

MS0500

Electrical Resistance Monitor

Metal Samples Company

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I. Principles of Operation and General Information

Introduction

Metal Samples' Electrical Resistance (ER) monitoring systems use the principle of electrical resistance to determine the average corrosion rate of a metal specimen immersed in a corrosive environment. The electrical resistance of a metal specimen is a physical property dependent on the specimen's physical dimensions (length, width and thickness), and on the metal's inherent resistivity which is a function of temperature. All other factors remaining constant, any decrease in the thickness of a metal specimen will increase its resistance.

Electrical Resistance monitoring systems are used in process systems for which appropriately designed ER probes are available. Such systems include nonaqueous, nonconductive process streams, aqueous systems where erosion-corrosion occurs, and process streams having either a predominant liquid or vapor phase. Examples of industries where such process streams are found include chemical plants, refineries, gas plants, oil and gas production systems, paper mills, power plants, and tank farms.

A basic ER monitoring system consists of the MS0500 Electrical Resistance Monitor with integral probe cable and an ER probe (see Figure 1). The portable MS0500 monitor is a lightweight, battery-powered instrument designed for taking electrical resistance measurements in a laboratory or process environment. A single instrument can be used with several ER probes installed at widely separated locations because connection to a probe is required only at the time a resistance measurement is taken. The MS0500 monitor's portability and ease of operation allow an operator to carry the MS0500 to an ER probe location, connect the monitor to the probe, and take a resistance measurement in only a few minutes.

In order to minimize the effects of signal loss that can occur in probe extension cables, the integral MS0500 probe cable incorporates a signal-boosting transformer. This helps to ensure accurate instrument measurements when the MS0500 and ER probe are used with an extension cable.



Figure 1. MS0500 Electrical Resistance Monitor

The use of Metal Samples shielded extension cables allows the MS0500 monitor to be operated at distances of up to 1,000 feet from the ER probe location. Shielded extension cables are covered with a protective coating that shields the cable from stray electromagnetic fields. Metal Samples shielded extension cables must be used with the portable MS0500 monitor. The use of other cables may alter probe-to-instrument signals and result in erroneous instrument readings.

Each MS0500 is supplied with a meter prover. The meter prover is used during the performance verification procedures, **Verifying that the ER Monitoring Instrument Operates Properly**, that begin on page 14. Each MS0500 is calibrated during final assembly and calibration is verified prior to shipment; however, the operator can check the monitor's calibration and function by following the performance verification procedure. If instrument mishandling or damage makes recalibration necessary, return the instrument to Metal Samples following the **Instructions for Returning the Instrument for Repair** on page 27.

Principles of Operation

The MS0500 monitors the change in electrical resistance occurring at an ER probe installed in an experimental or actual process stream. All Metal Samples ER probes contain a continuous sensing device. So that the probe obtains relevant corrosion data, this sensor must be constructed of the same metal common to the process system of interest. Each sensor is divided into “elements”. All ER probes have a **measuring element** and a **reference element** connected in series. The measuring element is exposed to the corroding environment. The resulting loss of metal decreases the measuring element’s thickness and causes an increase in the element’s resistance. The reference element is protected from the corroding environment and retains its original thickness and resistance.

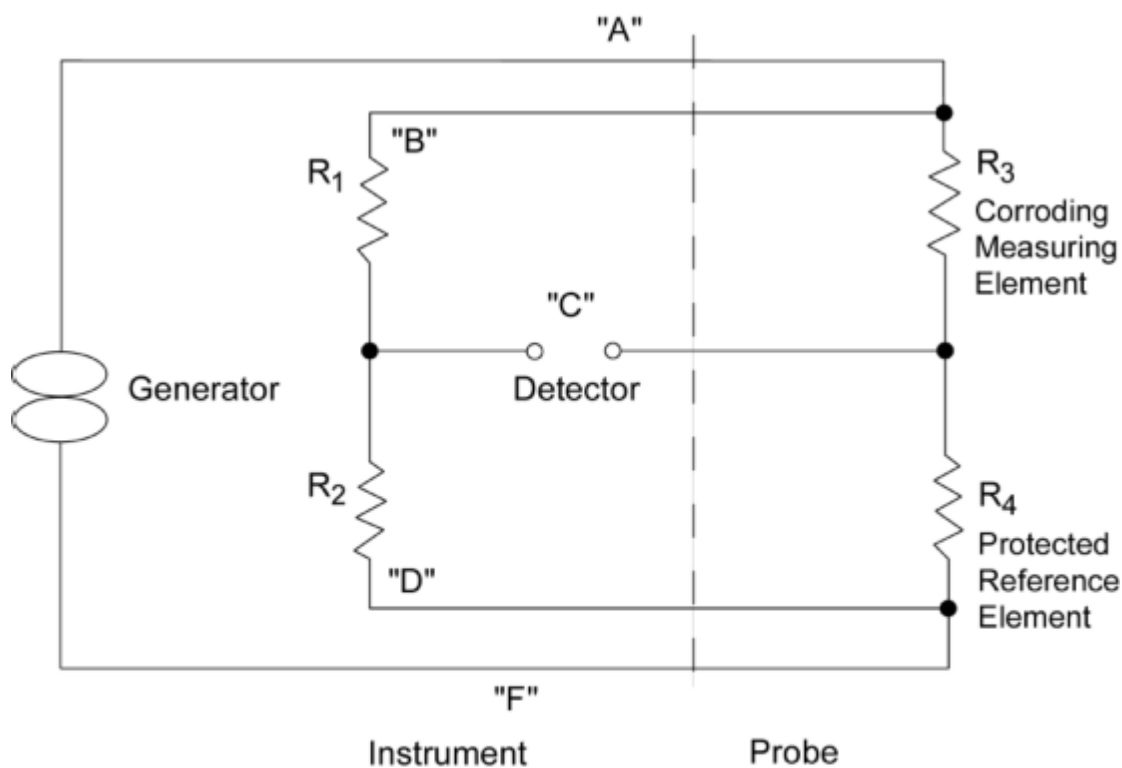
The measuring circuit of a Metal Samples Electrical Resistance Monitor does not directly measure the measuring element’s changing resistance to electrical current flow. Instead, instrument circuitry measures the ratio of the resistance of the corroding measuring element to that of the protected reference element. Measuring the ratio eliminates ambient temperature dependency from the resistance measurement. The instrument then converts the electrical resistance ratio to linear “units” that are displayed on the instrument’s digital indicator, the Probe Reading Dial (refer to Table 1). Substituting Probe Reading Dial unit readouts into special formulas permits the researcher to determine the measuring element’s metal loss and average corrosion rate. These formulas appear in **Determining Mils of Metal Loss** (page 16) and in **Determining Corrosion Rate** (page 17).

When measuring the electrical resistance ratio, the Metal Samples ER Monitoring System sums the electrical resistances occurring at each crosssectional point or area along the measuring element’s length. The ER instrument interprets the electrical resistance sum as being divided equally among the measuring element’s crosssectional areas. Probe Reading Dial unit readouts therefore indicate the measuring element’s electrical resistance and metal loss as being uniform or equal at each of the measuring element’s crosssectional areas. However, this may not be the case for all corrosion measurement situations.

If corrosion occurs uniformly over the measuring element’s surface, then the electrical resistance at each of the measuring element’s crosssectional areas will be equal and will increase linearly as corrosion progresses. However, if localized pitting corrosion occurs, the electrical resistance of the crosssectional areas where pitting takes place will increase nonlinearly and cause the Probe Reading Dial to indicate substantial corrosion when in fact overall corrosion is not as great as indicated. (This is especially true of wire loop elements.) A pit can greatly decrease the area at the crosssectional point where it occurs and subsequently greatly increase that crosssectional point’s electrical resistance. The sum of electrical resistances occurring at all crosssectional areas along the measuring element’s length will therefore be weighted toward those crosssectional areas where pitting has occurred. If pitting continues, the summation of electrical resistances will continue to increase nonlinearly until the measuring element is finally served by a pit. The ER probe will then become nonfunctional. (Cylindrical element probes are considerably less affected by pitting and may be substituted for wire loop probes wherever pitting is a problem.)

Probe Reading Dial unit readouts also correspond to the measuring element's **functional thickness**. The functional thickness for all Metal Samples measuring element types, except for wire loop elements, is one-half the element's thickness when new. The functional thickness of a wire loop measuring element is one-quarter of the element's thickness when new. The Probe Reading Dial is calibrated from 000 (zero) to 1000, and each whole number on the Probe Reading Dial represents 0.001 of the measuring element's functional thickness. Probe Reading Dial readouts increase as corrosion progresses. For example, a reading of 750 indicates that 75% of the measuring elements functional thickness has been lost to corrosion. The initial Probe Reading Dial unit readout taken when a probe is first installed will vary from 000 to 100.

Some ER probe sensors have a third element called a **check element**. Like the reference element, the check element is protected and retains its original thickness and electrical resistance. The check element is used in a measurement process that quickly identifies defective probes which have leaked and caused the check element to corrode. When the instrument's Probe Selector (refer to Table 1) is positioned at **CHECK**, the electrical resistance ratio between the reference and check elements is measured and the equivalent unit reading is displayed on the Probe Reading Dial. Since both reference and check elements are protected, their resistance ratio remains virtually unchanged unless the probe's internal components become damaged.



$$\text{Balance } \frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Figure 2. Four Resistor Bridge Circuit

The ER Monitoring System’s electrical resistance measuring circuit is a four-resistor bridge circuit (as shown in Figure 2). A detector, located within instrument circuitry, indicates a null condition (balance) when the ratio of resistor One (R_1) over resistor Two (R_2) equals the ratio of resistor Three (R_3) over resistor Four (R_4). The values of both R_1 and R_2 are known. R_4 is a non-corroding, compensation resistor whose value is also known. Since the values of three resistors are known, the unknown R_3 value can be determined.

Resistors One and Two are connected in series and are located within instrument circuitry. These schematic resistors consist of a single variable potentiometer and two fixed resistors. The two fixed resistors are part of the detector’s circuitry. There is one pair of fixed resistors for each Probe Selector position (refer to Table 1). The selection of a different set of resistors for each Probe Selector position allows the instrument’s Probe Reading Dial to standardize measurements of the probes’ metal loss.

Resistor Three is the exposed measuring element. Since the measuring element is exposed to corrosion attack, its resistor value will change over time. Resistor Four is connected in series with resistor Three. Located within the probe, resistor Four is the protected reference element whose value is fixed. Turning the Probe Reading Dial to null the instrument's Meter (refer to Table 1) causes the ratio of resistors One and Two to approach the ratio of resistors Three and Four (the measuring and reference elements). When the two ratios are equal, the instrument's Meter is nulled and the Probe Reading Dial displays the corrosion readout.

The resistivity of a metal specimen is temperature dependent, but the operation of the ER Monitoring System's measurement circuitry is relatively independent of the process stream's temperatures. Temperature changes affect the resistance of both the exposed measuring element and the protected reference and check elements in the same manner. Temperature fluctuations as high as 5°F./minute can occur without altering ER Monitoring System performance. However, if the process stream in which the ER probe is installed undergoes a more rapid change in temperature, the temperature of the exposed measuring element will change more rapidly than will the temperature of either the protected reference and check elements. Readings taken before all elements have reached equilibrium will therefore be in error. Fortunately, errors due to temperature fluctuations are temporary and non-cumulative. When the temperature of the process stream stabilizes, exposed and protected elements will be in equilibrium with the process stream in just a few minutes. For more information on the **Effects of Temperature** on ER probes and elements, refer to page 38.

The following table provides the user with a brief introduction to the function and location of the MS0500 controls and features. The use of each control and feature is discussed in greater detail in later sections of the manual. Refer to Figure 1 while reading the table.

TABLE 1. MS0500 Controls and Features

DESCRIPTION	FUNCTION
Function Selector	<p>A five-position rotary selector located at the left-hand side of the instrument's control panel. The function of each position is as follows:</p> <p><u>OFF</u> - Turns the instrument off. To avoid depleting the battery charge, always turn the Function Selector to this position when the instrument is not in use.</p> <p><u>NORMAL</u> - This position is used when corrosion and check readings are taken. Most readings will be taken with the Function Selector turned to this position.</p> <p><u>HIGH</u> - This position may sometimes be used when corrosion and check readings are taken. This position provides greater meter sensitivity than the NORMAL position.</p> <p><u>NOTE</u> Changing the sensitivity setting while taking a corrosion or check reading will not change the instrument's accuracy or Probe Reading Dial unit readout (refer to the description of the Probe Reading Dial).</p> <p><u>+V</u> - This position is used to check the charge of the instrument's positive battery. When the Function Selector is turned to this position, the battery is under load. If the battery is functioning properly, the meter needle will enter the meter's right-hand side and remain in the square labeled +V.</p> <p><u>-V</u> - This position is used to check the charge of the instrument's negative battery.</p>

DESCRIPTION

FUNCTION

NOTE:

When the Function Selector is turned to this position, the battery is under load. If the battery is functioning properly, the meter needle will enter the meter's left-hand side and remain in the square labeled -V.

If the meter needle does not behave as described above, check the battery charge by following the instructions outlined on page 25.

Probe Selector

The Probe Selector is located in the center of the instrument's control panel. Three of the selector positions correspond to probe element configurations and are used in procedures for corrosion readings. The following describes the five Probe Selector positions:

WIRE - Turn to this position when operating the MS0500 in conjunction with a probe having a wire element.

TUBE - Turn to this position when operating the MS0500 in conjunction with a probe having a tube or strip element.

SPEC - Turn to this position when operating the MS0500 in conjunction with Metal Samples special probes (for example, the cylindrical element probe).

NOTE:

Once the measuring element's functional thickness is depleted (equivalent to a Probe Reading Dial readout of 1000), measurements made with the Probe Selector in the WIRE, TUBE or SPEC position will no longer provide accurate corrosion data.

DUAL - This position is not presently used. In the future, it will be used with Metal Samples probes currently being developed.

DESCRIPTION

FUNCTION

CHECK - Turning the selector to the CHECK position enables the instrument to measure the ratio of the electrical resistance of the reference element to that of the check element. The resistance ratio of the protected reference and check elements should vary little over the operational lifetime of the probe. Large variations indicate that internal components of the probe have been damaged.

Probe Reading Dial

This balance potentiometer is located in the lower right-hand corner of the instrument's control panel. Calibrated from 000 (zero) to 1000, each dial unit (whole number) represents 0.001 of the measuring element's functional thickness. Turning this control provides numerical values for corrosion and check readings. The numerical corrosion value can be substituted into formulas (refer to page 16 & 17) to determine the measuring element's total metal loss (in mils) and the average corrosion rate (in mils per year) occurring at the probe location.

Meter

The meter is located in the upper right-hand corner of the instrument's control panel. When the meter needle is centered at the meter's vertical white line, the instrument is in the null state. For accurate corrosion or check readings, the instrument must be in the null state. Turning the Probe Reading Dial nulls the meter.

Probe Cable and Transformer

The integral probe cable and transformer assembly is permanently attached to the lower left-hand corner of the control panel. The 6-pin female connector on the end of the transformer plugs directly into any standard ER probe, high pressure probe adapter, or probe extension cable.

DESCRIPTION

FUNCTION

Meter Prover

The meter prover is used during instrument performance verification. The meter prover is not a precisely calibrated device. However, if the instrument is operating properly, the meter prover will cause the Probe Reading Dial to display a readout equal to the value shown on the meter prover. The meter prover is encapsulated and no attempt should be made to open the unit for examination or repair as damage to its circuitry will result.

CAUTION - To avoid depleting the instrument's battery charge, do not store the instrument with the meter prover attached.

Technical Specifications

Model

MS0500 - ER Corrosion Meter (Ordering # IN0500)

Physical Data

Instrument Weight:	2.38 lb. (1.08 Kg)
Total Weight w/ Carrying Case and Accessories:	4.62 lb. (2.10 Kg)
Instrument Dimensions:	3"H x 5"W x 6.75"D (7.62cm x 12.7cm x 17.15cm)
Carrying Case Dimensions:	6.0"H x 6.0"W x 8.75"D (15.24cm x 15.24cm x 22.23cm)
Operating Temperature:	32° to 122°F (0° to 50°C)
Storage Temperature:	32° to 122°F (0° to 50°C)

Performance Data

Measurement Type:	ER measurement using any standard ER probe type (Wire Loop, Tube Loop, Cylindrical, Flush, Strip, etc.) w/ check reading.
Range:	0-1000 digits representing 0-100% of probe life
Resolution:	1 digit

Electrical Data

Power Requirements:	Two 9V Batteries
Maximum Probe Cable Distance:	1000 ft (304.8 m)

Special Features

- Simple user interface
- Built-in battery check
- Portable

Accessory Items

Carrying Case, 6' Probe Cable (attached), Meter Prover, Operation Manual

Warranty

Metal Samples warrants that any part of their instruments and accessories which proves to be defective in material or workmanship within one year of the date of original shipment to Purchaser will be repaired or replaced, at Metal Samples option, free of charge. This warranty does not cover (1) probe assemblies, (2) items expendable in nature, or (3) items subject to damage from normal wear, misuse or abuse, or failure to follow use and care instructions.

All damaged items are to be shipped at Purchaser's expense to and from Metal Samples which shall have the right to final determination as to the existence and cause of a defect.

The foregoing shall constitute the sole and exclusive remedy of any purchaser of Metal Samples products for breach of warranty and is exclusive and in lieu of all other warranties, expressed, implied or statutory, including the implied warranties of merchant-ability and fitness. In no event shall Metal Samples be liable for special or consequential damages, or for any delay in the performance of this warranty due to causes beyond its control.

Orders or requests for additional information should be addressed to:

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The technical information and suggestions contained herein are believed to be reliable, but they are not to be construed as warranties since conditions of use are beyond our control.

II. Verification Procedures

Receiving the Instrument

Check the instrument for damage when it is first received. If there is obvious damage to the shipping carton, request that the responsible carrier's agent be present when the instrument is unpacked.

To unpack the instrument, proceed as follows:

1. Verify that the shipping carton contains the following items:

- One Portable MS0500 Electrical Resistance Monitor housed in a leather carrying case
- Two 9V alkaline batteries installed in the instrument
- One six-foot, coiled probe cable permanently attached to the MS0500
- One meter prover
- One technical manual

2. Examine the instrument for any dents, scratches, broken connectors or other mechanical damage.

Verifying that the ER Monitoring Instrument Operates Properly

Before placing the MS0500 into service, complete the following performance verification to ensure that the instrument operates properly.

1. Connect the meter prover to the probe cable.
2. Turn the Function Selector to +V. The meter needle should enter the meter's right-hand side and remain in the square labeled +V.
3. Turn the Function Selector to -V. The meter needle should enter the meter's left-hand side and remain in the square labeled +V.
Note: if the meter needle does not behave as described above, check the monitor's batteries by following procedures outlined on page 25.
4. Turn the Function Selector to NORMAL.
5. Turn the Probe Selector to WIRE.
6. Turn the Probe Reading Dial and null the instrument's meter. The meter is nulled when the needle is centered at the vertical white line. The Probe Reading Dial should read the value indicated on the meter prover.
7. Turn the Function Selector to OFF.

III. Operating the ER Monitor

Operating the ER Monitoring Instrument

After installation in the process stream, the ER probe can be used almost immediately to take probe measurements. Only a few minutes are required for both protected and exposed ER probe elements to equilibrate with the process stream temperature. To operate the MS0500 with an ER probe installed in the process stream of interest, proceed as follows:

1. Attach the probe cable to the installed ER probe.
2. Conduct the CHECK measurement.
 - a. Turn the Probe Selector to CHECK.
 - b. Turn the Function Selector to NORMAL.
 - c. Turn the Probe Reading Dial and null the monitor's meter.
 - d. Record the Probe Reading Dial unit readout as the CHECK value for the subject probe.
3. Turn the Probe Selector to the control position corresponding to the subject probe's element configuration (WIRE, TUBE, SPEC, or DUAL).
4. Turn the Probe Reading Dial and null the monitor's meter.
5. Record the Probe Reading Dial corrosion readout.
6. When the measurement process is completed, turn the Function Selector to OFF.
7. Disconnect the monitor from the probe.
8. To calculate mils of measuring element metal loss or to determine corrosion rate, refer to page 16 & 17.

Recording the Data

Keep a separate log record sheet for each probe location. Instrument readings should be immediately recorded on the probe location's log sheet. Record check readings, corrosion readings, time and date, and any remarks. Additional information such as temperature, pH, and pressure variations can be added to aid in the interpretation of instrument results.

Probe Multipliers

Metal Samples ER probes are available in a variety of types and sizes. In order to standardize the measurement process so that a single instrument may be used with all ER probes, each probe is assigned a correction factor or "multiplier." Probe multipliers are used in the following special formulas to determine the mils of metal loss and the average corrosion rate of the probe's measuring element. The multiplier value is engraved on the probe.

Determining Mils of Metal Loss

Use the following formula to determine the amount of measuring element metal loss:

$$\Delta \text{ Probe Reading Dial Readout} \times \frac{\text{Probe Multiplier}}{1000} = \text{Mils of Metal Loss}$$

For example, the probe multiplier for a 0.040" wire ER probe is 10. If the Probe Reading Dial reads 250 and the previous Probe Reading Dial readout was 150, total metal loss is determined as follows:

$$(250 - 150) \text{ or } 100 \times \frac{10}{1000} = 1 \text{ Mil of Metal Loss}$$

Determining Corrosion Rate

It is not recommended that corrosion rates be calculated for each individual Probe Reading Dial corrosion readout as this method tends to magnify the significance of small deviations. However, on occasion it may be necessary to quickly determine the approximate corrosion rate occurring at the probe immersed in the process system. On such occasions, the following formula should be used:

$$\frac{\Delta \text{ probe Reading Dial Readout}}{\Delta \text{ time (days between Probe Reading Dial readouts)}} \times \frac{\text{Probe Multiplier}}{1000} \times \frac{365 \text{ Days}}{\text{Year}} = \text{Corrosion Rate in Mils Per Year}$$

When time permits a more accurate determination of Corrosion rate, use the following formula:

$$\frac{\text{Slope of the Straight Line}}{\text{Slope of the Straight Line}} \times \frac{\text{Probe Multiplier}}{1000} \times \frac{365 \text{ Days}}{\text{Year}} = \text{Corrosion Rate in Mils Per Year}$$

To determine the quantity referred to as Slope of the Straight Line, plot on graph paper Probe Reading Dial corrosion readouts as a function of time (days). The data should indicate a positive or upward slope. After five or more corrosion readings have been plotted, draw a straight line through the points and determine the magnitude of the slope of the straight line using the following formula:

$$\frac{\text{Slope of the Straight Line}}{\text{Slope of the Straight Line}} = \frac{y_2 - y_1}{x_2 - x_1}$$

where x_1 , x_2 , y_1 and y_2 are the x and y coordinates of two points on the straight line.

If data points are not perfectly linear, the researcher may prefer to draw a straight line using the “eyeball” technique or the least squares line of best fit. A good reference book on statistical analysis or analytical geometry will provide procedures for determining the least squares line of best fit.

Interpreting Corrosion Data

As a general rule, corrosion readings when plotted on graph paper approximate a straight line having an upward slope. However, exceptions to this rule may occur and possible causes are described below.

Nonlinear Increases in the Corrosion Graph

Pitting corrosion of wire or tube measuring elements can cause nonlinear increases in electrical resistance and subsequent nonlinear increases in the graph paper plot of Probe Reading Dial corrosion readouts. (Cylindrical ELEMENT Probes are less affected by pitting and can be substituted for wire or tube probes wherever pitting is a problem.) Nonlinear increases in the corrosion graph do not usually appear until the second half of the measuring element's operating lifetime (when Probe Reading Dial readouts are greater than 500).

Nonlinear increases in corrosion data are a function of the number of pits and the severity of corrosion attack at each pit. For example, a 20-ohm electrical resistance value for a wire measuring element can be represented as twenty 1-ohm resistors in series. If the resistance of one 1-ohm resistor is increased by pitting to 10 ohms, then the total resistance value of the measuring element is 29 ohms. If pitting continues, a second resistor may increase its resistance to 100 ohms in the same amount of time as the first resistor increased its resistance from 1 to 10 ohms. The total resistance for the measuring element is then 128 ohms. Such increases in electrical resistance will continue until the measuring element is finally severed by a pit.

Widely Scattered Data Points

Widely scattered data points may indicate that temperature fluctuations are occurring within the process system. Measurements obtained by the ER Monitoring System are independent of the temperature of the corrosive environment. Of course, if that environment undergoes rapid changes in temperature, the temperature of the unprotected measuring element will change quicker than the temperature of the protected reference element. Therefore, a reading taken before both measuring and reference elements have reached equilibrium will be in error by an amount dependent upon the temperature lag of the reference element. Fortunately, errors due to temperature fluctuations are noncumulative. For more information concerning the **Effects of Temperature** (refer to page 38).

If the measuring element's surface becomes plated by an electrically conductive corrosion product or process stream component, widely scattered data points will result. Any addition of conductive material to the measuring element's surface will cause a decrease in the ER Monitoring System's corrosion measurements. Examples of conductive materials which tend to plate measuring element surfaces are: copper on a steel measuring element, cadmium on a steel measuring element, and iron sulfide (FeS) on any metal element. If the operator suspects that conductive material has plated the measuring element, it is recommended that the ER probe be retrieved and replaced, or that the measuring element be thoroughly cleaned (refer to **Cleaning the Measuring Element** on page 34).

Scattered data points can result if moisture of any kind penetrates the connecting cable's protective jacket. Moisture can affect the transfer of signals through the cable and result in completely erroneous instrument readings. It is recommended that all cable used in the ER Monitoring System be protected from moisture contamination.

Interpreting Check Data

A consistent check reading for an individual probe indicates that the probe's internal reference and check elements are intact and that the resistance of the reference element is unchanged. Changes in the Probe Reading Dial readout of only a few units are not unusual and are considered normal, particularly if the changes are up and down and not only in one direction. However, if large changes in the check readings suddenly begin after a period of stability, particularly if the change is in one direction, corrosion of the reference and check elements is indicated. If this occurs, ER monitor corrosion readings are no longer reliable and the probe should be replaced.

Using Extension Cables

Use Metal Samples special shielded extension cables to provide access to ER probes installed at locations not within easy reach of the operator. Only shielded cables should be used with the MS0500 monitor. Metal Samples shielded extension cables are covered with a protective coating that shields the cable from stray electromagnetic fields.

NOTE: The use of extension cables may change ER monitor readings, but the change should be constant.

To avoid "noise" or "crosstalk", do not run extension cables near generators or other equipment that generates an electromagnetic field. Do not permit extension cables to contact hot equipment or be subjected to abrasion or chemical attack. Avoid unnecessary flexing or movement of the cable. Changes in the cable's position in the presence of external electrical fields can cause fluctuating instrument readings. Wherever possible, run cable through conduit or flexible sleeving. When used as conduit, mild steel is superior to other metals as it provides magnetic shielding. For cable not in conduit, runs in excess of 20 feet should be fixed in position by tying at intervals to accessible structures and conduit runs. Fixing the cable's position will reduce outside field effects.

Do not permit extension cables to contact moisture of any kind. Although extension cable is covered with a protective jacket, moisture may penetrate the cable and interfere with the transfer of signals. If extension cable must be used in damp environments, it is recommended that the customer supply waterproof protection for the cable. If moisture does penetrate the cable, replace the cable, or cut back the wet portion of the cable, or allow cable to thoroughly dry in a moisture free environment.

IV. MS0500 Maintenance and Repair

MS0500 Preventive Maintenance

Proper handling and storage of the MS0500 will substantially increase its operating lifetime. A preventive maintenance program should be developed that considers the following:

Connector Contact Resistance

Connector pin corrosion at the probe or probe cable can create high resistance contact points that randomly cause distortions of electrical resistance or check measurements. To help prevent this problem, keep all connectors clean and dry. Except when taking a measurement, keep the ER probe connector covered with the protective connector cap supplied with the probe. The use of commercial “contact cleaners” may also reduce the occurrence of this problem.

Contact resistance between a probe and probe cable and/or a probe cable and extension cable that have been joined together for extended periods of time may slowly increase. The effect of this increase on instrument readings may be so gradual that the operator does not realize that a problem exists. To avoid a gradual increase in contact resistance, Metal Samples recommends that the operator periodically disconnect and then reconnect the probe and cable.

Switch Contacts

If the switch contacts of the ER monitor’s controls become fouled or even slightly corroded, the instrument will not perform properly. To prevent switch contact fouling and corrosion, occasionally rotate instrument control knobs through all positions.

Cable

Periodically move the cable attached to the ER monitor back and forth a few times. Observe the instrument’s meter. If the cable is in good condition, the instrument’s meter needle will not “jump”. If the meter needle jumps, the cable has a partial or temporary short. To prevent erroneous instrument readings, replace the cable.

Batteries

Two 9V alkaline batteries are installed as standard components in every MS0500. Always store the MS0500 with the Function Selector positioned at OFF. If the instrument is stored with the Function Selector placed at an operating position, the battery charge will be rapidly depleted. If the batteries must be replaced, refer to instructions for Replacing the Batteries on page 26. **CAUTION:** The MS0500 is rated intrinsically safe and batteries must be replaced only in safe areas.

Instrument Housing

Remove all foreign matter from the instrument housing using a light, forced air flow or a vacuum cleaner with a Teflon (8) nozzle.

Temperature Limits

Operate and store the ER monitor at temperatures no lower than 32° F. and no higher than 120° F.

Moisture

The ER monitor is not weatherproof. Be careful when using the instrument in damp environments. Always store the ER monitor in a dry location.

Repair

If the MS0500 monitor appears to be operating incorrectly, a quick operating check can be made following the procedures for **Verifying that the ER Monitoring Instrument Operates Properly** that begin on page 13. The meter prover is substituted for the probe in these procedures. If the MS0500 cannot satisfactorily complete the verification procedures, refer to Table 2. Table 2 lists possible causes of operating problems and remedies. If remedies listed in Table 2 do not solve the operating problem, return the ER monitor to Metal Samples for repair. Other than the batteries, there are no components of the MS0500 monitor which should be serviced by the user.

CAUTION: If the ER monitoring instrument is under warranty, do not attempt internal repairs. User repairs may void the warranty. Return the ER monitor to Metal Samples for repair by following procedures outlined on page 27.

SYMPTOMS	POSSIBLE CAUSE	REMEDY
Decreasing instrument readings.	Corrosion of the probe's protected reference and check elements.	Conduct a check measurement as outlined on page 16. If significant changes in the normally stable check measurement are indicated, replace the probe.
	The measuring element has been coated by conductive corrosion products or process stream components.	Retrieve and inspect the probe. Clean the measuring element according to the procedures that begin on page 34. If this is a reoccurring problem, a change in probe location is indicated. Review the <u>Guidelines for ER Probe Placement</u> on page 37 and change the probe location accordingly.
Both check and corrosion readings are continually decreasing.	Check element is corroding.	Replace the probe.
Check measurements continually increase while the corrosion reading decreases.	Reference element is corroding.	Replace the probe.
The instrument begins the measurement process normally, then the meter needle goes off scale. Or, the instrument will not take corrosion measurements.	Corrosion has severed the measurement element.	Replace the probe.
	Batteries are defective.	Complete procedures for <u>Checking Battery Charge</u> on page 25.

SYMPTOMS	POSSIBLE CAUSE	REMEDY
Significant changes in corrosion and/or check readings.	Corrosion at the probe or cable connection is creating high resistance contacts.	Break connections and examine connector pins closely. Replace corroded connectors and ER Monitoring System components.
	Moisture has penetrated the cable's protective jacket.	Replace the cable or cut back the wet portion of the cable, or allow the cable to thoroughly dry.
Meter needle remains off-scale.	Probe Selector is turned to the wrong position.	Place Probe Selector at the correct position.
	The measuring element has corroded through.	Replace the probe.
	One or more electrical leads in the probe and/or cable are open or have shorted out.	Substitute the probe in use for a probe known to be operational. If the problem persists, substitute cable known to be operational or check cable continuity with a volt-ohmmeter. Replace any suspect components.

SYMPTOMS	POSSIBLE CAUSE	REMEDY
Drifting meter needle.	A temperature differential exists between the measuring and reference elements.	Wait a few minutes before taking a measurement. The needle should stop drifting, indicating that the temperature of the measuring and reference elements is the same.
	Batteries are defective.	Complete procedures for Checking Battery Charge on page 25.
Jumping needle.	Defective connections exist at the probe, cable, or instrument connections.	Check connectors. Conduct an instrument performance verification and probe check measurement. Replace defective system components as they are identified.
	Electrical noise is interfering with the signal.	Shield or relocate ER monitoring system components.
	Batteries are defective.	Complete procedures for Checking Battery Charge on page 25.
Meter needle will not deflect from center zero.	Batteries are not properly installed or battery charge has been depleted.	Complete procedures for Checking Battery Charge on page 25.
	The instrument has been damaged internally.	Contact Metal Samples or return the instrument for repair following instructions on page 27.

Checking Battery Charge

Two 9-volt alkaline batteries are installed in the MS0500 before shipment to the customer. These batteries will give ten hours of operation in normal service if the instrument is stored with the meter prover disconnected and the Function Selector turned to OFF. If batteries are suspected of being defective, check battery charge by completing the following procedures:

1. Turn the Function Selector to +V. The meter needle should enter and remain in the box labeled +V.
2. Turn the Function Selector to -V. The meter needle should enter and remain in the box labeled -V.
3. If the meter needle does not behave as described in steps 1 and 2, remove the instrument from its leather carrying case. Open the instrument's battery cover by removing the two retaining screws (refer to Figure 3). **CAUTION:** The MS0500 is designed to be intrinsically safe. However, when the battery cover is removed, this can no longer be assumed. Therefore, remove the battery cover in safe areas only.
4. Turn the instrument over. The battery cover will fall out of the instrument.
5. Ensure that batteries are properly installed (refer to figure 4). If batteries are not properly installed, reinstall the batteries and recheck battery charge.
6. If batteries are properly installed, but steps 1 and 2 cannot be completed, replace the batteries by following the instructions outlined on page 26.

Replacing the Batteries

If batteries are defective, replace them by completing the following procedures. **CAUTION:** The MS0500 is designed to be intrinsically safe. However, when the battery cover is removed, this can no longer be assumed. Therefore, replace batteries in safe areas only.

1. Remove the instrument from its leather carrying case.
2. Remove the instrument's two retaining screws that hold the battery cover in place (Figure 3).
3. Turn the instrument over. The battery cover will fall out of the instrument.
4. Remove the two batteries and replace them with new batteries (Figure 4). Ensure that new batteries are in good electrical contact with the battery holder's terminals.
5. Replace and secure the instrument's battery cover.

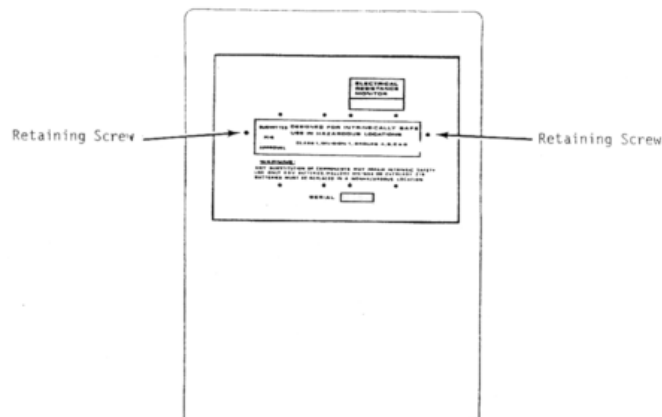


Figure 3. MS0500 Battery Cover

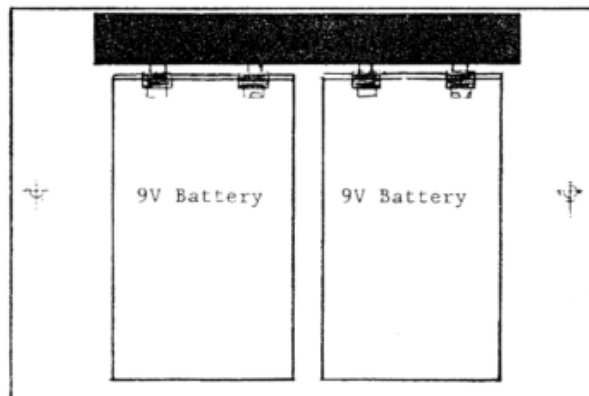


Figure 4. MS0500 Battery Placement

Instructions for Returning the Instrument for Repair

If it is necessary to return any Metal Samples instrument for repair, the following procedures are recommended to ensure the fastest possible repair and return cycle. The user may elect to contact Metal Samples to verify that return of the instrument is necessary.

1. If possible, pack the instrument in the original shipping carton. If the original carton is not available, pack the instrument in a rigid cardboard or wooden carton. Surround the instrument with a minimum of three inches of resilient packing material such as foam rubber or shredded newspaper.
2. Ship the instrument prepaid via Air Freight or Air Express to:

**Metal Samples
152 Metal Samples Rd.
Munford, AL 36268**

3. Contact Metal Samples by telephone (256) 358-4202 or fax (256) 358-4515 or e-mail msc@alspi.com and tell them:
 - (a) the name of the airline carrying the instrument
 - (b) the flight number
 - (c) the estimated time of arrival
 - (d) the waybill number and delivery instructions
4. When the instrument is packed, include a copy of the form on the next page, filled in as required, to expedite the repairs.

Maintenance and Repair Instructions

This form may be photocopied for use when returning instruments to Metal Samples for repair. Please fill in all known information. Enclose a copy of the filled in form with the instrument.

1. Check one:

- Repair this instrument under warranty.
- Repair this instrument regardless of problem or cost of repair.
- Inspect the instrument and advise the customer of the approximate cost of repairs if the instrument is not covered under warranty. (Note: This procedure may delay the return of the instrument to you.)

2. Instrument Identification:

Instrument Model # _____ Serial # _____
Date and Location of Purchase _____
Company's Purchase Order # for Original Sale _____

3. Return the Instrument to:

Company Name _____

Address/Location _____

Telephone Number: _____

4. Description of Trouble: (a clear description of the problem may shorten repair time) _____

5. Urgency of Repairs: _____

V. Electrical Resistance Probes

Introduction

An essential component of the ER Monitoring System, the Electrical Resistance (ER) Probe acts as an environmental bridge between the measuring element immersed in a corrosive media and the atmosphere where the electrical leads are connected. Metal Samples ER probes are available in fixed length or retractable (adjustable) length models and in retrievable models. Figures 5, 6 and 7 show examples of these available probe models. Fixed probes are easier to install than retractable models; however, fixed probe installation and inspection require the process system to be shut down. Installation and inspection of retractable probes does not require a system shut down and these probes are recommended for use in systems that must operate continuously. Retrievable models are used with high pressure access fittings. All Metal Samples ER probes are supplied with MIL environmental electrical connectors unless specifically ordered otherwise.

General Specifications for ER Probes

	PROBE TYPE		
	<u>Fixed Length</u>	<u>Retractable</u>	<u>Retrievable</u>
Threads:	1/2" & 3/4" NPT models	1/2" & 1" NPT models	Access Fitting
Temperature Rating:	300°F & 400°F models	300°F & 700°F models	300°F, 400°F & 700°F models
Pressure Rating:	3000 psi	1000 psi	500 psi to 3600 psi
Length:	24", 30", & 36"	Models available in lengths of 4" to 32"	Specified by customer - 24" maximum

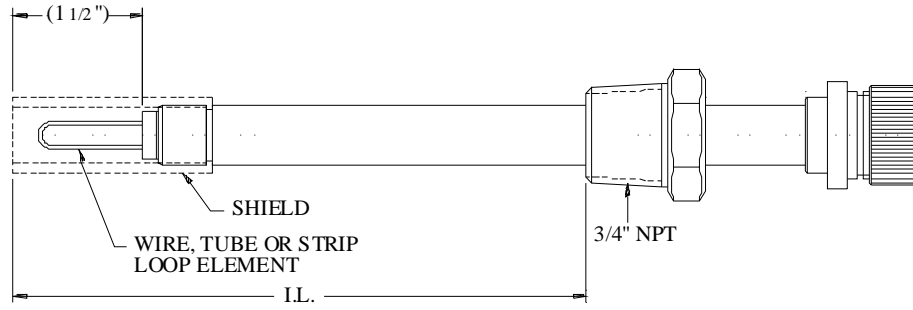


Figure 5. Fixed Length ER Probe

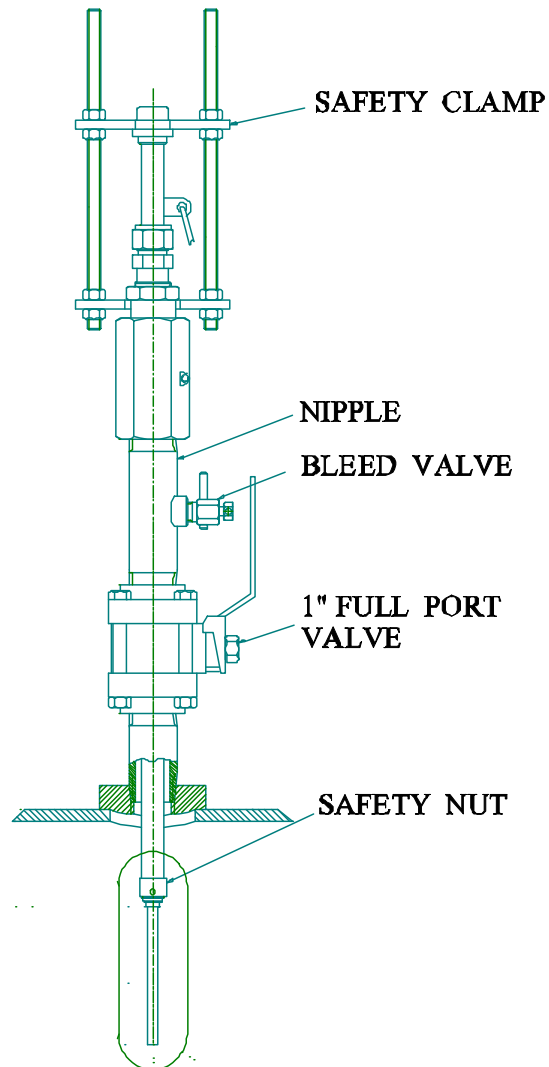


Figure 6. Retractable ER Probe

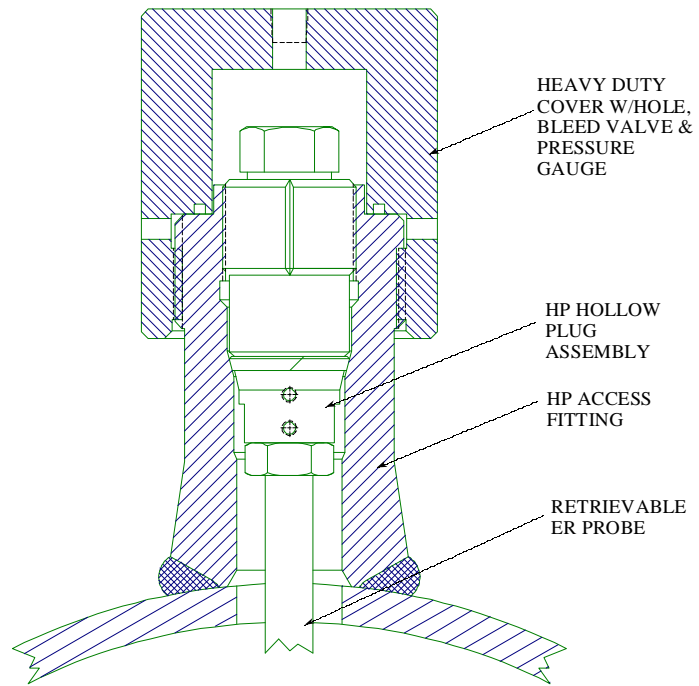


Figure 7. Retrievable ER Probe

Probe Elements

Five types of probe elements are available from Metal Samples: the tubular loop, wire loop, cylindrical, flush element, and strip element. Both the tubular and wire loop elements are available with either a Teflon or glass pressure seal. All elements are available in a variety of alloys and thicknesses. The thicker the element, the longer its operational lifetime; the thinner the element, the greater its sensitivity.

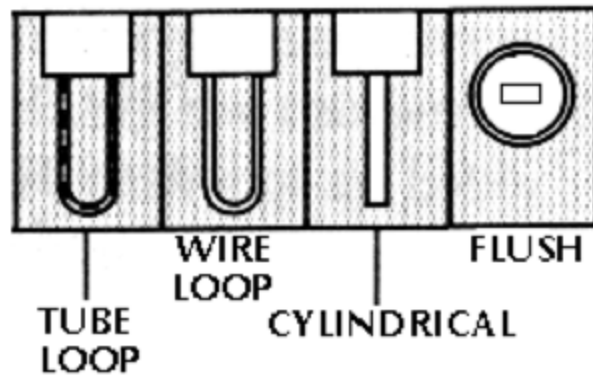


Figure 8. Element Types

Offering greater sensitivity than any other ER sensing element, the tubular loop element is recommended for use in systems where the smallest change in corrosion rate must be quickly detected. The tubular loop is constructed of a small diameter, hollow tube with a hairpin configuration.

Second in sensitivity only to the tubular loop, the wire loop is available in more alloys than any other ER element, making it ideal for monitoring systems requiring a diverse sample of alloy materials. Constructed of a length of solid wire, the wire loop sensing element has a hairpin loop configuration.

Resistant to high temperatures and mechanical damage, the cylindrical element is particularly suited for installation in high temperature and/or high velocity process streams. Process probes equipped with the thin-walled, cylindrical element are supplied with a welded, all-metal pressure seal.

The flush element is designed to fit exactly flush with the interior surface of a pipe or vessel wall. The element is then affected by the same process conditions that are occurring at the interior surface and will not interfere with pigging operations.

The strip element is designed for use with the Metal Samples special underground, concrete, and underwater probes. The thin, solid metal strip element, typically of 1018 mild steel, is embedded in an epoxy body and is permanently attached at one edge to a probe cable.

Safety Shields

Pressure fluctuations in high velocity process systems may distort the tubular and wire loop elements and cause erroneous corrosion measurements. To prevent element damage, process probes equipped with these elements are supplied as standard with safety shields. To avoid galvanic effects, the safety shield is made of the same material as the probe.

Installing the ER Probe

All Metal Samples ER probes are degreased and bead-blasted prior to shipment to the customer. If the probe is carefully stored and the measuring element kept free of dirt and oil, the probe may be installed in the process stream without further cleaning. To prevent contamination of the measuring element, do not touch the measuring element with the fingers or handle the element in any way. If the measuring element does become contaminated, or if the probe is to be cleaned and reinstalled at another location, refer to instructions for **Cleaning the Measuring Element** (page 34).

Always inspect the surface of the measuring element before installing the probe in the process system. The surface of the measuring element should be shiny and light-colored. Any dulling or darkening of the element's surface indicates the presence of an oxide film or other contamination. Visible oxidation products may be removed prior to probe installation (refer to instructions for **Cleaning the Measuring Element** on page 34).

If the ER probe is to be installed in a system where water is present, test the measuring element to ensure that its surface can be moistened by water: Immerse the probe in fresh water and agitate for several minutes. Remove the probe. If a continuous film of water remains on the measuring element's surface, the probe is ready to be installed in the process stream. If water beads are visible on the measuring element's surface, degrease the element before installation in the process system (refer to **Cleaning the Measuring Element**). If a probe without visible surface deposits is to be installed in a nonaqueous medium, special precautions are not necessary.

Cleaning the Measuring Element

The measuring element must be cleaned if its surface becomes contaminated or if the probe is to be moved from one location to another. The measuring element can be cleaned by abrasive, chemical or electrochemical methods.

Cleaning methods using abrasives are superior to other cleaning methods. An experienced operator can complete an abrasive cleaning procedure with less than 10 to 20 microinches of base metal loss.

Chemical cleaning can result in excessive base metal loss. In addition, reagents used in the chemical cleaning process can leave the measuring element's surface in either a passive state or can cause the formation of oxide films. Corrosion of passive metal surfaces is inhibited and a passivated measuring element will indicate a corrosion rate lower than the corrosion rate actually occurring within the process system. Oxide films distort test results obtained in process streams that do not contain oxygen or other strong oxidants. Therefore, before installation in process streams that do not contain oxidizing solutions, the surface of a chemically cleaned measuring element must be reduced by electrochemical cleaning methods.

Electrochemical methods that involve cathodic cleaning do not always completely remove deposits from the measuring element's surface. In such cases, the measuring element must still be cleaned by a minor abrasive such as steel wool. Anodic cleaning methods require the measuring element to behave as an anode. In this condition, the element's base metal will dissolve. Anodic cleaning can also passivate the surface of the measuring element.

The following describes the three types of cleaning methods suitable for ER probe measuring elements:

Abrasive Cleaning Methods

Bead-blasting, the preferred abrasive cleaning method, is suitable for all Metal Samples ER probes. To thoroughly clean the measuring element of films or deposits, use a small, hand-held bead-blasting gun powered by compressed gas (for example air or nitrogen) at pressures no greater than 50 to 100 psi. Use only clean, finely divided grit such as 200 to 270 glass beads or mesh sand.

Measuring elements that are accessible from all sides can be cleaned by polishing with fine (3/0 or 4/0) garnet paper or emery cloth until the element's surface obtains a bright shine. Before polishing, degrease the element by rinsing with a spray contact cleaner or a similar solvent. Measuring elements accessible from all sides can also be degreased by scrubbing with household-scouring powder. After scrubbing, rinse with water and dry thoroughly. Note: Water can rust and pit the surface of the measuring element; therefore, the element and probe sites where the element enters the probe body must be thoroughly dry before storing the probe.

Chemical Cleaning Methods

Chemical reagents used for cleaning purposes are usually water based. In order for such reagents to penetrate surface deposits, the measuring element must be free of oil and grease. To degrease the measuring element, soak the ER probe in an organic solvent such as trichloroethylene or petroleum thinner. If hard, greasy deposits remain, boil the probe in one of the "soak cleaners" used by the metal finishing industry. If the element's surface is accessible from all sides, use steel wool to remove clinging deposit

After oil and grease are removed, use hot (160° to 180°F.) acid solutions to remove oxides and corrosion products from the measuring element. It is recommended that the activated ER monitor be connected to the probe to monitor metal loss during chemical cleaning. Hot 6 to 12 N hydrochloric acid should remove rust from steel. Sulfuric acid will also clean steel, but not as efficiently as hydrochloric water acid. Immerse the probe in the acid solution and agitate until rapid, uniform hydrogen bubbling occurs over the surface of the probe. Do not use "pickling" or acid inhibitors during the acid bath as these inhibitors deposit surface films that are difficult to remove. After the acid treatment, immediately rinse the probe with water.

If the probe is to be immediately installed in a process stream, no neutralizing or drying is necessary. However, to avoid surface contamination, do not expose the clean, water-wet probe to air for periods longer than 10 to 20 seconds. If the probe will be exposed to air for longer than 20 seconds, neutralize its surface by dipping the probe in a 1% solution of sodium hydroxide. Rinse with water and shake off excess water. Alternate dipping the probe in alcohol and shaking off excess alcohol. Blow dry all probe surfaces with clean, dry compressed air or nitrogen.

Electrochemical Cleaning Methods

When cleaned electrochemically, the measuring element is immersed in an electrolytic solution while connected to an external circuit that forces electrical current to pass between the element and an auxiliary electrode. The external circuit should consist of a 1.5-volt dry-cell battery, a variable resistance potentiometer, and a milliammeter in series between the measuring element and the auxiliary electrode. The probe cables electrical terminals may be used to connect the measuring element to the external circuit.

Cathodic cleaning requires the measuring element to be immersed in an acid electrolytic solution and agitated at maximum capability for 15 to 30 minutes. Sulfuric acid (0.1 N) is a good electrolyte. Do not use acid inhibitors as they deposit surface films that are difficult to remove. The measuring element is connected to the negative terminal of the external circuit and acts as the cathode. Use a piece of mild steel or stainless steel with several square inches of surface area for the auxiliary electrode. When current is applied, the measuring element obtains an active metal surface. Hydrogen bubbling occurring at the metal surface reduces oxidation products and loosens scale and other deposits. A current density of 10-20 milliamperes per square centimeter of probe surface is required to electrochemically clean the measuring element. For example, if the surface area of the probe is 10 square centimeters, the required current will be 100 to 200 milliamperes.

Anodic cleaning dissolves base metal and should only be used to etch polished surfaces. The measuring element is connected to the external circuit's positive terminal and behaves as an anode. A suitable electrolyte for anodic cleaning is a 10% salt solution acidified with hydrochloric or sulfuric acid. Do not apply a current density greater than 10 milliamperes per square centimeter of probe surface area. At this current density, base metal is dissolved at a rate of 12 microinches per minute; therefore, do not immerse the probe for longer than 5 to 10 minutes. Anodic cleaning should be followed by cathodic cleaning to remove any passivating films. Use the same procedures for rinsing and drying as described in the section on **Chemical Cleaning Methods**.

Probe Storage

Clean, thoroughly dry probes should be stored in a clean, dry place. If possible, store in the presence of a desiccant, preferably anhydrous calcium chloride or silica gel.

VI. Effects of Process Variables on Corrosion Behavior and Guidelines for ER Probe Placement

Introduction

When designing investigative studies of corrosion behavior, the researcher must consider a number of variables which may influence study results. Changing any of the variables can result in a change in the corrosion behavior of the ER probe's measuring element. Unfortunately, all variables may not be known or Considered and this can lead to erroneous conclusions. To help the researcher obtain more accurate data, this section of the manual names and describes the effects of variables that may influence experimental and process system Corrosion studies made with a Metal Samples Electrical Resistance (ER) Monitoring System.

Effects of Time and Equilibrium

Once installed in the process stream of interest, ER probes can be used almost immediately to take Corrosion measurements. Generally, only a few minutes are required for both protected and exposed ER probe elements to equilibrate with process stream temperatures.

Effects of Fluid Velocity

If the process stream under consideration is normally flowing, then ER probes used laboratory experiments should be subjected to approximately the same flow velocity. This may prevent an alteration in the diffusion rate of reactants and a subsequent misleading alteration in the ER monitor's corrosion reading. The effects of erosion-corrosion can also be monitored.

Placing ER probes in stagnant spots within the process stream should be avoided unless it is necessary to study corrosion under stagnant conditions. Changes in process variables are slow to effect a "dead-spot", and corrosion rates in these locations generally vary less than elsewhere in the system.

The accumulation of solid conductive corrosion products or process stream components on the ER probe's measuring element in a stagnant area can also cause inaccurate corrosion readings and may cause severe pitting of the element.

A moderate flow velocity can affect diffusion rates and subsequent corrosion readings in two ways. (1) Fresh liquid corrodent, possibly containing dissolved oxygen or other reducible species, will be brought into contact with metal surfaces as fluid flows past the probe. Fresh corrodent will provide supplies if desired reactants while removing any excess of spent reactants. For example, increased oxygen or hydrogen sulfide concentrations may accelerate cathodic reactions, thereby promoting anodic reactions and increasing measuring element corrosion rates and instrument corrosion readouts. (2) If corrosion inhibitors are used, a moderate flow velocity should increase diffusion and provide an efficient supply of inhibitor to the metal surface of the measuring element. Such action would reduce corrosion readouts.

High flow velocities can mechanically accelerate corrosion and subsequent corrosion readouts in two ways. (1) Protective films formed by inhibitors or corrosion products can be swept away. This action would subject the measuring element to increase corrosion. (2) Erosion-corrosion mechanisms such as impingement and cavitation will be accelerated by the fluid's velocity and by air abrasion caused by entrained air bubbles.

Effects of Temperature

Other factors being constant, an increase in temperature will be accompanied by an increase in chemical reaction rates. Therefore, the most severe corrosion will be found in the experimental or process system area where the temperature of the corrodent is highest. There are a few exceptions and these are usually due to a decrease in the oxygen content of the corrosive solution as the temperature is raised, particularly near the boiling point. If the oxygen is removed from a corrosive solution by boiling, the cathodic reaction slows down, and this in turn reduces the anodic reaction.

If variables in corrosion readings cannot be attributed to other variables, it is advisable to check temperature fluctuations. A good inhibitor film will lessen the effects of high temperature and the ER Monitoring System can be used to monitor inhibitor effectiveness.

If the corroding environment in which the ER probe is installed undergoes a sudden temperature change, corrosion readings will be erratic and will not reflect the process system's true corrosion rate. This is due to the fact that the temperature of the exposed measuring element will equilibrate faster than will the temperature of the protected reference element. However, errors due to sudden temperature fluctuations are temporary. Once the probe is allowed to reach complete equilibrium with the corroding environment, corrosion readings will again be representative of true process stream conditions. Sudden and temporary temperature fluctuations can also create temperature differentials between the protected reference and check elements, thus causing temporary changes in the check reading.

Temperature fluctuations of liquid systems generally have little effect on ER probe equilibrium. Temperature changes as high as 5°F./minute can occur without altering probe performance. Since temperature fluctuations in most liquid systems do not exceed this rate, erratic corrosion readings do not usually occur in such systems.

Greater temperature fluctuations generally do occur in vapor systems, particularly in steam lines. In vapor systems, it is recommended that ER probes be installed in process locations where liquid condensate is allowed to collect. Liquid has a higher heat capacity than vapor and will therefore minimize the effects of sudden temperature fluctuations at the probe location. To determine if any fluctuations in data due to temperature fluctuations are occurring, it is recommended that more than one corrosion reading be obtained each time an ER probe installed in a vapor system is monitored.

Effects of Previous Environment

If the equilibrium of a system is disturbed by a change in operating procedures or by a corrosion inhibitor, it is possible that a probe will require a considerable amount of time to reach a state of equilibrium in the changed environment. Corrosion readings taken during the transition period are valuable in most instances as they show how the change is affecting the components of the experimental or process system. In other cases where a change in operating procedures or inhibitor type or dosage is to be studied, the action of film produced by the previous conditions masks the effect of the new conditions. If operating or inhibitor conditions are to be evaluated, then it is recommended that two ER probe assemblies be used in the following manner: a previously installed assembly, allowed to equilibrate under the original conditions, should be used to monitor the interactions between old and new conditions. Near the location of this first probe, a second probe with a new or cleaned measuring element should be installed to monitor the new conditions.

Effects of Corrosion Products

If corrosion products form a protective film or scale on the surface of the measuring element, then the film is likely to inhibit corrosion of additional fresh metal by isolating the element from the corrosive environment. In a process stream, this action can be desirable if it parallels and reflects the condition of the process metal surfaces. However, if an electrically conductive corrosion product plates the measuring element, corrosion readings will not be representative of process stream corrosion rates. The addition of conductive material to the measuring element's surface causes a decrease in the ER Monitoring System's measurements and subsequent corrosion rate determinations. Examples of conductive materials which tend to plate measuring element surfaces are: copper on a steel measuring element, cadmium on a steel measuring element and iron sulfide (FeS) on any metal element.

Guidelines for ER Probe Placement

Although it is unlikely that a Single probe location can provide quantitative Corrosion rate data for an entire process system, it should be noted that a single probe can supply corrosion data for that particular process location as well as information on the general behavior pattern of corrosion throughout the process system. Although corrosion rates at several localized corrosion cells may vary considerably, any major change in a process variable should effect all cells in about the same proportion. For example, if the addition of a corrosion inhibitor reduces the corrosion rate at a process location by 90% then all surfaces of the same corroding metal that are coated by the inhibitor should experience about a 90% corrosion rate reduction. Obviously, measurements made at several probe locations will give the most complete corrosion rate data. But changes in the corrosion rate data at a single probe can permit the quick identification of process changes that can effect the entire process system

To place ER probes in process stream locations that will quickly and accurately reflect changes in process conditions or that will remain relatively unaffected by conditions the researcher does not want to consider in a corrosion study, review the following guidelines:

1. To accentuate process changes, place the probe at a location that experiences corrosion rates slightly higher than the system average.
2. Avoid locating the probe in a stagnant section of the process system where solids are likely to collect and distort measurements. Large accumulations of solids may also accelerate pitting corrosion of the measuring element.
3. To obtain data representative of erosion-corrosion processes, locate the probe so that the measuring element will experience the approximate flow velocity experienced by the pipe walls.
4. For convenience in probe retrieval, install the probe in a bypass loop. The effects of velocity can also be analyzed if the bypass valves are throttled.
5. Locate the probe in the warmest section of a continuous liquid phase.
6. Do not place the probe at a location where drastic temperature fluctuations are known to occur.
7. In vapor systems, install the probe in a low spot or vertical tee where liquid condensate can collect. The condensate has a higher heat capacity than the vapor and will therefore minimize the effects of sudden temperature fluctuations that result in widely scattered corrosion graph data points.
8. If the process system is normally closed to air contact, install the probe as far as possible from an open end which could introduce uncontrolled oxygen levels.