

Continuous Corrosion and Erosion Monitoring in Geothermal Power Facilities

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ABSTRACT: CONTINUOUS CORROSION AND EROSION MONITORING IN GEOTHERMAL POWER FACILITIES

Continuous measurement presents a step change in monitoring corrosion and erosion, the levels of corrosion rates that can be determined and the accuracy of that determination.

Pipework and vessels in geothermal facilities are always at risk of corrosion or erosion, and continuous monitoring substantially reduces the risk of failure, increases safety for the workers and the environment, and reduces operational interruption, repairs and reputational damage.

This paper will illustrate the application, deployment and real-time monitoring capabilities of Permasense corrosion and erosion monitoring systems. These systems provide asset and integrity managers with a real time picture of how their facility is coping with the high demands placed upon it by corrosive fluids and erosive solids. Continuous corrosion and erosion monitoring solutions can be deployed almost everywhere in geothermal power facilities but are particularly focused on:

- Superheated steam vessels, pipework and systems
- Cooling towers and condensate piping
- Heat exchangers
- Well casings and liners

The data to desk capability of these systems proves valuable real-time information to enable specialists remote from the plant to support local teams in using the data to optimise operations. For instance, these systems can provide direct feedback on the effectiveness of inhibitor injection as lines suffer from ever changing levels of corrosivity, and the data can provide valuable information to optimise inhibitor strategies over short timescales to prevent the frequent replacement or repair of metalwork. The unique self-contained wireless and battery systems are meeting the monitoring needs of power generation facilities, including high temperature applications such as boiler vessels and associated pipework, typically on insulated lines at temperatures around 350°C, and on wall thicknesses up to 150mm (6 inches). Where flow-accelerated corrosion is a problem these systems allow direct correlation between operation conditions over particular periods and wall loss rates over the matching period.

In summary we will show how continuous ultrasonic pipe thickness measurement can be used in real time to understand corrosion and erosion rates on critical parts of the installation and when combined with wireless transmission can bring significant cost, safety and environmental benefits to the operators of Geothermal installations.

1. INTRODUCTION

Continuous measurement presents a step change in monitoring corrosion and erosion, the levels of corrosion rates that can be determined and the accuracy of that determination.

Pipework and vessels in geothermal facilities are always at risk of both corrosion and erosion, and continuous monitoring substantially reduces the risk of failure, increases safety for the workers and the environment, and reduces operational interruption, repairs and reputational damage.

Plant integrity and safety continues to be of the utmost importance to operators. The prevention of corrosion/erosion through live monitoring provides asset and integrity managers with a real time picture of how their facility is coping with the high demands placed upon it by corrosive and erosion products. This information also assists in risk management, auditing and process optimisation.

2. PLANT INTEGRITY

Steel pipework and vessels are always at risk of corrosion or erosion. Unless monitored there is a risk of failure which may impact the safety of workers and the environment, quite apart from the financial costs of operational interruption, repairs and of reputational damage.

Permanently installed sensor systems can deliver a plant wide continuous picture of asset condition over time, from areas not accessible or dangerous to operators at a fraction of the cost. This picture can be correlated with process conditions that may be causing corrosion or erosion, and strategies to minimise corrosion such as inhibitor use can be implemented or optimised. This enables the asset manager to move beyond merely knowing whether corrosion or erosion is occurring to understanding why and at what rate. This understanding allows better quality decisions; cost-effectively improving plant integrity and thus safety.

3. THE NEED FOR CONTINUOUS MONITORING

There are various established techniques for the periodic assessment of pipe and vessel integrity. The drivers of corrosion and erosion - process conditions, process constituents and abrasive solids - and the inhibitors to hold corrosion rates in check are familiar.

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Periodic inspections do not, however, deliver continuous piping and vessel condition data that can be correlated with either corrosion drivers or inhibitor use to enable understanding of the impact of process decisions and the use of inhibitors on plant integrity. Manual acquisition of ultrasonic wall thickness data is also frequently associated with repeatability limitations and data logging errors.

Some locations in a facility can be hard to reach, meaning technicians incur safety risks in gaining access. Where high pipework/vessel temperatures are involved ensuring technician safety during manual inspection becomes even more challenging.

An ever-increasing proportion of facilities are in areas of the world in which availability of suitably qualified inspection personnel is a challenge for example politically unstable regions, or in which there are heightened risks to personnel – offshore, regions of kidnap risk.

Permanently installed sensor systems are proving an efficient and safe way for these personnel to monitor the integrity of pipework with the delivery of continuous data of high quality, to their desks anywhere in the world.

The data to desk capability of these systems provides valuable real-time information to enable specialists remote from the plant to support local teams in using the data to optimise operations.

The system allows the retrieval of reliable data to spot corrosion activity before it is too late. It allows operators the freedom to choose monitoring locations irrespective of how inaccessible they are, thanks to the use of wireless networks for data retrieval.

The unique self-contained wireless and battery systems are meeting the monitoring needs of geothermal and conventional power generation facilities, including high temperature applications such as boiler vessels and associated pipework, typically on insulated lines at temperatures around 350°C, and on wall thicknesses up to 150mm (6 inches). Where flow-accelerated corrosion is a problem these systems allow direct correlation between operation conditions over particular periods and wall loss rates over the matching period.

4. CORROSION IN GEOTHERMAL FACILITIES

In Geothermal facilities process flows can be extremely variable and transients are often outside the limit of operational control. High temperatures, high pressure, high salt concentrations and entrained solids can all lead to corrosion and erosion within a geothermal facility. Acidic wells produce highly corrosive steam output which is detrimental to both well heads and flow lines.

If plant fails due to corrosion or erosion, an accident can happen extremely fast and aggressively, which can impact the integrity of the facility. Online monitoring can reliably detect corrosion and erosion before it is too late and avoid the consequential financial, operational and reputational damage which can have very serious consequences.

Permanently installed monitoring systems show that where corrosion is taking place, the rates vary, depending on the operating conditions. To move beyond simply knowing whether corrosion or erosion are taking place to understanding what is driving them it is thus essential to be able to correlate thickness data over time with process and / or other parameters. Online monitoring therefore is incredibly useful to manage operations rather than manual inspections which can be infrequent.

Permanently installed corrosion monitoring systems offer effective monitoring of assets while minimising the exposure of personnel to challenging and potentially hazardous working environments including high temperatures and difficult-to-access locations which would be impossible to monitor using conventional systems.

This innovative permanently installed integrity monitoring solution for real-time monitoring has been tried and tested in some of the most inhospitable oil and gas environments, and continuously delivers high integrity data, reliably and securely. The risk to personnel in collecting data is eliminated.

5. SYSTEM DESIGN

At the core of the system is an ultrasonic sensor mounted on stainless steel waveguides. The waveguides isolate the sensor electronics from extreme temperatures and guide the ultrasonic signals to the pipe wall and back without excessive signal degradation and distortion. The system can monitor pipe wall thicknesses in a wide range of steels and other alloys up to 6 inches (150mm thick). The frequent measurement of corrosion and trending software allows for metal loss detection at the level of 10s of microns.

Each sensor is equipped with a radio and communicates with other sensors and a gateway (base station) within a conservative 50m (55yd) range. The sensors form an independent mesh or wireless network and each sensor radio can act as a relay, or repeater, enabling the network to span hundreds of metres from the gateway.

Data is channeled via the gateway to a database on a connected computer. If, as is usual, this computer is networked, browser-based visualisation software enables the corrosion/inspection engineer to view the data at their desk. The data can also be exported in any of the file formats required by the various process monitoring applications, enabling seamless transfer and read-in to those packages and thus correlation with the process data at the sensor location.

This sensor has been certified as intrinsically safe for use in the most hazardous of environments, and proven in operation over a number of years in refinery environments, onshore and offshore upstream facilities, and more recently in Geothermal facilities.

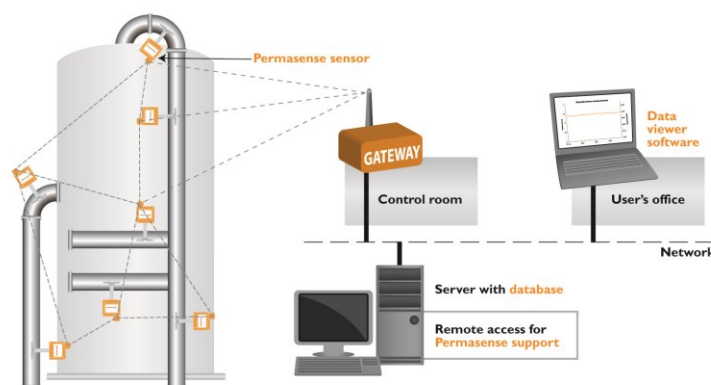


Figure 1: Short range system

6. DRIVER FOR DEPLOYMENT

A key driver for the deployment of permanently installed sensors is to maintain availability of plant – if the plant is not running it is not profitable.

These permanently installed solutions monitor conditions continuously, which is critical in geothermal facilities as process conditions constantly change, causing a high variability of corrosion and erosion activity.

In plant with aggressive rates of corrosion or erosion – particularly where the corrosion or erosion is intermittent and the remaining life is uncertain – frequent manual inspection is common. Where operating temperatures are sufficiently high that shutdown is necessary to enable manual inspection (or for safety reasons) the loss of throughput can come at a high cost.

As the system can be installed on live equipment, operators do not have to lose availability of plant to install sensors. Permanently installed systems reduce the safety risks associated with collection of plant condition data. In several chemical production facilities users have also been able to eliminate the periodic shutdowns they had previously required to enable operator access.

Sensors deployed on well head lines can assist in managing the ever changing levels of high corrosivity in geothermal plants. Installed on carbon steel lines, the sensors can monitor the effects of hydrochloric acid corrosion.

The equipment metallurgy can be upgraded, often at substantial capital cost, or the site can adopt a combination of corrosion monitoring and inhibition, which will largely fall within operating expenses. Thus, the choice of strategy often evolves as a product of the tension between availability of capital versus the drive to minimise operating expenses. In capital constrained situations, the monitoring/inhibition strategy is very popular. These innovative permanently installed sensors can provide direct feedback on the effectiveness of mitigation strategies for example with caustic inhibitor injection being used as mitigation.

The widely adopted approach of periodic manual inspections does not capture the often intermittent, and sometimes accelerated and non-linear nature of corrosion. It is therefore very difficult to use this data to correlate directly with either corrosion drivers or inhibitor use to enable an understanding of the impact of feedstock and process decisions and the use of inhibitors on plant integrity.

Permanent corrosion monitoring therefore represents a significant step forward in enabling effective use of corrosion inhibitors and in providing asset and integrity managers with a real-time picture of the infrastructure.

By deploying a permanently installed integrity monitoring system, the engineer is provided with data on pipeline condition that provides information to minimise risk, reduce danger to personnel, increase safety and integrity, and improve operational performance and reliability. By monitoring the data at desk means action can be taken immediately to maintain integrity and availability.

The system has been tried and tested in some of the most inhospitable environments. Systems are currently deployed in over 50 Oil & Gas facilities worldwide. Operators using this solution for continuous corrosion monitoring have a more accurate and timely understanding of the corrosion and erosion rates occurring in their facilities.

The real-time provision of data allows potential corrosion hotspots to be remotely monitored and at time intervals of the operator's choosing, from as frequent as every few minutes if necessary. This insight allows asset managers to make more informed decisions to the benefit of plant integrity, safety and operating costs.

7. SENSOR INSTALLATION

The sensors can be deployed on wall thicknesses up to 150mm (6 inches). Continuous corrosion and erosion monitoring solutions can be deployed almost everywhere in geothermal power facilities but are particularly focused on:

- Superheated steam vessels, pipework and systems
- Cooling towers and condensate piping

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- Heat exchangers
- Well casings and liners

The sensors are battery powered, and transmit their data by radio. This means that cabling to monitoring locations is not required, which minimizes the cost of installation, and enables deployment in difficult to access and remote areas.

Securing sensors is straightforward, on studs which are mounted on the pipe, or, for pipe wall temperatures below 100°C (200°F), on clamps, that are in turn mounted on the pipe.

This allows the sensors to be dry coupled; no couplant is required between the sensor and the pipe. This, together with multi-year battery life, eliminates the need for expensive maintenance visits.

Sensors are now in service on a full range of materials including carbon and cast carbon steel, P5/5 chrome, P9/9 chrome, 1% Cr (5130), Duplex, P265GH (430-161), 1.4571 (316Ti), P295GH (17Mn4), Monel, HR120, Inconel, Incoloy and Hastelloy.



Figure 2: Carbon steel U-bend with sensor

8. DATA MANAGEMENT

Data from installations is showing that where corrosion is taking place it is often intermittent rather than continuous and it is particularly valuable to be able to correlate thickness data over time with process and/or inhibitor parameters. With the Permasense system very accurate data is continuously streamed to users, which provides a valuable insight into the impact of operating parameters on corrosion / erosion activity.

Moreover, the data can highlight which prevention or mitigation strategies are most effective.

Sophisticated data management and viewing software is an integral part of this solution to support the interpretation of data provided from continuous monitoring. The system's data management and visualisation suite, Data Manager, offers an overview of all locations monitored, direct to desk.

With drill-down functionality, the latest system offers additional analysis features including rates over various periods of time, remaining wall thickness to retirement and seven-day average measurement.

Automatic classification of data by locations indicating an excess of corrosion rate thresholds - as determined by the user - allows quick and easy determination of where corrosion activity is occurring across the facility.

Measurement checks ensure excellent data validation and simple diagnostics. Functionality and display features can be easily tailored by the user. The full waveform (ultrasonic a-scan) viewing feature allows manual data interpretation for example at those locations where the data indicates short-term changes in corrosion rate.

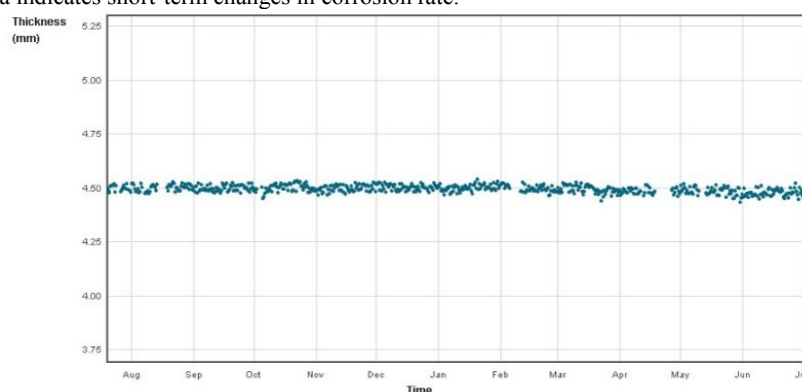


Figure 3: Continuous integrity monitoring data

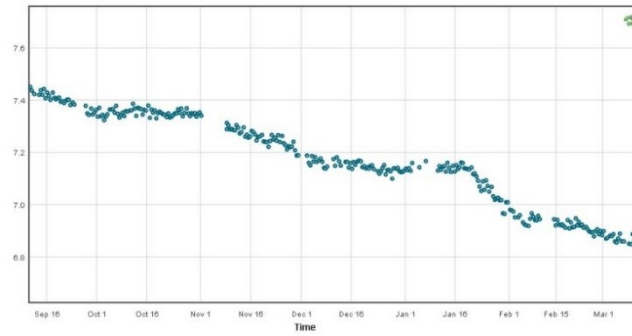


Figure 4: Data showing intermittent corrosion

9. CONCLUSION

Operators using this permanently installed continuous integrity monitoring solution have a more accurate and timely understanding of the corrosion and erosion rates occurring in their facilities.

The system facilitates an understanding of why corrosion is occurring through the correlation of process condition changes with changes in corrosion activity.

The system enables direct measurement of wall thickness as frequently as desired, even from inaccessible or hot locations, without risk to personnel or the need for plant shut downs.

The significant benefits provided by these systems reduce danger to personnel, increase safety and integrity, and improve operational performance and reliability. Permanently installed systems are also now delivering data where inspector availability is limited or access is difficult for environmental reasons.