

Serial Number \_\_\_\_\_

**AQUAMATE™  
USER MANUAL** 

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# Contents

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# Contents

<b>Chapter 1 Introduction .....</b>	<b>1</b>
<b>Chapter 2 Specifications .....</b>	<b>3</b>
<b>Chapter 3 CORRATER Probe Installation .....</b>	<b>5</b>
<b>Chapter 4 Operation .....</b>	<b>7</b>
<b>Chapter 5 Maintenance.....</b>	<b>13</b>
<b>Appendix A</b>	
<b>Theory of Operation of CORRATER</b>	
<b>Systems.....</b>	<b>17</b>
<b>Appendix B</b>	
<b>Declaration of Conformity.....</b>	<b>23</b>

# Contents

---

## Figures and Drawings

<b>Figure</b>	<b>Page</b>
1-1 General View of AquaMate Unit .....	1
3-1 Probe Orientation Relative to Flow .....	5
3-2 Probe Orientation at a Tee Fitting .....	6
4-1 Front Panel of AquaMate.....	7
4-2 Battery Compartment .....	8
<b>Table</b>	<b>Page</b>
5-1 CORRATER Multiplier Factors .....	16
<b>Appendix A</b>	<b>Page</b>
A-1 Equivalent Circuit of LPR Probe .....	18
A-2 Typical LPR Current vs. Time Decay Curve .....	19
A-3 Operating Rate of LPR Instruments Corrosion Rate vs. Solution Conductivity .....	20
A-4 Rohrback Cosasco 3-Electrode Probe Configuration .....	21

# Chapter 1

## Introduction

The AquaMate CORRATER instrument is a hand held corrosion monitor for process, cooling, or potable water systems. The AquaMate CORRATER instrument was designed to help improve facility operations by enabling the user to directly monitor corrosion rate, imbalance, conductivity and temperature.

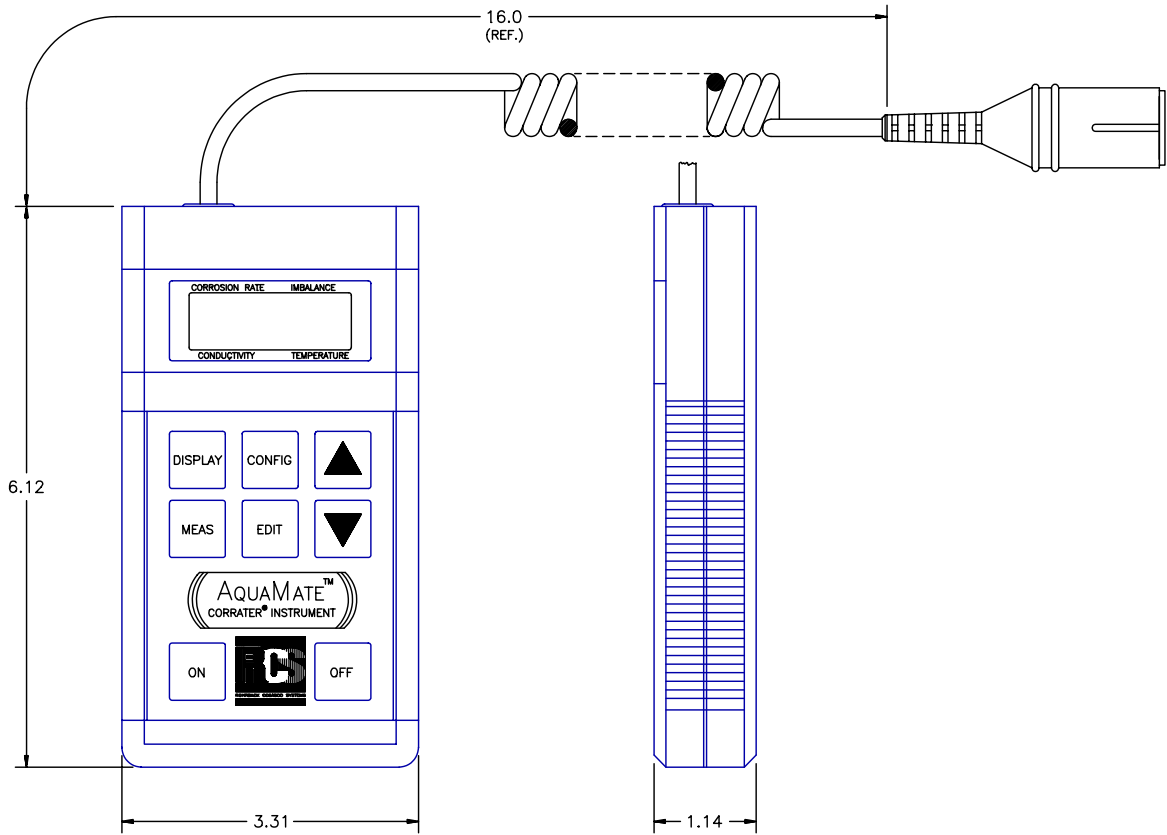


Figure 1-1 General View of AquaMate Unit

## 2 AquaMate Reference Manual

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The AquaMate instrument, in particular, represents a major advance in Portable Linear Polarization Resistance (LPR) corrosion rate measurement.

An LPR instrument determines the corrosion rate by measuring the current from a small applied potential difference between two measurement electrodes of the alloy being monitored. AquaMate extends the range of solution resistance range over which corrosion rate measurements can be made. This is achieved by the use of a patented AC technique which automatically compensates for the solution resistance between the corrosion measuring electrodes. It does this without resorting to a third electrode or correction curves. AquaMate is however, compatible with all two or three electrode probes already in use. A discussion of the LPR method of corrosion rate measurement is presented in Appendix A of this manual.

The AC measurement technique is also used to perform the conductivity measurement. When a suitable conductivity probe is connected to the instrument, the solution resistance is measured by the AC technique. The conductivity is then computed from this measurement.

Temperature measurements are performed by AquaMate when suitable CORROTEMP CORRATER probes are used. These probes measure temperature with a platinum resistance temperature device (RTD) located inside the probe near the process end. By measuring the RTD resistance, AquaMate can calculate and display the temperature of the water where the probe is installed.

The AquaMate is designed for the convenience of the user. Automatic solution resistance compensation improves the utility, convenience and accuracy of corrosion rate measurements. AquaMate also monitors a form of Electrochemical Current Noise (ECN) between the electrodes called imbalance or pitting tendency. This is a qualitative and very useful indication of instability in the material surface consistent with pitting or localized corrosion.

The operator only needs to perform an initial setup to set the cycle time (if other than automatic), probe multiplier or other parameters of interest. Initial setup is performed via front panel keys while monitoring the liquid crystal display. A description of user definable parameters is given in the operation section of this manual. In some cases, initial setup will not be required since factory defaults have been set.

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# Chapter 2

## Specifications

### Operational

#### Input:

Single Channel CORROTEMP CORRATER Probe

#### Corrosion Rate Ranges:

Autoranging 0.01 to 200 MPY, 0-5.08 mmpy, 0-5080  $\mu$ mpy

#### Conductivity:

(Conductivity probes will be sold separately)

**Range:** 50-2000  $\mu$ mhos/cm ( $\mu$ S/cm)

**Accuracy:** 10% (excluding probe error)

#### Temperature Measurement:

**Range:** 0 deg C to + 260 deg C (0 - 500 deg F)

**Accuracy:**  $\pm$  2 deg C (Does not include probe error)

**Repeatability:**  $\pm$  1 deg C

**Resolution:** 0.1 deg C

#### Imbalance Ranges: (pitting index)

Autoranging 0 to 1000 with mpy units, 0 to 5.08 with mmpy units, 0 to 5080 with  $\mu$ mpy units

#### Operating Range:

Conductivity ( $\mu$ mhos/cm) divided by corrosion rate (mpy) > 4

#### Probe Compatibility

Two Electrode CORRATER

Two Electrode CORROTEMP CORRATER

Three Electrode CORRATER

#### Probe Connectors:

6 Foot Coiled Cable with Standard 6 pin Probe Connector

200 ft. measurement capability

#### Calibrated Probes:

1 point calibrated test probe (part no. 710617)

#### Measurement Cycle Time:

## 4 AquaMate Reference Manual

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Provisions for manual and auto modes. Adjustable 2 -20 minutes in ½ minute increments, default to 3 minutes (polarization time is 25% of (cycle time - 1 minute) manual mode only). Fast measure mode, corrosion rate only-1 minute, 15 seconds.

### **Multiplier Range:**

0.25 - 3.00

### **Display:**

Liquid Crystal Display (Two lines, 12 characters per line)

### **Power Requirements:**

One 9V DC, transistor radio type battery. Alkaline recommended.  
NEDA 1604A, Duracell MN 1604, or EVEREADY 522

### **Battery Life:**

10 hours continuous operation

### **Instrument Operating Temperature:**

32 deg F - 122 deg F (0 deg C to 55 deg C)

### **Instrument Storage Temperature:**

-4 deg F to 131 deg F (-20 deg C to 55 deg C)

### **Unit Weight:**

14 oz

## Chapter 3

# CORRATER Probe Installation

AquaMate is intended to be used with any standard 2-electrode CORRATER probes. Three electrode probes can also be used, but for simplicity and economy, it is recommended that 2-electrode probes be used. Probes with replaceable cylindrical electrodes are generally referred to as "standard" probes, and probes with disc electrodes are referred to as "flush" probes because the electrodes are flush with the end surface of the probe. The probes are available in many designs including fixed, adjustable, retractable and retrievable mounting configurations. Also, probe electrodes are available in many element and alloy materials. The material selected should closely match the material of construction of the pipe or vessel for which corrosion information is desired.

Probes should be installed where corrosion is most likely to be greatest so that readings will truly represent the most aggressive system corrosion rates. Preferably, they should be located where the liquid flow velocity past the electrode exceeds 1 foot per second (0.3 m/sec.) if it is required to measure corrosion rates representative of a flowing environment. Alignment of the electrodes relative to the direction of process flow is important to obtain reliable corrosion rate measurements. Proper alignment is with the imaginary line connecting the centerlines of the two electrodes perpendicular to the direction of the process flow. Refer to Figure 3-1. With this orientation, one electrode does not "shade" the other electrode, and both are subject to nearly the same corrosive environment. If a probe is installed in an elbow fitting, where flow changes direction, position the probe so that the electrodes "face" the oncoming flow. Refer to Figure 3-2.

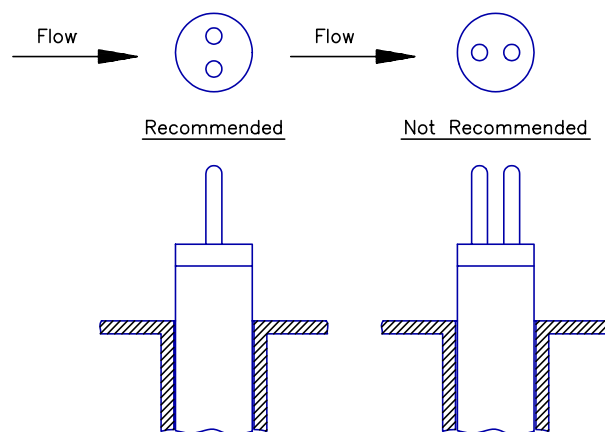


Figure 3-1 Probe Orientation Relative to Flow

## 6 AquaMate Reference Manual

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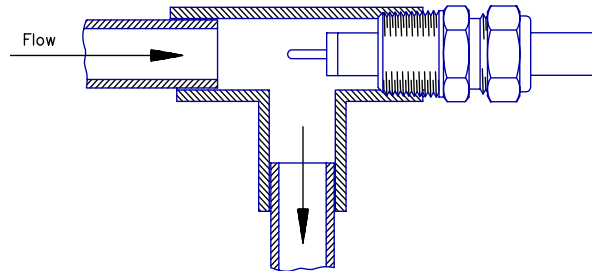


Figure 3-2 Probe Orientation at a Tee Fitting

### Probe Connection

AquaMate is supplied with one coiled probe cable terminated in a 6 pin connector. The connector is suitable for direct connection to all CORRATER probes. The only exception is interconnection to a Model 6080 High Pressure CORRATER probe where a portable probe connecting adapter is also required.

# Chapter 4 Operation

## General

When the AquaMate CORRATER instrument is turned on, the software revision level is indicated followed by indication of battery voltage. Once the initial setup of the instrument is performed, the selections remain in effect until individually changed by the operator. If the indicator is showing near empty, replace the battery. Even if the unit is switched off and back on again, the instrument does not need to be reconfigured.

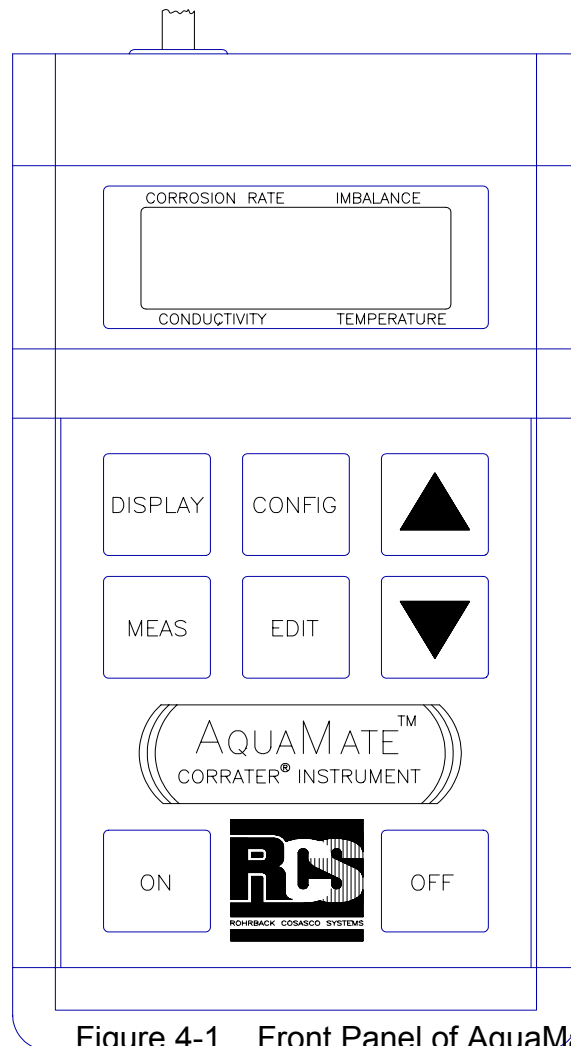
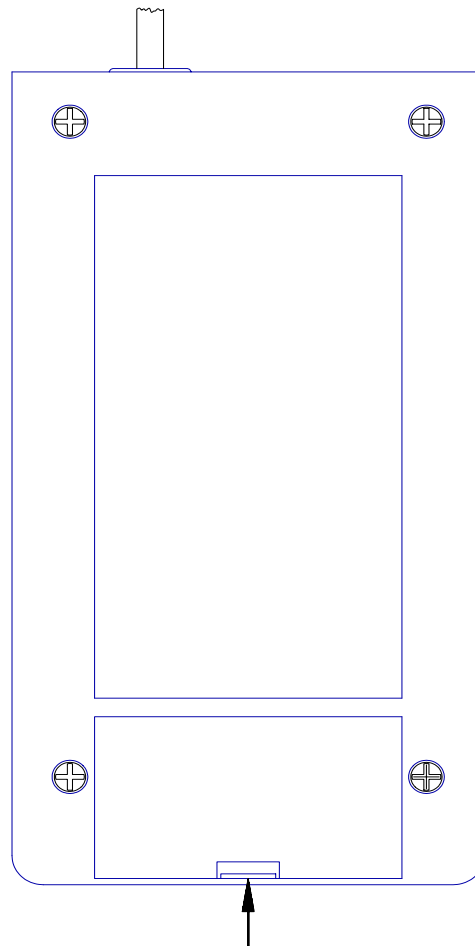


Figure 4-1 Front Panel of AquaMate

## 8 AquaMate Reference Manual

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PUSH UP  
TO RELEASE  
BATTERY COVER

Figure 4-2 Battery Compartment

### Initial Setup

Operation of the instrument is accomplished via the front panel keys. A description of each key and the function it performs follows:

- Display:** This key displays the measured corrosion, imbalance, conductivity, and temperature.
- Configure:** This key displays the beginning of a list of user definable operating parameters. Repeatedly pressing this key or the arrow keys allows you to scroll through the list.

## Chapter 4 Operation 9

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**Edit:** Press this key to begin or end the editing of a parameter. The parameter to be edited will flash asterisk's in the second line of the display, indicating that its value can be changed.

### Up and Down

**Arrow Keys:** These keys are used to scroll through the list of parameters. They are also used in conjunction with the EDIT key to edit specific parameters. If you press the EDIT key during an editing session, the current value displayed will be stored permanently. If you want to exit an editing session and return to the initial parameter value, press the CONFIGURE key. This will interrupt the editing session without storing any changed parameter values.

Initial setup requires the operator to choose various parameters specific to the process being measured. Becoming familiar with the following parameter list will identify which parameters can be changed and provide information about the instruments' capabilities.

## Parameter List

The parameter lists are organized in two layers, a basic list for parameters that are frequently changed and an advanced list. The parameter lists all have similar format. The top line displays which parameter will be edited. The second line is the parameter value which can be increased or decreased with the UP and DOWN arrow keys. A brief description of the parameter list follows:

**PROBE MULTIPLIER:** The alloy correction multipliers are adjustable from 0.25 to 3.00. The factory default is 1.0.

**CYCLE TIME:** Cycle time is adjustable from 2 to 21 minutes. In addition a FAST or AUTO mode can be selected. The FAST mode performs a measurement in about 1 minute 10 seconds without performing conductivity, imbalance or temperature measurements. Solution resistance compensation techniques are not employed in this mode resulting in faster measurements. The AUTO mode is used to let AquaMate decide how long the cycle time should be. The factory default is 3 minutes.

**PROBE ELEMENT STYLE:** The available selections are STANDARD and FLUSH. The factory default is standard

**PROBE TYPE:** The available selections are 2 Electrode, 3 Electrode and CORROTEMP CORRATER probes. The factory default is 2 Electrode.

**ADVANCED OPTIONS:** Selecting YES in this mode will present another parameter list, typically representing parameters that are less frequently used. The factory default is NO.

## Advanced Parameter List

**ENGINEERING UNITS:** The selectable units are either mils per year (MPY), millimeters per year (mmPY) or micrometers per year (umPY). The factory default is MPY.

**TEMPERATURE UNITS:** These units are either Celsius or Fahrenheit. The factory default is degrees Celsius.

## 10 AquaMate Reference Manual

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**CONDUCTIVITY DISPLAY:** The display of the conductivity measurement can be turned ON or OFF. The factory default is OFF.

**CELL CONSTANT K:** The conductivity cell constant, usually referred to as K factor, is selectable from 0 to 1.0. For use on standard platinum or stainless steel conductivity probes with constant of 0.1/cm set K to 0.1. AquaMate measures conductivity by performing an AC ohms measurement across the probe terminals effectively measuring the solution resistance. The factory default is 0.1.

***NOTE:** If taking a conductivity measurement on a CORRATER probe, values are generally only useable on low corroding alloys (less than 2 mpy). Calibration can be performed by adjusting the K factor to provide the correct reading when known buffer solutions are measured. Rohrbach Cosasco Systems provides a stainless steel conductivity probe, with an embedded RTD temperature sensor, as part number 032165. This probe will mate with the AquaMate probe cable without modification. If other conductivity probes are used, connect one electrode of the conductivity probe to the A and C terminals of the AquaMate connector, and the other electrode to the D and F terminals. If an RTD is available, connect one side to the B and E terminals, the other side to the D and F terminals.*

**CONDUCTIVITY TEMPERATURE CORRECTION C:** The conductivity measurement can be temperature compensated if desired. The temperature correction factor C is selectable from 0 to 10 % per degrees Celsius. This compensation has the effect of adjusting the conductivity reading as if the measurement were performed at 25 degrees Celsius. If temperature compensation is not desired, a NONE selection is available. The factory default is 2 %. If taking a conductivity measurement on a CORRATER probe, values are generally only useable on low corroding alloys (less than 2 mpy). In these cases, carry out a calibration against a conductivity probe and adjust  $K_1$  to provide the correct answer.

**RESETTING FACTORY DEFAULT VALUES:** The factory default settings are reset by holding down both arrow keys simultaneously and then applying power to the unit. AquaMate will display a brief message confirming that the factory defaults have been set immediately after the power is turned on.

## Interpretation of Operating Parameters and Readings

### Imbalance Readings:

Imbalance is often referred to as "pitting tendency". It is actually a sample of Electrochemical Current Noise (ECN) between the two electrodes when the electrodes are connected to a zero-impedance ammeter effectively measuring the short circuit current. AquaMate measures this current and displays the results in units of  $0.5 \mu\text{A}$  per square centimeter of surface area of each electrode (with mpy units and at a multiplier of 1.00). Regular electrodes are 5.0 square centimeters and therefore one imbalance or pitting unit

## Chapter 4 Operation 11

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is 2.5 microamps of current (with mpy units and at a multiplier of 1.00). Scaling of this reading is modified by the probe multiplier and metric unit conversion. The purpose for this scaling is to make the imbalance reading meaningful when compared to the corrosion rate reading. It has been found empirically that when the imbalance reading is less than the corrosion rate reading or close to zero, corrosion is general corrosion with insignificant pitting. If the imbalance becomes more erratic and similar to or greater than the corrosion rate value, this is indicative of increased pitting. If the imbalance is up to ten times greater than the corrosion rate or very erratic this is indicative of a significant pitting which should be verified by visual inspection of the probe electrodes.

Imbalance can be caused by several factors:

1. Severe pitting. Pitting is generally irregular and non-uniform, consequently the greater this irregularity or non-uniformity, the greater is the probability of imbalance between the two electrodes. Pitting is generally accompanied by an increase in imbalance and also greater irregularity and fluctuation of the reading.
2. Improper or inadequate inhibitor film formation. Where filming inhibitors are used and are not established due to inadequate flow or quantity of inhibitor, imbalance is greater and shows greater fluctuation. This will often anticipate an increasing corrosion rate with reducing inhibitor film.
3. Differential scaling or fouling of the electrode.
4. Damage to an electrode or a loosened electrode.

***NOTE:*** *Imbalance readings will typically increase when corrosion rate values increase. There should be concern for pitting when the imbalance increases significantly without a similar increase in corrosion rate.*

### Cycle Time Selection

The cycle time setting, when properly set, allows sufficient settling time to make accurate polarization resistance measurements on the probe. The chemistry of the process determines the time required for proper settling. In order that measurements are not made on the "slope of some curve" it is better to have a cycle time greater than that required in order to provide for some margin in the event that the process shifts in direction.

Corrosion rate measurements on new electrodes may not be representative of those on the system until the probe has been exposed to the flowing corrodent for several hours up to one or two days. This length of time is required to allow the electrode surfaces to stabilize or age to that similar to the material of the plant. New material typically corrodes at a higher rate during this period. The default cycle time setting for the AquaMate is set to 3 minutes to provide a rapid reading that is convenient for a portable instrument. However, if greater accuracy is required, it is recommended that cycle time on the AquaMate be set to automatic. The automatic mode monitors the signal decay characteristic and takes a reading as soon as it stabilizes. This may take significantly longer than the default time.

### Multiplier Selection

## 12 AquaMate Reference Manual

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The AquaMate calibration has been normalized to use a multiplier value of 1.00 when standard CORRATER mild steel probe electrodes are used. The electrode area is 5 square centimeters for standard electrodes and 0.5 square centimeters for flush electrodes. If alternate electrode sizes are used or other alloys, the multiplier value will need to be appropriately changed to provide accurate corrosion rate readings.

Table 5-1 lists the recommended multiplier settings, when using normal size electrodes, for various commonly used electrode materials. The multiplier should be set to the value nearest the recommended setting.

If electrodes other than RCS standard (5 cm<sup>2</sup>) or flush (0.5 cm<sup>2</sup>) electrodes are used, the multiplier can be adjusted to compensate for the size. Generally, the multiplier value is inversely proportional to the electrode area. For example, if 9 square centimeter electrodes were used with the probe type set to standard, the alloy multiplier value should be adjusted to the (listed value x 5/9). For example for 9 cm<sup>2</sup> electrode in mild steel set the multiplier to 0.55. (Normal alloy multiplier 1.00 x 5/9 = 0.55)

The multipliers given in the table are based on the common corrosion reactions that occur with the constituent elements of those alloys. In certain environments, these reactions may be different and possibly require a different multiplier. In the absence of other information, the multiplier may be calculated empirically by comparing corrosion rate on the electrodes determined by weight loss with the average indicated corrosion rate from the instrument over the same period. The existing multiplier used on the unit is then modified by the ratio:

Corrosion rate by weight loss / Integrated Average corrosion rate from instrument.

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# Chapter 5

## Maintenance

### Introduction

Routine maintenance of AquaMate is not required except for battery replacement. Probes, however, should be inspected at intervals and electrodes replaced when required. If a problem is suspected with the AquaMate instrument, the following tests can be performed to verify proper operation of the instrument.

### Instrument and Probe Cable Test

The instrument is shipped from the factory with CORROTEMP test probes, RCS part number 710617. These test probes have a nominal 5 MPY at a multiplier of 1.0 corrosion rate and a 100 deg C temperature simulated within the probe. If acceptable readings are performed on test probes, then problems are likely to be caused by the process itself or the probe in service. A fouling problem, for example, can bridge the electrodes and yield readings outside the normal measurement range of the instrument.

***NOTE:*** *Note: Be sure to set the multiplier parameter to 1.0 when measuring test probes and to return it to its previous setting.*

### Probe Replacement

Probe replacement is not required except due to damage or deterioration. Replace the probe if there is physical damage or a low resistance (less than 1 meg ohm) between the electrodes when disconnected from the electronics.

### Probe Cleaning and Electrode Replacement

As supplied from the factory, CORRATER electrodes have grit blasted surfaces and require no further cleaning before they are used. Probes should be checked at intervals particularly for conductive debris "shorting" out the electrodes which may be indicated by a very high corrosion rate reading. They should be cleaned and polished to a dull shine with an emery cloth. After cleaning, the electrodes should be thoroughly degreased in a suitable solvent, and handled with a clean cloth or paper towel to prevent contamination. The important factor is that the electrodes should be **REPRESENTATIVE** of the conditions to be monitored. New electrodes may be more responsive to changes in the corrosivity of the fluid. Electrodes which have been in used for some time will be more representative of corrosion rates on the more aged plant material, which will have some film build up.

# 14 AquaMate Reference Manual

**Table 5-1 CORRATER MULTIPLIER FACTORS**

**NOTE:** These factors are recommended for use with the AquaMate when setting the MULTIPLIER value, as described in Section 4. They are based upon use of CORRATER electrodes which have surface areas of 5cm<sup>2</sup> for "standard" probes and 0.5 cm<sup>2</sup> for "flush" probes.

UNS Code	Material	Multiplier
K03005	Pipe Grade Carbon Steel	1.00
A91100	Aluminum 1100-0	0.94
A92024	Aluminum 2024	0.88
C11000	Copper 110 ETP Comm. Pure	2.00
C44300	CDA 443 Arsenical Admiralty	1.67
C44500	CDA 445 Phosphorized Adm.	1.68
C64200	CDA 642 Al Silicon Bronze	1.48
C68700	CDA 687 Alum. Brass Arsenical	1.62
C70610	CDA 706 90/10 Copper/Nickel	1.80
C71500	CDA 715 70/30 Copper/Nickel	1.50
G41300	AISI 4130 Alloy Steel	1.00
L50045	Lead	2.57
N04400	Monel 400 Nickel	1.13
N05500	Monel K-500 Nickel	1.04
N06022	Hastelloy C22	0.85
N06600	Inconel 600 Nickel	0.95
N08020	Carpenter 20 CB3 SST	0.98

UNS Code	Material	Multiplier
N08800	Incolloy 800	0.89
N08825	Incolloy 825	0.88
N10276	Hastelloy C276	0.86
R50400	ASTM B-348 Grades 2-4 Titanium	0.75
S30400	AISI 304 Stainless Steel	0.89
S31600	AISI 316 Stainless Steel	0.90
S31603	AISI 316L Stainless Steel	0.90
S31803	2205 Duplex Stainless Steel	0.89
S32750	2507 Duplex Stainless Steel	0.88
Z17001	Grades 1A, 1, 2, 3, or 5 Zinc	1.29

Electrodes should be replaced when the diameter is reduced 1/32 inch (0.794 mm) or more. CORRATER electrodes are nominally 3/16 inch (4.76 mm) diameter and 1 1/4 inch (31.75 mm) long when new. As corrosion occurs on the electrodes, their diameter decreases and begins to significantly affect the accuracy of the corrosion readings. When installing new or cleaned electrodes on a standard probe body, do not use pliers. They should be screwed on the mounting studs only "finger-tight", slightly compressing the rubber O-rings at the base of the studs. Handle the electrodes with a clean cloth or paper towel to avoid depositing any contaminating oily film. In the event of contamination, a suitable degreaser can be used to clean the electrodes.

### **Electrode Pretreatment**

Pretreatment of the electrodes may be done in some instances, but is only recommended if the same type of treatment is used on the plant whenever new material is installed. Generally, a full strength sample of the treatment chemical is used. The new electrodes are carefully placed into the solution for a 6-12 hour period and then threaded onto the probe and placed into service.

Some systems have an initial high level of treatment before the inhibitor rate is reduced to a maintenance level. The treatment relative to the probe electrodes should be considered.

If the electrodes are installed without pretreatment the corrosion rate indicated will be that which would occur on new material put in the system. This may typically take a few hours to a few days to decrease to the normal on-going value. Pretreatment may artificially protect the material so that it is unrepresentative of any new material that may be put in the system.

### **Correlation with Electrodes as Coupons**

Weigh the electrodes in the same manner as a coupon would be weighed, on a balance scale graduated to 0.0001 gram before placing them in service. The coupon should be placed into service at the same time. After a 30, 60, or 90 day period, remove both, clean them and analyze them in the same manner. The readings from the instrument integrated over a period of time, and the data from the electrodes and coupons should correlate.



# Appendix A

## Theory of Operation of CORRATER Systems

CORRATER systems measure the instantaneous corrosion rate of a metal in a conductive fluid using the linear polarization resistance ("LPR") measurement technique. Corrosion is an electrochemical process in which electrons are transferred between anodic and cathodic areas on the corroding metal resulting in oxidation (corrosion) of the metal at the anode and reduction of cations in the fluid at the cathode.

Sterns and Geary originally demonstrated that the application of a small polarizing potential difference ( $\Delta E$ ) from the corrosion potential ( $E_{\text{corr}}$ ) of a corroding electrode resulted in a measured current density ( $i_{\text{meas}}$ ) which is related to the corrosion current density ( $i_{\text{corr}}$ ) by equation (1):

$$\frac{\Delta E}{i_{\text{meas}}} = \frac{b_a b_c}{(2.303 i_{\text{corr}}) (b_a + b_c)} \quad (1)$$

where:       $b_a$  = Anodic Tafel Slope  
                $b_c$  = Cathodic Tafel Slope

Since the Tafel coefficients are more or less constant for a given metal/fluid combination,  $i_{\text{meas}}$  is proportional to  $i_{\text{corr}}$  which is proportional to the corrosion rate. Equation (1) and the entire LPR technique are only valid when the polarizing potential difference is very low (typically up to 20 mV). In this region the curves are linear, hence the term LPR.

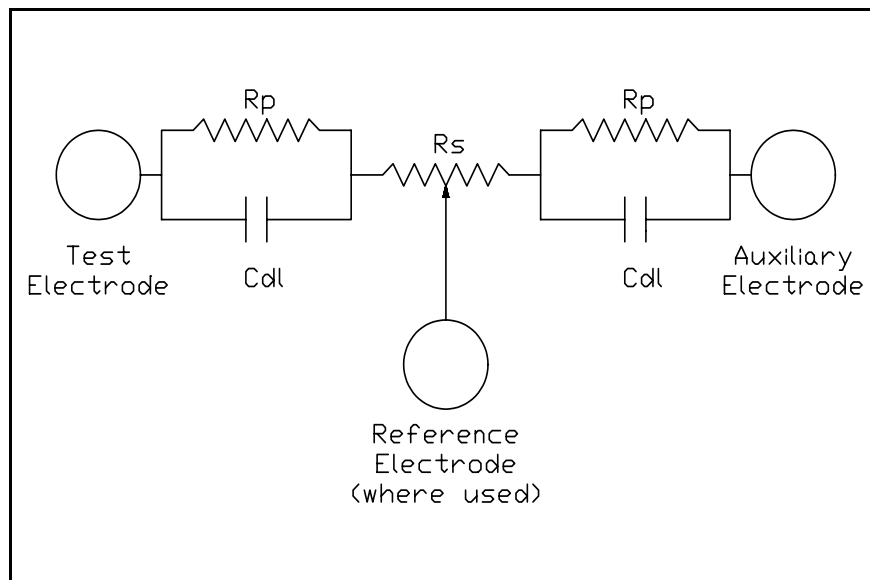
Inspection of Equation (1) shows that the result is a resistance, the Polarization Resistance,  $R_p$ . While strictly speaking, there are both anodic and cathodic  $R_p$  values, which can differ, they are usually assumed to be equal. The resistance to current flow between anode and cathode on the LPR probe is the sum of both polarization resistance values and the resistance of the solution between the electrodes ( $R_s$ ) as shown in Equation (2):

$$E = i_{\text{meas}} (2R_p + R_s) \quad (2)$$

## 18 AquaMate Reference Manual

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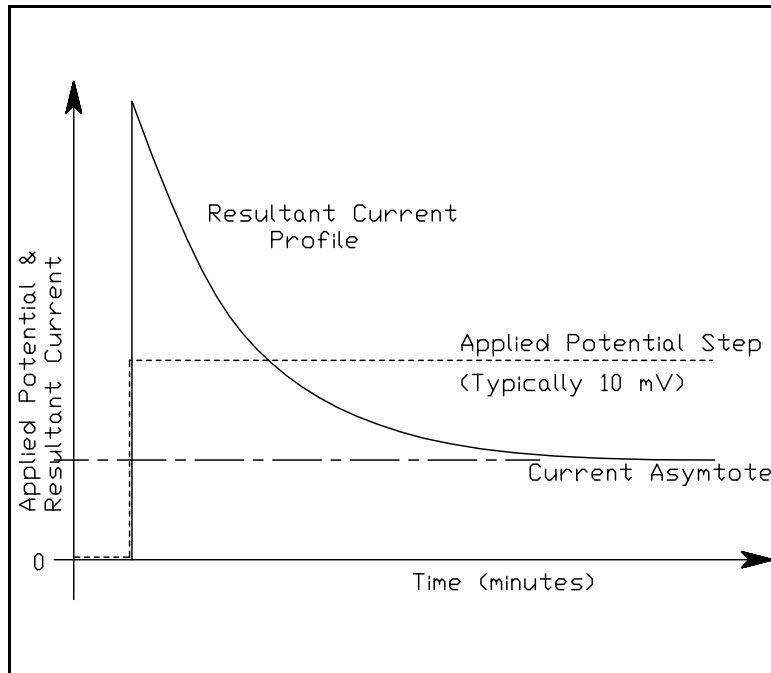
From Equations (1) and (2), obtaining results from the LPR technique would seem to require only instantaneous readings of resistance. In practice, however, the determination of polarization resistance is complicated by a capacitance effect at the metal-fluid interface (double-layer capacitance). Figure A-1 is an equivalent electrical circuit of the corrosion cell formed by the measuring electrodes and the fluid, showing the importance of  $R_s$  and double-layer capacitance effects.



**Figure A-1 Equivalent Circuit of LPR Probe**

The effect of the double-layer capacitance is to require the direct current flow to initially charge-up the capacitors, resulting in a decaying exponential current flow curve vs. time after application of the polarizing potential difference. A typical LPR current vs. time curve is shown in Figure A-2.

Each metal/fluid interface has its own characteristic capacitance which in turn determines the amount of time required to obtain valid measurements of  $i_{corr}$  and corrosion rate. The actual time required can vary from a few seconds up to 20 minutes, depending upon the metal/process combination being measured. Choosing too short a polarization time can result in current readings much higher than the true  $i_{corr}$  thus causing measured corrosion rate to be lower than actual, sometimes by a significant amount.

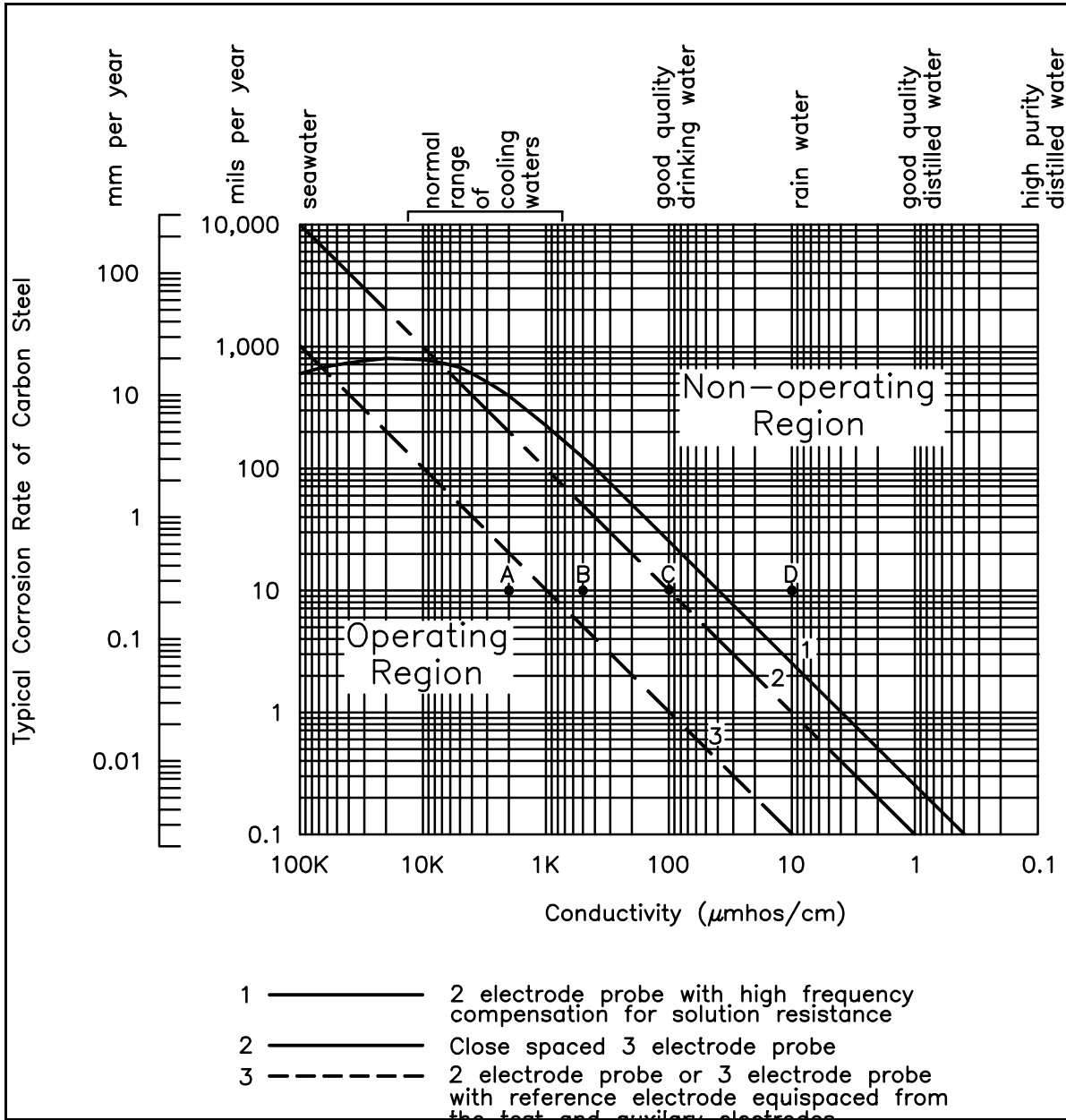


**Figure A-2 Typical LPR Current vs. Time Decay Curve**

Solution resistance can also have a significant effect on accuracy if it is relatively high compared to the polarization resistance. In most industrial water applications, conductivity of the solution is high and solution resistance is low compared to the polarization resistance, so  $i_{meas}$  is an accurate measure of polarization resistance, and therefore, corrosion rate.

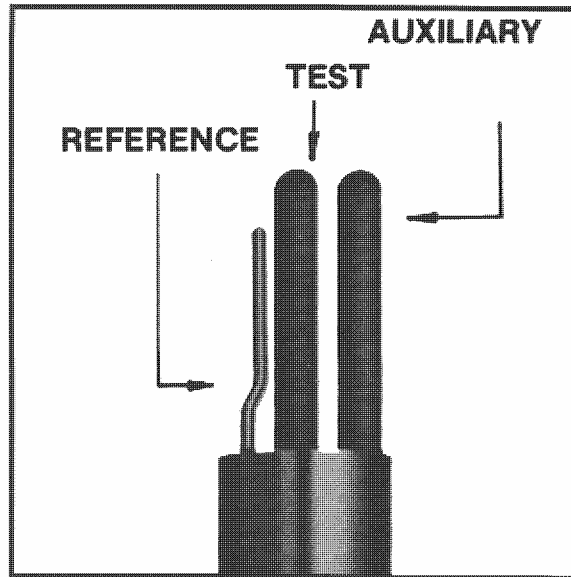
A serious problem develops, however, when the solution resistance increases or the polarization resistance decreases enough to make the solution resistance a significant portion of the total resistance to current flow between the electrodes. In these cases, the accuracy of the LPR measurement is affected. This situation tends to occur at high corrosion rates (low polarization resistance) and in solutions with low conductivity (high solution resistance) and is manifested by the indicated (measured) corrosion rate being lower than the actual corrosion rate. The graph in Figure A-3 shows the effect of this limitation on the recommended operating range of LPR instruments.

# 20 AquaMate Reference Manual



**Figure A-3 Operating Range of LPR Instruments  
Corrosion Rate vs. Solution Conductivity**

Several techniques have been used over the years to minimize the impact of solution resistance on LPR measurements. The most common techniques involved the use of a three electrode probe. The effectiveness of the reference electrode in reducing the effect of solution resistance has been shown to be dependent upon the proximity of the reference electrode to the measurement electrode. Rohrback Cosasco three-electrode probes (see Figure A-4) are unique compared to other major LPR probes because they utilize a closely-spaced electrode.



A better way to deal with this problem, however, is to directly measure and compensate for the solution resistance. Rohrback Cosasco has exclusive patent rights to the Solution Resistance Compensation (SRC) technique incorporated in most of the CORRATER range of instruments. In this method, a high-frequency a.c. voltage signal is applied between the electrodes short-circuiting  $R_p$  through the double-layer capacitance, thereby directly measuring the solution resistance. The state-of-the-art, patented SRC technology also eliminates the need for a third electrode, even in low conductivity solutions. Consequently, Rohrback Cosasco's two-electrode probes have become the standard RCS offering, with the three-electrode probe available on special order only.

The above points are clearly indicated in ASTM Standard Guide G96 which quotes:

- 3.2.8 Two-electrode probes and three-electrode probes with the reference electrode equidistant from the test and auxiliary electrode do not correct for effects of solution resistance without special electronic solution resistance compensation. With high to moderate conductivity environments, this effect of solution resistance is not normally significant.

## 22 AquaMate Reference Manual

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- 3.2.9 *Three-electrode probes compensate for the solution resistance  $R_s$  by varying degrees depending on the position and proximity of the reference electrode to the test electrode. With a close-spaced reference electrode, the effects of  $R_s$  can be reduced up to approximately ten fold. This extends the operating range over which adequate determination of the polarization resistance can be made.*
- 3.2.10 *A two-electrode probe with electrochemical impedance measurement technique at high frequency short circuits the double-layer capacitance,  $C_{dl}$ , so that a measurement of solution resistance  $R_s$  can be made for application as a correction. This also extends the operating range over which adequate determination of polarization resistance can be made."*

### Imbalance (or Pitting/Index)

In addition to general or uniform corrosion, localized corrosion (pitting) may occur in a system. This can result in much more rapid failure of a structure than a simple measure of corrosion rate would indicate. A pit on the metal surface is the result of a localized, high anodic current density. Positive ions flow away from the pit into the solution and electrons flow away from the pit into the surrounding metal.

If it were possible to place a zero-impedance ammeter between the pit and the nearby metal surface, the current in the anode-cathode system of the pit could be measured. Individual measurements are not practical because the areas are small. Instead, current flow between the two metallurgically identical electrodes of a CORRATER probe under short-circuit conditions can be used to indicate pitting tendency. All Rohrbach Cosasco CORRATER instruments include a imbalance/pitting reading. The user should note that this is a qualitative measurement (or index) and utilize it accordingly. It has proven very useful in many applications (e.g. cooling water treatment) and offers information not generally available about a system except by coupons which lag behind actual events and offer no way of detecting upsets.

If the pitting reading is low compared to the corrosion reading, the pitting problem will probably be minimal. On the other hand, a pitting reading which is high compared to the corrosion reading can indicate that pitting or crevice corrosion will be the main form of corrosive attack. When the readings are about equal, some pitting is indicated, but the pits will probably be broad and shallow.

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## Appendix B

### Manufacturer's Declaration of Conformity

We the manufacturer hereby declare that this product:

**PRODUCT NAME:** AquaMate Hand Held Portable CORRATER  
**MODEL:** "AquaMate"

is in full compliance with all applicable EU Product Directives and required standards as noted below:

**EMC DIRECTIVE 89/336/EEC**

**PRODUCT STANDARDS:**

**Radiated Emissions - EN 55011:1991, Group 1, Class A**

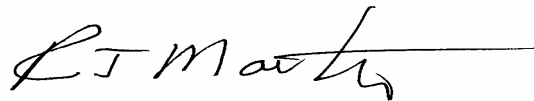
**Immunity (Heavy Industrial) - EN 50082-2: 1995**

**Electrostatic Discharge - EN 61000-4-2: 1995**

**Radiated EM Field - ENV 50140: 1994**

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Rohrback Cosasco Systems  
Santa Fe Springs, California USA

**AUTHORIZED SIGNATURE:**



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**Ronald J. Martinez**  
Director of Quality Assurance