

Analytical Instrumentation

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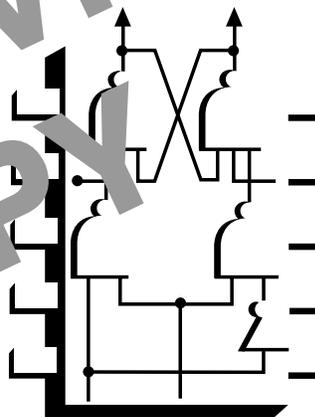
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ANALYTICAL INSTRUMENTATION

Lesson One

***Measuring
Conductivity***

PREVIEW
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TPC Training Systems

27801

Lesson**1****Measuring Conductivity****TOPICS**

Ion Concentration
Conductivity
Variables Affecting Conductivity
Conductivity Probes
Probe Calibration
Liquid Standard Calibration

Wire Loop Calibration
Checking a Grab Sample
Probe Installation
Maintenance
Stack Gas Analyzers

OBJECTIVES

After studying this Lesson, you should be able to...

- Define conductivity and discuss the basic principles governing conductivity.
- Compare the operation of electrode probes and inductive probes.
- Describe two procedures for calibrating conductivity probes.
- Discuss proper installation and maintenance practices for conductivity probes.
- Discuss the operation of stack gas analyzers.

KEY TECHNICAL TERMS

Ion 1.01 a charged particle
Conductance 1.03 a measure of the ability of an electrical circuit to pass current
Siemens (mho) 1.03 a unit of conductance
Cell constant 1.15 a conductivity probe factor, supplied by the probe manufacturer
Zero standard 1.28 a calibration standard at the minimum of an instrument's range

Span standard 1.28 a calibration standard at the maximum of an instrument's range
Grab sample 1.31 a sample of a process liquid taken for an independent check—for example, of conductivity
Dosimeter 1.55 a portable gas-measuring device that monitors the exposure of a worker to a particular gas

The ability to measure a process liquid's conductivity is essential in controlling a process system. This Lesson explains how conductivity changes with a liquid's chemical concentration, contamination, and temperature. It also describes the instruments used to measure conductivity and explains how conductivity is used to monitor stack gases. In addition, this Lesson describes the installation, adjustment, and calibration of conductivity-measuring instruments.

Ion Concentration

1.01 An *ion* is a charged particle. *Ionization* is the breaking up of molecules into two or more oppositely charged ions. Every water solution of an ionizable material has a certain number of charged particles in it. Materials that do not ionize in solution—for example, sugar or starch—do not produce charged particles. The accumulation of ions can provide information about the concentration, contamination, or corrosiveness of the solution.

1.02 Measuring the level of ion concentration allows you to monitor many process conditions. Applications include checking for the degree of purity or impurity in steam boiler water and checking the level of contaminants in chemical and power plant cooling systems. A *contaminant* is an unwanted chemical in the process stream. Ion concentration can also indicate the concentration of chemicals in a chemical solution.

Conductivity

1.03 *Resistance* is a measure of the ability of an electrical circuit to oppose current flow. *Conductance* is a measure of the ability of a circuit to pass current. The symbol for conductance is G . The *siemens* is a unit of measurement for conductance, and is the reciprocal of resistance (R) in ohms:

$$G = \frac{1}{R}$$

The siemens has replaced the *mho* (ohm spelled backwards) as the term for expressing conductance, but you will still sometimes see *mho* used.

1.04 The *conductivity* of a substance is the conductance of a unit length and unit cross-sectional area of that substance. To measure conductivity in a liquid, you insert two plates in the liquid. As shown in Fig. 1-1, these plates (called *electrodes*) are each 1 cm square. The plates must be parallel to each other and

separated from each other by 1 cm for conductivity to be equal to resistivity. Other dimensions introduce a multiplier, referred to as a cell constant, into the calculation. Then you apply a charge of 1 volt across the plates. The measurement instrument indicates the conductivity by displaying the amount of measured current on a meter, screen, or recorder.

1.05 Remember that according to Ohm's law, $E = IR$. If you apply a potential of 1 V to the plates and measure a current of 0.8 amperes, the conductivity is 0.8 siemens/cm:

$$E = IR$$

$$1 \text{ V} = (0.8 \text{ A})R$$

$$R = \frac{1 \text{ V}}{0.8 \text{ A}} = 1.25 \text{ ohms}$$

$$G = \frac{1}{R} = \frac{1}{1.25 \text{ ohms}} = 0.8 \text{ siemens / cm}$$

In actual usage, for dimensional correctness (cm) you would include the cell constant in the calculation.

Fig. 1-1. Electrode probe conductivity measurement

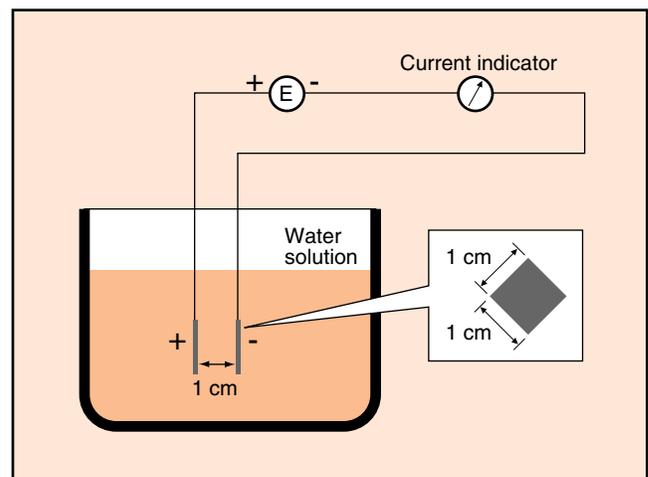
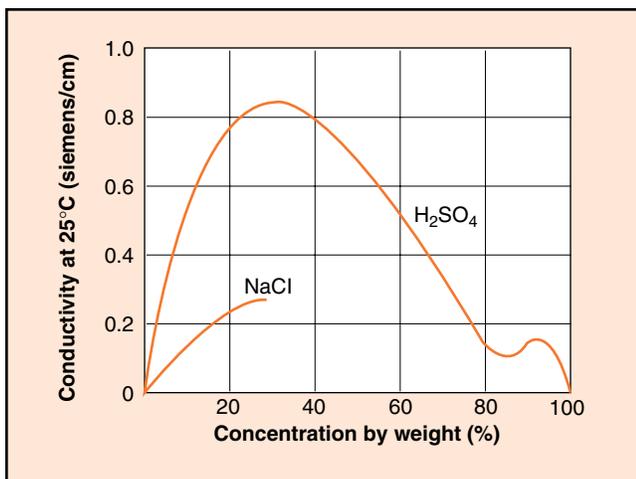


Fig. 1-2. Conductivity of sulfuric acid and salt solutions

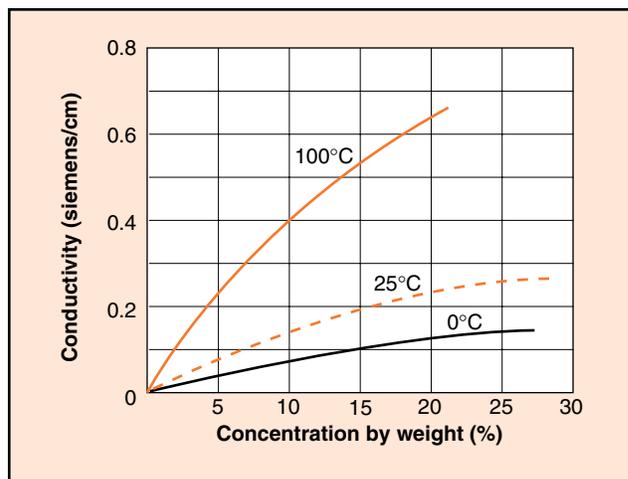
1.06 Figure 1-2 shows in graph form the conductivity of ionic solutions of sulfuric acid (H_2SO_4) and salt (NaCl) in water at various concentrations. A high conductivity indicates that electrons can flow freely through the liquid—the liquid contains a large number of ions. A low conductivity indicates that less current flows because of the higher resistance caused by fewer ions in the liquid.

1.07 Pure, deionized water presents a very high resistance to electron flow, and its conductivity is therefore very low. On the other hand, a solution of sulfuric acid has many ions in solution and a very low resistance to electron flow. The low resistance allows electric current to flow through the liquid more easily. The conductivity of the sulfuric acid solution is much higher than that of deionized water.

Variables Affecting Conductivity

1.08 Several variables affect the conductivity of process liquids. Three important variables are temperature, concentration of chemicals, and presence of contaminants.

1.09 A process may require a certain concentration of an ionizable chemical. That concentration can be measured by monitoring the process liquid's conductivity. For example, the conductivity of a 50% concentration of sulfuric acid is different from that of a 60% concentration. Figure 1-2 shows this relationship, which is *nonlinear*. That is, the rela-

Fig. 1-3. NaCl solution conductivity at various temperatures

tionship does not produce a straight-line graph. Notice the double-valued curve for H_2SO_4 —the concentration at a conductivity of 0.6, for example, is either 15% or 52%.

1.10 If two ionizable chemicals are present in the same solution, the total conductivity is the sum of the individual conductivities. Measuring the concentration of either one of the chemicals becomes very difficult.

Application 1-1

Water used for the manufacture of semiconductors, transistors, TV tubes, and other electronic components must be of very high purity and contain negligible ionic contaminants. Ionic contaminants—for example, salt—have been found responsible for high failure rates and shortened component life.

The high-purity water is usually prepared in two steps. In the first step, deionizers prepare water of equal quality to distilled water (about 0.000005 siemens/cm). The first-step deionizers are of high capacity, but do let some ions through. In the second step, the purified water is passed through low-capacity but high-strength deionizers that lower the conductance to about 0.00000005 siemens/cm. This water must be used immediately, because it degrades rapidly on standing. Conductivity meters are used to measure both steps of the process.

1.11 Contaminants in a liquid change its conductivity. For example, pipe scale or materials from a boiler's steam drum can change the conductivity of a system. By monitoring the conductivity, you can tell if the system is becoming contaminated.

1.12 Temperature has a great effect on conductivity. Increasing the temperature of a liquid decreases its viscosity, thus increasing the mobility of its ions and therefore its conductivity. Figure 1-3 shows the effect of temperature on the conductivity of a salt (NaCl) solution. Conductivity measurement can be corrected for temperature variation in the Wheatstone bridge circuit supplying voltage to the plates.

Application 1-2

The textile dye manufacturing industry typically adds salt (NaCl) to water-soluble azo dyes (dyes that contain nitrogen) during their manufacture. Azo dyes are usually made by a batch process in water. The water acts as a solvent and as a safety precaution, because many diazo compounds can rapidly decompose or explode when dry.

After the synthesis of the dye is finished, often as much as 20% salt is added to lower the solubility (salting out) of the dye in the water. The dye/water/salt mixture is then filtered to recover the dye. Most of the water and salt remain in the filtrate, but some water and salt remain with the wet dye presscake. Even small amounts of salt in the dye can damage the properties of the finished product.

The usual way of removing the remaining salt is by washing the dye presscake with water until the amount of salt is below acceptable levels, as determined by continuous monitoring with a conductivity meter. This meter turns off the water when the wash is complete, thus saving water, time, and waste disposal costs.

The conductivity meter has appropriate solenoid valves that can be set to direct wash water to two different waste streams. Wash water with high salt levels is sent to a concentrated waste stream. Wash water with low salt levels is sent to a dilute waste stream that requires less treatment or can even be recycled.

Conductivity Probes

1.13 Several kinds of sensors, or probes, are used to measure the conductivity of a process liquid. The two main kinds are:

- electrode probe
- inductive (electrodeless) probe.

1.14 **Electrode probe.** The *electrode probe* operates by applying a fixed-amplitude, square-wave voltage across two electrodes of known size and known separation immersed in the process liquid (the arrangement in Fig. 1-1). If the liquid contains ions, allowing a current to flow, the current is measured and converted to a conductivity reading. An alternating current is used to avoid polarizing the liquid, a condition that would make a reading impossible. *Polarization* is the production of a gaseous layer on the surface of the electrodes.

1.15 If the size of the electrode plates is changed, the amount of current changes. Therefore, the indicated conductivity changes although the voltage has *not* changed. This procedure is referred to as changing the *cell constant* of an instrument.

1.16 Each cell with fixed electrodes has its own cell constant. Cell constants range from 0.01 to 100 and vary by multiples of ten. An instrument with a cell constant of 0.01 has a range of 1 to 10 microsiemens, an instrument with a cell constant of 0.1 has a range of 1 to 100 microsiemens, an instrument with a cell constant of 1.0 can measure 1 to 1000 microsiemens, and so on. The lower ranges are used for fluids of lower conductivity and the higher ranges for those of higher conductivity. By changing the cell constant, you can adapt an instrument for the range of conductivity of the liquid you are measuring.

1.17 Figure 1-4 on the following page shows several typical electrode conductivity probes. All must be mounted so that they are in direct contact with the process liquid at all times. Each probe is connected to an indicator or transmitter by a 3 to 4 wire cable. The extra wire(s) are used for temperature compensation.

1.18 **Inductive probes.** The *inductive magnetic field probe*, also referred to as an *electrodeless*

probe, operates on a different principle from the electrode probe. The inductive probe is made up of two completely enclosed electrical coils. During operation, the probe is entirely immersed in the process liquid. The probe is enclosed in a corrosion-resistant coating.

1.19 Figure 1-5 shows the operation of the induction probe. The instrument sends an alternating current through the *primary coil*. This current creates an alternating magnetic field that induces an alternating current in the *pickup coil*. The conductivity of the process liquid affects the magnetic coupling between the coils. The induced current in the pickup coil is directly proportional to the conductivity of the liquid.

1.20 No direct contact is necessary between the coils and the solution, thus reducing potential maintenance problems. This system normally transmits a 4 to 20 mA dc signal that is proportional to the measured conductivity. To change the cell constant, you change the probe.

1.21 Figure 1-6 shows several typical inductive probes. Each probe is connected to an indicator-transmitter by a cable with at least six wires. Two pairs of wires are connected to the coils. The remaining wires are used for temperature compensation. The indicator-transmitter sends a current to the inductive probe. It then reads the pickup coil current, converts that current to conductivity, and displays a reading of the measurement. The electrodeless probe is corrosion-

and erosion-resistant, but requires higher conductivities and is more complex and more costly.

Probe Calibration

1.22 *Calibration* is the adjustment of an instrument after comparison to a known standard. You can calibrate either kind of probe by using a liquid of known standard conductivity. You can calibrate an inductive probe by using a wire loop. In practice, an instrument should have a range of about twice the full-scale value of the expected conductivity of the liquid being measured. Always follow the manufacturer's directions carefully when calibrating your instruments.

1.23 It is important to make sure your conductivity instruments are always calibrated correctly. As an instrument is used, it can lose its calibration and fail to indicate the presence of improper conductivities. For example, it could fail to detect contaminants in a boiler's steam generation system. The result could be excessive corrosion and costly, premature repair.

1.24 A strip- or circular-chart recorder that keeps a continuous record of process conductivity can indicate the condition of process instruments. If the chart shows a constant conductivity when either the product or a grab sample test (discussed below) indicates that the conductivity has changed, the probe might be damaged or coated with some pro-

Fig. 1-4. Electrode conductivity probes

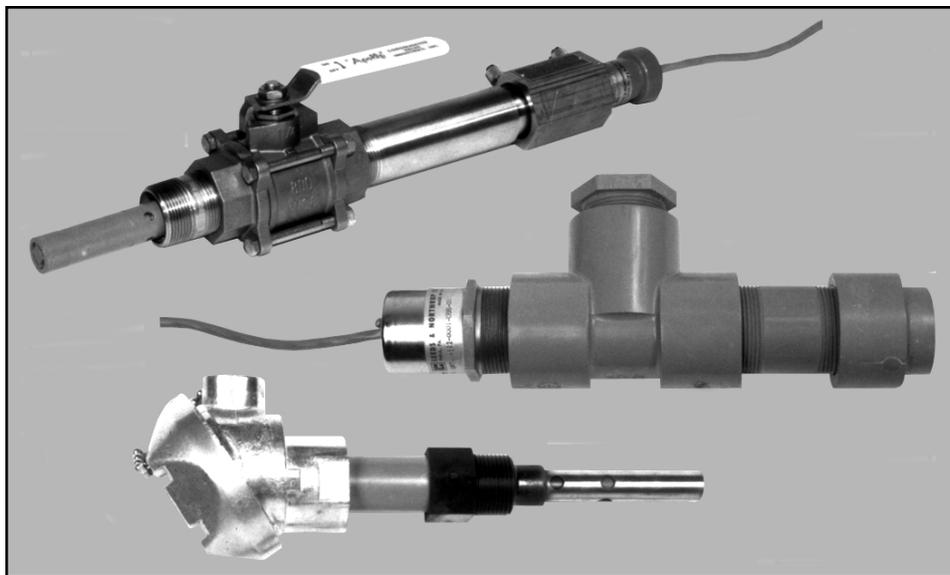
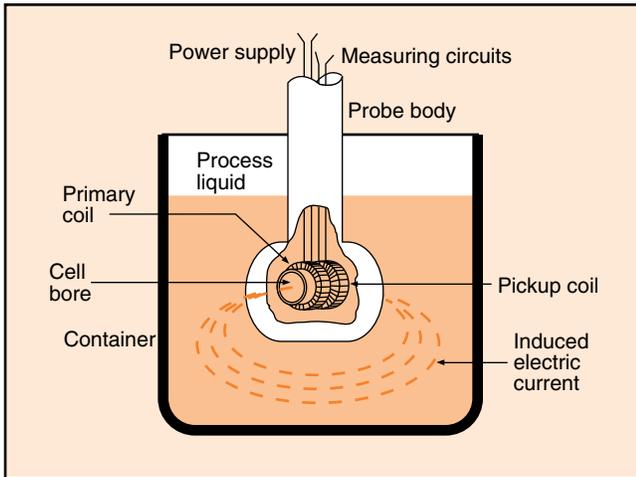


Fig. 1-5. Inductive conductivity measurement**Fig. 1-6. Inductive probes**

cess chemical. Either of these conditions can cause false constant readings.

1.25 If the chart shows widely varying values, the liquid could be changing conductivity rapidly. This is not usually the case in a properly controlled process. The probe or the instrument might be damaged, or the probe might be improperly installed so that it is not completely covered with liquid.

Liquid Standard Calibration

WARNING:

Avoid skin or eye contact with hazardous calibration liquids. Always use care when handling these liquids.

1.26 The liquids used as standards often contain the same chemicals as process liquids. These chemicals can be extremely dangerous, especially if they are strongly acidic or strongly basic. Always follow

published plant safety regulations when handling potentially dangerous materials.

1.27 When using standard liquids, you first immerse the probe in the liquid of known conductivity and then adjust the instrument to that conductivity. You should calibrate the instrument using two or more known liquid standards that are within the instrument's range.

1.28 If only two liquids are used, it is best to use one that is at the low end of the instrument's range and one that is at the high end. The low end is often at or near 0.0 microsiemens/cm and is referred to as the *zero standard*. The high end of the range is referred to as the *span standard*. The span of the instrument is the difference between the span standard and the zero standard.

The Programmed Exercises on the following page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

10 Programmed Exercises

<p>1-1. The unit of measurement for conductance is the _____, formerly known as the _____.</p>	<p>1-1. SIEMENS; MHO Ref: 1.03</p>
<p>1-2. When you measure the current flowing across two plates immersed in a process fluid, you are measuring the _____ of the liquid.</p>	<p>1-2. CONDUCTIVITY Ref: 1.04</p>
<p>1-3. Electrons can flow freely through a liquid that contains a large number of _____.</p>	<p>1-3. IONS Ref: 1.06</p>
<p>1-4. Because pure water has a high resistance to electron flow, its conductivity is _____.</p>	<p>1-4. LOW Ref: 1.07</p>
<p>1-5. Increasing the temperature of a liquid _____ its conductivity.</p>	<p>1-5. INCREASES Ref: 1.12</p>
<p>1-6. Cell constants range from _____ to _____.</p>	<p>1-6. 0.01, 100 Ref: 1.16</p>
<p>1-7. No direct contact is necessary between the coils and the solution in a(n) _____ probe.</p>	<p>1-7. INDUCTIVE Ref: 1.20</p>
<p>1-8. You should always avoid _____ contact with hazardous calibration liquids.</p>	<p>1-8. SKIN or EYE Ref: 1.26</p>

Wire Loop Calibration

1.29 You can use a wire loop to calibrate an inductive probe conductivity instrument. With this method, no hazardous chemical standard liquids are needed. To perform the calibration, you insert an 18 to 20 gauge wire through the sensing port of the conductivity probe, as shown in Fig 1-7. Then you connect the wire loop to a variable resistor in the range of the conductivity of the liquid the probe will be testing. For most applications, a variable resistor with a calibrated range from 1 to 1000 ohms is sufficient.

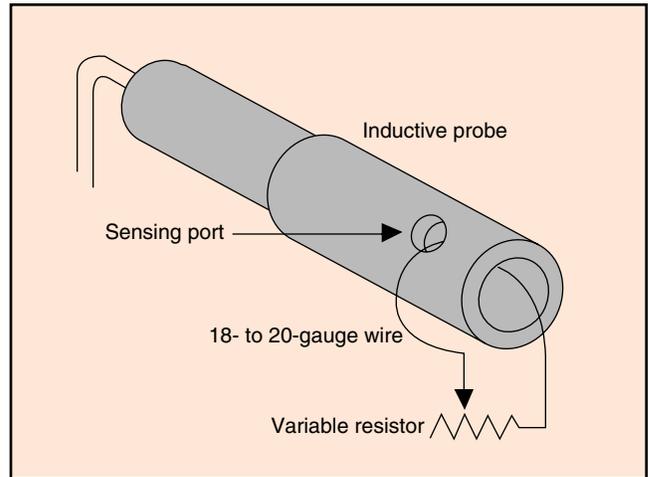
1.30 Next you set the variable resistor to the reciprocal of a conductivity at the low end and then at the high end of the instrument’s range and adjust the instrument with each setting. Finally you set the resistor to give the conductivity expected in the process liquid and readjust the instrument, if necessary.

Checking a Grab Sample

1.31 Whenever you have any doubt about a probe’s accuracy, you should check it against off-line instruments. To do so, you draw a *grab sample* of the process liquid from the system. You then check the grab sample with another instrument and compare the result that you get with the reading of the on-line meter.

1.32 This method can verify the instrument’s accuracy at only one value in the process liquid’s conductivity range. If possible, you should remove

Fig. 1-7. Wire loop calibration



the probe and conduct the zero and span calibration tests described earlier.

Probe Installation

1.33 Figure 1-8 shows several possible locations for probe installation in process piping:

- In each, the outlet pressure is lower than the inlet pressure. If the outlet is at an equal or higher pressure, the liquid will not flow through the test installation.
- You should never install an inductive probe in a steel pipe or near any strong magnetic

Fig. 1-8. Probe installation locations in process piping

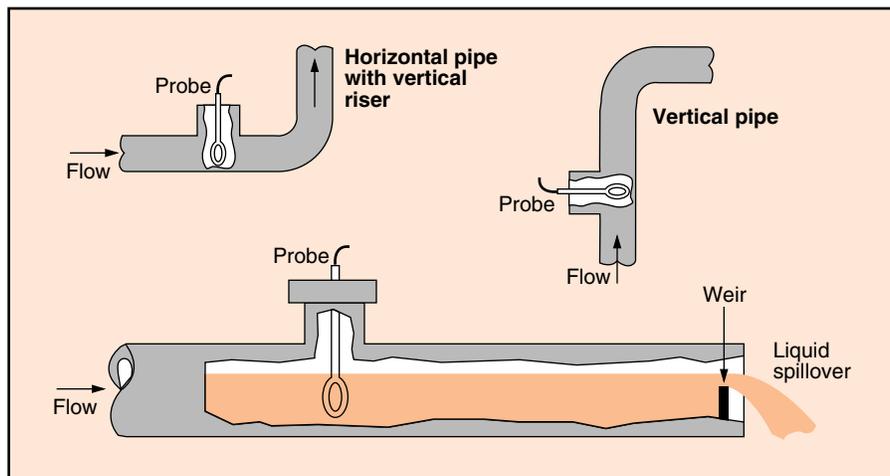
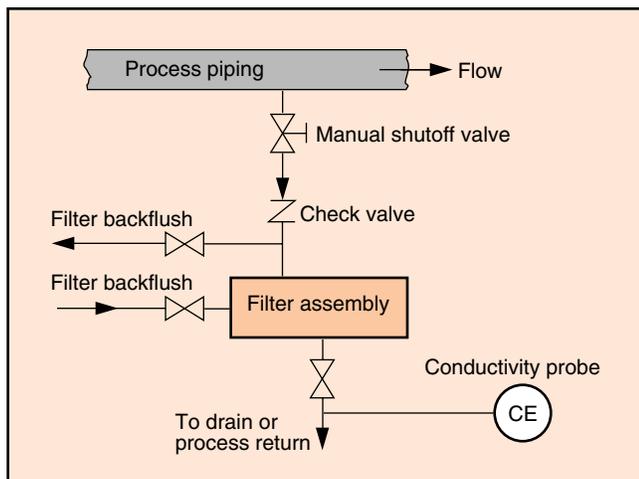


Fig. 1-9. In-line filter protection

field, because the presence of either will cause inaccurate readings.

- Remember that either kind of probe must be installed so that its measuring head is always completely covered by the process liquid. The weir in the lower example is a dam that keeps liquid covering the probe.
- The probe must almost always be installed so that it can be removed for servicing without shutting down the flow in the pipeline.

1.34 Wherever a probe is installed, you should have some means of obtaining a grab sample of the process liquid at or near that location to verify the accuracy of the probe at any time. Therefore, the probe should be located near a sample line or tap.

1.35 Conductivity probes must be protected from three conditions that could damage them:

- erosive materials in the liquid—for example, titanium particles
- excessive temperature—perhaps above 150°, for example
- excessive pressure—perhaps above 100 psi, for example.

Every probe is designed to withstand these conditions to certain limits. You should consult the

manufacturer's design specifications before initial installation and any time you think a probe might be operating beyond specifications.

1.36 **Erosive materials.** Thin plates of gold or platinum cover the electrodes in electrode probes. Particles in the process liquid can erode or pit the surfaces of the plates, decreasing the probe sensing area and, in time, destroying the probe's ability to measure conductivity properly.

1.37 You can often prevent erosion problems by installing an in-line filter to remove excess particles from the liquid before it reaches the probe. Figure 1-9 shows a typical filter installation. The filter can be cleaned through the filter backflush line by isolating the electrode and then opening the backflush valves. As shown, a manual shutoff valve is included to guarantee freedom from contamination of the process stream.

1.38 **Excessive temperature.** Probes are designed to withstand certain maximum temperatures. For example, one manufacturer's standard models have upper limits of 100, 158, 212, 220, and 250°F. If the process liquid being tested is above that temperature, you must cool the liquid before sampling it.

1.39 One way of cooling the liquid is by using the plant cooling water and a heat exchanger setup similar to the one shown in Fig. 1-10. The sample enters through a check valve that prevents backflow and a

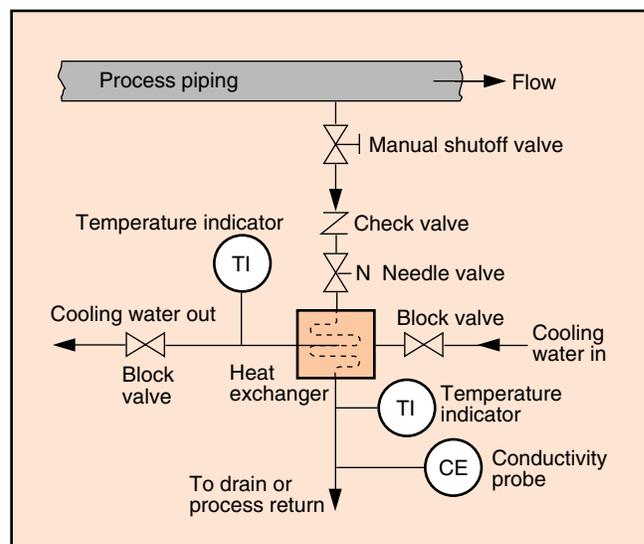
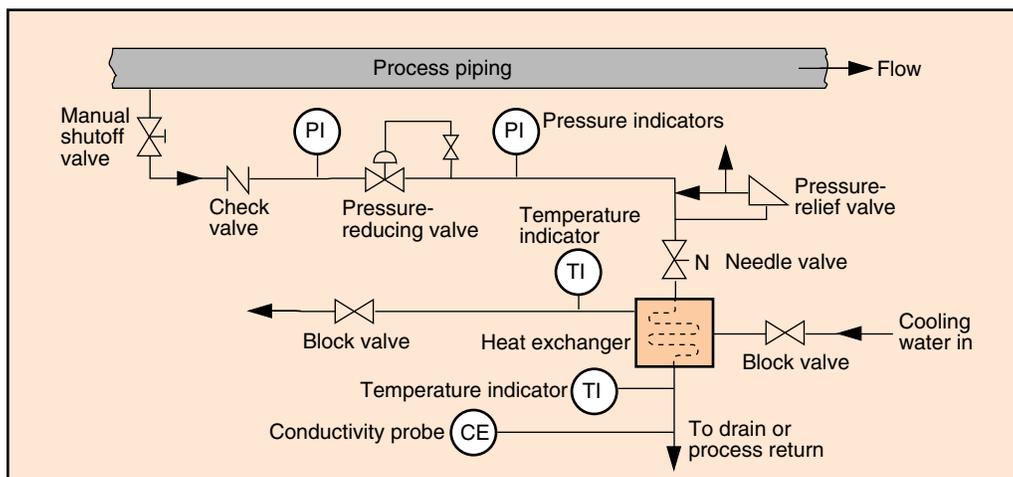
Fig. 1-10. Heat exchanger protection

Fig. 1-11. Pressure-reducing valve protection



needle valve that controls the volume of flow. The sample then passes through the heat exchanger, where it is cooled to an acceptable temperature. If the temperature must be decreased even more, you can use a small refrigeration unit or sample bath.

1.40 **Excessive pressure.** Probes are also designed to withstand certain maximum pressures. For example, one manufacturer's standard models have upper limits of atmospheric pressure, 10, 100, and 125 psi. You should always be sure to check the manufacturer's specifications to verify probe pressure limits.

1.41 You can reduce sample pressure by using a pressure-reducing valve in the sample line, as shown in Fig. 1-11. Note the installation of a pressure-relief valve after the pressure-reducing valve. The pressure-relief valve prevents damage or injury if the pressure-reducing valve fails and allows high-pressure liquid to pass. Any liquid passing through the relief valve should be directed to a safe place. Note that this installation also includes a heat exchanger to lower the sample's temperature.

1.42 Figure 1-12 on the following page shows the installation of a conductivity probe in a typical boiler blowdown loop. This kind of installation automatically checks the conductivity of the boiler water and protects the system by opening the blowdown control as the conductivity increases. Note that this installation also includes a heat exchanger for cooling the conductivity sample before it is measured by the conductivity probe.

Maintenance

1.43 Conductivity probes usually require little maintenance as long as the process liquid does not contain contaminants that can either coat or erode the electrodes. Proper probe maintenance is important in keeping the conductivity probe working at peak efficiency. When cleaning the probe, always follow the manufacturer's maintenance directions closely, and always use only recommended cleaning chemicals.

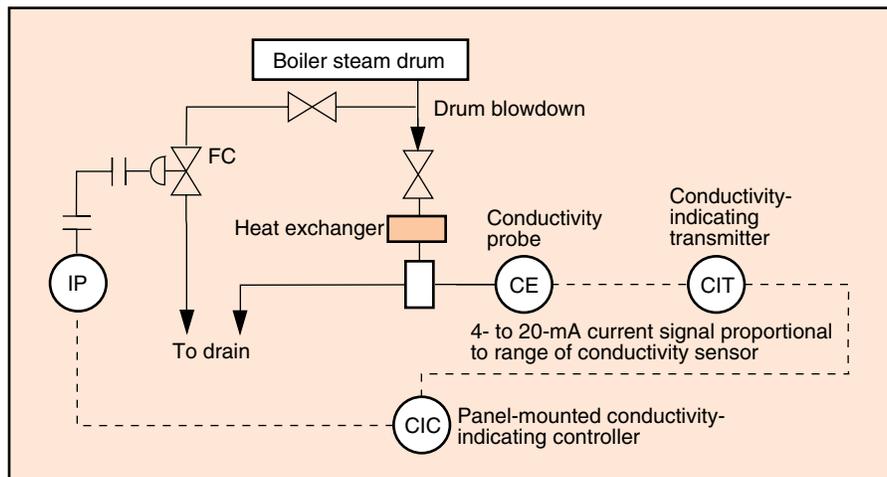
1.44 A severely eroded or overheated probe usually must be replaced. The new probe must then be calibrated as described earlier. To install or remove a probe, always follow the manufacturer's directions.

1.45 A typical insertion-style conductivity probe is shown in Fig. 1-13 on the following page. This kind of probe is easier to maintain than others, because you can install and remove it without reducing the process liquid pressure or flow. Note the safety cable attached to the probe's terminal box and the gauge valve body. This safety feature is designed to keep the probe from accidentally blowing out of its casing during installation or removal. Occasionally a locking mechanism is provided instead of the cable.

Stack Gas Analyzers

1.46 Stack gas analyzers continue to be important, partly because of steadily increasing government regulations. Pollution control requires the monitoring of hazardous emissions—for example, oxides of sulfur

Fig. 1-12. Boiler blowdown loop



and nitrogen. Sulfur dioxide is the main contributor to acid rain, and oxides of nitrogen are a major (or perhaps primary) contributor to smog.

1.47 Stack gas monitoring can be either continuous or by means of grab sample testing. Grab sampling methods were more common in the past and consisted of obtaining one or more grab samples and performing the tests away from the emission source. The grab samples were often submitted to a laboratory for testing. Modern technology has made it possible to perform most stack gas emission monitoring on a continuous basis.

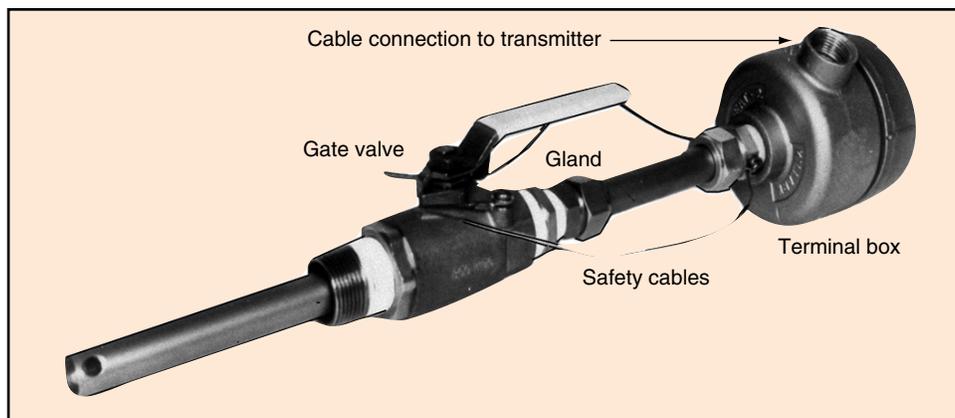
1.48 One way to monitor stack gases is by *selective absorption*, often referred to as the *ORSAT* method. The component of interest is absorbed by an absorbent

(usually a solution) and later measured by one of several methods. Absorbents are chosen so that they dissolve or react only with the component to be measured and usually are *proprietary* mixtures. (The rights to proprietary mixtures are owned by the manufacturer.)

1.49 The measurement of carbon dioxide can serve as an example. Certain stack gas samples can be bubbled through a basic (alkaline) solution of dilute sodium hydroxide, which will dissolve and react with carbon dioxide (which is acidic). The rest of the gases in this example are unaffected by the sodium hydroxide and pass through the solution.

1.50 The amount of carbon dioxide present in the sample can be determined in several ways:

Fig. 1-13. Insertion-style conductivity probe



- A gas burette can be used to measure the volume of the stack gas sample before and after passage through the sodium hydroxide. The difference in sample volume (corrected for temperature and pressure, if necessary) provides the amount of carbon dioxide in the sample.
- The sodium hydroxide could be *titrated* (brought to neutrality, neither acid nor base) with a known concentration of acid—for example, hydrochloric acid. The difference between the theoretical volume of acid needed to titrate the sodium hydroxide and the actual volume of acid used provides the amount of carbon dioxide absorbed by the sodium hydroxide.
- The amount of carbon dioxide absorbed can be determined by the conductivity of the sodium hydroxide solution before and after the stack gas is passed through it. This method is by far the easiest and also most readily permits continuous monitoring.

1.51 Nitric oxide can be measured in a similar fashion if first converted to nitrogen dioxide by a suitable oxidation method. The sample is measured twice, once without the oxidation step and once with the oxidation step. The former measures only nitrogen dioxide, and the latter measures both nitrogen dioxide and nitric oxide. The amount of nitric oxide is determined by the difference.

1.52 Conductivity measurement is used for both grab samples and continuous monitoring of stack

samples. In both cases, the component of interest in the stack gas is selectively absorbed by a suitable solution. The resulting change in conductivity of the absorbing solution is used to determine the amount of the component of interest. Hydrogen sulfide, sulfur dioxide, ammonia, chlorine, hydrogen chloride, and carbon monoxide are often determined by selective absorption and conductivity measurement analysis.

1.53 For continuous monitoring, constant flow rates of both stack gas and the absorbing solution are necessary. Usually two conductivity cells are used. One cell measures only the absorbing solution and the other cell measures the mixture of stack gas and absorbing solution. An alternating voltage is applied to the conductivity cells, which are part of a Wheatstone bridge. Any difference in conductivity produces a current, which is amplified and converted into the amount of the component of interest.

1.54 In addition to control of flow rates, temperature control is necessary to eliminate the effect of temperature on conductivity, reaction rate, and flow rates. Sensitivity is usually in the part per million range.

1.55 Increased awareness of personal exposure to harmful gases has created an industry specializing in *dosimeters*. These lightweight, portable gas-measuring devices monitor the exposure of a worker to a particular gas. They are designed to measure the total dose received by the worker rather than the concentration at a certain time. Many are based on selective adsorption rather than absorption. (A substance is taken up by an *absorbent*, but adheres to the surfaces of an *adsorbent*.) The component of interest is adsorbed by a solid adsorbent, and the resulting color formation indicates the dosage.

16 Programmed Exercises

<p>1-9. You can use a wire loop to calibrate a(n) _____ probe conductivity instrument.</p>	<p>1-9. INDUCTIVE Ref: 1.29</p>
<p>1-10. You can check a probe's accuracy against off-line instruments by means of a(n) _____.</p>	<p>1-10. GRAB SAMPLE Ref: 1.31</p>
<p>1-11. You should never install a(n) _____ probe in a steel pipe or near any strong magnetic field.</p>	<p>1-11. INDUCTIVE Ref: 1.33</p>
<p>1-12. The _____ of a conductivity probe must always be completely covered by the process liquid.</p>	<p>1-12. MEASURING HEAD Ref: 1.33</p>
<p>1-13. Conductivity probes must be protected from erosive materials in the liquid, excessive _____, and excessive _____.</p>	<p>1-13. TEMPERATURE; PRESSURE Ref: 1.35</p>
<p>1-14. To install or remove a probe, always follow the _____.</p>	<p>1-14. MANUFACTURER'S DIRECTIONS Ref: 1.44</p>
<p>1-15. One way to monitor stack gases is by the ORSAT method, also referred to as _____.</p>	<p>1-15. SELECTIVE ABSORPTION Ref: 1.48</p>
<p>1-16. The _____ monitors the exposure of a worker to a particular gas.</p>	<p>1-16. DOSIMETER Ref: 1.55</p>

Answer the following questions by marking an "X" in the box next to the best answer.

- 1-1. The ability of a circuit to pass current is its
- a. conductance
 - b. conductivity
 - c. resistance
 - d. resistivity
- 1-2. The mathematical expression for conductance is
- a. $E = IR$
 - b. $G = (E + I)/R$
 - c. $G = 1/R$
 - d. $R = I/E$
- 1-3. Deionized water has a _____ resistance to electron flow and a _____ conductivity.
- a. high; high
 - b. high; low
 - c. low; high
 - d. low; low
- 1-4. To change the cell constant of an electrode probe, you change the
- a. depth of immersion
 - b. distance between the plates
 - c. size of the plates
 - d. voltage across the plates
- 1-5. An instrument with a cell constant of 10 can measure conductivity over a range of 1 to _____ microsiemens.
- a. 10
 - b. 100
 - c. 1000
 - d. 10,000
- 1-6. In an electrodeless probe, an alternating current of known value is sent through the _____ coil.
- a. inductive
 - b. pickup
 - c. primary
 - d. solenoid
- 1-7. The wire loop calibration method
- a. can be used only for electrode probes
 - b. is the only way you can check inductive probes
 - c. requires a variable resistor
 - d. requires hazardous liquids
- 1-8. It is good practice when installing an inductive conductivity probe to be sure that
- a. outlet pressure is equal to inlet pressure
 - b. outlet pressure is higher than inlet pressure
 - c. the liquid completely covers the sensor
 - d. the pipe is of steel
- 1-9. To prevent conductivity probe problems due to erosive materials, you can install a(n)
- a. check valve
 - b. heat exchanger
 - c. in-line filter
 - d. sample bath
- 1-10. A dosimeter indicates the total exposure to a gas by means of
- a. color formation
 - b. conductivity readings
 - c. curie readings
 - d. current readings

SUMMARY

Conductivity probes measure the current that passes through a liquid containing ionized particles. Units of conductance are the siemens and the mho. Conductance is the inverse of resistance ($G = 1/R$).

The two common kinds of conductivity probe are the electrode probe and the inductive (electrodeless) probe. The electrode probe measures conductivity with two electrodes in contact with the process liquid. The inductive probe is completely enclosed and measures conductivity by inducing a current in the process liquid and measuring the resulting current in a pickup coil.

Both kinds of probe can be calibrated against standard conductivity liquids. The inductive

probe can also be calibrated with a wire loop and variable resistor. A grab sample is a means of checking the operation of a probe against another instrument.

Inductive and electrode probes must be installed with their measuring surfaces completely covered by the process liquid. Installation must also account for temperature, pressure, and erosive materials in the process liquid.

Stack gas monitoring can be either continuous or by means of grab sample testing. In the selective absorption method, the component of interest is absorbed and later measured by one of several methods, including measurement of conductivity. Many dosimeters are based on selective adsorption.

Answers to Self-Check Quiz

- 1-1. a. Conductance. Ref: 1.03
- 1-2. c. $G = 1/R$. Ref: 1.03
- 1-3. b. High; low. Ref: 1.07
- 1-4. c. Size of the plates. Ref: 1.15
- 1-5. d. 10,000. Ref: 1.16
- 1-6. c. Primary. Ref: 1.19
- 1-7. c. Requires a variable resistor. Ref: 1.29
- 1-8. c. The liquid completely covers the sensor. Ref: 1.33
- 1-9. c. In-line filter. Ref: 1.37
- 1-10. a. Color formation. Ref: 1.55

Contributions from the following sources are appreciated:

- Figure 1-4 Leeds & Northrup
A Unit of General Signal
- Figure 1-6 Courtesy of The Foxboro Company
- Figure 1-13 Electro-Chemical Devices, Inc.