Sensors and Actuators B 181 (2013) 22–28

Contents lists available at SciVerse ScienceDirect

Sensors and Actuators B: Chemical

journal homepage: www.elsevier.com/locate/snb

Multi-sensor monitoring of the corrosion rate and the assessment of the efficiency of a corrosion inhibitor in utility water installations

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ARTICLE INFO

Article history:
Received 26 September 2012
Received in revised form 31 January 2013
Accepted 5 February 2013
Available online 14 February 2013

Keywords:
Corrosion monitoring
Linear polarization resistance
Electrical resistance

ABSTRACT

This paper presents an implementation of the monitoring of the corrosion rate and the assessment of the efficiency of a corrosion inhibitor in a utility water installation using an automated corrosion monitoring system. Due to the fact that the corrosion inhibitor was added to water intended for human consumption, it was necessary to build a multi-sensor monitoring system. In order to implement corrosion monitoring using a linear polarization and resistometric methods, the system was subjected to lab testing, which allowed for determining the commensurability of measurements using both techniques. Based on the research, an automatic utility water monitoring system was implemented, both before and after the application of an inhibitor. The research has shown, that the inhibitor, when used, is effectively limiting the corrosion rate, though the characteristics of the measurement require a detailed analysis of the changes in the corrosion rate as a function of time and water temperature fluctuations.

1. Introduction

For many years, there were problems with the quality of water from the municipal network in the city of Gdańsk. Water pumped through the municipal pipelines was highly corrosive and contributed to the intensification of corrosion in steel pipes. The problem of high water aggressiveness was due to the specific properties of water. The water is drawn from the lake, thus there are significant differences in chemical and physical composition of the water in an annual cycle. In the summer the temperature of the water is increasing and thus the corrosive aggressiveness of water is increasing. This resulted in low-quality water with a characteristic reddish tint caused by the presence of the products of iron corrosion. Given the need to ensure adequate water quality, the water supply management company was forced to apply technologies reducing the aggressiveness of the water. In this case, the application of corrosion inhibitor was chosen. This method involved dosing calcium polyphosphate. Calcium polyphosphate as a corrosion inhibitor was applied to reduce the processes of corrosion by creating a protective layer, inhibiting the growth of bacteria, sludge stabilization and the reduction of water's brown color due to the presence of iron ions (III). Calcium polyphosphate reacts in water environment with the dissolved carbon dioxide, leading to the formation of calcium carbonate, which results in a tight, stable protective layer[1]. The use of phosphates in less than stoichiometric amounts also prevents an excessive precipitation of calcium carbonate. It is important to determine an appropriate dosage of the inhibitor to reduce the rate of corrosion processes on the other hand and on the other, to not induce the formation of excessively large amount of deposits consisting of calcium carbonate. Studies have shown that even the addition of polyphosphate at the level of 0.5 ppm significantly reduced the tendency to form sediments [2]. It was also found that the optimal dosage of the corrosion inhibitor should be at the level of 5 ppm. In the case of inhibitor protection of such a strategically important installation, which has to provide potable water, the amount of inhibitor applied should be as low as possible. On the other hand, the amount of inhibitor has to be sufficient to limit the speed of pipeline corrosion. Potable water is supplied to surface intakes, which makes its chemical composition fluctuate seasonally, which in turn made a continuous corrosion monitoring system a necessity [3,4]. The automatic corrosion monitoring involved two speed measuring methods:

- determining the instantaneous corrosion rate based on the measurement of linear polarization resistance (LPR),
- determining the average corrosion rate based on electrical resistance (ER).

The first measurement technique allows the direct determination of corrosion rate during the study using electrochemical measurements [5–9]. The second technique allows for evaluating

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http://dx.doi.org/10.1016/j.snb.2013.02.015

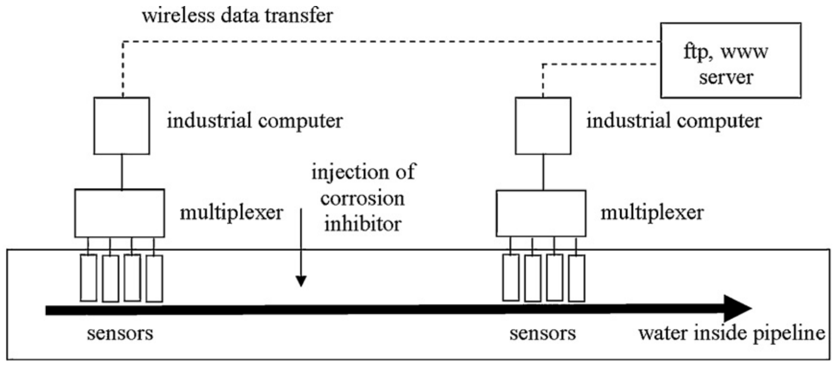

Fig. 1. The working principle of an automatic corrosion monitoring system.

the risk of corrosion of installations in the period between the two tests based on electrical measurements [10,11]. Corrosion monitoring systems that are commercially available are usually based on one measuring technique. Polarization resistance method is most often used for aquatic environment, while for nonconductive environment, a resistometric method is used. The use of two measurement methods in one sensor, along with temperature measurement, ensures an increase of measurement scope. The use of two independent measurement methods gives us the ability to gather more information of corrosion processes taking place, thus making it possible to explain the reasons of fluctuations of corrosion rate in time. It allows us to eliminate the errors of results of corrosion rates obtained due to a sensor malfunction, as well as allowing us to dose the water with required inhibitor amounts much more accurately. In order to determine the reasons for corrosion rate fluctuations, the temperature and water flow were monitored using one measuring system equipped with multi-sensor heads.

2. Materials and methods

2.1. Methodology

The basic construction of an automatic corrosion monitoring system [3,4].

Fig. 1. shows the basic construction of an automatic corrosion monitoring system.

The corrosion monitoring system consists of:

- industrial computers containing:
  - an analog-digital card – performing measurements;
  - software for performing the measurements and analysing the results;
  - a GSM data transmission system,
- control and data conditioning systems consisting of:
  - a system for conditioning the signals from temperature, flow, polarization and resistometric sensors,
  - a multiplexer to control the sensors,
- sensors placed inside the water supply system,
- a web server to visualize the transmitted data.

The monitoring system is managed digitally. The digital system includes a data conditioning module and a module for controlling sequential measurements from individual sensors [12,13]. The data conditioning system is also connected to the measuring computer.

2.2. Corrosion sensors

The corrosion processes occurring in water are electrochemical in nature, so their rate should also be measured using electrochemical methods. Fig. 2a shows a typical triple-electrode electrochemical sensor mounted on a lance with an electrical connection.

Each of the three sensor electrodes can be used as an indicator electrode, while the other two act as an auxiliary and reference electrodes. Therefore, the sensor presented is very versatile and can be

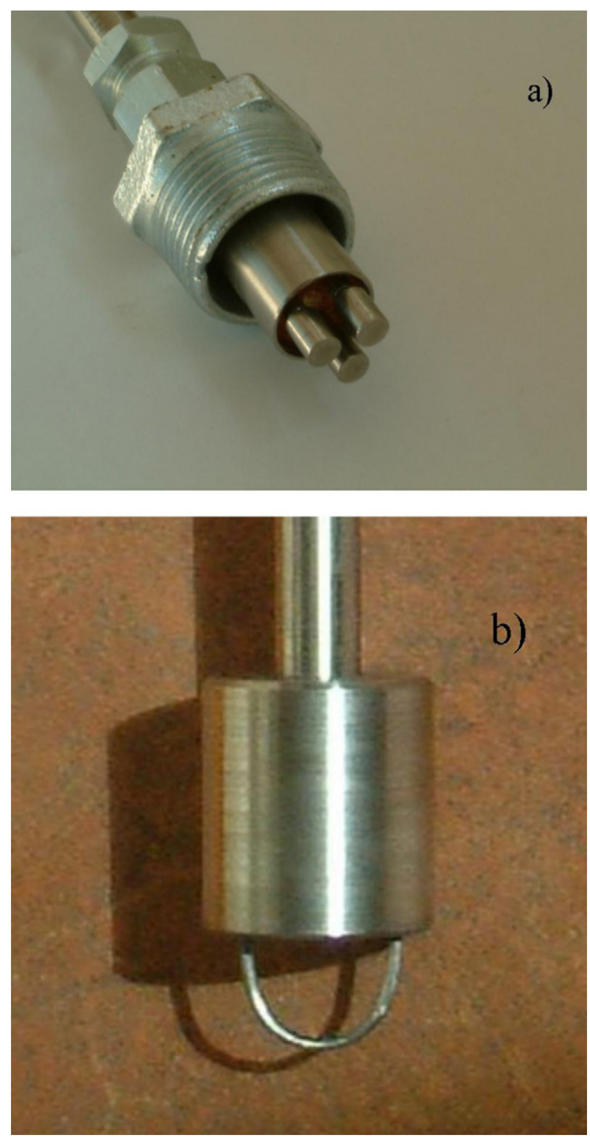

Fig. 2. Sensors for monitoring the corrosion rate and temperature: (a) a polarization sensor and (b) a resistometric and temperature sensor.