vti VIRGINIA TECHNOLOGIES INC.

ECI-1 Embedded Corrosion Instrument

Corrosion Monitoring of Steel Reinforced Concrete Structures Using Embedded Instrumentation

The ECI-1 is an embeddable non-destructive evaluation (NDE) corrosion-monitoring instrument. It is capable of measuring parameters important to long term corrosion monitoring including linear polarization resistance (LPR), open circuit potential (OCP), resistivity, temperature and a potential related to chloride ion concentration ($[Cl^-]$). Each ECI-1 Instrument is a digital peripheral connected on an embedded local area network. The instruments communicate with each other and an external data logger using the SDI-12 industry standard protocol.

The ECI-1 has many applications in the construction and maintenance of commercial and civil structures. These structures can include but are not limited to high rise buildings, parking garages, bridges, dams, spillways, flood control channels, piers, pylons and erosion control structures. During construction, engineers, builders and supervisors can monitor parameters such as chloride concentration, resistivity and temperature. These parameters can identify errors at an early stage of construction. One error that may be detectable is the use of sea water or contaminated water during mixing of the concrete ($[Cl^-]$). The moisture content and temperature of the structure can be monitored during the curing process to ensure maximum strength of the concrete. Once construction is complete the instrument can be used to conduct long term monitoring of corrosion conditions over time.

The Industrial Challenge

Civil structures such as bridges and dams are extremely large construction efforts costing millions to billions of dollars and spanning several years. In the United States alone repairs for corrosion damage to federal bridges are estimated at $50 billion annually. These structures are vital to commerce and the standard of living of millions of people in the United States and billions of people worldwide. Worldwide estimates to repair reinforced concrete structures are $200/m^2 of exposed surface.

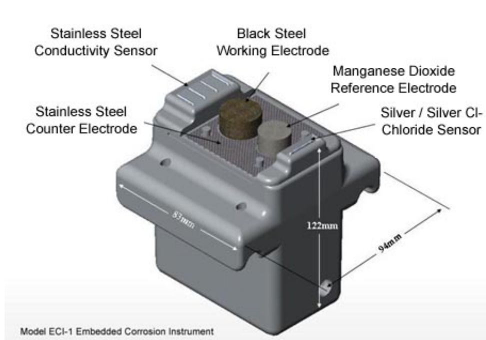
Premature or unexpected failures of these structures are often catastrophic in terms of time, money and lives. The high costs of corrosion due to replacement and premature failures mandate the need for integrated in-situ NDE systems. These NDE systems should provide information based on changes in the structure's corrosion condition to effect timely maintenance interventions.

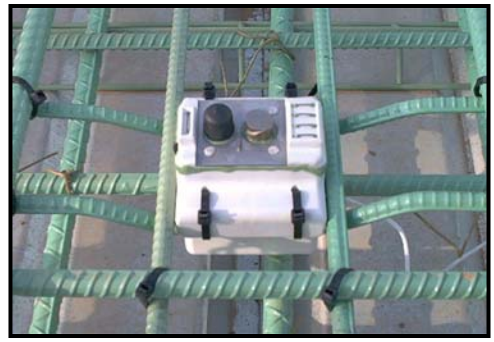
The VTI Solution

Until now corrosion monitoring in steel reinforced structures has been conducted using embeddable probes. The probes measure analog signals that can be interrogated using electronic devices external to the structure. Since the signals produced by these probes are small in amplitude, they are subject to corruption from nearby EMI sources such as power lines, radios, cell phones and therefore must have limited lead lengths. To address these limitations, VTI has developed a fully embeddable corrosion monitoring instrument incorporating all required electrodes and signal processing electronics. The ECI-1 approach allows the leads connecting the low-level analog signals to signal processing electronics to be kept short (approximately 1 inch). Short analog signal leads allow for a higher signal to noise ratio and more accurate and repeatable measurements. The ECI-1 communicates with other instruments and an external datalogger using a digital protocol which is highly resistant to corruption from nearby EMI sources.

Advantages

The ECI-1 embeddable corrosion instrument packs 5 sensors into one small package that can be easily installed and placed wherever needed to provide adequate coverage of a structure





The ECI-1 During Installation in a Bridge Deck

during construction. The instruments are modular and uniquely addressable allowing the system to be easily scaled to the needs of the specific structure. The ECI-1 is less susceptible to electromagnetic interference (EMI) than other corrosion probes on the market by virtue of its extremely small lead lengths. Many embedded corrosion probing systems rely on external electronics to drive (stimulate) the embedded probe and to measure the resulting signals. Often these measurements have to be made over cables of up to 10 meters in length which can act as antennas for EMI sources such as power lines, cell phones and radio waves. The leads between the electrodes and data acquisition electronics in the ECI-1 are only about 1 inch in length and are converted to digital data right at the source. The data is transmitted over a digital network, which is relatively immune to interference.

ECI-1 Attributes

- Measures the most pertinent corrosion related parameters
- Contains all required electrodes and electronics
- Serves as a digital network peripheral
- Data resistant to corruption from nearby EMI sources
- Utilizes the SDI-12 industry standard protocol
- Each network connection can be up to 200 feet in length.
- System can be powered using optional solar collector and rechargeable battery.
- Wireless communication provided via an external wireless transceiver.

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Operational Principle

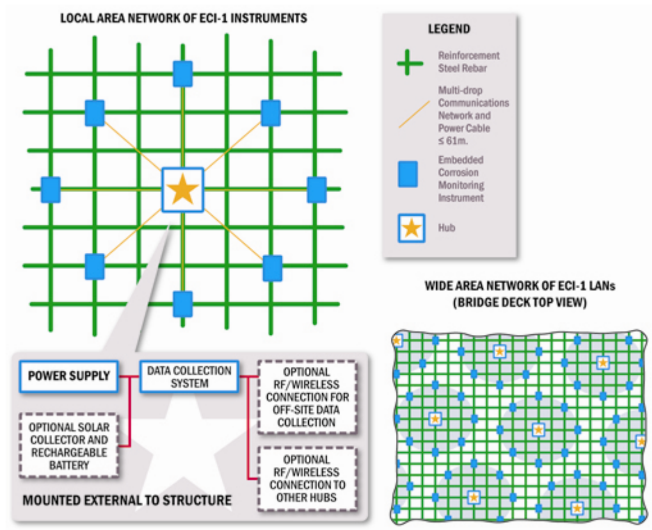
Polarization resistance is measured using a steel working electrode (WE), a stainless steel counter electrode (CE), and a MnO2 reference electrode (RE). The WE is a sacrificial electrode made of black steel and is meant to corrode at the same rate as ASTM 615/A compliant steel. Defective areas of protective coatings on structural steel such as epoxy or stainless steel cladding can be compared to the corrosion characteristics of black steel.

The resistivity sensor uses four stainless steel electrodes to measure the resistivity of the surrounding concrete. The Ag/AgCl ion specific electrode (ISE) in combination with the reference electrode is used to measure chloride ion concentration. A potential will develop between Ag/AgCl and REF electrodes that is proportional (~ -59 mV / decade) to the local chloride concentration in the concrete surrounding the steel. The chloride measurement results are reported back to the user as a voltage which can be used to track changes and trends in chloride concentration.

A solid state temperature sensor on board provides information on the temperature within the concrete.

The microcontroller sequences all of the sensor measurements and controls sensor drive and data acquisition through the digital-to-analog (DAC) and analog-to-digital (ADC) converters. The microcontroller performs all necessary calculations for corrosion measurements. Data can be stored onboard in local non-volatile memory or it can be directly transmitted via the network connection. A unique address as well as any calibration and location data can be stored onboard. The microcontroller can place the various system components on low power or off modes to provide power management control for low power remote operations (battery powered, solar). Typically, the ECI-1 is used to monitor the corrosion of reinforcement steel in a concrete bridge deck. The instruments are placed within the bridge during construction before the concrete is poured. The ECI-1 is placed with the electrodes facing the top surface of the bridge at the level of the top reinforcement steel. This orientation insures that the sensor electrodes of the ECI-1 encounter the same environmental and corrosion conditions as the reinforcement steel it is monitoring.

The ECI-1 enclosure is engineered to provide environmental and structural protection for the embedded sensors and electronics without compromising the integrity of the structure in which it is embedded. The molded plastic enclosure gives moisture and chemical protection to the instrument's electronics while providing a rigid base for the electrodes. A small cage of #3 rebar can be placed around the ECI-1 during installation to further isolate the instrument from mechanical stresses. This reinforcement cage also serves to hold the instrument at the appropriate level in the structure and is directly attached to the reinforcement mat.



The embedded ECI-1 instruments are connected to a multi-drop serial communications network. A variety of network configurations and protocols are possible. The preferred implementation for the ECI-1 is the local area network using the SDI-12 protocol.

The data collection system, in this case a datalogger, is located external to the structure in an environmentally protective enclosure such as a NEMA-4 box. The datalogger connects to the multi-drop serial communication network cables exiting the structure. The datalogger supplies power to the SDI-12 network and thus to all of the connected instruments. The datalogger is powered either by local electrical power lines or optionally a battery that is recharged by a solar collector. The datalogger can be programmed to periodically turn the ECI-1 instruments on and off and to issue commands to collect and send data. The datalogger can then timestamp the returning corrosion data with the identification number and location of responding instrument. This data can then be downloaded on site to a laptop or other portable-computing device. Optionally the datalogger can interface with a wireless transceiver or cell phone modem to provide for remote data collection and operation. Once the data and instrument locations have been collected it can be processed to form a "corrosion map" of the structure. This information can be used to indicate when, where and what kind of maintenance is needed based on the condition of the structure. By knowing the corrosion rate in a structure the remaining life and replacement scheduling can be predicted without costly, time and labor intensive destructive evaluation methods.

ECI-1 Specifications

Physical Dimensions	83 mm (L) x 94 mm (W) x 122 mm (H)
Enclosure Material	VALOX™ Plastic, Epoxy Potted, Water Tight Seal
Chloride Voltage Trend Indicator	Range: ±1.3 Volts Electrodes (2): Ag / AgCl 15 mm (L) x 1 mm (Dia.), MnO2 reference electrode, Force Institute Model ERE 20
Resistivity Meaurement	Range: 1,000 to 19,000 Ohm-cm Electrodes (4): 316L SS (4) 12 mm (L) x 1 mm (Dia.) spaced at 8 mm
Polarization Resistance Measurement	Range: 1 KOhm-cm2 to 1 MOhm-cm2 Electrodes (3): 316L SS counter electrode (1) 18 cm2 x 1 mm thick, MnO2 reference electrode, Force Institute Model ERE 20, Steel working electrode 15.5 mm (Dia.) x 10.0 mm (H)
Temperature Sensor	Range: -40° C to +70° C
Open Circuit Potential	Range: ±1.3 Volts
Estimated Power Requirements	Inactive: 1.5 mAmps @ 12 Volts Active: 4.5 mAmps @ 12 Volts
Communications	SDI-12 V1.2 compatible

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