

# MS1500L LPR Data Logger

**Metal Samples Company**

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# I. Introduction

## A. Instrument Function Overview

The MS1500L is a hand-held measurement and data collection device. It is lightweight, easily handled, and battery operated so that it can be carried to any location where measurement or data collection is required.

The MS1500L has several measurement functions:

- 3-Electrode Linear Polarization (corrosion-rate)
- 2-Electrode Linear Polarization (corrosion-rate)
- “Pitting Index”
- Zero Resistance Ammetry
- Electrode Potential

This versatility allows the unit to be used with all commercially available corrosion-rate probes. Additionally, it can be used with all types of galvanic probes to measure bimetallic corrosion, changes in the oxidizing power of the process fluid and, with suitable electrode combinations, crevice and pitting attack, as well as stress corrosion cracking.

Using galvanic probes with an appropriate combination of corroding, redox, and reference electrodes, it is possible to measure the corrosion potential of a corroding electrode, or the redox potential of the process fluid, which provides a wide range of information on such phenomena as active/passive transitions, inhibitor film persistency, inhibitor mechanisms, cathodic protection criteria, as well as providing an alternative means to measure the onset of pitting a crevice attack and conjoint action failure phenomena (e.g., stress cracking).

All measurements made with the MS1500L may be stored in the onboard memory that will hold as many as 3000 readings from up to 100 individual probes. All stored data may be called to the instrument screen and reviewed at any time. A backup battery will hold all data stored in memory for up to 12 months, in event of failure of the main instrument battery.

Data may be selectively deleted from memory to accommodate additional information, once the 3000 reading capacity is reached. Alternatively, information may be downloaded to a PC as a comma-delimited ASCII file for import into any of the standard data analysis (spreadsheet) program such as Microsoft Excel.

In addition to its measurements function, the MS1500L may be used as a data collection and transfer terminal for Metal Samples' MS3500L remote LPR data logger. In this capacity the accumulated data from several MS3500L field-based units may be locally downloaded to the portable MS1500L and transferred to a PC for further analysis.

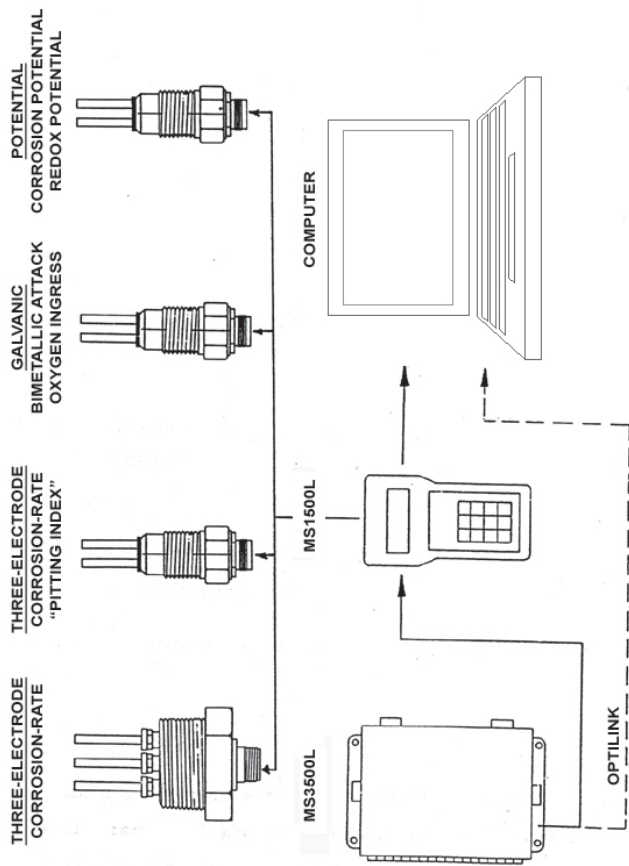


Figure 1 - MS1500L Measurement Functions

## B. Instrument Parts List

The MS1500L comprises the following items:

<u>Part No.</u>	<u>Qty.</u>	<u>Description</u>
M-7500-M	1	Operations Manual
IN1500L-3	1	Meter Prover
ET0352	1	Serial Port Cable
IN1500-3	1	9-Pin Serial Port Adapter
IN1500L-5	1	6-Pin Cable to 5-Pin Probe Adapter
MS1500L	1	Instrument
IN1500L-2	1	Instrument Carrying Case
B-8400-B	1	9-Volt Battery

The user should check, upon receipt, that the above accessories are included with the MS1500L unit. Any shortage should be reported immediately to:

Metal Samples Company  
152 Metal Samples Rd.  
Munford, AL 36268  
Phone: (256) 358-4202  
Fax: (256) 358-4515  
E-mail: [mvc@alspi.com](mailto:mvc@alspi.com)



## C. Specifications

### Model

MS1500L - Handheld LPR Corrosion Data Logger (Ordering #IN1500L)

### Physical Data

Instrument Weight:	1.4 lb. (0.64 Kg)
Total Weight w/ Carrying Case and Accessories:	5.26 lb. (2.39 Kg)
Instrument Dimensions:	7.63”H x 4.15”W x 2.0”D (19.38cm x 10.54cm x 5.08cm)
Carrying Case Dimensions:	10”H x 11.75”W x 5.4”D (25.40cm x 29.85cm x13.72cm)
Operating Temperature:	32° to 122°F (0° to 50°C)
Storage Temperature:	-4° to 158°F (-20° to 70°C)

### Performance Data

Measurement Type	Range	Resolution
2-Electrode	0 to 200 mpy	0.01 mpy
3-Electrode	0 to 200 mpy	0.01 mpy
Galvanic	± 999 µA	1 µA
Potential	± 999 mV	1 mV

### Electrical Data

Power Requirements:	One 9V Battery
Maximum Probe Cable Distance:	6 ft (1.83 m)
Output Specifications:	RS-232 Output in Comma-Delimited ASCII Text Format

### Special Features

- Microprocessor-based electronics
- Data storage capacity of 3000 readings on 150 different probes, with battery backup
- Menu-driven interface using a 12-key keypad and a 4-line LCD display
- Low-battery detection
- Portable

### Accessory Items

Carrying Case, 6’ Probe Cable (attached), Meter Prover, 6 to 5-Pin Adapter, Galvanic Adapter, Communications Cable and Connector, Operation Manual

## D. Battery Installation

Open the battery compartment by removing the “slip-fit” cover on the rear of the instrument (shown below) and insert one 9-volt battery.

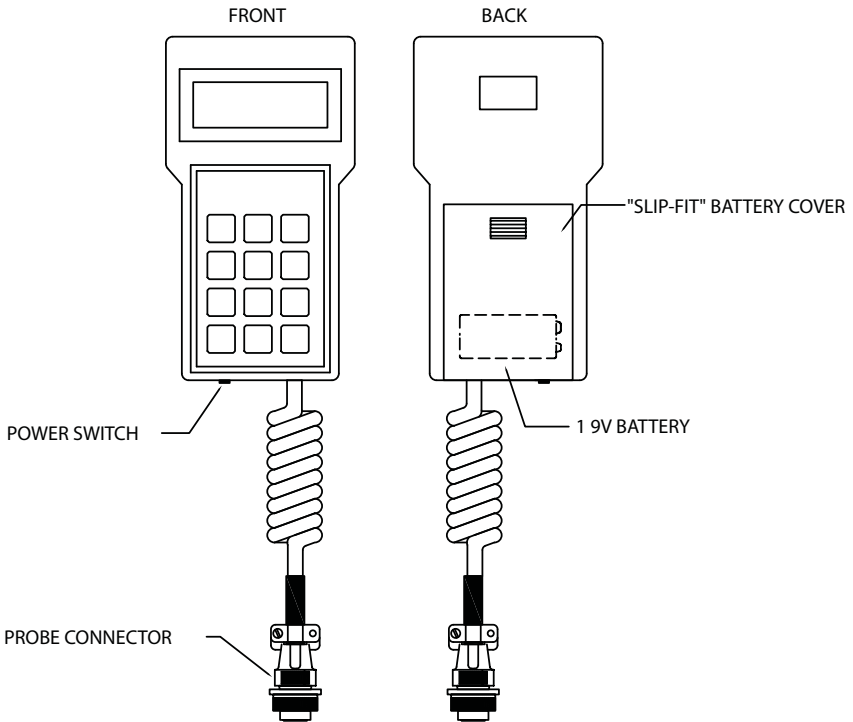
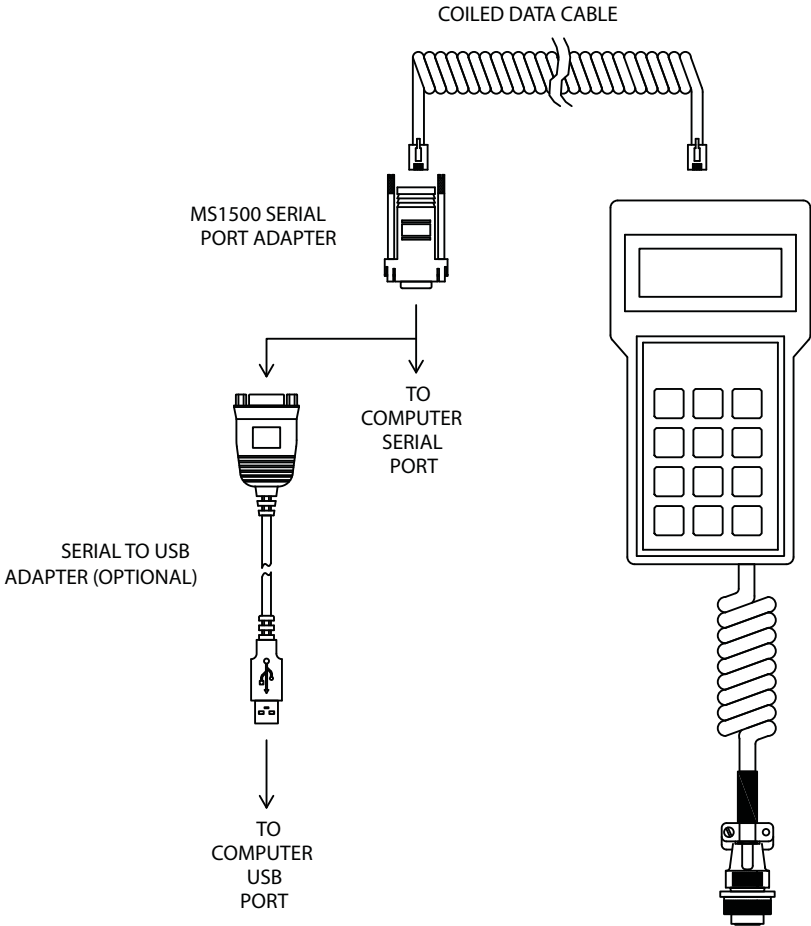


Figure 2. Battery Installation

## E. Computer Download Hook-Up

Use this cable to connect the MS1500L to a computer via serial port or USB port.

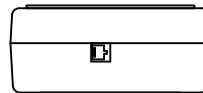


**Figure 3. Computer Download Hook-Up**

Use the port on top of the MS1500L for connecting to a computer (with the cable provided) or to the MS3500L (with the Opti-link cable.)

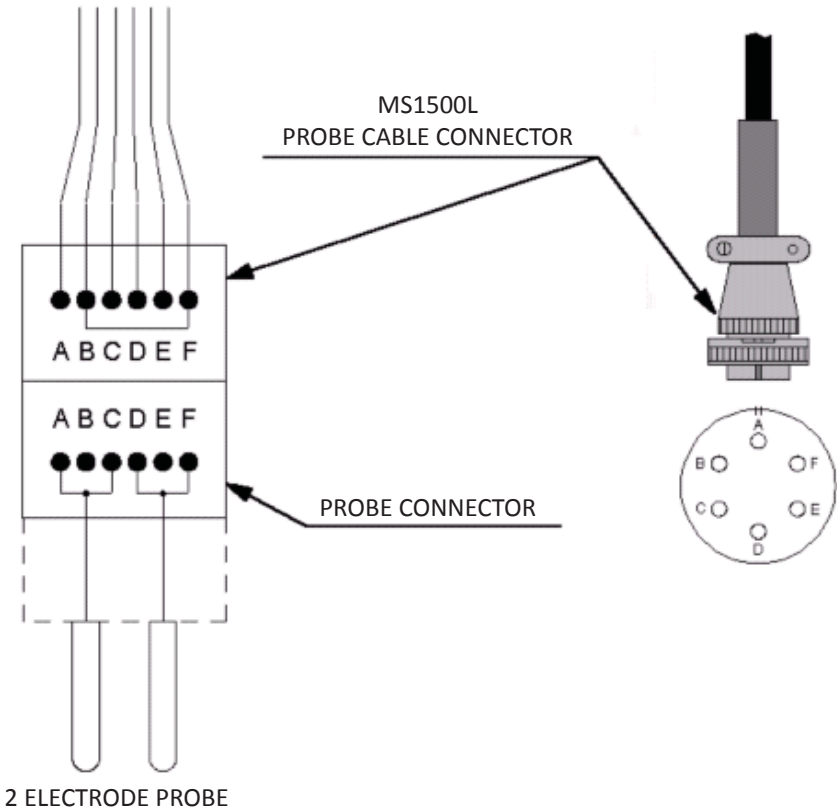
See **Communications** (p. 32) for more information.

*Top View of MS1500L*



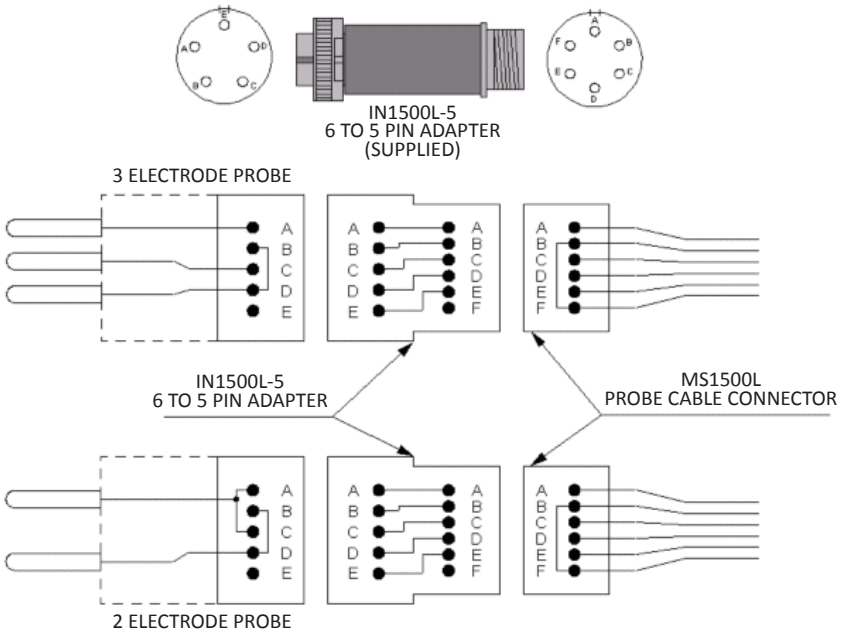
## F. Adapter Use

The probe connector on the MS1500L is a six-pin, female, MIL-SPEC (MS-3106F-14S-6S) fitting. It is designed for direct connection to any standard electrochemical probe manufactured by Metal Samples (see illustration below).



**Figure 4. Conventional Probe / Instrument Connection**

The IN1500L-5 (6 to 5 pin adapter) is a special adapter designed to mate with all two- or three-electrode probes that use a five-pin connector instead of the conventional six-pin connector.



**Figure 5. Adapter Connection for 2- or 3-Electrode Probes**

The user may, from time-to-time, encounter probes with a non-standard probe connection, especially if the probes are of a non-commercial variety. To account for this possibility, the IN1500L-4 cable adapter is available. This comprises a conventional six-pin connector, attached to a cable with leads, terminated in alligator clips. This allows for individual terminations to be made to any non-conventional probe, provided the probe connector pin-out is known. If the user is unfamiliar with the pin-out on any particular probe, this can be established prior to probe installation by performing a simple continuity check between the probe electrodes and the probe connector pins.

## II. Instrumentation Operation

### A. Start-Up and Operations Overview

Having installed the battery, as discussed on page 6, the unit is ready for operation. The instrument may be activated, using the toggle switch on the left side of the base of the instrument.

When switched on, the instrument will initially show the self-test screen, display the free storage, then automatically jump to instrument functions as shown below:

Metal Samples  
MS1500L V/X.X  
SYSTEM TEST: XXXX

“SYSTEM TEST SCREEN”

AUTOMATIC

Metal Samples  
MS1500L V/X.X  
FREE STORAGE: XXXX

“FREE STORAGE SCREEN”

AUTOMATIC

> SELECT PROBE I.D.  
MAKE MEASUREMENT  
RECALL READINGS  
DELETE READINGS

UNS CONST. TABLE  
COMMUNICATIONS  
SET TIME & DATE

“MAIN FUNCTION SCREEN”

The initial screen showing the system test will scroll the four digit number until it has counted all the free storage. The free storage is then displayed on the second screen, which appears automatically.

***A new instrument should show a free storage of 3000. If a number lower than 3000 is shown, the instrument contains stored data from factory testing. Any such data should be located through the "SELECT PROBE I.D." function and deleted (see Select Probe I.D., p.14, and Delete Readings, p.27 ).***

Once the free storage has been displayed, the screen moves automatically to the instrument function screen. This screen shows a series of cursor-selectable options that allow the user to enter data, or perform some measurement or action.

Prior to any other action, the user should use the down arrow on the keyboard to select "SET TIME AND DATE," followed by the enter key to access the function sub-menu screens that have the following sequence:

SET TIME & DATE  
HH:MM DD/MM/YR  
  
UP ARROW WHEN DONE

SET TIME & DATE  
HH:MM DD/MM/YR  
  
ENTER TO ACCEPT

Individual digits of the date and time can be set using the keyboard numbers. Once an individual group (e.g., hours) is set, the up arrow will shift the user to the next group of digits to be set. Once the year group digits are set, the up arrow will bring up a confirmation screen, the command “enter” will set the time and date as shown. An “exit” command will leave the time and date as previously set. Whether the “enter” or “exit” command is applied, the user will be returned to the function screen automatically. At this point, the user may either re-enter the “SET TIME AND DATE” submenu to enter the correct time and date or, if satisfied with the current time and date function, proceed to other measurements or data input.

***The instrument clock will run on backup battery should the main battery fail so, once the time and date is originally entered, there should not be reason to further reset this parameter. Should the user decide for any reason to reset the time and date after the initial setting, the time continuity of any stored data will be disrupted and data will prove tedious to analyze subsequent to the time change.***

The purpose of the remaining menus displayed on the function screen is described in detail in subsequent sections of this manual. However, the following gives a brief overview of these functions, and their use:

**SELECT PROBE I.D.:** This allows a probe to be given a unique reference number, a selected measurement mode, an electrode alloy identification and, where necessary, a measurement time cycle and electrode area modifying factor.

**MAKE MEASUREMENT:** This instructs the instrument to make a measurement, and save the resulting data.

**RECALL READINGS:** This allows the stored data from any or all probes to be called to the instrument screen and reviewed.



- DELETE READINGS:** This permits the deletion of redundant or obsolete data from memory.
- UNS CONSTANT TABLE:** This permits the insertion of correction factors when the user employs electrodes of nonstandard surface area.
- COMMUNICATIONS:** This executes the download of data from the MS1500L to a PC, for further processing and analysis.
- SET TIME AND DATE:** This allows the user to alter the setting of the instrument clock.

## B. Select Probe I.D.

### 1. General

This function menu is central to the whole operation of the instrument. With the exception of the “UNS CONSTANT TABLE” and the “SET TIME AND DATE”, no function menu can be used prior to the selection of a probe I.D. The menu allows you to identify a specific probe with data already in memory, for which the user requires to make additional measurements, review existing data stored for that probe, or delete data for the probe selected. It also allows the user to enter a new probe I.D., together with a requirement measurement function, alloy identification, and time cycle (if required).

The “SELECT PROBE I.D.” function may be entered by selecting this option on the main function screen using the cursor, then pressing the “ENTER” key. The initial submenu screen will appear as shown below:

ENTER NEW PROBE		
DELETE PROBE		
XXXX	XXXXXX	XXXXXXX
XXXX	XXXXXX	XXXXXXX
XXXX	XXXXXX	XXXXXXX

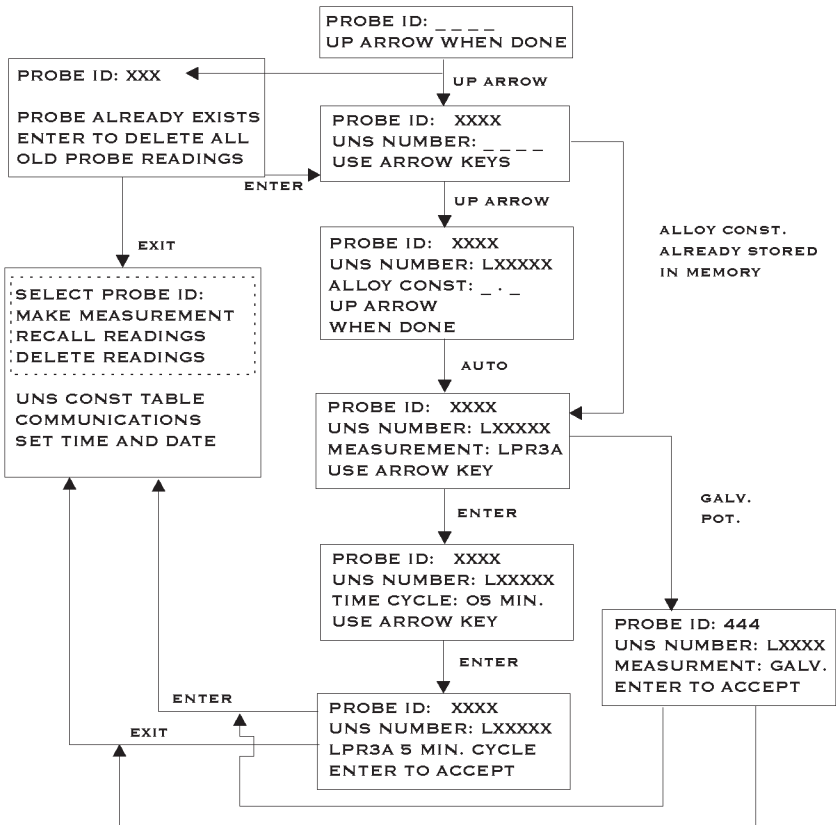
The screen lists options for entering a new probe, deleting a probe and also lists all identities for probes with data already stored in memory. Those probes already in use are listed as a four-digit I.D. number, three to five letters and digits describing the measurement type, and single letter followed by five digits designating the UNS alloy code (p. 57 lists the most common alloys and their UNS codes).

If the user simply wishes to make a measurement, recall readings, delete reading, or download data for an existing probe, the specific probe is selected, using the cursor and arrow keys, followed by the

“ENTER” key. The probe is now selected, and the user will be returned to the main function screen to make a measurement, recall readings, delete readings, or download data for the probe selected.

## 2. Enter New Probe

Whenever a new probe location is to be monitored, the user will need to enter a unique probe I.D. number, an instruction as to measurement type, and an alloy designation code. To do this, select “ENTER NEW PROBE” from the initial screen of the sub-menu using the cursor and arrow key, and activate the option with the “ENTER” key. This will initiate the following screen sequence:



The initial screen allows the user to insert a probe I.D. of up to four digits, using the keyboard numbers. When the appropriate I.D. number is entered, which may be any digital sequence the user cares to adopt, the “UP ARROW” key will transfer the user to the next screen.

***If the user has selected a probe I.D. already in use, the menu will divert from the normal sequence, inform the user that the selected I.D. is already in use, and ask if old probe readings are to be deleted. Unless the user wishes to delete existing probe readings, the “EXIT” key should be selected, which will return the user to the main function menu, allowing re-entry to the “SELECT PROBE I.D.” menu, so that the user may select a probe I.D. that is not in use. Should the user wish to delete readings already stored under the selected probe I.D., “ENTER” should be selected, existing probe readings will be deleted, and the probe I.D. will be free for reuse.***

Assuming a unique probe I.D. has been selected, or the user has elected to delete existing data as described in the previous paragraph, a screen will be shown allowing entry of the UNS code for alloy identification. This will be a letter, followed by a five-digit number.

***For most measurement applications, the UNS code is merely used as reference data. However, in the case of a 2-electrode, linear polarization measurement, the UNS number will trigger the use of an alternate proportionality constant in the instrument’s calculation of corrosion rates. (See UNS Constant Table, p.57.)***

The initial letter of the UNS constant is selected from the keyboard, and confirmed using the “ENTER” key. The subsequent five digits are selected using the keyboard and confirmed using the “UP ARROW” key. The screen will automatically change to the alloy constant screen or the measurement type screen.

If the UNS code entered for this particular probe is already contained in “UNS CONST. TABLE”, the instrument will already have a record of the alloy constant, and will pass directly to the measurement type screen, if not the instrument will automatically pass to the alloy constant screen. The alloy constant screen allows the user to input a two-digit number from the keyboard. This will be a number less than ten given to the first decimal place, using the “UP ARROW” when complete to pass to the measurement type screen.

***The alloy constant is a correction factor used to account for variation in electrode surface area when making a two-electrode corrosion rate measurement. A look-up table for forty-five of the commonest alloy constants is programmed into the MS1500L and, should the user select one of these alloys, the instrument will automatically enter this constant without showing the alloy constant screen. Additional alloy constants are automatically added to the look-up table as the user programs them through the “SELECT PROBE I.D.” menu; alternatively they can be added directly to the look-up table through the “ALLOY CONST. TABLE” menu (see UNS Constant Table, p. 57). The look-up table will hold a maximum of fifty alloy constants together with their UNS codes, so that the user may occasionally wish to delete alloy constants and UNS codes to make room for more frequently used designations; this is also accomplished through the “ALLOY CONST. TABLE” menu. (A table of common UNS codes, together with appropriate alloy constants is given on p.57).***

The measurement type screen, which is shown automatically after the UNS code screen or the alloy constant screen, allows the user to select the measurement type by using the “ARROW” keys to scroll, and the “ENTER” key to select. The measurement types that are selectable are:

- LPR3A: 3-electrode, linear polarization (corrosion rate) using anodic polarizing current.
- LPR3C: 3-electrode, linear polarization (corrosion rate) using cathodic polarizing current.
- LPR2: 2-electrode, linear polarization (corrosion rate).
- GALV.: 2-electrode, zero-resistance, current measurement.
- POT.: 2-electrode potential measurement.

Once the measurement type has been selected, one of two screens will present itself to the user. If galvanic or potential measurement has been selected, a screen showing the probe I.D. number, the UNS code, and measurement type will be shown. If the information shown on the screen is consistent with the user's requirement, the "ENTER" key will accept this information and return the user to the main function menu from which actual measurements may be made. Should the screen show incorrect information, the user can use the "EXIT" key to return to the main function menu, from which the "ENTER PROBE I.D." function can be re-accessed to correct the probe I.D. information.

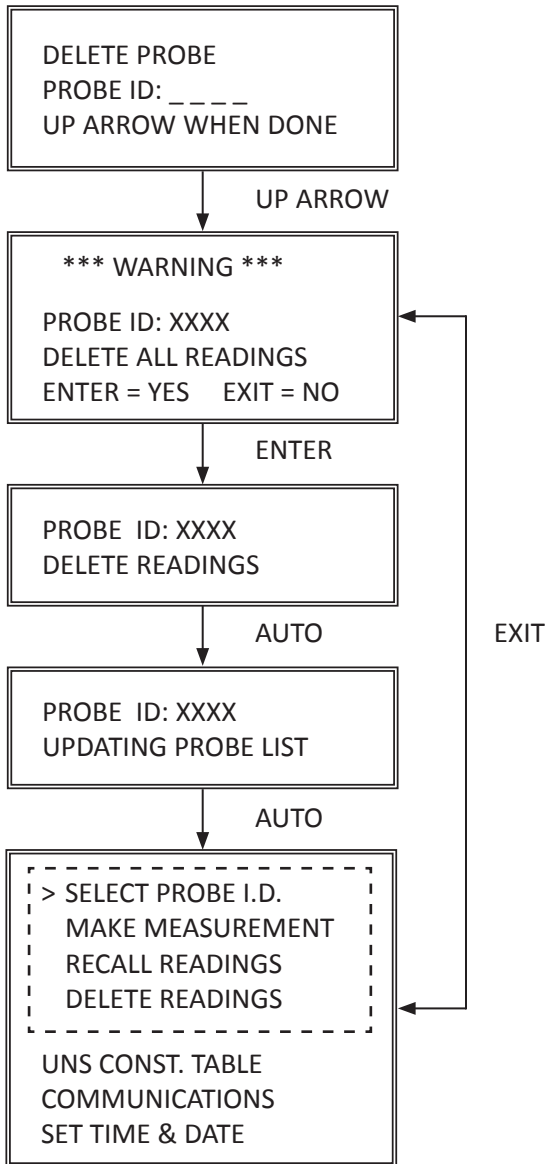
If the user has selected either two or three-electrode linear polarization measurement, a time cycle screen will be shown subsequent to the measurement type screen. ***Unlike galvanic or potential measurement, linear polarization is not truly instantaneous. A period of time is required, following the imposition of the polarizing voltage, during which capacitive discharge takes place at the electrode prior to the establishment of an equilibrium polarizing current. If insufficient time is allowed for the establishment of the equilibrium current, the resultant corrosion rate measurement will be falsely high. The time required for the establishment of equilibrium will vary from system to system.***

The time cycle screen allows the user to set a time cycle for the linear polarization measurement between one and five minutes. This is selectable using the “ARROW” keys, and confirmed using the “ENTER” key. Once the time cycle is entered, the screen will automatically display the probe I.D., the UNS code, the measurement type, and the time cycle. The “ENTER” key will accept this information, and return the user to the main function screen, from which the user may elect to make a measurement. Should the information prove incorrect, the user may employ the “EXIT” key to return to the main function screen, re-access the “ENTER PROBE I.D.” menu and correct errors in the probe I.D.

Once a probe I.D. is entered, it will be stored and can be re-accessed at a future date directly from the list of probe I.D.’s given on the first screen of the “SELECT PROBE I.D.” menu. The probe I.D. will be retained until the user deletes it, or downloads the information for that probe I.D. to a computer.

### **3. Delete Probe**

The second option listed in the first screen of the “SELECT PROBE I.D.” sub-menu is “DELETE PROBE”. This is a convenient alternative for deleting unwanted or obsolete probe data from the instrument memory. Probe data may also be deleted using the main function “DELETE READING” (see Delete Readings, p.27). Deletion using the “ENTER PROBE I.D.” route can be selected using the cursor, “ARROW” keys, and the “ENTER” key. The following screen sequence will be activated:





***The user should scan the list of probe I.D.'s to identify and memorize the probe I.D. to be deleted, since this will be requested. If the probe I.D. in question is not known, the user will have the tedious task of returning to the main function screen, scanning the probe I.D. list, and finally re-entering the "DELETE PROBE" sequence.***

Once the "DELETE PROBE" sequence is entered, the screen will request the I.D. of the probe to be deleted. This is entered using the numeral keys, and the "UP ARROW" key at the conclusion. A warning screen will now appear listing the probe I.D. to be deleted, and a request for confirmation. ***If the user is in doubt, the "EXIT" key should be used, to return the user to the main function screen without deletion of any data.*** Having decided that the probe data is of no further value, use the "ENTER" key to delete the probe data. The instrument screen will now automatically sequence through a "DELETING READINGS" screen followed by an "UPDATING PROBE LIST" screen, and finally returning the user to the main function screen.

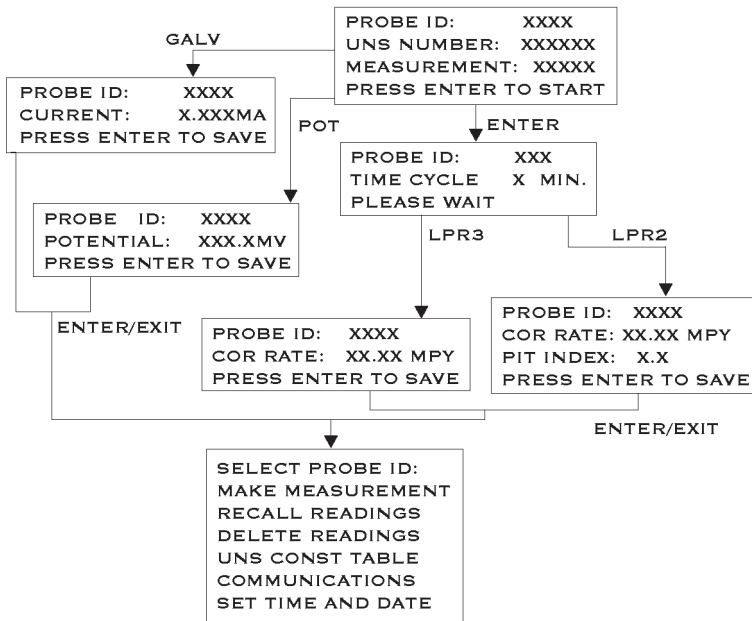
Once this sequence is complete, the probe data and probe I.D. are removed from the MS1500L memory.

## C. Make Measurement

Before any measurement can be made, a probe I.D. must be selected. This may be done in one of two ways. If the probe is one for which a probe I.D. and data are already stored in memory, simply enter the “SELECT PROBE I.D.” submenu, scan the existing probe I.D. listings, and select the appropriate probe I.D. using the cursor, “ARROW” keys, and the “ENTER” key when the cursor is set on the required probe I.D. The probe is then selected, and the user will be returned to the main function menu, from which the user may enter the “MAKE MEASUREMENT” submenu, to measure the selected probe. ***Unless the instrument is switched off, or a new probe I.D. selection is made, the probe remains selected, and any number of measurements may be made without re-selection.***

If the probe to be measured is a new probe without an I.D. in memory, the user must enter a probe I.D. (see Enter New Probe, p. 15). Upon completion of the “ENTER NEW PROBE” sequence, the user is automatically returned to the main function menu, the new probe automatically has been selected, and measurements may be made by selecting the “MAKE MEASUREMENT” submenu. As with an existing probe, a new probe may be subjected to as many measurement cycles as desired without re-selection, provided the instrument is not switched off.

Once a new, or existing, probe has been selected, the make measurement sequence may be entered from the main function menu using the cursor, “ARROW” keys, and the “ENTER” instruction. This will initiate the screen sequence shown on the next page:



The first screen of the “MAKE MEASUREMENT” submenu displays the probe ID, UNS code, and measurement type. If this is correct, the user should use the enter key to start the measurement cycle. If the probe ID is incorrect, the user should use the “EXIT” key to return to the main menu and then enter the “SELECT PROBE I.D.” submenu to select the correct probe I.D.

If the measurement type is galvanic or potential, after initiation with the enter key, the measurement will be completed in less than fifteen seconds. The screen showing the measurement value will appear displaying either probe I.D. and current (expressed milliamps to three decimal places), or the probe I.D. and potential (expressed millivolts to one decimal place). Either screen will instruct the user to use the “ENTER” key to save the measurement. If the user does not require to save the measurement, the “EXIT” key can be used. Both the “ENTER” and the “EXIT” key will return the user to the main function menu allowing subsequent measurements on the same probe or selection of a new probe for measurement.

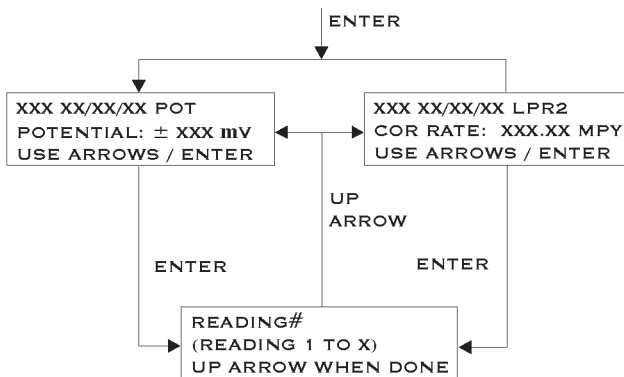
If the measurement type is either two or three-electrode linear polarization, the “ENTER” will initiate the measurement time cycle as set by the user in the “SELECT PROBE ID” sequence. During the measurement time cycle, the screen will display the probe I.D. and the time cycle shown in whole minutes; a request to wait is also displayed. During the measurement cycle, the minute indicator will flash at one second intervals, and will count down whole minutes to zero. ***Since the 2-electrode measurement involves two polarization cycles, one anodic and one cathodic, the actual time cycle set by the user is half the total measurement time; the user should ensure that the cycle set for a 2-electrode linear polarization measurement is half the desired total measurement time.***

At the conclusion of the linear polarization measurement cycle, the 3-electrode measurement will display the probe I.D. and the corrosion rate in MPY (“MIL PER YEAR”). The two-electrode measurement will also display the pitting index. Either screen will instruct the user to “PRESS ENTER TO SAVE”, which will save the measurement and return the user to the main function menu, to make further measurements. The “EXIT” key will also return the user to the main menu, but will not save the measurement.

## D. Recall Readings

This main function allows the user to recall all readings stored under any probe I.D. to the instrument screen for review. As with most functions, the precursor to use is to select the probe of interest. This is accomplished by entering the “SELECT PROBE ID” submenu, reviewing the list of probe I.D.’s stored, and using the cursor coupled with the “ENTER” instruction to select the probe and return to the main function menu.

Once the probe I.D. is selected, the “RECALL READINGS” submenu is entered using the main function menu cursor, directed by “ARROW” keys, and activated with the “ENTER” key. The following screen sequence comprises the “RECALL READINGS” submenu.



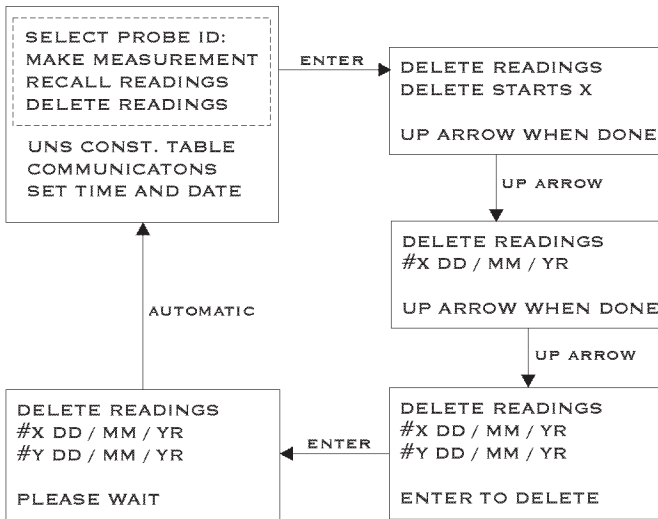
The initial screen of the “RECALL READINGS” submenu shows the last reading number, date, and measurement type sequentially on the top line. The reading number is merely the total number of readings stored, which is also the number of the most recent reading stored. The date is shown in the European form of day/month/year. The next line shows the measured value, which may be millivolts, milliamps, or corrosion rate depending on the measurement type. If the measurement type is 2-electrode linear polarization, a third line will show a dimensionless number, the so-called pitting index.

The last line is an instruction to use either the "ARROW" keys or the "ENTER" key. The "ARROW" keys allow the user to scroll backwards ("DOWN ARROW") and forwards ("UP ARROW"), sequentially, through the stored readings for the selected probe. In instances where several hundred readings are stored, and the user wishes to access a specific reading, use of "ARROW" keys and scrolling can prove tedious. In such a case, the user should use the "ENTER" key which will call up the reading number screen. The user can insert the reading number of specific interest and use the "UP ARROW" to recall the initial screen at the reading number selected; scrolling either side of the selected reading number can be resumed using the "ARROW" keys. The user can, at any time, return to the main function menu using the "EXIT" key.

## E. Delete Readings

This function is more selective than the “Delete Probe” function (p.19) found in the “SELECT PROBE I.D.” submenu. Using the “Delete Readings” function, it is possible to selectively delete individual readings stored under any given probe I.D.

Having selected a probe the user may select the “Delete Readings” function using the cursor and “ENTER” key on the main function screen. The following screen sequence illustrates the use of the “Delete Readings” sub-menus:



The first screen of the sub-menu requires the user to insert the reading number at which the deletion process should start. For example, if the user wishes to delete the first 50 readings, the number “1” will be the reading number at which deletion starts. Once the appropriate number is entered, the ‘UP ARROW’ will take the user to the new sub-menu screen.

This second screen displays the reading number at which deletion is to start, together with the date of this reading displayed in European format. The screen also requests the process is to stop. Once the number of the final reading to be deleted is entered, the 'UP ARROW' will then display an action confirmation screen.

This action confirmation screen shows the user both the initial and final ending number in the deletion sequence, together with the date of each reading. If the user wishes to proceed with deletion, the enter key is used and, after a short waiting period, the deletion is complete. At this point, the screen automatically reverts to the main function screen and, the selected readings have been deleted. Should the user not wish to proceed with deletion, the user should press the "EXIT" key, returning automatically to the main function screen without deletion of any readings.



## F. UNS Constant Table

### 1. General

As explained in the “ENTER NEW PROBE” section, the UNS alloy code is used exclusively for reference in the case of 3-electrode linear polarization measurement, galvanic measurements, and potential measurements. It merely allows the user, through the probe I.D. listings in the “SELECT PROBE ID” submenu, to have a permanent record of the type of alloy used for the electrodes of a specific probe.

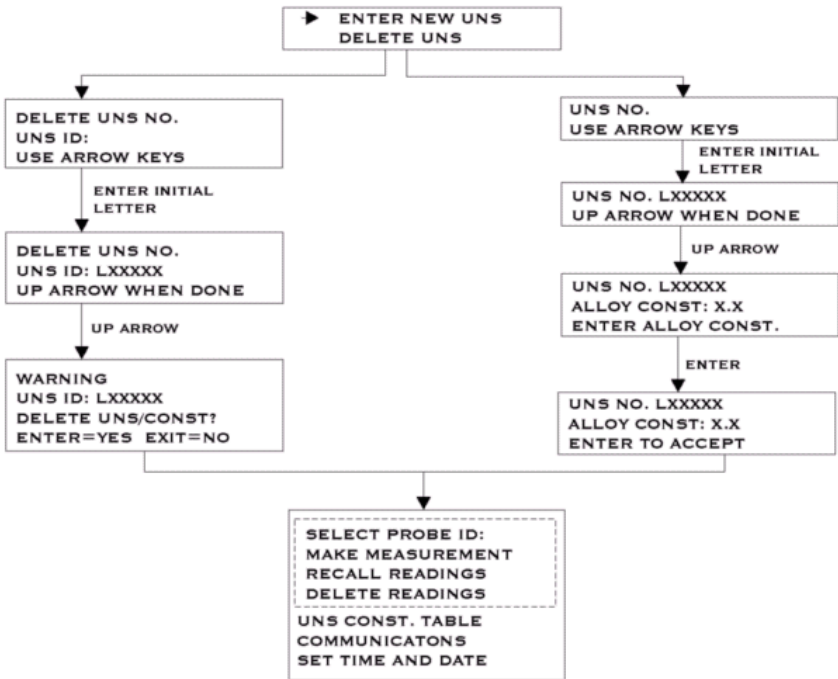
The exception to this function is when the measurement type is a 2-electrode linear polarization measurement. In this case, the UNS code will alter the constant of proportionality, used in the corrosion rate calculation. This is necessary since each alloy/metal has a unique factor in the equation relating polarizing current to corrosion rate. This factor is the equivalent weight divided by the density. In conventional 3-electrode measurements, this uniqueness is accounted for by varying the surface area of the working electrode from alloy to alloy to account for these variations. Essentially, the surface area of the working becomes part of the instrument constant. However, the major manufacturer of electrodes for the two-electrode linear polarization measurement uses a constant electrode surface area, irrespective of alloy. Consequently, when making a two-electrode polarization measurement, an additional factor must be incorporated into the instrument constant to account for the variable density and equivalent weights. Precise derivation of the “alloy constant” is shown in Appendix 1 of this manual, as is a table of common alloys their UNS code, and the appropriate alloy constant.

The “UNS CONST TABLE” contains a listing of 45 of the most common alloys, which is used as a look-up table, automatically applying an appropriate alloy constant to each two-electrode linear polarization measurement. The “UNS CONST TABLE” function is accessible to the user through the main function menu, to allow additions or deletions from the UNS/alloy constant table.

*The table has a maximum capacity of fifty listings. Attempts to add more than the total of fifty, either directly through the “UNS CONST TABLE” or through the “SELECT PROBE ID” function will overwrite the initial listings in the table. To avoid elimination of regularly used alloy constants, the user should delete constants and UNS codes that are rarely used before adding new ones, once a total listing of fifty has been reached.*

**2. Addition / Deletion of UNS Codes**

Access to the “UNS CONST TABLE” function is achieved, as with all main functions, by use of cursor “ARROW” keys, and “ENTER” key in the main function menu. Unlike most functions, entry into the “UNS CONST TABLE” does not have to be preceded by a probe I.D. selection. This submenu sequence for this function is illustrated below:



The first screen of the “UNS CONST TABLE” submenu offers two options, “ENTER NEW UNS” and “DELETE UNS”. Either of these options can be selected using the cursor in conjunction with the “ARROW” keys, followed by the “ENTER” key.

If the “ENTER NEW UNS” option is selected, the second screen will request the UNS number. The user should select the initial letter of the UNS number, using the “ARROW” keys to scroll, and the “ENTER” key. This will activate the third screen that allows the user to enter the five digits using the keyboard, and confirm entry with the “UP ARROW” key. The fourth screen is now activated, and the user should enter the alloy constant (one integer and first decimal) followed by the “ENTER” key confirmation. This will activate a final screen showing the UNS number and alloy code, which the user should confirm using the “ENTER” key. At this point, the user may also use the “EXIT” key if the UNS number or alloy code is incorrect. Either command will return the user to the main function screen for further measurements, or to re-access the “UNS CONST TABLE” function to enter correct codings.

If the “DELETE UNS” option is selected, the second screen of the sequence will request the UNS ID. The user should use the “ARROW” key to scroll to the appropriate initial letter and the “ENTER” key to confirm the selection. This will activate the second screen, allowing the user to enter the remaining five digits using the keyboard, and finally confirming the entry with the “UP ARROW” key. This will activate the final screen of the sequence showing the UNS code and requesting an “ENTER” instruction to delete, or an “EXIT” instruction to abort deletion. Either instruction will return the user to the main function screen for further measurements or data input.

## G. Communications

The MS1500L Data Logger has the ability to store readings as they are taken. These readings can later be transferred to your PC via serial port or USB port. To transfer data to a PC it is necessary to install the Corrosion Data Management Software.

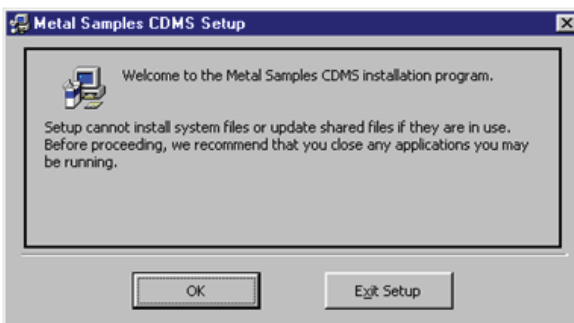
### Installing the Software

To run the Corrosion Data Management Software, you need a PC that meets the following requirements:

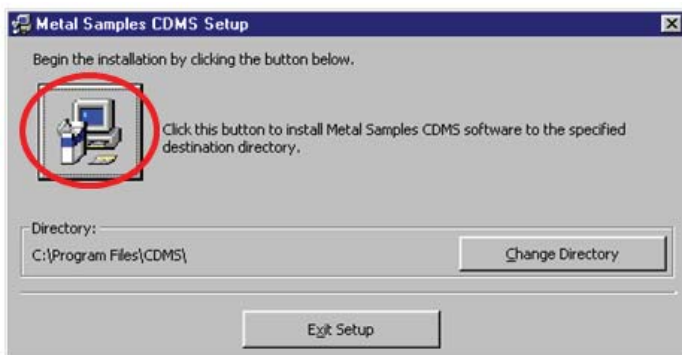
- Pentium® class processor
- Windows® 95 or higher operating system
- 16 MB of RAM
- 10 MB of available hard-disk space
- VGA monitor with 800 600 or greater resolution
- Mouse or pointing device recommended
- Available 9-pin serial port or USB port
- CD-ROM drive for software installation

To install the Corrosion Data Management Software:

1. Insert the setup disk provided in your accessory kit.
2. You will be prompted to close any open programs. After you have done so, click *OK* to continue.



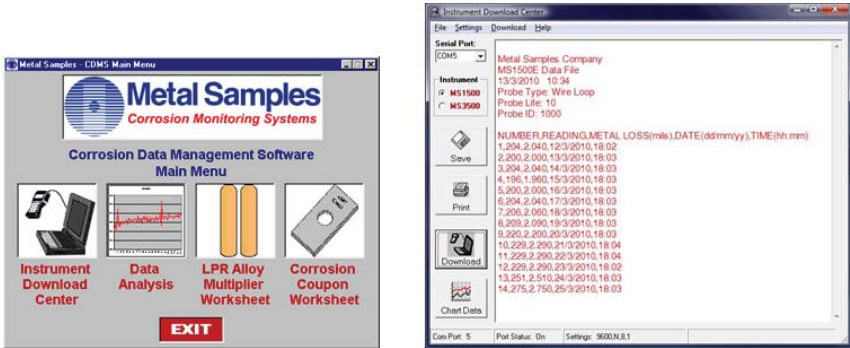
3. Click the install button to begin installation. Note, it is recommended that you install the software in the default directory.



4. After clicking the install button, the software will be installed on your PC.
5. When the software installation is complete you should remove the setup disk, then reboot your computer.

## Instrument Download Center

The Instrument Download Center is a simple tool for retrieving data from Metal Samples ER and LPR data logger instruments.



To download data from an instrument:

- Connect the instrument to an available PC serial port or USB port (see page 3.)
- Turn the MS1500L on.
- Run the Corrosion Data Management Software
- Open the Instrument Download Center
- Select the serial port and instrument
- Click the *Download* button (ensure that Part Status toggles to “On”).
- From the main menu of the instrument, go to the Select Probe I.D. menu and select the probe data you wish to download.
- From the main menu of the instrument, go to the Communications menu and select Computer Upload.

Data will begin to transfer from the instrument to the PC, and will appear in the data window of the Instrument Download Center as shown above. If the data appears garbled, the wrong instrument type has been selected. Select another instrument type and try again. If data does not appear in the data window at all, verify that:

- The instrument is connected to a valid serial or USB port
- All cables are securely connected
- The message “Port Status: On” appears in the status bar
- There are no errors on the instrument
- If using a USB adapter, ensure that the device drivers have been installed.

### **Selecting a Serial Port**

Use the *Serial Port* selection box to select the port to which the instrument is connected. If the COM port number is unknown, it can be found in Windows Device Manager under “Ports (COM & LPT)”.

### **Selecting an Instrument**

Use the Instrument option box to select the model of Metal Samples instrument being downloaded. This sets the appropriate communication parameters, which will be displayed in the status bar at the bottom of the window (“9600,N,8,1” for an MS1500, “2400,N,8,1” for an MS3500).

### **Downloading Data**

To toggle the selected port on and off, click the *Download* button. Toggling the port on and off will also clear the data window.

Once a valid serial port and instrument have been selected, click the Download button to turn the port on and enable the computer to receive data. If a valid serial port has been selected, the status bar at the bottom of the window will display the message “Port Status: On”. If an invalid serial port has been selected, an error message will appear, and the status bar will display the message “Port Status: Off”. If this happens, another serial port should be selected.

## **Saving Data**

To save the data in the data window, click the *Save* button. The data is comma-delimited ASCII text. It can be saved to a standard text (.txt) file, or it can be saved to a comma-separated values (.csv) file, which greatly simplifies the process of importing the data into a spreadsheet program such as Excel®.

## **Printing Data**

To print the contents of the data window, click the *Print* button. A print dialog box will be displayed to allow printer selection and setup.

## **Charting Data**

To chart the contents of the data window, click the *Chart Data* button. If the data has not yet been saved, the user will be prompted to do so before the charting process begins. For more information on charting data, see the Data Analysis section.

## **Data Analysis**

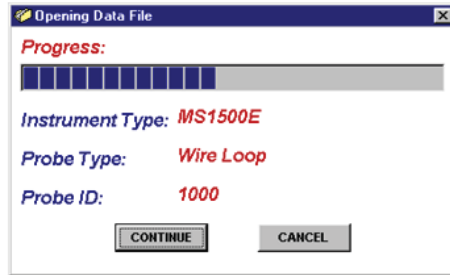
The Data Analysis utility is a convenient tool for charting data from Metal Samples ER and LPR data logger instruments. The Data Analysis utility can be opened from the Main Menu, or it can be opened directly from the Instrument Download Center.

If the Data Analysis utility is opened from the Instrument Download Center, the contents of the data window will be loaded into the chart. However, if the Data Analysis utility is opened directly from the Main Menu, a valid data file must be loaded. The *Select File* box will open to allow selection of a data file.



## Loading a Data File

After selecting a data file (or clicking the *Chart Data* button from the Instrument Download Center) a status window will display the progress of the file being opened, along with the Instrument Type, Probe Type, and Probe ID for the data file.



## Data Table

After a file has been successfully loaded, the data will be displayed in the Data Table for review. By default, all data points will be included in the chart. However, data points can be turned off, or excluded, from the chart. If the "Excluded" flag appears in the status column for a data point, that data point will not appear in the chart. To toggle the exclude/include status of a data point, double-click the data point, or select the data point and click *Exclude/Include* in the *Options* menu.

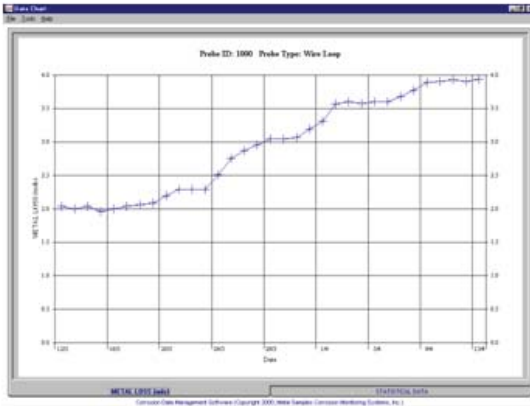
READING #	METAL LOSS (mils)	DATE (dd/mm/yy)	PROBE ID	PROBE TYPE	STATUS
1	2.040	12/3/2001	1000	Wire Loop	
2	2.000	13/3/2001	1000	Wire Loop	
3	2.040	14/3/2001	1000	Wire Loop	
4	1.960	15/3/2001	1000	Wire Loop	
5	2.000	16/3/2001	1000	Wire Loop	
6	2.040	17/3/2001	1000	Wire Loop	
7	2.060	18/3/2001	1000	Wire Loop	
8	2.090	19/3/2001	1000	Wire Loop	
9	2.200	20/3/2001	1000	Wire Loop	
10	2.290	21/3/2001	1000	Wire Loop	
11	2.290	22/3/2001	1000	Wire Loop	Excluded
12	2.290	23/3/2001	1000	Wire Loop	Excluded
13	2.510	24/3/2001	1000	Wire Loop	Excluded

## Printing Data

The data table can be printed by clicking *Print* in the *Options* menu. A print dialog box will be displayed to allow printer selection and setup.

## Creating A Chart

To chart the selected data, click the *Chart Data* button, or select *Chart Data* from the *Options* menu. The chart will be displayed in a new window.



## Printing a Chart

A chart can be printed using the *Print Chart* option in the *File* menu. A print dialog box will be displayed to allow printer selection and setup.

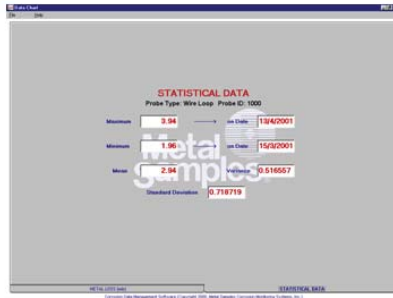
## Exporting a Chart

A chart can be exported to other applications using the *Copy Chart* option in the *File* menu. This will copy both the chart and the raw data to the Windows® Clipboard. The chart can then be inserted into other applications using the *Paste* function. Note: In some applications, using the *Paste* function will insert the raw data instead of the chart. In this case, use the *Paste Special* function, then select *Picture* to insert the chart.

## Chart Tools

- **Statistical Data**

The *Statistical Data* tab at the bottom of the Data Chart window will display a page with statistical information about the chart data. If the Statistical Data page is visible, this information can be printed by clicking *Print Statistical Data* in the *File* menu.



- **Finding A Data Points Value**

While viewing the chart, the value of any data point can be determined by simply clicking it. The value will be displayed in the charts tool-tip box (a small text box that is displayed near the mouse pointer). If the tool-tip box does not appear immediately after clicking the data point, hold the mouse pointer stationary over the chart background for a moment.

- **The Tools Menu**

The *Tools* menu contains a collection of utilities for viewing and manipulating the chart. The *Tools* menu can be accessed by clicking *Tools* on the menu bar, or by right-clicking anywhere on the chart.

Hide <u>D</u> ata Markers	Ctrl+D
Show <u>M</u> ean Value	Ctrl+M
Show <u>T</u> rend Line	Ctrl+T
<hr/>	
Title/Footnote Setup	Ctrl+F
Plot Setup	Ctrl+O
Data Series Color	Ctrl+L
<hr/>	
Zoom <u>I</u> n	F5
Zoom <u>O</u> t	F6
<hr/>	
<u>C</u> alculate Corrosion Rate	F7

- **Data Markers**

*Show Data Markers* toggles the data markers on and off.

- **Mean Value**

*Show Mean Value* toggles the mean value line on and off.

- **Trend Line**

*Show Trend Line* toggles the trend line on and off.

- **Title/Footnote Setup**

*Title/Footnote Setup* displays a window that allows the chart title and footnotes to be toggled on and off, and to be modified.

- **Plot Setup**

*Plot Setup* displays a window that allows configuration of Y-axis scaling, and of the chart type.

The Y-axis can be scaled to default values by checking the *Auto Scaling* option box. The Y-axis can be scaled to manual values by un-checking the *Auto Scaling* box, then entering the desired values in the *Minimum* and *Maximum* fields.

The chart type can be set to *Line Chart*, *Bar Chart*, or *Area Chart* by selecting the appropriate button in the *Chart Type* box. The default chart type is *Line Chart*.

- **Data Series Color**

*Data Series Color* displays a color selection box, which allows the user to select the brush color for the plot line. The default color for the plot line is Blue.

- **Zoom In**

*Zoom In* allows a region of the chart to be enlarged so that it may be viewed in greater detail. To enlarge a region of the chart, click on the two data points that define the left and right boundaries of the region.

In zoom mode, the mouse pointer will change to a cross-hair. When zoom mode ends, the mouse pointer will return to its normal state.

To cancel zoom mode, click *Cancel Zoom In* from the *Tools* menu, or simply press the *Esc* key.

- **Zoom Out**

*Zoom Out* restores the initial view of the chart, which displays the full data set.

- **Calculate Corrosion Rate**

If the chart contains ER data, the *Calculate Corrosion Rate* option will become available under the *Tools* menu. This option allows the corrosion rate to be calculated between any two data points on the chart. To calculate the corrosion rate click *Calculate Corrosion Rate*, then click two data points. The corrosion rate between those two data points will be displayed.

In calculate mode, the mouse pointer will change to an arrow/question mark. When calculate mode ends, the mouse pointer will return to its normal state.

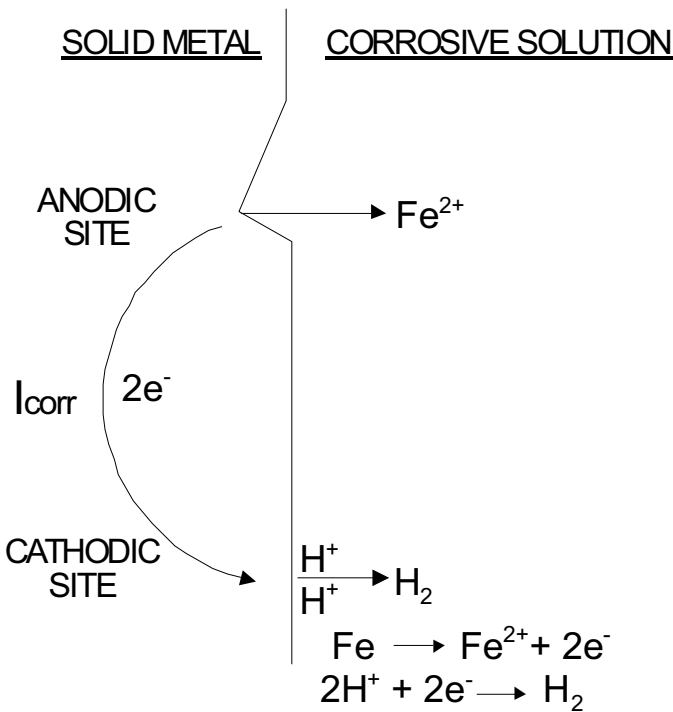
To cancel a calculation, click *Cancel Calculate* from the *Tools* menu, or simply press the *Esc* key.

### III. Theory of Operation

#### Overview of Linear Polarization

When a metal/ally electrode is immersed in an electrolytically conducting liquid of sufficient oxidizing power, it will corrode by an electrochemical mechanism. This process involves two, simultaneous, complementary reactions.

At anodic sites, metal will pass from the solid surface into the adjacent solution and, in so doing, leave a surplus of electrons at the metal surface. The excess electrons will flow to nearby sites, designated cathodic sites, at which they will be consumed by oxidizing species from the corrosive liquid. A simple example, of iron dissolving in acidic solution, is illustrated below:



This electron flow, or movement of electric charge, constitutes an electric current  $I_{COR}$ . Since the flow of electric current in such a situation can be equated to loss of metal mass, or volume, by Faradays Laws,  $I_{COR}$  is a measure of corrosion rate. The relationship of  $I_{COR}$  to corrosion rate is shown in Equation 1:

$$C = \frac{I_{COR}}{A} \times \frac{t}{F} \times \frac{E}{d} \times D \quad \dots\dots\dots (1)$$

- C = corrosion rate (MPY)
- $I_{COR}$  = corrosion current (mA)
- A = surface area of metal/alloy (cm<sup>2</sup>)
- t = no. of second in 1 year (31,536,000)
- F = Faraday’s constant (96,494 coulombs. (gm.equ.)<sup>-1</sup>)
- E = Equivalent weight of metal (gm.(g.equ.)<sup>-1</sup>)
- d = density of metal (gm.cm<sup>-3</sup>)
- D = conversion factor, centimeters to mils. (393.7)

Equation 1 reduces to:

$$C = \frac{I_{COR}}{A} \times \frac{E}{d} \times 128.67 \quad \dots\dots\dots (2)$$

Since E and d are known for all metals, and A can be fixed, a measurement of  $I_{COR}$  would allow corrosion rate to be determined. Unfortunately, direct measurement of  $I_{COR}$  is not possible, since anodic and cathodic sites on a metal surface are continually shifting within a continuously conducting surface.

Indirect measurement of  $I_{COR}$  is possible. This can be achieved by applying a small potential shift ( $\Delta E$ ) to a corroding metal surface, and measuring the current ( $\Delta I$ ) required to maintain this potential displacement. The value  $\Delta E/\Delta I$ , commonly called the polarization resistance, is inversely proportional to  $I_{COR}$ . This relationship is embodied in the Stern-Geary equation:

$$\frac{1}{R_p} = \frac{\Delta I}{\Delta E} = 2.3 \frac{(b_a + |b_c|)}{b_a \cdot b_c} \times I_{CORR} \dots\dots\dots (3)$$

- R<sub>p</sub> = polarization resistance (ohms)
- b<sub>a</sub> = anodic rate constant (mV. decade<sup>-1</sup>)
- b<sub>c</sub> = cathodic rate constant (mV. decade<sup>-1</sup>)

Rearrangement of equation 3 gives:

$$I_{CORR} = \frac{\Delta I \cdot (b_a \cdot b_c)}{2.3 (b_a + b_c) \Delta E} \dots\dots\dots (4)$$

Substituting from 4 into 2:

$$C = \frac{\Delta I \cdot (b_a \cdot |b_c|)}{2.3 \cdot A \cdot E \cdot (b_a + |b_c|)} \times \frac{E}{d} \times 128.67 \dots\dots\dots (5)$$

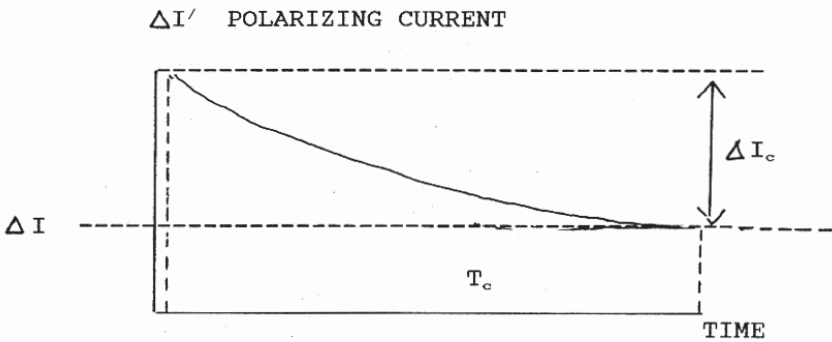
Practical measurement instruments fix the polarizing voltage at some small value, for which equation 3 holds true. This is usually 10mV or 20mV.

The ratio (b<sub>a</sub> • | b<sub>c</sub> | ) / (b<sub>a</sub> + | b<sub>c</sub> | ) is assumed to be constant. Although this is not strictly true, changes in b<sub>a</sub> and b<sub>c</sub> are largely canceled out in the ratio. Commercial instruments generally absorb this ratio into an empirical “constant”, which constitutes the average constant of proportionality derived from a large number of E/ I measurements made with corresponding weight loss data.

Variations in E/d values are practically accounted for by variations in the surface area of the test specimen, or by programming commercial instruments with an “alloy constant” for each possible E/d value; this latter process is explained in Appendix 1, as is the derivation of the equivalent weight of an alloy.



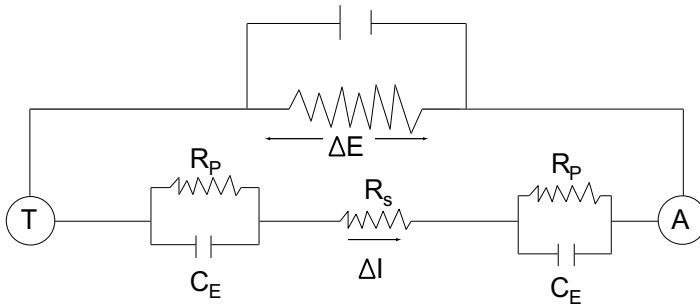
A final factor influencing any practical measurement, is the capacitive effect that is produced by polarizing a metal surface. Upon initial application of the polarizing voltage ( $\Delta E$ ), the resulting current flow ( $\Delta I$ ) is a combination of the true polarizing current ( $\Delta I$ ), and the charging current ( $\Delta I_c$ ) used in charging the double-layer “capacitor” at the metal/solution interface. This capacitive current discharges after a finite time leaving only the residual polarizing current that is the true measured value. This effect is illustrated below:



The true value of the polarizing current is the equilibrium value ( $\Delta I$ ), that is established after a time interval  $T_c$ . This time lag will vary, depending on the specific characteristics of the metal/environment system, between approximately 30 seconds and several hours. Typically, system exhibiting high corrosion rate with little film formation have short time cycles ( $T_c$ ), whereas low corrosion rate systems showing strong film formation have longer time cycles. Commercially available instruments provide a variable measurement time cycle to account for this phenomenon. Since the decay characteristic is asymptotic, even systems with extreme “capacitive inertia” will closely approach equilibrium within 15 minutes.

## Two-electrode Corrosion Rate Measurement

This technique is the simplest of all LPR corrosion rate measurements. This utilizes a sensor with two identical electrodes, made from the metal/alloy of interest. The notional, equivalent electric circuit, is illustrated below:



$R_p$  = Polarization Resistance

$R_s$  = Solution Resistance

$C_E$  = Electrode Capacitance

20mV are applied between the test and auxiliary electrodes, for the predetermined (user-selectable) time cycle, and the polarizing current at the end of the cycle ( $I_F$ ) is stored. The applied potential is then automatically reversed, and the equilibrium polarizing current ( $I_R$ ) value is again stored. The average value of the polarizing current in the forward and reverse polarizations is then automatically used to calculate, and display corrosion rate, directly as MPY. This manipulation is based on equation 5, p.44.

Since no instrumental method is used to account for variations in  $E/d$  from metal to metal, this is preprogrammed into the measurement by menu selection of alloy constant.

An additional factor that is displayed is the, so called, pitting index. This is, in fact, the ratio of the forward and reverse polarizing currents ( $I_F/I_R$ ). Some manufacturers claim that this value gives some indication of the pitting characteristics of the system. Metal Samples cautions the user to interpret the “pitting index” with considerable skepticism. This value merely indicates some form of asymmetry between the two electrodes, of which pitting is on manifestation of many. Some other possible sources of asymmetric polarization are non-uniform flow characteristics or scale deposition, small differences in electrode composition or presence of surface inclusions, and variations in electrode surface roughness.

Although the two-electrode measurement is electronically simple, and allows the use of comparatively small sensors, it does have a serious limitation. No means is incorporated into this technique to allow for solution resistance errors. For solutions of significant resistance, the polarizing voltage  $\Delta E$  is partially “dropped” across the solution resistance  $R_S$ . Consequently, the amount of polarizing voltage used to measure the polarization resistance is lower than that anticipated. This can be quantified as follows:

$$\Delta E = \Delta I R_p - \Delta I R_S \dots\dots\dots (6)$$

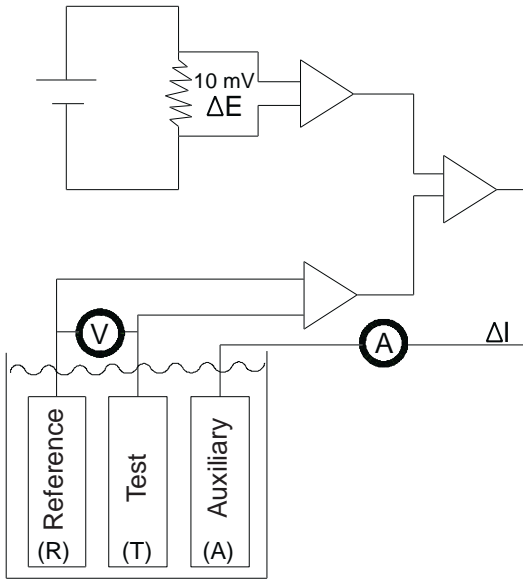
In effect, the true corrosion rate is under estimated by a percentage given by:

$$\text{PERCENT ERROR} = (1 - R_S / R_p) \times 100$$

The “IR-Drop Error” in this technique is directly proportional to solution resistance and to corrosion rate. It is difficult to set absolute limits on applicability, however, fluids with a solution resistance of more than  $50\text{-}100\Omega \text{ cm}^{-1}$  are likely to produce unacceptable errors. The technique should be confined to such fluids such as brines, sea-water, cooling waters, and electrolyte solutions with a concentration of 0.1M and higher.

### Three-electrode Corrosion Rate Measurement

The three-electrode method uses a true potentiostatic circuit to shift the potential of a test electrode 10mV. from the corrosion potential (open-circuit, “equilibrium” potential). Such a circuit may be notionally represented as shown below:



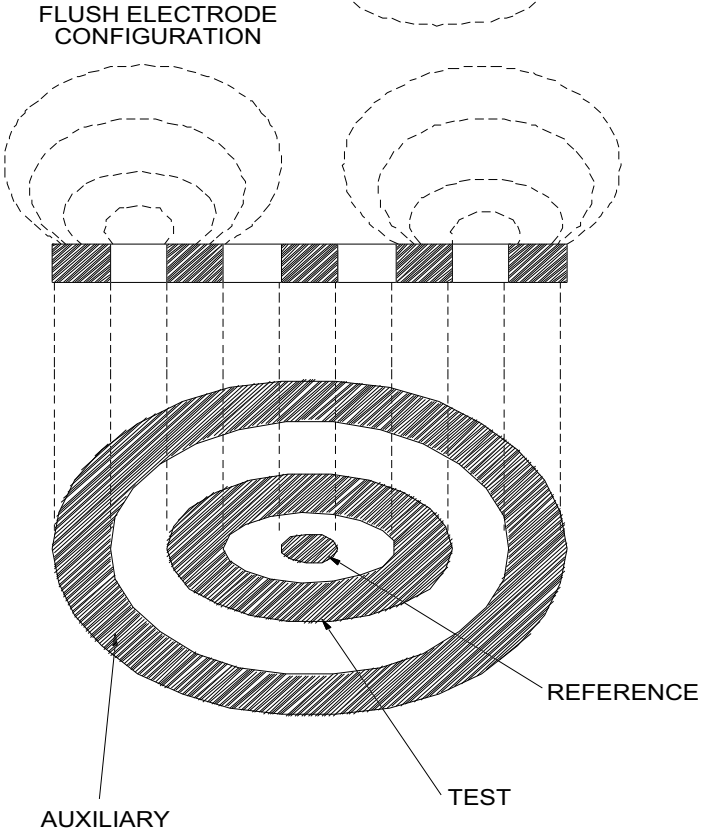
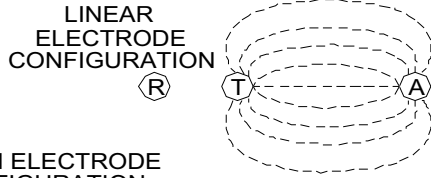
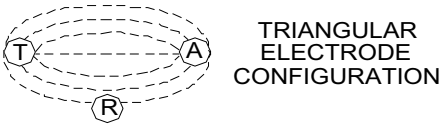
When a measurement is made, the instrument will initially null any residual potential difference between the reference electrode and the test electrode. After which, current will flow from the auxiliary electrode onto the test electrode. The flow of current, between the auxiliary electrode and the test electrode, will increase until the test electrode potential is shifted 10 mV with respect to the reference electrode. The current ( $\Delta I$ ) required to sustain the 10 mV potential shift is used to compute  $R_p$ , which in turn is used to provide a direct read out of corrosion rate.

This technique does not require the individual programming of alloy constants to allow for variations in  $E/d$  from alloy to alloy. This variation is accounted for by varying the surface of electrodes in direct proportion to  $E/d$  from alloy to alloy, so that compensation is automatic.

The major advantage of the three-electrode LPR technique is that it considerably lowers the effect of solution resistance errors. This is achieved by measuring the polarizing voltage, as the potential shift of the working electrode relative to a reference electrode, in a high impedance circuit. Negligible current flows in this potential measuring circuit and, IR-drop errors are virtually eliminated.

Some residual IR-drop error does occur in highly resistive solutions, due to the spreading of the current field generated by the flow of current between the test electrode and the auxiliary electrode. Excessive current spread will cause the field to impinge on the reference electrode, which will introduce an IR-drop error. The extent of this error is largely a function of electrode geometry as illustrated on the next page.

As can be seen, the “field effect” error is greatest with a triangle electrode configuration, less so with a linear electrode configuration, and almost non-existent with a concentric ring arrangement. An appropriate choice of electrode geometry, will allow measurements to be made in solutions with resistivities of 1000 - 2000  $\Omega\cdot\text{cm}^{-1}$ . While this technique is a significant improvement on the two-electrode measurement, it will give erroneous information in discontinuous electrolytes, and poorly conducting fluids such as distilled water. In these latter cases, as with gases, the user must resort to electric resistance corrosion measurement sensors.



In making the three electrode LPR measurement, the MS1500L uses a high impedance potential measuring circuit. Advantage is taken of this circuitry to provide the user with a means of directly measuring both redox and corrosion potentials. The uses of such information in corrosion diagnostics are many and various, and a full discussion of this topic is beyond the scope of this manual. However, a few examples are given below, to provide the reader with some insight into the versatility of potential measurements.

<b>Application</b>	<b>Criteria of Assessment</b>	<b>Electrode System</b>
Cathodic Protection	-850mV vs. Cu/CuSO <sub>4</sub> or Negative Swing of 200mV	Cu/CuSO <sub>4</sub> or Ag/AgCl Reference vs. Protected Structure
Oxygen Ingress	Positive Potential Swing	Platinized Niobium vs. Ag/AgCl Reference
Active-Passive Transitions	Passivation - Positive Potential Swing Activation - Negative Potential Swing	Ag/AgCl Reference vs. Alloy of Construction
Pitting	Rapid Potential Transients with Time	Identical Electrodes of the Constructional Alloy

With an appropriate choice of electrode combinations, potential measurements will provide extensive information on film formation and breakdown, localized attack, and indicate the presence of the various oxidizing species necessary for corrosive attack.

## IV. Testing the MS1500L with the LPR Meter Prover

An LPR Meter Prover is provided to allow routine checks of the MS1500L instrument. The LPR Meter Prover simulates a 3-electrode LPR probe at a fixed value which is printed on the Meter Prover label (as shown below.)



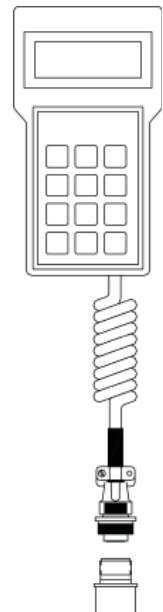
To test the MS1500L with the Meter Prover:

- 1) Enter a new Probe ID in the MS1500L menu with the following settings:
  - Probe ID: Enter any ID number that does not conflict with probe ID's in use.
  - Probe Type: LPR3A
  - UNS Number: G10100
  - Cycle Time: 1 Minute

See "ENTER NEW PROBE" on page 15 of the user's manual for detailed instructions.

Note: This Probe ID can be used for future checks with the Meter Prover.

- 2) Connect the LPR Meter Prover to the MS1500L probe connector as shown to the right.



- 3) Perform a measurement by selecting "MAKE MEASUREMENT" from the main menu (see page 22 of the user's manual.)



- 4) Allow the measurement to finish. The measured value should match the value on the Meter Prover label, and should be within the printed tolerance. If the reading is out of tolerance then further troubleshooting may be required.

It is important to remember that the LPR Meter Prover simulates a 3-electrode probe. If the 2-electrode setting is used to measure the Meter Prover, the results will not match the printed value.

# V. Appendices

## Appendix 1 - Derivation of Alloy Constant

The variation of the Stern Geary equation, relating the corrosion current  $i_{cor}$ , to the polarization resistance  $\Delta E/\Delta I$  is given by:

$$i_{cor} = \frac{\Delta I B_a B_c}{2.3 \Delta E (B_a + B_c)} \dots\dots\dots (1)$$

which reduces to:

$$i_{cor} = K \Delta I \dots\dots\dots (2)$$

- $i_{cor}$  = current due to corrosion (amps)
- $\Delta E$  = applied polarizing voltage (volts)
- $\Delta I$  = measured polarizing current (amps)
- $B_a + B_c$  = rate constants (volts/decade)
- $K$  = constant (dimensionless)

To convert the polarizing current to the conventional MPY (“MILS PER YEAR”) units of corrosion, Faraday’s laws are applied as follows:

$$C = \frac{i_{cor} \times S}{A \times F} \times \frac{E}{d} \times \frac{1000}{254} \dots\dots\dots (3)$$

$$= \frac{\Delta I \cdot k \times S}{A \times F} \times \frac{E}{d} \times \frac{1000}{254} \dots\dots\dots (4)$$

$$= \frac{\Delta I k}{A} \times \frac{E}{d} \times 128,668.6 \dots\dots\dots (5)$$

- $S$  = number of seconds in one year
- $F$  = Faraday’s constant (coulombs)
- $A$  = working electrode surface area in  $cm^2$
- $E$  = equivalent weight of corroding metal (gms)
- $d$  = density of corroding metal ( $gms. cm^{-3}$ )
- $C$  = corrosion rate (mpy)

Consequently, when the instrument calculates the corrosion rate (mpy) from the measured polarizing current ( $\Delta I$ ), a means needs to be found whereby the instrument can “know” the appropriate value of E/d, and perform the correct calculation of corrosion rate. This is achieved in the conventional, three-electrode LPR measurement by varying the surface area of working electrode in proportion to the E/d value of the metal/alloy in question, thus avoiding the need to program special correction factors into the instrument for each and every alloy.

Unfortunately, the major producer of the two-electrode probe uses a constant surface area for the working electrode, irrespective of the metal/alloy under examination. Thus a correction factor has to be applied for each metal/alloy under consideration. This is, in fact, the alloy constant used for two-electrode corrosion rate measurements in the MS1500L unit. The basic formula for derivation of the correction factor is:

$$A_k = \frac{0.55 \times E}{d} \dots\dots\dots 6$$

- $A_k$  = alloy constant
- $E$  = equivalent weight of metal/alloy in question (gms)
- $d$  = density of alloy in question (gms.  $\text{cm}^{-3}$ )

For pure metals, if the appropriate alloy constant does not appear in the MS1500L memory already, the user can apply equation 6 to calculate, and program, the appropriate alloy constant into the instrument memory.

Difficulties arise when trying to work out the equivalent weight of alloys. This is approached by use of a weighted average, assuming all major metallic constituents corrode in proportion to their weight percent for the alloy in question.

In general, metallic constituents present in amounts smaller than 1% are disregarded for the purposes of this calculation. An example of this is given below for AISI 302 Stainless Steel.

<u>Element</u>	<u>Percent</u>	<u>Eq. Wt.</u>	<u>Eq. Wt. x Percent</u>
Chromium	18	17.34	3.12
Nickel	9	29.35	2.64
Iron	73	27.92	20.39
	Alloy Eq. Weight	=	<b>26.15</b>

## UNS Constant Table

The following lists many of the common constructional metals/ alloys with their appropriate alloy constants. All of these values are already programmed into the MS1500L memory. Additional alloy constants can be added by the user, applying the calculation principles outlined previously, and with reference to the Table of Equivalent Weights on p. 59.

<b><u>UNS#</u></b>	<b><u>Alloy Const.</u></b>	<b><u>Alternate Designation</u></b>	<b><u>Major Constituents (or common names)</u></b>
F12101	1.0	-	Gray Cast Iron
F13502	1.0	-	Gray Cast Iron
G10100	1.0	AISI 1010	0.1% Carbon Steel
G10180	1.0	AISI 1018	0.18% Carbon Steel
G10200	1.0	AISI 1020	0.20% Carbon Steel
K03504	1.0	ASTM A105	0.35% Carbon Steel
K03006	1.0	ASTM A106	0.3% Carbon Steel
K02504	1.0	ASTM A53	0.25% Carbon Steel
K03011	1.0	ASTM A350LF2	0.3% Carbon Steel
K01800	1.0	ASTM A516	0.18% Carbon Steel
G41300	1.0	AISI 4130	1% Cr 0.2% Mo Steel
K41545	1.0	ASTM A199	5% Cr 0.5% Mo. Steel
S50400	1.0	ASTM A199 (T9)	9% Cr 1.0% Mo. Steel
S30400	1.0	AISI 304	18% Cr 8% Ni S.S.
S30403	1.0	AISI 304L	18% Cr 8% Ni (Low Carbon) S.S.
S31600	1.0	AISI 316	18/Cr 10/Ni/ 3/Mo S.S.
S31603	1.0	AISI 316L	" (Low Carbon) S.S.
S32100	1.0	AISI 321	Ti Stabilized 18/8 S.S.
S41000	1.0	AISI 410	12% Cr. S.S.
S43000	1.0	AISI 430	17% Cr. S.S.

<b><u>UNS#</u></b>	<b><u>Alloy Const.</u></b>	<b><u>Alternate Designation</u></b>	<b><u>Major Constituents (or common names)</u></b>
S31200	1.0	ASTM A182	26 Cr 6 Ni Duplex SS
S31803	1.0	ASTM A276	22 Cr 5 Ni 3 Mo. Duplex S.S.
C11000	2.0	AMS 4500	99.90 Copper
C26000	1.8	AMS 4505	70-30 Brass
C28000	1.8	ASME SB111	Muntz Metal (60% Cu)
C23000	1.9	ASME B16.22	85-15 Brass
C63000	1.9	AMS 4640	Aluminum Bronze
C68700	1.9	ASME SB111	Aluminum Brass (Arsenical)
C44300	1.8	ASME B111	Admiralty Brass
C70690	1.9	ASTM F96	90-10 Copper Nickel
C71590	1.6	ASTM F96	70-30 Copper Nickel
N04400	1.2	AMS 4544	Monel 400
N08825	1.0	ASME B163	Incoloy 825
N06600	1.0	AMS 5540	Inconel 600
N06625	1.0	AMS 5401	Inconel 625
N10001	1.0	AMS 5396	Hastelloy B
N10002	1.0	AMS 5388	Hastelloy C
N10276	1.0	ASME B366	Hastelloy C-276
N02201	0.9	AMS 5553	Nickel 201
N08904	1.0	ASME B625	23-1-4-25 Cr-Cu-Mo-Ni
Z13001	1.3	ASTM B6	99.990 Zinc
R05200	0.6	ASTM B364/365	Tantalum
R50250	0.7	ASTM F67	Titanium
R60701	1.0	ASTM B493	Zirconium
A96061	0.9	AA6061	Aluminum

## Table of Equivalent Weights

<u>Name</u>	<u>Symbol</u>	<u>Atomic Wt.</u>	<u>Valence</u>	<u>Equivalent Wt.</u>
Actinium	Ac	(227)		
Aluminum	Al	26.98	3	8.99
Americium	Am	243		
Antimony	Sb	121.76	3	40.58
Arsenic	As	74.92	3	24.97
Barium	Ba	137.36	2	68.68
Berkelium	Bk	(247)		
Beryllium	Be	9.013	2	4.51
Bismuth	Bi	208.99	3	69.66
Cadmium	Cd	112.41	2	56.20
Calcium	Ca	40.08	2	20.04
Cerium	Ce	140.13	3	46.71
Cesium	Cs	132.91	1	132.91
Chromium	Cr	52.01	3	17.34
Cobalt	Co	58.94	2	29.47
Columbium, See Niobium				
Copper	Cu	63.54	1	63.54
Curium	Cm	(247)	3	82.33
Dysprosium	Dy	162.51	3	54.17
Erbium	Er	167.27	3	55.75
Europium	Eu	152.0	2	76.0
Francium	Fr	223	1	223

## Table of Equivalent Weights (continued)

<u>Name</u>	<u>Symbol</u>	<u>Atomic Wt.</u>	<u>Valence</u>	<u>Equivalent Wt.</u>
Gadolinium	Gd	157.26	3	52.42
Gallium	Ga	69.72	2	34.85
Germanium	Ge	72.60	4	18.15
Gold, Arum	Au	197.0	3	65.66
Hafnium	Hf	178.50	4	44.62
Holmium	Ho	164.94	3	54.98
Indium	In	114.82	3	38.27
Iridium	Ir	192.2	3	64.06
Iron	Fe	55.85	2	27.92
Lanthanum	La	138.92	3	46.30
Lead,				
Plumbum	Pb	207.21	2	103.6
Lithium	Li	6.94	1	6.94
Lutetium	Lu	174.99	3	58.33
Magnesium	Mg	24.32	2	12.16
Manganese	Mn	54.94	2	27.47
Mercury	Hg	200.61	1	200.6
Molybdenum	Mo	95.95	2	47.97
Neodymium	Nd	144.27	3	48.09
Neptunium	Np	(237)	5	47.40
Nickel	Ni	58.71	2	29.35
Niobium				
(Columbium)	Nb	92.91	5	18.58
Osmium	Os	190.2	8	23.77
Palladium	Pd	106.4	2	53.2
Platinum	Pt	195.09	2	97.55
Plutonium	Pu	(244)	5	48.80
Potassium	K	39.1	1	39.1



## Table of Equivalent Weights (continued)

<u>Name</u>	<u>Symbol</u>	<u>Atomic Wt.</u>	<u>Valence</u>	<u>Equivalent Wt.</u>
Praserodymium	Pr	140.92	3	46.97
Promethium	Pm	(145)	3	48.33
Radium	Ra	226	2	113
Rhenium	Re	186.22	4	46.55
Rhodium	Rh	102.91	3	34.30
Rubidium	Rb	85.48	1	85.48
Ruthenium	Ru	101.1	3	33.7
Samarium	Sm	150.35	2	75.17
Scandium	Sc	44.96	3	14.98
Selenium	Se	78.96		
Silver	Ag	107.87	1	107.9
Sodium	Na	22.99	1	22.99
Strontium	Sr	87.23	2	43.81
Tantalum	Ta	180.95	5	36.19
Technetium	Tc	(97)	6	16.16
Tellurium	Te	127.61	3	42.53
Terbium	Tb	158.93	3	52.97
Thallium	Tl	204.39	1	204.39
Thorium	Th	(232)	4	58.0
Thulium	Tm	168.94	3	56.31
Tin, Stannum	Sn	118.70	2	59.35
Titanium	Ti	47.90	4	11.97
Tungsten	W	183.86	4	45.96
Uranium	U	238.07	4	59.51
Vanadium	V	50.95	2	25.47
Ytterbium	Yb	173.04	2	86.52

## **Appendix 2 - Returning an Instrument for Repair**

If it is necessary to return any Metal Samples instrument for repair, the following procedure is recommended to ensure the fastest possible repair and return cycle. You may contact Metal Samples to verify that returning 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 wood 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  
Phone: (256) 358-4202  
Fax: (256) 358-4515  
E-mail: [msc@alspi.com](mailto:msc@alspi.com)

3. When the instrument is packed, include a copy of the form on the next page, filled in as required to expedite the repairs.

*Copy this form when you need to return an instrument. Send a copy of this form filled in as completely as possible.*

1. Check one:

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

2. Instrument Model #: \_\_\_\_\_

Serial #: \_\_\_\_\_

Date of purchase: \_\_\_\_\_

Customer's original purchase order #: \_\_\_\_\_

3. Return this instrument to: \_\_\_\_\_

Company: \_\_\_\_\_

City/State/Zip: \_\_\_\_\_

\_\_\_\_\_

Telephone: \_\_\_\_\_

E-mail: \_\_\_\_\_

4. Describe problem fully - this may shorten repair time.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

5. Urgency of repairs: \_\_\_\_\_

### **Appendix 3 - Warranty**

Metal Samples warrants that any part of Metal Samples corrosion rate 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 the option of Metal Samples, 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. Metal Samples shall have the right to final determination as to the existence and cause of the 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 or merchantability 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:

Metal Samples  
152 Metal Samples Rd  
Munford, AL 36268  
Phone: (256) 358-4202  
Fax: (256) 358-4515  
E-mail: [msc@alspi.com](mailto:msc@alspi.com)

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.