ANALATOM

Structural Health Monitoring Solutions

Application Note #002
AN110 – Pipelines

Analatom, Inc., 3210 Scott Blvd., Santa Clara, CA 95054-3007
Phone: (408)-980-9516 • Fax: (408)-980-9518 • Email: info@analatom.com

1 Overview

Corrosion represents a significant problem for the nearly 500,000 miles of pipelines that transport natural gas, crude oil, and hazardous liquids in the United States. This critical infrastructure cost companies an estimated $100 billion to install and over $2 billion annually to maintain. Maintenance costs associated with these transmission lines involve monitoring, repairing, corrosion mitigation, life assessment, and risk modeling. Incorporating a system capable of directly identifying corrosion on pipelines can produce considerable cost savings by minimizing overall maintenance costs and preventing service interruptions.

1.1 Technology Description

Analatom's corrosion health monitoring system (CHMS), shown in Figure 1, consists of a network of AN110 Data Acquisition (DAQ) nodes. Each node connects to eight micro-linear polarization resistance (μLPR) sensors and one external temperature & relative humidity sensor. Each unit is battery powered, but can also be operated on external power.

1.2 Benefits

As demand increases for products commonly transported by pipelines, so too does the cost associated with maintenance. Direct monitoring of electrochemical activity on gathering and transmission pipelines compliments cathodic protection and remote monitoring strategies by sensing oxidation-reduction reactions occurring on pipeline surfaces. This strategy is particularly beneficial with systems that cannot be effectively cathodically protected, such as insulated pipes, above ground installations, pipes susceptible to AC induced corrosion, encased pipes, and compressing stations. Early intervention on these critical structures prevents service interruptions, reduces risk to public safety, and ultimately reduces corrosion-related repair costs.

2 How it Works

2.1 μLPR Sensor

Corrosion is an electro-chemical process that takes place on a metallic surface. The μLPR sensor is comprised of a sample of metal fabricated from the same material as the structure to be monitored. The sensor is placed in areas where corrosion is likely to occur, such as joints and welds. When corrosion occurs on the μLPR sensor metal surface, a current signal is generated. This current signal is generated by a reduction-oxidation (redox) reaction taking place between the metal surface and the environment. The total amount of mass loss is proportional to the total charge generated due to the redox reactions. An absolute measure of total mass loss is derived by integrating the current signal and multiplying by a constant of proportionality dependent on known material properties and physical constants.

2.2 AN110 DAQ Node

LPR data is measured and stored locally on the unit. The AN110 can be configured to wirelessly transmit data using IEEE 802.15.4 (ZigBee). This allows the AN110 to transmit data long distances using commercial off the shelf (COTS) radios / repeaters in a wireless mesh network.

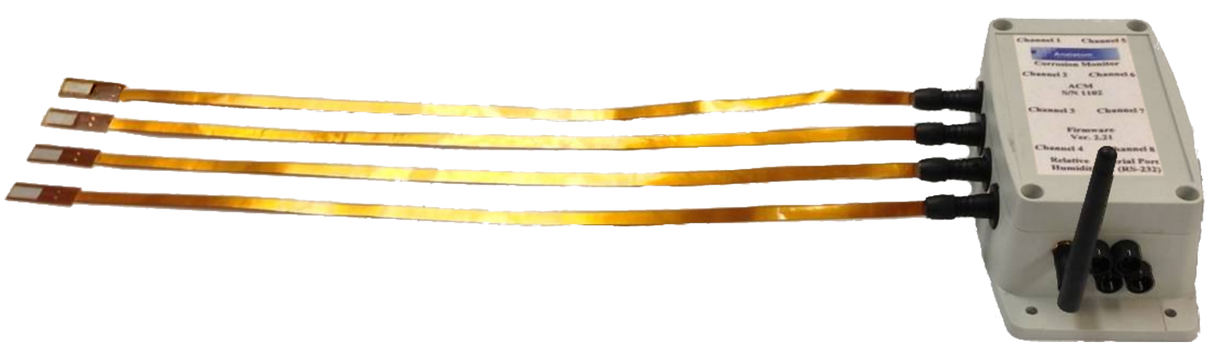

Figure 1: Wireless CHMS consisting of a AN110 DAQ node connected to four μLPR sensors.

Post processing performed on the measured LPR data allows computation of mass loss per unit area due to corrosion.

3 Advantages

There are several advantages that μLPR has over other corrosion monitoring techniques:

- **Direct Measure** – The μLPR sensor is fabricated from the same material as the structure. This allows for a direct measure of corrosion when compared to other methodologies that infer corrosion from environmental parameters such as time of wetness, relative humidity, and temperature.
- **Measurement Speed** – Changes in the corrosion rate can be detected in minutes, providing a near-instantaneous measuring system. This fast response allows an operator to evaluate process changes and is particularly useful in monitoring the effectiveness of a prevention program.
- **Defect Localization** – Post processing of LPR data streams can be used not only to determine the total surface loss at sensor sites, but also to holistically evaluate the pipe. Interpolation of data streams enables surface losses over the external area of the pipe to be calculated and provides localization of defect sites in protective coatings.

4 Comparison

Direct corrosion monitoring measures a response signal, such as a current or voltage, as a direct result of corrosion. Examples of common direct corrosion monitoring techniques are: corrosion coupons, electrical resistance (ER), electro-impedance spectroscopy (EIS), and LPR techniques. Whereas, indirect corrosion monitoring techniques measure an outcome of corrosion and not the process itself. Two common indirect techniques are ultrasonic/acoustic testing and radiography testing. Each method has advantages and disadvantages, as shown in Table 1.

5 Example Application

The μLPR has been evaluated on a fusion-bonded epoxy coated natural gas pipeline. Application of an AN110 DAQ node installed on a natural gas pipeline in an environmental chamber is illustrated Figure 2.

In this evaluation, eight μLPR sensors were installed at various distances from a 1/8" defect placed in the fusion-bonded epoxy surface of an API 5L ERW Grade-B D.R.L. steel pipe. Sensor installation was accomplished by locally buffing off the fusion-bonded epoxy layer and attaching the sensors to the pipe surface with industrial epoxy. After installation the sensors were covered with an epoxy field patch material. Data gathered during this experiment enabled corrosion activity to be monitored in real-time as it spread from the defect along the pipe surface-epoxy interface. Further, this experiment showed the high sensitivity of μLPR sensor measurements allowing corrosion to be detected at distances greater than 18" from defect sites.

Table 1: Comparing corrosion monitoring techniques.

Parameter	**LPR**	**ER**	**Coupons**	**EIS**	**Ultrasonic**	**Radiography**
Power	Low	Low	None	Med	High	High
Weight	Low	Low	Low	Med	Med	High
Direct Measure	✓	✓	✓	✓	–	–
Non-Intrusive	–	–	–	–	✓	✓
Processing	Low	Low	Low	Med	High	High

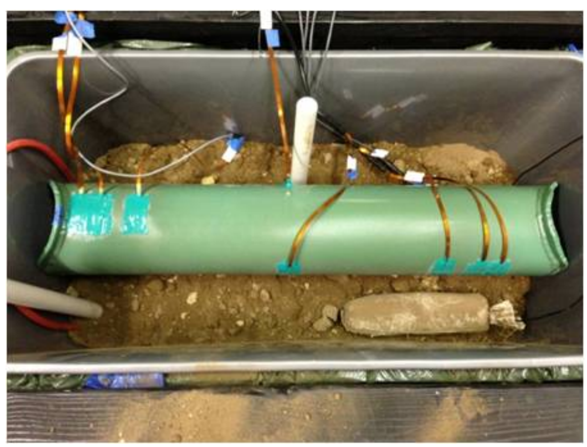

Figure 2: AN110 installed on a mock natural gas pipeline inside an environmentally controlled chamber.