ANALYTICAL PROCESS CONTROL

5

LEARNING ACTIVITY PACKET

pH ELECTRODES

AMATROL®

B33303-AB05AEN

pH ELECTRODES

INTRODUCTION

One of the most commonly controlled chemical properties is pH. The control of pH is prevalent in applications such as brewing, pharmaceuticals, petrochemical refining, and wastewater treatment.

To properly control pH, some method of measuring pH is required. This measurement is often accomplished using pH electrodes. This LAP covers the construction and operation of various electrodes used to measure pH.

ITEMS NEEDED

Amatrol Supplied
- T5554 Analytical Process Control Learning System

School Supplied
- pH Buffer Solutions (4, 7, and 10 pH)
- Distilled Water
- Squirt Bottle
- Vinyl Tape
- Electrode Storage Solution
- Multimeter
- pH Test Strips
- Small Beaker (250 mL)

FIRST EDITION, LAP 5, REV. A

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SEGMENT 1

MANUAL pH MEASUREMENT

OBJECTIVE 1 DEFINE pH AND EXPLAIN ITS IMPORTANCE

The term pH is an abbreviation of the Latin phrase pondus hydrogenii (English translation: hydrogen exponent). In theory, pH is a measure of the hydrogen ion activity within a solution. It is stated as the negative logarithm of hydrogen ion activity as follows:

$$pH = -log_{10} a_{H+}$$

In practice, pH is a measure of the level to which a solution is acidic or basic. Acidic solutions have a higher concentration of hydrogen ions, or a low pH. Basic or alkaline solutions have a lower concentration of hydrogen ions, or a high pH. To simplify things, a pH scale is used, as figure 1 shows.

The pH scale ranges from 0 to 14. A pH of 7 indicates that a solution is neutral (neither acidic nor basic).

pH RANGE

<table>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td colspan="4">Strongly Acidic</td><td colspan="3">Weakly Acidic</td><td>Neutral</td><td colspan="3">Weakly Basic</td><td colspan="4">Strongly Basic</td></tr>
</table>

Figure 1. pH Scale

The table in figure 2 shows the relationship between the pH scale and the actual hydrogen ion concentrations. For example, if the pH of a solution changes from 8 to 7, the hydrogen ion concentration increases by a factor of 10.

pH TO HYDROGEN ION H+ CONCENTRATION		
RANGE	**pH**	**H+ CONCENTRATION (mol/L)**
ACID	0	1
	1	0.1
	2	0.01
	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. Relationship Between pH Scale and Hydrogen Ion Concentrations

Safety is the primary concern when measuring and controlling pH. For example, industries that use water as part of their process are required to adjust the pH of their wastewater to a specified safe range before returning it to the environment. If the pH is low (acidic), the waste water can be corrosive to pipes, sewers, and pumps.

OBJECTIVE 2 DESCRIBE THE PROPERTIES OF ACIDIC, BASIC, AND NEUTRAL SOLUTIONS

Read This

The pH of any solution falls into one of three regions: acidic, basic (alkaline) or neutral.

Acidic Solutions

Acidic solutions have a pH less than 7, as figure 3 shows. Acidic solutions have the following characteristics:

- Change the color of acid-base indicators (blue to red)
- Release gaseous carbon dioxide when carbonate ions are added
- React with and neutralize a base
- React with and dissolve certain metals

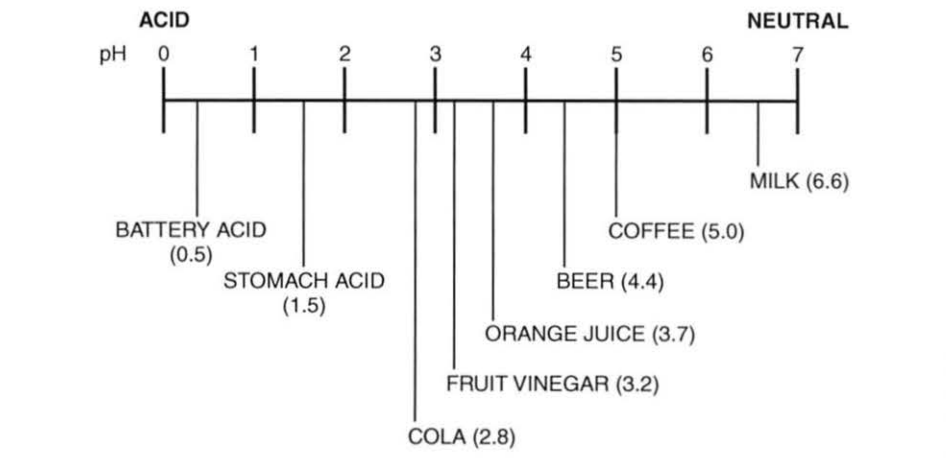

Figure 3. Acidic Solutions

Examples of acidic solutions include: orange juice, vinegar, colas, coffee, stomach acid, and battery acid.

Basic (Alkaline) Solutions

Basic or alkaline solutions have a pH greater than 7, as figure 4 shows. Basic solutions have the following characteristics:

- Soapy or slippery feeling to the touch (due to the base dissolving a layer of skin)
- Change the color of an acid-base indicator (red to blue)
- React with and neutralize an acid
- Create a precipitate when added to solutions containing certain metals

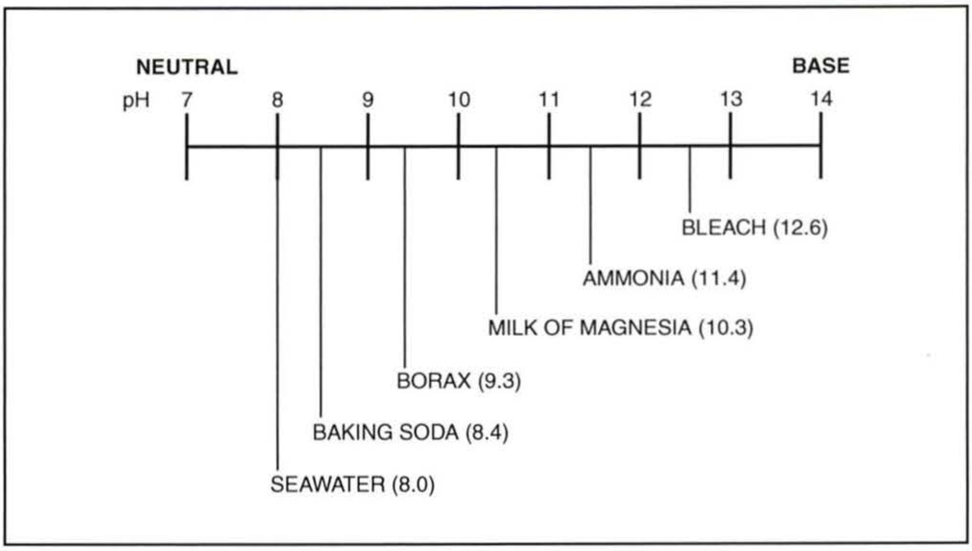

Figure 4. Basic Solutions

Examples of basic solutions include: ammonia, bleach, milk of magnesia, and seawater.

Neutral Solutions

A neutral solution has a pH of 7, as figure 5 shows. It has characteristics of neither an acid nor a base. In other words, it is neutral.

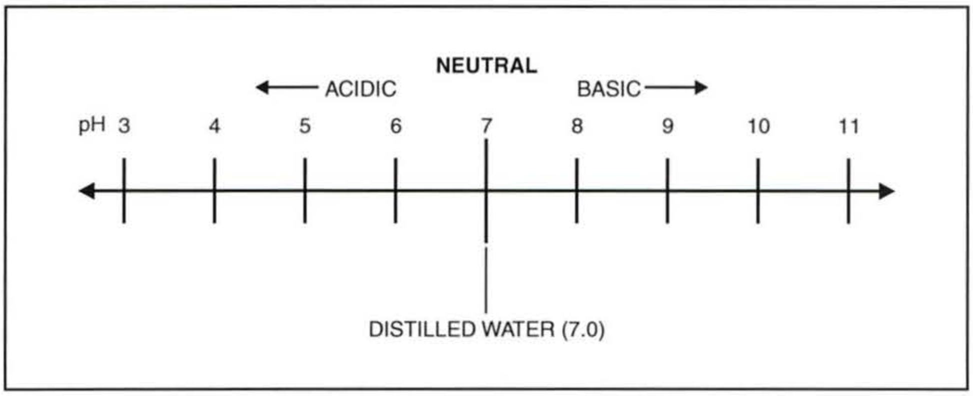

Figure 5. Neutral Solution Has a pH of 7

An example of a neutral solution is distilled water. Distilled water is often used to clean pH probes.

OBJECTIVE 3 DESCRIBE HOW TO MEASURE PH USING PH TEST STRIPS

Read This

One manual method of measuring pH is to use pH test strips, similar to the one shown in figure 6. The strips are designed to change color based on the pH of the solution in which they are dipped. The color indicates the approximate pH of the tested solution.

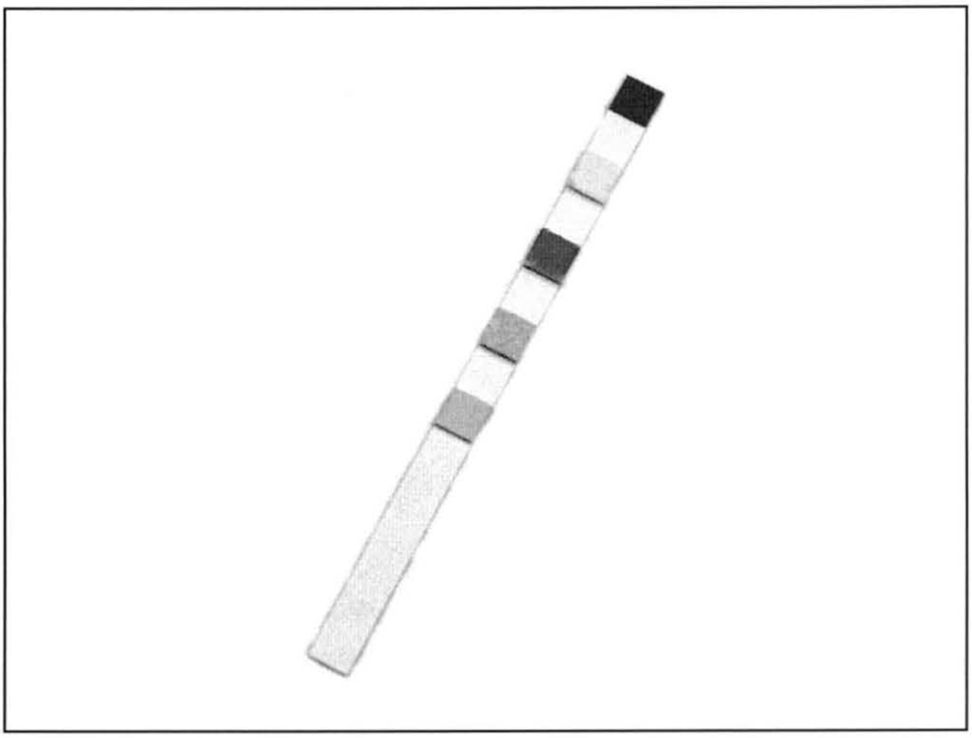

Figure 6. pH Strip

The steps to measure pH using a pH strip are:

Step 1: Acquire a test strip

Test strips often come in a container like the one in figure 7. Select one of the strips from the container. The strips are usually limited to a certain pH range. Therefore, it is important to make sure the strip has a large enough range for the solution being tested.

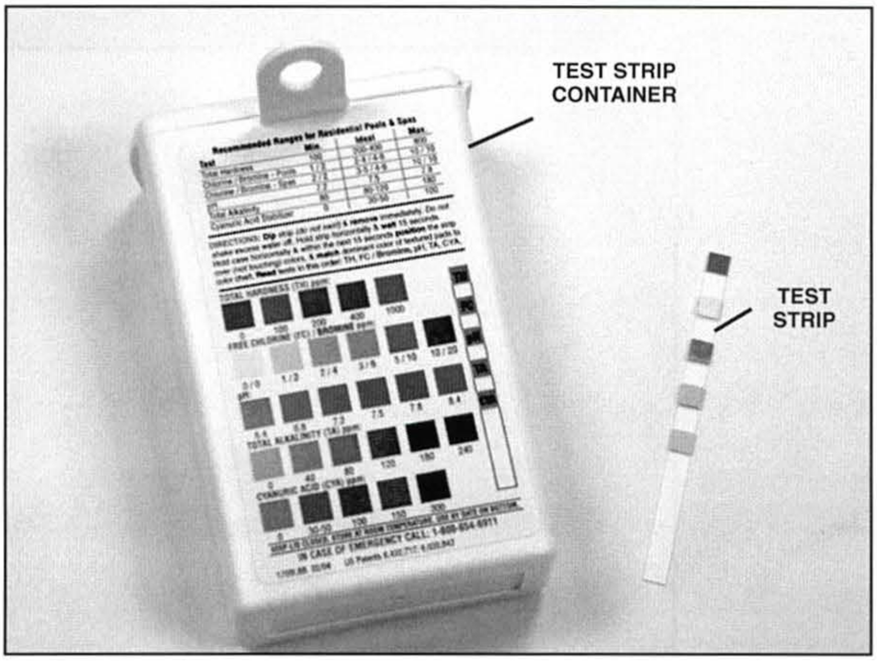

Figure 7. Test Strip Container

Step 2: Place the test strip in the solution

Place the test end of the strip in the solution for the recommended time on the pH strip container. Typically, this involves holding the strip in the solution by hand, as shown in figure 8.

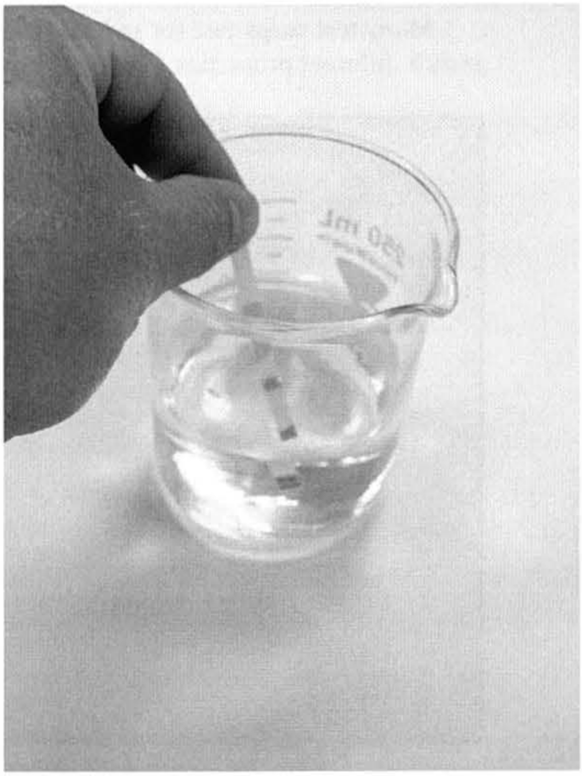

Figure 8. Test Strip Placed in Solution

Step 3: Remove the test strip and determine indicated pH

Once the recommended time has passed, remove the test strip from the solution. Locate the color chart that comes with the test strips, similar to figure 9. Compare the color on the test strip to the colors on the color chart, as figure 9 also shows, to determine the approximate pH value.

Many test strips test for several different properties. The test strip in figure 9 tests 5 different properties. The third row down is the pH chart.

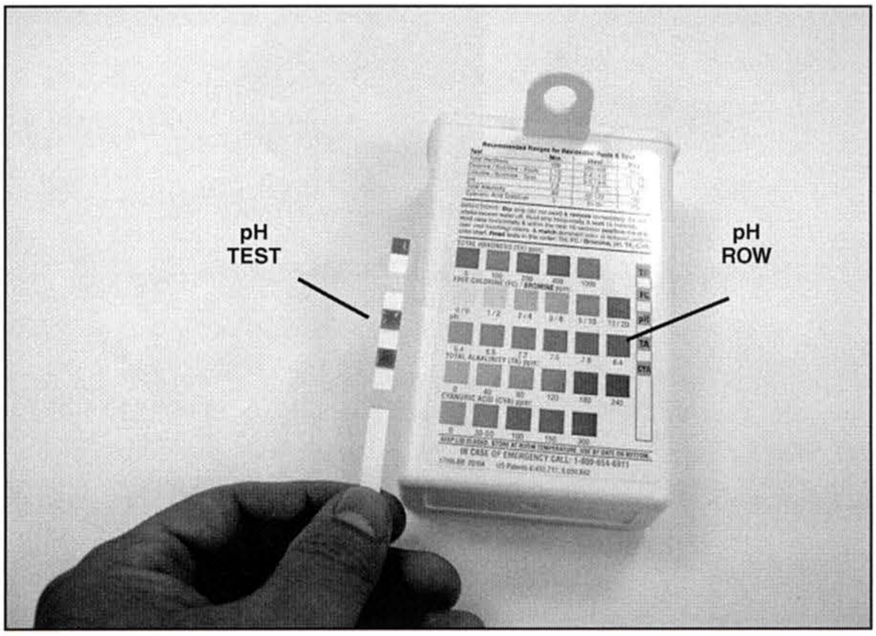

Figure 9. pH Test Strip and Color Chart

This method provides only an approximation of the actual pH level of the solution. Therefore, it is not a good choice when the application requires a high degree of accuracy.

Applications of pH strips include checking the pH of the water in swimming pools, hot tubs, and aquariums.

SKILL 1 TEST THE PH OF A SOLUTION USING PH TEST STRIPS

Procedure Overview

In this procedure, you will use pH test strips to test the pH of tap water and distilled water.

❑ 1. Locate the following items, shown in figure 10:
- pH test strip container
- Small beaker or container
- Bottle of distilled water
- Tap water source (not shown)

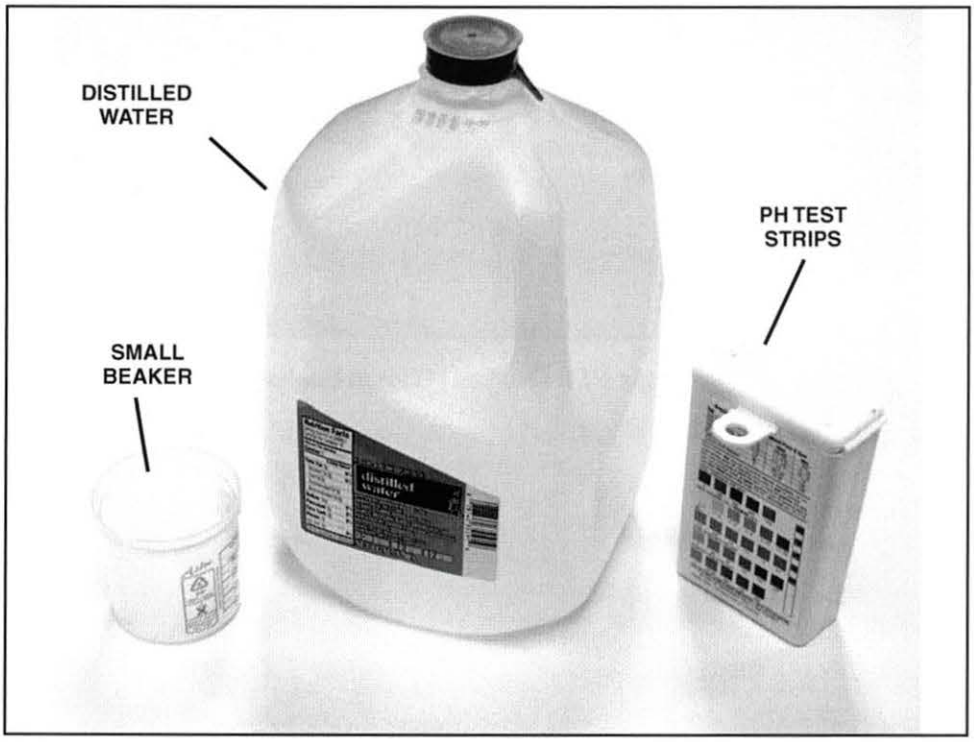

Figure 10. Items for pH Testing

❑ 2. Perform the following substeps to test the pH of distilled water with a test strip.

A. Take one test strip from the pH strip container.

B. Pour a small amount of the distilled water into the small beaker or container, similar to figure 11.

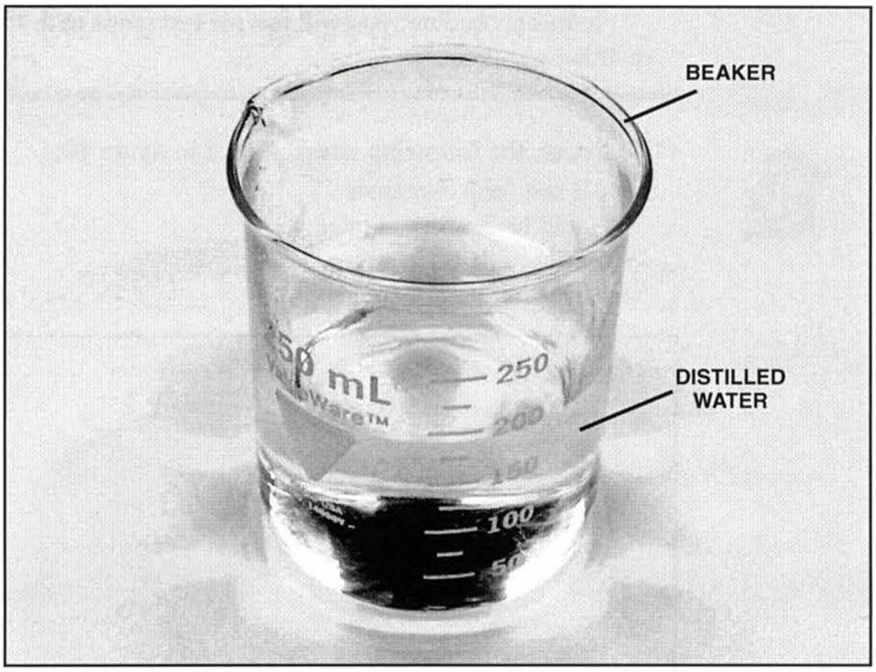

Figure 11. Distilled Water in Beaker

C. Take the pH test strip and dip it into the distilled water in the beaker/ container. Hold it there for about 10 seconds.

D. Compare the colors on the test strip with the color chart provided with the test strips, as figure 12 shows, and determine the indicated pH.

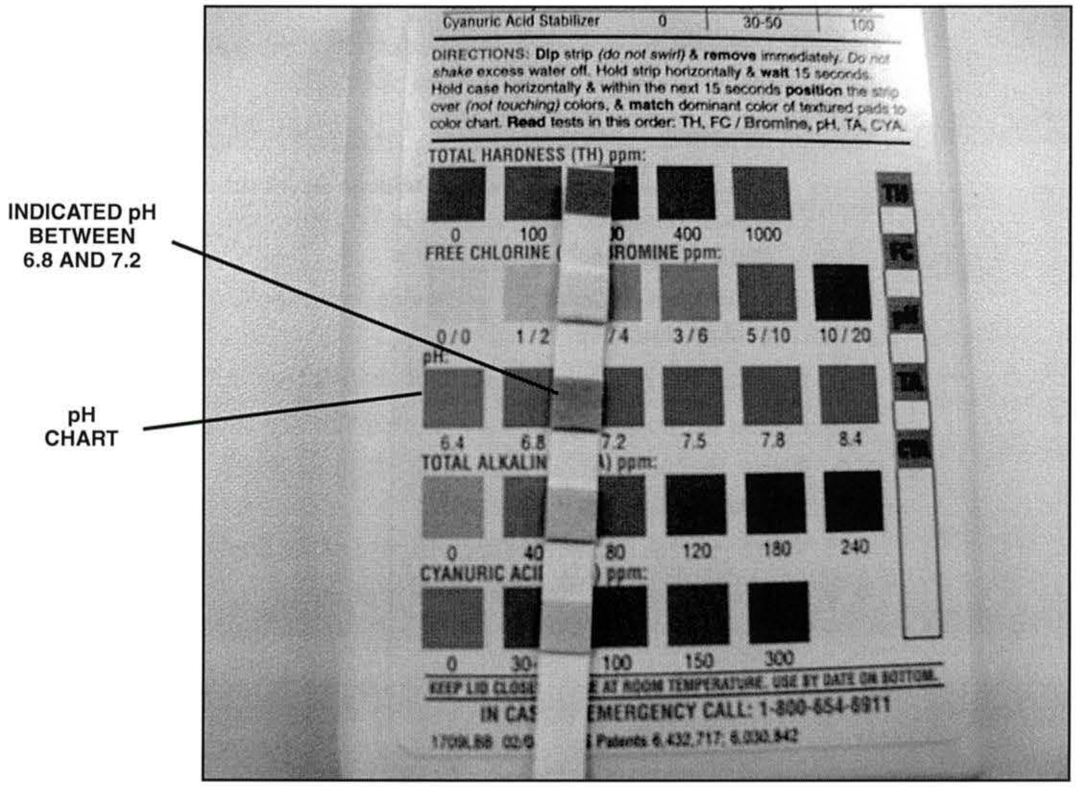

Figure 12. Compare Test Strip to Color Chart

Indicated ______________________________ pH

You should find the indicated pH of the distilled water is between 6.8 and 7.2 on the chart. That means that distilled water has a pH near 7 and is a neutral solution.

E. Place the used test strip to the side and dispose of the used distilled water in the beaker/container.

- ❑ 3. Perform the following substeps to test the pH of tap water with a test strip.
  - A. Take another test strip from the pH strip container.
  - B. Pour a small amount of the tap water into the small beaker or container.
  - C. Take the pH test strip and dip it into the tap water in the beaker/container. Hold it there for about 10 seconds.
  - D. Compare the colors on the test strip with the color chart provided with the test strips to determine the indicated pH.

    Indicated ____ pH

    The pH of tap water varies widely from one location to another. The typical range for tap water pH is 7-9. However, a pH greater than 9 is not that uncommon.
  - E. Place the used test strip to the side and dispose of the used tap water in the beaker/container.
  - F. Rinse the beaker/container with distilled water.
- ❑ 4. Repeat the procedure to test any other solution approved by your instructor.

  Rinse the beaker/container with distilled water between each different solution.
- ❑ 5. When you are finished testing, dispose of the used test strips.
- ❑ 6. Return all items to their proper storage locations.

SEGMENT 1

SELF REVIEW

1. pH is a measure of the level to which a solution is _______________ or basic.

2. The pH scale ranges from 0 to __________.

3. If the pH of a solution changes from 7 to 6, the hydrogen ion concentration increases by a factor of __________.

4. _______________ solutions have a pH less than 7.

5. _______________ solutions have a pH greater than 7.

6. An example of a neutral solution is ___________________.

7. pH ____________________ are designed to change color based on the pH of the solution in which they are dipped.

8. It is important to make sure a pH test strip has a large enough ________ for the solution being tested.

SEGMENT 2

pH GLASS ELECTRODES

OBJECTIVE 4 DESCRIBE THE FUNCTION OF THREE BASIC COMPONENTS NECESSARY TO AUTOMATICALLY MEASURE pH

Read This

A process that controls pH requires some means of measuring the pH of a solution. The process also requires a means of converting the pH measurement into an electrical signal that represents the pH. The three components necessary to measure and convert the pH measurement are: a pH electrode, a reference electrode, and a pH meter. These components are shown in figure 13.

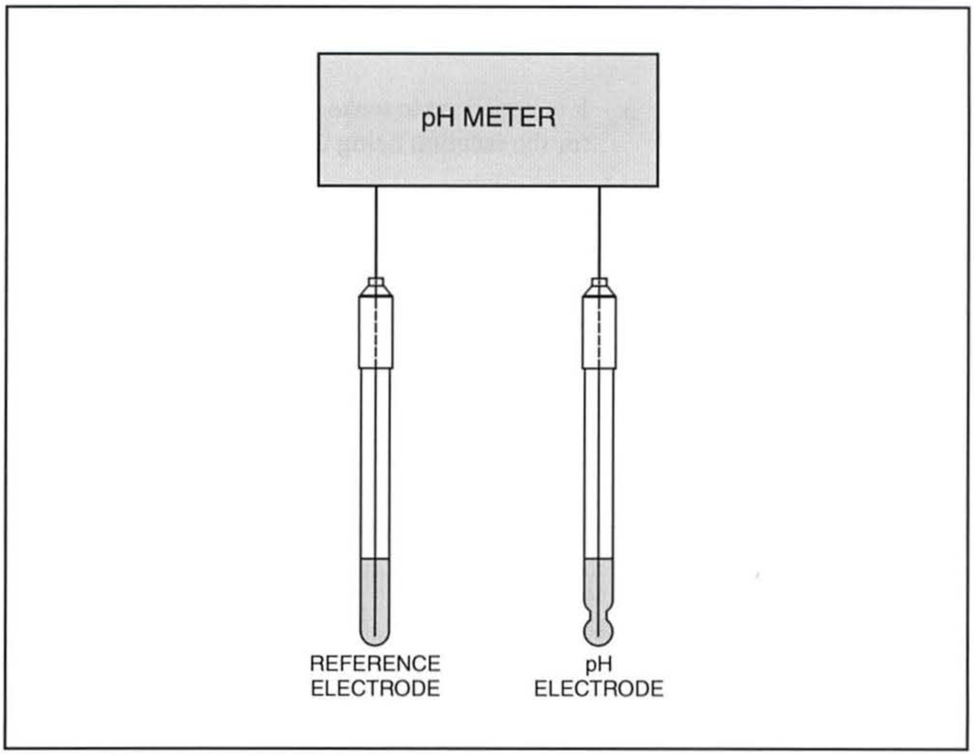

Figure 13. A pH Electrode, a Reference Electrode and a pH Meter

pH Electrode

The electrical potential of a pH electrode changes as the hydrogen ion concentration of a solution changes. Placing a pH electrode in an acidic solution causes hydrogen ions (H+) to diffuse into the electrode, as figure 14 shows. This results in a positive charge on the electrode.

Placing a pH electrode in a basic solution causes hydrogen ions (H+) to diffuse out from the electrode, as figure 14 also shows. This results in a negative charge on the electrode.

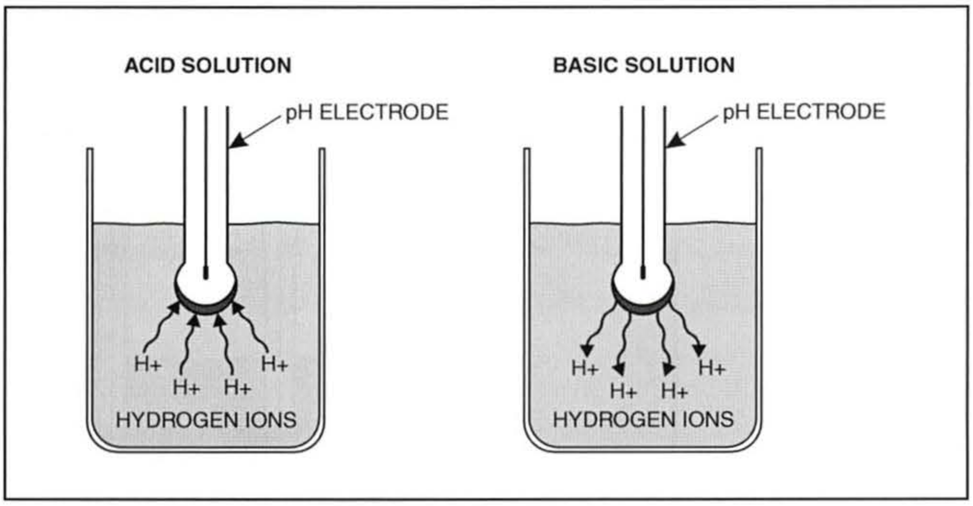

Figure 14. Diffusion of Hydrogen Ions to and from a pH Electrode

Reference Electrode

A reference electrode is much like a pH electrode except that its potential does not change, regardless of the pH of the solution. The reference electrode, as its name implies, provides a known and stable reference voltage against which the potential of the pH electrode is compared, as figure 15 shows. The potential (voltage) difference between pH electrode and the reference electrode represents the pH of the solution.

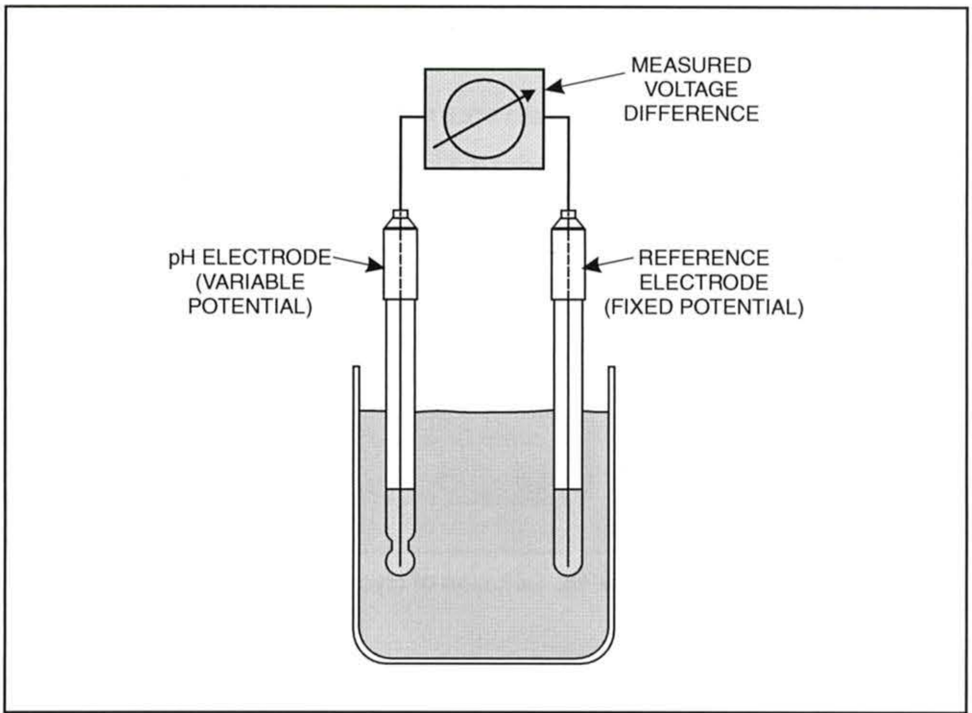

Figure 15. Reference Electrode Provides a Reference Voltage for the pH Electrode

pH Meter

A pH meter is a device that measures the difference in electrical potential between the pH electrode and the reference electrode, as figure 16 shows. This difference is measured in millivolts (mV).

A pH meter may also provide an analog output (e.g. 4-20mA) that is proportional to the pH measurement. This provides feedback to a control device.

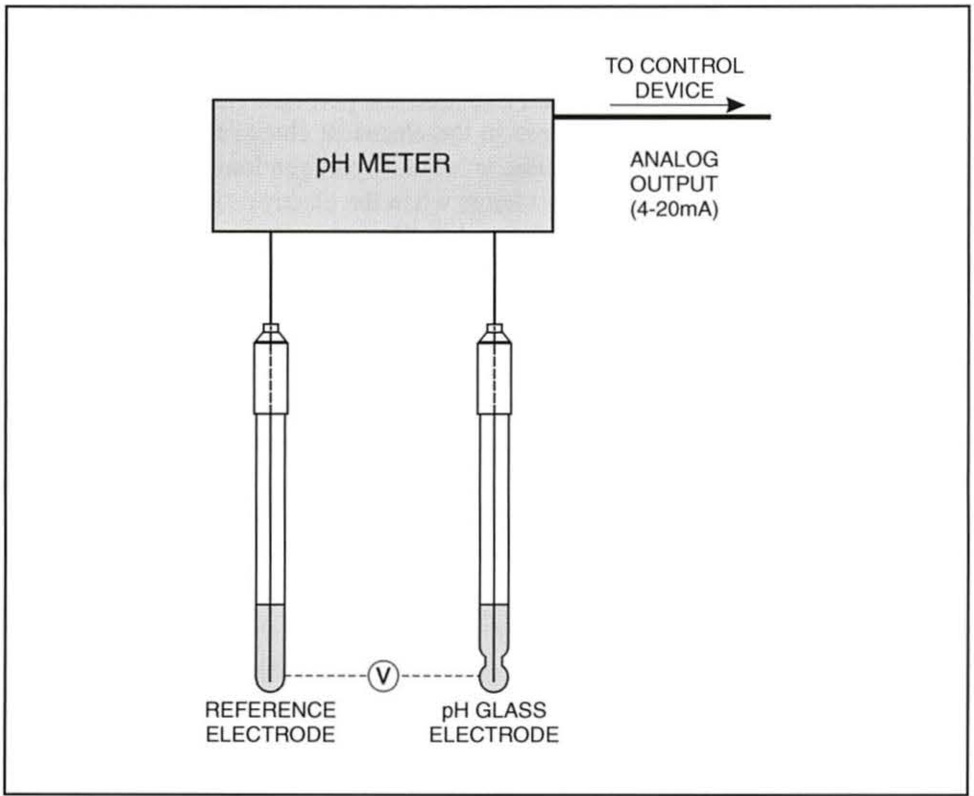

Figure 16. pH Meter Measures Potential (Voltage) Between the pH and Reference Electrodes

OBJECTIVE 5 DESCRIBE THE OPERATION OF A pH GLASS ELECTRODE

Read This

A standard pH electrode is typically enclosed in a glass or plastic tube. The basic components of a pH glass electrode, as shown in figure 17, are:

- **Glass or Plastic Body -** The body protects the wire element and isolates the inner buffer solution from the test solution. The glass used is a specially formulated glass that is especially sensitive to hydrogen ions.
- **Measurement Element -** This wire element measures the electrical potential and transmits the potential (mV) to the pH meter. The element senses an increase in the electrical charge that results from placing the electrode into an acidic solution (hydrogen ions enter electrode). It also senses a decrease in the charge when the electrode is placed in a basic solution (hydrogen ions exit electrode). The wire element is typically made of silver (Ag) with a silver chloride (Ag/CI) coating at the end where it is immersed in the inner buffer solution.
- **Inner Buffer Solution -** The inner buffer solution is a chloride buffer solution that has a stable pH of 7 (neutral).
- **Membrane** - The membrane is located at the tip of the electrode housing. The membrane is chemically doped with lithium ions. This makes the membrane especially sensitive to hydrogen ions and allows the hydrogen ions to easily pass into and out of the electrode.

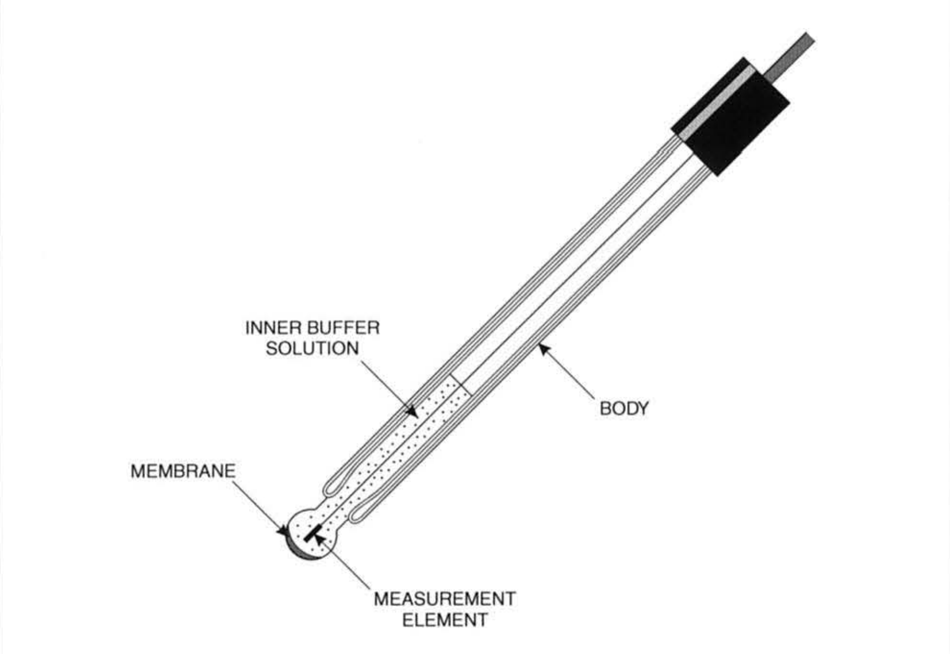

Figure 17. Basic Construction of a pH Electrode

Electrode Operation

Once the pH electrode is placed into a solution, a gel layer forms on the outside of the membrane, as figure 18 shows. A second gel layer forms on the inside of the membrane (the side of the membrane in contact with the buffer solution), as figure 18 also shows. The gel layers form due to the build up of hydrogen ions in those regions. Positively charged hydrogen ions diffuse either into or out of the outer gel layer, depending on whether the solution is basic or acidic.

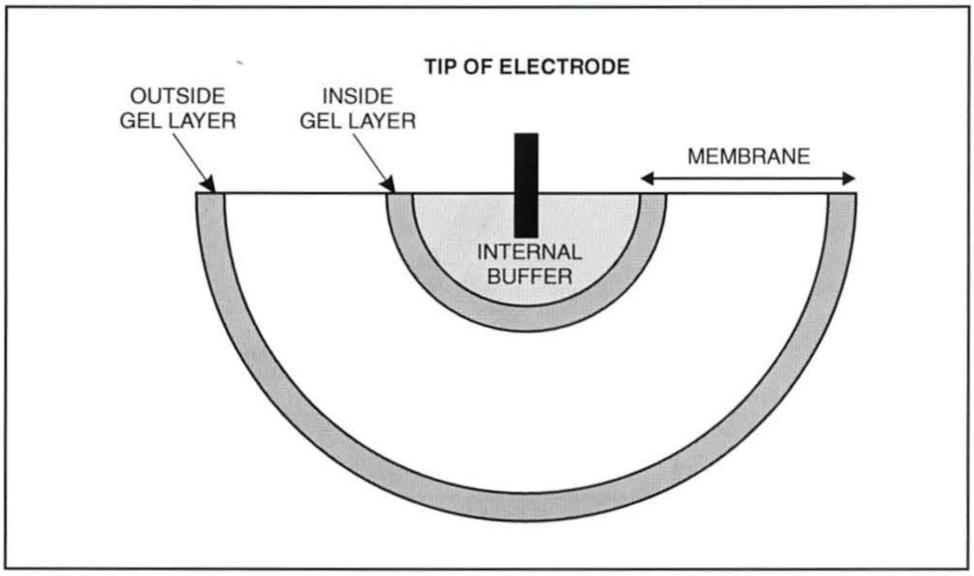

Figure 18. Gel Layers Develop on Membrane when Electrode Placed in a Solution

If the solution is basic, hydrogen ions (H+) diffuse out of the outside gel layer, as figure 19 shows. This results in a negative potential between the outer gel layer and the inner gel layer, since the inner gel layers charge is held constant by the inner buffer solution (stable pH of 7). Therefore, basic solutions result in negative potentials.

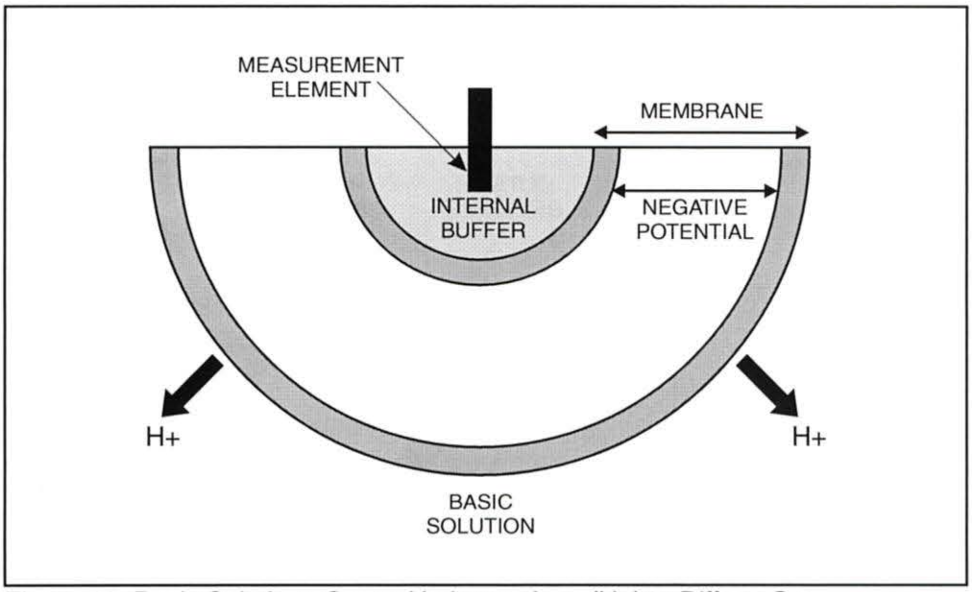

Figure 19. Basic Solutions Cause Hydrogen Ions (H+) to Diffuse Out

In an acidic solution, hydrogen ions diffuse into the outside gel layer, as figure 20 shows. This creates a positive potential between the outer gel layer and the inner gel layer. Therefore, acidic solutions result in positive potentials.

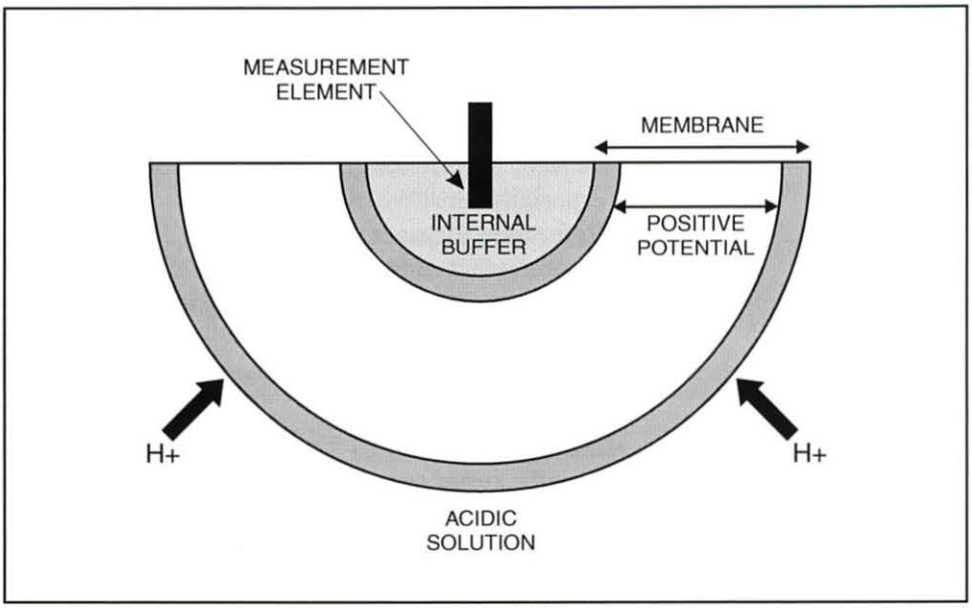

Figure 20. Acidic Solutions Cause Hydrogen Ions to Diffuse In

If the solution has a pH of 7 (neutral), there is no diffusion of hydrogen ions. Therefore, the potential is zero. The following table better shows the relationship between pH and potential.

pH/Potential Relationship		
SOLUTION	**pH**	**POTENTIAL (mV)**
Acidic	< 7	Positive
Neutral	= 7	Zero (0)
Basic	> 7	Negative

The wire element senses the potential and supplies the reading to a pH meter.

OBJECTIVE 6 DESCRIBE THE OPERATION OF A REFERENCE GLASS ELECTRODE

Read This

A reference electrode has a slightly different construction and operation than a pH electrode. The basic components of a reference electrode, as shown in figure 22, are:

- **Glass or Plastic Body -** As with the pH electrode, the body protects the wire element and isolates the inner solution from the test solution. The glass is especially sensitive to hydrogen ions.
- **Reference Element -** The reference element serves the same purpose as the measurement element in the pH electrode. It, too, is most often made of silver wire coated with silver chloride at the end.
- **Electrolyte Solution -** The electrolyte solution, typically potassium chloride (KCI), is used in reference electrodes because an electrolyte solution easily conducts electricity.
- **Reference Junction -** The reference junction is made of a porous material (usually either ceramic or plastic). This junction allows only very limited interaction between the electrolyte solution and the measured solution.
- **Refill Opening -** Most reference electrodes include an opening that allows you to add more electrolyte solution when necessary.

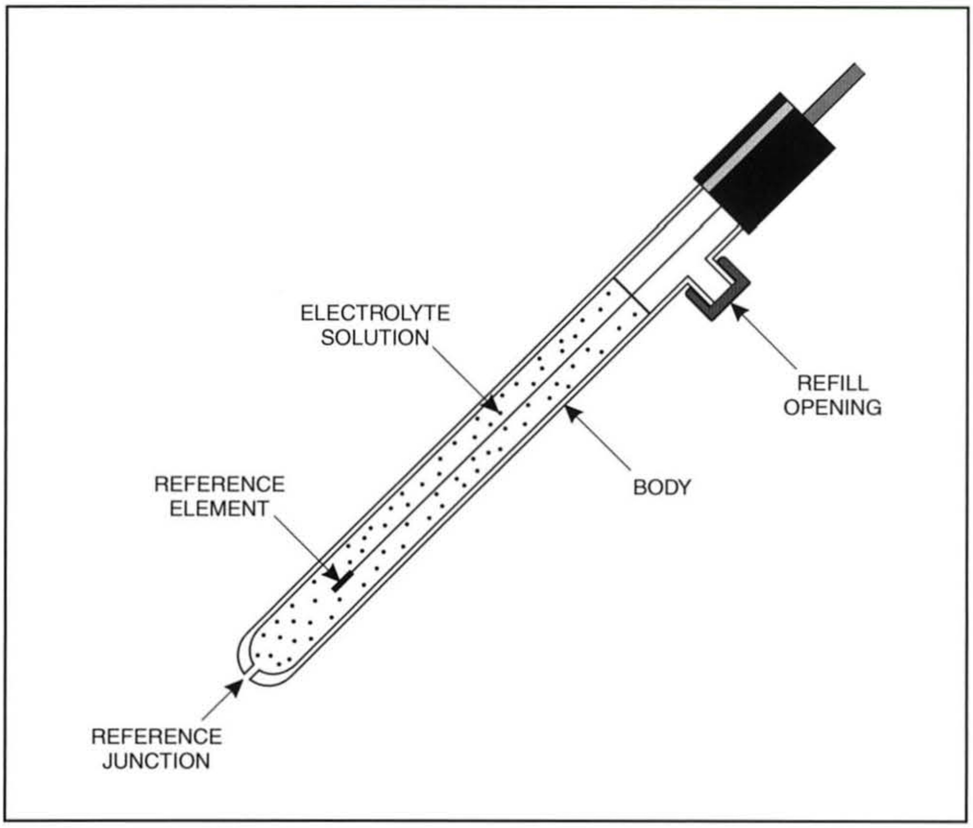

Figure 22. Basic Construction of a Reference Electrode

The contact between the reference electrodes electrolyte solution and the measured solution through the reference junction in effect completes the electrical circuit between the pH electrode and the reference electrode. The two electrodes (pH and reference) form a basic galvanic cell (i.e. like a car battery cell), as figure 23 shows. The pH of the solution determines the voltage level between the electrodes.

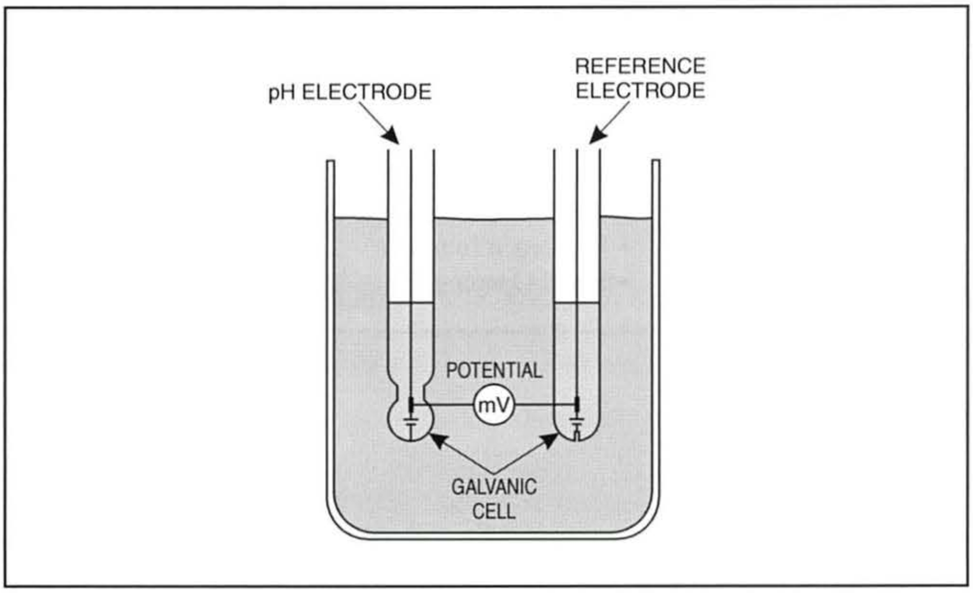

Figure 23. The Electrodes Form a Galvanic Cell

OBJECTIVE 7 DESCRIBE THE OPERATION OF A COMBINATION GLASS ELECTRODE

Read This

A combination electrode, as its name implies, is a combination of a pH electrode and a reference electrode in one housing, as figure 24 shows. The basic components of a combination electrode are:

- Glass or Plastic Body
- Measurement Element
- Inner Buffer Solution
- Membrane
- Reference Element
- Reference Electrolyte Solution
- Reference Junction
- Refill Opening

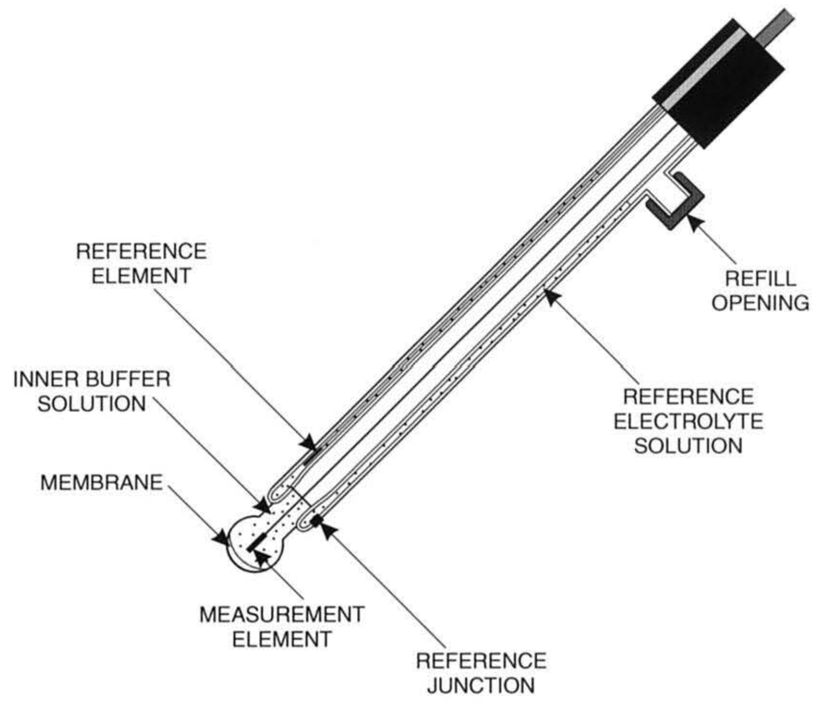

Figure 24. Basic Construction of a Construction Electrode

Figure 24 shows that the reference electrolyte solution surrounds the pH measurement element. The measurement element and the reference element are made of the same material, silver (Ag) and silver chloride (Ag/CI). Typically, the inner buffer and reference electrolyte solutions are as close as possible. Both are saturated with potassium chloride (KCI).

When the combination electrode is placed in a solution, the pH of the solution creates a measurable potential (mV) between the measurement element and the reference element, as figure 25 shows. The combination probe supplies this potential to a pH meter.

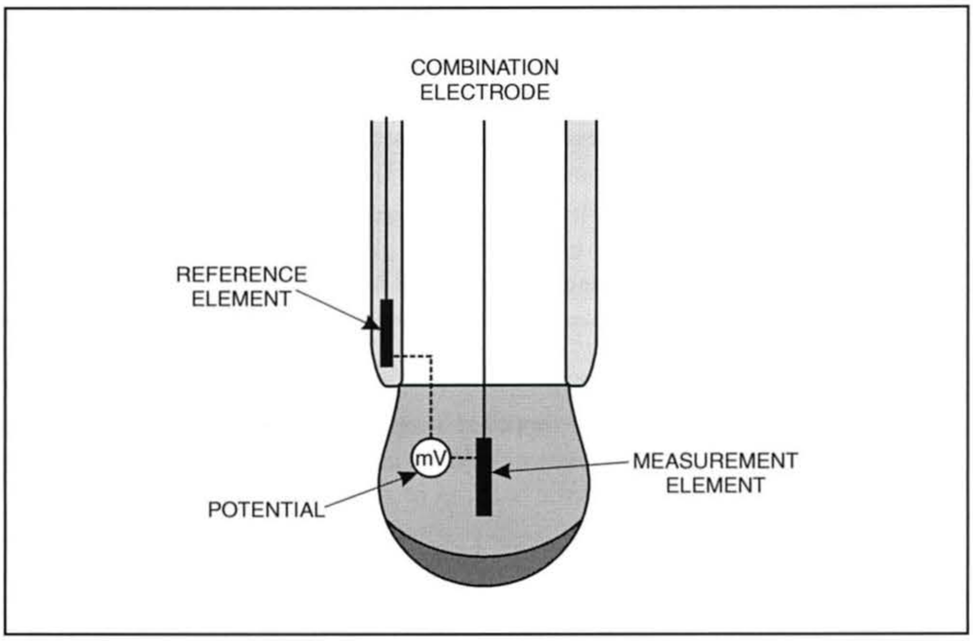

Figure 25. Measurable Potential between the Elements

Most of todays applications use combination electrodes since they are easier to handle. In addition, temperature affects the pH measurement. Therefore, having the two elements close together inside the same housing helps to minimize the effects of temperature differences on the pH measurement.

SKILL 2 MEASURE THE OUTPUT OF A COMBINATION GLASS ELECTRODE WITH A MULTIMETER (OPTIONAL)

Procedure Overview

In this procedure, you will measure the output of a combination glass electrode with a multimeter by placing the electrode in solutions with various pH levels. For this procedure, you will need distilled water and two buffer solutions (4 and 10 pH).

This skill is optional and may be skipped if you do not have a combination glass electrode. The glass electrode is included in the optional T5554-A1 Advanced pH Control Module.

❑ 1. Locate a combination glass electrode, like the one shown in figure 26.

The optional combination glass electrode provided with the T5554 is a Honeywell Meridian II combination electrode, shown in figure 26. A hard plastic housing protects the electrode.

The sensing bulb is exposed on one end. On the other end, a yellow housing protects the electrodes edge connector. The edge connector allows the indicating transmitter to be connected to the electrode.

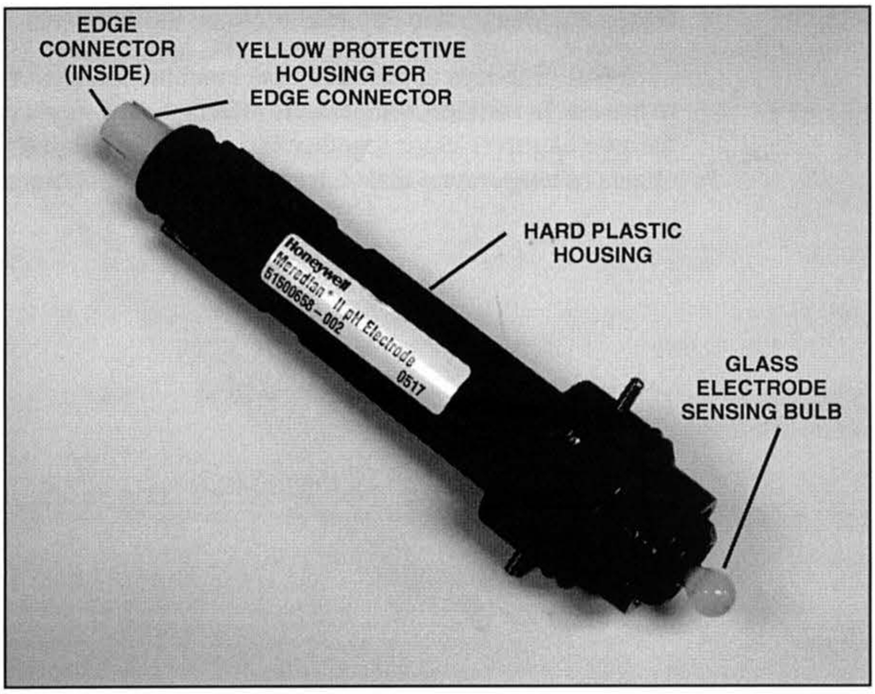

Figure 26. The Honeywell Meridian II Combination Glass Electrode

❑ 2. If the combination glass electrode is currently connected to the T5554, perform the following substeps to remove the electrode.

A. If the indicating transmitter is attached to the electrode, as shown in figure 27, turn the locking screw on back counterclockwise to loosen it and remove the indicating transmitter by gently pulling up on it.

The indicating transmitter simply snaps onto the top of the electrode and should easily come off when you pull up on it, as long as the locking screw is not engaged.

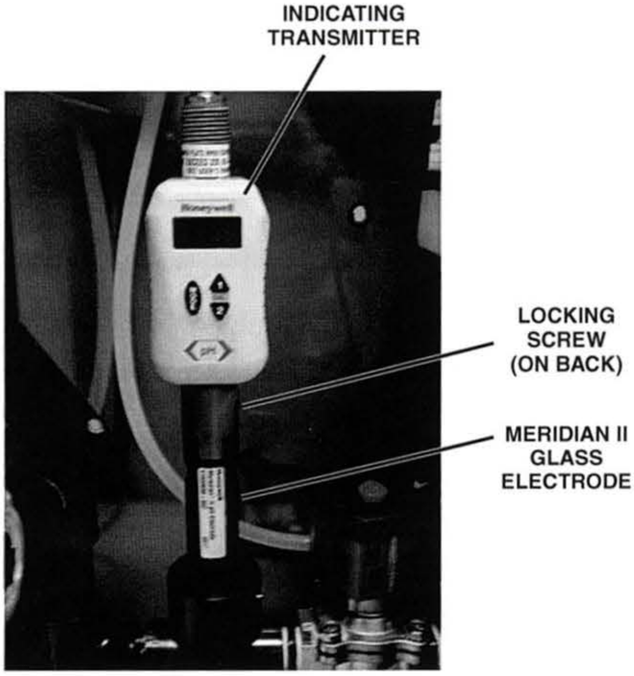

Figure 27. Indicating Transmitter Connected to Electrode

The electrode is mounted in a bayonet-type fitting. To remove the electrode, you must turn the electrode counterclockwise and then lift the electrode from the fitting.

B. If the reactor tank is filled with water, turn on the main circuit breaker and place the **TANK INLET SOL. VALVE** selector switch in the **ON** (turn CW) position.

This will close the tank inlet solenoid valve, which is normally open, and prevent water from escaping the tank through the inlet solenoid valve.

NOTE

If you do not close the tank inlet solenoid valve when the reactor tank is filled, a large amount of water will leak out of the open fitting when the electrode is removed.

C. Turn the electrode counterclockwise so that the studs on the electrode housing are released from the locking channels, as shown in figure 28.

This allows the electrode housing to be lifted up and out of the fitting.

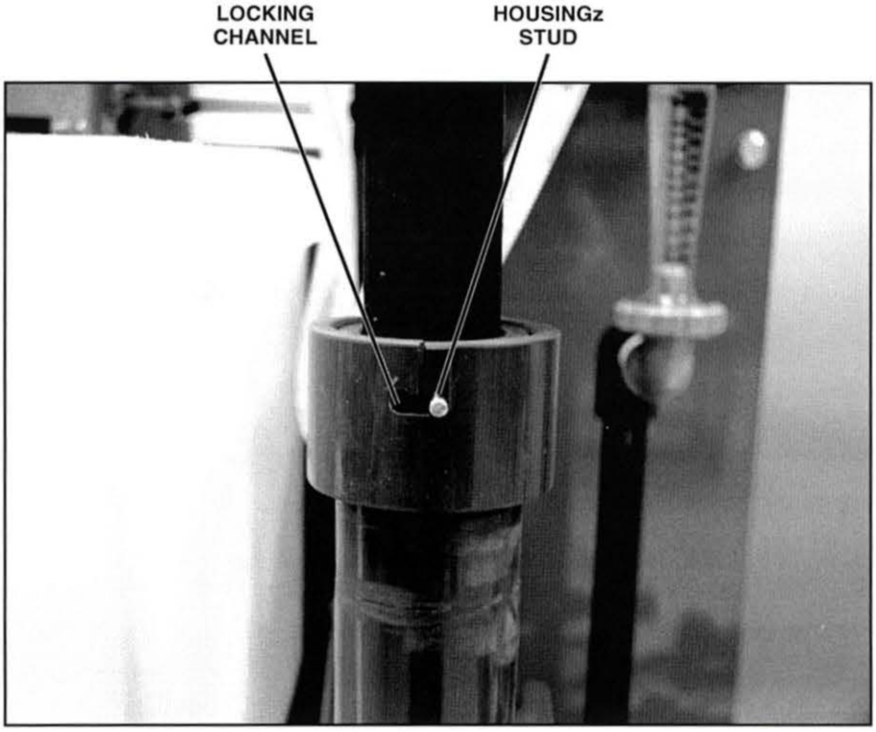

Figure 28. Electrode Housing Studs Released from Locking Channels

D. Pull the electrode housing straight up and out of the fitting, as shown in figure 29.

The fit is extremely tight and requires you to rock the electrode housing back and forth as you lift it. However, be careful that you do not flex the housing so much that you break the electrode housing.

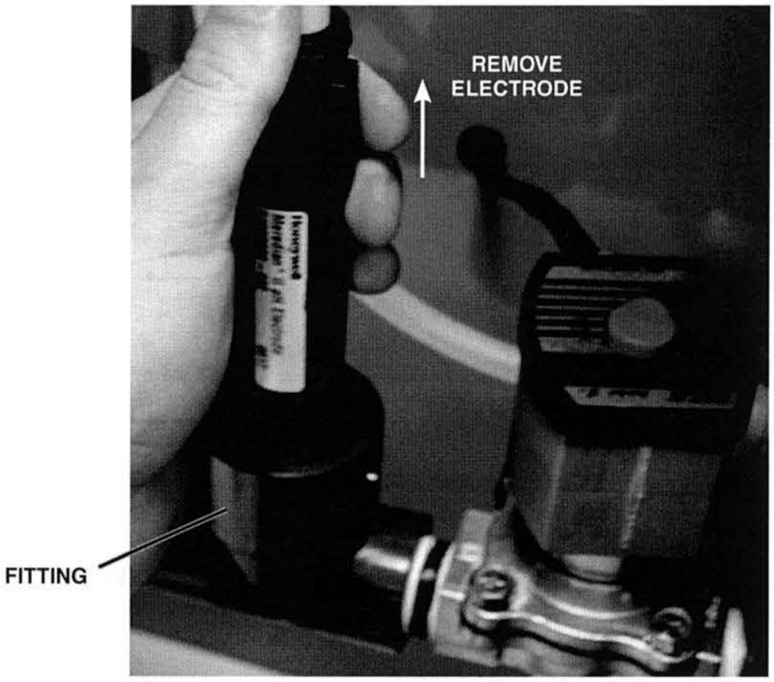

Figure 29. Removing Electrode Housing from the Fitting

❑ 3. Locate a digital multimeter, similar to figure 30, and set it to measure DC volts at the lowest range setting.

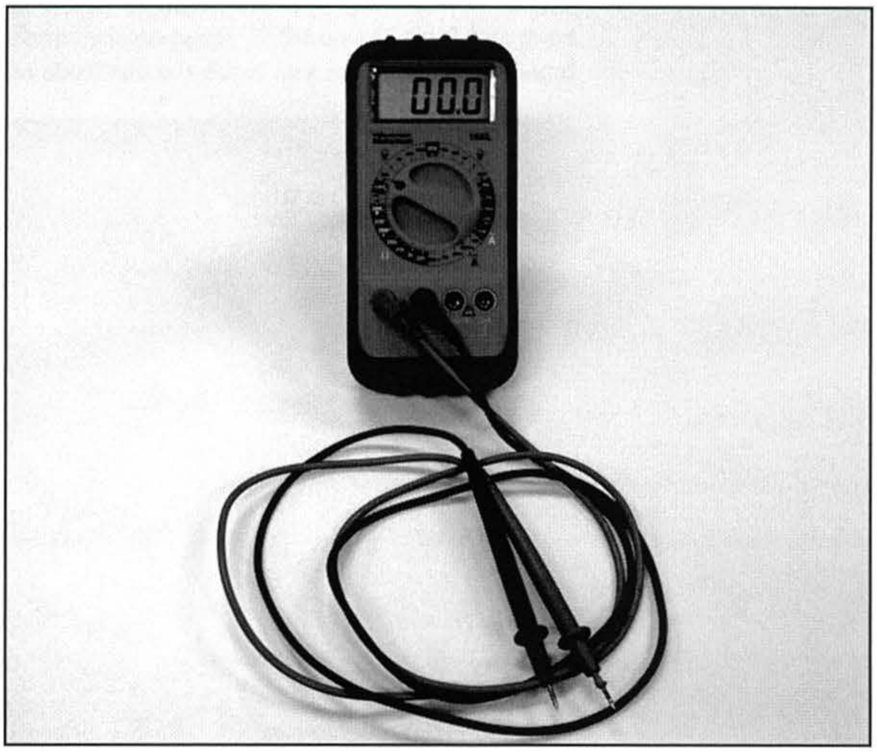

Figure 30. A Digital Multimeter

❑ 4. Perform the following substeps to measure the output of the electrode in distilled water using the digital multimeter.

A. Locate a clean container, such as the beaker shown in figure 31, and fill it about 1/4 full with distilled water.

Remember that distilled water has a pH of approximately 7, which should result in a potential (voltage) near zero.

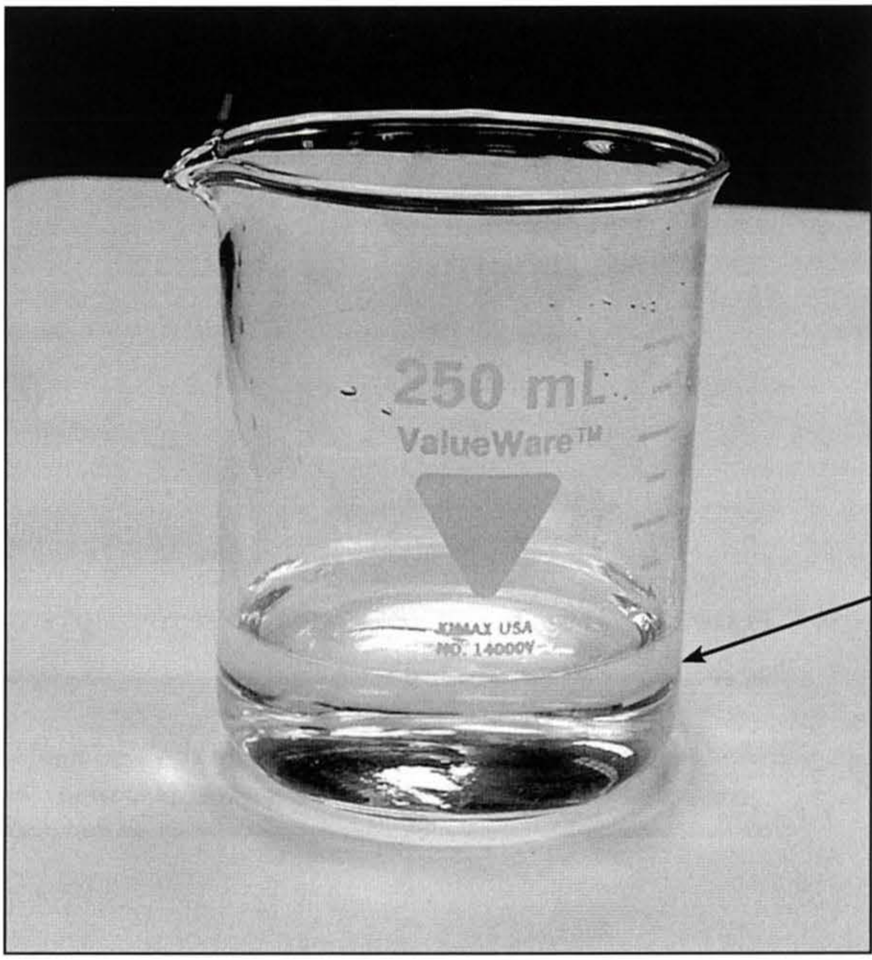

Figure 31. Container 1/4 Filled with Distilled Water

B. Place the electrode into the distilled water, as shown in figure 32, and leave it there for approximately 2 minutes.

This gives the electrode time to stabilize, which results in a more reliable reading.

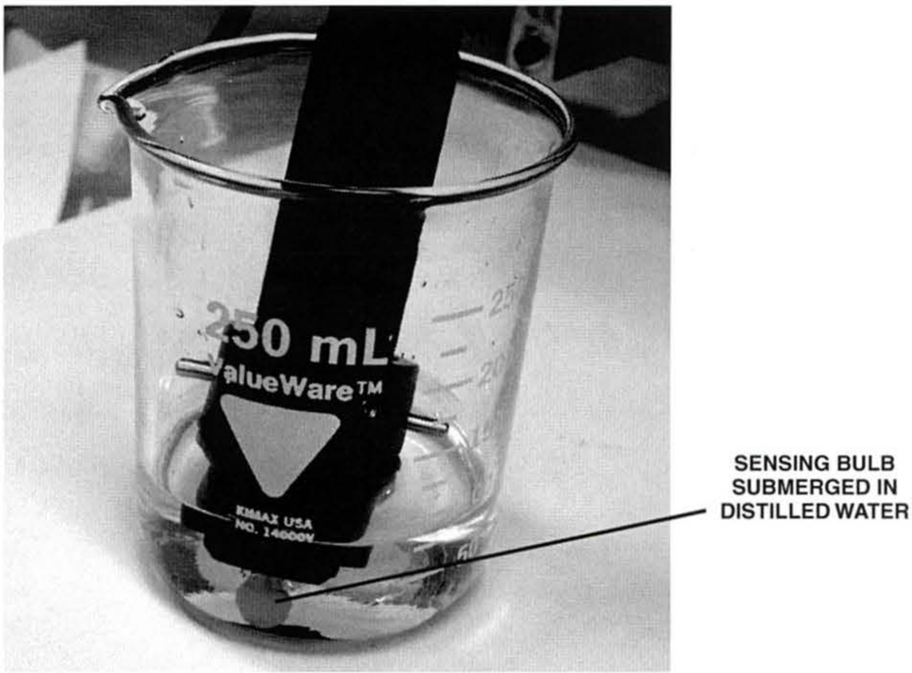

Figure 32. Electrode Placed in Distilled Water

NOTE

Be careful not to touch the sensing bulb with your fingers. Touching the sensing bulb will contaminate the bulb and could eventually lead to damage.

C. Unscrew and remove the yellow plastic protective housing from around the electrodes edge connector, as shown in figure 33. You must turn the yellow plastic housing counterclockwise to unscrew it.

This allows you easy access to the edge connector to make your measurements.

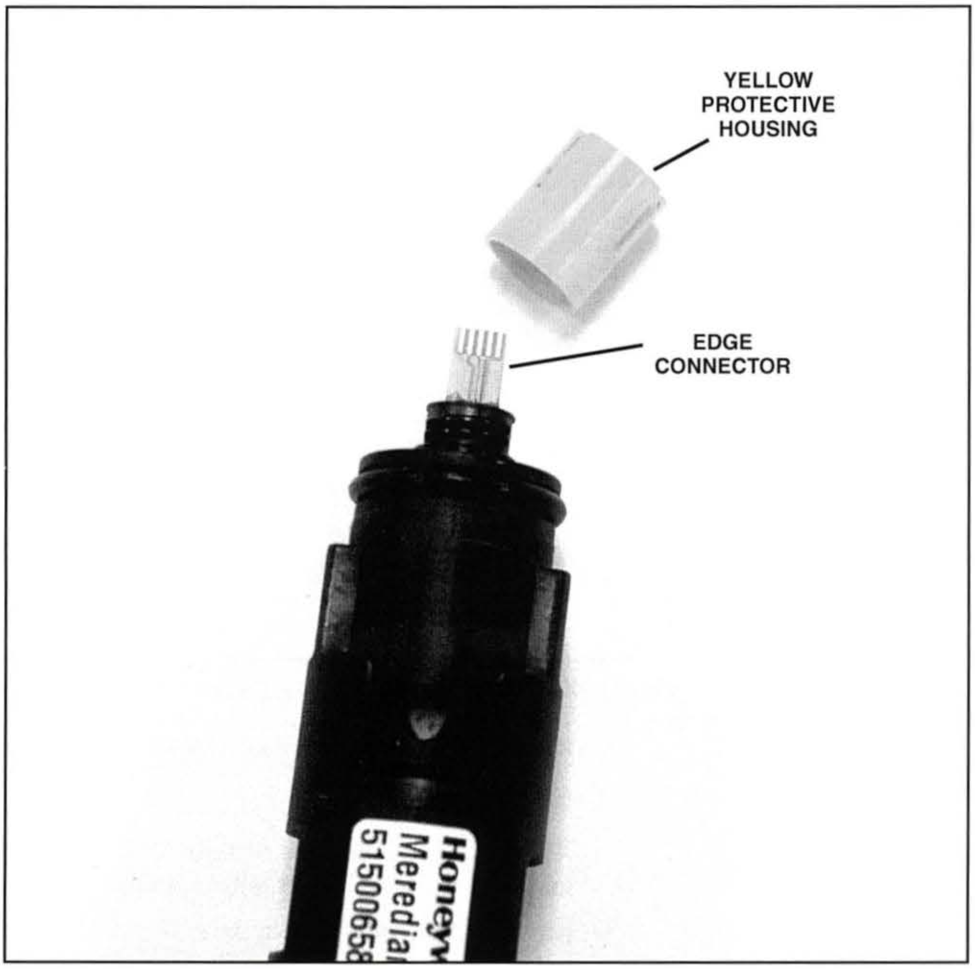

Figure 33. Yellow Plastic Protective Housing Removed

D. Turn the electrode so that the side of the edge connector that has a tab in front of it is accessible, as shown in figure 34.

E. After 2 minutes, measure the potential (voltage) using the multimeter, as shown in figure 34.

Measure across the second and third traces from the right on the edge connector, as figure 34 shows. Be careful not to touch the meter probe tips with your fingers, as this will affect the measurement.

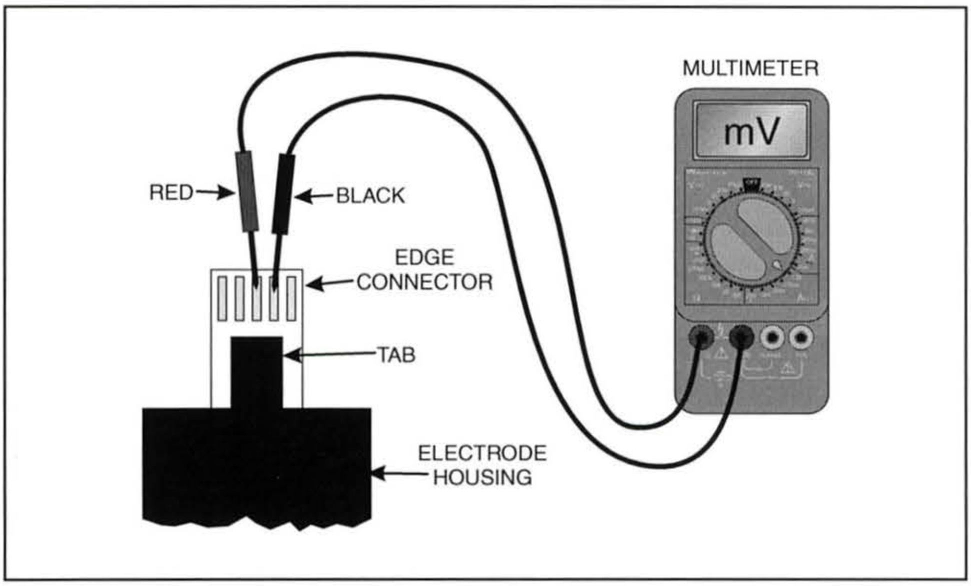

Figure 34. Measuring Potential (Voltage) at Edge Connector with Multimeter

F. Record the DC voltage reading from the multimeter.

DC Voltage Reading ______________________ (mV)

You should find that the voltage reading is very near zero. However, it may vary a few millivolts, either positive or negative.

G. Remove the electrode from the distilled water and pour the distilled water out of the container.

❑ 5. Perform the following substeps to measure the output of the electrode in a 4 pH buffer solution using the digital multimeter.

A. Now fill the container about 1/4 full with the 4 pH buffer solution.

B. Place the electrode into the buffer solution and leave it there for approximately 2 minutes.

C. After 2 minutes, measure the DC potential (voltage) using the multimeter and record the reading.

DC Voltage Reading ______________________ (mV)

You should find that the voltage reading is positive since the solution is acidic (pH less than 7).

D. Remove the electrode from the 4 pH solution and rinse the sensing bulb of the electrode with distilled water, as shown in figure 35.

It is best to clean the sensing bulb by pouring or squirting the distilled water on it. Then, dab the sensing bulb dry using a paper towel or soft cloth. DO NOT rub the sensing bulb as it could damage the membrane and ruin the electrode.

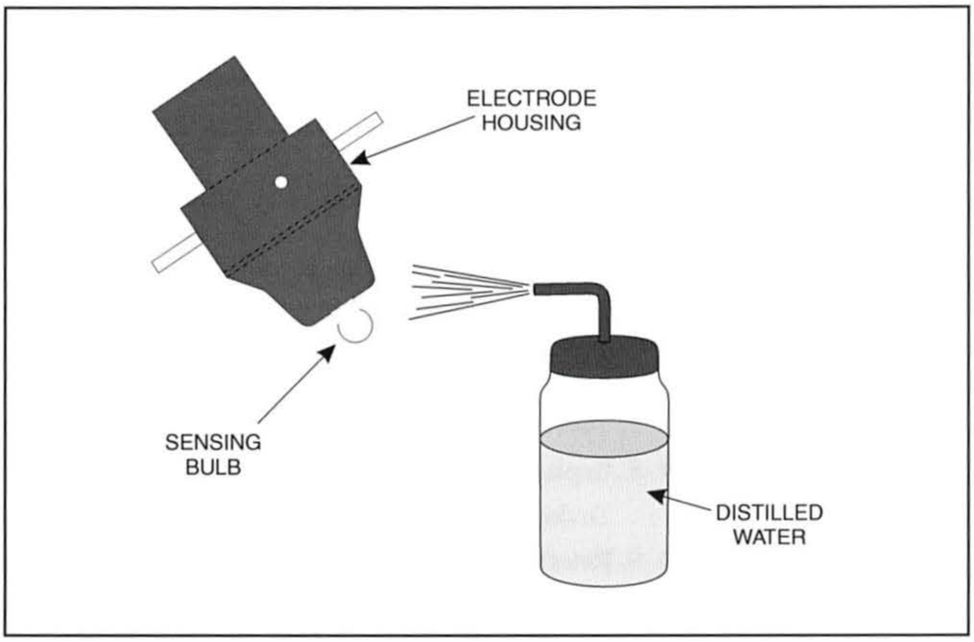

Figure 35. Rinsing Electrode Sensing Bulb with Distilled Water

E. Pour out and discard the 4 pH solution. Do not pour the used buffer solution back into the buffer solution container. Rinse the container with distilled water.

❑ 6. Perform the following substeps to measure the output of the electrode in a 10 pH buffer solution using the digital multimeter.

A. Now fill the cleaned container about 1/4 full with the 10 pH buffer solution.

B. Place the electrode into the buffer solution and leave it there for approximately 2 minutes.

C. After 2 minutes, measure the DC potential (voltage) using the multimeter and record the reading.

DC Voltage Reading ________________________________ (mV)

You should find that the voltage reading is negative since the solution is basic (pH less greater than 7).

D. Remove the electrode from the 10 pH solution and rinse the sensing bulb of the electrode with distilled water. Pat the bulb dry with a paper towel or soft cloth.

E. Pour out and discard the 10 pH solution. Do not pour the used buffer solution back into the buffer solution container. Rinse the container with distilled water.

❑ 7. Turn off the multimeter and return to the proper storage location.

❑ 8. Replace the yellow protective housing around the edge connector.

To do so, screw the housing back on in a clockwise direction.

❑ 9. Return the glass container to the proper storage area.

❑ 10. If the reactor tank is filled, leave the main circuit breaker on and the tank inlet solenoid valve closed (TANK INLET SOL. VALVE selector switch ON).

Leave the combination glass electrode disconnected from the T5554. In the next skill, you will install the electrode in the process.

SKILL 3 INSTALL AND CONNECT A COMBINATION GLASS ELECTRODE (OPTIONAL)

Procedure Overview

In this procedure, you will install the combination glass electrode on the T5554 Analytical Process Control System and connect the indicating transmitter.

This skill is optional and may be skipped if you do not have a combination glass electrode which is part of the optional T5554-A1 Advanced pH Control Module.

Do This

❑ 1. Locate the optional combination glass electrode provided with the T5554, shown in figure 36.

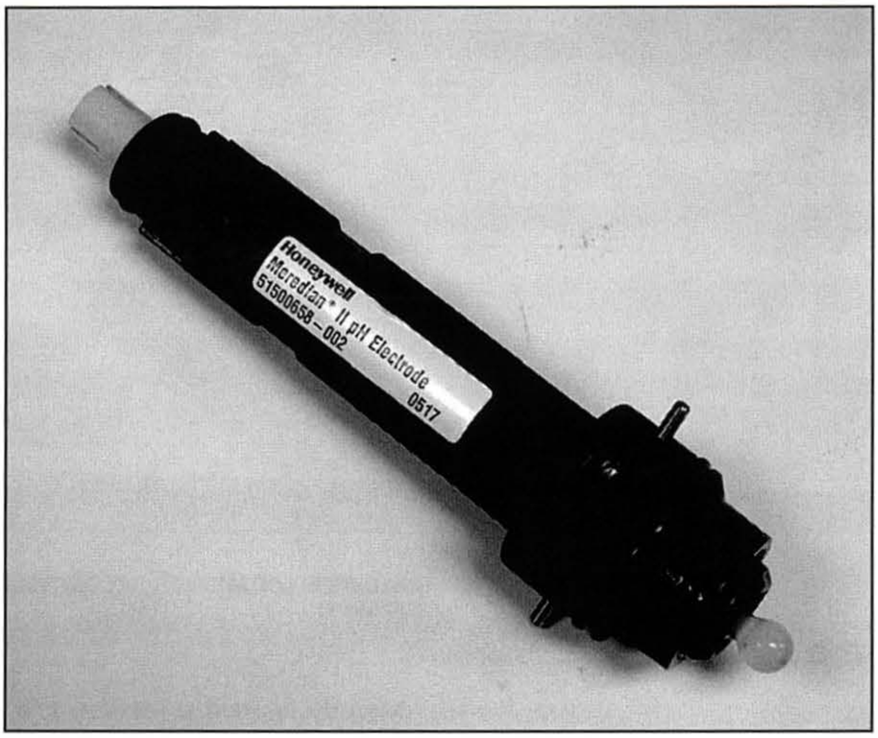

Figure 36. Optional Combination Glass Electrode

❏ 2. Determine a location to install the electrode on the T5554.

The T5554 has three different locations to install an electrode, as identified in figure 37. You will be installing the electrode at the inlet of the reactor tank (LOCATION 1).

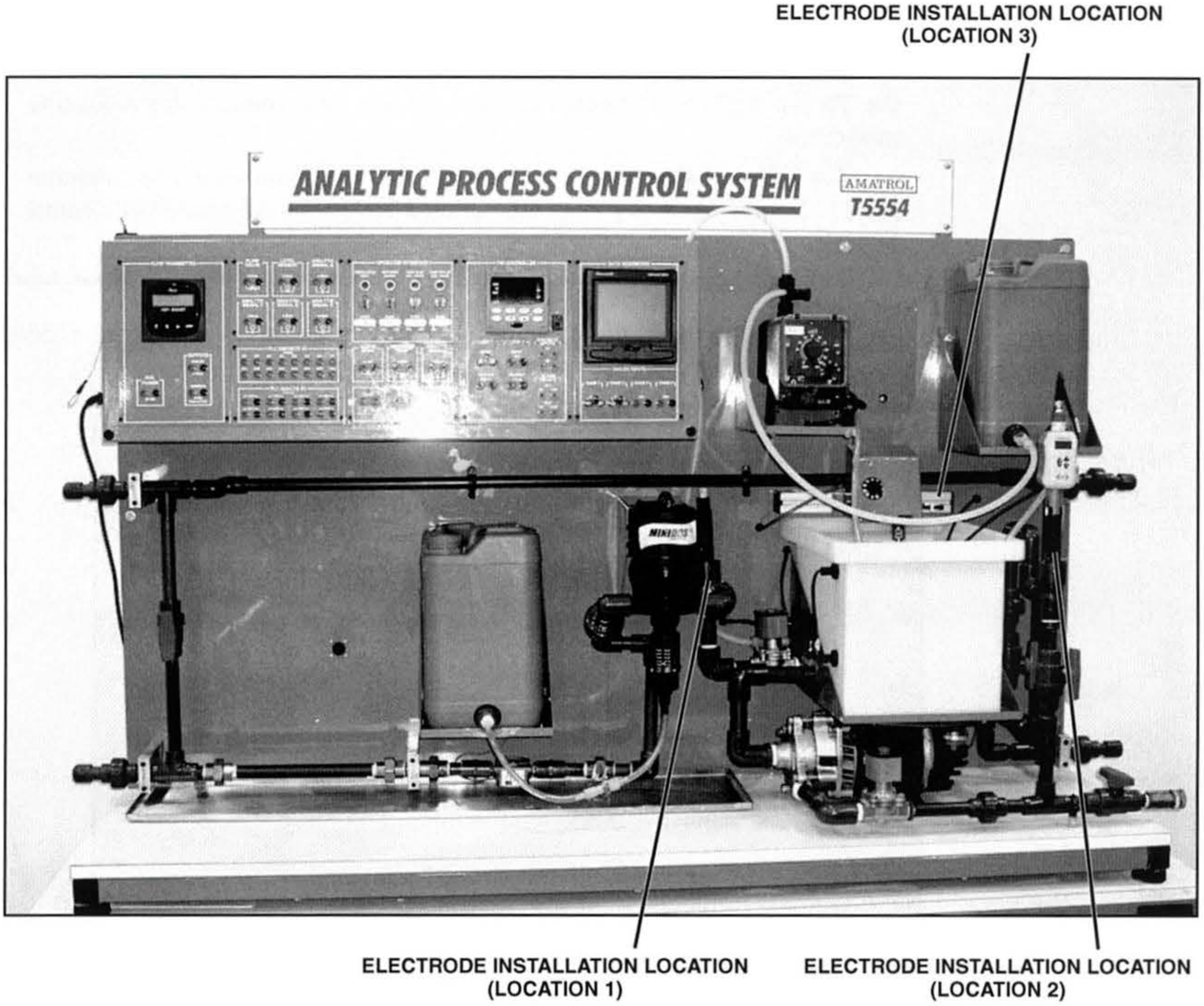

Figure 37. Electrode Installation Locations on the T5554

If there is a cup currently inserted at location 1, it must be removed before installing the electrode.

❏ 3. If present, remove the cap at location 1 by turning it counterclockwise to remove the studs from the slots in the fitting and then pull the cap up to remove it.

❑ 4. Insert the electrode housing into the open fitting on the inlet side of the reactor tank (LOCATION 1), as shown in figure 38. Make sure the studs on the housing fit into the slots in the fitting and push the electrode housing down until it is fully seated in the fitting.

When inserting, the notch in the housing should be pointing forward so the display on the transmitter will face forward when the transmitter is installed (see figure 40).

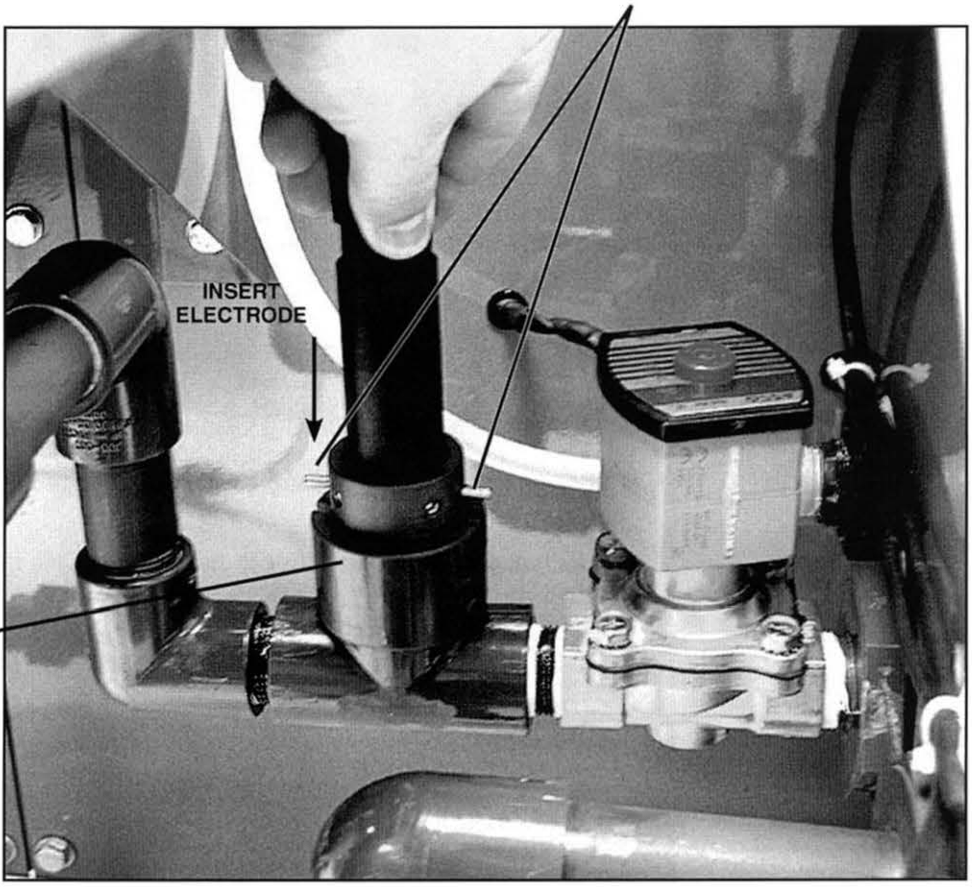

Figure 38. Insert Electrode Housing into Fitting

NOTE

Some water may seap out when inserting the electrode. This is due to trapped water in the pipes.

❑ 5. Twist the electrode housing clockwise, as shown in figure 39, to lock the electrode in place.

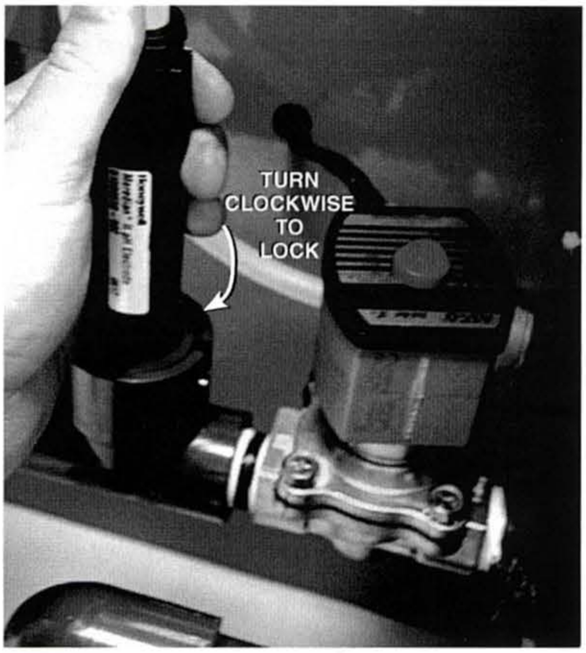

Figure 39. Twist Electrode Housing Clockwise to Lock

❑ 6. Locate the indicating transmitter, shown in figure 40, and attach it to the top of the electrode housing.

This connects the transmitter to the electrode via the edge connector on the electrode.

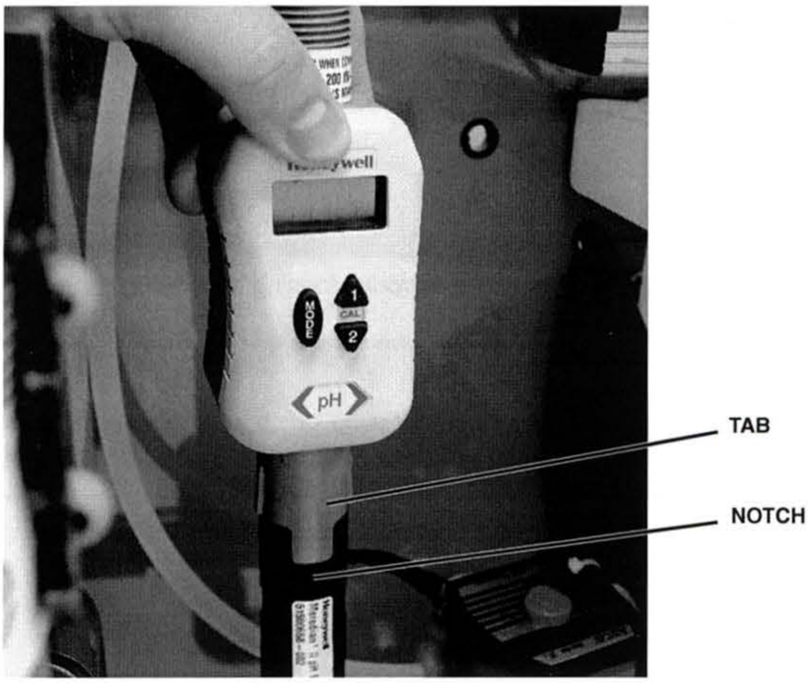

Figure 40. Attach Indicating Transmitter to Electrode Housing

❑ 7. Locate the locking screw on the back of the indicating transmitter, shown in figure 41, and turn it clockwise to lock the indicating transmitter in place.

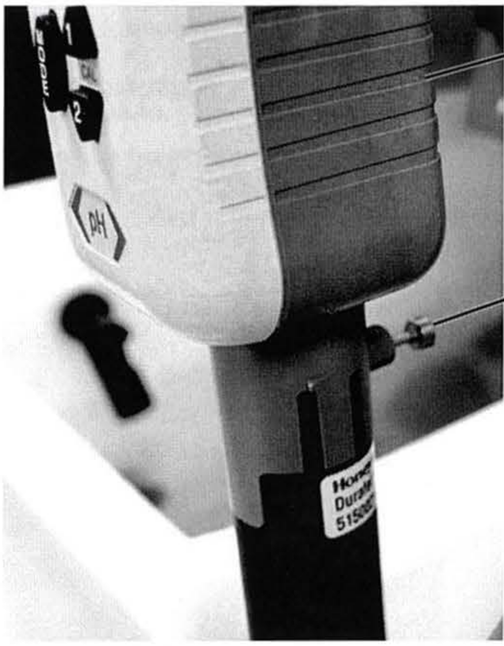

Figure 41. Locking Screw on Back of Indicating Transmitter

☐ 8. Locate the communication cable for the indicating transmitter and connect it to the port on top of the indicating transmitter, as shown in figure 42.

The cable connects the indicating transmitter to the appropriate connection terminals on the control panel.

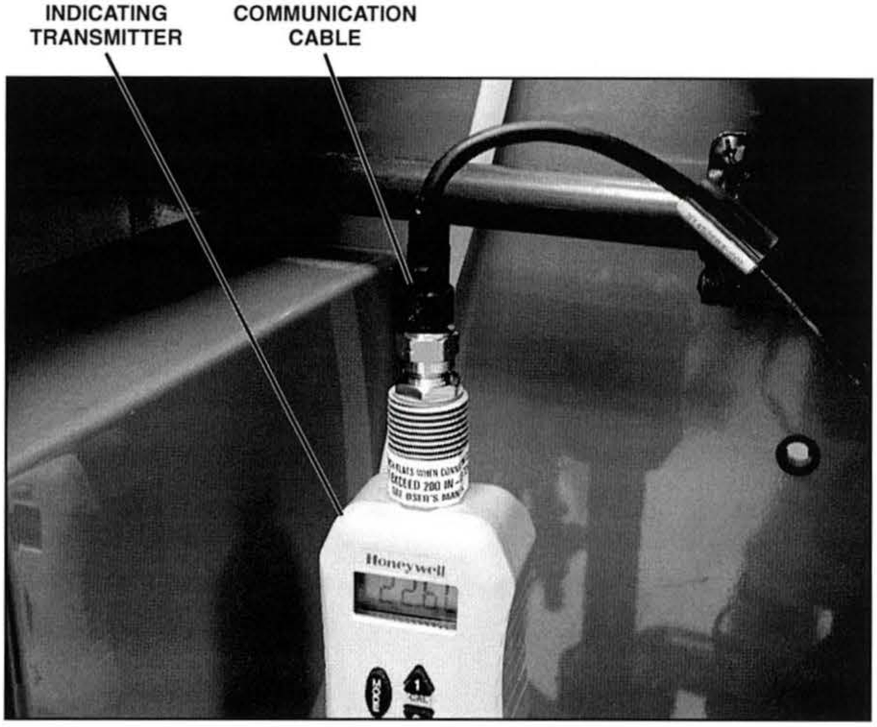

Figure 42. Communication Cable Connected to Indicating Transmitter

That completes the installation of the combination glass electrode.

☐ 9. Turn off the **TANK INLET SOL. VALVE** selector switch to de-energize the solenoid valve.

This will return the solenoid valve to its normally open condition.

☐ 10. Turn off the main circuit breaker.

SEGMENT 2

SELF REVIEW

1. The three components necessary to measure and convert pH measurements are: a ____________________, a reference electrode, and a pH meter.

2. Placing a pH electrode into an acidic solution causes hydrogen ions to diffuse ______________ (into/out of) the electrode.

3. The potential of a reference electrode ______________ (does/does not) change.

4. The wire element used in pH electrodes is typically made of ______________ with a silver chloride coating at the end.

5. The _________ is chemically doped with lithium ions to make it especially sensitive to hydrogen ions.

6. A solution with a pH of 7 results in ______________ potential.

7. A(n) ______________ solution easily conducts electricity.

8. A pH and a reference electrode form a basic ____________________.

9. A ____________________ electrode combines a pH electrode and a reference electrode in the same housing.

10. Having the pH measurement and _________ elements in the same housing helps to minimize the effects of temperature differences on pH measurement.

SEGMENT 3

SOLID-STATE pH ELECTRODES

OBJECTIVE 8 DEFINE ISFET TECHNOLOGY AND EXPLAIN ITS IMPORTANCE

Read This

Recently, there has been an increasing trend to replace glass electrodes with solid-state electrodes in many applications. Solid-state electrodes use ISFET (Ion-Sensitive Field Effect Transistor) technology to sense pH instead of the standard ion-sensitive membrane on a glass electrode. Figure 43 shows a Honeywell solid-state electrode, the Durafet II pH electrode.

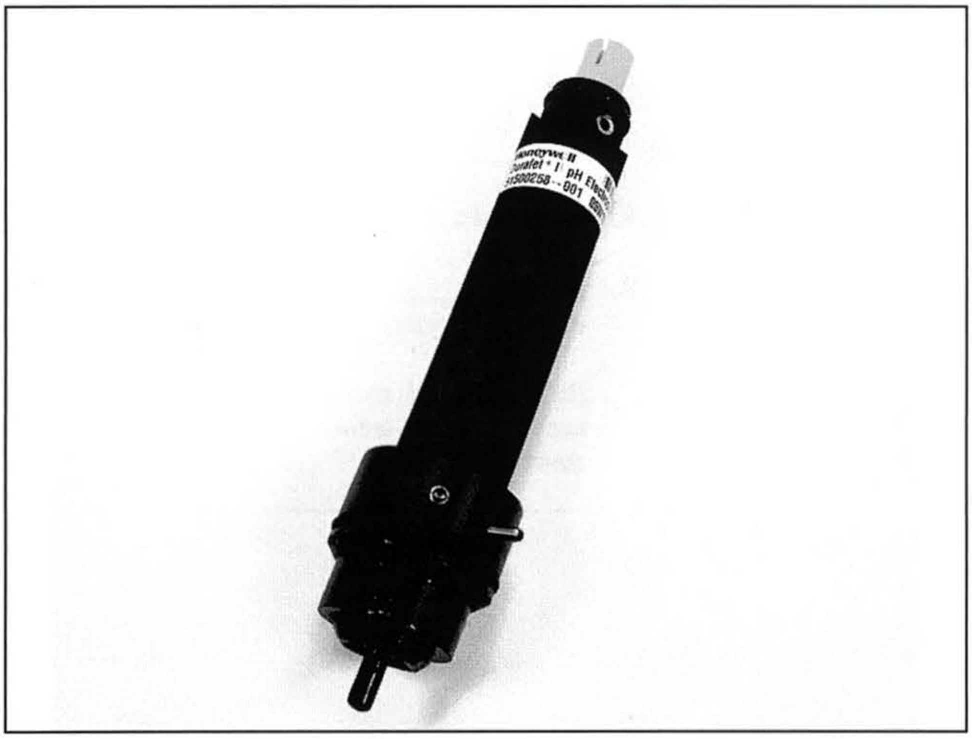

Figure 43. The Honeywell Durafet II pH Electrode

A solid-state electrode like the Honeywell Durafet II pH electrode can be used in place of a glass electrode in any application. Also, there are some extreme applications where a glass electrode cannot be used, but a solid-state electrode can.

Solid-state electrodes provide numerous advantages over glass electrodes. One advantage is that the ISFET technology is much more sensitive than standard glass electrodes. This results in quicker and more reliable response. Another advantage is that the solid-state electrodes are much more rugged and durable than glass electrodes, which means less maintenance and fewer replacements.

OBJECTIVE 9 DESCRIBE THE OPERATION OF THE HONEYWELL DURAFET pH ELECTRODE AND GIVE AN APPLICATION

Read This

The Honeywell Durafet II pH electrode uses an ion-sensitive (ISFET) transistor to replace the sensing element of a combination glass electrode. An ISFET electrode is composed of four basic components: the source, the drain, the gate and a reference electrode. The ISFET construction is shown in figure 44 along with its schematic symbol.

The source and the drain are placed on the same semiconductor substrate, with the gate between them. The gate, which is insulated from the source and drain, is coated with a special oxide that is very sensitive to hydrogen ions.

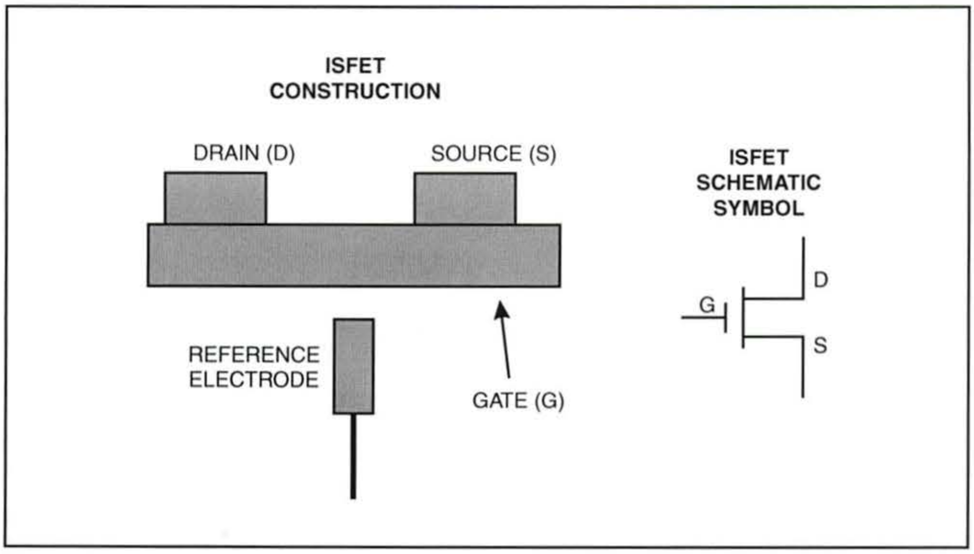

Figure 44. ISFET Construction and Schematic Symbol

Figure 45 shows a cutaway view of the sensing tip on the Honeywell Durafet II pH electrode. The measured solution enters the sensing tip through the reference junction, shown in figure 45. This allows the solution to interact with the ISFET inside the sensing tip.

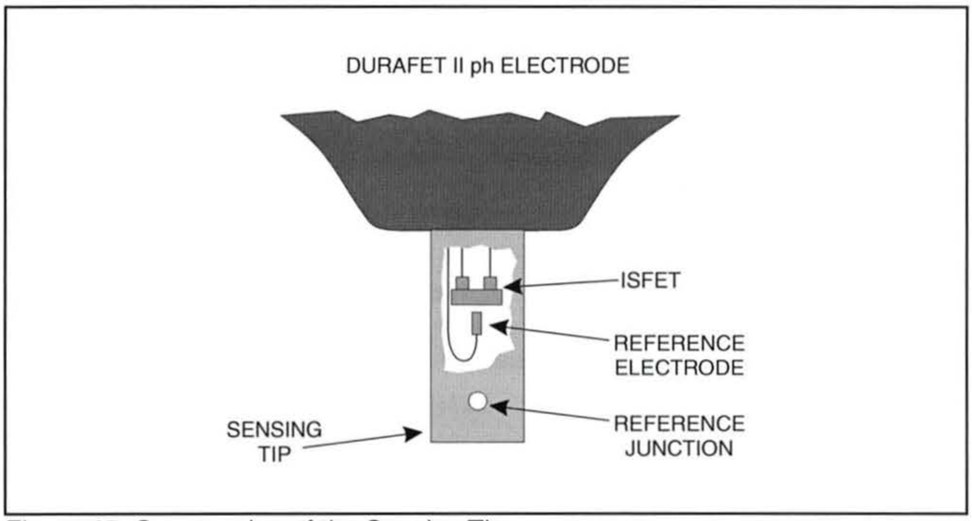

Figure 45. Construction of the Sensing Tip

When the ISFET comes in contact with the solution, hydrogen ions build up on the gate's oxidized coating as figure 46 shows, in proportion to the hydrogen ion concentration of the solution. This causes a potential (voltage) to build between the gate and the reference electrode.

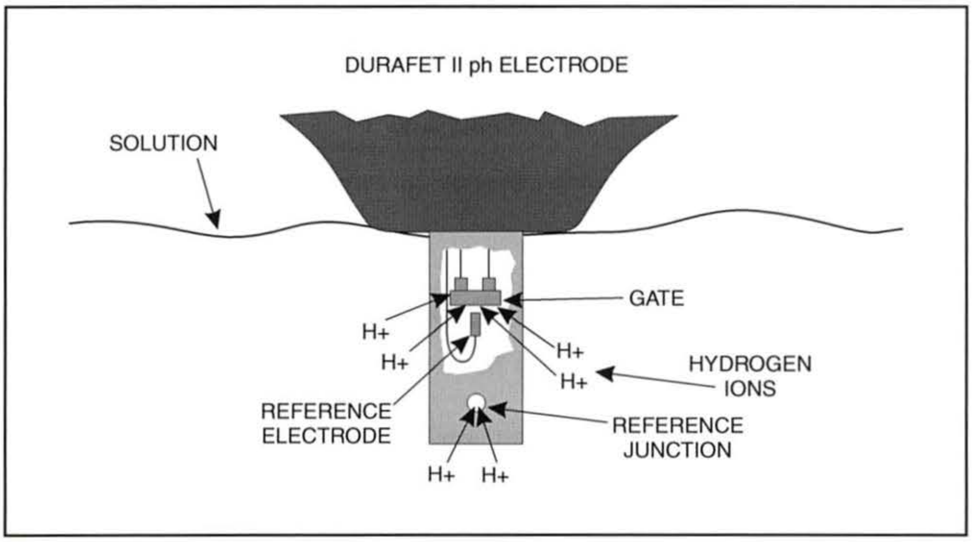

Figure 46. Hydrogen Ions Buildup on the Gate's Oxidized Coating

For a typical field effect transistor (FET), changing the voltage on the gate controls the amount of current that flows between the source and drain. However, for an ISFET, the source/drain current is held constant. The potential difference between the gate and the reference electrode (labeled as Vgs in figure 47) is the value measured to indicate the pH.

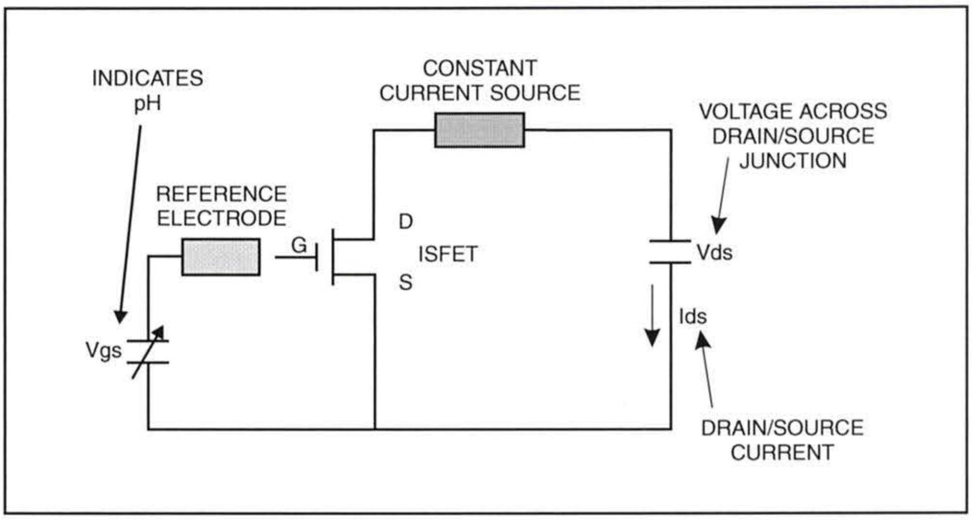

Figure 47. Potential Difference Between the Gate and the Reference Electrode (Vgs)

Since the hydrogen ions do not have to pass through a membrane, the response time for a Durafet electrode is much faster than for a standard glass electrode (typically 10 times faster). In addition, electrodes using ISFET technology remain very accurate over a wide time span. This makes ISFET electrodes very desirable in applications that require very tight control of the pH.

Honeywell Durafet electrodes are used extensively in the pharmaceutical industry and in the food processing industry.

Procedure Overview

In this procedure, you will install the Honeywell Durafet II electrode on the T5554 Analytical Process Control System and connect the indicating transmitter.

Do This

❑ 1. Locate the Honeywell Durafet II electrode provided with the T5554, shown in figure 48.

If the electrode is already installed on the T5554, ask the instructor to remove it so you can continue with the skill.

Figure 48. The Honeywell Durafet II Electrode

❑ 2. Determine a location to install the electrode on the T5554.

The T5554 has three different locations to install an electrode, as identified in figure 49. At least one of the locations should currently be empty.

ELECTRODE INSTALLATION LOCATION
(LOCATION 3)

ELECTRODE INSTALLATION LOCATION
(LOCATION 1)

ELECTRODE INSTALLATION LOCATION
(LOCATION 2)

Figure 49. Electrode Installation Locations on the T5554

In this case, you will install the electrode in LOCATION 2, at the outlet side of the reactor tank.

❑ 3. Open the branch valve directly under the electrode fitting and shut the other branch valve, as shown in figure 50.

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

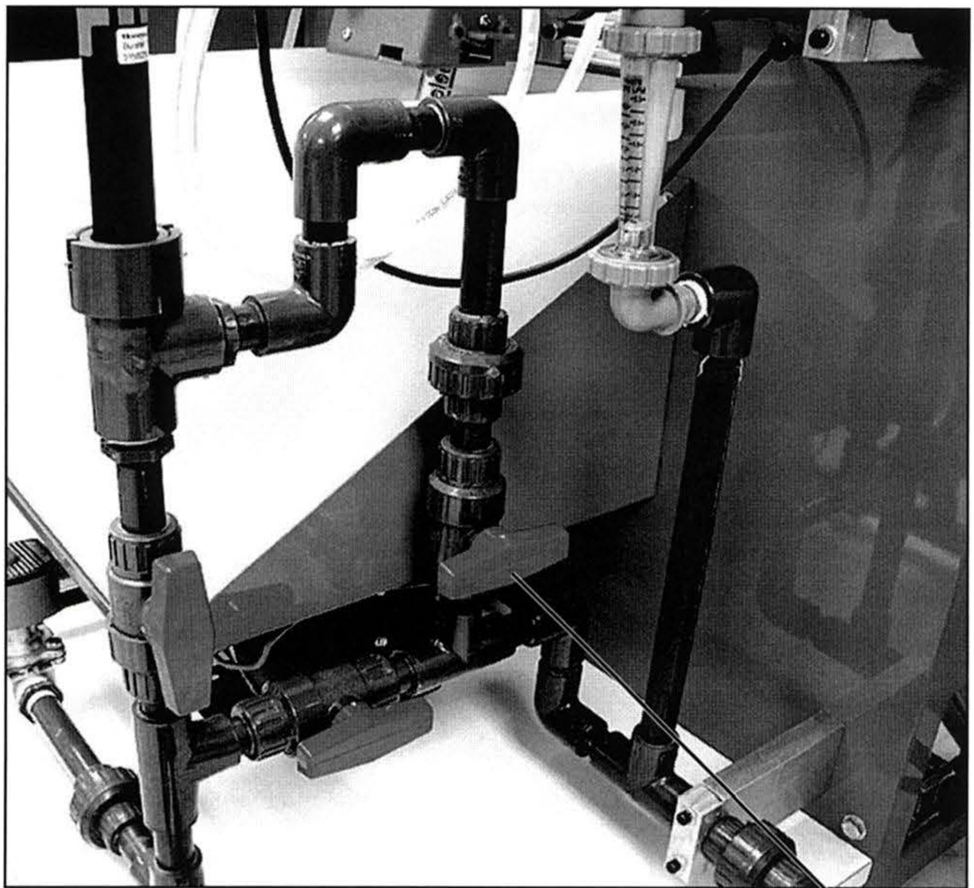

Figure 50. One Branch Valve Open and the Other Closed

❑ 4. Insert the electrode housing into the open fitting, as shown in figure 51. Make sure the studs on the housing fit into the slots in the fitting and push the electrode housing down until it is fully seated in the fitting.

Also, the notch in the housing should be pointing forward so that the display on the transmitter will be facing forward when later installing the transmitter.

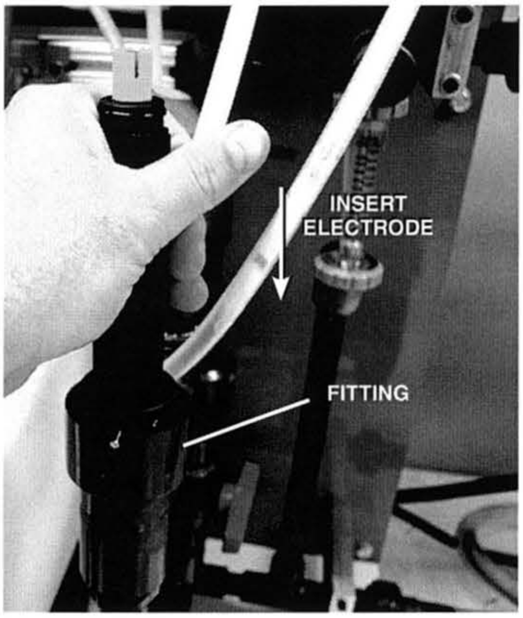

Figure 51. Insert Electrode Housing into Fitting

❑ 5. Twist the electrode housing clockwise, as shown in figure 52, to lock the electrode in place.

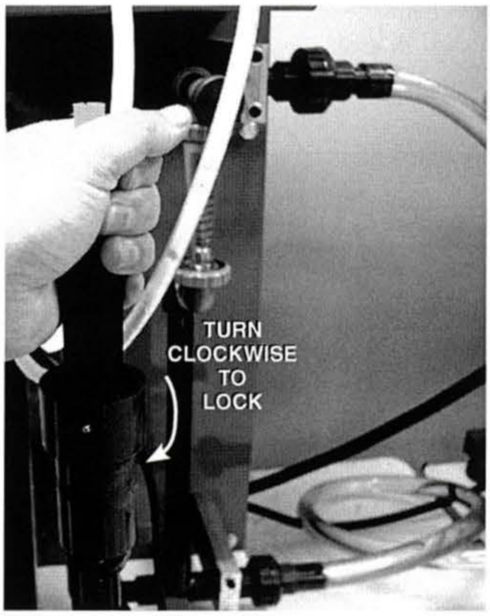

Figure 52. Twist Electrode Housing Clockwise to Lock

❑ 6. Locate the indicating transmitter, shown in figure 53, and attach it to the top of the electrode housing.

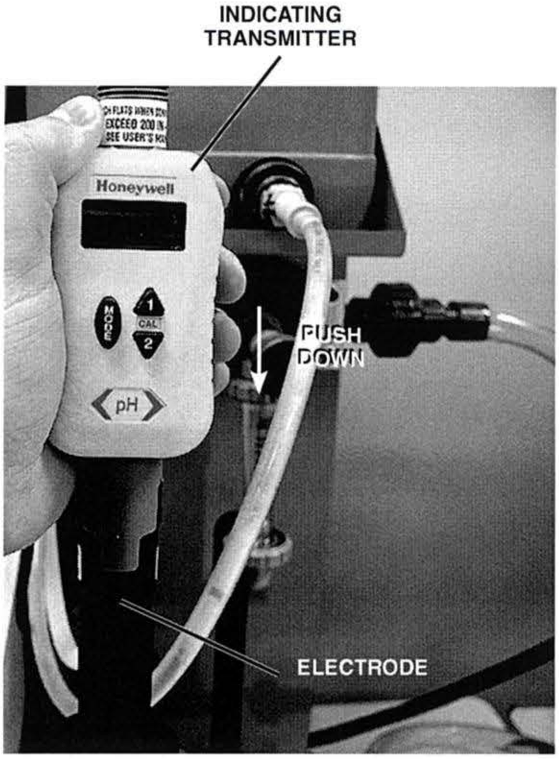

Figure 53. Attach Indicating Transmitter to Electrode Housing

❑ 7. Locate the locking screw on the back of the indicating transmitter, shown in figure 54, and turn it clockwise to lock the indicating transmitter in place.

Figure 54. Locking Screw on Back of Indicating Transmitter

❑ 8. Locate the communication cable for the indicating transmitter and connect it to the port on top of the indicating transmitter, as shown in figure 55.

The cable connects the indicating transmitter to the appropriate connection terminals on the control panel.

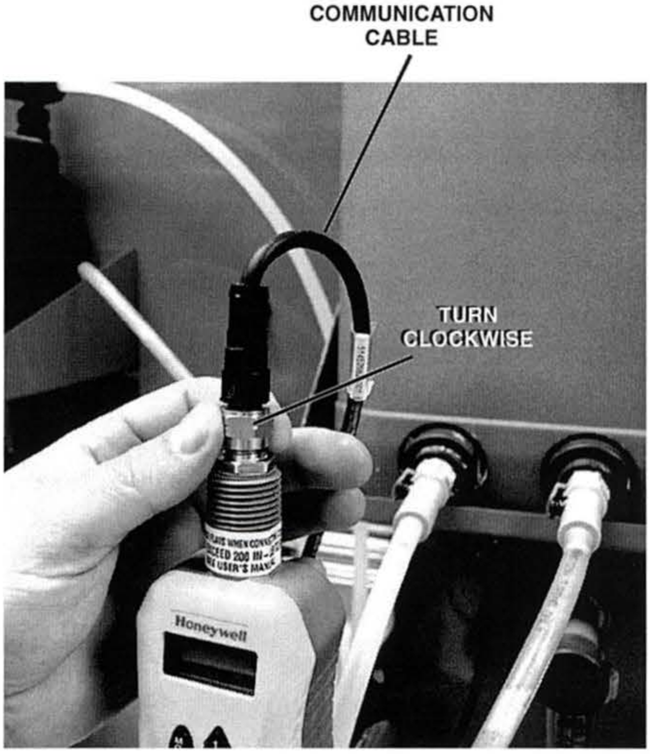

Figure 55. Communication Cable Connected to Indicating Transmitter

That completes the installation of the Durafet II electrode.

SEGMENT 3

SELF REVIEW

1. Solid-state electrodes use ____________________ technology to sense pH instead of the standard ion-sensitive membrane on a glass electrode.

2. A solid-state electrode _______________ (can/cannot) be used in place of a glass electrode in any application.

3. One advantage of ISFET electrodes is they are much more _______________ than standard glass electrodes.

4. An ISFET electrode is composed of four basic components: the source, the drain, the _______________ and a reference electrode.

5. The gate of an ISFET is coated with a special _______________ that is very sensitive to hydrogen ions.

6. When the ISFET comes in contact with the solution, ____________________ build up on the gate's oxidized coating in proportion to the hydrogen ion concentration of the solution.

7. Honeywell Durafet electrodes are used extensively in the pharmaceutical industry and in the ____________________ industry.

SEGMENT 4

ELECTRODE CLEANING AND STORAGE

OBJECTIVE 10 DESCRIBE HOW TO CLEAN A HONEYWELL DURAFET pH ELECTRODE AND EXPLAIN THE IMPORTANCE

Read This

Over time, crystals build up on the sensing area of the electrode, shown in figure 56, due to minerals in the water. Therefore, it is important to clean the electrode occasionally to keep the crystal buildup from becoming excessive.

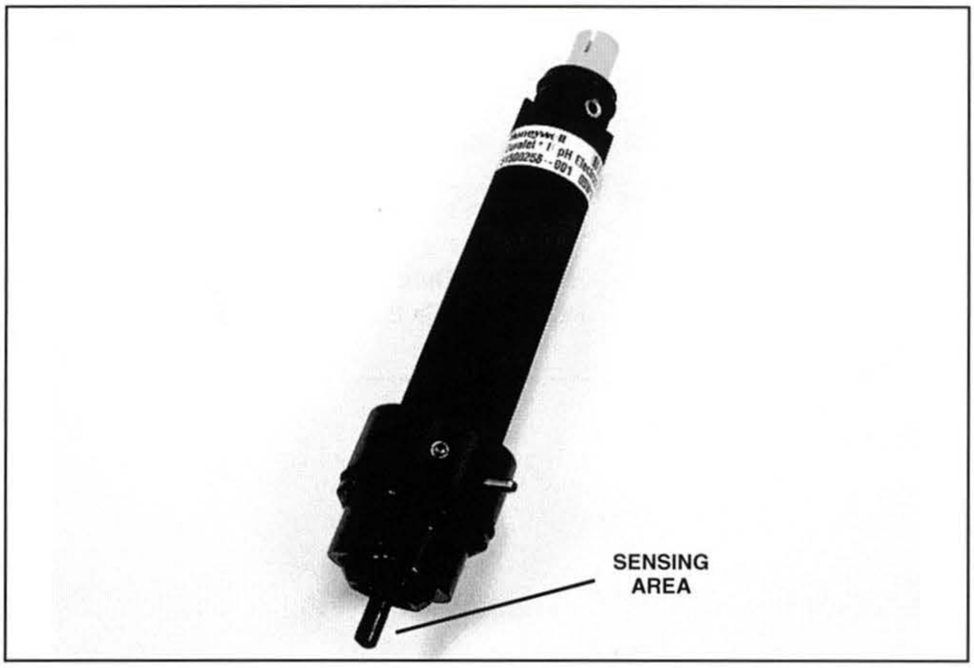

Figure 56. Sensing Area of Durafet pH Electrode

Use the following steps to clean a Honeywell Durafet pH electrode:

Step 1: Remove the electrode from the process

The electrode must be removed from the process for cleaning. Care must be taken when removing the electrode to avoid damaging the electrode.

Step 2: Rinse the sensing area with warm tap water

The crystals are removed from the sensing area by placing the sensing area of the electrode under warm tap water, as shown in figure 57. The warm tap water dissolves the crystals. Do not scrub the sensing area as it may damage the electrode.

Figure 57. Rinse Sensing Area with Warm Tap Water

Step 3: Dry sensing area using soft cloth or paper towel

It is best not to rub the sensing area. Instead, dab it with a soft cloth or paper towel. Rubbing could result in damage to the sensing area, rendering the electrode useless.

Step 4: Reinstall the electrode into the process

Once the sensing area is clean and dry, reinstall the electrode into the process. If the pH readings do not seem to be accurate after reinstalling the electrode, it may be necessary to calibrate the electrode. The calibration process is cover later.

Crystal buildup on the sensing area of the electrode leads to inaccurate pH readings and could be harmful to the process. Therefore, it is extremely important to check the electrodes often and clean them as necessary.

SKILL 5 CLEAN A HONEYWELL DURAFET pH ELECTRODE

Procedure Overview

In this procedure, you will remove the Honeywell Durafet pH electrode from the T5554 Analytical Process Control System and clean the sensing area. When the electrode is clean and dry, you will return the electrode to the system.

❑ 1. Perform a lockout/tagout.

❑ 2. Perform the following substeps to make sure the T5554 Analytical Process Control System is set up as shown in figure 58.

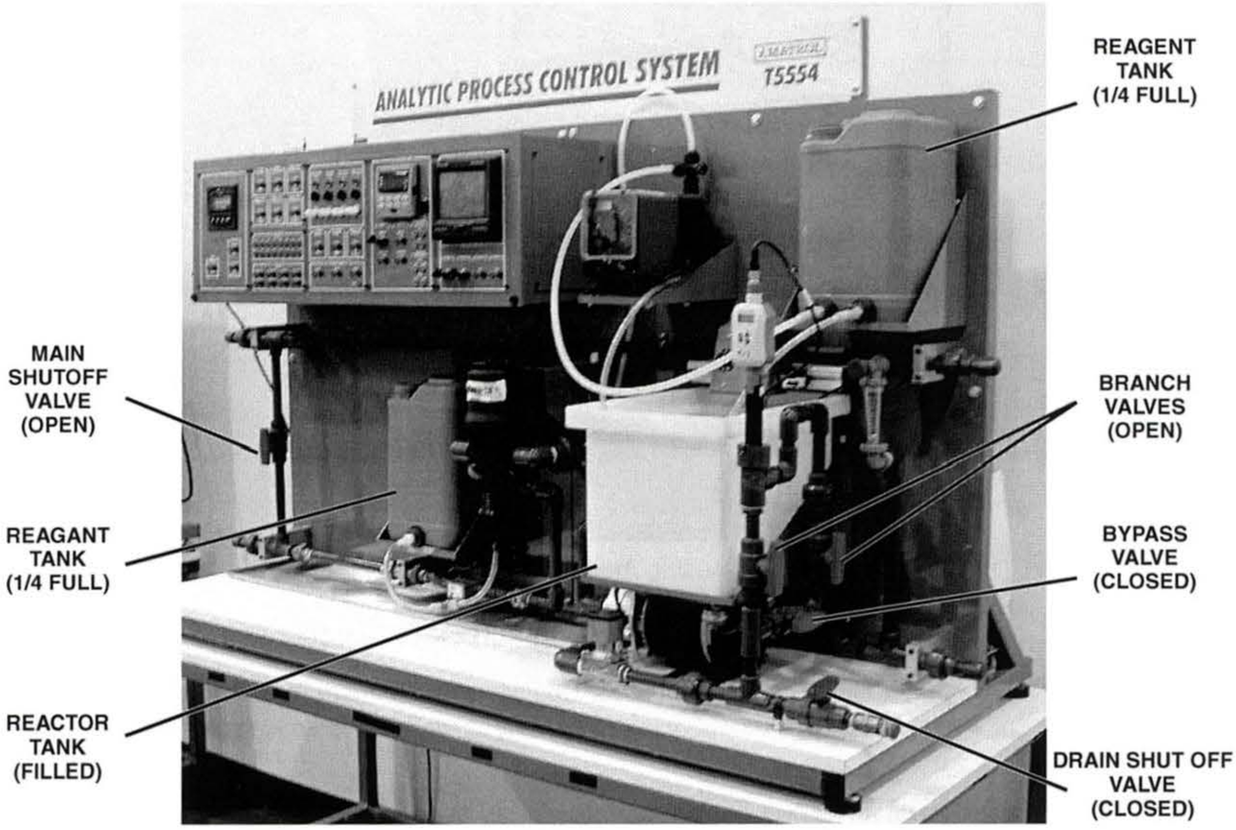

Figure 58. T5554 Setup

A. Make sure the reactor tank is filled with tap water to a level between the high level sensor and low level sensor.

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

C. Make sure the main shutoff valve is open.

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

The lower reagent tank should have a sodium bisulfate solution and the upper reagent tank should have a sodium carbonate solution.

E. Make sure the bypass valve is closed and the branch valves are open.

❑ 3. Locate the Honeywell Durafet II electrode on the T5554.

You should find that it is located to the right of the reactor tank, as shown in figure 59. If not, notify your instructor.

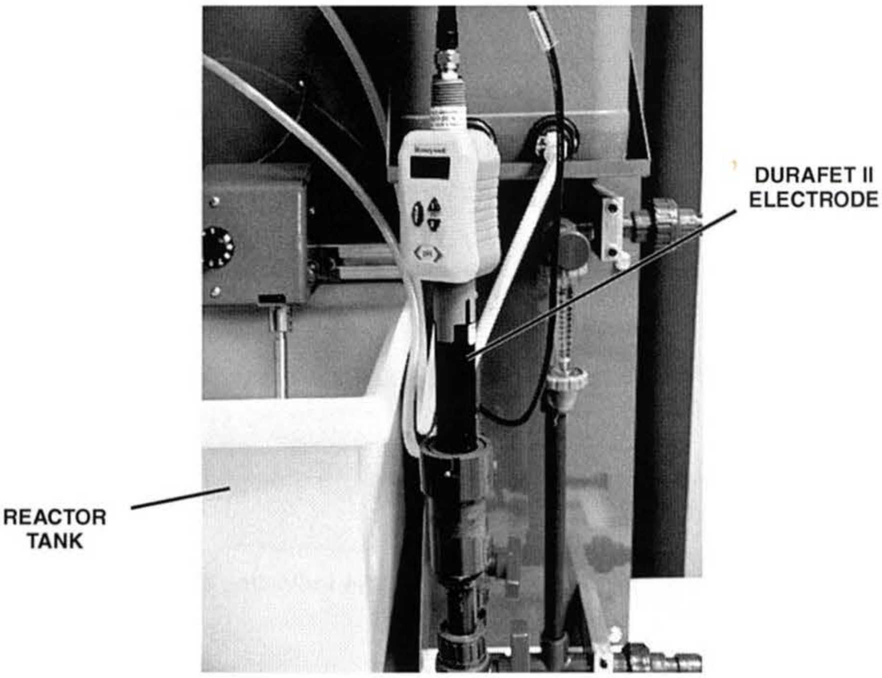

Figure 59. Location of the Durafet II Electrode

❑ 4. If the Durafet II electrode has the indicating transmitter connected to it, as shown in figure 60, remove the indicating transmitter by loosening the securing screw (on back) and lift the transmitter up and off the electrode. Leave the communication cable connected to the transmitter and set the transmitter to the side.

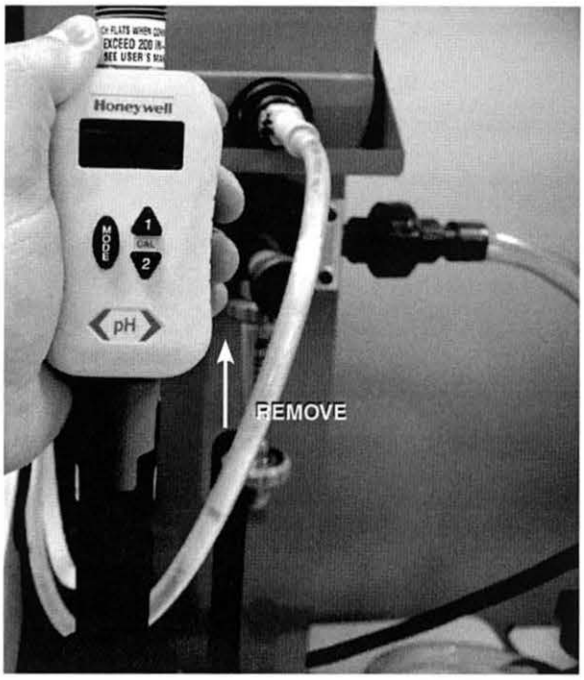

Figure 60. Removing the Indicating Transmitter

❑ 5. Leave the branch valve directly under the electrode fitting open and close the other branch valve.

❑ 6. Perform the following substeps to remove the electrode from the fitting.

A. 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 61.

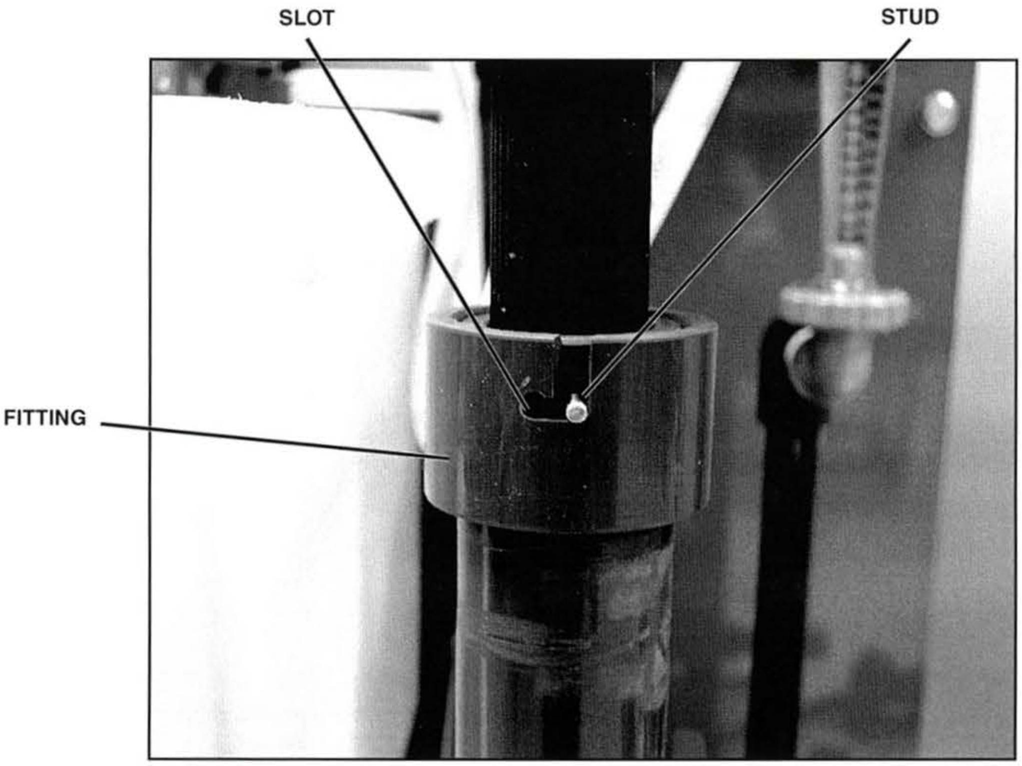

Figure 61. Studs Disengaged from Slots in Fitting

B. 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 bypass valves and make sure the one under the electrode fitting is open. Strong resistance is an indication of backpressure.

NOTE

There may be some water leakage from the fitting after the electrode is removed. This is due to the trapped water in the process piping.

C. When the electrode is completely removed from the fitting, examine the sensing area, shown in figure 62.

The sensing area may or may not have crystals built up. Regardless, you will clean the sensing area to become familiar with the process.

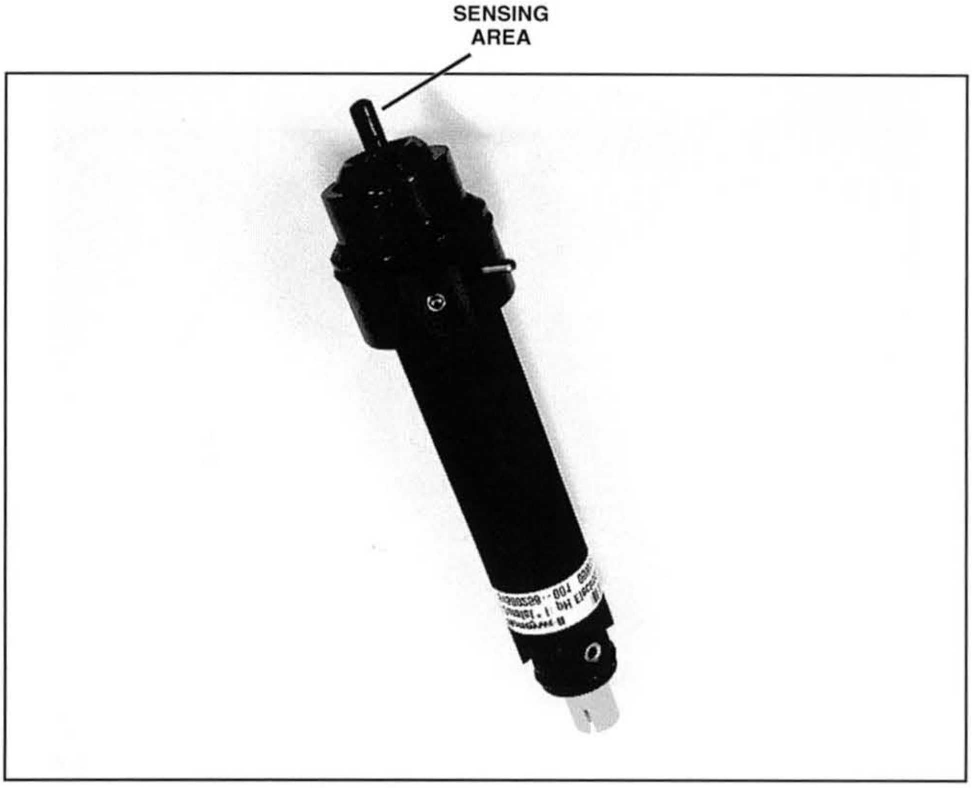

Figure 62. The Sensing Area of the Electrode

❑ 7. Perform the following substeps to clean the sensing area of the electrode.

A. Take the electrode to a sink that has both hot and cold water.

B. Set the hot and cold water controls so the water is warm.

C. Place the sensing area of the electrode under the running water, as shown in figure 63. Leave the sensing area under the warm water until all of the crystals are gone.

Figure 63. Sensing Area Under Running Water

D. When the sensing area is clean, remove it from the water and turn off the water supply.

E. Dry the sensing area by dabbing it with a soft cloth or paper towel, as shown in figure 64. Do not rub the sensing area.

Figure 64. Sensing Area Dried with Cloth or Paper Towel

❑ 8. Leave the electrode removed from the T5554.

In the next skill, you will prepare the electrode for storage.

OBJECTIVE 11 DESCRIBE HOW TO STORE A HONEYWELL DURAFET pH ELECTRODE AND EXPLAIN ITS IMPORTANCE

Read This

There are times when an electrode may not be used in a process. During these times, it is necessary to properly store the electrode to protect it and preserve its life. The Honeywell Durafet electrode is no different.

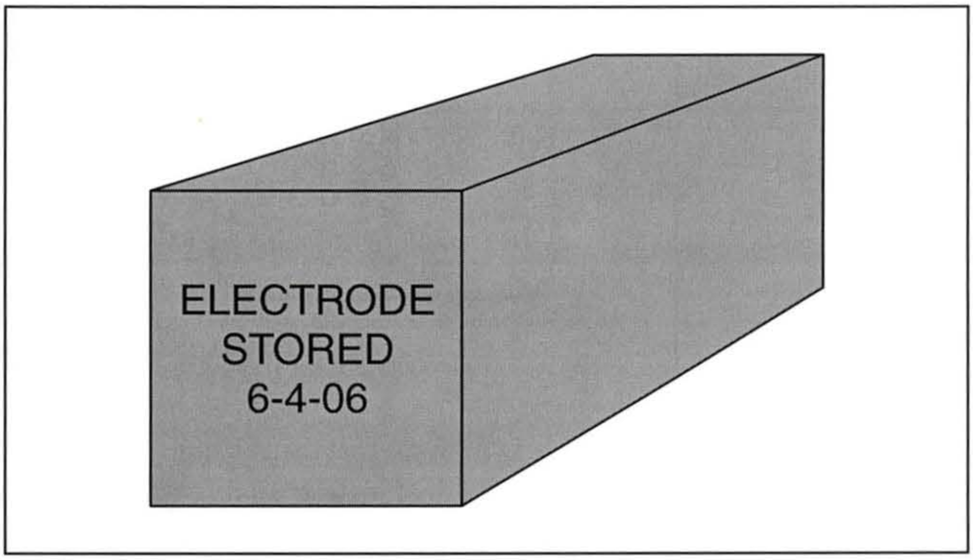

Figure 65. Proper Storage of a Honeywell Durafet pH Electrode

The steps to properly store a Honeywell Durafet pH electrode, as shown in figure 65, are:

Step 1: Clean the electrode sensing area

If the electrode is removed from a process, the sensing area should be cleaned before the electrode is stored. Cleaning is done with warm tap water.

Step 2: Pour storage solution into the electrode protective cap

Provided with an electrode is a protective cap that fits over the sensing area of the electrode. Before the cap is placed on the electrode, the cap should be filled with the storage solution, as shown in figure 66. If no storage solution is available, a buffer solution (typically 7 pH) can be used. The storage solution helps to protect the sensing area during storage.

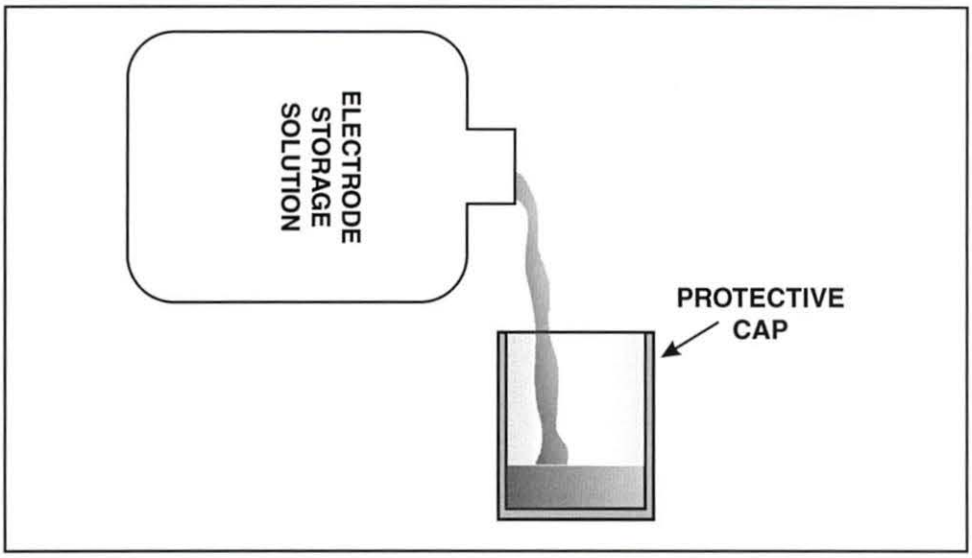

Figure 66. Pouring Storage Solution in Protective Cap

Step 3: Install the protective cap over the sensing area

Once the cap has the storage solution, the cap is place over the sensing area of the electrode, as shown in figure 67. In many cases, the cap screws on, like the one shown in figure 67.

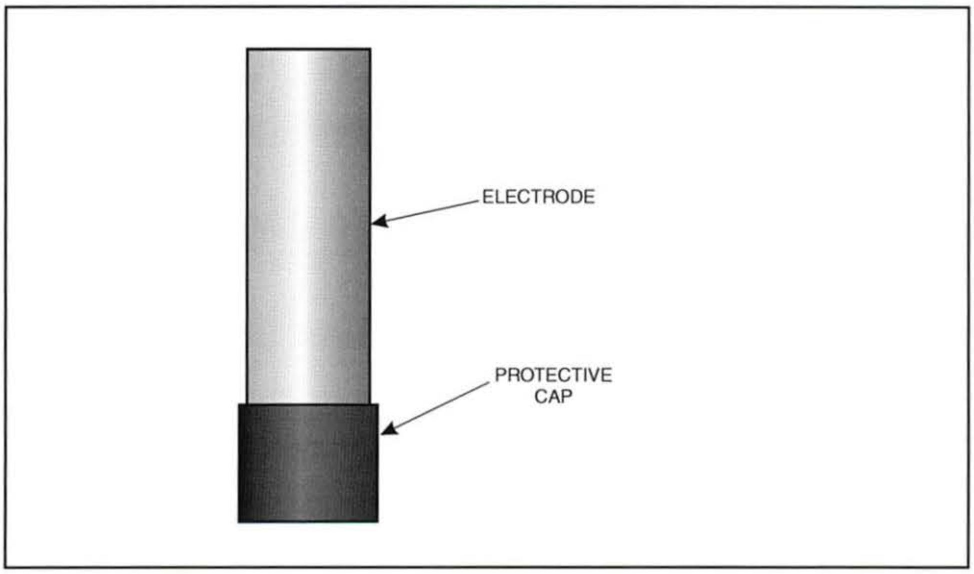

Figure 67. Protective Cap Installed over Sensing Area

Step 4: Tape the protective cover in place with vinyl tape

Wrapping vinyl tape around the protective cap, as shown in figure 68, helps to secure the cap and prevents the solution from leaking out.

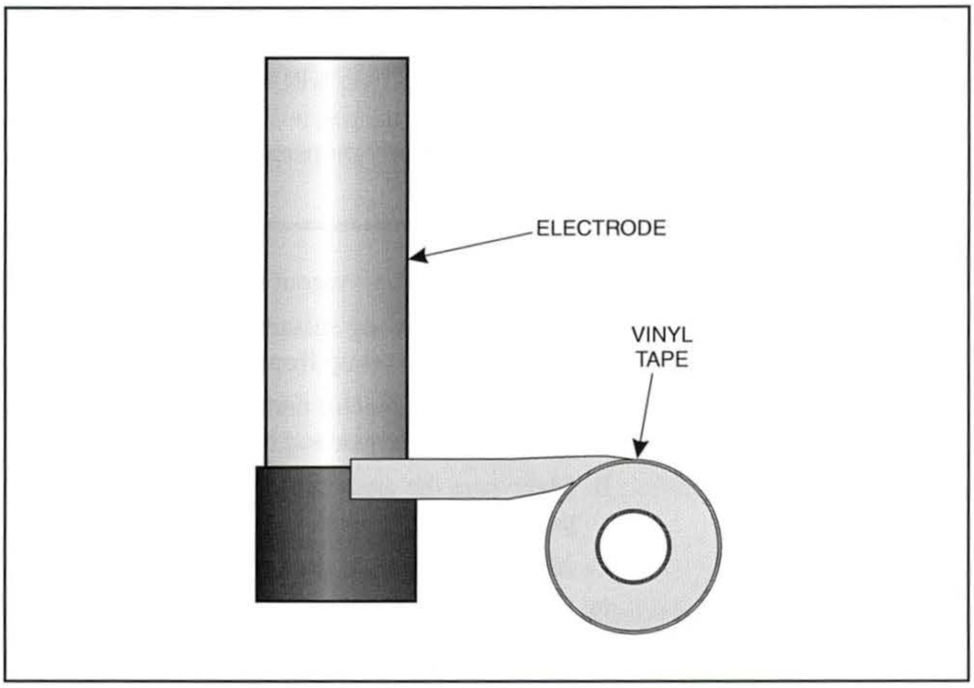

Figure 68. Wrapping Vinyl Tape around the Protective Cap

Step 5: Place the electrode in a storage container and label with date

Once the protective cap is secure, the electrode is placed in a storage container. The date the electrode was placed into storage is written on the container and the container is placed in the appropriate storage area.

Properly storing an electrode allows the electrode to remain on the shelf for extended periods without damage to the sensing area. This keeps replacement electrodes available in case of electrode failures.

SKILL 6	PREPARE A HONEYWELL DURAFET pH ELECTRODE FOR STORAGE

Procedure Overview

In this procedure, you will remove the Honeywell Durafet pH electrode from the T5554 system. You will then prepare the electrode for storage. After the electrode is properly prepared for storage, you will return the electrode to the T5554 system.

- ❑ 1. Make sure the lockout/tagout is still in place. If not, perform a lockout/tagout.
- ❑ 2. Perform the following substeps to make sure the T5554 Analytical Process Control System is set up from the previous skill.
  - A. Make sure the reactor tank is filled with tap water to a level just between the high level sensor and the low level sensor.
  - B. Make sure the drain shutoff valve is closed (shut) and the drain cap is in place.
  - C. Make sure the main shutoff valve is open.
  - D. Make sure the reagent tanks are filled at least 1/4 full.

    The lower reagent tank should be filled with sodium bisulfate solution and the upper reagent tank should be filled with sodium carbonate solution.
  - E. Make sure the branch valve under the electrode fitting is open and the other branch valve is closed.
- ❑ 3. Locate the Honeywell Durafet II electrode that you removed in a previous skill.

❑ 4. Perform the following substeps to prepare the electrode for storage.

A. Locate the special protective cap for the electrode, as shown in figure 69.

This protective cap is designed to work with the special fitting connected to the Durafet electrode used on the T5554. The fitting on the electrode is designed to fit into a bayonet-style fitting for quick removal and installation.

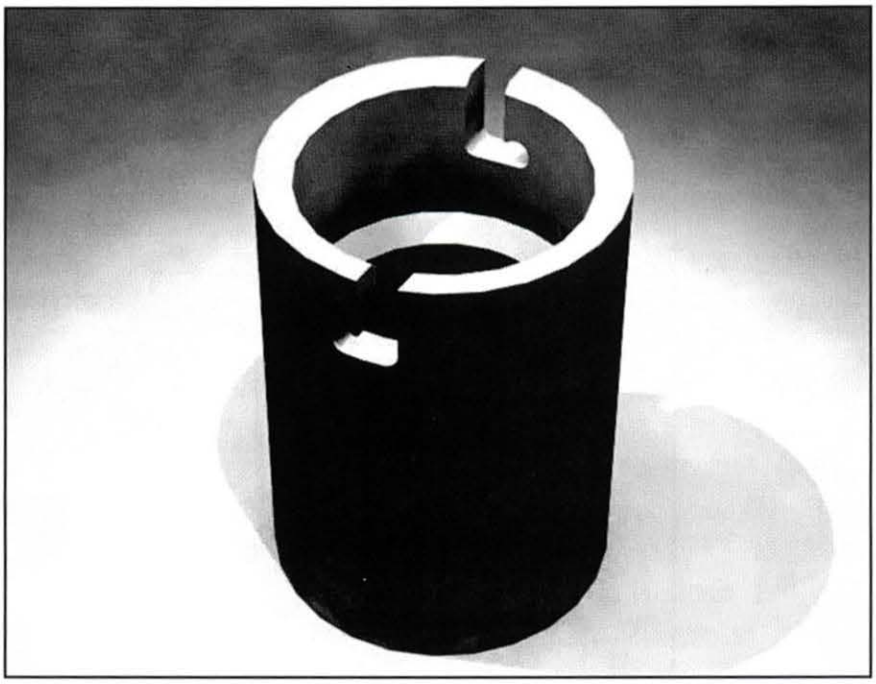

Figure 69. Special Protection Cap

B. Fill the protective cap about 2/3 full with the storage solution such as potassium chloride.

   If no storage solution is available, you can use a buffer solution of 7 pH instead.

C. Insert the sensing end of the electrode into the protective cap, making sure that the studs on the electrode are aligned with the slots in the cap.

   Be sure to hold the cap and electrode upright to prevent spilling the solution.

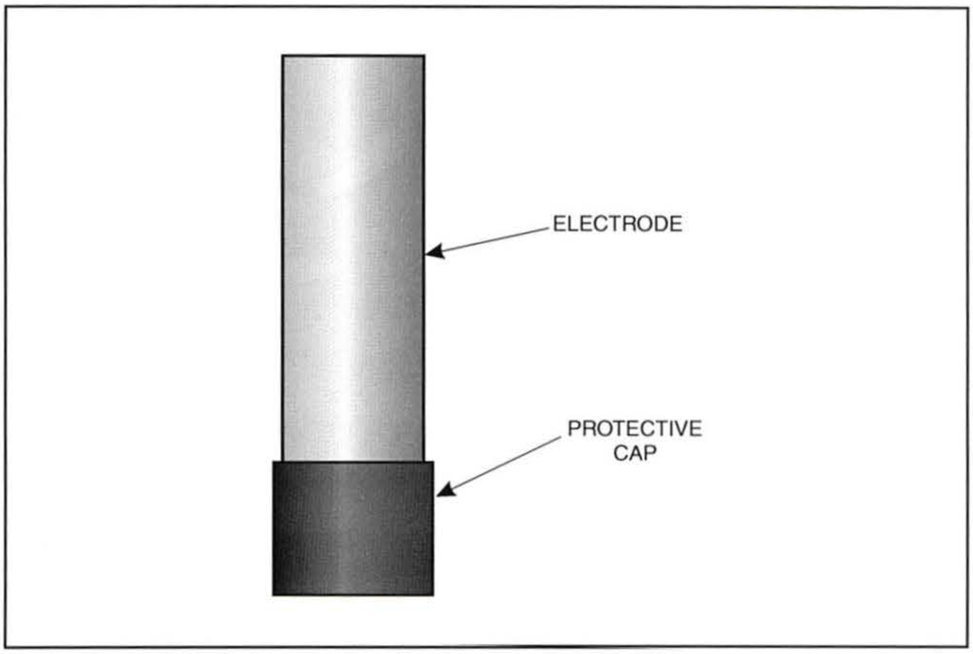

Figure 70. Sensing End of Electrode Inserted into Protection Cap

D. While holding the protective cap with one hand, turn the electrode housing counterclockwise, to lock the cap in place.

E. Make sure the area to be taped is clean and dry so the tape will stick.

F. Locate the vinyl tape and tape the connection between the cap and the electrode fitting, as shown in figure 71.

G. Show the electrode/cap combination to the instructor.

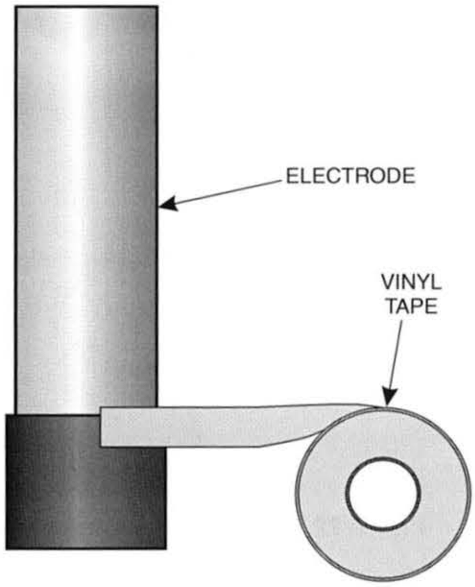

Figure 71. Vinyl Tape Applied to Connection

After completing the taping, the next step would be to store the electrode in a storage container and enter the date on the container. It is important to make sure the electrode is stored in such a way that the sensing end remains covered by the storage solution. However, since you will be returning the electrode to the T5554, you will skip this step.

❑ 5. Perform the following substeps to reinstall the electrode on the T5554.

A. Remove the vinyl tape.

B. While holding the protective cap in one hand, turn the electrode housing clockwise and then remove the electrode from the protective cap.

C. Pour the storage solution from the protective cap.

D. Rinse the sensing area of the electrode with warm tap water and dab dry using a soft cloth or paper towel.

E. Make sure the branch valve directly under the electrode fitting is open and the other branch valve is closed.

F. Insert the electrode housing into the open fitting, as shown in figure 72. Make sure the studs on the housing fit into the slots in the fitting and push the electrode housing down until it is fully seated in the fitting.

Also, make sure the notch on the housing is facing forward so the transmitter display will be visible when it is installed.

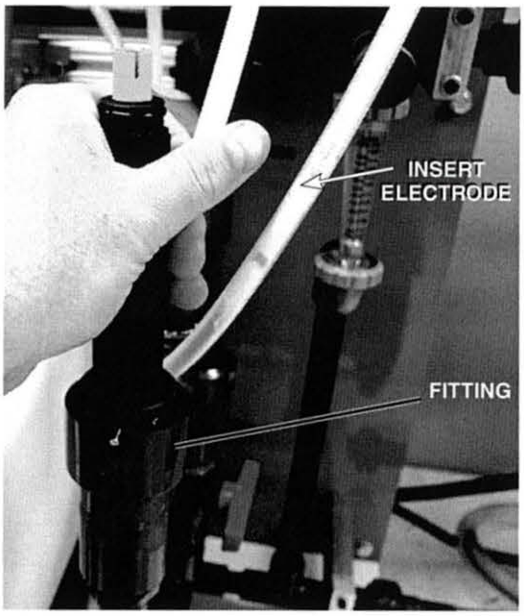

Figure 72. Insert Electrode Housing into Fitting

G. Twist the electrode housing clockwise to lock the electrode in place.

H. Locate the indicating transmitter and attach it to the top of the electrode housing, as shown in figure 73.

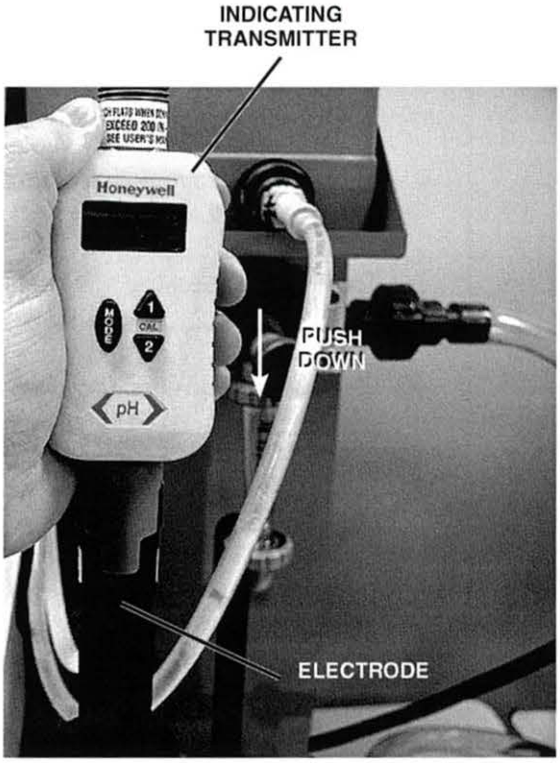

Figure 73. Attach Indicating Transmitter to Electrode Housing

I. Locate the locking screw on the back of the indicating transmitter and turn it clockwise to lock the indicating transmitter in place.

The communication cable should still be connected to the transmitter. If not, connect it to the connector at the top of the indicating transmitter.

Open both of the branch valves.

The electrode is now clean and returned to the process.

❑ 6. Remove the lockout/tagout.

SEGMENT 4

SELF REVIEW

1. _______________ build up on the sensing area of a Honeywell Durafet electrode over time due to minerals in the water.

2. The crystals are removed from the sensing area by placing the sensing area of the electrode under _________________ water.

3. To dry the sensing area of a Durafet electrode, it is best to _______________ the sensing area with a soft cloth or paper towel.

4. Crystal buildup on the sensing area of the electrode leads to _______________ pH readings.

5. Provided with an electrode is a(n) ____________________ that fits over the sensing area of the electrode.

6. Before the cap is placed on the electrode, the cap should be filled with the ____________________.

7. Wrapping ____________________ around the protective cap helps to secure the cap and prevents the solution from leaking out.

8. Once the electrode is placed in a storage container, the _______________ is written on the container.