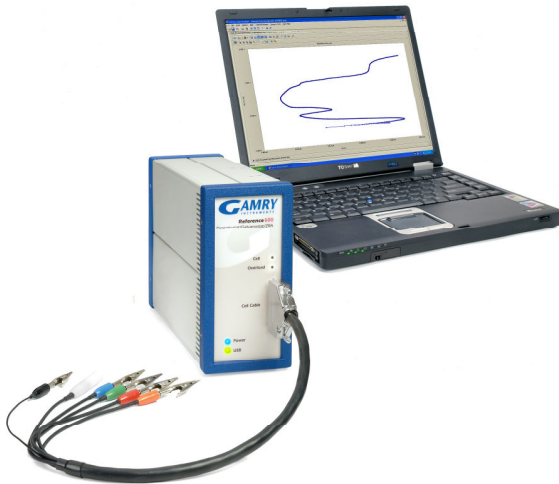


Corrosion Techniques Software

The Corrosion Techniques Software provides a complete range of electrochemical corrosion experiments for the corrosion scientist and corrosion engineer.

Electrochemical techniques are much more sensitive *and* faster than more traditional methods for measuring corrosion rate, such as weight loss. They are also very versatile and can be used to assess localized corrosion susceptibility and evaluate passivity, galvanic corrosion, and sensitization.

Most electrochemical corrosion techniques are standardized and many are recognized by ASTM and ISO. For these experiments, the DCI05 Software provides an easy-to-use Setup with results calculation and a display that is totally automated. A new Gamry electrochemical corrosion measurement system in your lab can generate reliable results in a matter of hours.



The Corrosion Techniques Software in a Windows-compatible computer controls a Gamry Potentiostat to perform the electrochemical corrosion measurement.

Like most Gamry software, the **Framework™** and a Gamry Potentiostat use the Gamry Framework™ Software for data acquisition and the Echem Analyst™ for data analysis. All of the electrochemical techniques, therefore, have a common look-and-feel, so moving from one experiment to another is easy. Call us for the brochure entitled "Overview of Gamry Software", which describes the general features of the Gamry Framework and the Gamry Echem Analyst.

Gamry has the widest range of electrochemical products for corrosion measurement on the market. Other Gamry software includes Electrochemical Impedance Spectroscopy, Electrochemical Noise, Electrochemical Frequency Modulation, and Critical Pitting Temperature. You can use our **Sequence Wizard** to combine different techniques into a single experiment. The ECM8 Multiplexer can automate multiple experiments at a very low cost. Gamry also has several electrochemical cells to accommodate your sample. You can be confident that Gamry and your Gamry system will support you as your electrochemical needs evolve.

A Gamry Corrosion Measurement System can be configured for a desktop or a notebook computer for experiments in the field or convenient transport to other locations. Every Gamry Potentiostat is electrically floating, so you can perform experiments on grounded samples in the lab (autoclaves, strain rate testers) or in the field (pipelines, vessels). Data files in the **gZkUfY** are simple tab-delimited ASCII text and are easily imported into other data analysis or presentation software.

The **7cfcgcbHWblei YgCZkUfY** performs the following electrochemical corrosion techniques:

- Corrosion Potential
- Polarization Resistance
- Rp/Ec Trend
- Tafel Plots
- Potentiodynamic Plots
- Cyclic Polarization
- Critical Pitting Potential
- THE Repassivation Potential
- Cyclic Galvanostaircase
- Galvanic Corrosion
- Electrochemical Reactivation
- Potentiostatic
- Galvanostatic
- Galvanodynamic

Electrochemical techniques have been developed for a wide range of corrosion applications. These techniques and their implementation in the **gftware** are discussed throughout this brochure.

Corrosion Potential

The Corrosion Potential, or Open Circuit Potential, may be measured versus time prior to every experiment to make sure the sample has reached steady state. You may also specify the acceptable degree of stability of E_{oc}.

Corrosion Rate

The most popular application of electrochemical corrosion techniques is the determination of the rate of uniform corrosion. Based on the Stern-Geary relationship, the measurement of corrosion rate with electrochemistry has a theoretically sound foundation and is used every day in thousands of laboratories with excellent results. The two electrochemical techniques for corrosion rate determination are Polarization Resistance and Tafel Plots.

Polarization Resistance

Polarization Resistance (ASTM G 59) offers both practical and theoretical advantages for measuring corrosion rate. Polarization Resistance involves the potentiostatic measurement of the voltage-current curve in the immediate vicinity of the open-circuit potential, E_{oc}. Measurement of the slope of this curve allows the calculation of the corrosion rate.

Parameter	Value
Pstat	42003
Test Identifier	Polarization Resistance
Output File	CoolingTwr2_1185.DTA
Notes...	Condensate as received, 1080 Steel
Initial E (V)	-0.005 vs Eref vs Eoc
Final E (V)	0.005 vs Eref vs Eoc
Scan Rate (mV/s)	0.166
Sample Period (s)	2
Sample Area (cm ²)	5.075
Density (gm/cm ³)	7.87
Equiv. Wt	27.92
Beta An. (V/Dec)	0.12
Beta Cat. (V/Dec)	0.12
Conditioning	Off Time (s) 15 E (V) 0
Init. Delay	On Time (s) 300 Stab. (mV/s) 0.05
IR Comp	Off
Equil. Time (s)	30

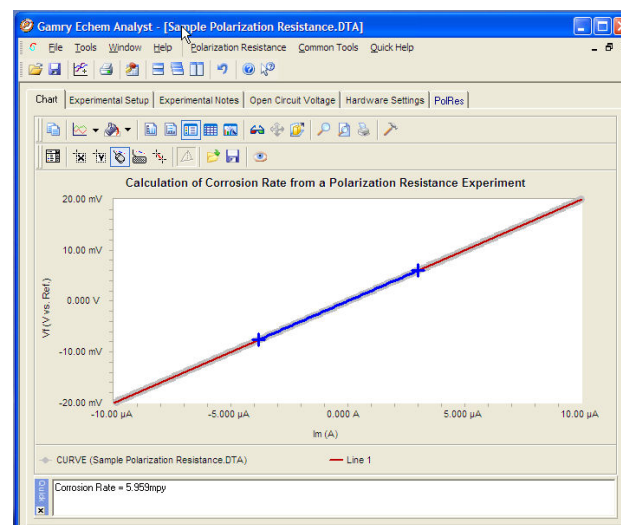
Setup Window for Polarization Resistance. Every parameter required to make the Polarization Resistance measurement is available on the single Setup Window. Click **Save** to archive an experimental setup for easy **Restore** later.

Since several techniques, including Polarization Resistance, involve a potentiostatic scan relative to E_{oc}, the DCI05 allows easy parameter entry in that format. For example, we wish to scan a 20 mV window centered around E_{oc}. By entering the Initial and Final Potentials and checking "vs. E_{oc}", the software can initiate the experiment, allow E_{oc} to stabilize (see Initial Delay above), and apply the correct potential value. A stabilized E_{oc} of -0.465 V would result in a potential scan from -0.475 V to -0.455 V.

The data acquisition proceeds without operator intervention. The Gamry Potentiostat measures the cell current and adjusts to the appropriate current range. All potentiostat functions are orchestrated by the software. With the *lowest noise specification among commercial potentiostats*, a Gamry Potentiostat with the *7cfcgcb HWblei YgCzkUFY* provides data with minimum instrumental noise.

The analysis of Polarization Resistance data takes place in the Gamry Echem Analyst. With the crisp sharp display of the Echem Analyst, working with your electrochemical data is a visual pleasure! It's particularly impressive when two or more data sets are overlaid for comparison.

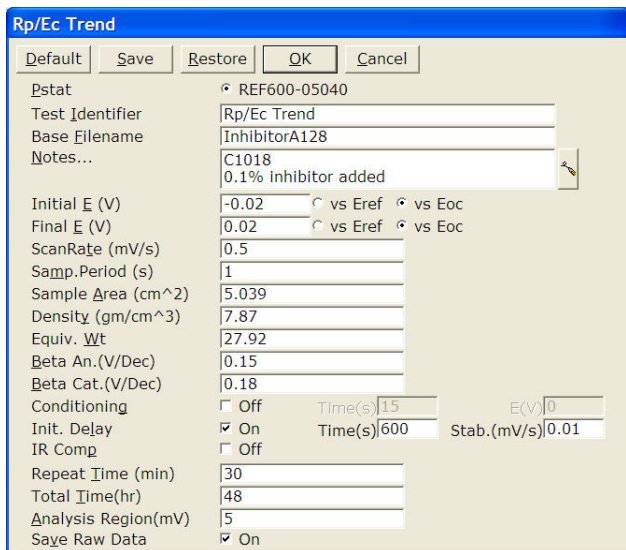
Calculating the corrosion rate is simple. Select the portion of the curve that you wish to use for the R_p (slope) calculation, then press "Polarization Resistance". Accept or change the Tafel Constants, and get Corrosion Rate in mmpy, mpy, or a user-selectable unit of your choice.



A Polarization Resistance Experiment Displayed in the Echem Analyst. The dark blue curve segment is used to calculate the corrosion rate. Note the Corrosion Rate on the lower portion of the display. More detail is available on the PolRes tab.

R_p/E_c Trend

R_p/E_c Trend is a standard software experiment in which the Corrosion Rate of a sample is measured by Polarization Resistance as a function of time. The Corrosion Potential is also measured prior to each R_p curve. R_p/E_c Trend is primarily used by corrosion engineers assessing the time dependent activity of corrosion inhibitors, but there are a number of other important applications.



Setup Window for Rp/Ec Trend. An Rp/Ec Trend setup is identical to Polarization Resistance for the electrochemical parameters. The Total Time of the experiment is entered along with the repeat time of the Rp measurements. The Analysis Region is the voltage range around E_{oc} where the slope of the curve is measured. The Base Filename is the file name used to save the multiple data sets in an incremental format.

The Rp/Ec Trend can also be used with the Gamry ECM8 Multiplexer to perform the experiment on eight samples simultaneously. Since, by definition, an Rp/Ec Trend is a lengthy experiment, the ECM8 Multiplexer is a low-cost way to dramatically increase sample throughput.



The ECM8™ Electrochemical Multiplexer partners with any Gamry Potentiostat to sequentially perform experiments on up to eight cells.

Tafel Plots

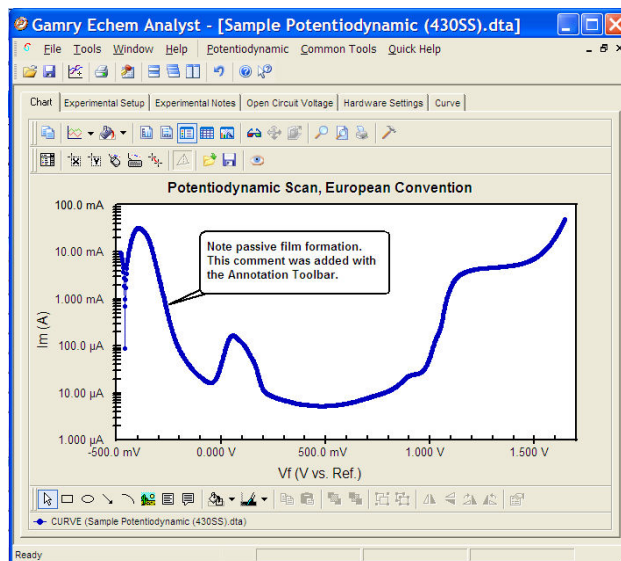
Tafel Plots allow the direct measurement of the corrosion current from which the corrosion rate can be quickly calculated.

The corrosion rate can be calculated from a Tafel Plot in the DCI05 Software by three different techniques:

- Select a data region, then click "Tafel Fit" to perform a non-linear least squares fit of the Butler-Volmer equation to the data.
- Select a data region, then click "E Log I Fit" to fit a straight line to the data region and extrapolate to the E_{oc} to calculate the corrosion current, then corrosion rate
- Use the "Freehand Line" to visually fit the linear portion of the Tafel Plot and measure I_{corr} directly.

Potentiodynamic Scan

A Potentiodynamic Scan (ASTM G 5) is a qualitative experiment to assess the passivation tendencies of a metal sample. The currents measured during a Potentiodynamic Scan can easily range over 6-7 decades, so you'll appreciate the 9 or 11 decades of automatic current ranging available with a Gamry Potentiostat.



Potentiodynamic Scan. This Potentiodynamic Scan is plotted with the European convention of log current on the Y-axis. The plotting format can be easily reversed if you prefer. Note the annotation and the Annotation Toolbar on the bottom.

Localized Corrosion

Pitting and crevice corrosion are particularly aggressive forms of corrosion that focus on a small area and are, therefore, termed "localized". The pitting rate cannot be quantitatively measured, but it is possible to determine if a sample is prone to pitting in a particular environment and qualitatively rank a series of metals.

Cyclic Polarization

Cyclic Polarization (ASTM G 61) is a modified Potentiodynamic Plot in which the anodic potentiostatic scan is continued until pitting is initiated, then the scan direction is reversed. The relative positions of the anodic and cathodic scans reveal the pitting tendency of the sample.

Gamry's implementation of Cyclic Polarization is entirely automated and allows unattended operation. The user can choose to reverse the scan direction at a specific current density or specific potential.

Critical Pitting Potential

The Critical Pitting Potential (F 746) technique is available in Gamry's DCI05 Software. The Critical Pitting Potential experiment takes a more aggressive attitude toward pitting than does Cyclic Polarization by stepping to a very anodic potential to insure that pitting has been initiated. A

sophisticated algorithm in the gZkUy monitors the trend in the cell current during both pit initiation and re-passivation to conduct the experiment reliably and automatically.

THE Crevice Repassivation Potential

THE (Tsujikawa-Hisamatsu Electrochemical) Technique (ASTM G 192) is available in Gamry's 7cfcgcbHWbjei Yg Software. This technique combines a potentiodynamic scan, a galvanostatic activation, and potentiostatic steps to assess the tendency of your sample to undergo crevice corrosion. It has been used to study crevice corrosion in Alloy 22.

Cyclic Galvanostaircase Polarization

Cyclic Galvanostaircase (ASTM G 100) was developed to determine the relative susceptibility of aluminum alloys to localized corrosion. This technique allows the measurement of the breakdown and the protection potentials in controlled current mode.

Galvanic Corrosion

Galvanic Corrosion results from the direct connection of two dissimilar metals in a corrosive environment. Galvanic currents are easily measured with Gamry's Galvanic Corrosion Technique by automatically placing the instrument in Zero Resistance Ammeter mode.

It is sometimes easier to understand the driving force for a galvanic couple by studying the relative positions of the individual Potentiodynamic Plots. This is particularly easy with the outstanding visualizing and overlay capability of the Echem Analyst software.

Electrochemical Reactivation (EPR)

Electrochemical Potentiokinetic Reactivation (ASTM G 108) is a technique developed to quantitate the degree of sensitization on heat-treated samples. Sensitization is most common in the heat-affected zone of welds.

Other Techniques in the Software

Potentiostatic

The Potentiostatic experiment allows a potential to be applied to a sample for a specified time while measuring the current. Potentiostatic is useful for long-term polarization studies or cathodic delamination of organic coatings.

Galvanostatic and Galvanodynamic

In these experiments, the Gamry Potentiostat is automatically switched to galvanostatic, or controlled current, mode. Although there are no specific corrosion applications for these techniques, they are useful electrochemical tools to have in your laboratory.

Applications Assistance

If you're in the early stages of using electrochemical corrosion techniques, we can help. Pay a visit to www.gamry.com, go to the App Note section, and take a look at "Getting Started with Electrochemical Corrosion Measurement." There's an excellent list of references at the end of the Application Note. For specific questions, you'll always find a friendly technical advisor at our home office or your local Gamry Distributor.

System Information

The Corrosion Techniques Software requires a Gamry Potentiostat to conduct experiments. Microsoft® Windows® XP, Vista®, or Windows 7® is required for operation of the gZkUy

Gamry Instruments can supply complete systems including the above items and system software installed in a desktop or notebook computer. Custom computer configurations, software, training, and installation are available by special order.

Specifications

Minimum Scan Rate: 0.02 μ V/s
Sampling Period: <200 μ s – 600 s
Minimum Step Height: 12.5 μ V
Maximum Points per Curve: 262,143
IR Compensation: Current Interrupt

See Potentiostat specifications for additional information.

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