INTERCORR 2008
28° Congresso Brasileiro de Corrosão
2nd International Corrosion Meeting
Mar Hotel, Recife / PE • 12 a 16 de maio de 2008

NON-INTRUSIVE MONITORING OF INTERNALCORROSION IN PIPELINES AND HIGH TEMPERATURE APPLICATIONS IN REFINERIES

Kjell R. Wold [1], Marte A. Theodorsen [2], Hallgeir Jenssen [3], Anna Maria Carvalho[4]

Abstract

Non-intrusive field signature method (FSM) technology has been in the market for more than 15 years, and has been used for a wide range of land-based, offshore and subsea applications.

The paper will summarize applications and experience with the FSM technology in general. Examples from high temperature use in refineries will be presented, with typical system description and results. Furthermore, a new on-line data logging system based on FSM is being introduced, expected to be attractive for corrosion monitoring of remote pipelines, prepared for wireless communication solutions already tested in Brazil.

Key Words: corrosion, non-intrusive technology, FSM technology, wireless communication solutions.

INTRODUCTION

The field signature method (FSM) concept was originally developed as a method for crack monitoring by SI (now SINTEF) in the mid eighties. CorrOcean (now Roxar) acquired the commercial rights to the technology for internal corrosion monitoring, and started product development on that basis. The first offshore installation was made in 1991, and the first subsea installation was made in 1994. Since then, field signature equipment has been supplied to a large number of clients world wide, for a wide range of applications, and there has been a continuous development of products and improvements based on the technology.

A summary of the history of the field signature technology was given during NACE 2007 in Nashville, Tennessee, USA, March 2007.[1]

Corrosion monitoring of remote pipelines is often a problem because:

- Corrosion is often most severe at the bottom section of the pipeline because this is the location where water is most likely to be present. In particular, low spots of pipelines may be exposed to internal corrosion since this is where water could be accumulated and form a stable water phase. Monitoring such locations with traditional probes require access to the bottom of the pipe, which would again require big pits under the pipeline with space for access fittings and space for operating retrieval tools. However, non-intrusive sensors installed directly at the pipe wall require less space;

[1] Commercial Manager Topside Corrosion/Erosion - Roxar ASA
[2] Deputy Coomercial Manager Topside Corrosion/Erosion – Roxar ASA
[3] Senior Sales and Services Engineer – Roxar ASA
[4] Roxar do Brasil Ltda

the pipeline can be buried in the soil as the rest of the pipeline after installation of the sensors.

- Pipelines are normally scraped. Non-intrusive sensors will not interfere with pigging operations.
- Collecting data at remote locations is costly with respect to money and personnel resources. Continuous data transfer directly to client's offices would save time and money for the client.
- Due to the cost and time required for data collection at remote locations, the frequency of data collected is limited. On-line communication from remote locations allows a higher measurement frequency, improving quality and accuracy of the information provided.

The need for remote monitoring solutions was discussed by da Silva et al at the Rio Pipeline conference 2007.[2]

DESCRIPTION OF THE ELECTRIC FIELD SIGNATURE TECHNOLOGY

The field signature method is based on feeding a current through a selected section of the structure to be monitored, and sensing the electric field pattern by measuring small potential differences set up on the surface of the monitored object.[3, 4] The first measurement (signature) is unique to the geometry of the object. When general or local corrosion takes place, the pattern of electric field will change and can be compared to the signature. By proper interpretation of the changes in the potential differences, conclusions can be drawn regarding general wall thickness reduction or localized corrosion.

Figure 1 shows an illustration of the principle. The induced electric current in a pipe will create a pattern determined by the geometry of the structure and the conductivity of the metal. This pattern is represented by current flow lines and equi-potential lines which are normal to the current flow. The subsequent potential measurements on each pin pair (up to 400 pin pairs can be applied in a matrix) are compared to the unique field signature and the changes processed to define the change in pipe wall over time.

The accuracy and resolution of the field signature method depends on factors like:

- Wall thickness of monitored object
    - Thinner walls give better absolute resolution
- Distance between sensing electrodes at the monitored object
    - Longer distance gives better resolution for general corrosion
    - Shorter distance gives better resolution for localized attacks
    - Hence, sensing pin distribution is normally adapted for each individual case, based on the purpose of monitoring and the type of corrosion expected.
- Measurement frequency
- Available power

Based on the above, it is difficult to give a general statement for the resolution, but the following rules of thumb are normally applied:

- Permanent monitoring stations – sensitivity for general corrosion is 1/1000 or 0.1% of the monitored object's wall thickness
- Subsea systems – sensitivity for general corrosion is 3/10000 or 0.03% of the monitored object's wall thickness

- Systems with manual data collection and direct current feeding – with a limited measurement frequency sensitivity for general corrosion is 5/1000 or 0.5% of the monitored object's wall thickness
- Permanent logging instrument based on direct current feeding principle (under development) – expected sensitivity for general corrosion is 3/10000 or 0.03% of the monitored object's wall thickness

The resolution of the system is less than that of intrusive corrosion probes, but is considered significantly better than other inspection methods like ultrasonics, radiography, etc.

The field signature method can also identify localized attacks at the monitored object, e.g. weld root corrosion or localized corrosion attacks. The method measures such localized attacks between the sensing electrodes, hence, localized attacks within the monitored area will be detected.

With the software package normally used with the system, localized pits will be identified, and propagation of such attacks can be followed directly by the user.

1.1 Permanent FSM Stations

The FSM stations for continuous logging are based on the transformer based current excitation technique, and can be supplied as a stand alone battery powered logging stations. The equipment comprises:

- The instrumented pipe section with current feeding transformer, sensing pins with wires and connectors, and a protective cover.
- A self-contained, battery powered logging station, preprogrammed for automatic interrogation at regular intervals, and storage capacity for several months of operation based on one reading per day (monitoring frequency can be set by the operator).
- Data communication system. Three main options are available:
    - A data retrieval unit for downloading the readings directly to a PC.
    - On-line communication with RS 232 cable or fiber optics.
    - Digital communication - several monitoring stations may be fitted locally, one at each location, and connected via a two pair field bus cable to a field interface unit (FIU). FIU can be installed in the control room or in a protective enclosure in the field. In the latter case, a range of (wireless) communication options are available (see section on communication options).
    - A dedicated software package.

Transformer based systems are convenient for long term battery operation and therefore suitable for autonomous monitoring stations in the field. Transformer based systems can be supplied with certification for zone 1 (Class 1 Division 1). Figure 2 shows the hardware of an FSM system installed on an underground pipeline in South America.

1.2 Field Signature Measurements – Manual Data Collection

In order to make a more flexible and cost effective alternative the IT (Inspection Technology) version was developed. The main elements of the "IT" version of the system are as follows:

- A Sensing Matrix (SM) of electrodes is attached to the external wall of the pipe or vessel to be monitored. Current feeding is applied directly to the monitored section (a transformer as used for permanent stations is not applied).
- A Sensing Matrix Interface (SMI) forms the interface between the SM and a portable instrument for taking measurements.
- A portable instrument providing direct current feed to the SM, data acquisition and data storage. Data is transmitted from the portable instrument to a PC where the MultiTrend software is installed.
- MultiTrend software for data storage, analysis and reporting.

This concept reduces the cost per monitored location significantly compared to the traditional FSM stations.

Figure 3 shows a typical arrangement for use of field signature method with a portable meter for data collection.

Applications:

The "IT" version of the system has many applications, but the most important have shown to be;

- Corrosion monitoring at high temperature locations in refineries, typically for monitoring naphtalenic corrosion and to control the effect of high tan crudes. High temperature SMs can be installed at pipes up to 450 ^{o}C
- Installation at underground pipelines or piping/pipelines, particularly for applications under sour conditions.

Figure 4 shows the equipment for manual data collection installed in Canada. Results from use of this technology in Canada are presented in several papers by Bich et al.[5, 6, 7]

1.3 New On-line, Continuous Monitoring System based on "Direct Current Feeding Technology".

A limitation with the "IT" version of the system is that manual data collection at remote locations is time consuming and costly. Even for monitoring locations closer to the user (e.g. in refineries) the manual data collection limits the amount of data that will be acquired and therefore available for data analysis and trending.

A new field signature instrument is now being developed based on the direct current feeding technology, with the following objectives:

- Continuous logging of data at an affordable cost
- Continuous data will increase data available for analysis and trending, and will increase the resolution of the system significantly
- Reduced cost through reduced operator and transport cost for data collection
- Integration with other corrosion monitoring technologies in an integrated system, e.g. for remote wireless communication direct to client's offices
- Option for upgrading of "IT" systems for manual data collection to on-line logging systems

The new on-line system will be available early 2008.

2 HIGH TEMPERATURE APPLICATIONS IN REFINERIES.

Important advantages of the FSM technology are;

- The method is non-intrusive, and does not create any risk of leaks of hot or aggressive fluids. At high temperatures, sealing is more complicated, and consequences of leaks can be more serious.
- FSM matrixes can be installed at pipes with temperatures up to 500 ^{o}C

These advantages have made the portable FSM technology attractive for use in refineries, where there are many monitoring locations. In a refinery several permanently monitored locations can reasonably efficient be handled by one portable instrument.

Refineries often use different types of crude oils. Different crudes have different price, but also corrosivity. Generally more acidic crudes (higher TAN numbers) are more corrosive than less acidic crudes (lower TAN numbers). Hence, for the more acidic crudes active corrosion mitigation are important. Good and reliable monitoring of the crude corrosivity contributes to optimized use of potentially more corrosive crudes (opportunity crudes) and thus reducing cost, while still controlling corrosion and the integrity of the plant.

The data examples shown in figure 5 are from a refinery where FSM with manual data collection is used for optimizing use of various crudes. It shows FSM data from a refinery, showing reduction of corrosion rates for a high TAN crude from 5, 9 mm/year to approximately 0,2 mm/year through using corrosion inhibitors. The slight negative trend over the period september to march can be explained by seasonal temperature changes. This effect can be eliminated by using tempeature compensation for the data.

Figure 6 shows a close up of data in period May to August 2005, showing effect of changed crudes and actions to control corrosion. In period June 10 to June 23 crude “A” was used, in the period June 23 to July 26 a Crude “B” and “C” were used. From approx June 25, crude with corrosion inhibitor was used. The plot shows clearly effect on corrosion rates with a different type of crudes, and the effect of using corrosion inhibitors.

Figure 7 shows how information from all pin pairs of the FSM matrix can be presented as an alternative bar graph plot. This plot version makes identification of localized attacks easier. In this case corrosion seems to be relatively uniformly distributed over the monitored area.

Although refinery applications are good for using portable monitoring systems, an on-line system would still provide more monitoring data, giving increased resolution, more realiable trending and earlier information to client. Client has now therefore ordered on-line FSM systems for their new refinery project.

3 COMMUNICATION OPTIONS

Instruments for intrusive corrosion and sand/erosion probes, as well as field signature instruments can receive power and communication through field interface units (FIUs). Up to eight corrosion or sand/erosion instruments, or four field signature instruments can be connected on-line to one FIU instrument.

The on-line system is designed with the flexibility to use the communication solution most convenient in each individual case and offers the following options:

- Hardwired digital communication (RS 232, RS 485)
- LAN/Ethernet
- Radio modems
- Telephone: Standard telephone modems, GSM or Satellite telephone

The system can schematically be presented shown in Figure 8.

Power consumption for the FIU is only 7 W, which makes the system suitable for powering via solar panels, see figure 9.

4 PILOT INSTALLATION AT PIPELINE, BRASIL

A pilot wireless system was installed in South America comprising of the following components:

- Two corrosion instruments for ER probe monitoring
- One field signature measurement station for permanent non-intrusive corrosion monitoring
- One Field Interface Unit (FIU) for providing power and communication with the 2 CorrLog instruments and the FSM station
- One solar panel for providing power to the FIU
- Modem for data communication via GSM network from the location.

Although some initial problems were encountered mostly due to the selection of GSM telephone operator and provision of the right type of SIM cards, the wireless communication system has worked well. This indicates that the system can be controlled and data be received from any location, e.g. from the operator's main offices, or even from the supplier service base in Norway. Results from this pilot installation were presented by ad Silva et al in the Rio Pipeline conference 2007.[2]

Figure 9 shows the equipment for wireless communication installed for this pilot installation (Picture kindly yielded by Petrobras).

5 SUMMARY AND CONCLUSIONS

- Monitoring internal corrosion in remote pipelines utilizing traditional methods is costly and requires a lot of personnel time. An on-line, continuous monitoring system would reduce recourses required, and at the same time increase accuracy and quality of data obtained.
- The high temperature and non-intrusive features of the FSM makes it suitable for use in refineries, and FSM has become an important tool to optimize use of various crudes in refinery processes.
- A new version of on-line field signature measurement will be released to the market shortly, providing higher accuracy and a more affordable price than before.
- A range of wireless communication options are available, and a pilot test has been performed in Brasil verifying that such technology can be used in the field. Solar panels can be used to provide power.

- With the flexibility in communication options available, wireless communication can be applied more or less at any pipeline location.

ACKNOWLEDGEMENT

Thanks to Petrobras for kind approval to use of pictures of remote monitoring system and to Reliance Industries Limited approval to refer to their use of the FSM technology in refineries.

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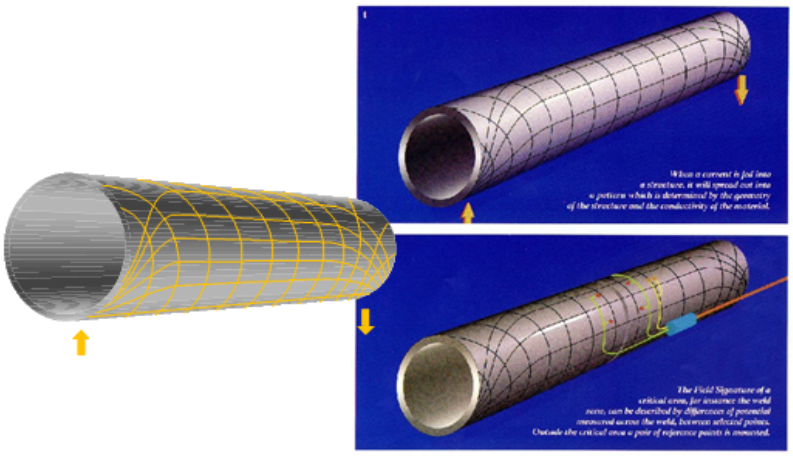


Figure 1 – Technical Principle of Field Signature Method

Figure 2 – Permanent field signature equipment installed on underground pipeline equipment later to be buried

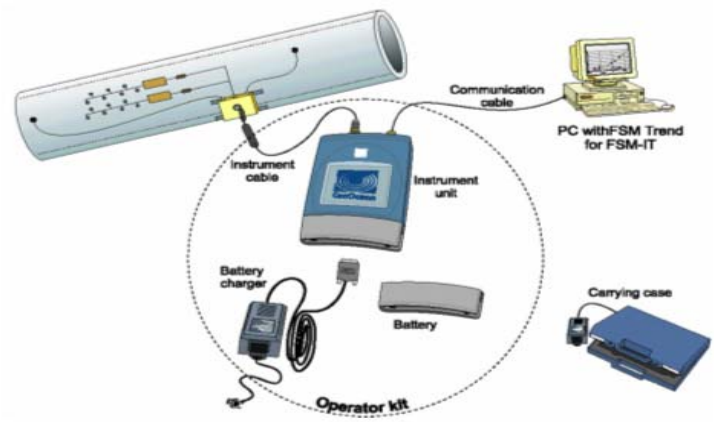
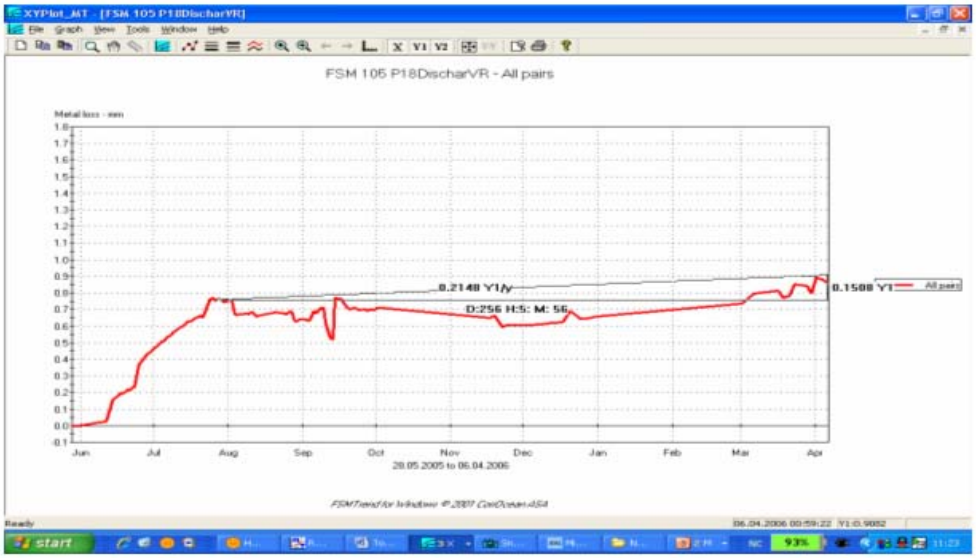


Figure 3 - Typical arrangement for "IT" version of the field signature method – data collection using portable meter

Figure 4 - shows IT installed on underground pipelines in Canada
a) installation of sensing pin matrix to the pipe
b) providing external protection to monitored area
c) the only visible item on location today is the connection post



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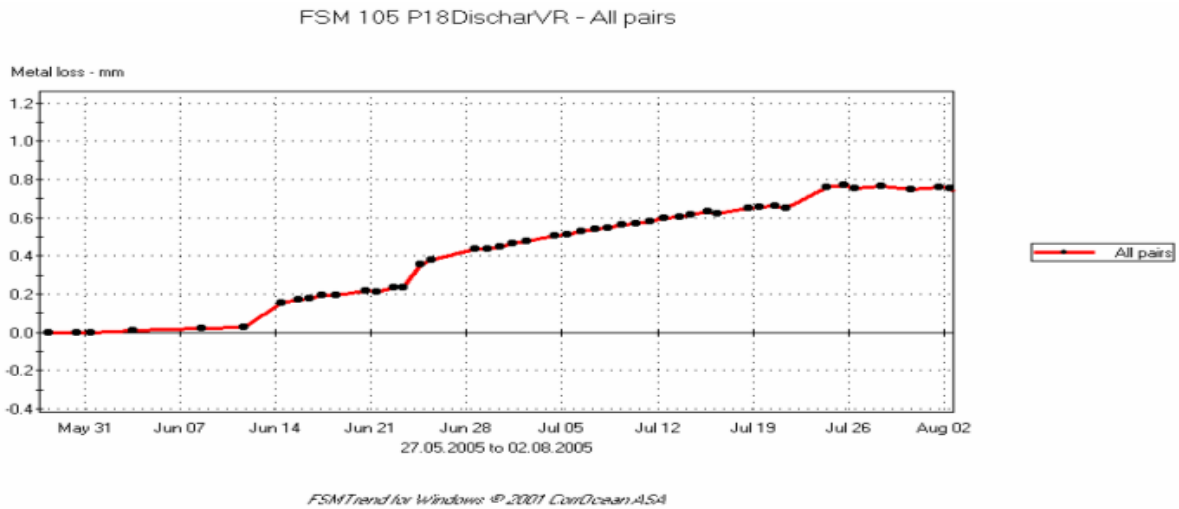

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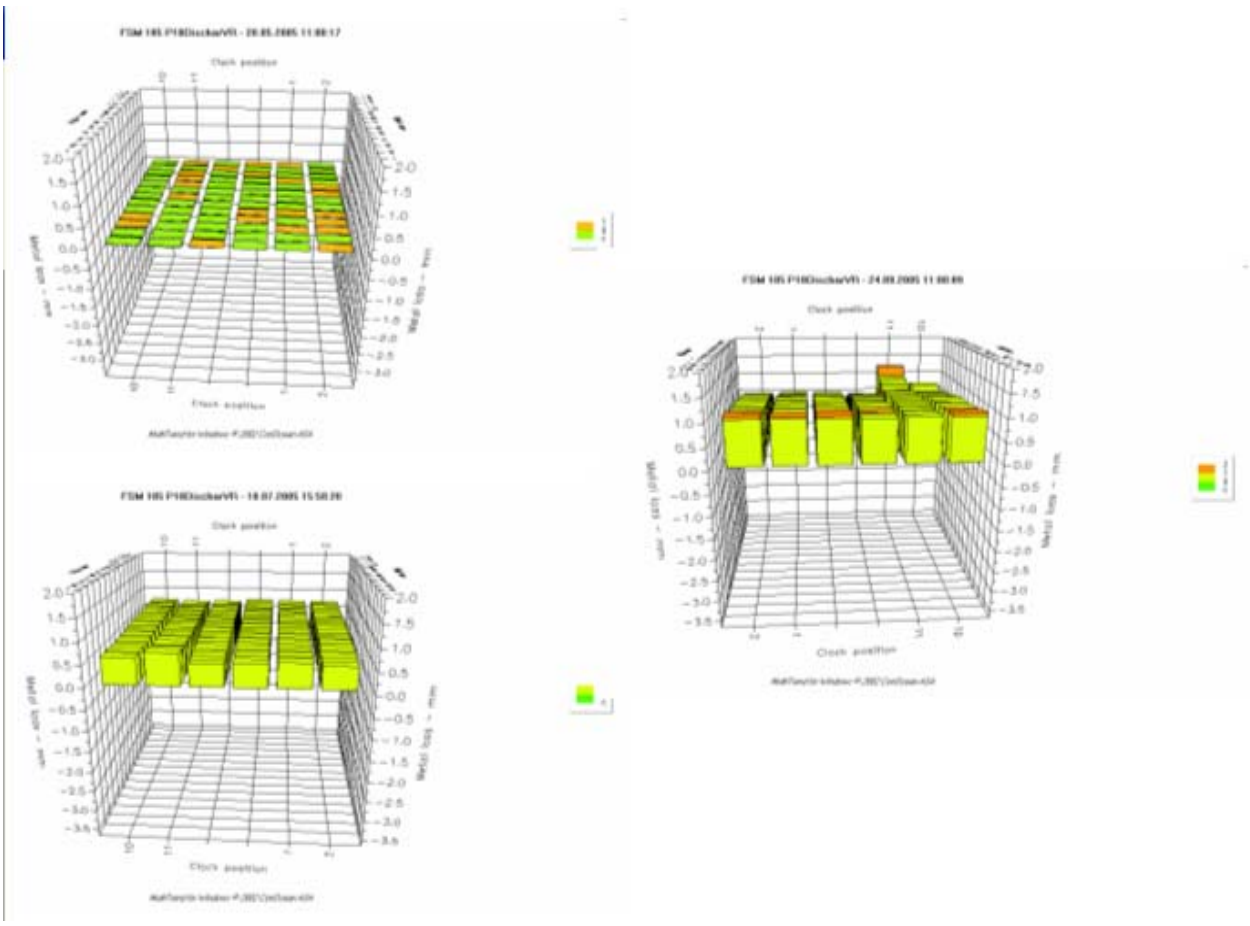

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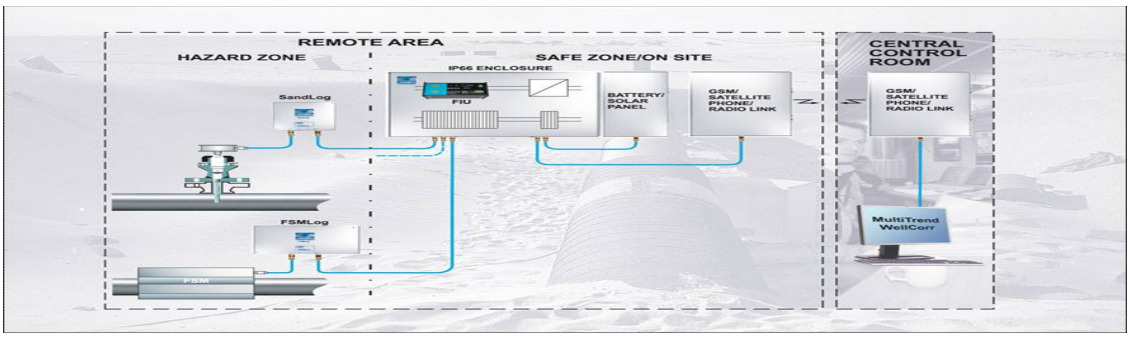

Figure 8 - Typical configuration for wireless corrosion monitoring system. FSMLog and SandLog instruments are connected to same Field Interface Unit, which is powered by solar panels. System communicates with main office via GSM modems

Figure 9 - Corrosion probes installed in hydraulic access fittings, CorrLog instrument, FSM instrument and Field Interface Unit installed in pit. Power supply via solar panel. (Picture kindly yielded by Petrobras)