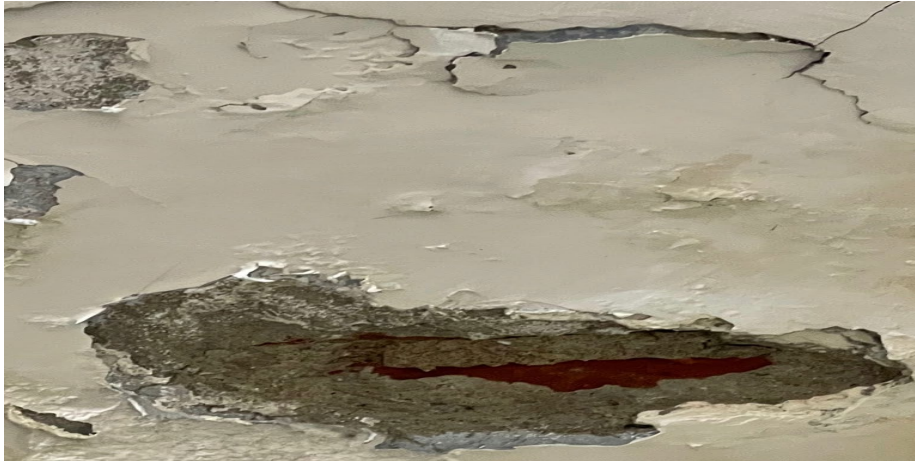


DATA SHEET



CORROSION MONITORING SYSTEM

For Structural Health Monitoring

Model ECS- 101

INTRODUCTION

Corrosion of reinforcement is a major factor causing premature deterioration of large scale concrete infrastructure Worldwide. Early failures of structure due to premature reinforcement corrosion may result in damage to people and assets. To prevent degradation as well as to maintain the structure, an effective monitoring solution is needed to assess the corrosion. Encardio-rite offers a cost effective, reliable, early warning system for corrosion monitoring to track and predict initial stages of corrosion in existing as well as to be constructed concrete structures.

Mini anodic and cathodic areas are formed in the reinforcement during the corrosion process. At the anode, iron dissolves and iron ions diffuse into the concrete towards the cathode where these iron ions combine with oxygen and moisture to form rust. Rust is an expansive product. The rate of corrosion depends upon how easily the iron ions can move through the concrete and the availability of oxygen and moisture near the cathode.

FEATURES

- Easy to install in new or old structures
- Can be exposed to chlorides and carbonatization
- Has stable potential, as a linear function to pH in the alkaline area
- Monitors Corrosion Rate, Humidity, Temperature, Resistance and Current in reinforced concrete
- Suitable for monitoring cathodic protection.

APPLICATIONS

- Inaccessible areas e.g. in tunnels and bridges in the corrosive marine environment
- Bridge decks and underground parking garages heavily influenced by de-icing salt
- Structural elements in public swimming pools, amusement parks
- Structures under influence of acid rain, e.g. chimneys, funnels, and smokestacks etc.



BRIEF DESCRIPTION

Reinforced steel bars embedded in good quality concrete should not generally corrode. Concrete has typically a high alkalinity of around pH 12/13 which passivates the steel surface by forming a protective oxide coating reducing its dissolution rate to a very low value of around 0.1 $\mu\text{m}/\text{year}$.

Concrete is however porous and when carbon dioxide [CO_2] in air penetrates into it, it reacts with calcium hydroxide [$\text{Ca}(\text{OH})_2$] and calcium oxide [CaO] in cement to form calcium carbonate [CaCO_3]. This reaction is called carbonation, and it causes the alkalinity of concrete to decrease. When pH drops below 9, the protective oxide coating is damaged and in the presence of moisture and oxygen, the steel reinforcement corrodes. Chloride penetration can also attack the steel reinforced bars and wire mesh that are used for reinforcement of the concrete. Summarizing, concrete degradation generally takes place by:

- Carbonation i.e. reaction of the calcium compound with atmospheric CO_2
- De-passivation of the reinforced by ingress of active ions like chlorides in coastal areas due to brackish water or in high mountains/colder climates where de-icing salts are used. Chlorides reduce electrical resistance of concrete allowing corrosion current to flow more easily.

When carbonation depth exceeds concrete cover or when chloride ions penetrate in concrete more than the threshold value, it initiates the corrosion. Once initiated, corrosion of the steel reinforcement is self sustaining. The dissolution rate of steel may go up to 10 $\mu\text{m}/\text{year}$. The volume of the corrosion product is more than that of the corroded steel leading to cracking, delamination and then spalling of concrete from the reinforcement.

This results in further ingress of CO_2 , water, oxygen and chlorides etc. which may finally result in eventual failure. The rate of corrosion affects the remaining service life of structures.

Corrosion of reinforcement steel concrete structures affects safety and durability as follows:

- Steel cross section is reduced, weakening the structure.
- Concrete cracks due to the volume increase in rust.
- Cracking and spalling reduce steel to concrete bond.

CORROSION MONITORING SYSTEM

For safety of structures, corrosion needs to be monitored.

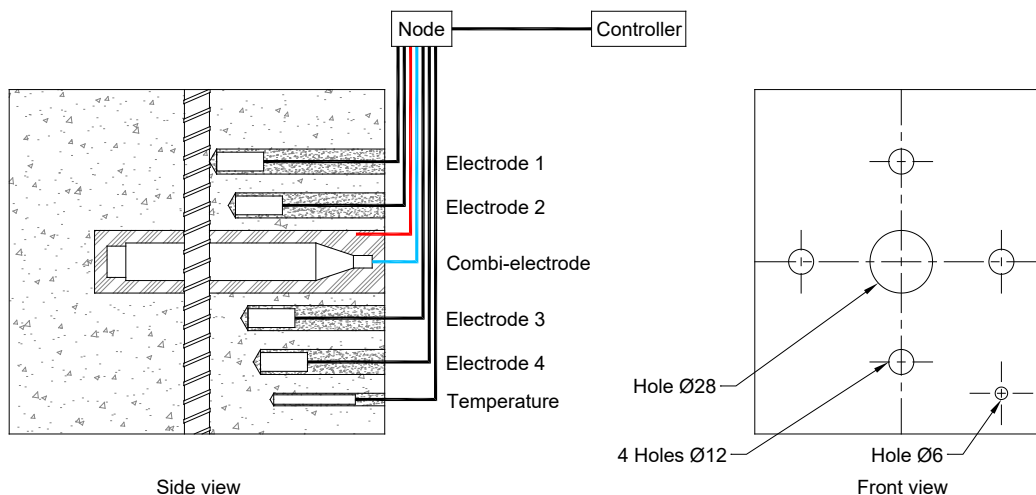
With embedded sensors, accurate information about the in-situ durability parameters of concrete structures, such as corrosion current density, concrete resistivity, ions concentration and temperature is obtained and diagnostic information is provided. An early warning on structural durability can then be given to prepare maintenance strategies and to introduce corrosion control measures.

To evaluate corrosion activity and for its long term monitoring, Encardio-rite offers a **corrosion monitoring system** based on the following electro-chemical methods:

- Potential measurement using reference electrode.
- Corrosion rate monitoring by means of linear polarization measurement.

Corrosion monitoring system basically consists of electrodes/sensors embedded in concrete, data processing nodes, datalogger and data management software to monitor the current corrosion state as well as rate of corrosion of the reinforcement.

4-6 anodes are placed in varying, but defined depths from the exposed concrete surface, along with a reference electrode. The depth of anodes is flexible and can be adjusted according to the concrete cover thickness. These monitor the progress of chloride or carbonation corrosion through the concrete cover of structures. ECS-101/01N sensors can be retrofitted on existing structures. In case the structure is under construction a different set of sensors (ECS-101/01E) is available for installation during construction (please refer to section 1.4 on page 3).



Typical installation scheme of ECS-101 corrosion monitoring system using ECS-101/01E anodes,



A typical installation of four metallic anodes with combi-electrode, retrofitted in an existing structure, is illustrated in the schematic below. The combi-electrode consists of a reference electrode and a mesh cathode. A humidity sensor can be used for better evaluation of data. The sensors are connected to measurement nodes that transmit data through a single digital bus cable to a controller/datalogger.

Corrosion system for single or multiple installations in a structure

The corrosion monitoring system is scalable with various solutions available for small as well as large structures.

Items 1-5 below are required at each installation location. Items 6 & 7 below are optional.

(Quantity to be multiplied by number of installation location):

Item	Qty
1. Reference electrodes to measure actual state of corrosion in reinforcement - per location (ECS-101/02R)	1 no.
2. Mesh cathode to monitor corrosion rate by means of linear polarization measurement - per location (only required with retrofitting type metallic anodes) (ECS-101/02M)	1 no.
3. Metallic anodes to identify/warn future corrosion risks - embedded during construction or retrofit later on existing structure - per location (ECS-101/01N anodes for new structure, ECS-101/01E anodes for existing structure)	4 or 6 no.
4. Temperature probe to record temperature measurement - per location (ECS-101/03T)	1 no.
5. Measurement Node for metallic anodes - can connect up to 6 anodes, 1 reference electrode, 1 mesh electrode & 1 temperature probe - per location	1 no.
6. Humidity probe - optional - per location (ECS-101/04H)	1 or 2 no.
7. Humidity Node for humidity sensor - can connect 2 humidity probes or 1 humidity and 1 temperature probe - optional (if humidity probe is installed) - per location	1 or 2 no.
8. Bus cable connects all installed nodes in series; is terminated to the controller	As req.

Following items are required in control room/data acquisition location (one set per project).

Item	Qty
9. Controller Console (ECS-101C) consisting of Camur III Controller with 4G modem and power supply in a weather proof enclosure.	1 no
10. Web service with Data Management Software	1 no.

All measurement nodes, from each installation location, are connected in series to a single digital bus cable and terminated at the ECS-101C Controller Console.

ECS-101 CORROSION SYSTEM COMPONENTS

Sensor probes

1.1 Reference electrode - ECS-101/02R

Encardio-rite uses ECS-101/02R, a long life reference electrode, for monitoring corrosion rate. It provides a stable voltage for more than 30 years. It is embedded in the concrete structures to monitor the corrosion condition in reinforced steel.



The reference electrode can be installed in both new and existing structures. Based on well-known battery technology, the reference electrode is a half-cell using manganese dioxide in a very alkaline electrolyte, placed in a stainless steel case and with an ionic membrane of cement mortar ensuring good affinity to the concrete.

Measurements may be performed online with a datalogger or by use of a handheld volt meter with high input impedance (>100 M Ohm).

1.2 Mesh cathode - ECS-101/02M

Mesh cathode is embedded along with the ERE 20 reference electrode in the concrete structure. Together, they are referred to as combi-electrode.



In retro-fitted sensor systems, the cathode is installed at the centre of all the metallic anodes embedded at different depths in the structure. This provides corrosion rate by means of linear polarization measurement.

1.3 Metallic anode (retrofitting) - ECS-101/01E

These probes/anodes are installed in the concrete cover of existing structure, between the surface and the outermost layer of reinforcement. They can be retrospectively installed in any completed structure. The anodes are preferably made of the same material as that of the reinforcement. A group of 4 to 6 anodes are mounted at well-defined depths of the concrete cover layers in a circular arrangement in 12 mm Φ drilled holes as shown in the schematic on page 2.

1.4 Embeddable probe/anode - ECS-101/01N

This probe is designed to be installation during construction. A typical probe is illustrated in the picture in the next column. It consists of a multi-sensory arrangement, which in the standard version consists of four steel anodes and one noble metal cathode. It is cast during construction into the cover of concrete structures. The steel anodes are positioned at various distances between the concrete surface and the reinforcement.

1.5 Temperature probe - ECS-101/03T

Corrosion measurement is affected by temperature. To record temperature measurements in the concrete structure, at the time of corrosion measurement, a temperature sensor can be embedment near anodes and connected to same measurement node with anodes.

1.6 Humidity probe - ECS-101/04H (optional)

Humidity also effects the corrosion measurement. To monitor humidity in the concrete structure, at the time of corrosion measurement, a humidity probe is installed near anodes. The sensor is connected to Humidity node for collection of data.

Measurement Nodes and Controller

The datalogging system is designed for automatic monitoring of corrosion in concrete, with data retrieval and control features through phone line, mobile phone or internet.

1.7 Measurement Node - ECS-101MN

Model ECS-101MN measurement node is placed near each monitoring location where the metallic probes are installed. It contains Camur III node with A/D converter, a microprocessor and has galvanic separation between analogue and digital side. The measurement node automatically monitors Linear Polarization Resistance (LPR), AC-resistance, potential, current and temperature.

The ECS-101MN measurement node supports 4-6 anode sensors along with a temperature sensor. Data is transferred from node to Controller through a single digital bus cable.

1.8 Humidity node - ECS-101HN

Model ECS-101HM Humidity node can connect two relative humidity probes or one humidity probe with temperature sensor. Humidity node consist of Camur III hum node and has a built-in power supply. It can monitor sensor output in the range 0-5 V. The input channels are galvanically separated from the bus side.

When humidity sensor is used with anodes, Hum node is installed beside the measurement node (for anodes). Data is transferred from the Hum node to the ECS-101C Controller through a single digital bus cable and processed in the controller and cloud.



Metallic probe/anode (retrofitting) - ECS-101/01E



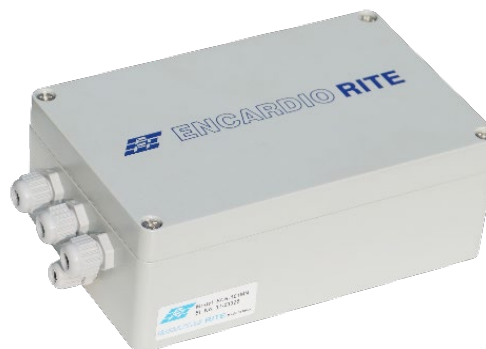
Embeddable probe/anode - ECS-101/01N



Temperature probe - ECS-101/03T



Humidity probe - ECS-101/04H



Measurement Node - ECS-101MN



Humidity Node - ECS-101HM



1.9 Controller Console - ECS-101C

ECS-101C Controller Console houses the Camur III control module (datalogger), power supply, 4G router and other accessories in a weatherproof enclosure.

The controller can support a maximum number of 100 nodes, to cover a distance up to 1 km from the controller to the most distant installation. A repeater is available in case the distance is more than 1 km.

The controller is essential for configuring and monitoring the sensors. It controls the status of connected nodes, handles schedules and recordings and stores recorded data until they are transferred to the cloud. It powers the nodes through the bus cable. The controller has an internal memory of 1.5 million values.

The data processing is split between the ECS-101C Controller and the cloud service.

1.10 Data transfer options

Model ECS-101C Controller Console can transmit data to a central cloud based remote server using cellular communication modem or internet over WiFi network.

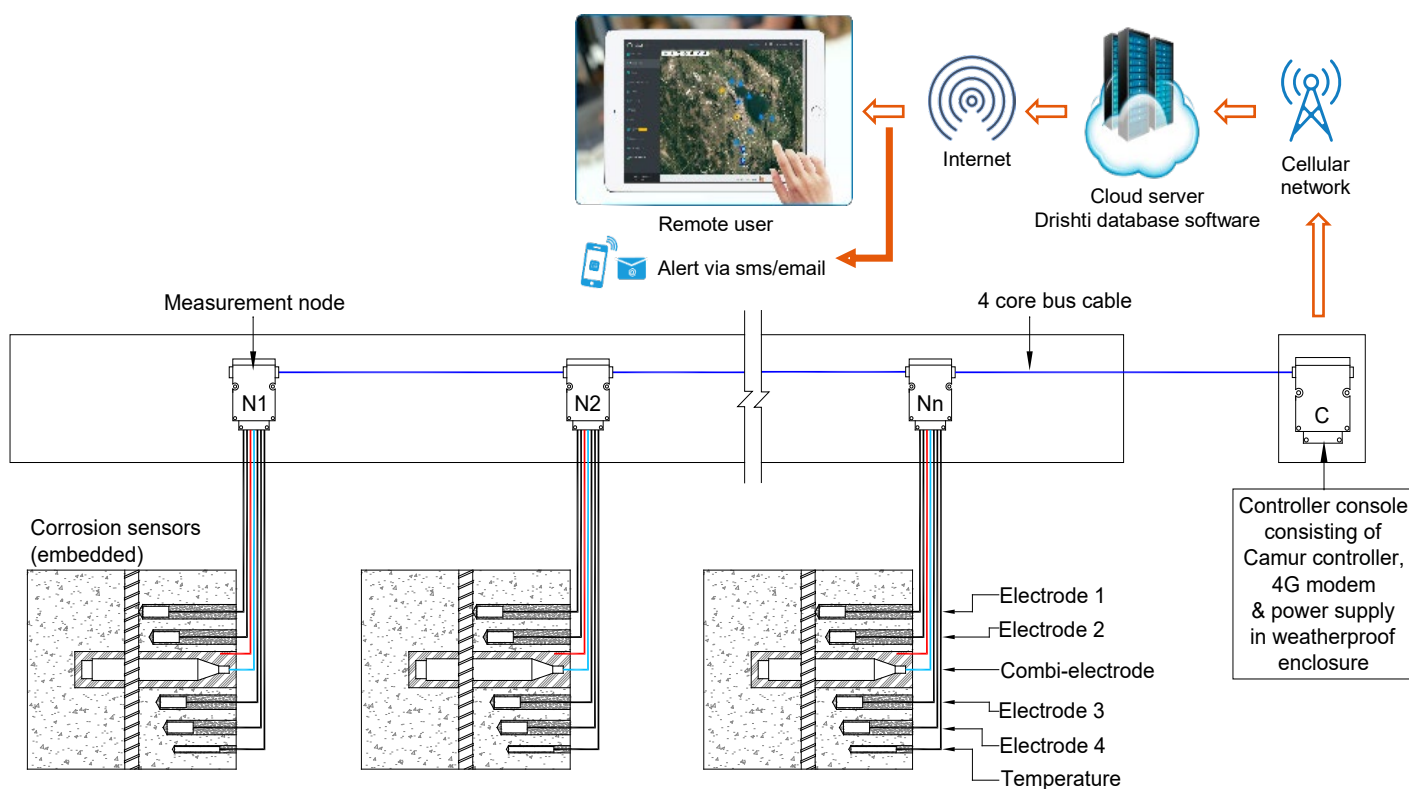
1.11 Power supply options

The suggested power supply for ECS-101 corrosion monitoring system is AC mains. It can be supplied with solar power supply, if ordered separately.



Controller Console - ECS-101C

The choice of network for data transmission and power supply is made taking into consideration the installation location and customer requirement.



Corrosion Monitoring Schematic for ECS-101/01E electrodes installed at multiple locations.

Humidity sensor with humidity node can be added to the system in similar fashion. Same Controller Console will collect the data.



ONLINE MEASUREMENTS

When interfaced with model ECS-101C Controller Console datalogging system, the system provides corrosion information by performing scheduled potential decay measurements which will indicate the proper operation of potential measurement.

With anodes and reference electrode, initial corrosion is discovered when threshold values of the potentials or current have been exceeded. The potential of the equilibrium is measured between the combi-electrode and the individual electrodes in the concrete cover.

Some of the online measurements the system provides are:

1. Open circuit potential (OCP) or E_{corr} between standard cell and each of the 4 (or 6) anodes. OCP is highest between the standard cell and anode at greater depth from the surface.
2. Resistivity in Ohm cm between each of the 4 (or 6) anodes. This will be highest between electrodes 1 & 2 in the figure on page 2.
3. Linear polarization resistance (LPR) to give corrosion rate and predict start of corrosion in reinforcement concrete. In retrofit installations, the mesh electrode is embedded along with the reference electrode. In installation during construction, a special metal cathode is used along with the reference electrode.

The anode is perturbed by a small amount from its equilibrium potential. This can be accomplished potentiostatically by changing the potential of the anode by a fixed amount, ΔE with respect to the potential of the true reference electrode and monitoring the current, ΔI through the mesh cathode/special cathode, after a fixed time.

MANUAL MEASUREMENTS

1.12 Zero-Ohm Ammeter – Model ECS-101R

Model ECS-101R is a readout device for taking manual measurements from installed anodes (ECS-101/01N anodes for new structure and ECS-101/01E anodes for existing structure).



ECS-101R is typically a Zero-Ohm Ammeter, specially designed to measure very small corrosion currents in the range of micro-Amperes. It has measuring channels for corrosion current and potential, up to 6 channels, along with temperature. It can store data up to 999 measurements. The unit comes with battery lifetime of ~200 hours and an enclosure having IP-65 protection.

In contrast to standard devices, Zero-Ohm Ammeter counters the effect of the inserted resistance by keeping the voltage drop across the input terminals below a few microvolt. The current used to maintain the null voltage across the terminals is precisely measured, displayed and made available at the output measurement pins. Because there is no burden on the measured circuit, the reported current is extremely precise.

In case humidity is also to be manually measured, a separate readout unit is available.

ORDERING INFORMATION

Following information is required while ordering:

- Type of anode probe for measurement
 - ECS-101/01E for existing structure and
 - ECS-101/01N for new construction
- Number of anode probes - this will vary depending upon the configuration customer chooses (4 or 6 anode).
 - ECS-101/01N-4 (4 anodes for new structure)
 - ECS-101/01N-6 (6 anodes for new structure)
 - ECS-101/01E-4 (4 anodes for existing structure)
 - ECS-101/01E-6 (6 anodes for existing structure)
- Total number of installation locations
- Distance between monitoring locations and controller console (datalogger).
- Medium for data transmission
- Power supply option
- Additional parameters to be monitored like humidity

Based on above information a cost effective suitable corrosion monitoring solution will be provided. Accessories and other equipment needed for installation are to be sourced by client.

*All specifications are subject to change without prior notice

DATASHEET | 2111-21 R04



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