ANALYTICAL PROCESS CONTROL

8

LEARNING ACTIVITY PACKET

pH CONTROL SYSTEMS

AMATROL®

B33303-AB08AEN

pH CONTROL SYSTEMS

INTRODUCTION

Controlling pH is more challenging than controlling other process variables such as level, flow, or temperature because pH cannot be controlled in a linear manner. This LAP covers the unique challenges of pH control as well as two common methods for controlling pH: batch control and continuous control.

ITEMS NEEDED

Amatrol Supplied
- T5554 Analytical Process Control Learning System
- T5554-C1-A Single-Loop PID Controller or
- T5554-C2-A Dual-Loop PID Controller

School Supplied

1	Municipal Water Supply and Drain
2	Garden Hose
1	3/16 Hex Wrench
1	Distilled Water
	pH Buffer Solutions (4, 7, and 10)
1	Beaker or Small Container
1	Squirt Bottle

FIRST EDITION, LAP 8, REV. A

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SEGMENT 1

pH ADJUSTMENT

OBJECTIVE 1 DEFINE TITRATION AND EXPLAIN ITS IMPORTANCE IN pH ADJUSTMENT

Read This

Titration is the process of creating a chemical reaction between two solutions by the controlled addition of one solution to another. Titration is the most common method used in pH control systems to adjust the pH of a solution. For example, the pH of an acidic solution can be increased by adding a controlled volume of a base.

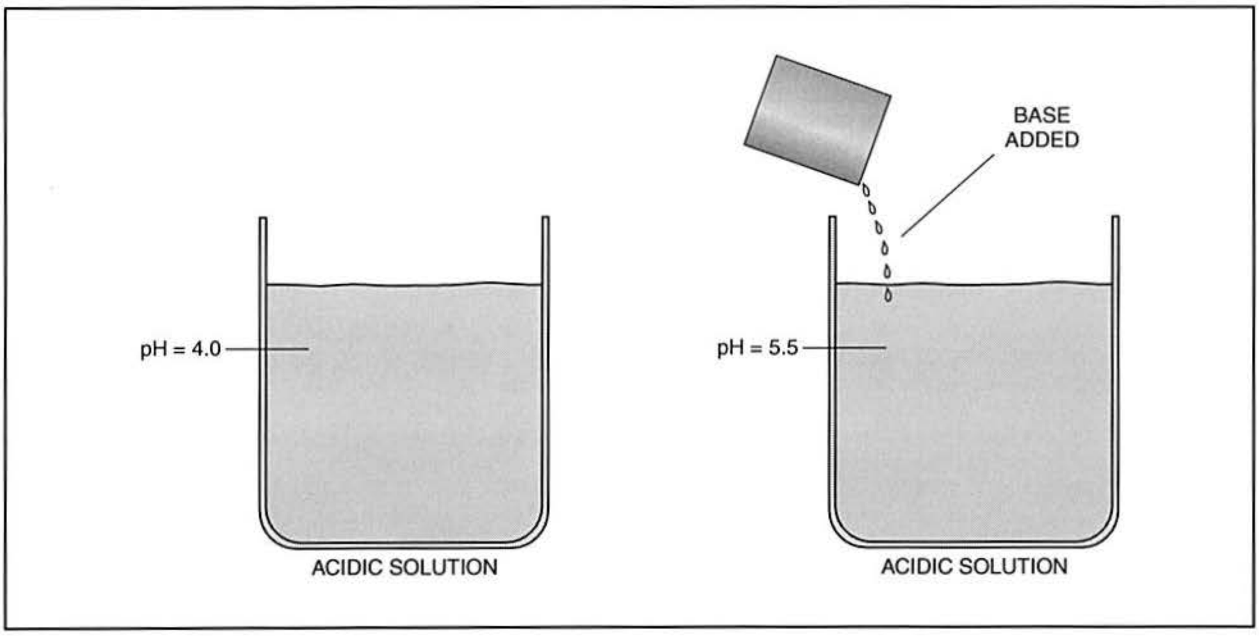

Figure 1. Adding Base to an Acidic Solution

Using titration to adjust the pH of a solution is tricky because the pH scale is not linear but is instead logarithmic. This means that when the pH of a solution changes by a factor of 1, the hydrogen ion concentration of the solution changes by a factor of 10. For example, a decrease in pH from 3 to 2 results in a times 10 increase in the hydrogen ion concentration, as shown in figure 2. Similarly, an increase in pH from 2 to 3 results in a times 10 decrease in the hydrogen ion concentration.

pH TO HYDROGEN ION H+ CONCENTRATION		
RANGE	pH	H+ CONCENTRATION (mol/L)
ACID	0	1
	1	0.1
	2	-1 0.01 +10X
	3	0.001
	4	0.0001
	5	0.00001
	6	0.0000001
NEUTRAL	7	0.00000001
BASIC/ ALKALINE	8	0.000000001
	9	0.0000000001
	10	0.00000000001
	11	0.000000000001
	12	0.0000000000001
	13	0.00000000000001
	14	0.000000000000001

Figure 2. pH vs. Hydrogen Ion Concentration

A titration curve, like the one in figure 3, shows the effects of the logarithmic scale on pH adjustments. As the pH of the solution nears the neutralization point, or more accurately the equalization point, a smaller amount of reagent is required to adjust the pH of the solution. This means that the amount of reagent required to adjust the pH of the solution by a specific amount is not consistent over the pH range. Therefore, any controller used in a pH control system must be capable of adjusting for the inconsistency.

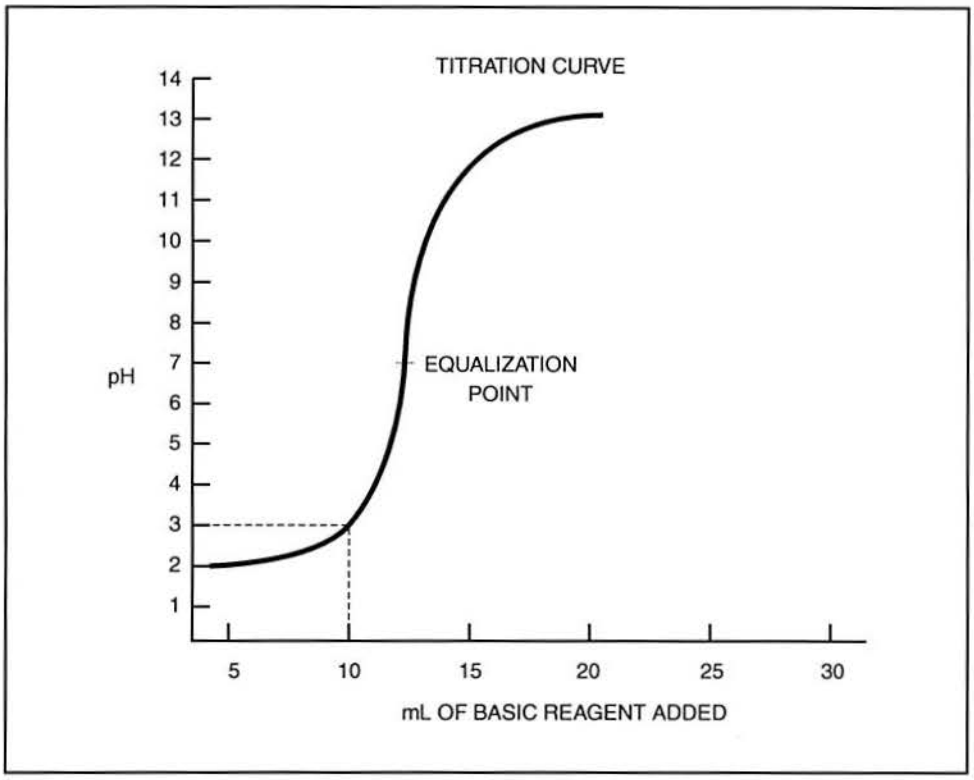

Figure 3. A Typical Titration Curve

Many pH controllers include special programs or parameters that allow the controller to adjust its output to minimize the effects of the non-linear pH scale. These special features prevent the controller from adding too much reagent, referred to as an overdose, when the solution is near the equalization point.

OBJECTIVE 2 DESCRIBE HOW MIXING IS APPLIED TO pH CONTROL SYSTEMS

Read This

The objective of a pH control system is to adjust and maintain the pH of the entire volume of a solution by adding the required amount of an acid or base. Mixing is required to make sure the pH adjustment of the entire volume is uniform. Without proper mixing, the pH adjustment only takes place in a localized portion of the solution when the reagent is added, as shown in figure 4.

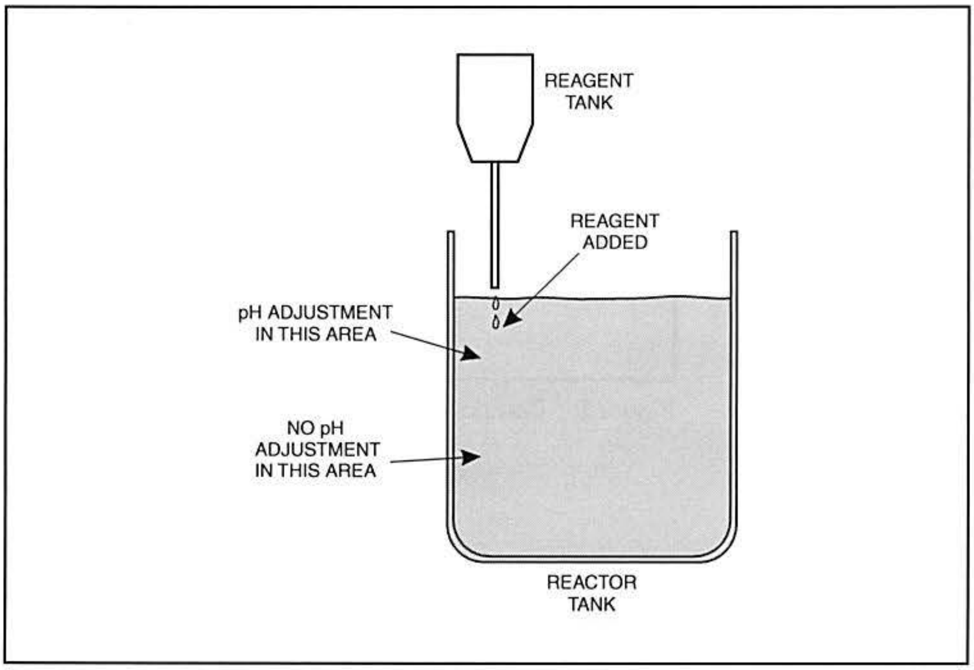

Figure 4. pH Adjustment Localized without Mixing

Mixing the solution evenly disperses the reagent throughout the entire volume of the solution, resulting in more reliable pH control. An agitator, like the one in figure 5, is frequently used to properly mix the reagent into the entire volume.

An agitator consists of a motor, a shaft, and a set of turbine blades. The motor controls the rotational speed and direction of the turbine blades. This allows the turbine blades to mix the reagent thoroughly into the solution.

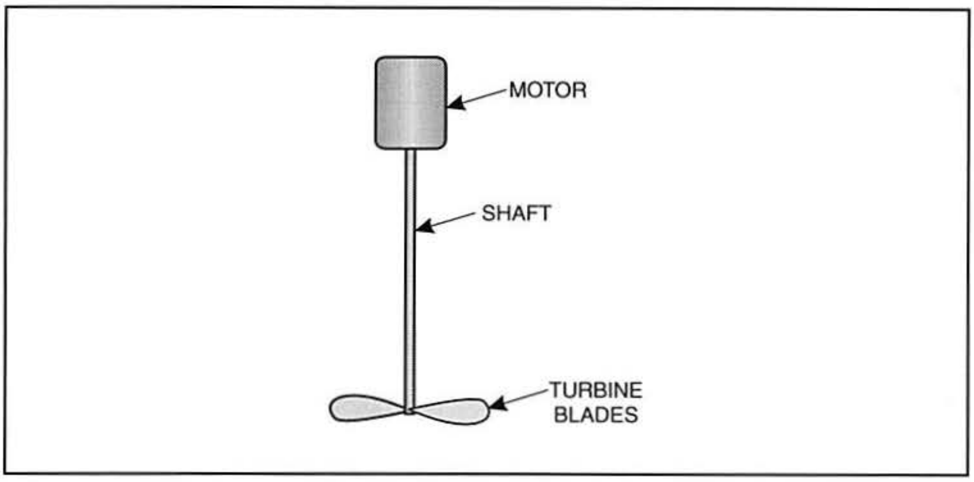

Figure 5. Components of an Agitator

Agitators used with pH control systems use pitched turbine blades that produce an axial flow pattern, as shown in figure 6. The agitator action pulls the solution down near the shaft and circulates the solution out along the bottom of the container to the walls. The solution then flows up along the walls. This pattern results in much more uniform pH levels throughout the entire volume.

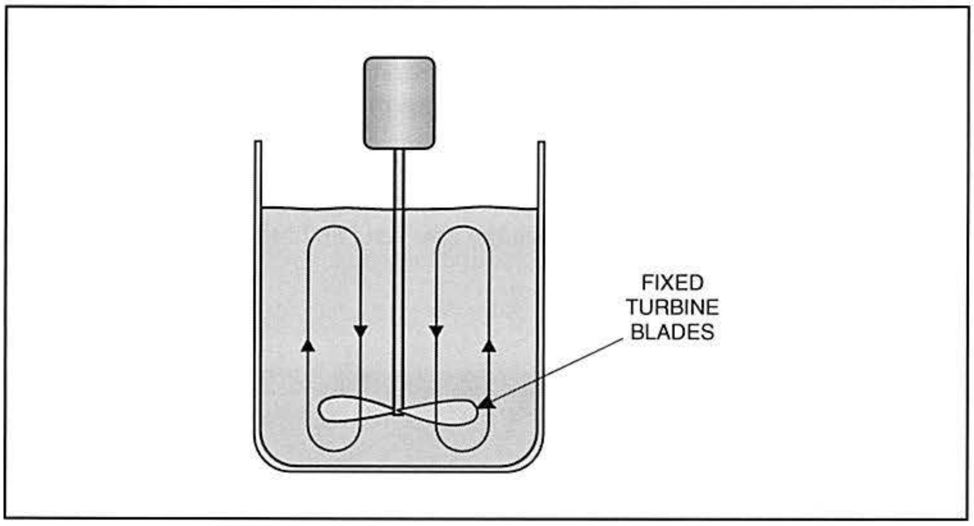

Figure 6. Axial Flow Pattern

Procedure Overview

In this procedure, you will fill the reactor tank and operate the agitator to become familiar with its operation. The agitator includes a speed control that you will use to adjust the speed of the agitator.

Do This

❑ 1. Make sure the reactor tank is filled with water to a level about mid-way between the low-level and high-level switches, shown in figure 7.

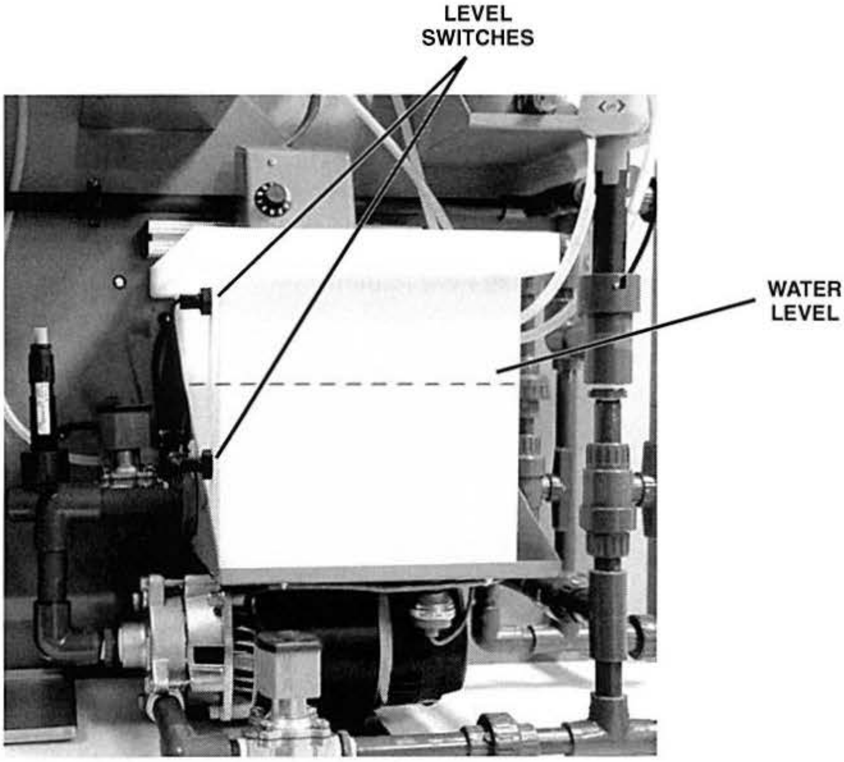

Figure 7. Water Level Between High-Level and Low-Level Switches

❑ 2. Look at the agitator turbine blades, shown in figure 8, and determine if the blades are pitched.

Agitator Blades Pitched ______________________________ (Yes/No)

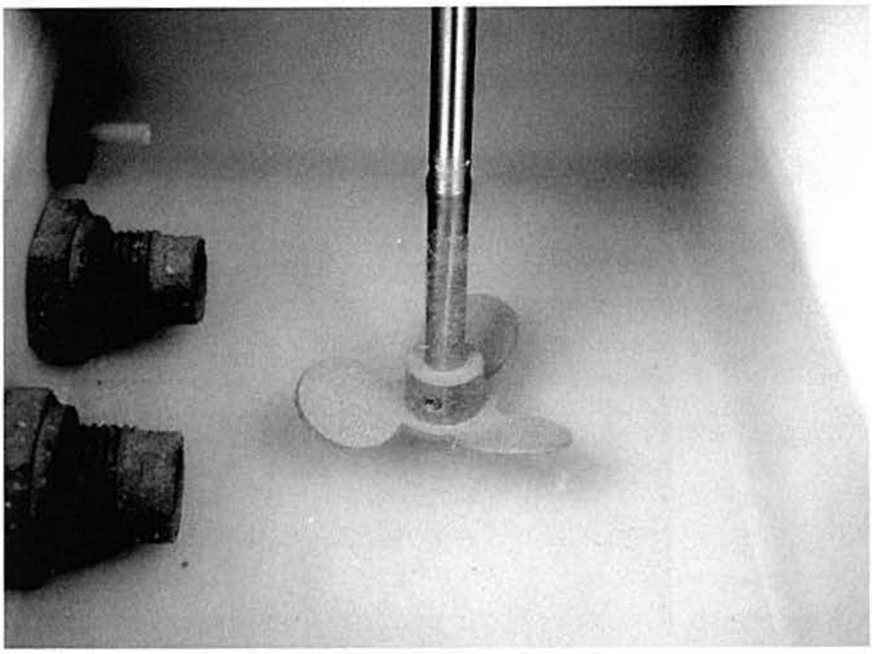

Figure 8. Agitator Blades

You should find that the blades are pitched (slightly twisted up). This should result in an axial flow pattern.

❑ 3. Make sure the **Agitator Motor** selector switch on the Operator Interface Panel is in the **OFF** position (CCW) and the **Speed Control** for the agitator shown in figure 9 is set to the minimum setting (fully counterclockwise). The agitator speed control is located just above the reactor tank.

This means that the agitator blades should not rotate when power is applied.

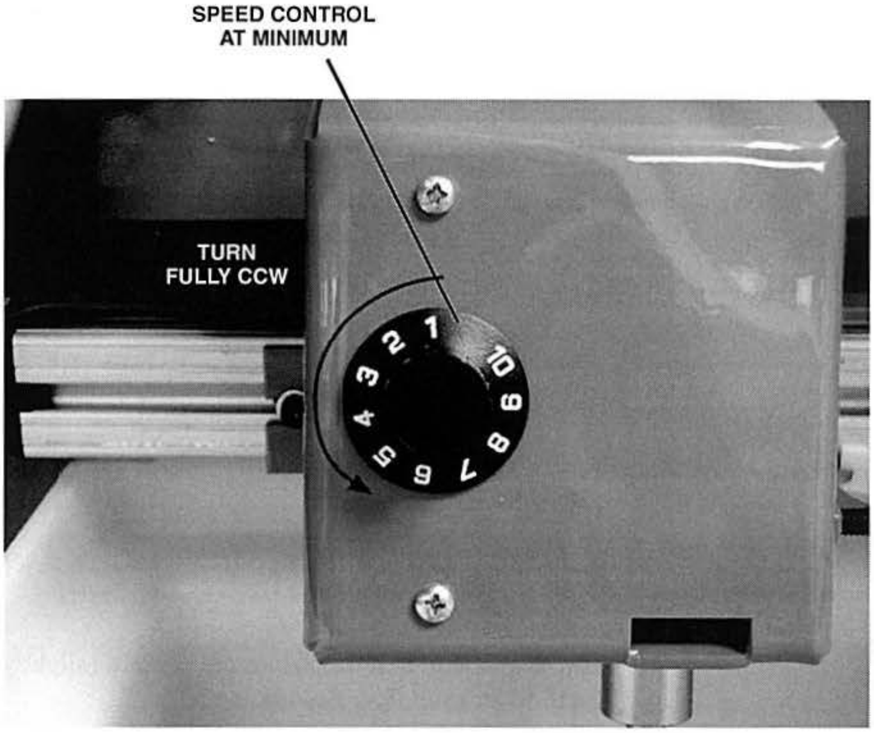

Figure 9. Agitator Speed Control Set to Minimum Setting

❑ 4. Make sure the T5554 is plugged into an electrical outlet and turn on the main circuit breaker for the T5554.

❑ 5. Apply power to the agitator motor by placing the **Agitator Motor** selector switch in the **ON** position (CW).

The indicator light above the switch should now be on.

❑ 6. Determine if the agitator blades are turning.

Agitator Blades Turning? ________________________________ (Yes/No)

You should find that even though power has been applied to the agitator motor, the blades are not turning because the speed control is set to the minimum setting (fully CCW).

❑ 7. Slowly turn the agitator **Speed Control** clockwise and observe the speed of the agitator blades.

Does the agitator blade speed increase? ____________________ (Yes/No)

You should find that the blade speed increases as the agitator speed control is turned clockwise. As the blade speed increases, the mixing action becomes more vigorous.

In addition, you should notice that the flow pattern is axial, indicated by the vortex near the agitator shaft, as shown in figure 10. The vortex is created because the pitched blades are pulling the water down near the shaft.

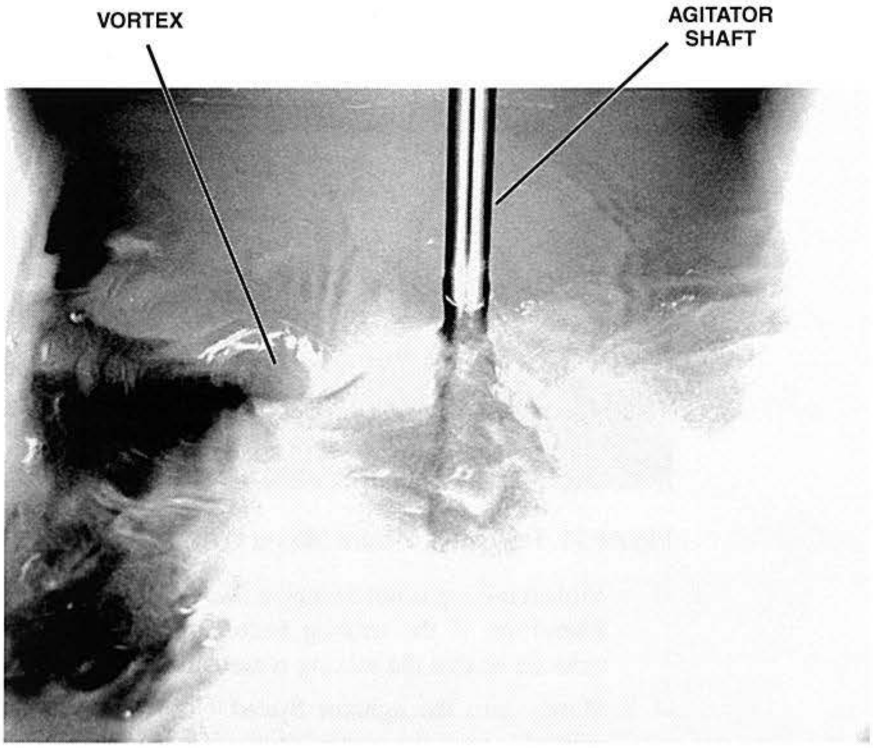

Figure 10. Vortex Created by Axial Flow

As the blade speed continues to increase, the mixing action becomes even more vigorous, approaching the point of being violent (splashing water over the sides of tank), as figure 11 shows.

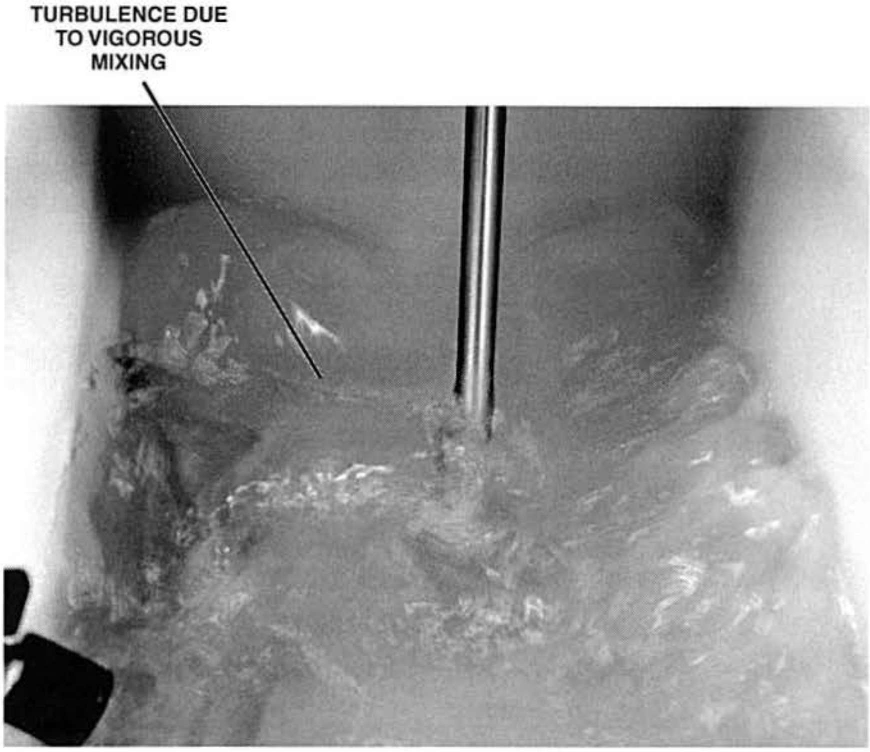

Figure 11. Results of Violent Mixing in the Reactor Tank

Violent mixing is not desirable because it can cause errors in pH measurement. Therefore, if the mixing becomes violent, the agitator speed should be reduced so that the mixing remains vigorous but not violent.

❑ 8. Slowly turn the agitator **Speed Control** counterclockwise until the speed control is near the center, somewhere between **5** and **6**.

This speed setting should produce a vigorous mixing speed that is not violent. This is the proper speed setting to use when controlling the pH of the solution in the reactor tank.

❑ 9. Slowly turn the agitator **Speed Control** fully counterclockwise.

This should cause the agitator blades to stop rotating.

❑ 10. Place the **Agitator Motor** selector switch in the **OFF** position (CCW).

❑ 11. Turn off the main circuit breaker for the T5554.

SEGMENT 2

pH BATCH PROCESSING

OBJECTIVE 3 DESCRIBE THE FUNCTION OF pH BATCH PROCESSING AND GIVE AN APPLICATION

Read This

Batch processing is one type of process used to adjust the pH of a solution. A batch processing system collects a specific volume of solution in a container, as shown in figure 12, and adjusts the pH before releasing the solution. The pH electrode is mounted in the collection container to measure pH.

Typically, batch processing does not control pH at a specific setting. Instead, pH is adjusted so that it is within a specified safe range (i.e. 6-8 pH).

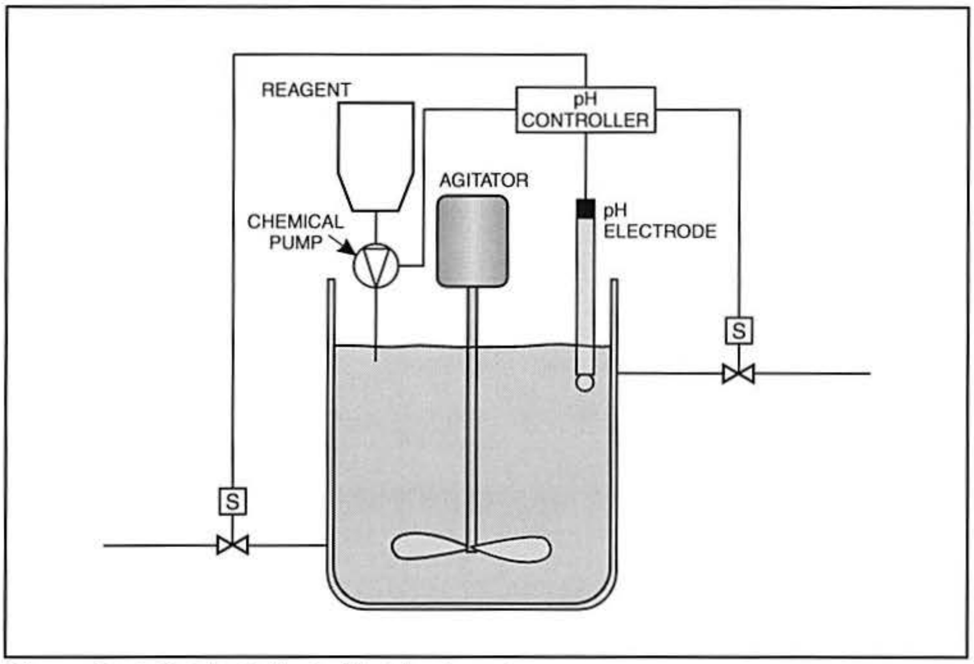

Figure 12. A Batch Collected for Treatment

SEGMENT 1

SELF REVIEW

1. _______________ is the process of creating a chemical reaction between two solutions by the controlled addition of one solution to another.

2. The pH scale is a(n) ____________________ scale.

3. As the pH of the solution nears the _______________ point, less reagent is required to adjust the pH of the solution.

4. _______________ evenly disperses the reagent throughout the entire volume of the solution, resulting in more reliable pH control.

5. An agitator consists of a motor, a shaft, and a set of ____________________.

6. Agitators used with pH control systems use pitched turbine blades that produce an __________ flow pattern.

Batch processing is used to adjust pH in applications where:

- Incoming flow is discharged in large batches.
- There are large fluctuations in incoming flow.
- Incoming flow chemistry is characterized by sizable pH swings.
- Incoming flow contains high concentration of acids or bases.
- Outgoing flow must be held within a range or band.

Batch processing is used extensively for wastewater treatment because the pH of the wastewater must be within the safe range before being released back into the environment.

Figure 13. Wastewater Treatment

OBJECTIVE 4 DESCRIBE THE OPERATION OF AN ON/OFF BATCH PROCESSING SYSTEM

Read This

An on/off batch processing system is a simple type of batch control system that uses a combination of discrete (on/off) control for the level in the container and closed-loop control for the pH.

Both the influent (input into the tank) and effluent (output from the tank) flows are controlled using solenoid valves, as shown in figure 14. This provides on/off control of the level in the tank.

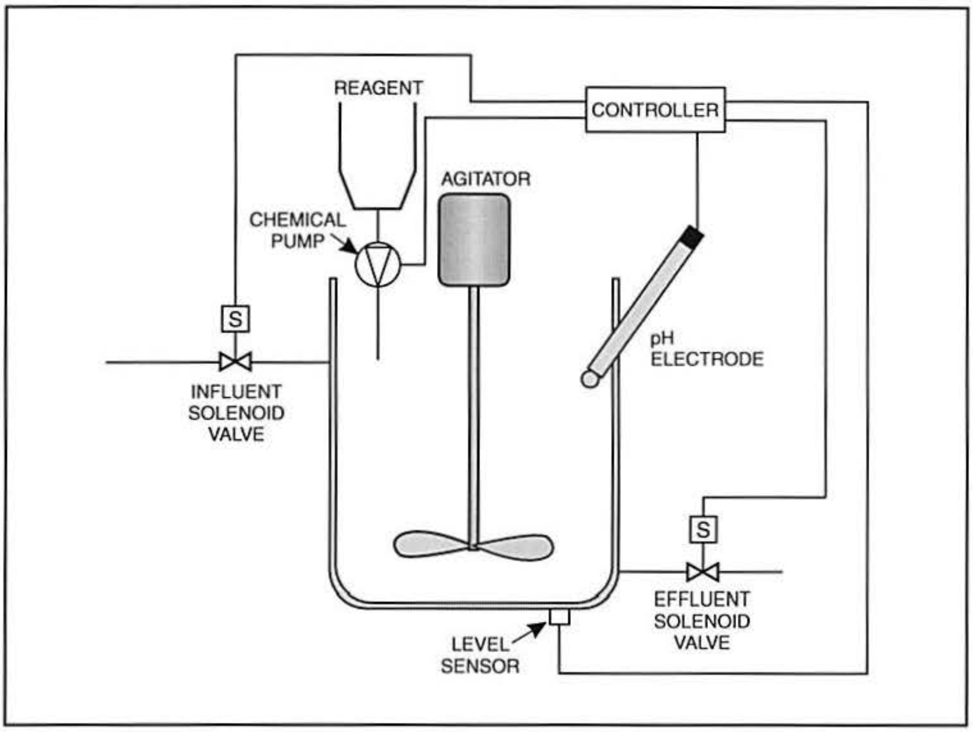

Figure 14. On/Off Batch Processing System

To begin the process, the controller causes the effluent solenoid valve to close and the influent solenoid valve to open. This allows the container to fill. A level sensor in the container provides level feedback to the controller. When the container is filled to the desired level, the controller closes the influent solenoid valve to stop the influent flow, as figure 15 shows.

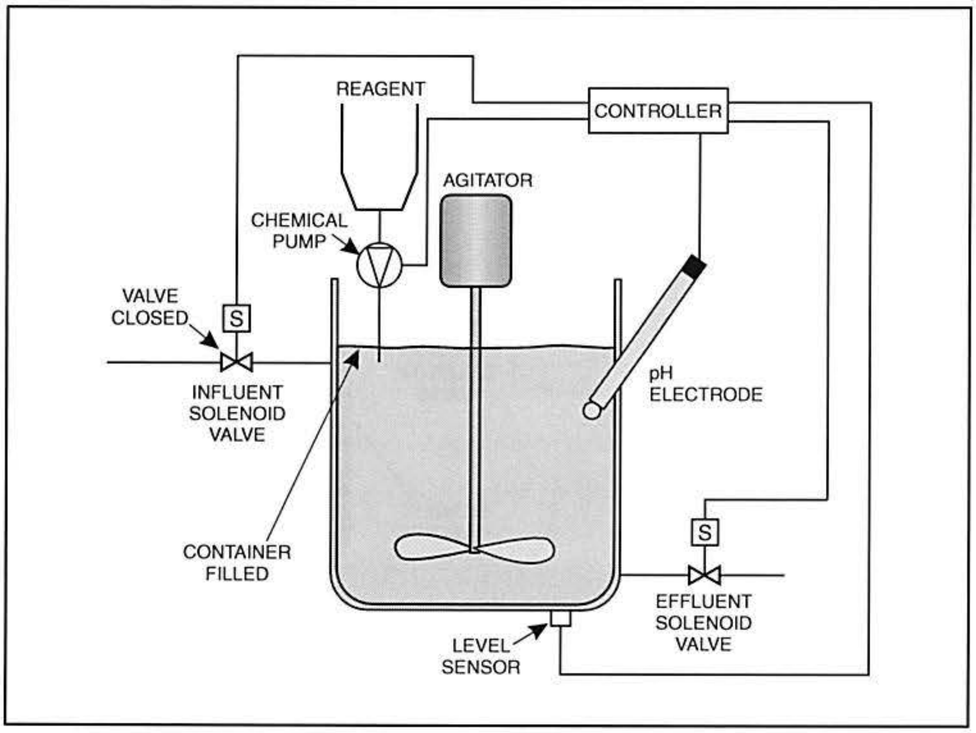

Figure 15. Container Filled and Influent Solenoid Valve Closed

Once the container is filled, agitation begins. The controller monitors the pH level in the container via the pH sensor and controls the output to the chemical pump, shown in figure 16, to inject the amount of reagent needed to adjust the pH to the required value.

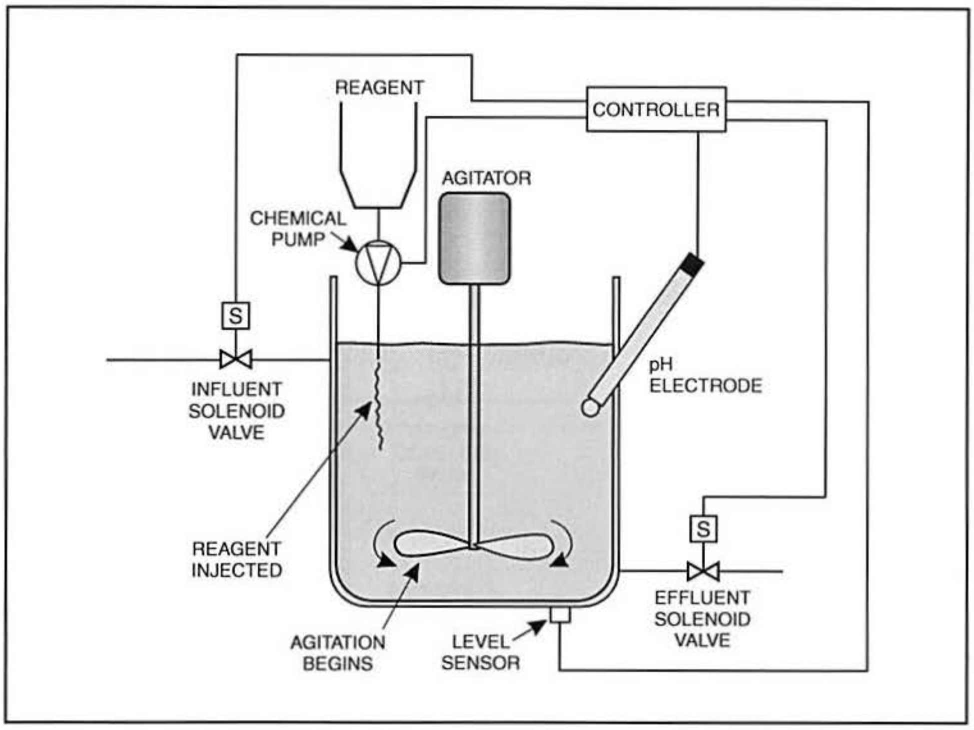

Figure 16. Controller Monitors and Adjusts pH using the Chemical Pump

When the pH reaches the desired value, the controller causes the chemical pump to stop injecting the reagent. Next, agitation stops and the controller opens the effluent solenoid valve. This allows the treated solution to be released from the container, as figure 17 shows. When the container is empty, the controller closes the effluent solenoid valve, opens the influent solenoid valve, and the process is repeated as necessary.

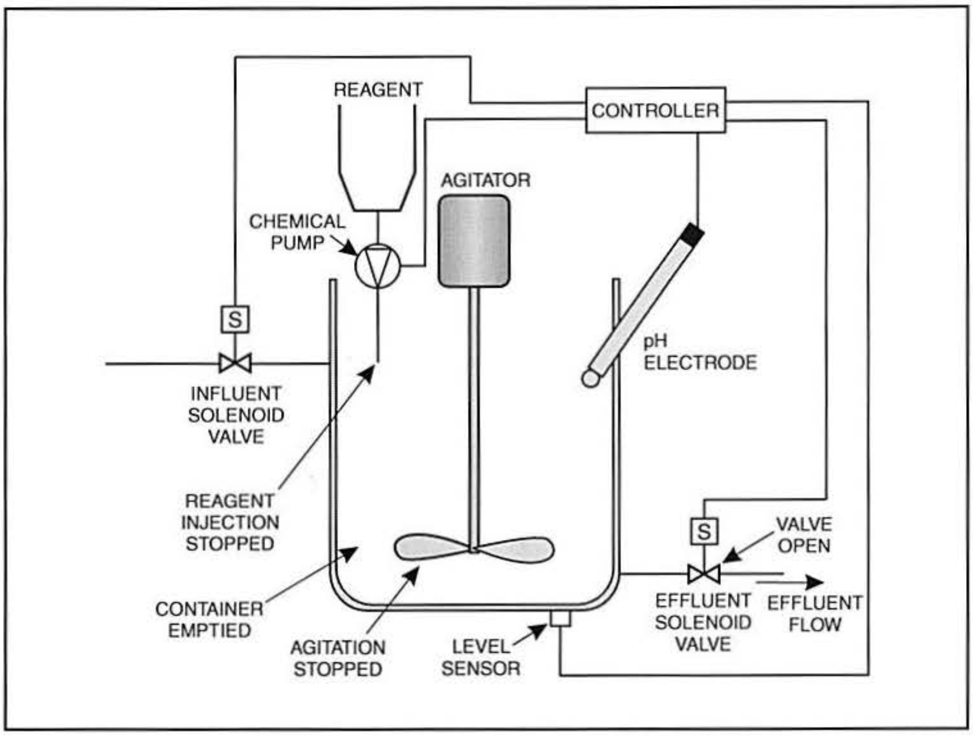

Figure 17. Treated Solution Released by Opening the Effluent Solenoid Valve

OBJECTIVE 5 DESCRIBE HOW TO CONFIGURE A HONEYWELL UDC 3500 FOR ON/OFF BATCH PROCESSING

Read This

A Honeywell UDC 3500 with two analog inputs and at least two relay outputs can be configured for on/off batch control. One analog input measures the level in the tank and the other analog input measures the pH of the batch.

The relays, which provide discrete control of the level, are connected to the influent and effluent solenoid valves, as shown in figure 18.

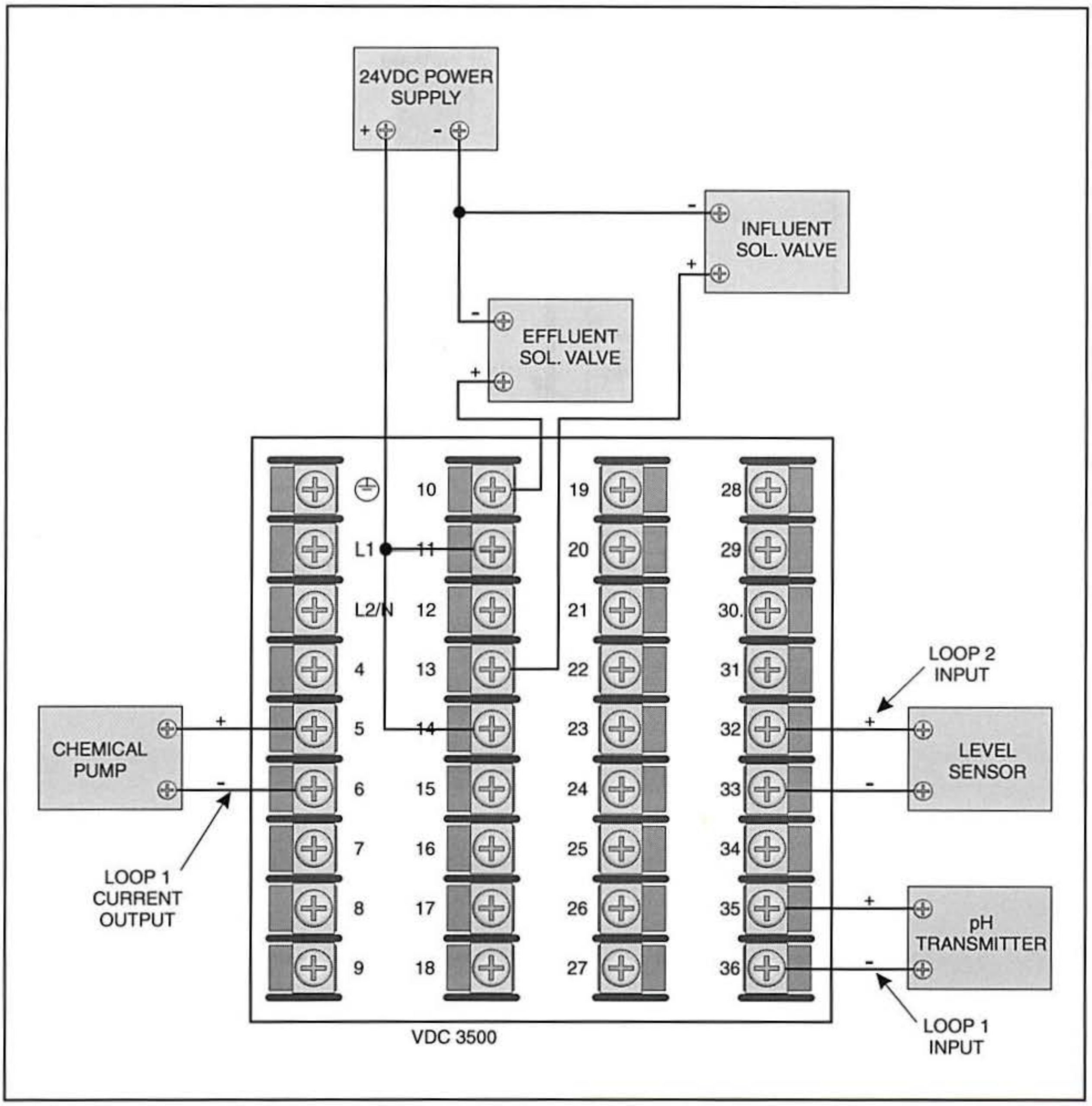

Figure 18. On/Off Batch Processing Connections for UDC 3500

Once the proper connections are made, the controller can be configured using the following steps:

Step 1: Set the required closed-loop parameters for pH control

Step 2: Set the required parameters for level control

Step 3: Set the setpoint for pH control

Step 4: Place the controller in the automatic mode to control the process

Step 1: Set the required closed-loop parameters for pH control

The controller will control the pH using automatic closed loop control. Since pH is the main process variable to be controlled, Loop 1 is used for pH. The parameters to be set include those listed in the table of figure 19.

Some of the parameters are not directly related to the pH control loop, but are needed to enable the second control loop (Loop 2) for level control. Other parameters may need to be checked and changed as well, but these are the parameters directly related to pH control.

LOOP 1 PARAMETERS FOR CLOSED LOOP PH CONTROL		
PARAMETER GROUP	PARAMETERS	DESCRIPTION
LOOP 1 TUNING	GAIN RATE MIN RSET MIN	The tuning parameters (LOOP1 TUNING) are set to achieve the desired degree of control. This involves setting the proportional (GAIN), integral (RSET MIN) and derivative (RATE MIN) to the desired values. For pH control, a combination of proportional and integral action is usually sufficient.
ALGORITHM	CONT ALG PIDLOOPS	The algorithms parameters (ALGORITHM) are set to determine the method of control. For example, CONT ALG is set to PIDA if automatic control is desired. Additionally, PIDLOOPS must be set to 2 LOOPS enabling loop 2 so it can be used for level control.
OUTPUT	OUT ALG C1 RANGE	The output parameters (OUTPUT) are set to determine the output from the controller. For example, OUT ALG is set to CURRENT and C1 RANGE is set to 4-20 to produce a 4-20mA analog output.
INPUT 1	IN1 TYPE XMITTER1 IN1 HIGH IN1 LOW	The input parameters (INPUT 1) are set to determine the type of input signal and what it represents. For example, IN1 TYPE may be set to 4-20mA, XMITTER 1 to linear, IN1 HIGH to 14, and IN1 LOW to 0 to scale the display to the pH scale (0-14).
CONTROL	PV SOURC SP HiLIM SP LoLIM ACTION I Hi LIM I Lo LIM	The control parameters (CONTROL) are set to determine how the controller actually controls the process. PV SOURC identifies which input represents the process variable, INPUT 1 for example. SP HiLIM and SP LoLIM are set to establish the high and low limits for the setpoint. The setpoint cannot be changed to a value outside these limits. ACTION is set to DIRECT or REVERSE depending on the type of valve or pump used. I Hi LIM and I Lo LIM are set to establish the high and low limits for the input current. These settings are set as a percentage of the maximum current value.
ALARMS	A1S1 TYPE A1S1 VAL A1S1 H L ALHYST1	The alarm parameters (ALARMS) are set so that one of the output relays can control the effluent solenoid valve. For example, A1S1TYPE must be set to identify the signal that triggers the alarm, INPUT 1 for example. A1S1VAL must be set to the desired process variable value to cause the output relay to open the effluent solenoid valve. A1S1 H L is set to establish whether the alarm condition is a high alarm or a low alarm. Finally, ALHYST1 is set to establish the value at which the alarm is reset, closing the effluent solenoid valve.

Figure 19. Parameters for pH Control (Loop 1)

Step 2: Set the required parameters for level control

The controller controls the level in the container using on/off control. The level in the container is measured by a level sensor that provides an analog signal to the controller. The parameters to be set include those listed in the table of figure 20.

Since the level will be controlled using the on/off method, there are no tuning parameters for Loop 2. In addition, the setting of the CONT2ALG parameter does not matter since the output relays are used to control the solenoid valves.

LOOP 1 PARAMETERS FOR CLOSED LOOP PH CONTROL		
PARAMETER GROUP	**PARAMETERS**	**DESCRIPTION**
OUTPUT	OUT2 ALG	The only parameter that needs to be changed in the output parameters is the output algorithm parameter for Loop 2 (OUT2 ALG). It should be set to NONE since the analog output of Loop 2 is not used for control.
INPUT 1	IN2 TYPE XMITTER2 IN2 HIGH IN2 LOW	IN2 TYPE should be set for the analog signal (1-5V, 4-20mA, etc.) and XMITTER2 to linear. IN2 HIGH and IN2 LOW should be set to the desired values.
CONTROL	PV2 SOURC SP HiLIM SP LoLIM ACTION I Hi LIM I Lo LIM	The control parameters for Loop 2 (CONTROL2) are set to the desired values in a manner similar to the parameters for Loop 1. One difference will be the setting PV2 SOURC for the input to which the level sensor is connected, for example INPUT 2.
ALARMS	A2S1TYPE A2S1VAL A2S1 H L ALHYST2	The alarm parameters (ALARMS) are set so that another output can control the influent solenoid valve. For example, A2S1TYPE must be set to identify the signal that triggers the alarm, INPUT 2 for example. A2S1VAL must be set to the desired process variable value to cause the output relay to open the influent solenoid valve. A2S1 H L is set to establish whether the alarm condition is a high alarm or a low alarm. Finally, ALHYST2 is set to establish the value at which the alarm is reset, closing the influent solenoid valve.

Figure 20. Parameters for Level Control (Loop 2)

Step 3: Set the setpoint for pH control

Once all required parameters have been set, the next step is to exit the setup mode using the Lower Display key and enter the setpoint for the pH control loop. The Lower Display key then toggles between the setpoint (SP), output (OUT) and deviation (DEV). When SP is displayed, the up ▲ and down ▼ arrow keys change the value for the selected setpoint.

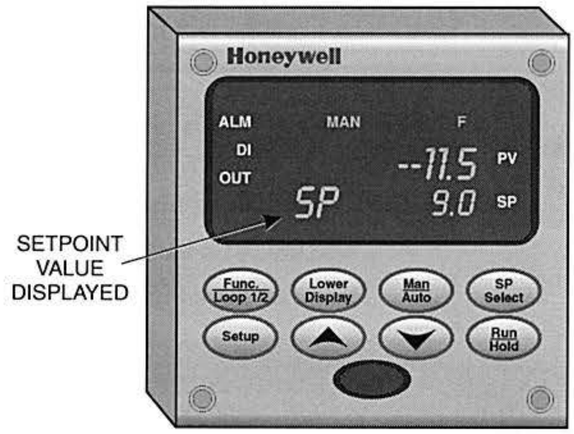

Figure 21. SP Displayed

Step 4: Place the controller in the automatic mode to control the process

Once all of the required parameters are set, the controller is placed in the automatic mode by exiting the setup mode and pressing the Man/Auto key. This allows the controller to automatically control the batch process.

Procedure Overview

In this procedure, you will program the Honeywell UDC 3500 controller to adjust the pH in the reactor tank. You will manually control the opening and closing of the inlet and outlet solenoid valves. This will allow you to fill the tank and release the batch once the batch has been treated.

- [ ] 1. If the reactor tank is filled, perform the following substeps to empty the tank. If the tank is empty, proceed to step 2.

  The reactor tank needs to be empty to begin this procedure.

  A. Close the drain hand valve shown in figure 22.

  When the valve is closed, the handle will be perpendicular to the piping.

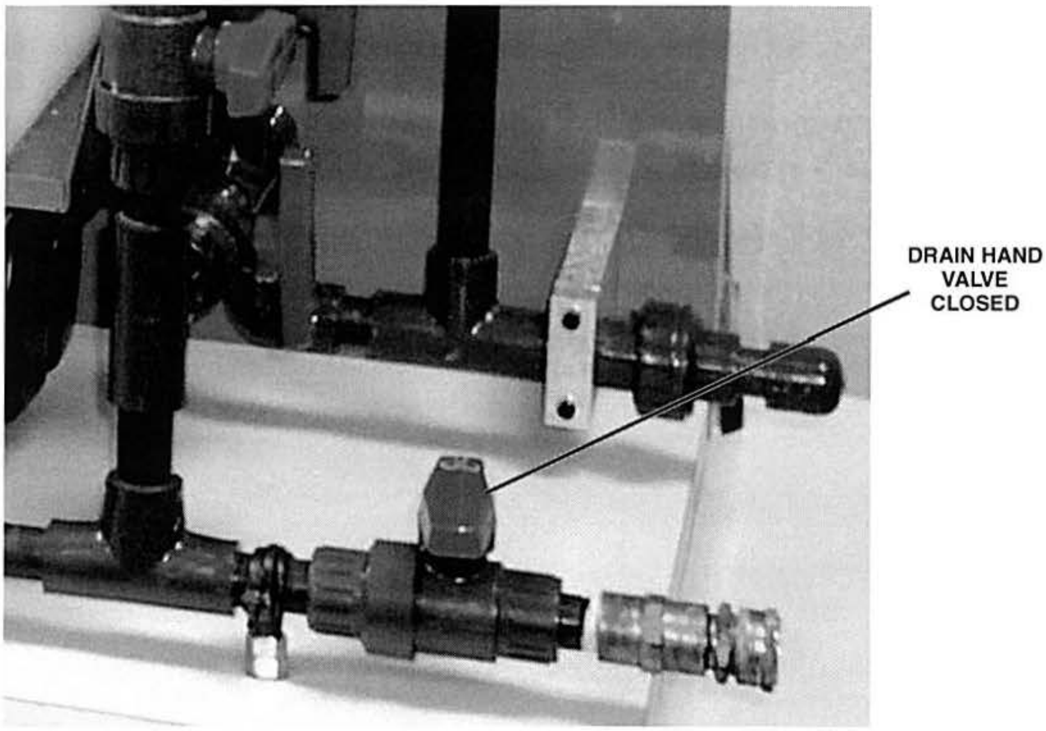

Figure 22. Drain Hand Valve

B. Loosen and remove the drain cap shown in figure 23.

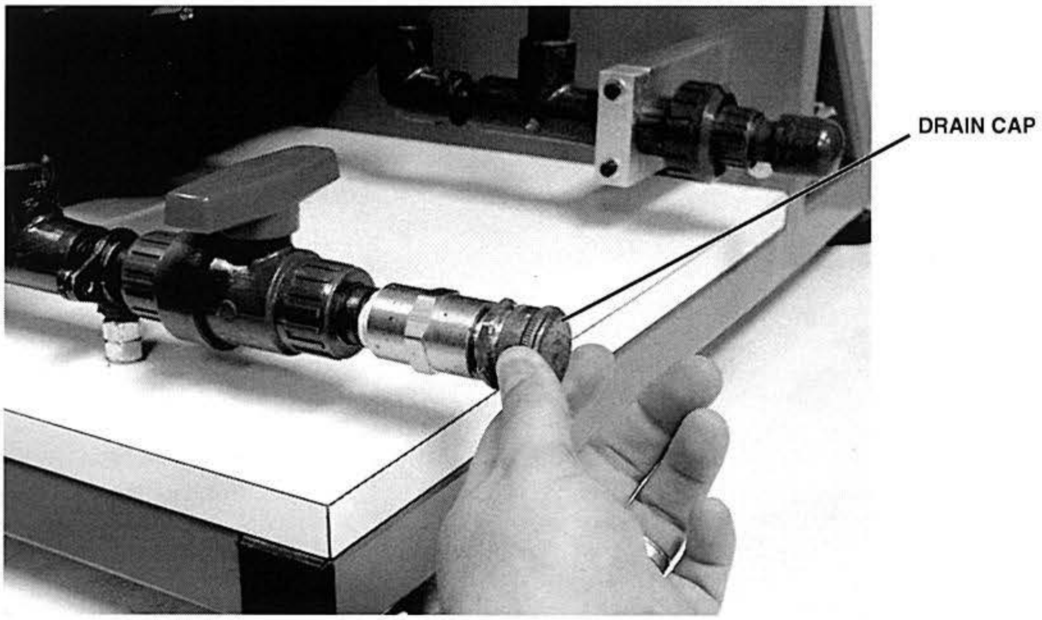

Figure 23. Drain Cap

C. Locate a garden hose, similar to the one in figure 24.

You will connect one end of the hose to the drain connection on the T5554 and place the other end of the hose in a sink or over a floor drain. This will allow you to drain the contents of the reactor tank.

Figure 24. Typical Garden Hose

D. Connect one end of the garden hose to the drain connection on the T5554, as shown in figure 25.

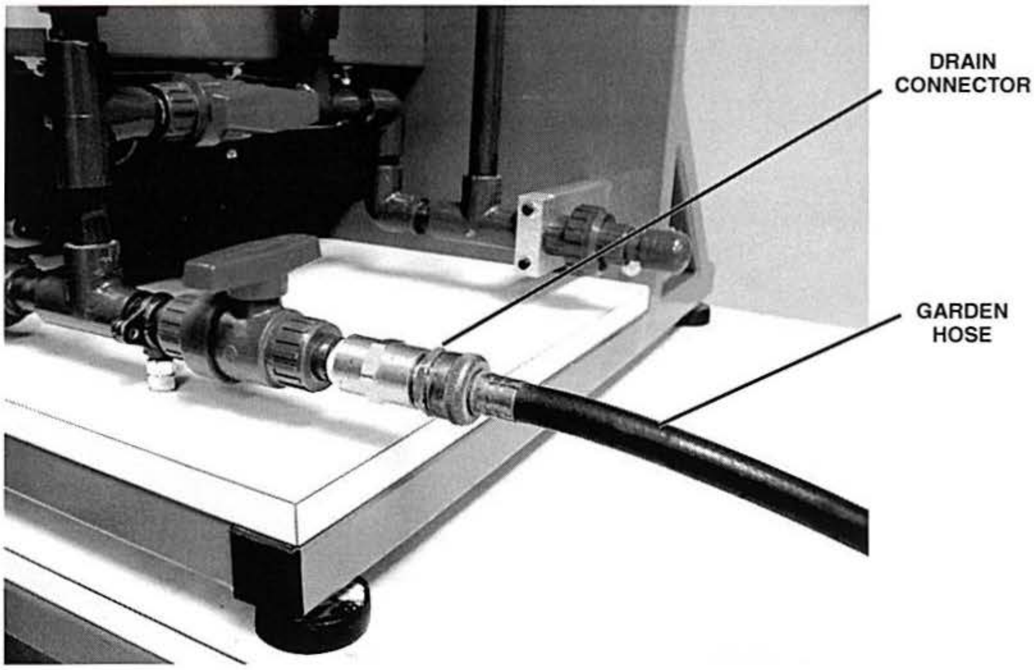

Figure 25. Garden Hose Connected to T5554 Drain Connection

E. Place the other end of the hose in a sink or over a floor drain.

If you use a sink, make sure it is lower than the drain of the T5554. This allows the tank to drain via gravity.

F. Open the drain hand valve.

The handle should now be parallel to the piping.

The contents of the reactor tank should begin draining. The solenoid valve on the output of the reactor tank is normally open. Therefore, it does not need to be energized.

G. Once you have drained all of the water you can from the reactor tank, close the drain hand valve.

There will still be some water left in the bottom of the tank. This can be removed using a shop vacuum or a sponge.

NOTE

Notice This

If your T5554 includes the optional pressure sensor in the bottom of the reactor tank, be careful not to place the shop vacuum hose over the opening for the sensor as it could damage the sensor.

H. Remove any remaining water in the reactor tank using whatever means is available (i.e. sponge or shop vacuum).

❑ 2. Perform the following substeps to make sure the T5554 Analytical Process Control System is set up as shown in figure 26.

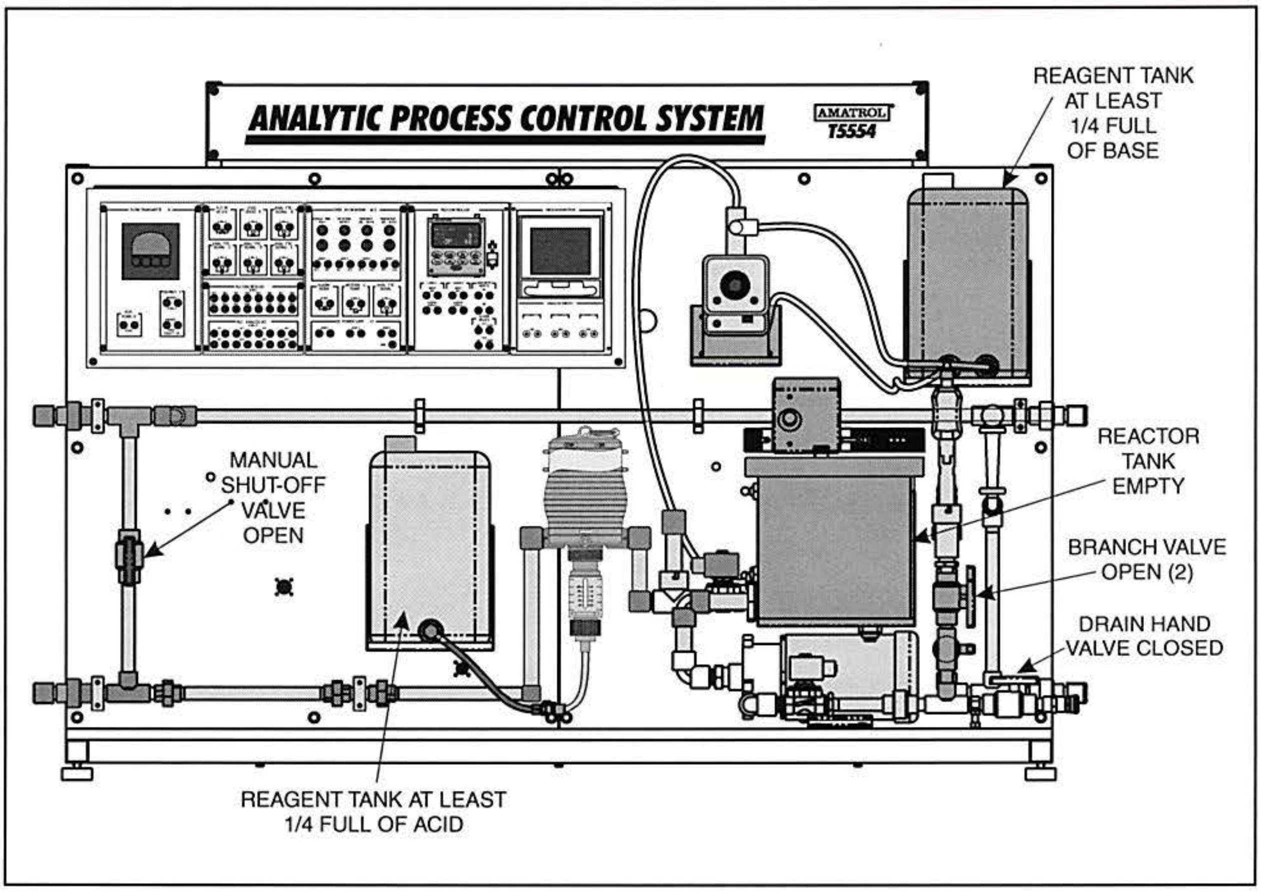

Figure 26. T5554 Setup

A. Make sure the reactor tank is empty.

B. Make sure the drain shutoff valve is closed (shut).

C. Make sure the main shutoff valve and the two branch valves are open.

D. Make sure the bypass valve is closed.

E. Make sure the reagent tanks are filled at least 1/4 full.

If reagent needs to be added, ask the instructor for the reagent solutions. If the solutions need to be mixed, the instructor will mix them.

For this procedure, the pH electrode must be located in the reactor tank. There is a mounting bracket for the electrode on the right side of the agitator speed control enclosure, as shown in figure 27. Before the electrode is placed here, it must be removed from it current location and calibrated.

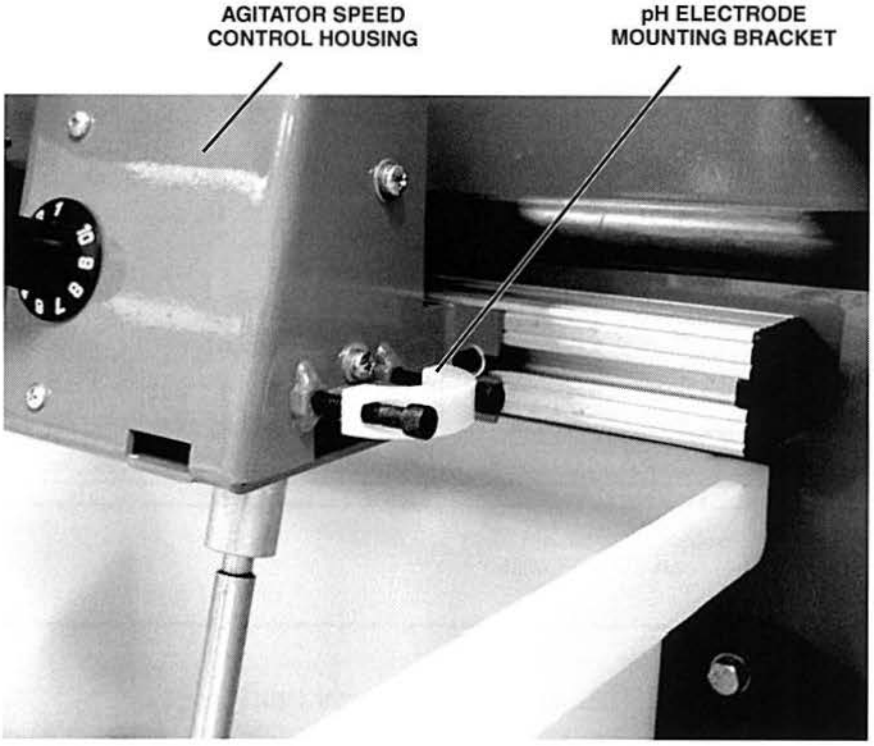

Figure 27. Mounting Bracket for Holding the pH Electrode in the Tank

- ❑ 3. Perform the following substeps to remove the pH electrode from the process piping on the right side of the reactor tank.
  - A. Open the branch valve directly under the electrode fitting and shut the other branch valve, as shown in figure 28.

    Labels on the handles of the valves indicate the open (O) and shut (S) positions.

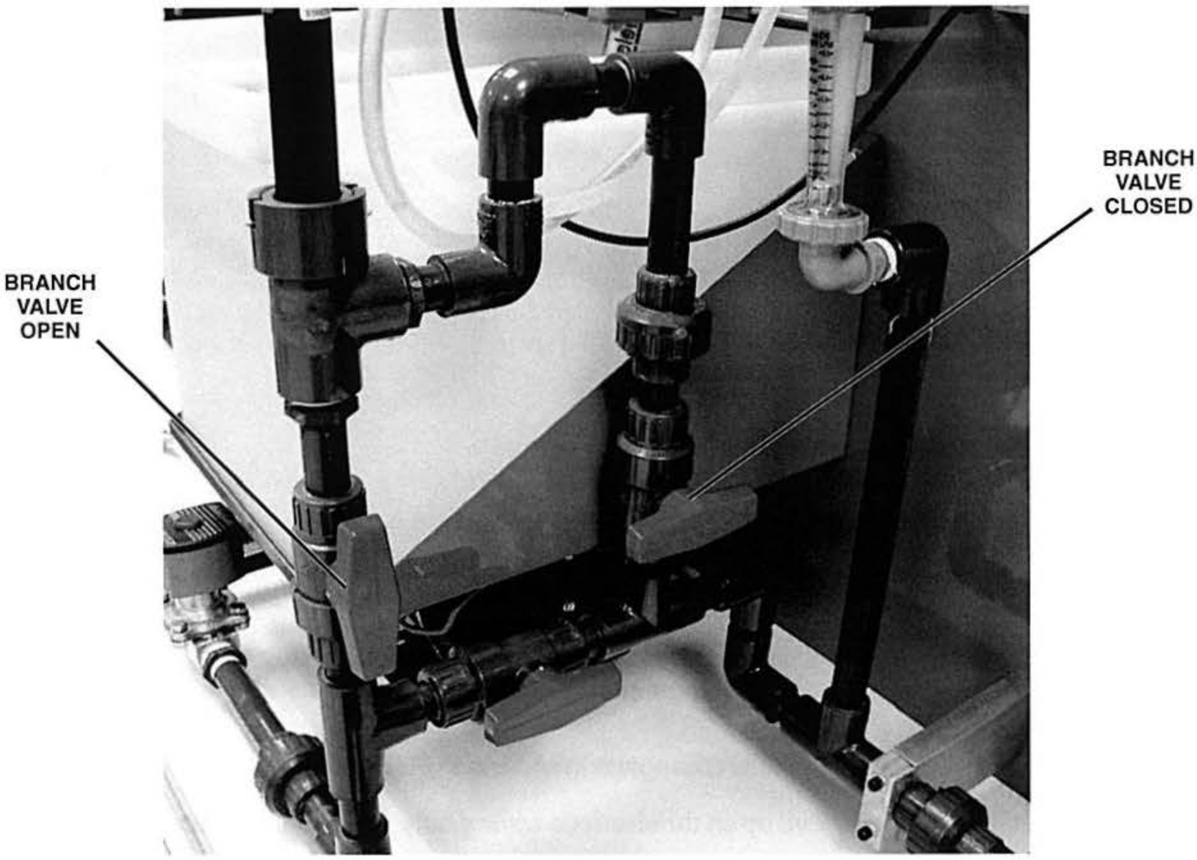

Figure 28. One Branch Valve Open and the Other Closed

B. Grasp the housing of the electrode and turn it counterclockwise until the studs on the electrode housing are disengaged from the slots in the fitting, as shown in figure 29.

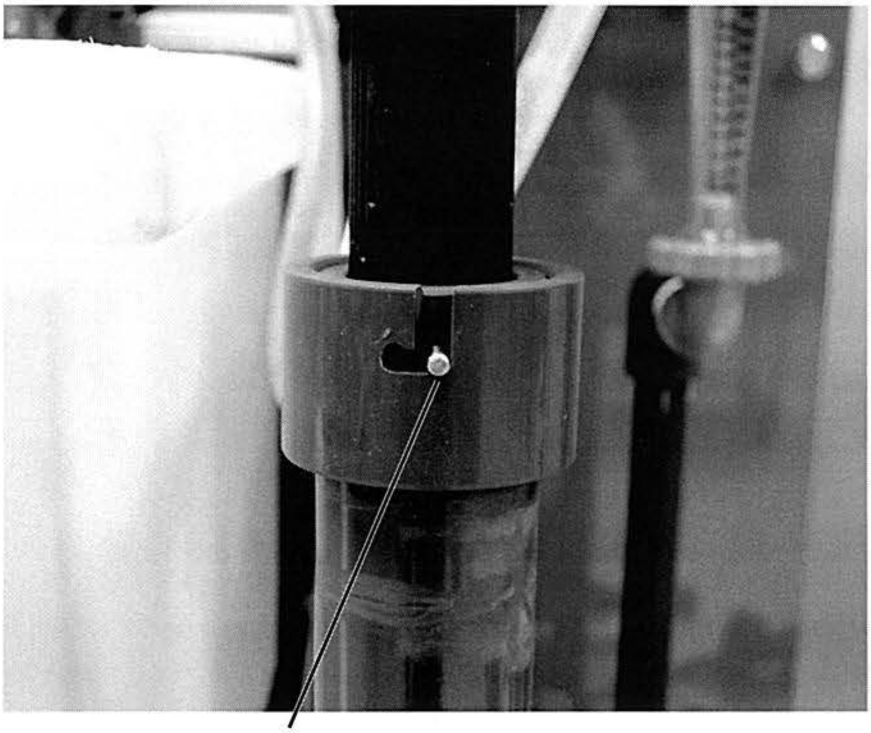

Figure 29. Studs Disengage from Slots in Fitting

C. Pull up on the electrode while gently rocking the electrode back and forth.

   The electrode should slowly come out of the fitting. If you encounter strong resistance, check the condition of the branch valves and make sure the one under the electrode fitting is open. Strong resistance is an indication of back pressure.

   Once the electrode is removed from the piping, you will be able to calibrate it.

D. Gently lay the electrode aside for the moment with the cable still attached.

E. Locate the fitting plug and insert it into the open fitting. Then close both branch valves.

❑ 4. Perform the following substeps to calibrate the pH electrode.

A. Connect the circuit shown in figure 30.

This connects the pH transmitter to 24 VDC.

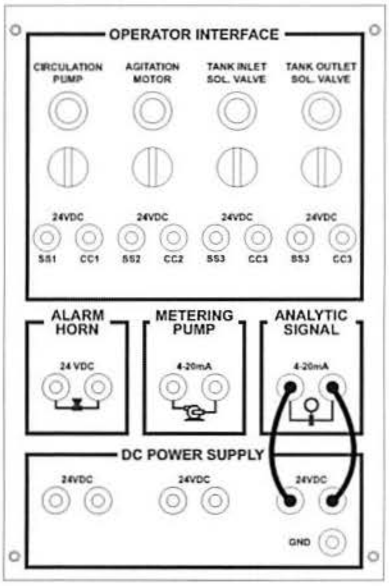

Figure 30. Connecting Transmitter to 24 VDC

B. Turn on the main power circuit breaker for the T5554.

This will provide power to the pH transmitter connected to the pH electrode.

C. Locate the buffer solutions (pH of 7 and 10).

The 7 pH buffer solution is typically green in color and the 10 pH buffer solution is typically blue in color. The other common buffer solution (4 pH) is typically pink.

D. Locate and clean a beaker or container with distilled water. Dry the beaker before adding a buffer solution.

E. Clean the sensing end of the electrode with distilled water and dab dry.

F. Pour about 2 inches of the 7 pH buffer solution into the container, as shown in figure 31.

This should be enough buffer solution to completely submerge the sensing end of the electrode.

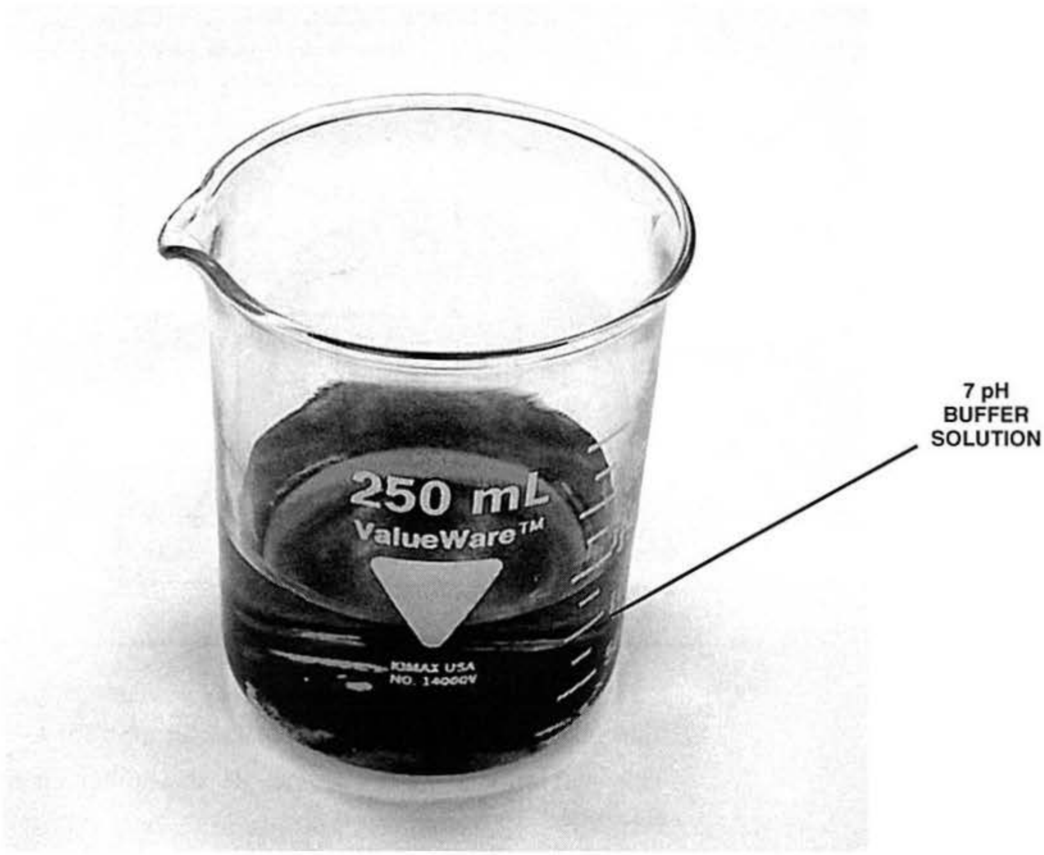

Figure 31.2 Inches of 7 pH Buffer Solution in a Container

G. Gently place the sensing end of the electrode into the buffer solution in the container. Make sure sensing end is completely submerged. If not, add more of the buffer solution.

You will need to hold the electrode/sensor module assembly with your hand.

CAUTION

Be careful not to push the sensing end of the electrode into the bottom of the container. This could damage the electrode.

H. Wait one minute for the reading on the transmitter display to stabilize.

I. With your free hand, press and hold the **CAL1** key on the sensor module, shown in figure 32, until the display changes from the pH reading to CAL1.

This sets the module to the zero calibration mode.

CAL1 KEY

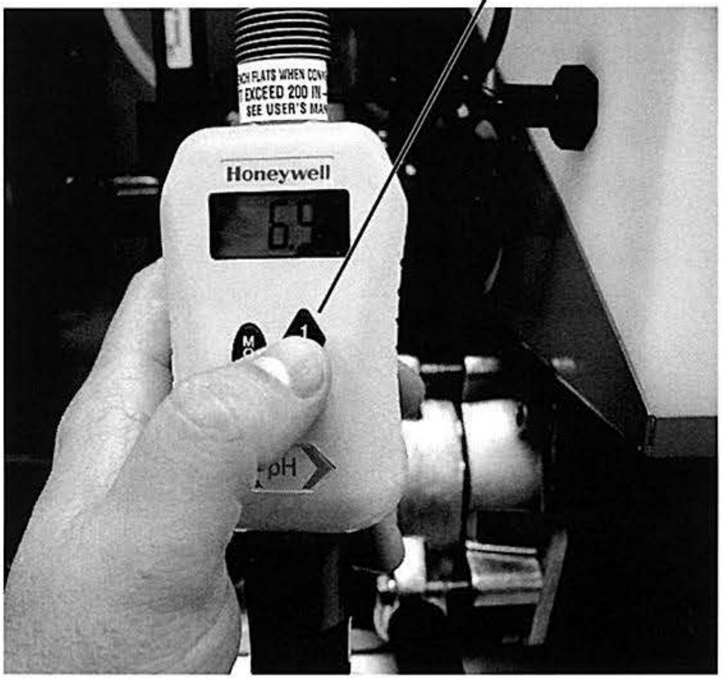

Figure 32. The CAL1 Key

J. Press the **CAL1** key again for 1 second.

This causes SCAL to briefly appear on the display, followed by the buffer pH value.

K. If the displayed value is not 7.0, use the **CAL1** and **CAL2** keys to adjust the value up or down until it reads **7.0**.

While you are adjusting the value, you should notice that the value on the display blinks to indicate that the value can be adjusted. Once the value is 7.0, the display should continue to blink until you accept the setting for the zero calibration.

L. Momentarily press the **MODE** key to accept the setting for zero calibration.

The module should return to the Online mode, with the pH value of the buffer solution on the display, as shown in figure 33.

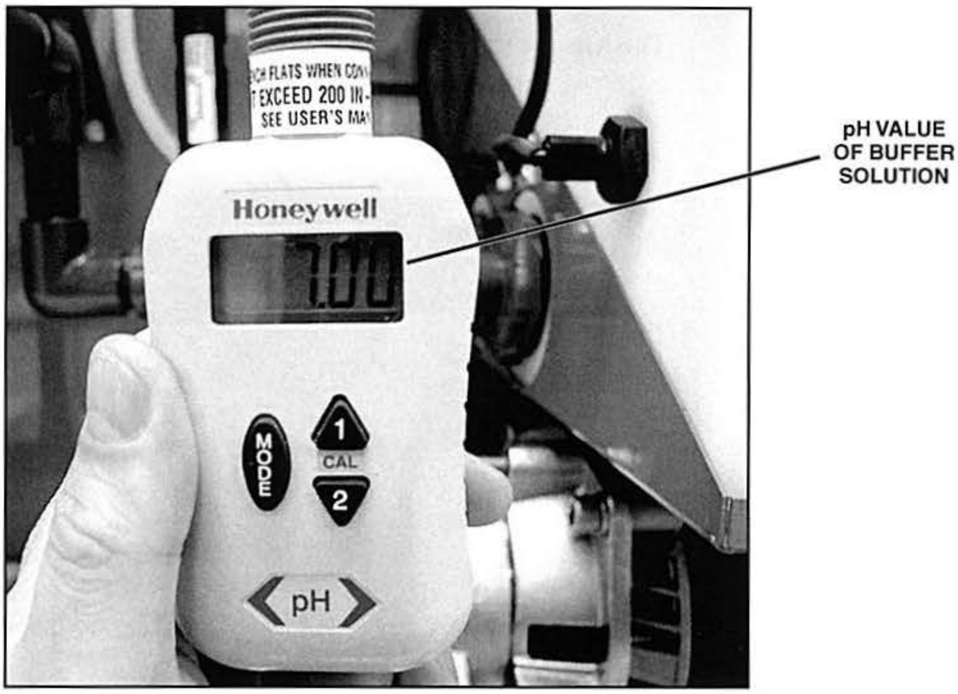

Figure 33. pH Value of Buffer Solution on Display

M. Remove the electrode from the buffer solution and rinse the bottom two inches of the sensing end with distilled water using a squirt bottle. Dab the sensing area dry with a cloth or paper towel.

N. Pour the used buffer solution from the container and rinse the container with distilled water. Dry the container before adding another buffer solution.

Do not pour the buffer solution back into the buffer solution bottle. This may contaminate the buffer solution. Instead, dispose of the used buffer solution by pouring it down an available drain.

O. Pour approximately 2 inches of the 10 pH buffer solution in the container for slope calibration.

P. Place the sensing end of the electrode into the buffer solution in the container and wait one minute for the reading to stabilize.

Q. With your free hand, press and hold the **CAL2** key on the sensor module until the display changes from the pH reading to CAL2.

This sets the module to the slope calibration mode.

R. Press the **CAL2** key again for 1 second.

This causes SCAL to briefly appear on the display, followed by the buffer pH value.

S. If the displayed value is not 10.0, use the **CAL1** and **CAL2** keys to adjust the value up or down until it reads 10.0.

While you are adjusting the value, you should notice that the value on the display blinks as it did when you set the zero calibration value. Once the value is 10.0, the display should continue to blink until you accept the setting for the slope calibration.

T. Momentarily press the **MODE** key to accept the setting for slope calibration.

U. Remove the electrode from the buffer solution and rinse the sensing end with distilled water using a squirt bottle. Dab the sensing area dry with a cloth or paper towel.

V. Pour the used buffer solution from the container and rinse the container with distilled water. Dry the container.

Do not pour the buffer solution back into the buffer solution bottle to avoid contamination. Instead, dispose of the used buffer solution by pouring it down an available drain.

❑ 5. Turn off the T5554 main power circuit breaker and disconnect the circuit.

❑ 6. Perform the following substeps to mount the pH electrode in the reactor tank.

A. Using a 3/16 hex wrench, loosen the two screws that secure the mounting bracket, shown in figure 34, and remove the loose half of the bracket.

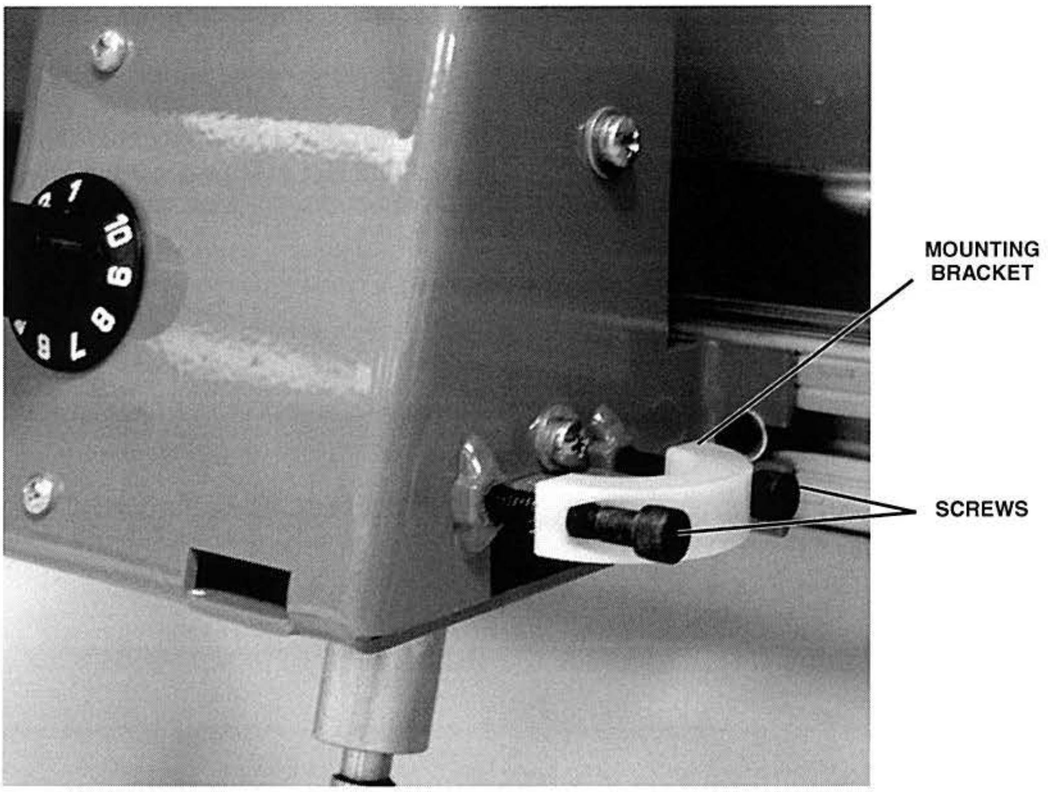

Figure 34. Screws that Secure the Mounting Bracket

B. Place the pH electrode inside the fixed half of the mounting bracket, as shown in figure 35, and hold it there. Be sure the actual sensing tip of the electrode is as deep in the reactor tank as possible.

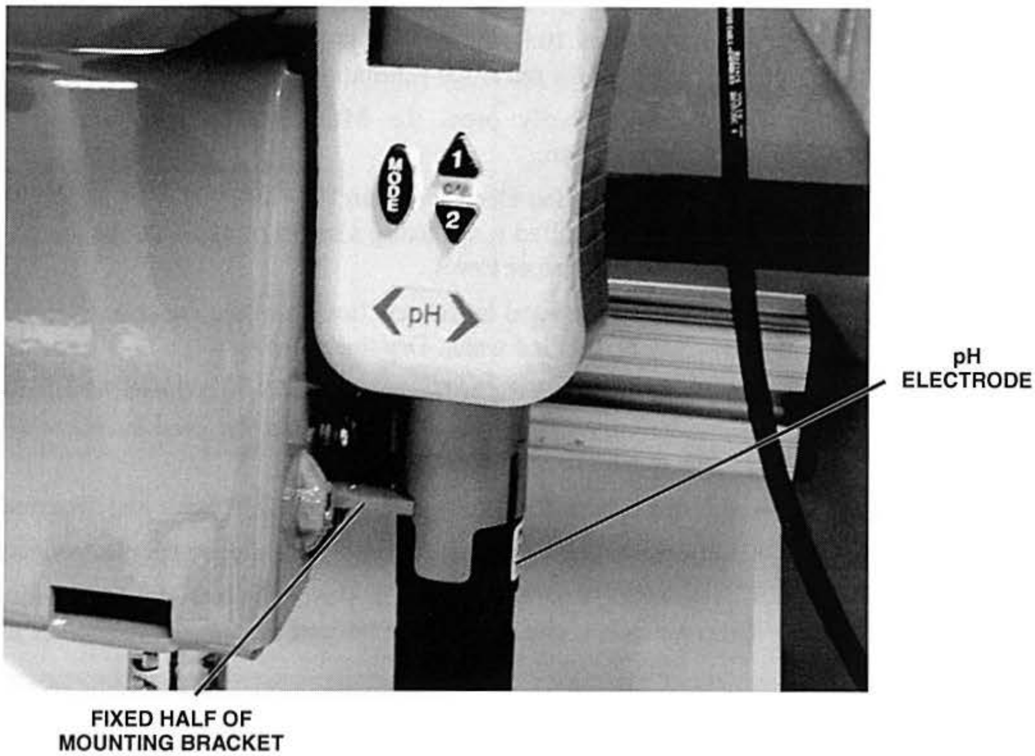

Figure 35. pH Electrode Placed Inside Fixed Half of Mounting Bracket

C. Replace the loose half of the mounting bracket around the electrode, as figure 36 shows, and tighten the screws using the 3/16 hex wrench.

CAUTION

Do not over tighten the screws. The electrode housing is made of plastic and may crack if too much pressure is applied.

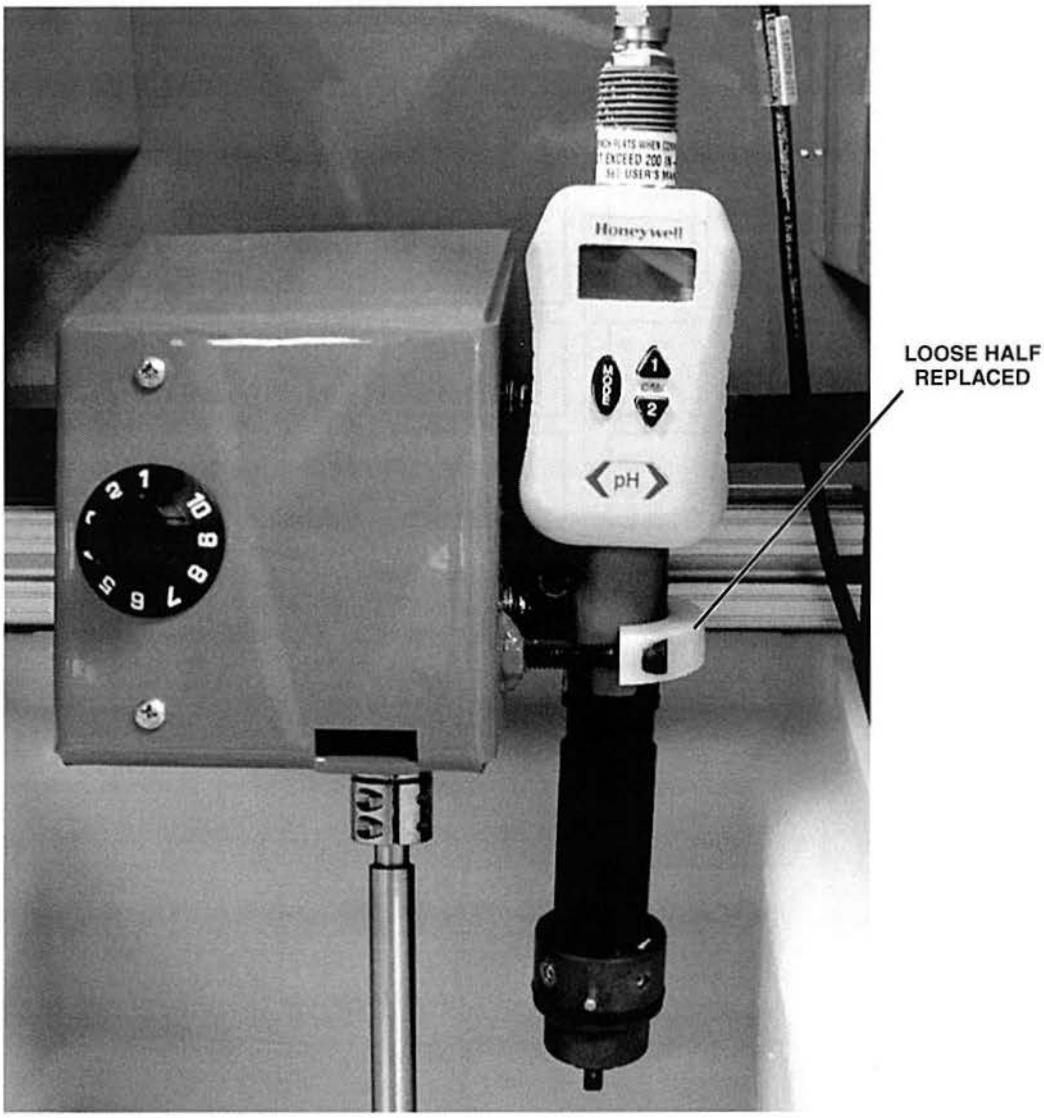

Figure 36. Loose Half of the Mounting Bracket Replaced

❑ 7. Connect the circuit shown in figure 37.

This will allow the controller to monitor the pH of the batch solution in the reactor tank and control the metering pump to add reagent to the batch until the pH is neutral (7 pH). Make sure to connect the 250-Ohm resistor module into the input of the controller, as shown in figure 37.

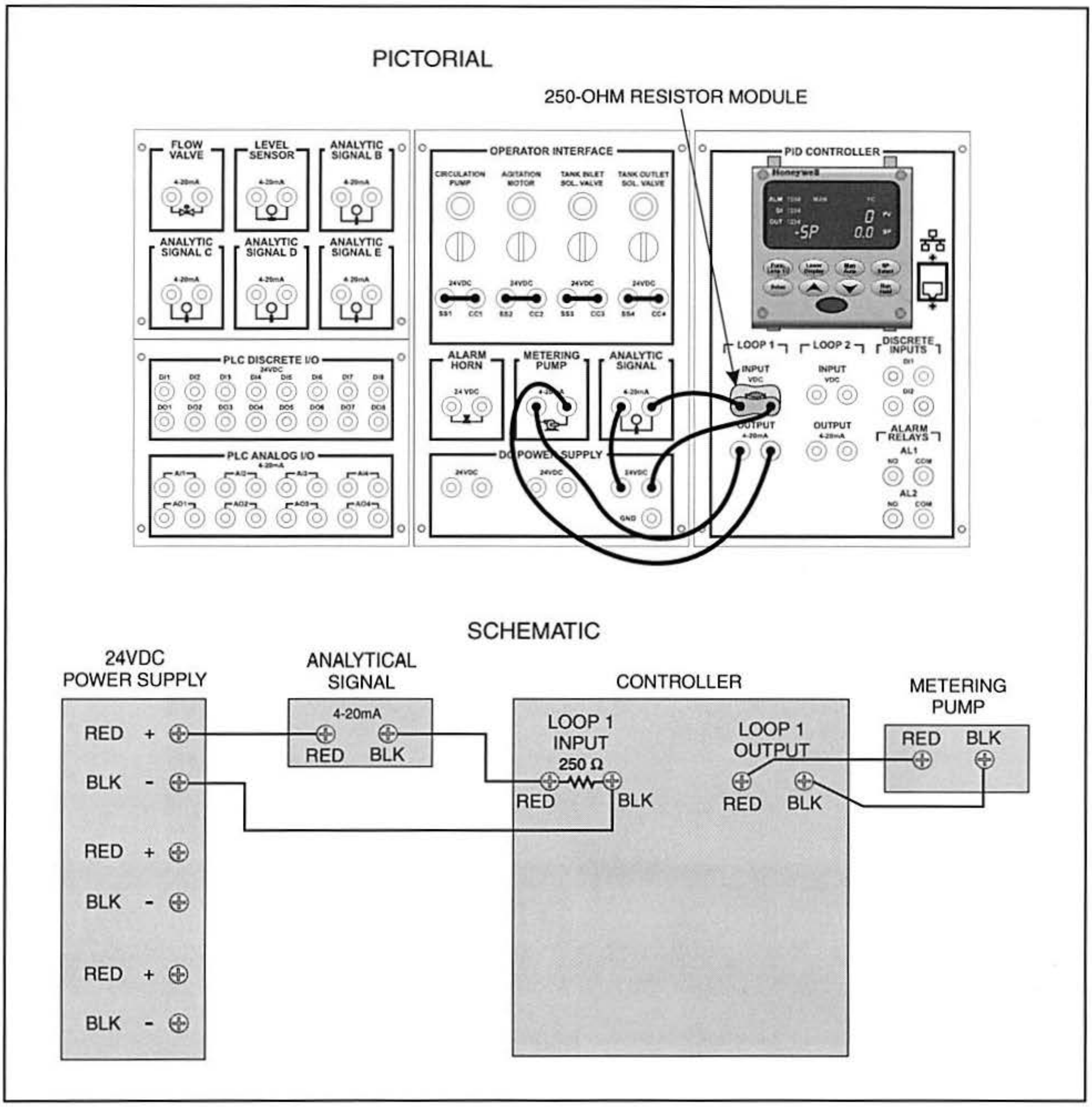

Figure 37. Circuit for Batch Control

❑ 8. Perform the following substeps to connect the garden hose adapter to the process piping of the T5554.

This will allow you to connect a second hose that will provide the influent flow to the reactor tank by connecting to a faucet, as figure 38 shows.

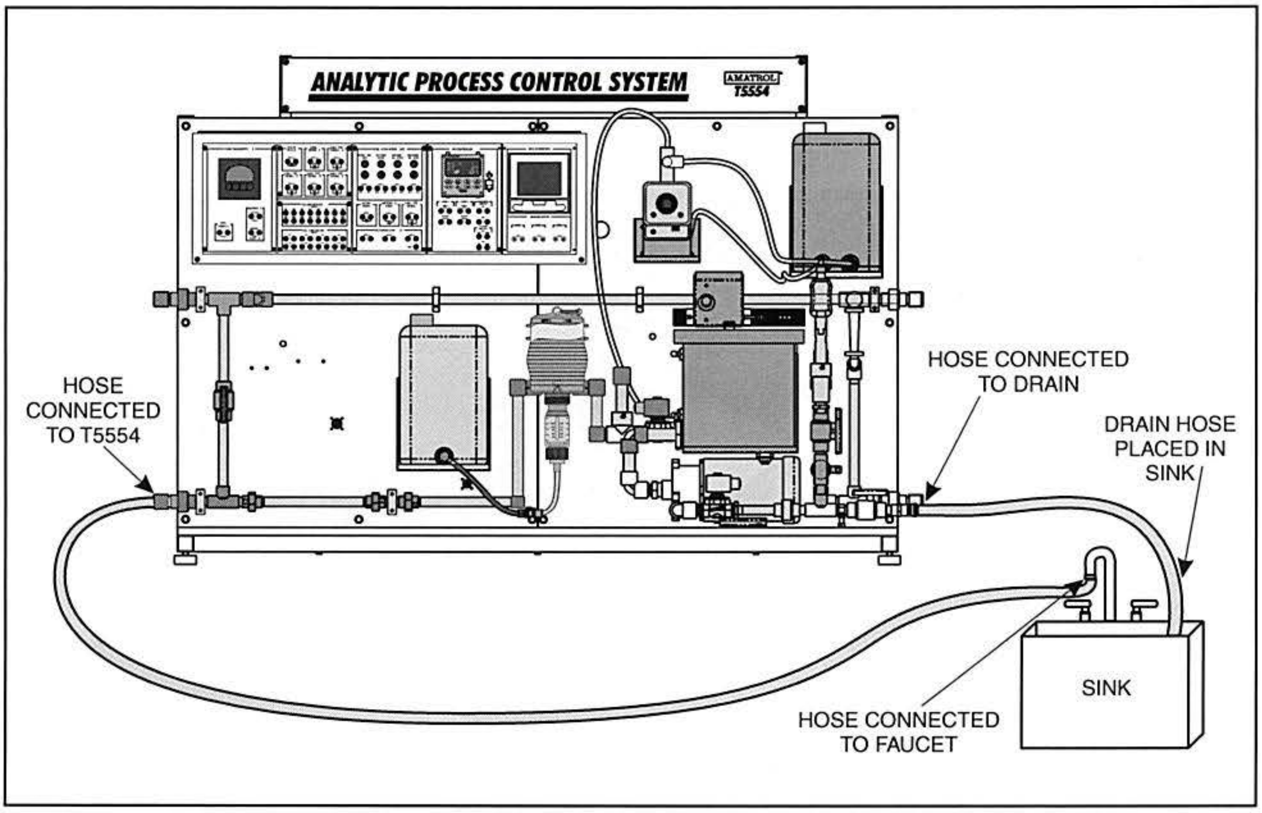

Figure 38. Garden Hose Connected from Faucet to T5554

A. Locate the end cap adapter on the lower left portion of the T5554, shown in figure 39.

B. Make sure that the drip pan is under the adapter so it will catch any water that is trapped in the piping when the adapter is removed.

C. Loosen the locking ring on the end cap adapter, shown in figure 39, by turning it clockwise.

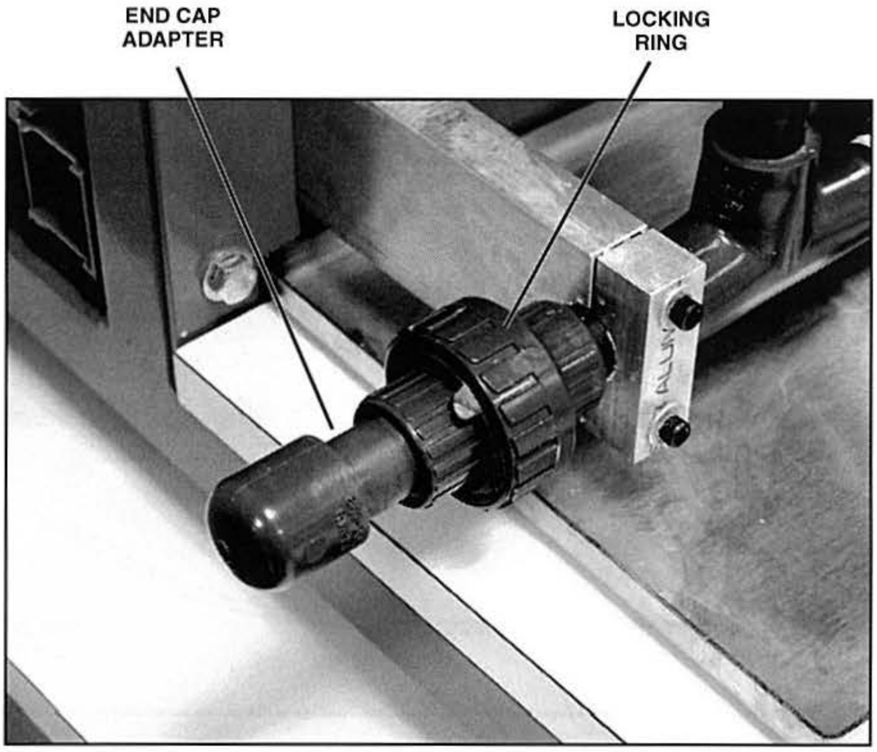

Figure 39. End Cap Adapter

D. When the locking ring is completely loose, remove the end cap as shown in figure 40.

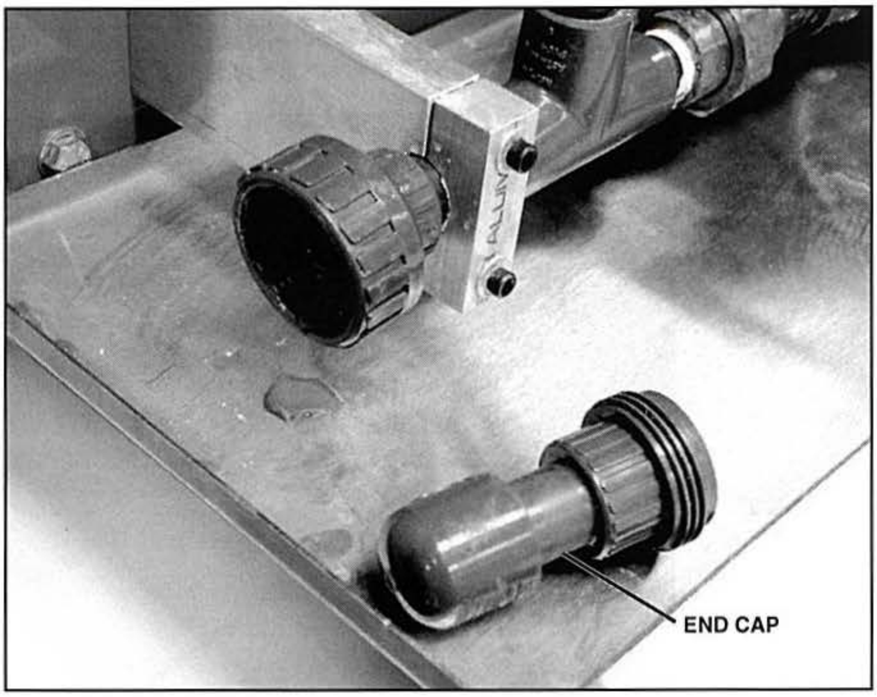

Figure 40. End Cap Removed

E. Locate the garden hose adapter shown in figure 41.

Figure 41. Garden Hose Adapter

F. Connect the garden hose adapter in the location where the end cap was removed, as shown in figure 42.

You will need to turn the locking ring counterclockwise to tighten it and secure the garden hose adapter. It should be as tight as you can get it by hand. DO NOT use a wrench to tighten it.

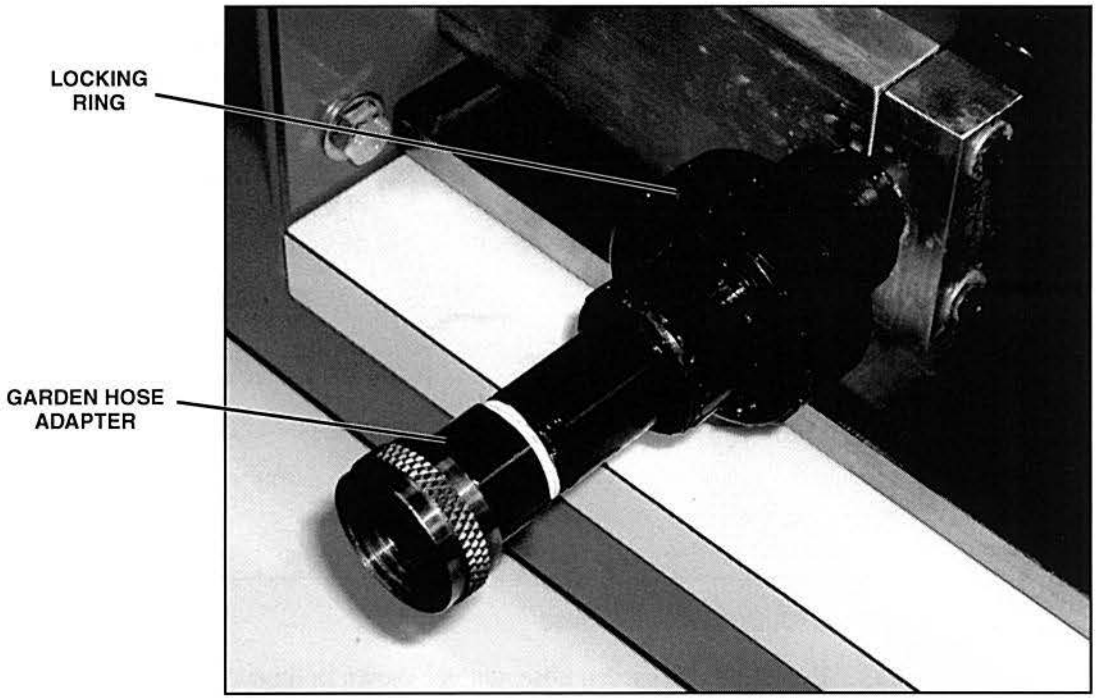

Figure 42. Garden Hose Adapter Connected in Place of End Cap

❑ 9. Locate another garden hose and connect it between the garden hose adapter and an available faucet, as figure 43 shows. However, DO NOT turn on the water faucet at this time.

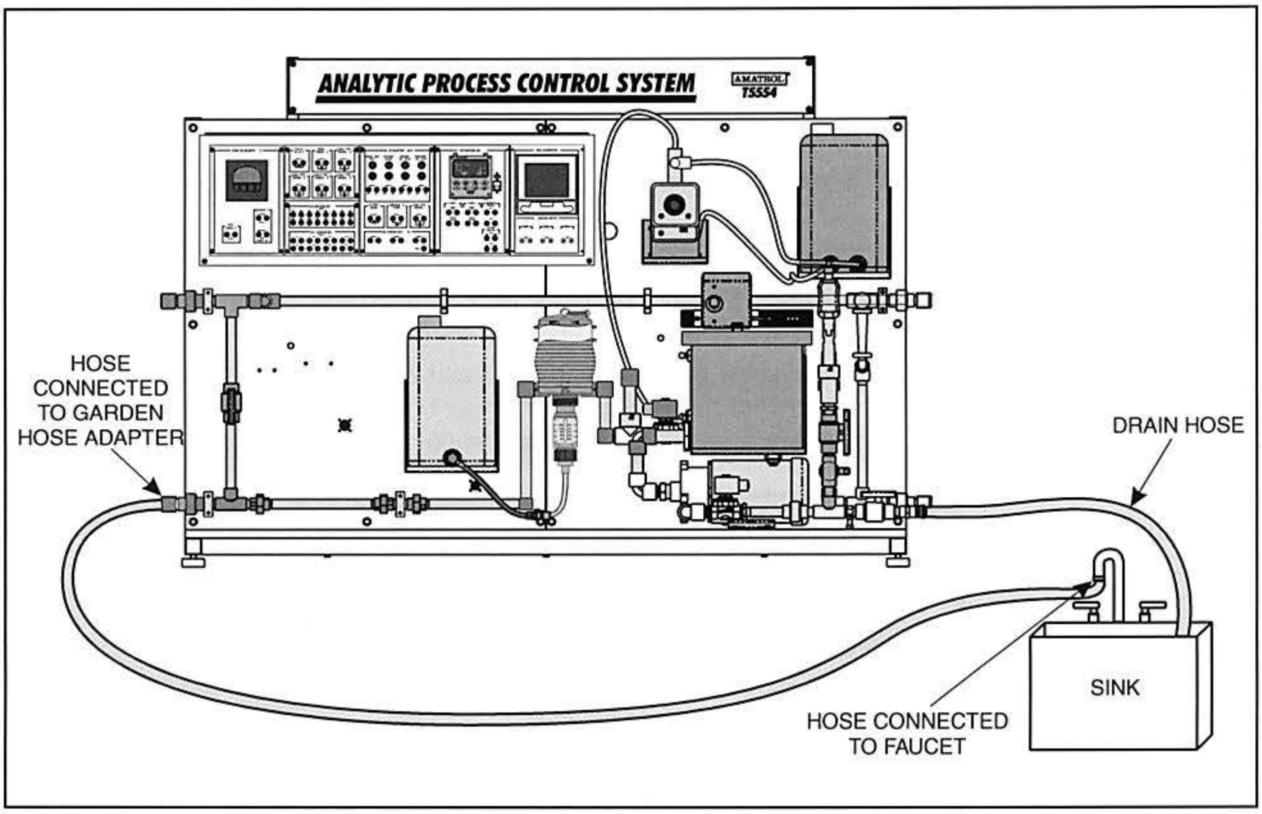

Figure 43. Garden Hose Connected between Faucet and Garden Hose Adapter

❑ 10. Make sure a hose is still connected to the drain, as figure 43 also shows, and that the drain valve is open.

❑ 11. Perform the following substeps to configure the Honeywell PID controller for on/off batch control.

A. Turn on the main circuit breaker.

B. Set all controller parameters back to factory defaults. If you do not recall how to do this, refer back to LAP 4 Skill 4.

C. Program Loop 1 of the Honeywell UDC 3500 dual-loop controller for pH control according to the parameters listed in the table of figure 44.

If you have the single-loop controller, you will see the LOOP TUNING and INPUT parameter groups.

Recall that the Setup key is used to scroll through the parameter groups and the Func Loop 1/2 key is used to select a parameter. The up and down keys (▲▼) are used to change parameter values.

Some of the parameter groups listed are not directly related to the Loop settings but are necessary for proper operation. These include the Options, Communications (COM), and Display parameter groups.

PARAMETER GROUP	PARAMETER	VALUE OR SELECTION
LOOP1 TUNING	GAIN RATE MIN RSET MIN	25.0 0.0 0.25
ALGORITHM	CONT ALG PIDLOOPS	PIDA 1 LOOP
OUTPUT	OUT ALG C1 RANGE	CURRENT 4-20
INPUT 1	IN1 TYPE XMITTER1 IN1 HIGH IN1 LOW	1-5V or 4-20 mA LINEAR 14.0 0.0
CONTROL	PV SOURC SP HiLIM SP LoLIM ACTION I Hi LIM I Lo LIM	INPUT 1 14.0 0.0 REVERSE 100.0 0.0
OPTIONS	DIG IN 1 DIG IN 2	NONE NONE
COM	ComSTATE	DISABL
DISPLAY	DECIMAL TEMPUNIT PWR FREQ	TWO NONE 60 HZ

Figure 44. Controller Parameters for Control Loop

D. Exit the setup mode by pressing the **Lower Display** key.

❑ 12. Use the Lower Display key to toggle to the setpoint (SP) and set it to **7.0**.

This makes the pH setpoint 7. This causes the controller to adjust the pH of the batch to 7 (neutral) before it is released.

❑ 13. Set the ratio control dial on the eductor pump to a ratio of **1:100 (1%)**.

❑ 14. Perform the following substeps to set the metering pump controls, as shown in figure 45.

A. Make sure the **Mode** selector switch is in the **Standby** (center) position.

B. Unlock the locking lever for the Percentage Stroke Length dial by placing it in the left position.

C. Set the Percentage Stroke Length dial to **30%**.

The Stroke Rate Percentage Setting does not matter. The output from the controller will control the stroke rate.

PERCENT STROKE LENGTH DIAL SET TO 30%

Figure 45. Setting for Metering Pump

❑ 15. Perform the following substeps to operate the pH batch system.

A. Open the water supply faucet about half way.

B. Make sure the **TANK INLET SOL VALVE** selector switch is in the **OFF** position (turn CCW). This keeps the inlet solenoid valve open and allows water to flow into the reactor tank.

As the water flows into the tank, you should hear the "click-clack" sound of the eductor pump injecting the acid reagent into the influent flow to induce a disturbance.

C. When the water level in the tank reaches a level so that the water level is about one inch below the upper level switch, place the **TANK INLET SOL VALVE** selector switch in the **ON** position (turn CW) to close the inlet solenoid valve.

D. Place the **AGITATION MOTOR** selector switch in the **ON** position (CW).

E. Set the **Agitator Speed** control to **6**.

This causes agitation to begin.

F. Place the **Mode Selector** switch on the metering pump in the Automatic mode position (turn CW).

G. Place the controller in the automatic mode by pressing the **Man/Auto** key.

The controller will control the metering pump to add base to the batch until the pH of the batch is neutral (7 pH). It will take several minutes for the pH to stabilize.

H. When the display of the transmitter and the controller indicate a pH of 7 ("0.2 pH), place the controller in the manual mode.

I. Place the **Mode Selector** switch on the metering pump in the **Standby** position (center).

J. Set the **Agitator Speed** control fully CCW.

K. Place the **AGITATOR MOTOR** selector switch in the **OFF** position (CCW).

L. Place the **TANK OUTLET SOL VALVE** selector switch in the **OFF** position (turn CCW) to open the outlet solenoid valve and allow the batch to drain from the reactor tank.

M. When the water in the reactor tank stops emptying, place the **TANK OUTLET SOL VALVE** selector switch in the **ON** position (turn CW).

N. If instructed to repeat the process by the instructor, repeat step 15. If not, continue.

O. Close the water supply faucet.

P. Turn off the main power circuit breaker.

❑ 16. Perform the following substeps to return the pH electrode to its previous location on the outlet side of the reactor tank, as shown in figure 46.

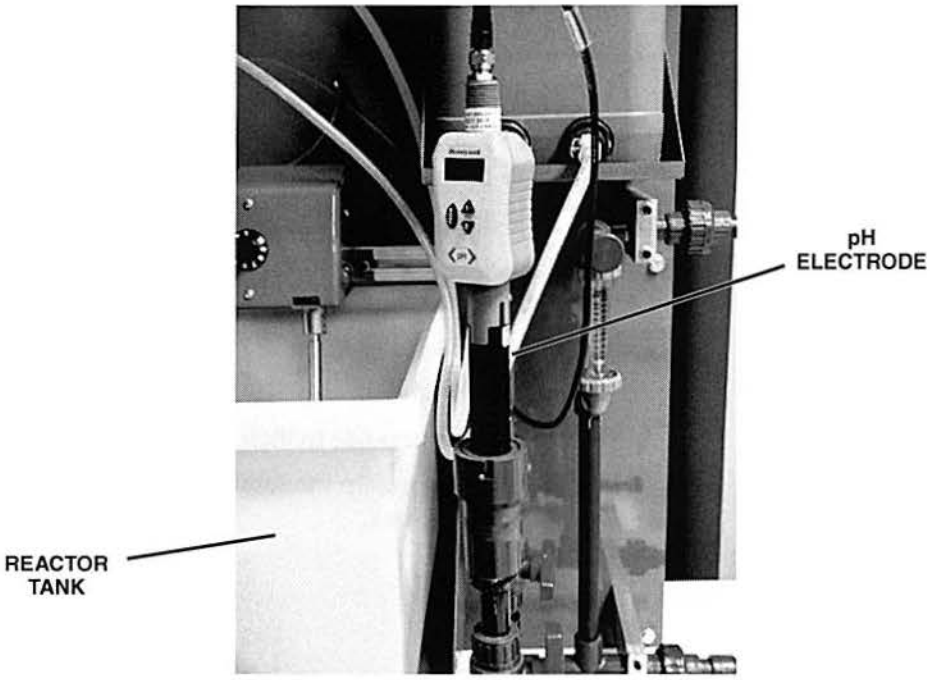

Figure 46. pH Electrode Returned to Outlet Side of Reactor Tank

A. Remove the plug from the fitting on the outlet side of the tank.

B. Grasp the pH electrode.

C. Loosen the two screws of electrode mounting bracket using a 3/16 hex wrench and remove the loose half of the bracket.

D. Remove the electrode from the mounting bracket.

E. Return the electrode to the fitting on the outlet side of the tank.

To install the electrode, you need to line up the studs on the electrode housing with the slots in the fitting. Push the electrode down into the fitting until it is fully seated. Then, twist the housing clockwise to lock the electrode in place.

F. Re-install the loose half of the mounting bracket.

❑ 17. Perform the following substeps to shut down the T5554.

A. Disconnect the garden hose from the faucet and place the end near the drain. This allows the water in the hose and the process piping to drain.

B. When the water stops draining, disconnect the garden hose from the garden hose adapter.

C. Remove the garden hose adapter from the T5554 process piping.

D. Re-install the end cap adapter on the T5554 process piping.

E. Close the drain hand valve on the T5554.

F. Disconnect the garden hose from the T5554 drain and allow the water in the hose to drain.

G. Replace the drain cap on the T5554 drain connection.

H. Disconnect the circuit.

I. Return the garden hoses to their storage location.

J. If necessary, use a shop vacuum or sponge to remove the remaining water from the reactor tank.

SEGMENT 2

SELF REVIEW

1. A(n) __________ processing system collects a specific volume of solution in a container and adjusts the pH before releasing the solution.

2. The pH of ______________ must be within the safe range before it is released back into the environment.

3. For on/off batch control, both the influent and effluent flows are controlled using ______________.

4. A Honeywell UDC 3500 with __________ analog inputs and at least two relay outputs can be configured for on/off batch control.

5. For on/off batch processing using a Honeywell UDC 3500, the controller will control the __________ using automatic closed loop control.

6. For on/off batch processing using a Honeywell UDC 3500, the controller controls the level in the container using __________ control.

7. When the container is filled to the desired level using on/off batch control, the controller closes the influent ______________ to stop the influent flow.

SEGMENT 3

pH CONTINUOUS CONTROL SYSTEMS

OBJECTIVE 6 DESCRIBE THE FUNCTION OF A CONTINUOUS CLOSED LOOP PH CONTROL SYSTEM AND GIVE AN APPLICATION

A continuous pH control system is a system in which the flow of the solution being treated is continuous, but not necessarily flowing at a constant rate. For this type of system, the reagent is injected as the solution continues to flow, similar to figure 47. The controller constantly monitors the pH of the solution and adjusts the output as necessary to keep the pH near the setpoint.

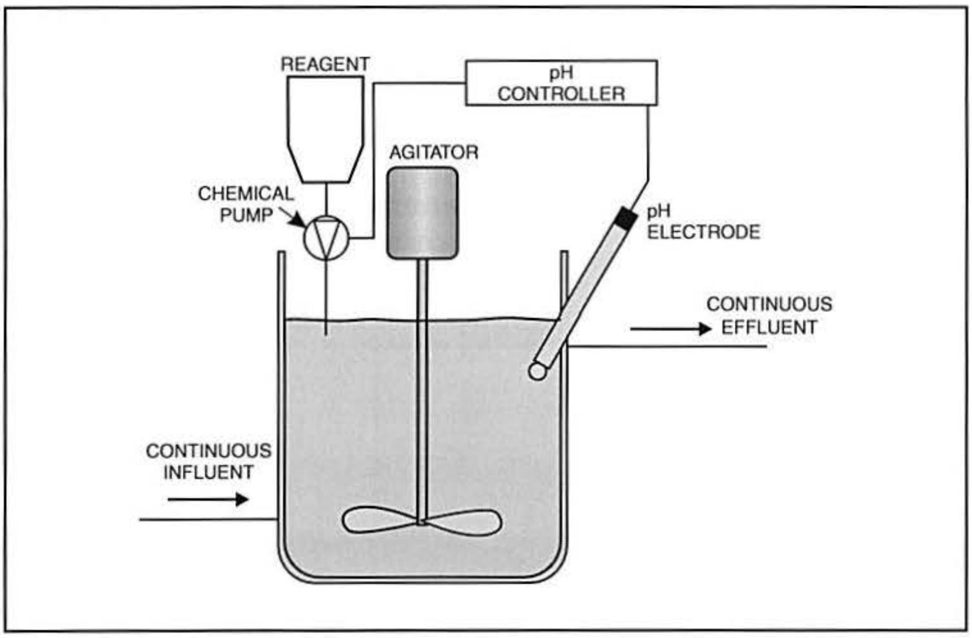

Figure 47. Continuous pH Control System

Continuous processing is used to adjust pH in applications where:

- Influent flow is relatively constant.
- There are no large surges in influent flow.
- Influent solution pH is relatively constant and not subject to large changes.

Continuous pH control is used in wastewater treatment applications in which the effluent volume is too great for standard batch processing. Continuous pH control is also used to neutralize semi-conductor acid wastes and in heavy metal reduction systems which precipitate metals at a high pH as metal hydroxides.

OBJECTIVE 7 DESCRIBE THE OPERATION OF A CONTINUOUS CLOSED LOOP PH CONTROL SYSTEM AND GIVE AN ADVANTAGE

Read This

There are two basic configurations for continuous closed loop pH control. One configuration involves using a tank with continuous flow through. The other configuration, continuous in-line pH control, does not use a tank.

Continuous pH Control with Tank

The components for this continuous pH control configuration, as shown in figure 48, are similar to the components for on/off batch control with a few differences.

For this system, influent and effluent flows are set so the tank always remains full. Therefore, when a given volume of influent enters the tank, an equal volume of effluent is discharged. In addition, the system uses two metering pumps, controlled by a pH controller, to add the required reagent to the solution. One pump adds an acid as needed. The other pump adds a base as needed.

An agitator is present in the tank to mix in the added reagent. The pH electrode is placed near the effluent discharge to measure the pH of the solution as it exits the tank.

In order for this system to operate properly, the untreated influent flow and pH must remain relatively constant. If the influent flow varies greatly, the system will not be able to reliably maintain the pH of the effluent.

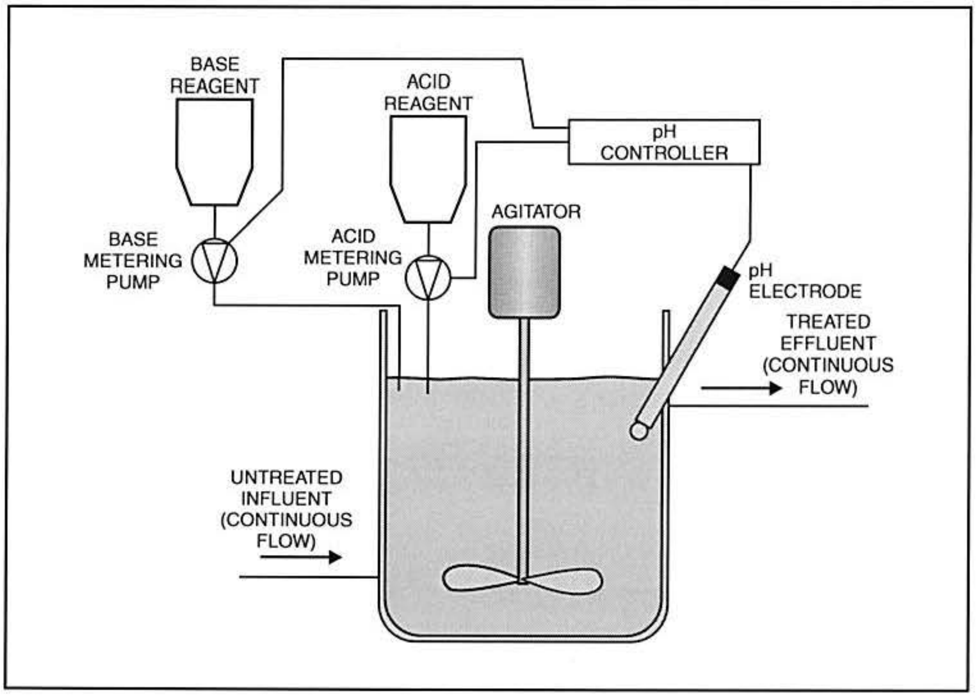

Figure 48. Continuous pH Control System with Tank

As the untreated influent flow enters the tank, it is mixed with the contents of the tank by the agitator. If the pH of the influent is different from the pH of the tank contents, a change in the pH of the tank contents occurs. The pH controller senses the change in pH using the provided feedback from the pH electrode. The controller constantly monitors the pH of the effluent and makes the appropriate adjustments by controlling the metering pumps.

If the influent causes the contents of the tank to become more acidic (lower pH), the controller causes the base metering pump to add more of the base to the tank, as shown in figure 49. This raises the pH back to the desired range.

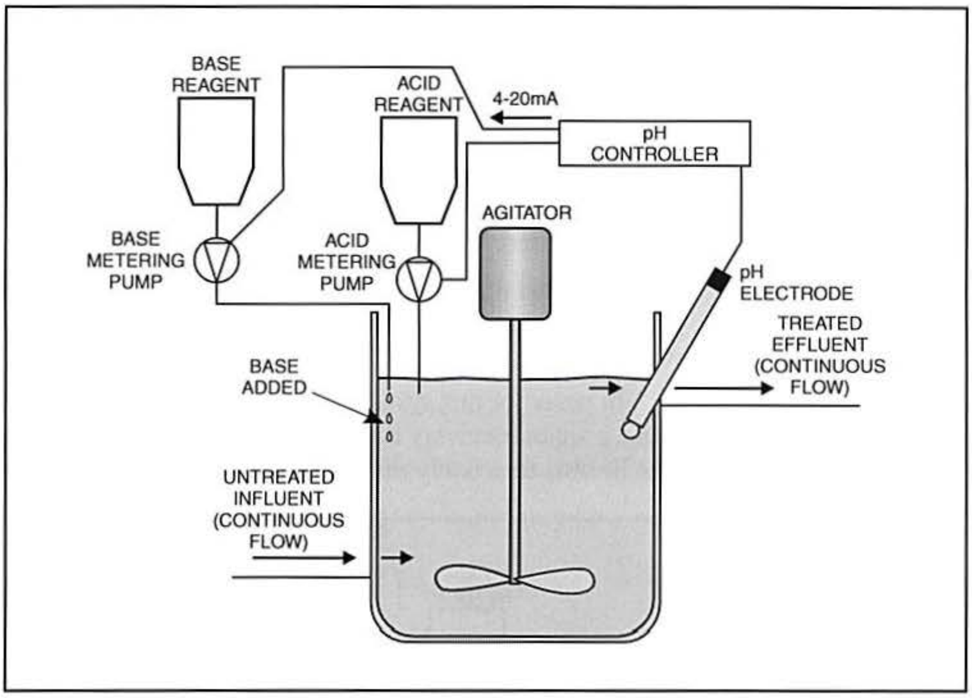

Figure 49. Base Added to Tank Contents to Raise pH

If the influent causes the contents of the tank to become more basic (caustic), the controller causes the acid metering pump to add more of the acid to the tank, as shown in figure 50. This lowers the pH of tank contents back to the desired range.

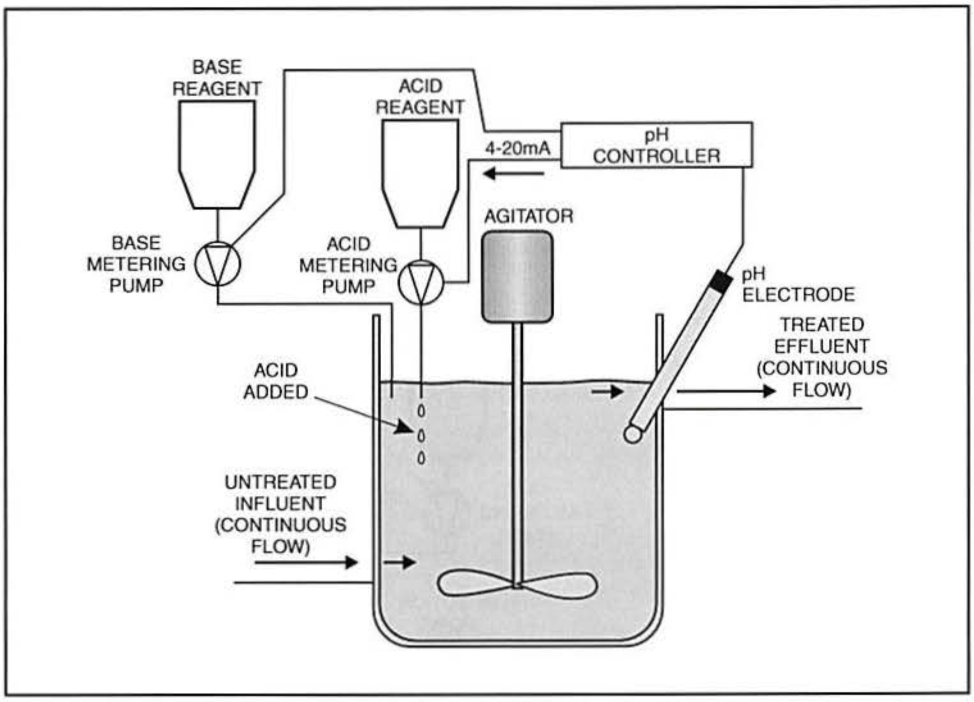

Figure 50. Acid Added to Tank Contents to Lower pH

The pH of the effluent cannot be controlled at a specific value using this system. This system can only control the pH within a desired range.

Continuous In-Line pH Control

This type of continuous pH control does not require a tank, as shown in figure 51. The reagents are injected directly into the piping that carries the influent by the metering pumps. The pH electrode is mounted directly in the piping and is located after the reagent injection point. This allows the controller to monitor the pH of the effluent after it has been treated.

Since there is no tank, a standard agitator cannot be used to mix the reagent into the effluent flow. Therefore, a static in-line mixer is added between the injection point and the pH electrode, as figure 51 also shows.

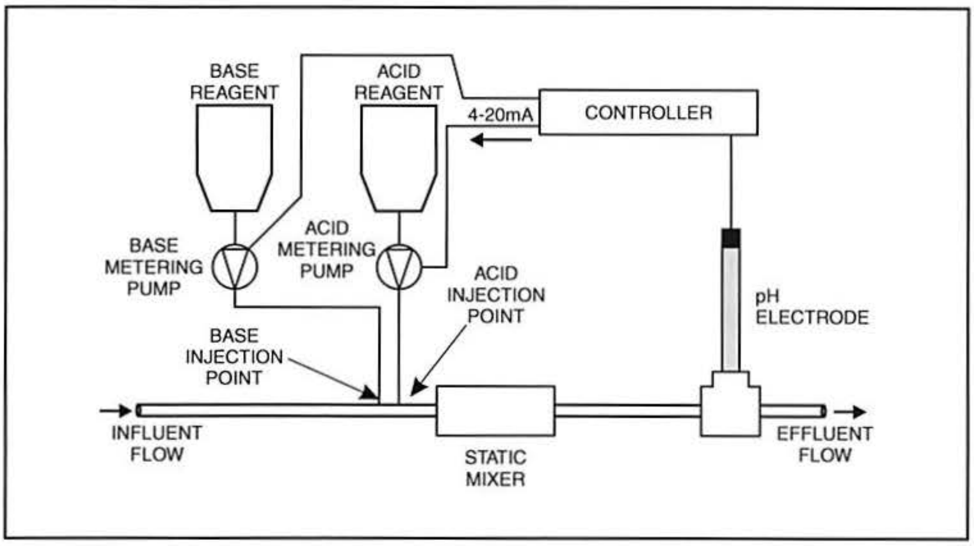

Figure 51. Continuous In-Line pH Control System

The static in-line mixer, shown in figure 52, mixes the reagent into the effluent flow before the mixture reaches the pH electrode. The mixer provides a much more consistent pH measurement, which is critical for this type of control system.

Figure 52. A Static In-Line Mixer

As the effluent flows through the piping, the controller monitors the pH of the effluent using feedback from the pH electrode and makes the appropriate adjustments by controlling the metering pumps.

If the pH of the effluent is too low (acidic), the controller causes the base metering pump to add more of the base to the effluent flow. This raises the pH back within the desired range. If the pH of the effluent is too high (basic or caustic), the controller causes the acid metering pump to add more of the acid to the effluent flow. This lowers the pH back within the desired range.

Continuous in-line control actually provides more accurate pH control as long as system conditions remain steady. However, large changes in the flow rate of the effluent make it difficult for the controller to maintain the desired pH range without making changes to the controller settings. In addition, large swings in the pH of the pretreated influent can make it difficult for the controller to maintain the desired pH range.

Both types of continuous pH control have advantages over batch control. Both have simpler construction (less components) and are much easier to program and maintain.

OBJECTIVE 8 DESCRIBE HOW TO CONFIGURE A HONEYWELL UDC 3500 FOR CONTINUOUS pH CONTROL

Configuring the Honeywell UDC 3500 for continuous pH control is much simpler than configuring for batch control. Two control loops are required if two reagent metering pumps are used (one for the base and one for the acid). However, only one pH electrode in needed to provide feedback for both control loops. Figure 53 shows the connections for continuous pH control.

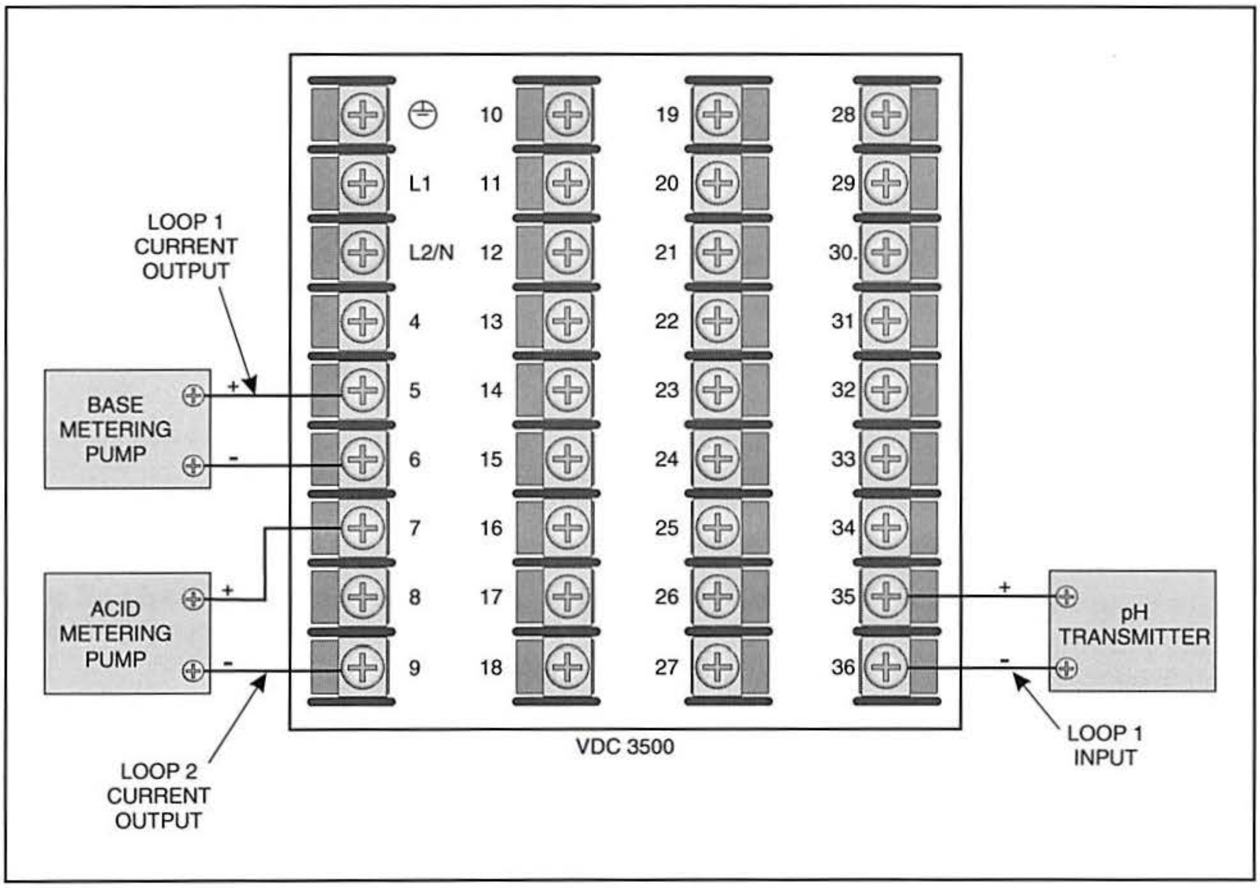

Figure 53. Continuous pH Control Connections for UDC 3500

Once the proper connections are made, the controller can be configured using the following steps:

Step 1: Set the required closed-loop parameters for continuous pH control

Step 2: Set the desired setpoint for the control loops

Step 3: Place the controller in the automatic mode to control the process

Step 1: Set the required closed-loop parameters for continuous pH control

The controller will control the pH using automatic closed loop control. The parameters to be set include those listed in the table of figure 54. This includes parameters for both control loops. Other parameters may need to be checked and changed as well, but these are the parameters directly related to continuous pH control.

PARAMETERS FOR CLOSED LOOP CONTINUOUS PH CONTROL		
PARAMETER GROUP	PARAMETERS	DESCRIPTION
LOOP1 TUNING	GAIN RATE MIN RSET MIN	The LOOP1 TUNING parameters are set to achieve the desired degree of control. In many continuous pH control applications, a combination of proportional (GAIN) and integral action (RSET MIN) is sufficient.
LOOP 2 TUNING	GAIN RATE MIN RSET MIN	The LOOP2 TUNING parameters are set to achieve the desired degree of control. In many continuous pH control applications, a combination of proportional (GAIN) and integral action (RSET MIN) is sufficient.
ALGORITHM	CONT ALG PIDLOOPS CONT2ALG	The ALGORITHM parameters are set to determine the method of control. For example, CONT ALG and CONT2ALG are set to PIDA if automatic continuous control is desired. Additionally, PIDLOOPS must be set to 2 LOOPS to enable both loops.
OUTPUT	OUT ALG C1 RANGE OUT2ALG C2 RANGE	The OUTPUT parameters are set to determine the output from the controller. For example, OUT ALG and OUT2 ALG are set to CURRENT, and C1 RANGE and C2 RANGE are set to 4-20 to produce a 4-20mA analog outputs.
INPUT 1	IN1 TYPE XMITTER1 IN1 HIGH IN1 LOW	The INPUT 1 parameters are set to determine the type of input signal and what that signal represents. For example, IN1 TYPE may be set to 4-20mA, XMITTER 1 to linear, IN1 HIGH to 14, and IN1 LOW to 0. This scales the display to the pH scale (0-14). Both loops will use the same input to monitor pH.
CONTROL	PV SOURC SP HiLIM SP LoLIM ACTION I Hi LIM I Lo LIM	The CONTROL parameters are set to determine how the controller actually controls the process. PV SOURC identifies which input represents the process variable. SP HiLIM and SP LoLIM are set to establish the high and low limits for the setpoint. ACTION is set to REVERSE for the metering pump. I Hi LIM and I Lo LIM are set to establish the high and low limits for the input current.
CONTROL2	PV2 SRC SP2 HiLIM SP2 LoLIM ACTION I Hi LIM I Lo LIM	The CONTROL2 parameters are set to determine how the controller actually controls the process. PV SOURC identifies which input represents the process variable. SP HiLIM and SP LoLIM are set to establish the high and low limits for the setpoint. ACTION is set to REVERSE for the metering pump. I Hi LIM and I Lo LIM are set to establish the high and low limits for the input current.

Figure 54. Parameters for Continuous pH Control

Step 2: Set the desired setpoints for the control loops

Once all required parameters have been set, the next step is to exit the setup mode and enter the setpoint for each loop. Pressing the SP Select key toggles between the setpoint for loop 1 (SP in the lower display) and the setpoint for loop 2 (2SP in the lower display). Pressing the up ▲ and down ▼ arrow keys change the value for the selected setpoint. For example, figure 55 shows the setpoint value for loop 2 (2SP).

Figure 55. Setpoint Value for Loop 2 (2SP)

Step 3: Place the controller in the automatic mode to control the process

Once the setpoints are entered, the controller is placed in the automatic mode by pressing the Man/Auto key. This allows the controller to control the process.

SKILL 3	CONNECT AND OPERATE A CONTINUOUS CLOSED LOOP PH CONTROL SYSTEM

Procedure Overview

In this procedure, you will program the Honeywell UDC 3500 controller to perform continuous control of the pH in the reactor tank. Then, you will place the controller in the automatic mode to control the process.

❑ 1. Perform the following substeps to make sure the T5554 Analytical Process Control System is set up as shown in figure 56.

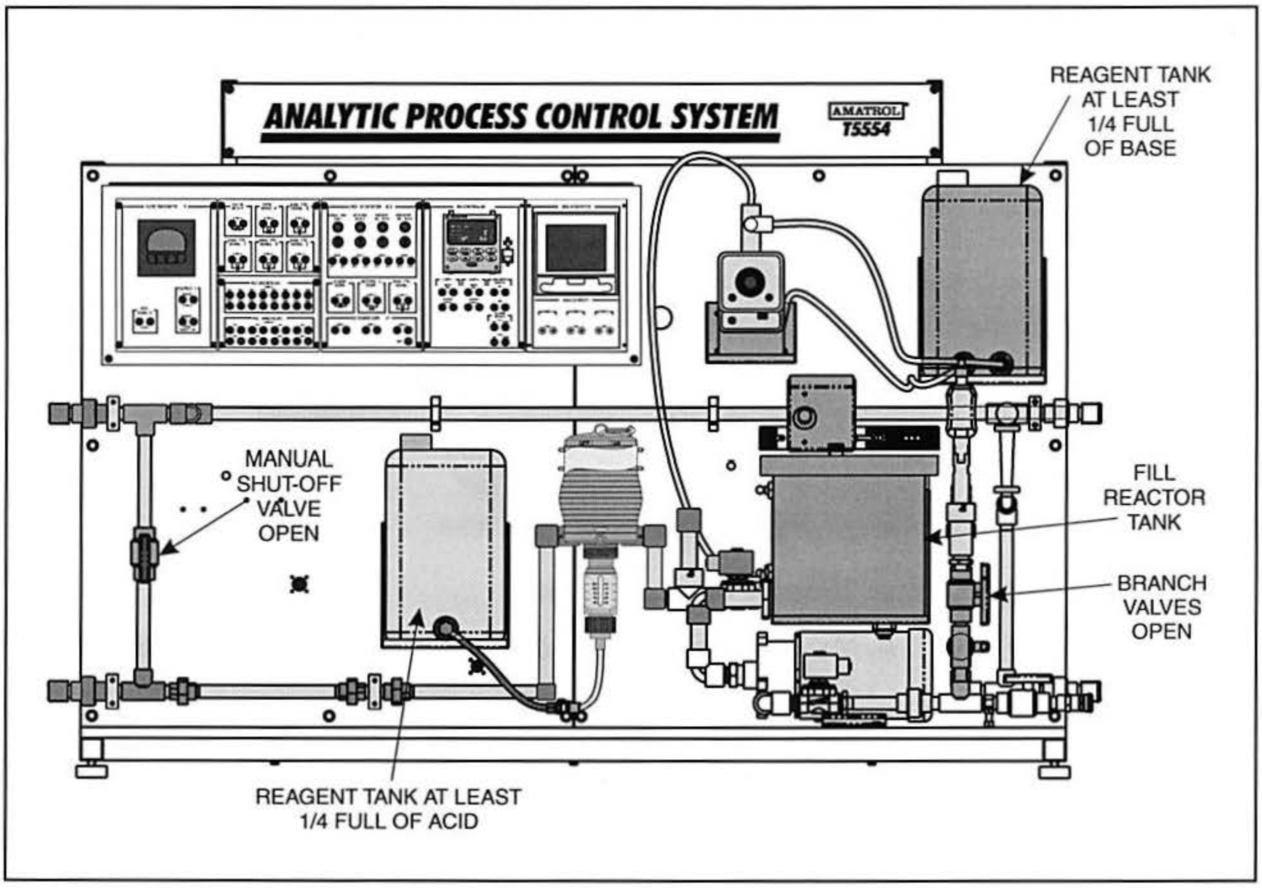

Figure 56. T5554 Setup

A. Fill the reactor tank with fresh water.

If the reactor tank includes a pressure sensor in the bottom of the tank, do not pour water directly over the sensor to avoid possible damage to the sensor.

Be sure to keep the water level below the high level switch, as shown in figure 57. If the water actuates the high level switch, the inlet solenoid valve is closed to stop flow into the tank.

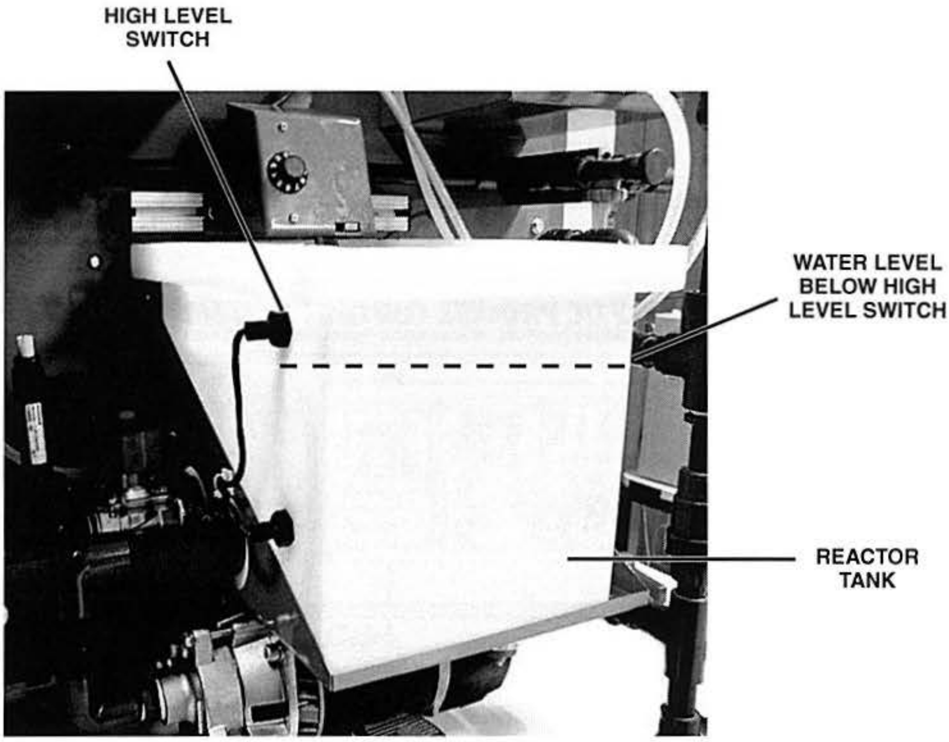

Figure 57. Water Below the High Level Switch

B. Make sure the drain shutoff hand valve is closed (shut) and the drain cap is in place.

C. Make sure the main shutoff valve and the two branch valves are open.

D. Make sure the reagent tanks are filled at least 1/4 full.

E. Make sure the bypass hand valve is closed.

❑ 2. Connect the circuit shown in figure 58.

This allows the controller to continuously monitor and control the pH of the process fluid. Make sure a 250-Ohm resistor module is connected to the Loop 1 input on the controller.

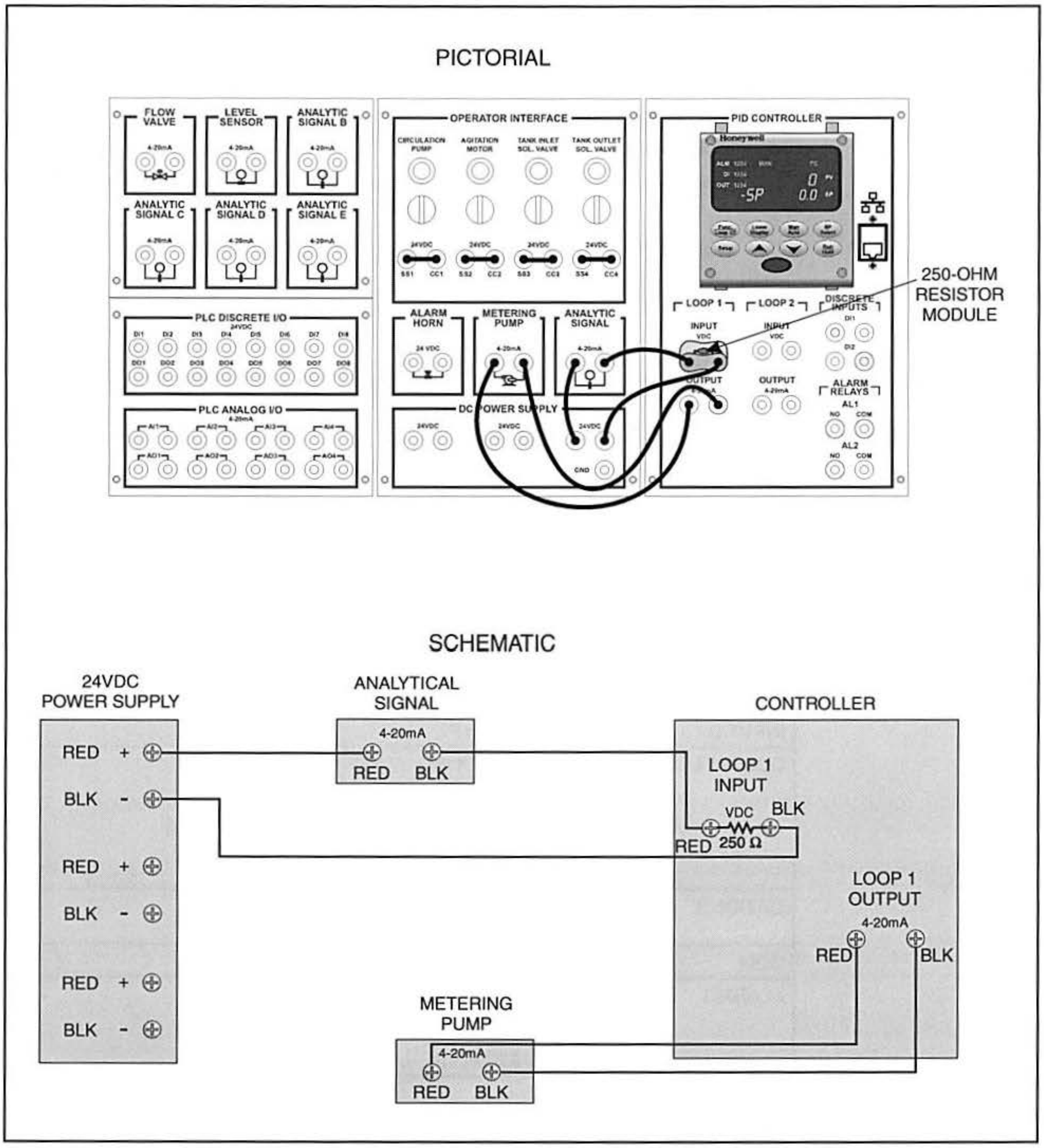

Figure 58. Continuous pH Control Circuit

❑ 3. Turn on the main circuit breaker.

❑ 4. Place the controller in the manual mode and program it for continuous pH control according to the parameters listed in the table of figure 59.

First, return all parameters to their default valves.

Recall that the Setup key is used to scroll through the parameter groups and the Func Loop 1/2 key is used to select a parameter. The up and down keys (▲▼) are used to change parameter values.

Some of the parameters are not directly related to continuous pH control but are necessary for proper operation.

NOTE

The T5554 only has one reagent pump for the reactor tank. Therefore, you will only need one control loop.

PARAMETER GROUP	PARAMETER	VALUE OR SELECTION
TUNING	GAIN RATE MIN RSET MIN	35.0 0.0 0.25
ALGORITHM	CONT ALG PIDLOOPS	PIDA 1 LOOP
OUTPUT ALG	OUT ALG C1 RANGE	CURRENT
4-20		
INPUT 1	IN1 TYPE XMITTER1 IN1 HIGH IN1 LOW	1-5 VLINEAR 14.0 0.0
INPUT 2	IN2 TYPE	DISABLE
CONTROL	PV SOURC SP HiLIM SP LoLIM ACTION I Hi LIM I Lo LIM	INPUT 1 14.0 0.0 REVERSE 100.0 0.0
OPTIONS	DIG IN 1 DIG IN 2	NONE NONE
COM	ComSTATE	DISABL
ALARMS	A1S1TYPE A1S2TYPE A2S1TYPE A2S2TYPE	NONE NONE NONE NONE

Figure 59. Controller Settings for Continuous pH Control

❑ 5. Exit the setup mode by pressing the **Lower Display** key.

❑ 6. Toggle to the setpoint (SP) display and set it to **7.0**.

☐ 7. Make sure the On/Off switch on the eductor pump, shown in figure 60, is in the On position.

☐ 8. Set the ratio control or the eductor pump to a ratio of **1:100 (1%)**.

This allows the eductor pump to inject the acid reagent into the process flow to create a disturbance in the system.

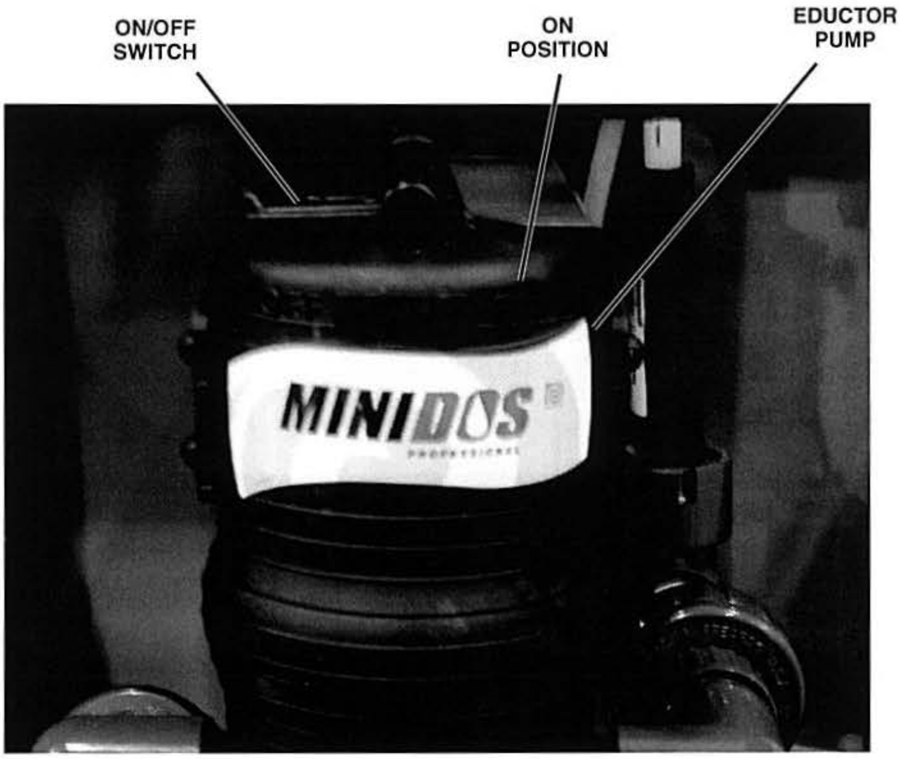

Figure 60. On/Off Switch on Eductor Pump

❑ 9. Perform the following substeps to set the metering pump controls.

A. Set the **Mode** selector switch to the **Automatic** position (turn CW).

B. Unlock the locking lever on the Percentage Stroke Length dial.

C. Set the Percentage Stroke Length dial to **50%**.

The setting of the Stroke Rate Percentage dial does not matter. The stroke rate will be controlled by the output of the controller.

❑ 10. Perform the following substeps to operate a continuous pH control system.

A. Place the controller in the automatic mode using the **Man/Auto** key.

B. Place the **CIRCULATION PUMP** and **AGITATOR MOTOR** selector switches in the **ON** (CW) position.

C. Set the **Agitator Speed** control to **6**.

D. Set the flow rate to **1.8 gpm** using the adjustment valve on the rotameter, shown in figure 61.

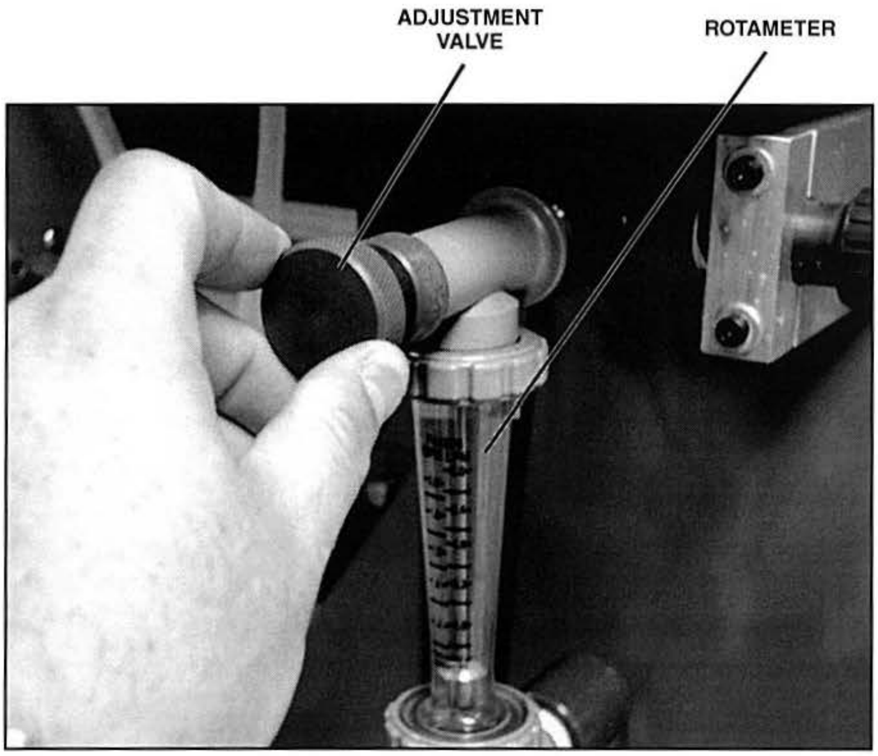

Figure 61. Adjustment Valve on Rotameter

E. Observe the operation of the system.

The controller should cause the metering pump to inject the base reagent into the water to neutralize the pH, measured at the outlet of the reactor tank. It will take several minutes for the system to neutralize the pH of the water.

F. Determine how long it takes the system to neutralize (pH = 7 ±0.1) the water.

Time to Neutralize pH ______________________________ (Min.)

It will take several minutes for the system to neutralize the water. The amount of time it takes depends on several factors. Two factors are the proportional gain setting of the controller and the percentage stroke length setting of the metering pump. Increasing either of those will allow the system to neutralize the water in less time.

G. When the pH of the water is neutralized, turn off the **CIRCULATION PUMP** and **AGITATOR MOTOR** selector switches.

H. Place the **Mode** selector switch on the metering pump in the **Standby** position.

I. Set the **Agitator Speed** control fully CCW.

J. Place the controller in the manual mode.

❑ 11. Perform the following substeps to shut down the T5554.

A. Turn off the main power circuit breaker for the T5554.

B. Disconnect the circuit.

SEGMENT 3 — SELF REVIEW

1. Continuous pH control is used in wastewater treatment applications in which the ______________ volume is too great for standard batch processing.

2. For a continuous pH control system, the reagent is injected as the solution continues to __________.

3. There are two basic configurations for continuous closed loop pH control: continuous in-line pH control and ______________________.

4. For continuous in-line pH control, a ______________ is placed between the injection point and the electrode.

5. Continuous in-line control actually provides more accurate pH control as long as system conditions remain ______________.

6. For continuous pH control, the controller needs __________ control loops if two reagent metering pumps are used.