MANAGING INTEGRITY OF FEED CONDENSATE PIPELINE: ON-LINE INTERNAL CORROSION MONITORING VIA ELECTRIC FIELD MAPPING (EFM) AND FIELD SIGNATURE METHOD™ (FSM™) TECHNIQUE

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1. Introduction

PETRONAS Gas Berhad (PGB), a subsidiary of Malaysia’s national oil and gas corporation, PETROLIAM Nasional Berhad (PETRONAS), processes, transports and supplies natural gas and utilities to petrochemical plants. PGB through its operating division, Transmission Operations Division (TOD) currently operates and maintains the nation’s 2,554 km of high pressure on-shore gas pipelines ranging from NPS 2 up to NPS 48. TOD has been operating the pipelines for more than 24 years and has kept good track record with regard to pipeline safety.

One of TOD’s pipelines is the 10” pipeline which carries high pressure i.e. 90 barg feed condensate to PGB’s gas processing plant for further processing to produce sales gas, propane, butane and stabilised condensate, which are the main sources of revenue to the company. The pipeline was commissioned in 1998 and it was equipped with the typical internal corrosion control and monitoring facilities i.e. corrosion inhibition skid and corrosion coupon respectively. Realising the importance of the pipeline in terms of business needs and the fact that the highest risk of pipeline failure is from internal corrosion, TOD in 2003 has installed relatively new technique for on-line internal corrosion monitoring i.e. the Electric Field Mapping/Field Signature Method (EFM/FSM™).

2. Objectives of the paper

This paper is a report on the evaluation of the usage of non-intrusive monitoring technique i.e. EFM and FSM™ to continuously monitor internal corrosion activity in the 10” feed condensate pipeline environment. FSM™ is located at 0.4 km and EFM at 13.5 km downstream the scrapper launcher station of this 15.1 km pipeline. The product flowing in the pipeline consists of humidified natural gas, condensates, organic/water mixture and the environments at 12 and 6 o’clock positions of this pipeline carrying multiphase gas/liquid flow. This paper will summarize on internal corrosion control and monitoring program of the feed condensate pipeline and also the effectiveness of the non-intrusive...
technique and its advantages against corrosion coupon and ER probe (the conventional monitoring systems).

3. Internal Corrosion Control Programs

Realising the corrosiveness of the transported product, a comprehensive internal corrosion control program is established for the pipeline that consist of (i) internal pipeline cleaning, (ii) corrosion inhibitor (CI) batching, and (iii) CI continuous injection. The integrity program was further enhanced in 2003 onwards by equipping the pipeline system with relatively new technology of internal corrosion monitoring systems i.e. FSM™ and EFM.

The internal pipeline cleaning activity is conducted using 2 sets of multi-diameter cleaning pig. A water base cleaning chemical called “Degreaser” with 10% concentration is being injected to the pipeline with a volume of 1,500 liter prior to the launch of the first cleaning pig. A 5% concentration of the same degreaser of the same amount is injected right after the first pig was successfully launched. The third run pig is a specially design multi-diameter filming pig. CI of 2,000 liter with 10% concentration is injected upfront then followed by the filming pig launching. The function of the filming pig is to form a very thin layer of CI film approximately 3-4 mils thickness. This film will protect the internal pipeline surface from the corrosive environment.

The formation of CI film is not as rigid as internal coating. It can be easily washed away by sludge or extreme flow regime of the product. This is where continuous injection plays its role. A total of 30 liters of CI with 35% concentration is being gradually injected every day to patch the defective CI film. The injection skid is equipped with 2 sets of pump and a 900 liter stainless steel CI tank. Only one pump runs at a time where the other one is put on standby. The pump operation will be switched every 2 weeks.

All the above corrosion control activities have been run for 8 years and the internal corrosion rate of the pipeline has been significantly reduced to an acceptable level.
Photo 1: Multisize Pipeline cleaning and CI filming Pig

Photo 2: Corrosive sludge / carry over after pigging
4. **Internal Corrosion Monitoring Programs**

The internal corrosion monitoring programs for the pipeline consist of the following:

i. Product/sludge analyses
ii. Corrosion coupon and ER probes monitoring
iii. EFM/FSM monitoring
iv. In-line inspection via MFL tool

In order to gauge the effectiveness of the implemented corrosion control programs, there should be a comprehensive internal corrosion monitoring program. The monitoring results obtained from various monitoring system shall be correlated and hence conclude the internal corrosion rate of the pipeline being monitored. Selection of monitoring location is also important and it will significantly affect the result. As for the 10” pipeline, it is installed with an intrusive and non-intrusive type of monitoring systems. The intrusive monitoring system consists of Corrosion Coupon and Electric Resistance (ER) Probe located at above ground piping of scrapper launcher and scrapper receiver stations. Both probes are installed at 6 and 12 o’clock orientation and located at the un-piggable section of the pipeline system. The non-intrusive type i.e. FSM™ is installed about 400 meters and EFM is located 13.5 kilometers downstream the scrapper launcher i.e. on the piggable pipeline section.

The collection of monitoring data frequency can be done by daily, monthly or yearly depending on needs. The more the data, the higher the resolution of the monitoring result obtained.

5. **EFM/FSM™ Design, Installation and Operation Philosophy**

The EFM/FSM™ monitoring system is used to measure corrosion damage over a relatively large section of a structure. It 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. The first measurement that is based on actual wall loss is unique to the geometry of the object. The induced electric current in a structure will create a pattern determined by the geometry of the structure and the conductivity of the metal. When general or local corrosion occurs the pattern of the electric field will change and can be compared with the first measurement. Essentially successive measurements are used for comparative purposes, to detect a change in the degree of corrosion damage.

A non-intrusive method of internal corrosion monitoring is having great advantages against other intrusive method such as corrosion coupon and ER Probe. Besides of having wider selection of possible installation location which is not restricted to above ground and underground application, the EFM/FSM™ measurement of internal corrosion rate is based on actual wall loss experienced by the pipeline. The result is more consistent throughout the monitoring period since the steel surface that is being monitored
remains the same and this system requires no consumables in order to continue its operation for years long.

The installation of EFM/FSM™ does not require any pipeline shutdown. With the enhancement in communication technology, the monitoring data can be transferred instantaneously from field to analyst’s desk top PC at any place in the world and at any time required. The operation of EFM is merely not requiring corrosion technician to come to the site to collect data throughout its operation.
The sensing element made of hundreds of pins that are arranged in a matrix to form a permanent monitoring plane on the external pipeline surface. Sensing pins, strategically positioned over the area of interest, are used to measure the voltage response to an induced current. These pins are typically separated by a distance of 2-3 times wall thickness. It is the change in the measured voltage distribution (the electrical field "pattern") that is related to a change in wall thickness of the instrumented structure. The advantage of having this monitoring plane is that the growth of existing pitting/metal loss area can be observed and the newly developed area can be detected as well. Since the sensing pins are permanent, the monitoring can be done at similar location for years and hence the accuracy of the result increases.
EFM also monitors pipe and ambient temperatures and adjust its potential measurement in real time, so that data can be analyzed for high-resolution monitoring of complex, internal corrosion with pitting that is invisible to other inspection techniques.

The heart of the EFM operation comes from the Remote Monitoring System (RMS) that is located at above ground. All potential measurements from pin pairs are directed and captured by sets of multiplexers inside the monitoring system. The data then converted to suitable communication format and transmitted via GSM data modem to user. The DMAT software is used to process the received data from field to provide operators with sophisticated 3-D data interpretation and analysis, with contour maps to highlight important data trends.

The basis of selecting the location to be installed with EFM/FSM™ is depending on operator’s preference. As for PGB, the in-line inspection result of Magnetic Flux Leakage (MFL) has become a guideline for location selection. The MFL report lists all locations of metal loss and based on this, a location that is having higher number of metal loss area has been chosen. For the purpose of optimization, pipeline section with lower percentage of metal loss was given higher priority to be equipped with EFM. By doing this, we can prolong the service life of EFM since pipeline repair / replacement can be scheduled at much later time (if required).
6. **Internal Corrosion Monitoring Results of EFM/FSM™**

The analysis on the monitoring result obtained from field will be performed by Fox Tek for EFM and Corrcana Technology for FSM™. The reporting frequency has been made on monthly basis and every submitted report will contain data of short term corrosion rate, long term corrosion rate and the deepest known defect corrosion rate. Since corrosion activity is highly depending on product composition and flow regime, it is not recommended to take the short term corrosion rate to represent the internal corrosion rate for the entire line. Long term corrosion rate will provide a better picture because it is a cumulative wall loss experienced by the pipeline since the monitoring begun.

![Figure 6: EFM DMAT 2D illustration](image1)

![Figure 7: EFM DMAT 3D illustration](image2)

Results from all monitoring systems will be integrated to justify the effectiveness of the internal corrosion control program. The alteration of current corrosion control program may be needed depending on the monitoring result. It is important to keep the corrosion control activities dynamic rather than routine for cost optimization purposes.
7. Conclusion

The EFM/FSM™ technique has proven beneficial in managing the risk of failure due to internal corrosion for the NPS10 feed condensate pipeline. Essentially, it provides the level of comfort and confidence in combating the internal corrosion in terms of the efficiency of the corrosion control program for mitigating internal corrosion risk for the pipeline. Comparing to corrosion coupon and ER Probe as previously used, the EFM/FSM™ is much more efficient in determining the internal corrosion growth due to the fact that it measures directly on the pipe body as suppose to coupon and probe that measures on reduction of the weight of the coupon/probe which is not part of the pipeline.

The EFM/FSM™ monitoring system has provided effective integrity management for the 10” pipeline. It has abled the pipeline operator to monitor and adjust the internal corrosion control programs accordingly that undoubtedly has prolong lifespan of the pipeline. The maintenance expenses i.e. for pipeline repair have been reduced as a result of the effective monitoring provided by EFM/FSM™. With the continuous on-line monitoring, pipeline repair can be planned well ahead thus eliminating emergency pipeline repair work and environmental impact which can be costly.