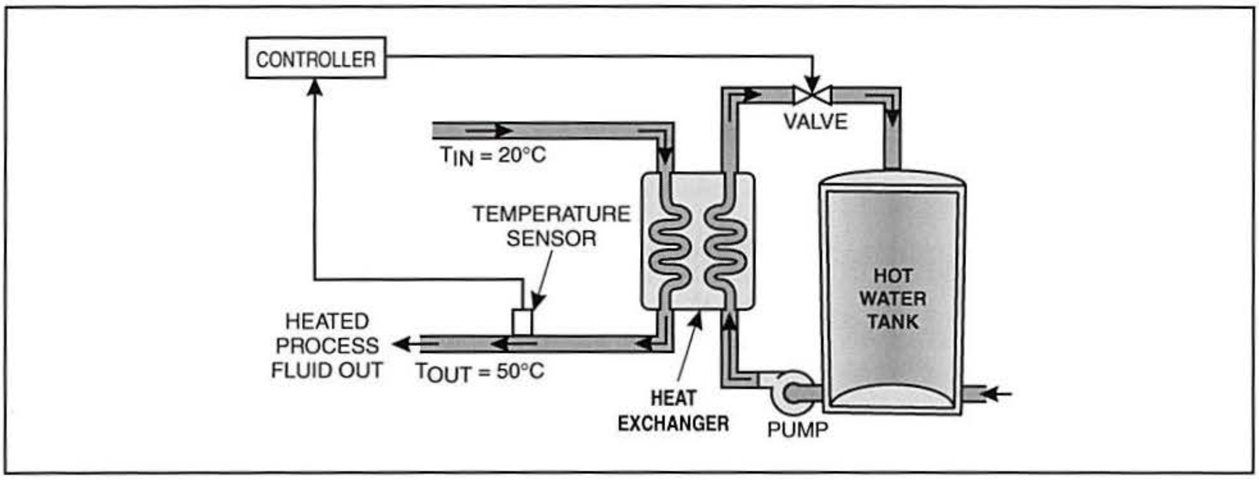

Figure 11. Temperature Control System

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.

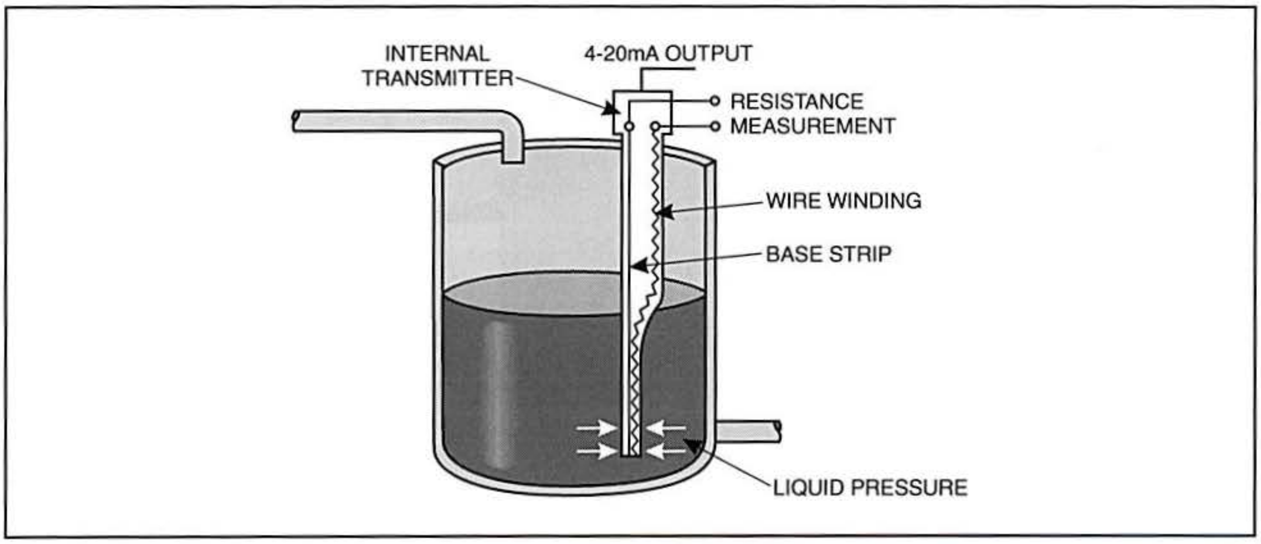

Figure 12. Liquid Density Measurement

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 is actually changed to control level is the flow rate out of the tank. Flow is therefore the manipulated variable in this process.

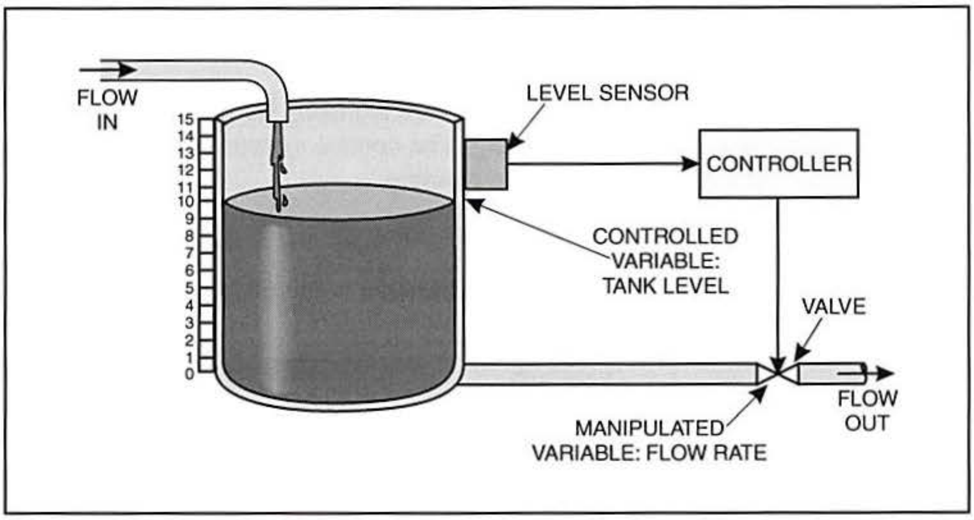

Figure 13. Controlling Level by Manipulating Flow

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.

Do This

❑ 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 ______________________________

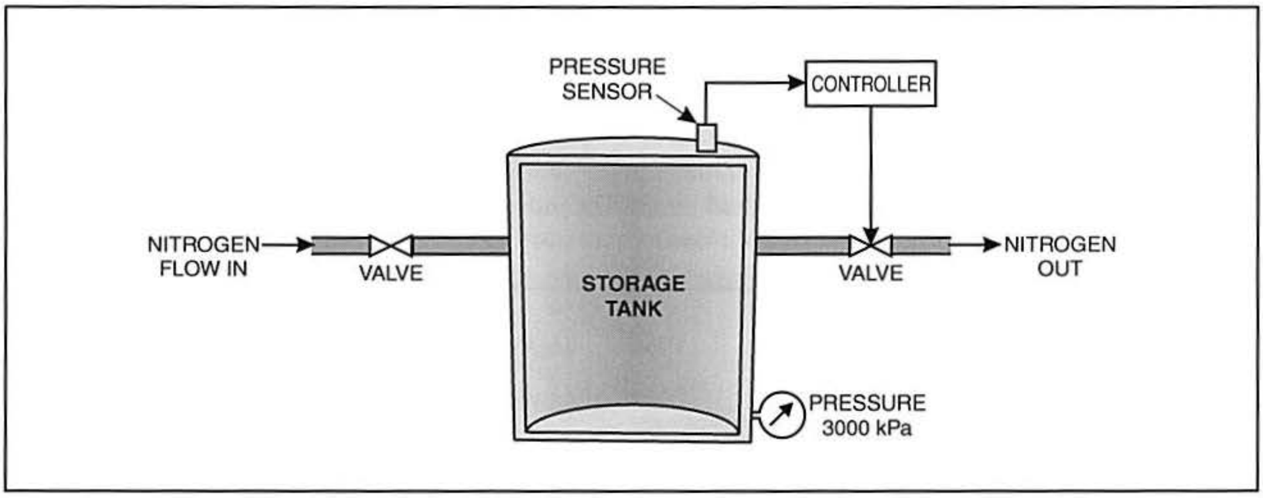

Figure 14. Example Control Loop

OBJECTIVE 6	DEFINE A PROCESS INSTRUMENT AND GIVE AN EXAMPLE

Read This

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.

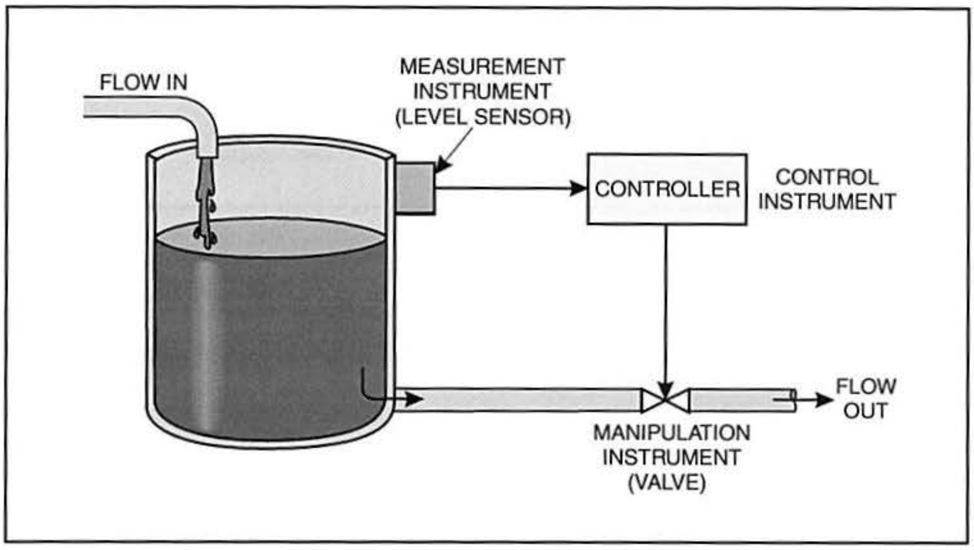

Figure 15. A Level Control Loop

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

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 changes in the process.

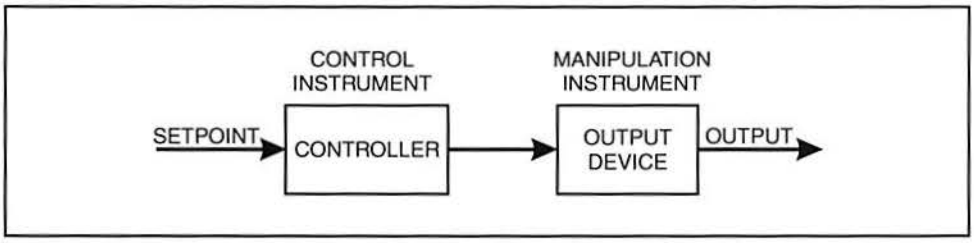

Figure 16. Open Loop Control System

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.

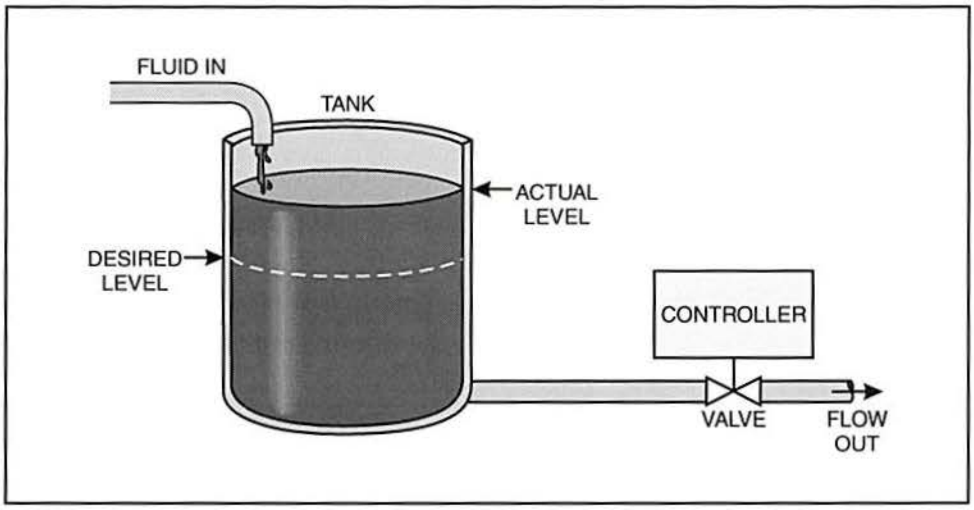

Figure 17. An Open Loop Level Control System

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.

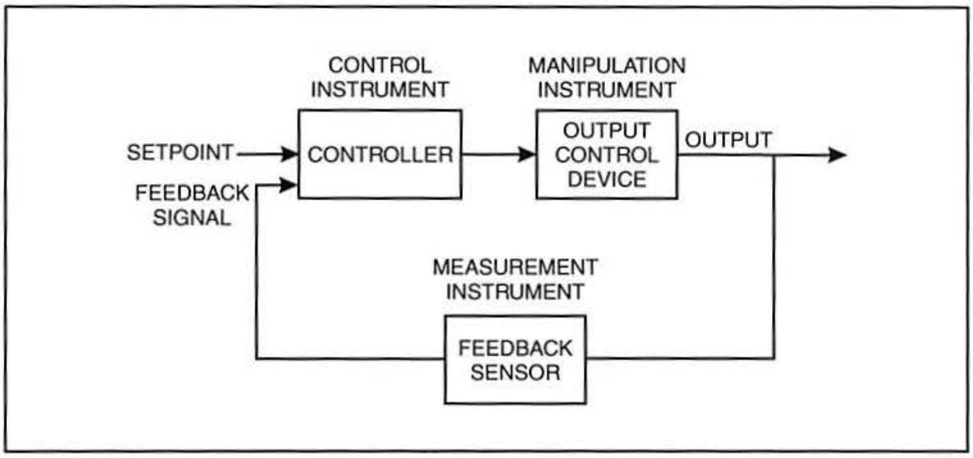

Figure 18. A Closed Loop Control System

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.

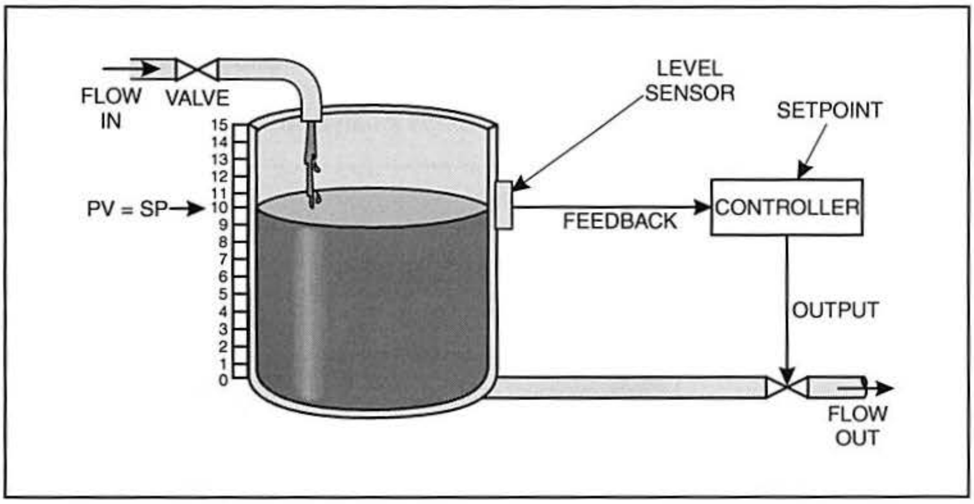

Figure 19. Closed Loop Level Control

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. T5554 System Familiarization

Procedure Overview

In this procedure, you will locate and become familiar with the major components of the T5554 Analytical Process Control System. The T5554 is designed to measure and control various chemical properties of water, including pH.

❑ 1. Locate the T5554 Analytical Process Control System, shown in figure 20.

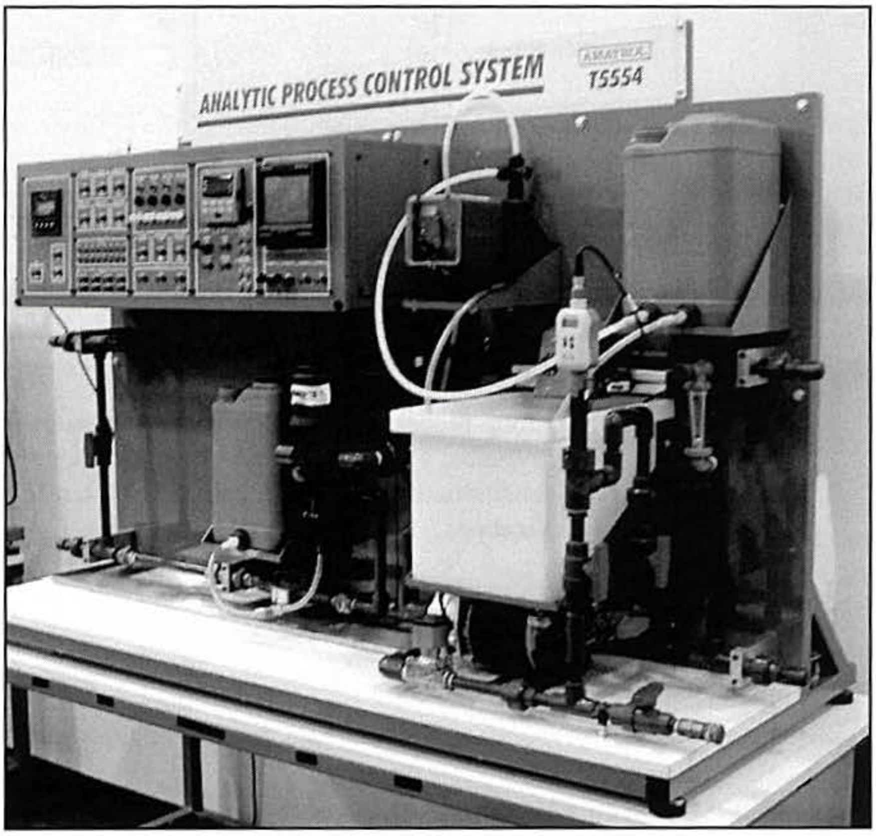

Figure 20. The Amatrol T5554 Analytical Process Control System

The T5554 system is made up of a single control loop, as shown in figure 21. It can be used as a self-contained system, where process flow starts and ends at the process reactor tank, driven by a circulation pump. It can also be set up to accept flow from an external source, such as a municipal water supply.

Figure 21 shows the basic components and concept of the pH control loop on the T5554. As water flows through the system, a special chemical pump called an eductor pump injects a chemical into the process flow to lower the pH, creating a disturbance in the system, before the water reaches the reactor tank.

Once the treated water reaches the reactor tank, a second chemical is injected into the reactor tank by another pump called a metering pump. The second chemical, which is mixed in using the agitator, is used to counteract the other chemical by raising the pH to bring the overall pH back to a desired level. A process controller monitors the pH reading from the pH sensor and controls the output of the metering pump to maintain the desired pH.

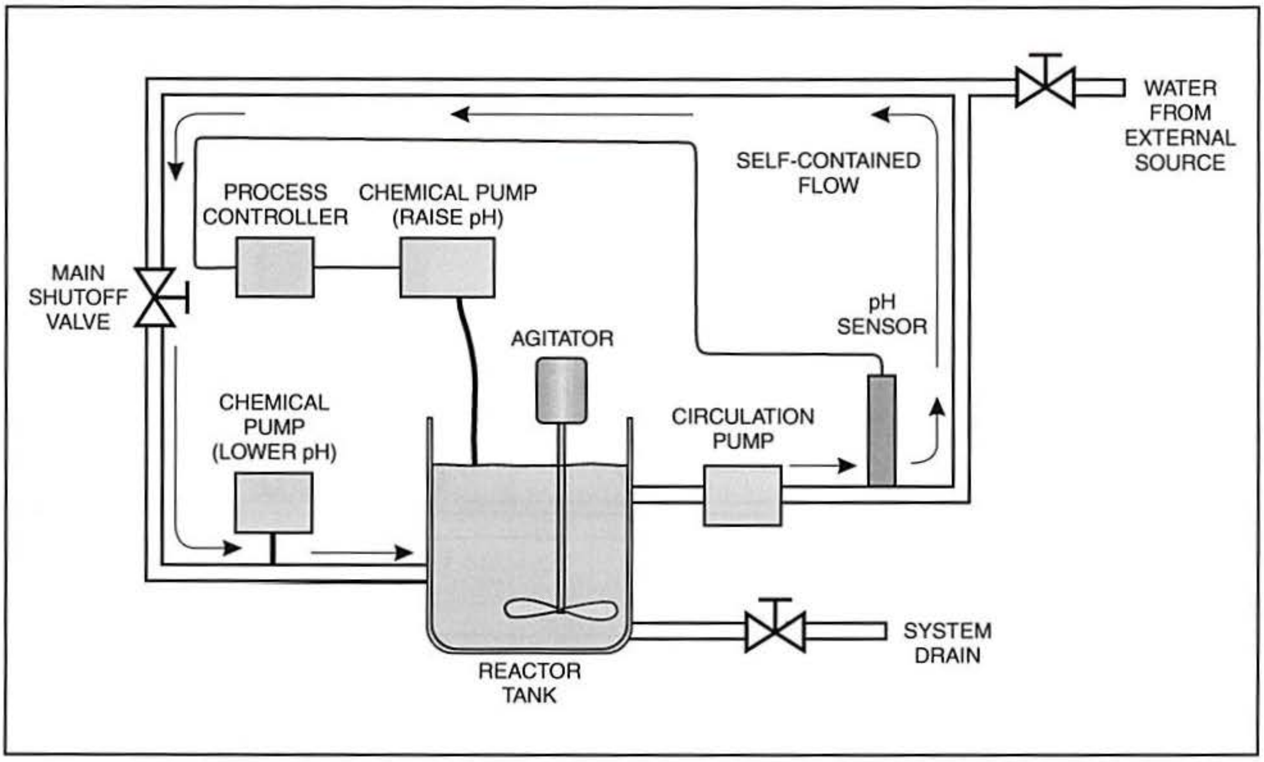

Figure 21. T5554 Basic System Concept

❑ 2. Locate the major sections of the T5554, as shown in figure 22.

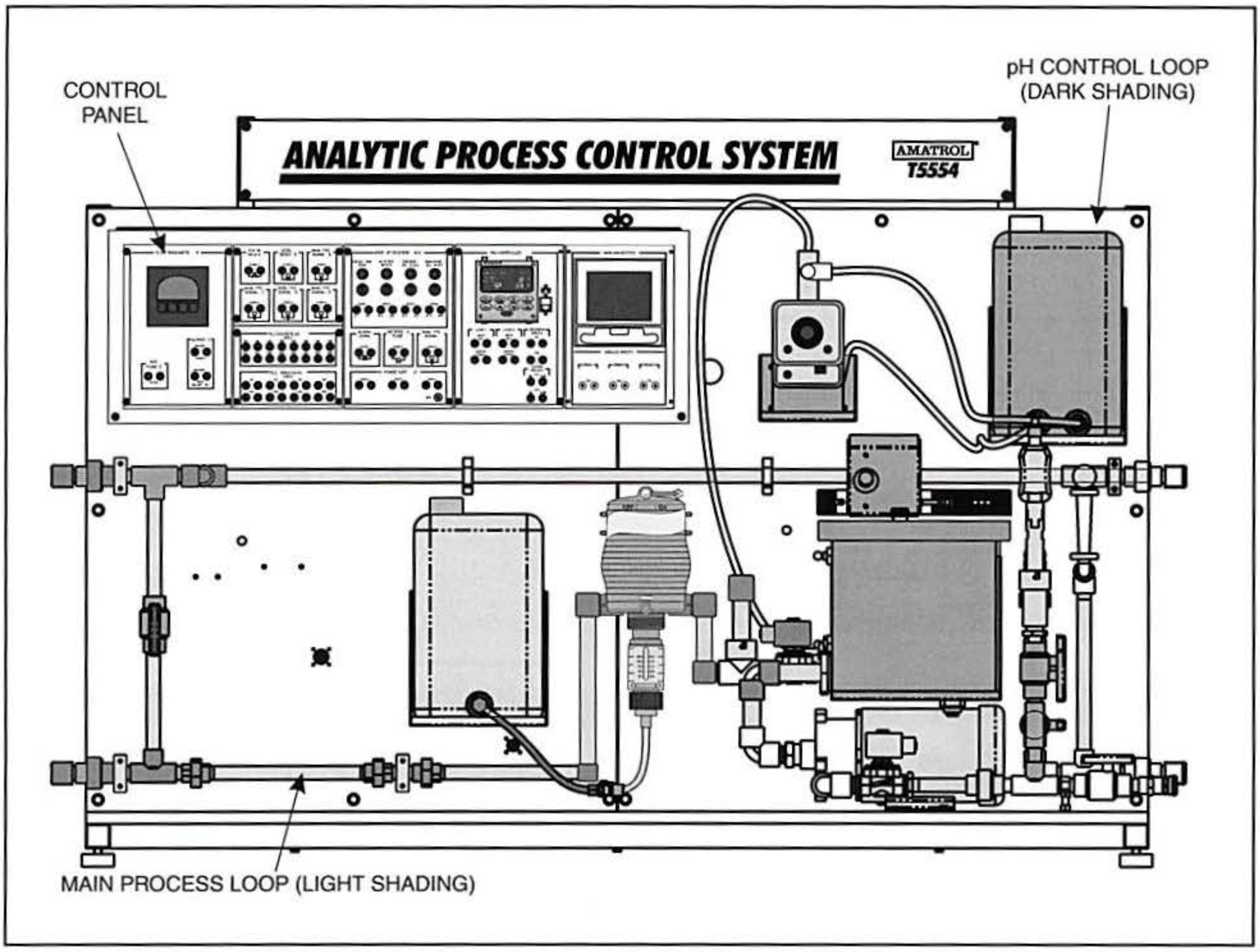

Figure 22. Major Sections of the T5554 Analytical Process Control System

- **Control Panel -** The control panel contains all of the required connections and control devices for the system. Some of the devices shown are standard components, while others are optional.
- **Main Process Loop -** The main process loop includes the piping, circulation pump, and a reagent injection system, which is used to inject an acid into the process to lower the pH of the process fluid (water).
- **pH Control Loop -** The pH control loop includes the piping, a reagent injection system, a reactor tank with an agitator, and a pH electrode with an attached pH transmitter. The reagent injection system for this loop injects a base solution into the reactor tank to return the pH of the process fluid to the desired level.

❑ 3. Perform the following substeps to locate the components of the T5554 control panel, shown in figure 23.

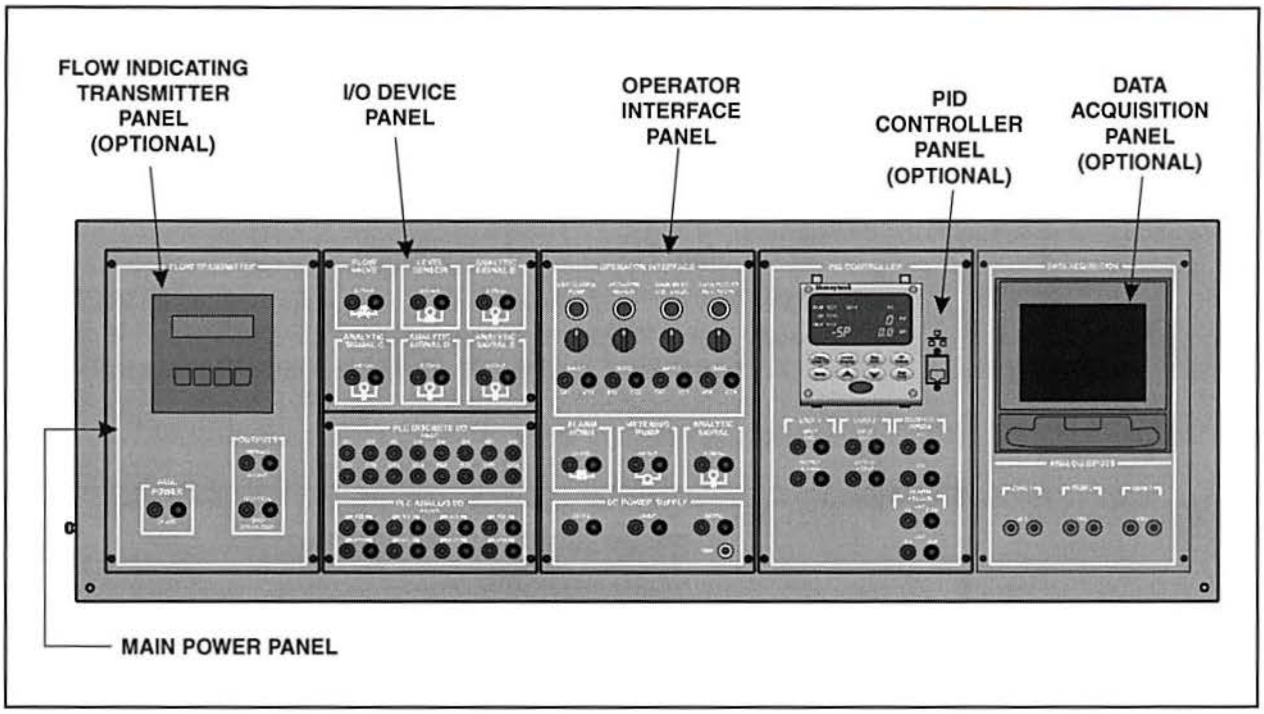

Figure 23. Control Panel Components

A. Locate the **Flow Indicating Transmitter Panel (optional)**, identified in figure 23, if present.

The flow transmitter displays the flow rate from the optional paddle wheel flow sensor in the main process loop. If your system does not have this option, there is a blank panel in its place.

B. Locate the **I/O Device Panel**, identified in figure 23.

The I/O device panel includes all of the connection terminals for the various analog and discrete devices on the T5554 system. This includes devices such as level sensors, analytical sensors (i.e. pH, dissolved oxygen, ORP, etc.), and flow valves. Also included on this panel are the connection terminals for the PLC interface. This includes discrete and analog I/O to the PLC.

C. Locate the **Operator Interface Panel**, identified in figure 22.

The operator interface panel includes selector switches to control the circulation pump, the agitator motor, the reactor tank inlet solenoid valve and the reactor tank outlet solenoid valve, with indicator lamps for each. Also included on the panel are the connections for the alarm horn, the electronic metering pump, the analytical signal (i.e. pH), and the 24 VDC power supply.

D. Locate the **PID Controller Panel (optional)**, identified in figure 23.

The PID controller panel contains either a single-loop or a dual-loop process controller and the connection terminals for the controller. If your system does not have this option, there is a blank panel in its place.

E. Locate the **Data Acquisition Panel (optional)**, identified in figure 23.

The data acquisition panel contains a Honeywell eZtrend QXe chart recorder along with the connection terminals for the chart recorder. If your system does not have this option, there is a blank panel in its place.

F. Locate the **Main Power Panel**, identified in figure 24.

The Main Power Panel, shown in figure 24, is located on the left side of the control panel enclosure. It contains the PLC interface cable connections (discrete I/O and analog I/O), the alarm horn, a control power LED, GFI duplex receptacles for external devices, and the main circuit breaker (on/off switch).

Figure 24. Main Power Panel Components

❑ 4. Perform the following substeps to locate the components of the main process loop, shown in figure 25.

Some of the items shown in figure 25 are optional items for the T5554 system.

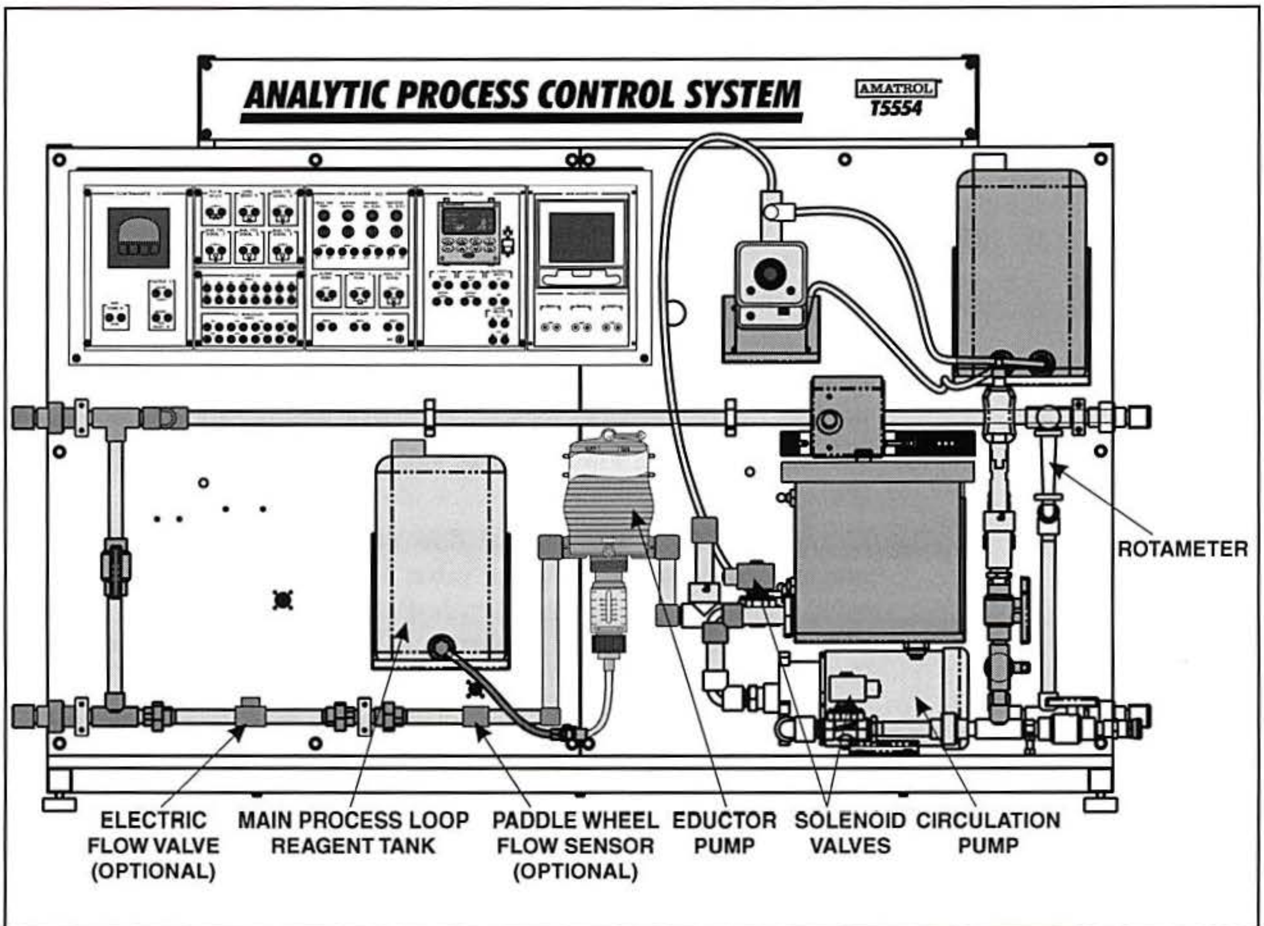

Figure 25. Components of the Main Process Loop

A. Locate the **Rotameter**, identified in figure 25.

The rotameter indicates the flow rate through the main process loop on a sight scale. It also has an adjustable shut off valve that provides a means to manually adjust the maximum flow rate within the main process loop.

B. Locate the **Main Process Loop Reagent Tank**, identified in figure 25.

This reagent tank holds the reagent (typically an acid such as sodium bisulfate) used to lower the pH of the process fluid. This tank can be removed from the system, to fill, empty, or clean as needed. It includes a handle for easy carrying. The tank is connected to the eductor pump with a flexible hose that can be disconnected during tank removal.

C. Locate the **Eductor Pump**, identified in figure 25.

The eductor pump, also called an injection pump, pumps the reagent from the main process loop reagent tank into the process fluid (water). The pump injects a selectable volume of the reagent into the process at a rate (frequency) determined by the flow rate of the process fluid. A higher flow rate results in a higher injection rate. A lower flow rate results in a lower injection rate.

D. Locate the **Circulation Pump**, identified in figure 25.

The circulation pump circulates the process fluid through the main process loop. It is located underneath the reactor tank. The control switch for the circulation pump is located on the operator interface panel.

E. Locate the **Solenoid Valves**, identified in figure 25.

One solenoid valve is located on the inlet side of the reactor tank. The other solenoid valve is located on the outlet side of the reactor tank. The controls for the solenoid valves are located on the operator interface panel.

F. Locate the **Electric Flow Control Valve (optional)**, identified in figure 25.

If your T5554 has the optional flow package, the main process loop contains an electric flow control valve. This is actually a solenoid valve with a proportional actuator attached to it. The proportional actuator allows the solenoid valve to operate in a proportional manner using a 4-20mA signal.

If your system does not include the optional flow package, a straight section of pipe appears in this location.

G. Locate the **Paddle Wheel Flow Sensor (optional)**, identified in figure 25.

If your T5554 has the optional flow package, the main process loop contains a paddle wheel flow sensor that connects to the optional flow indicating transmitter panel on the control panel.

If your system does not include the optional flow package, a straight section of pipe appears in this location.

❑ 5. Perform the following substeps to locate the components of the pH control loop, shown in figure 26.

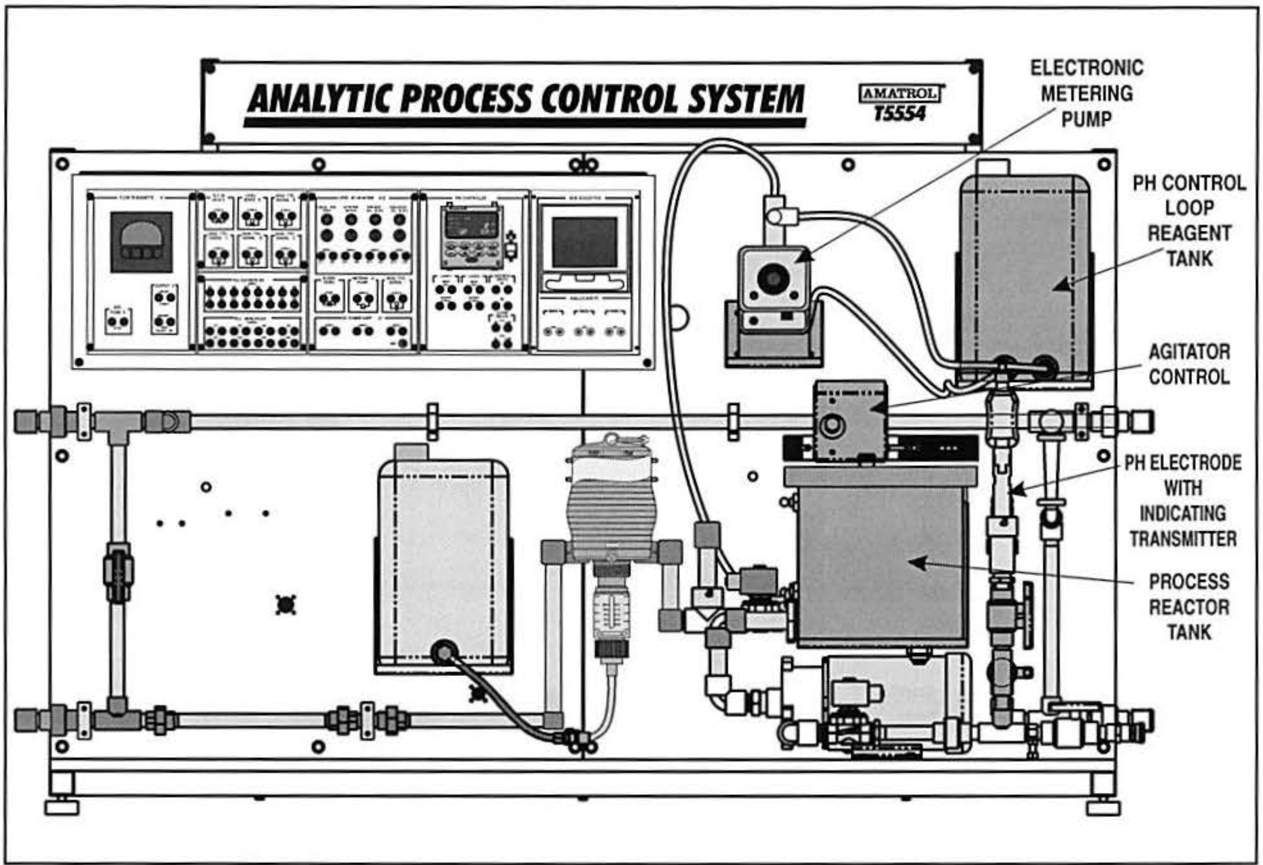

Figure 26. Components of the pH Control Loop

A. Locate the **pH Control Loop Reagent Tank**, identified in figure 26.

This tank holds the reagent (typically sodium carbonate) that neutralizes the acid added to the process fluid to raise the pH of the process fluid back to an acceptable level. This tank is also easily removed from the system, making it easy to fill, empty, or clean as needed. It includes a handle for easy carrying. The tank is connected to the electronic metering pump with flexible hoses that can be disconnected during tank removal.

B. Locate the **Electronic Metering Pump**, identified in figure 26.

The electronic metering pump pulls the reagent from the reagent tank and pumps it into the process reactor tank. The pump injects a specified volume of reagent into the reactor tank at a user-set rate (frequency). The pump can be operated manually or can be operated in the automatic mode using a 4-20mA control signal.

C. Locate the **Process Reactor Tank**, identified in figure 26.

The process reactor tank, shown in figure 27, holds the process fluid and allows the reagent to mix with it. The reactor tank includes an agitator to mix in the reagent. The reactor tank also includes high and low level switches, as well as an optional pressure sensor/transmitter mounted in the bottom of the tank to measure the level of fluid in the tank, if desired.

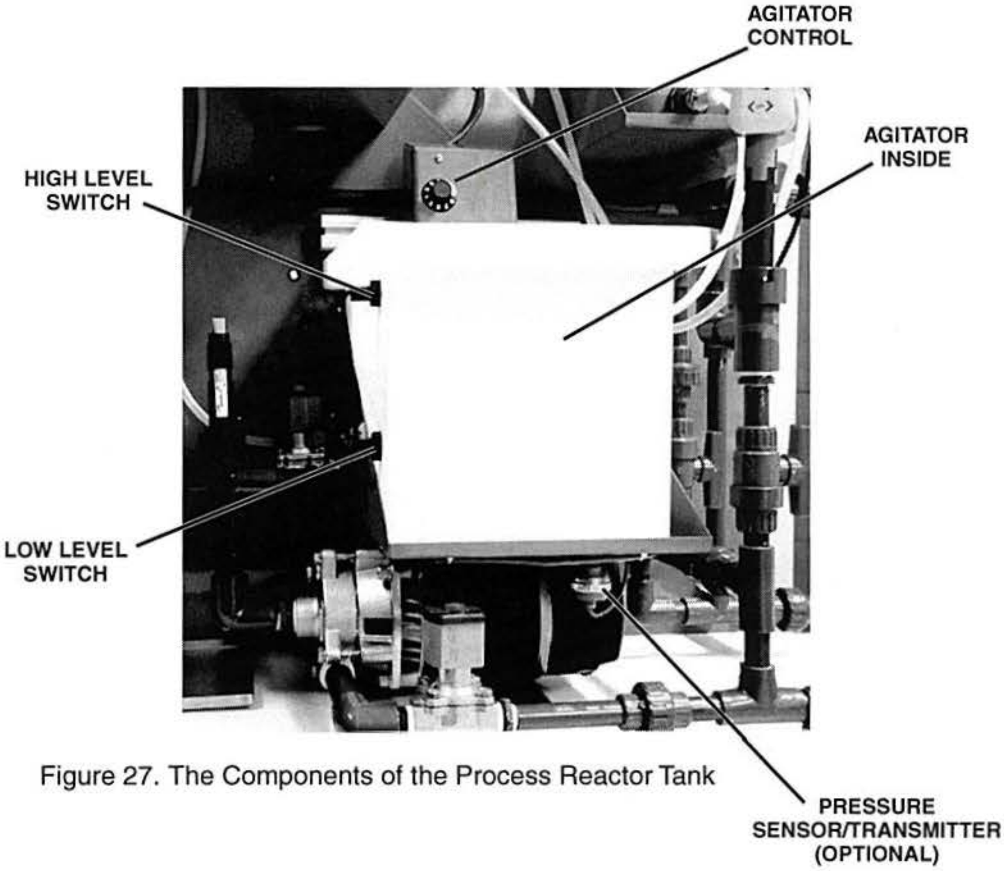

Figure 27. The Components of the Process Reactor Tank

D. Locate the **Agitator** and **Agitator Control**, identified in figure 27.

The agitator control allows the user to control the speed of the agitator by adjusting the speed control dial.

E. Locate the **pH Electrode w/Indicating Transmitter**, as identified in figure 26.

The pH electrode, a Honeywell Durafet electrode, is a solid-state electrode that uses a special type of transistor called an Ion Sensitive Field Effect Transistor (ISFET). Connected to the electrode is an indicating transmitter that displays the pH level measured by the electrode and transmits a 4-20mA signal that represents the pH measurement.

The electrode/transmitter combination can be placed in several locations on the system. Figure 28 shows the combination on the output side (right) of the reactor tank. As an option, a standard glass pH electrode can be used with the indicating transmitter.

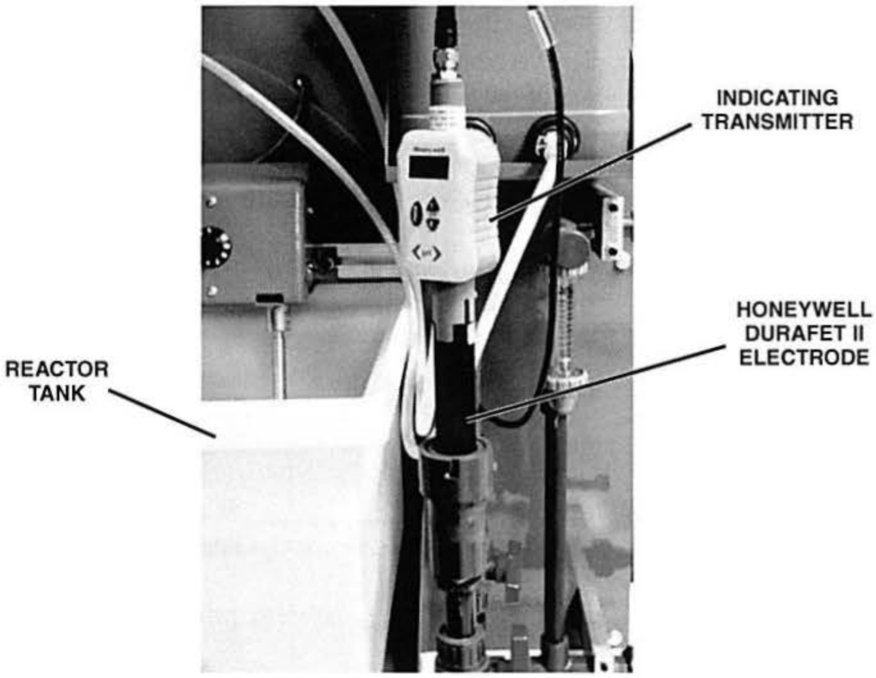

Figure 28. The Durafet pH Electrode with Indicating Transmitter

You have now located the major components of the T5554 Analytical Process Control System.

SELF REVIEW

1. The process ____________ is the aspect of the process that is being controlled.

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 variable that actually changes to alter the facet being controlled is called the ____________ variable.

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 difference between the setpoint and the process variable is called the __________.

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

9. A(n) ____________ system provides control of some facet of an industrial process.

10. The __________ industry uses process equipment to precisely control the blending of chemicals used to make drugs.

SEGMENT 2

SAFETY

OBJECTIVE 9 DESCRIBE SIX RULES OF 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. This often includes a hard hat, safety glasses with side shields, ear plugs if required, and safety shoes or boots. When working with chemicals, chemical resistant clothing, respirators, and gloves may be required.

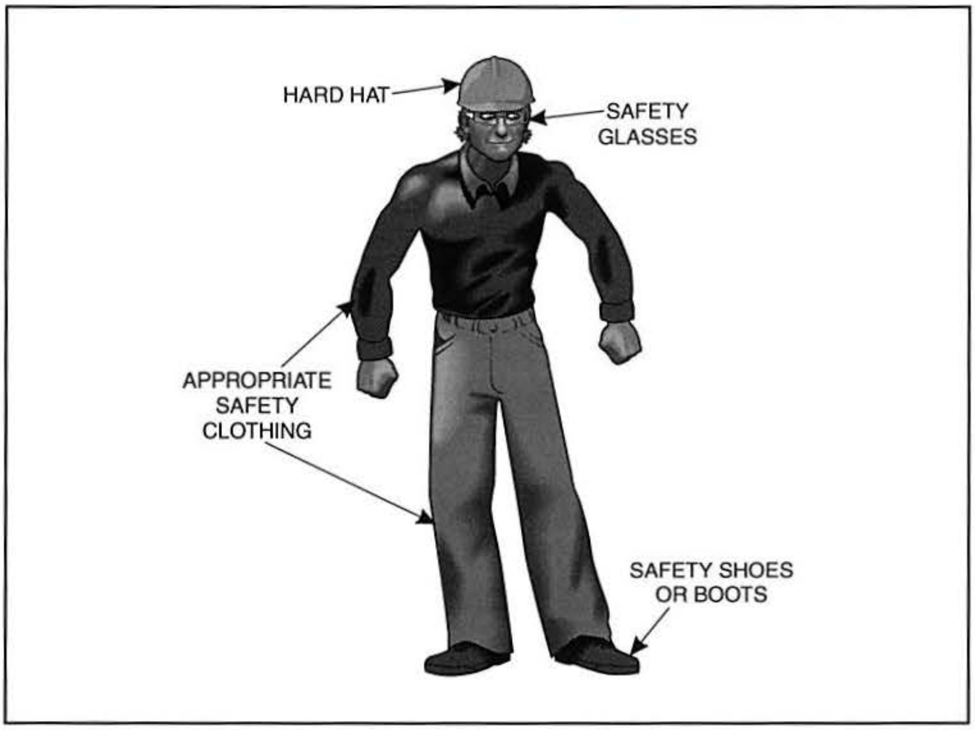

Figure 29. Safety Attire When Working with Processes

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

- Wear safety glasses with side shields 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.
- Wear appropriate safety clothing.
- When possible, 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. If gloves are required, use extreme caution.

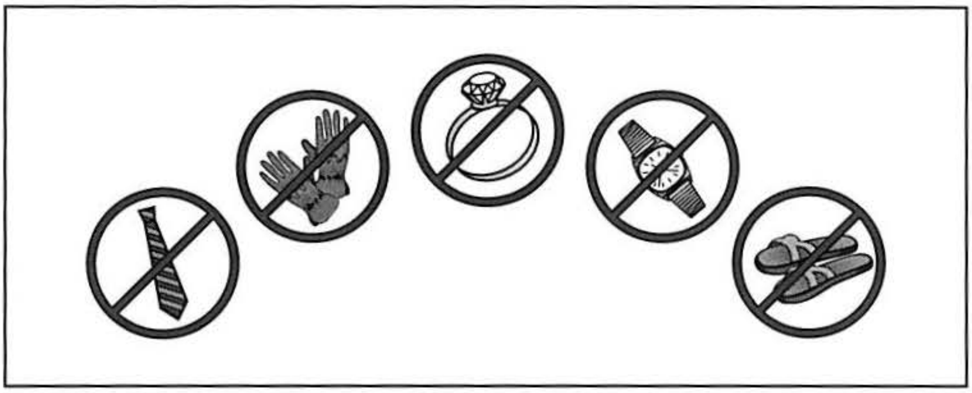

Figure 30. Rules for Safe Dress

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. These 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 shut off 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 for protection.** 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 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 31. 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 31.

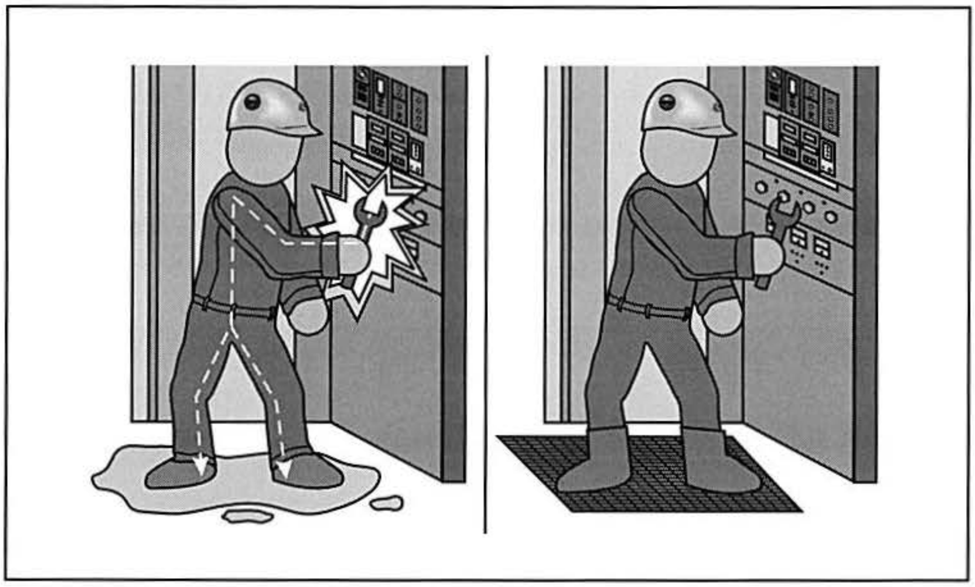

Figure 31. Do Not Work on Wet Floors

- **When possible, work with one hand when working with electrical components.** Working with one hand (put the other behind the back or in a pocket) avoids 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 a 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 helps in determining when 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 are 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.

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 32, the lockout device physically prevents the power switch from being placed in the ON position.

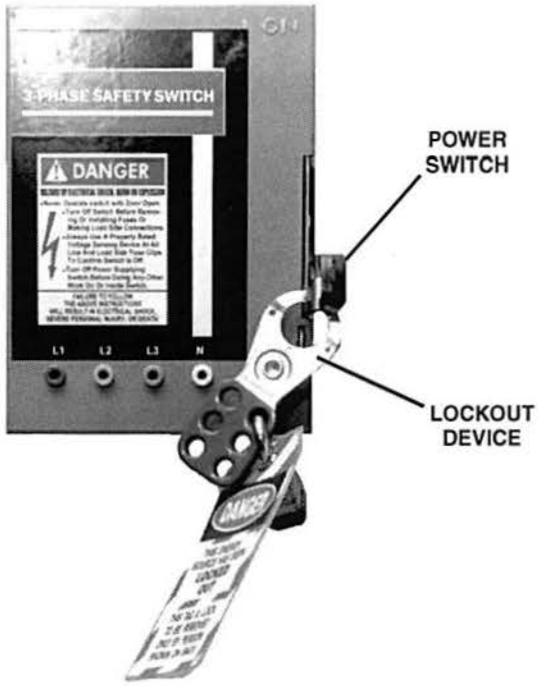

Figure 32. Electrical Lockout Device

Tagout involves placing a tag on the power source that warns others not to restore power, as figure 33 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.

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.

Figure 33. Tagout Device

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

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. In some applications, it may be necessary to ground all current-carrying conductors to prevent the possibility of back feeding current from other circuits still under power.

Lockout All Applicable Devices

Once all power sources to the process are shut off, apply the appropriate lockout devices to the equipment, as figure 34 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.

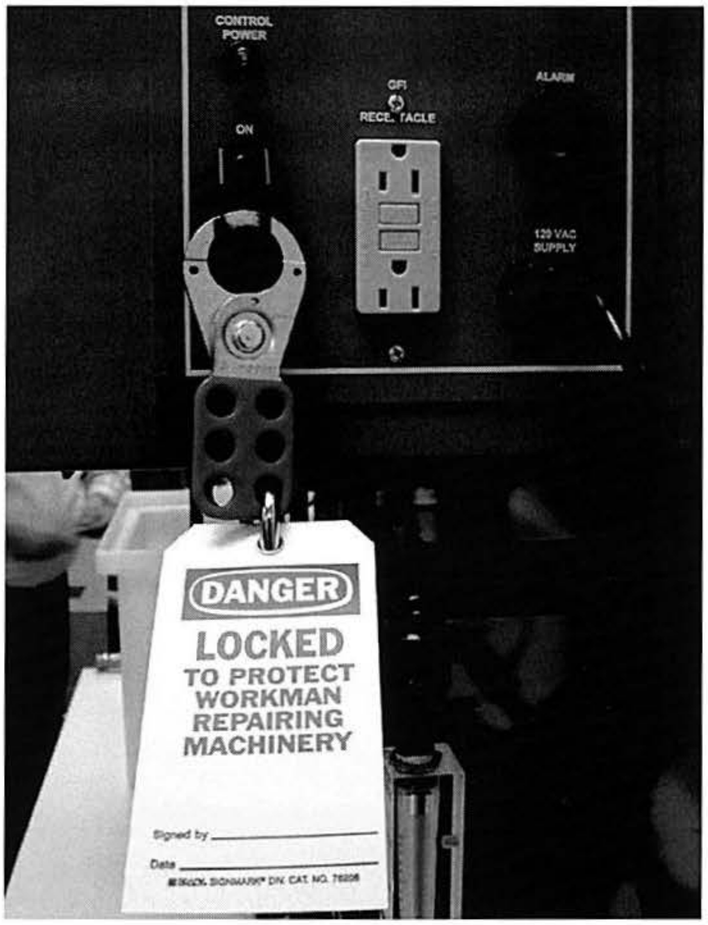

Figure 34. Lockout Device Installed

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 35 shows. The bleeder resistor provides a quick and safe means to dissipate this charge. If a bleeder resistor is not present, manually discharge the capacitor by shorting the leads. This must be done with caution because an electrical spark is created.

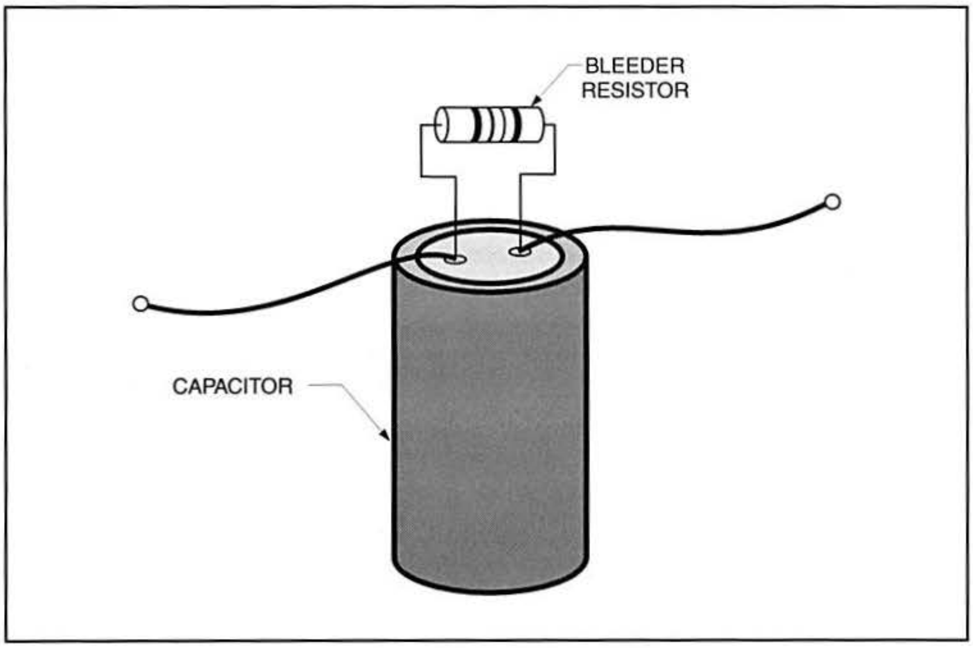

Figure 35. Bleeder Resistor Across a Capacitor

In fluid systems, there can be pressure trapped in the lines or stored in an accumulator even after removing power from 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, as figure 36 shows, and liquids are drained to a non-pressurized tank. In applications where it is not safe to vent trapped gas to the atmosphere, an approved vessel is used to collect the trapped pressure.

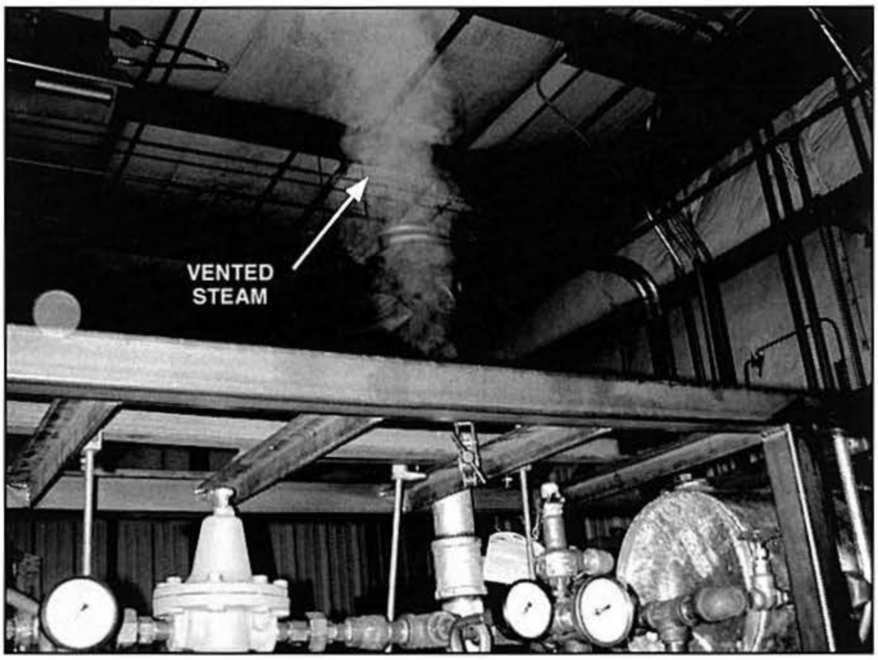

Figure 36. Venting Trapped Pressure

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

Procedure Overview

In this procedure, you will perform a lockout/tagout on the electrical supply to the T5554 Analytical Process Control System.

- [ ] 1. Locate the main circuit breaker on the left side of the control panel of the T5554, as figure 37 shows. This switch controls all electrical power to the T5554.

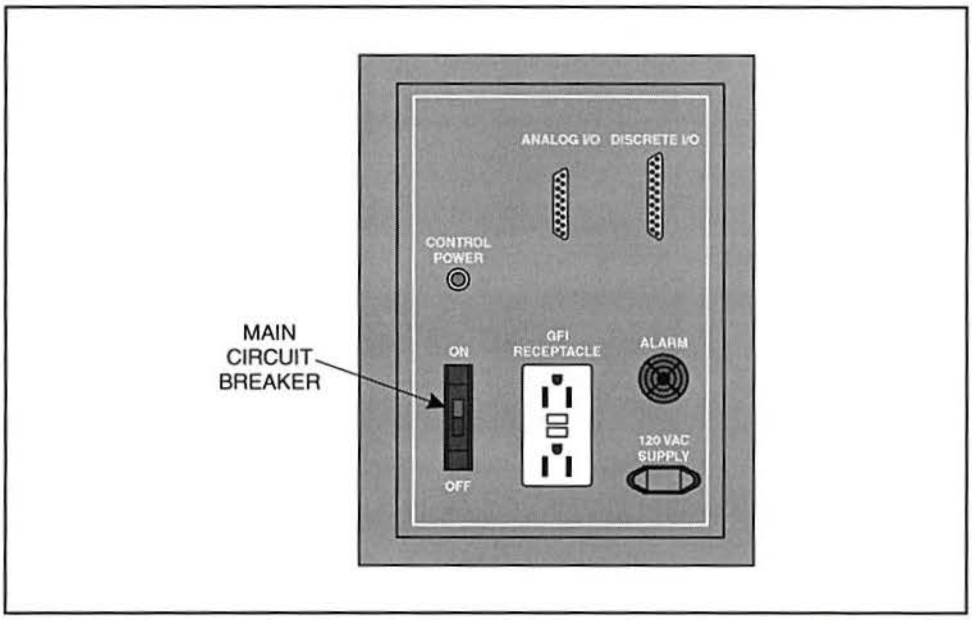

Figure 37. The Main Circuit Breaker

❑ 2. Perform the following substeps to lock out the main circuit breaker on the T5554.

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 38 shows. If you are working in teams, each person must have their own padlock and tagout tag.

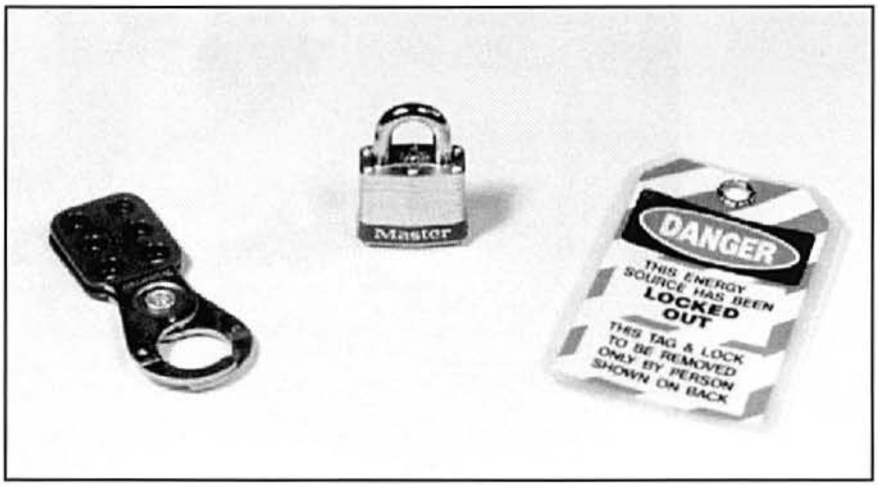

Figure 38. Lockout/Tagout Equipment

B. Make sure the circuit breaker is in the **OFF** or down position, as figure 39 shows.

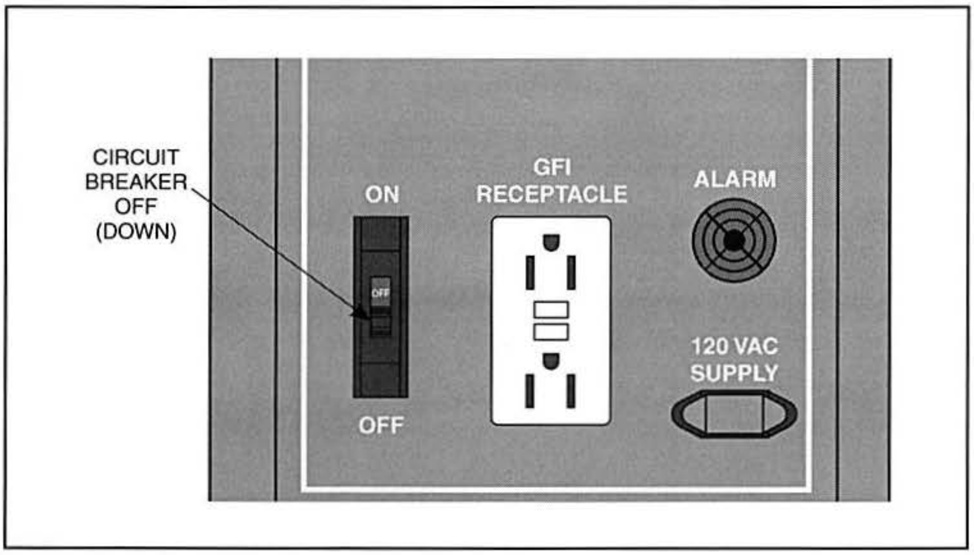

Figure 39. Main Circuit Breaker in the OFF Position

C. Open the lockout device and hook it through holes in the brackets on both sides of the circuit breaker, as figure 40 shows.

Figure 40. 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 41 shows.

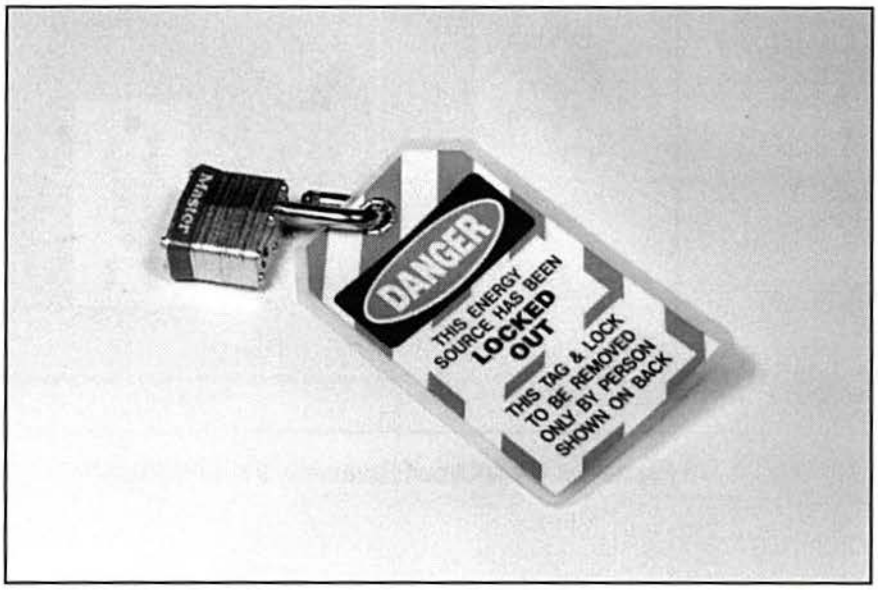

Figure 41. Tagout Tag Placed on Padlock Hasp

F. Install the padlock in one of the open holes in the lockout device and close the padlock, as figure 42 shows.

NOTE

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

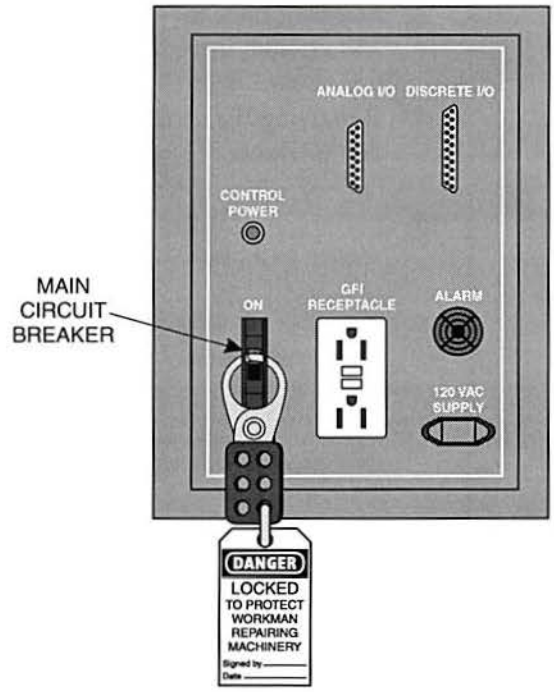

Figure 42. Padlock Installed on the Lockout Device

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 T5554.

This takes care of the electrical system.

Once the electrical system is locked out, other power systems such as pneumatics can be locked out as well. The T5554 does not have any other power sources.

- ❑ 3. Remove the lockout/tagout equipment from the circuit breaker.
- ❑ 4. Return all lockout/tagout equipment to the instructor.

SEGMENT 2

SELF REVIEW

1. __________ is the highest priority in all modern industrial plants.
2. The first line of defense against accidents with process equipment is proper __________.
3. Standing on a wet floor __________ the resistance between the body and ground, increasing the possibility of electric shock.
4. Removing the grounding prong on an AC plug eliminates the ground and produces a(n) __________ hazard.
5. __________ is the process of blocking the energy flow from a power source to a piece of equipment and assuring that it remains blocked.
6. A tagout tag should clearly read: ______________ or some other similar statement.
7. A(n) ____________ resistor provides a quick and safe means to dissipate the electrostatic charge stored in capacitors.

SEGMENT 3

MANUAL CONTROL

OBJECTIVE 13 DESCRIBE THE FUNCTION OF MANUAL CONTROL AND GIVE AN APPLICATION

Read This

In addition to classifying process control systems as either open or closed loop, they can also be classified as manual or automatic. A manual process control system uses an operator to perform the controller's function (decision making) and make manual adjustments to the process, such as opening or closing a valve, as shown in figure 43.

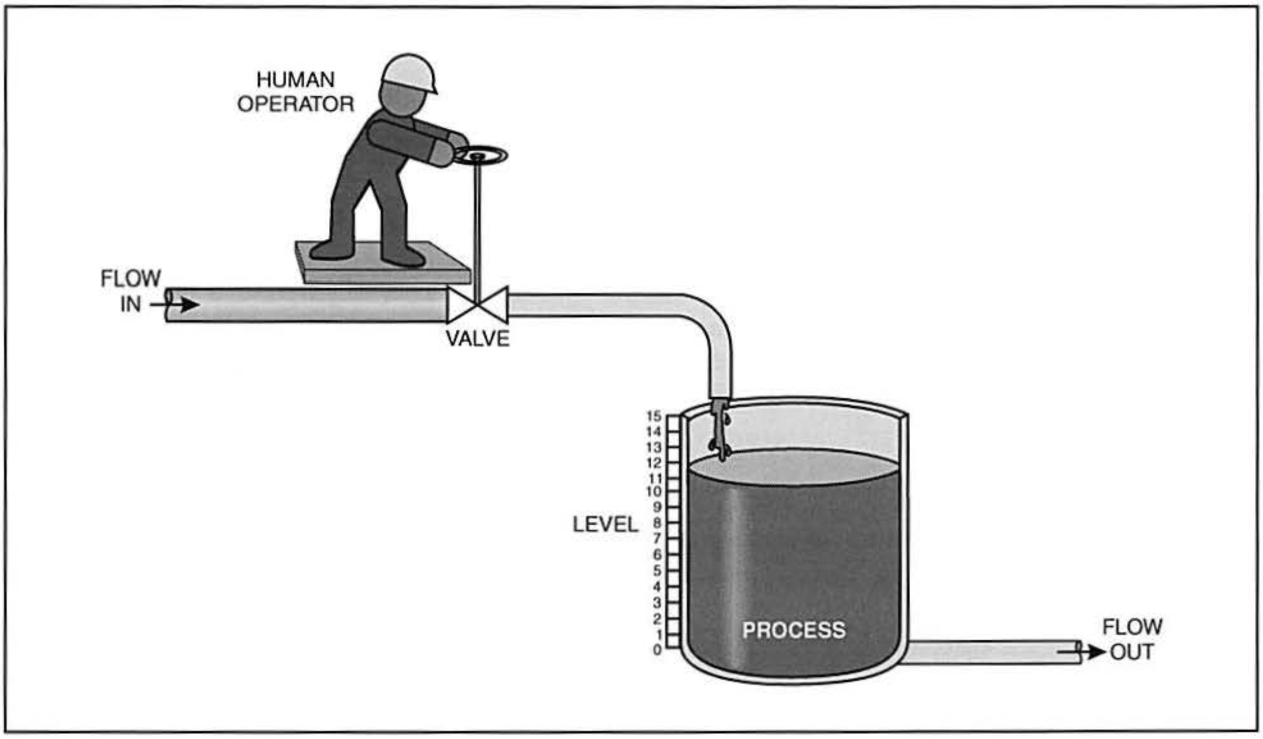

Figure 43. Typical Manual Open Loop System

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.

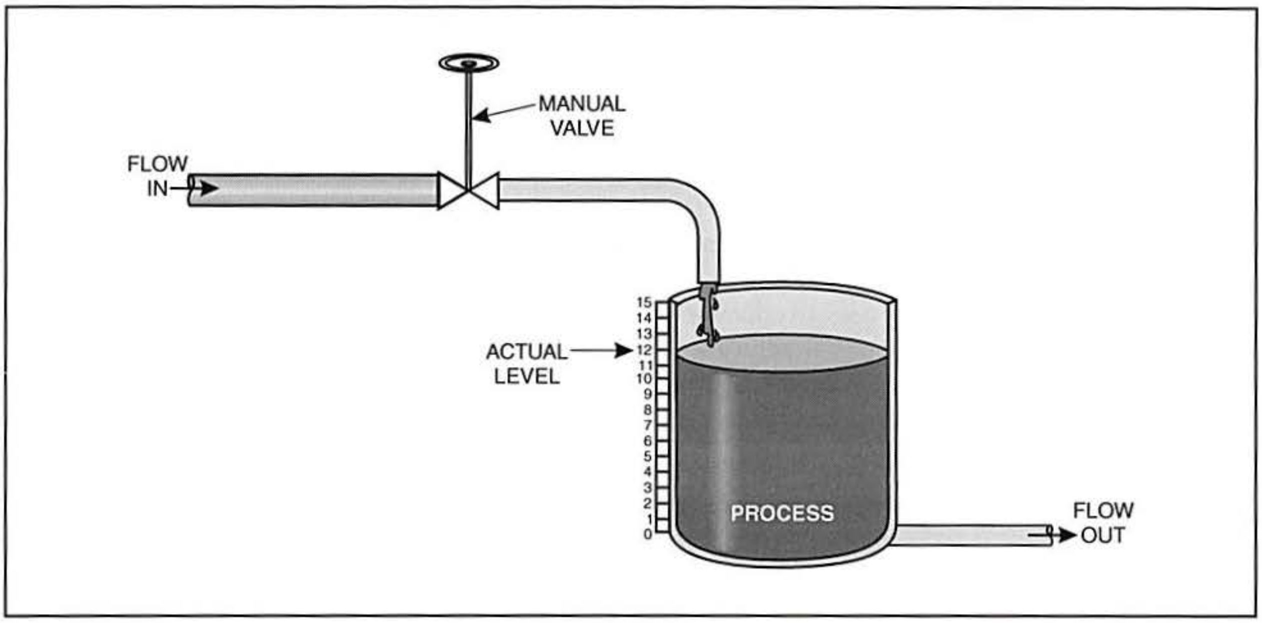

Figure 44. Typical Manual Open Loop System

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 open loop 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

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.

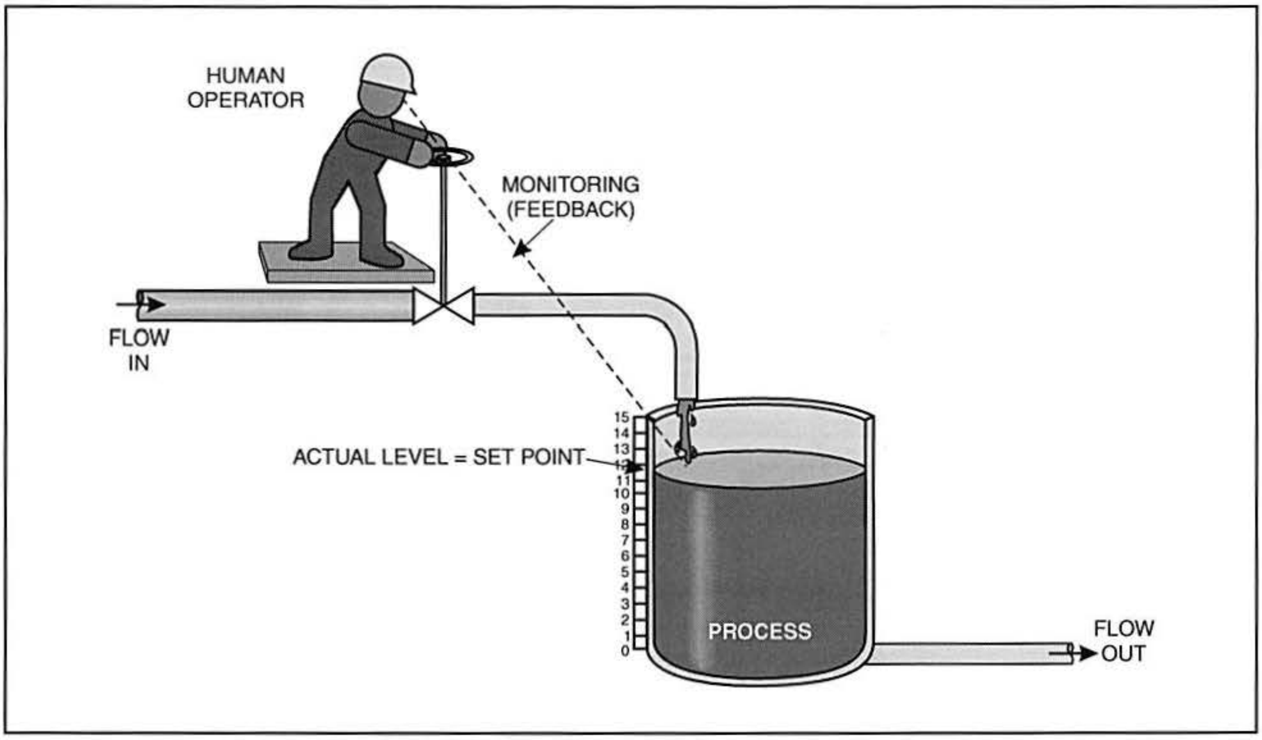

Figure 45. Manual Closed Loop Level Control System

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.

Procedure Overview

In this procedure, you will manually control the flow of fluid in the system using the adjustment valve on the rotameter.

- ❑ 1. Perform a lockout/tagout on the main power circuit breaker of the T5554.
- ❑ 2. Perform the following substeps to fill the reactor tank with fresh tap water.

  If the tank currently has water in it, the water must be drained from the tank before filling it with fresh water.

  A. If the tank needs to be drained, close the drain shutoff valve shown in figure 46. Observe the labels on the handle of the valve to determine the shutoff position.

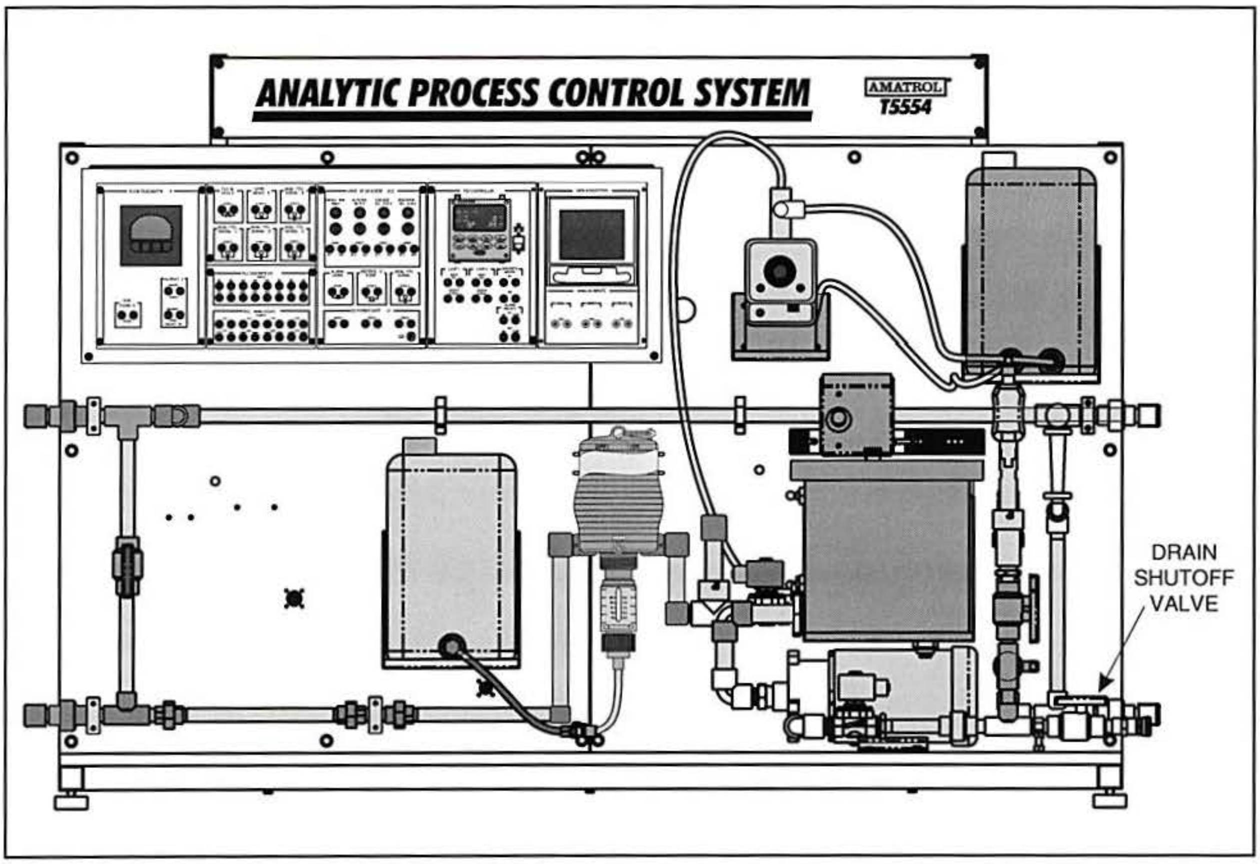

Figure 46. Drain Shutoff Valve

You can either drain the reactor tank using a hose or you can drain into a bucket.

B. Remove the drain cap from the drain connector, shown in figure 47, by turning it counterclockwise.

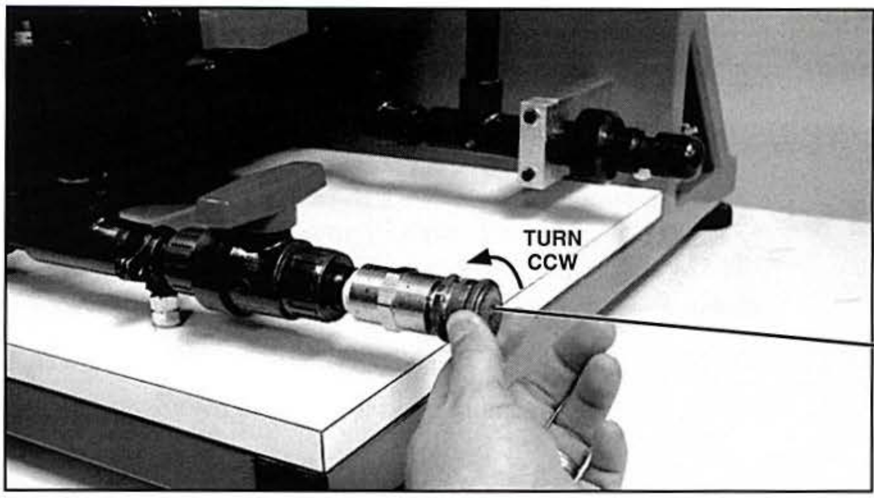

Figure 47. Remove Drain Cap

C. To use a hose, connect one end of the hose to the drain connector, as shown in figure 48, and place the other end of the hose in a sink or near a drain in the floor.

If you are draining into a bucket, simply hold the bucket beneath the drain connector and use the shutoff valve to start and stop the draining.

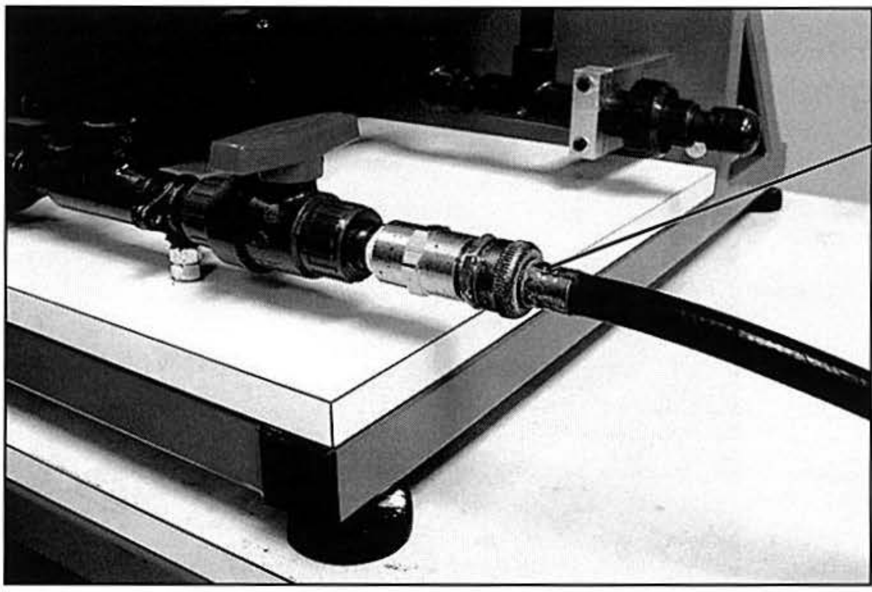

Figure 48. A Hose Connected to the Drain Connector

D. When ready, open the drain shutoff valve to allow the water to flow out of the reactor tank. If you are using a bucket, you must close the shutoff valve each time the bucket fills.

E. When the tank has drained, close the drain shutoff valve.

NOTE

Notice This

The reactor tank will not completely drain due to the location of the drain fitting in the tank. If you wish to completely empty the tank, you must use a sponge or a shop vacuum to remove the water that remains. Although the T5554 does not use dangerous chemicals, rubber gloves are advised.

F. If you are using a hose, disconnect it from the drain connector.

G. Replace the drain cap on the drain connector by turning it clockwise until it is tight.

You can fill the tank with fresh water using either a hose connected to a faucet (if the water supply is close by) or using a bucket.

H. Fill the reactor tank with fresh tap water until the level is just below the high level switch, as shown in figure 49.

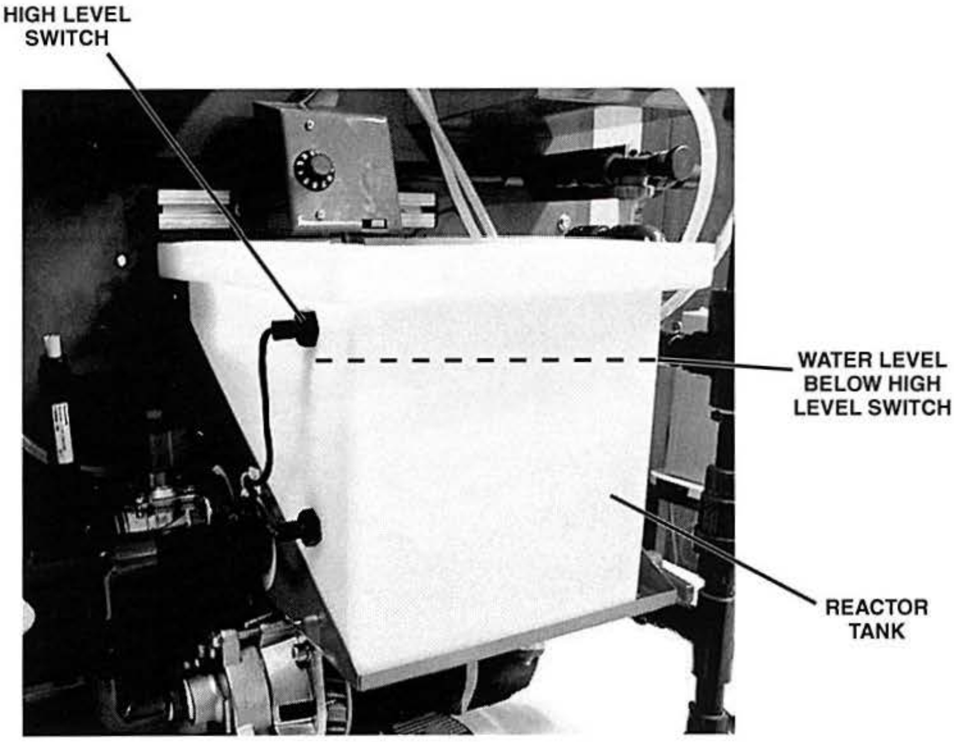

Figure 49. Water Level Just Below the High Level Switch

❑ 3. Make sure the reagent tank for the main process loop is at least 1/4 full. If not, add more of the reagent (sodium bisulfate solution) until the tank is at least 1/4 full.

The sodium bisulfate solution is mixed with water at a 10:1 ratio, 10 parts water to 1 part sodium bisulfate powder, measured by weight.

If necessary, you can remove the tank from its support bracket, as shown in figure 50, and place it on the table to fill it.

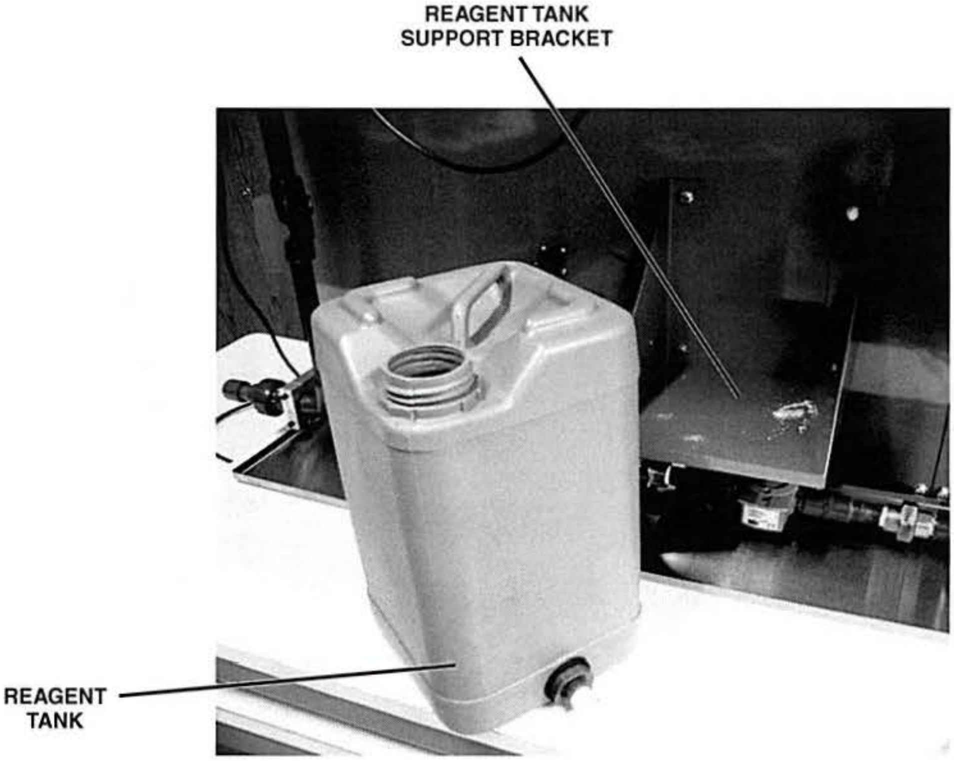

Figure 50. Main Process Loop Reagent Tank Removed from Support Bracket

☐ 4. Make sure the reagent tank for the pH control loop is at least 1/4 full. If not, add more of the reagent (sodium carbonate solution) until the tank is at least 1/4 full.

The sodium carbonate solution is mixed with water at a 10:1 ratio, 10 parts water to 1 part sodium carbonate powder, measured by weight.

This tank can also be removed from its support bracket. However, to set in on the table, you must disconnect the two hoses from the tank. To do this, you must press the release tabs on the connectors, shown in figure 51, and pull the hoses out of the connectors. The connectors are positive shutoff type connectors and will not allow the tank to leak when the hoses are removed.

To replace the hoses, simply push them into the connectors until they snap into place.

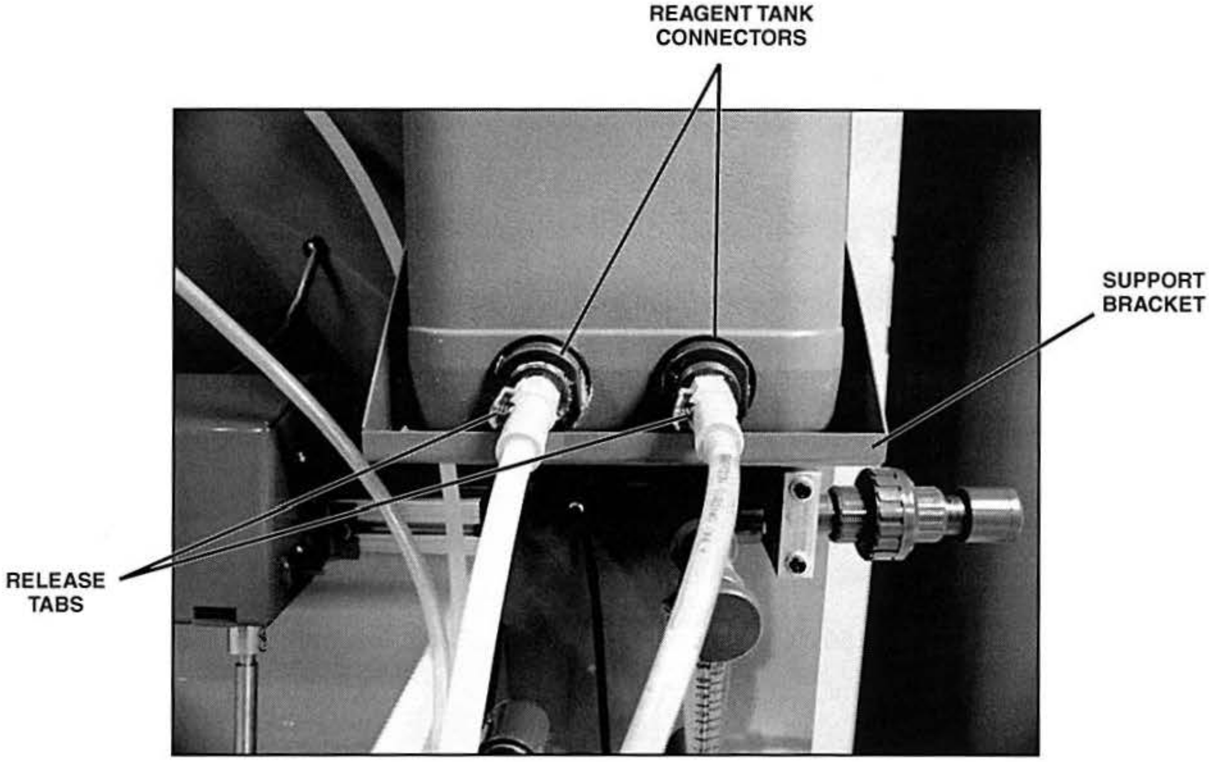

Figure 51. Release Tabs on the Reagent Tank Connections

Now that all of the tanks have been checked and filled (if necessary), you can safely operate the system.

❑ 5. Locate the On/Off switch on the eductor pump, shown in figure 52, and place it in the Off position.

This will prevent the eductor pump from injecting the acid into the process stream.

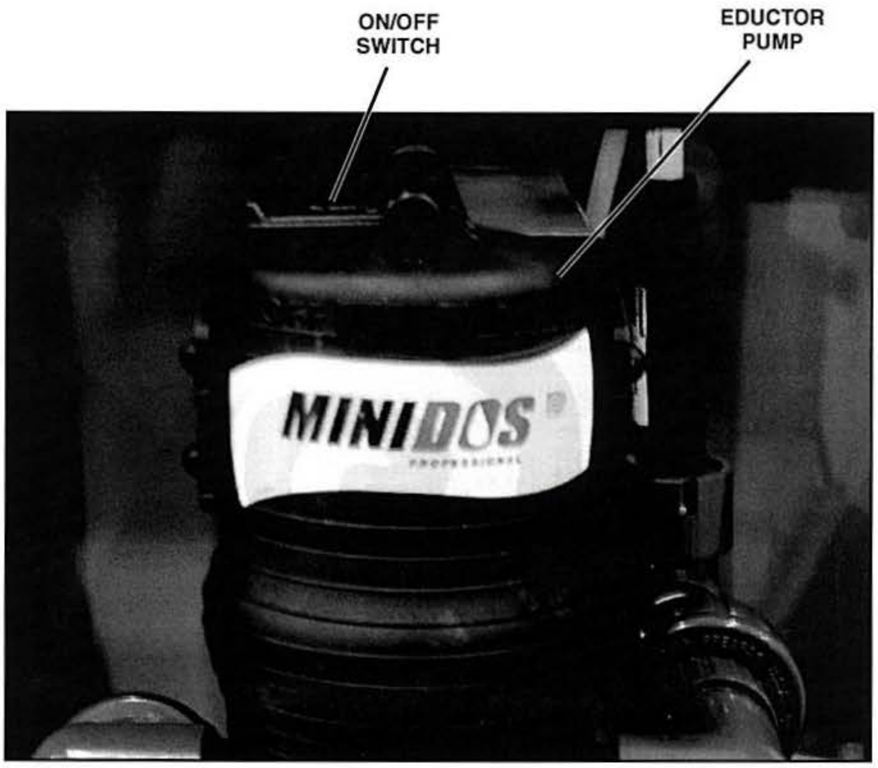

Figure 52. On/Off Switch on Eductor Pump

❑ 6. Remove the lockout/tagout.

❑ 7. Perform the following substeps to operate the system and control the flow.

A. Make sure the manual shutoff valve in the main process loop, shown in figure 53, is in the open position.

B. Make sure the bypass branch valves located to the right of reactor tank are open.

You can determine the open position by observing the label on the handle of each valve.

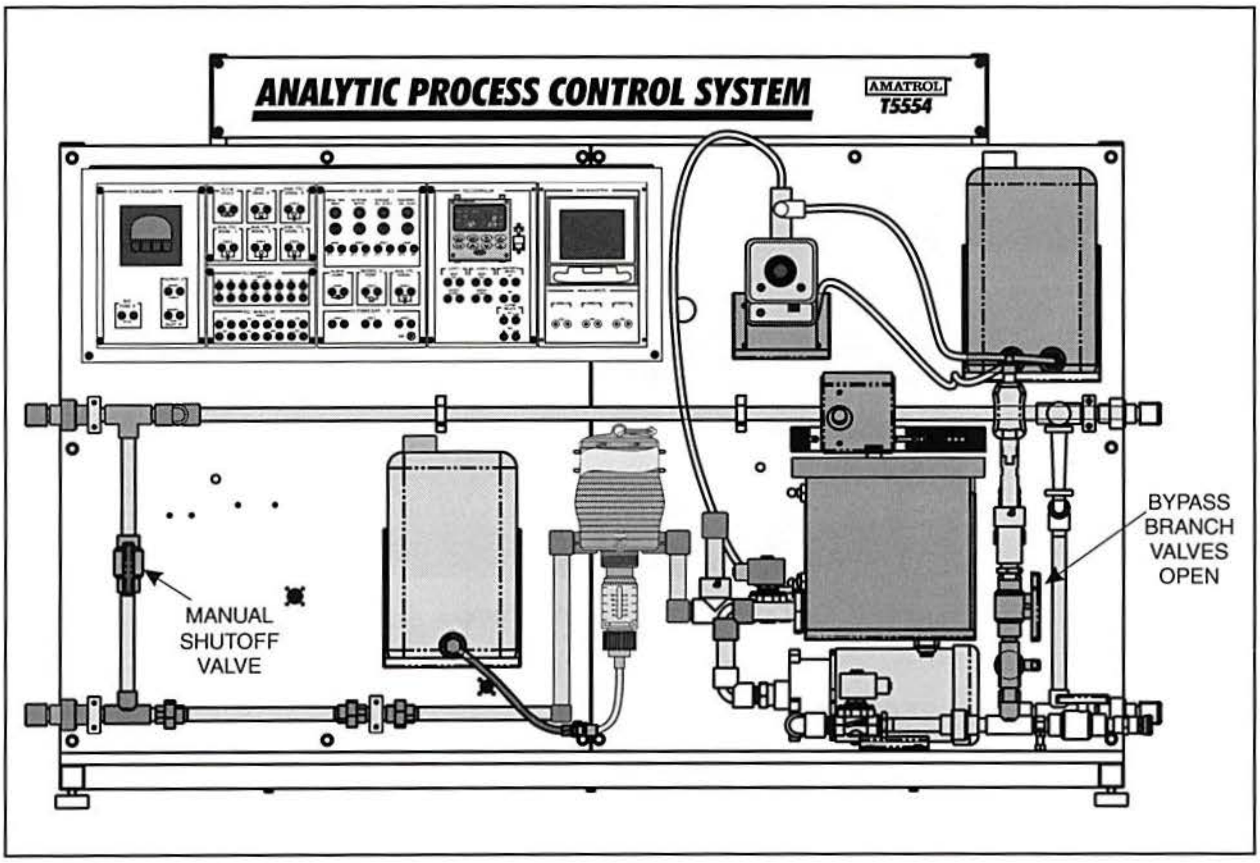

Figure 53. Manual Shutoff Valve in the Main Process Loop

C. Turn on the main power circuit breaker on the Main Power Panel.

This applies electrical power to the system.

D. Turn on the circulation pump by rotating the **CIRCULATION PUMP** selector switch on the Operator Interface Panel, shown in figure 54, to the ON position (clockwise).

This causes the circulation pump to start and circulate the water through the main process line. The flow rate of the water is controlled by the adjustment valve on the rotameter.

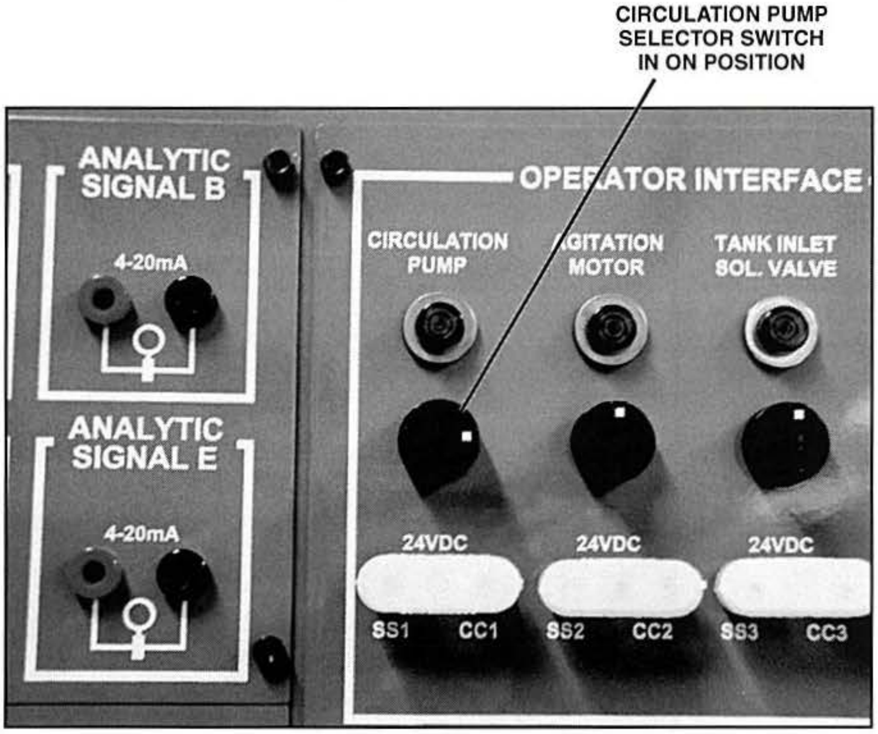

Figure 54. The Circulation Pump Selector Switch in the ON Position

❑ 8. Perform the following substeps to change the flow rate.

A. Reduce the flow rate of the water through the main process line by turning the flow control dial on the rotameter, shown in figure 55, clockwise.

This causes the rotameter's flow control valve to begin to close, reducing the flow rate.

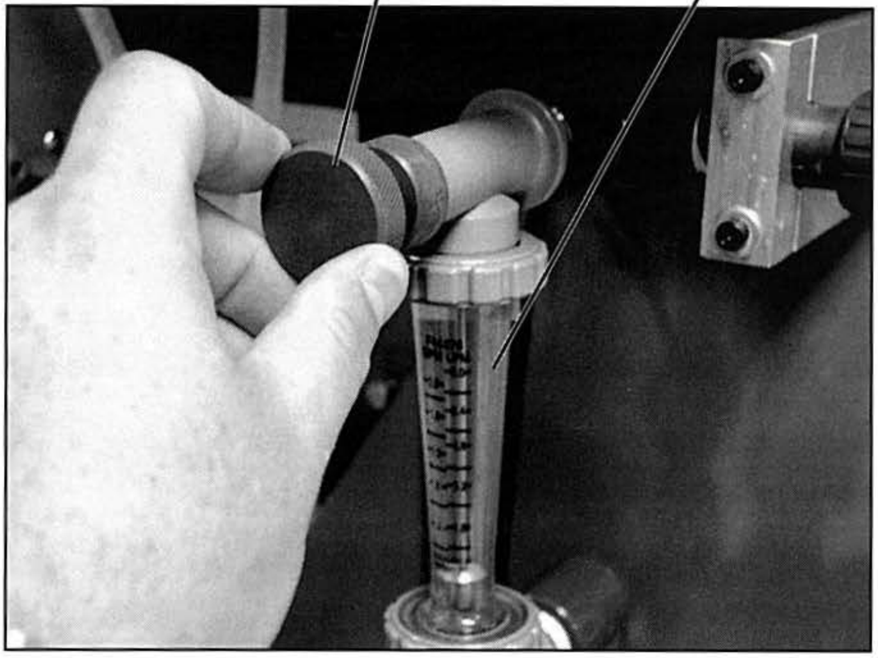

Figure 55. Flow Control Dial on Rotameter

B. As the flow rate slows, observe the indicated flow rate on the rotameter.

The flow rate is read at the widest part of the float inside the rotameter, as shown in figure 56. The scale on the left is for gallons per minute (gpm). The scale on the right is for liters per minute (lpm).

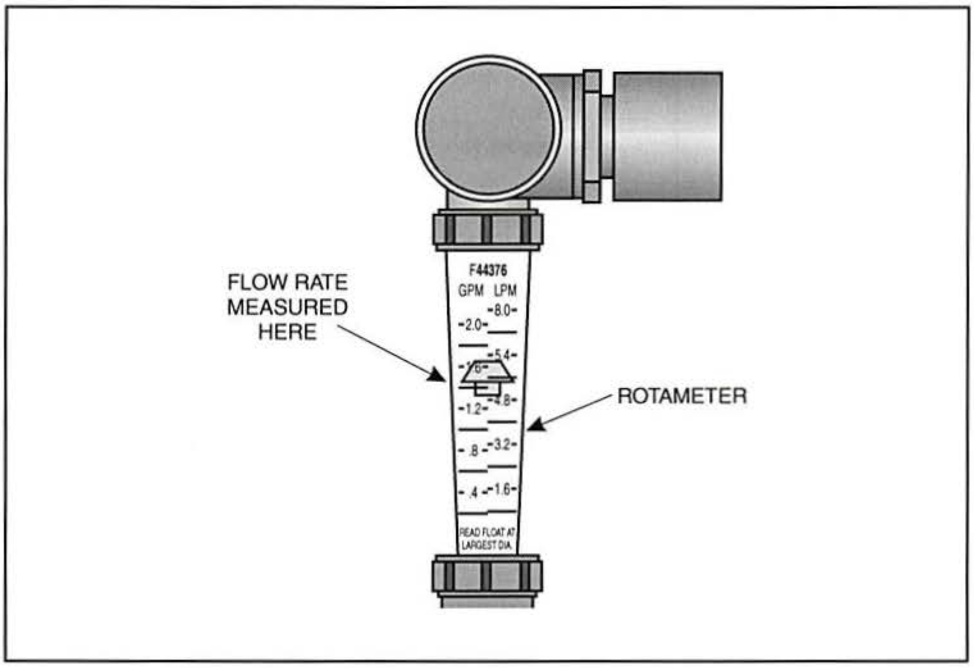

Figure 56. Rotameter Float Device Indicates Flow Rate

C. Increase the flow rate of the water by turning the flow control dial on the rotameter counterclockwise and observe the indicated flow rate on the rotameter.

You should find that the flow rate has increased.

D. Turn the flow control valve fully counterclockwise and record the maximum flow rate.

Max Flow Rate = ______________________________(gpm)

E. Turn the flow control valve fully clockwise and record the minimum flow rate.

Min Flow Rate = ______________________________(gpm)

F. Adjust the flow rate to 1.5 gpm using the flow control valve. Turning the valve counterclockwise increases flow.

❑ 9. Perform the following substeps to shut down the system.

A. Turn off the circulation pump by turning the **CIRCULATION PUMP** selector switch to the **OFF** position (counterclockwise).

B. Close the bypass valve on the eductor pump by turning it fully clockwise (CW).

C. Turn off the main power circuit breaker on the Main Power Panel.

This removes electrical power from 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. __________ closed loop control systems are uncommon because the cost of an operator is usually more than the cost of automating the process.
6. A(n) ____________ control system might be used to control the flow of city water into a plant.