GalvaPulse

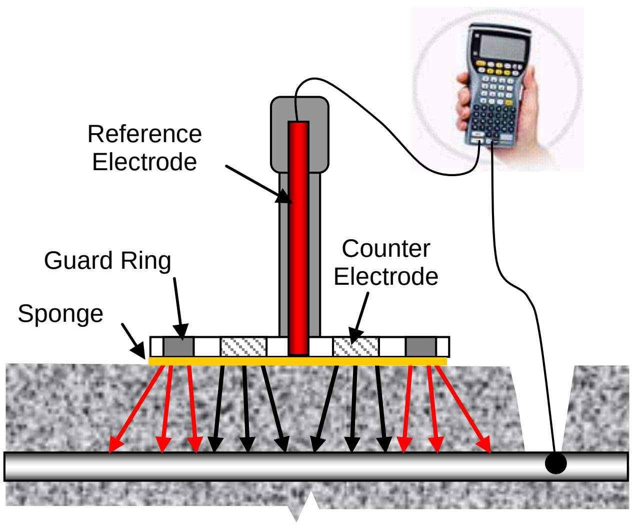
Purpose

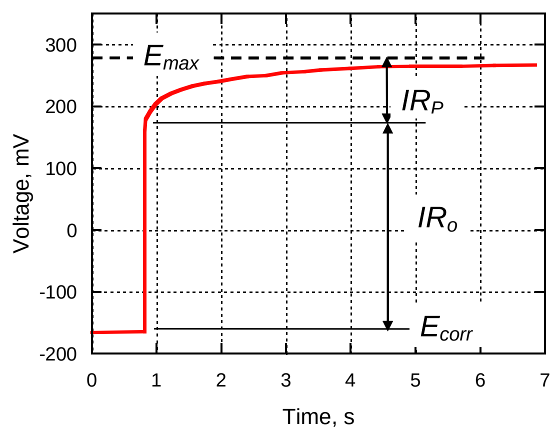
The **GalvaPulse** is used to measure half-cell potentials, electrical resistance and particularly the corrosion rate of reinforcement in concrete for the following typical applications:

- Monitoring corrosion activity in reinforced concrete structures
- Service life estimation
- Evaluating the efficiency of corrosion arresting measures such as application of inhibitors, membranes, electrochemical removal of chlorides, concrete realkalinization, etc.
- Condition surveys of suspect reinforced structures, especially structures in wet environments where the classic half-cell potential mapping may provide misleading or insufficient information
- Measuring corrosion activity in repaired areas

Principle

The **GalvaPulse** evaluates the corrosion rate of reinforcement by measuring polarization resistance using the **galvanostatic pulse** technique, as described below.





A current pulse $\boldsymbol{I}$ is imposed on the reinforcement from a counter electrode placed on the concrete surface. A guard ring confines the current to an area $\boldsymbol{A}$ of the reinforcement below the central counter electrode.

The applied current is usually in the range of 5 to 400 µA and the typical pulse duration is 5 to 10 seconds. The reinforcement is polarized in the anodic direction compared to its free corrosion potential, $\boldsymbol{E_{corr}}$. The resulting change of the electrochemical potential of the reinforcement is recorded as a function of time using a silver chloride reference electrode (Ag/AgCl). A typical potential response for reinforcement actively corroding is shown in the right figure above.

When the current is applied, there is an ohmic potential drop $\boldsymbol{IR_o}$ as well as change in potential due to polarization of the reinforcement, $\boldsymbol{IR_p}$. Assuming the Randles circuit model, the polarization resistance of the reinforcement $\boldsymbol{R_p}$ is calculated by curve fitting to the transient portion of the potential data. By means of the Stern-Geary equation for active corrosion ($\boldsymbol{I_{corr}} = (26\ \boldsymbol{A})/\boldsymbol{R_p}$) and Faraday's law of electrochemical equivalence, the corrosion rate is estimated as:

$$\text{Corrosion Rate } (\mu\text{m/year}) = 11.6\ \boldsymbol{I_{corr}}/\boldsymbol{A}$$

where $\boldsymbol{A}$ is the confined area (in cm^2) of the reinforcement below the central counter electrode. The factor 11.6 is for black steel.

The value of $\boldsymbol{R_o}$, the electrical resistance of the concrete between the counter electrode and the reinforcement, is also determined.

Variation and Accuracy

The accuracy of the corrosion rate estimation can only be evaluated by comparison with actual mass loss measurement of the reinforcement subjected to long term corrosion conditions. One such laboratory investigation produced the following comparison between corrosion rates calculated from measured mass loss measurements of actual steel bars and from the **GalvaPulse**.

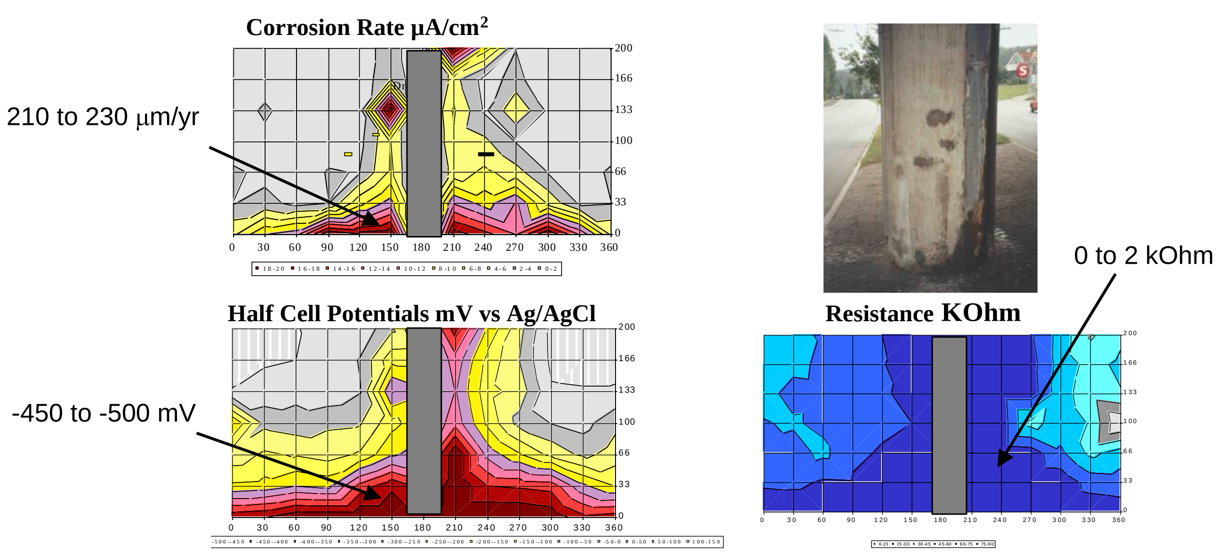
	Corrosion Rate (µm/year)	
Reinforcement	**Mass Loss**	**GalvaPulse**
A	53	36
B	56	29
A+B connected	55	61

Reference: Baessler, R. and Burkert, A., "Laboratory Testing of Portable Equipment," Brite/Euram Project Integrated Monitoring System for Durability Assessment of Concrete Structures, BAM (Federal Institute for Materials and Testing), Berlin, Germany, 2001

The findings support the general conclusion that the **GalvaPulse** is accurate well within a factor of two for estimating the corrosion rate in anodic areas. In addition, other uncertainties should be taken into account when evaluating on-site test results, e.g., the actual area of the reinforcement being polarized and the variation over time in corrosion rates due variation in temperature and moisture conditions.

In passive regions (corrosion rates < 1 µm/year), the **GalvaPulse** may overestimate the corrosion rate by a factor of 3 to 4. Such areas are, however, not interesting in terms of corrosion risk.

In a long term field study, 30-year old bridge columns subjected to deicing salts were examined regularly over a 20-year period since corrosion began. The chloride levels and moisture content in the concrete of the bridge were high. When the last measurements were performed, the temperature was 15°C and the following test results were obtained.



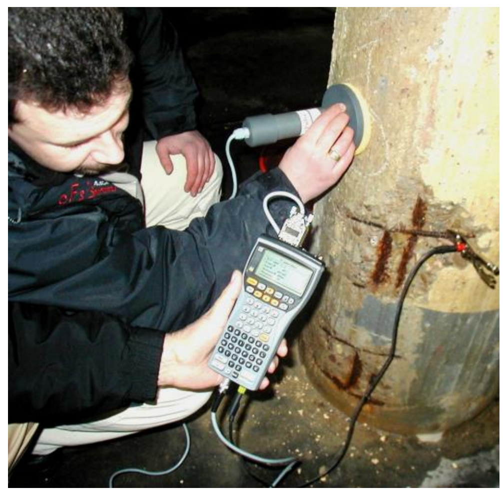
The fairly constant corrosion rate measured over the 20-yr period corresponds to a cross section loss of the reinforcement of 20 years times 0.22 mm/y = 4.4 mm. Removal of concrete at several locations at the bottom of the columns revealed also approximately 4 mm cross section loss of the reinforcement.

Testing Examples

Evaluation of corrosion rate in balcony slab of seaside condominium with the **GalvaPulse**

Highway bridge column being tested for corrosion rate with the **GalvaPulse**

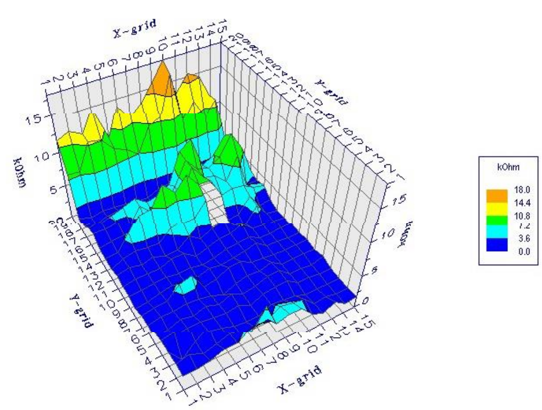
Corrosion activity being evaluated on a bridge wall with the **GalvaPulse**



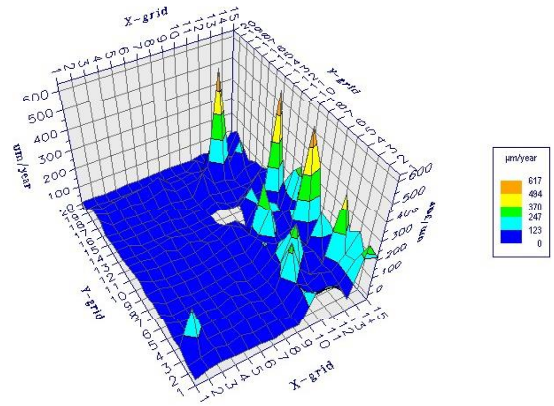
GalvaPulse *(older model) testing in progress for corrosion activity of a heavily corroded column*

Examples of the Graphic Displays to View GalvaPulse Data

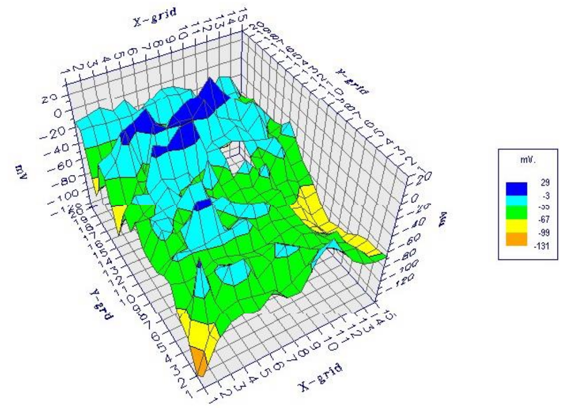
Following testing, the handheld computer is connected to a PC with the installed viewing and reporting software. The records are transferred to the PC and data can be viewed using 2D or 3D graphic displays. Here we see 3-D displays of the corrosion rates, the half-cell potential, and the electrical resistance. Such plots permit the display of a large amount of data in a concise manner for preparing test reports.



3-D Plot of resistance



3-D Plot of corrosion rate



3-D Plot of half-cell potential

GalvaPulse Features and Specifications

- Reliable evaluation of reinforcement corrosion in anaerobic concrete environment
- Lightweight, handheld equipment, easy to operate
- Kit includes a calibration box and a check concrete block with embedded bars
- Easy-to-use software for reporting test results in 2D or 3D graphics
- Two operation modes:
  (1) only for half-cell potentials and electrical resistance (1 to 2 s/test)
  (2) for corrosion rate, half-cell potentials and electrical resistance (5 to 10 s/test).
  The first mode is normally used to identify the anodic and cathodic areas, while the second mode is used in anodic areas, where corrosion rate is a decisive parameter to be measured
- Suitable for testing on rough or curved surfaces
- Uses Ag/AgCl (silver / silver chloride) reference electrode
- Storage capacity: 20,000 records
- Current pulse generated: 5 to 400 µA from 1 to 20 seconds
- Pulse guard ring diameter: 70 mm

GalvaPulse-5000 Kit Ordering Numbers

Item	Order #
Handheld computer with pulse generator	GP-5010
Calibration unit for pulse generator	GP-5020
Measuring cell with 3 meter cable	GP-5031
Sponge for measuring cell	GP-5040
Reinforcement locator	GP-5050
Reinforcement conductivity meter	GP-5060
Cable for data transfer to PC	GP-5070
Measuring cable	GP-5080
Two adjustable reinforcement clamps	GP-5090
Two reinforcement adaptors	GP-5100
12 mm and 18 mm drill bits	GP-5110
10 mm Allen key	GP-5120
Sponge for grinding of electrode rings	GP-5130
Hammer and chisel	GP-5140
Measuring tape and chalk	GP-5150
GalvaPulse software for data viewing/reporting	GP-5160
User Manual	GP-5170
Attaché case	GP-5180
Cable drum with 15 meters of cable **(a)**	GP-5190
Check block with embedded a corroding black steel bar and a stainless steel bar **(b)**	GP-5200

(a)

(b)