ADVANCEMENTS IN SPRAY PIG APPLICATIONS

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Corrosion Impacting Pipeline Integrity

Pipeline integrity is the goal of pipeline owners and operators throughout the world to ensure that the pipeline infrastructure remains fit for purpose with due regard to safety and the environment. PIM (Pipeline Integrity Management) Plans are commonly in place defining the appropriate responses to mitigate threats to pipeline integrity which occur throughout the pipeline's life cycle, from construction to operations to decommissioning. Corrosion is still the most common and frequent failure mechanism worldwide in aging or new facilities alike. A recent review of all transmission pipelines currently in service in the Gulf of Mexico [Ref.1] reported that 39% of damage was attributed to corrosion, with internal corrosion damage four times as frequently as external corrosion. These statistics could be considered more or less representative for the corrosion phenomenon globally.

Internal corrosion can lead to production reduction as corrosion by-products accumulate in the pipeline and, in the event of a through-wall failure, can cause extensive hazard to people and damage to asset and the environment. Corrosion therefore generally commands the highest attention in PIM Plans in terms of its detection, monitoring and treatment. The industry is creating innovative technologies and approaches as well as novel materials in a quest to continuously improve corrosion management practices. Two of these innovations are addressed in this paper.

Efforts to mitigate and control internal corrosion generally focus on corrosion prevention, achieved by eliminating or reducing the factors which cause corrosion. Typical measures are for instance:

- Eliminating the electrolyte for corrosion cells to develop by limiting the amount of moisture in the pipeline.
- Removal of corrosive products, such as hydrogen sulfide, carbon dioxide, oxygen and other contaminants such as sulfate reducing bacteria or acid producing bacteria.
- Limiting the number of low points and elevation changes during pipeline design to avoid areas where moisture naturally collects.
- Routine pigging of lines in service to remove water, service rust and deposits that affect the corrosion rate.
- Use of corrosion inhibitors such as conventional amine-based inhibitors. In most cases this is the most practical and effective method to prevent corrosion.

Corrosion Inhibitors

Corrosion inhibitors have proven to be very effective at reducing the overall corrosion rate when added to the pipeline product in small amounts. The inhibitors are generally introduced into the pipeline by injection, either as slug treatment or continuous injection, or most commonly as batch treatment employing a chemical column between two pigs. Two performance factors are important to ensure an effective inhibitor application program:

- Effective lifespan. Inhibitors typically perform for two to three months which requires frequent re-applications to ensure a continuous corrosion protective surface.
- Contact with all pipe wall internal surfaces. Pipe wall coverage is affected by flow type and velocity, and tendency of the inhibitor to fall to the bottom of the pipe or pool in low spots due to pipe geometry and elevation changes. This often results in inconsistent or inadequate pipe wall coverage in particular in the upper quadrant of the pipe circumference. This latter phenomenon can lead to top-of-the line corrosion (TLC) especially in wet, high carbon dioxide multiphase gas gathering lines. Subsea pipelines are particularly susceptible to TLC attack due to condensation settling in the upper circumference especially in the pipe section immediately following the riser pipe as seawater cools the gas while it goes down the riser.

Alternative Inhibition Methods
Operators seeking to overcome the limitations for an effective life efficiency and pipe wall coverage, often associated with conventional inhibitor applications, are looking for alternative treatment options. This may include the application of corrosion inhibitors by an innovative “spray pig” technology.

<u>The V-Jet® Spray Pig</u>
The novel method to apply corrosion inhibitor is based on patented V-Jet® “spray technology”. Developed by T.D. Williamson (TDW), the V-Jet® Pig features a series of front-mounted spray nozzles to ensure that the inhibitor, introduced into the line with the pig, is dispersed around the full circumference of the inner pipe wall, including the “hard to reach” top of the line areas in the upper quadrant. Using differential pressure and bypass flow, the inhibitor is siphoned from the bottom of the line and sprayed to the topside, giving the pipeline full, 360-degree coverage. The flow through the bypass creates a Venturi effect that draws up the inhibitor fluid from the bottom of the pipe and produces a dense inhibitor “cloud” ahead of the pig, extending the contact time and overall effectiveness of the inhibitor. Any third party inhibitor can be applied with the V-Jet® Pig. The V-Jet® Pig is highly effective at controlling TLC in multiphase gathering lines and was also found to be effective as a stand-alone dewatering pig.

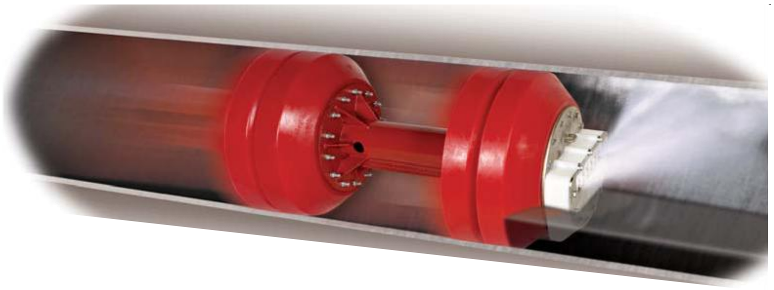

Figure 1: The V-Jet® Spray Pig

Application Method
The V-Jet® Pig can be run with any corrosion inhibitor. However, the recommended procedure for the inhibitor application remains the same and is listed below in a series of sequential steps:

1) Clean the pipeline, or validate the cleanliness.
2) Treat the line with biocide if needed.
3) Install corrosion coupons
4) Apply the corrosion inhibitor batch pig train
5) Check coupon to validate treatment coverage.

1) <u>Cleaning the Pipeline</u>
Inhibitors can be easily applied in newly constructed lines or on-stream flowing gas lines, or crude oil and product lines using a batching process. As with any type of inhibitor, it must be applied correctly to a clean surface in order to maximize its effectiveness. First, a series of proving/cleaning pigs should be run to determine if the line is piggable and clean or if further mechanical or chemical cleaning before applying the V-Jet® spray pig.

The cleanliness level should be equivalent to that required for an in-line inspection run. The inhibitor must contact the pipe wall in all at-risk areas including corrosion pits to be effective. This is where another innovation can be used, the PITBOSS™ Pig. This is a pit-cleaning brush pig which has individually sprung wires that can scrape into corrosion pits that conventional pig brushes cannot penetrate. These wires are effective in picking out debris stuck inside these pits so that sprayed chemicals will lubricate the pit cavities as well.

Figure 2. Various Cleaning Pigs, The PITBOSS™ Pig is shown on the right

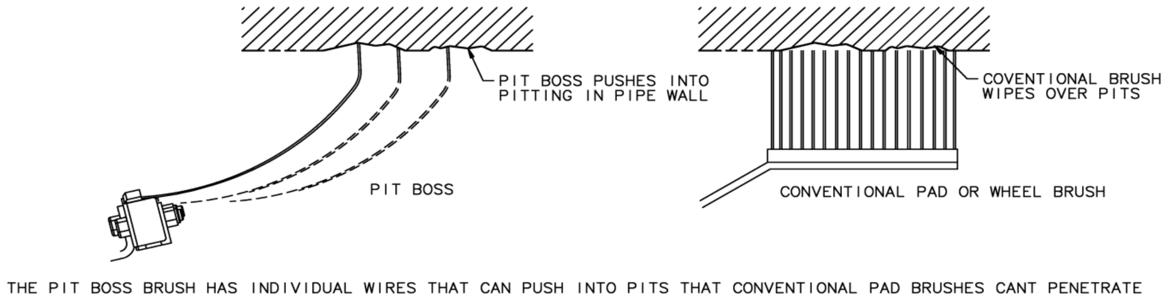

Figure 3. PITBOSS™ Pig Wires Vs. Conventional Brushes

2) Treating the line with biocide
   After cleaning, it is recommended to treat the line with a biocide to sterilize the pipe surface and kill any microbes that might contribute to micro-biologically influenced corrosion (MIC).This is to ensure that any remaining active colonies are starved or killed. The compatibility of the biocide with the inhibitor used must be established in conjunction with the inhibitor treatment.
3) Installing corrosion coupons
   If not yet installed, corrosion coupons or small hot tapped coupons should be strategically placed throughout the pipeline in order to determine coverage rate, inhibitor effectiveness and corrosion rates and knowing when to re-apply the coating system. Analysis of the retrieved coupons will provide this information.
4) Applying the inhibitor batch pig train
   Once the line is determined to be clean, a series of pigs including the V-Jet® pig are launched while injecting the inhibitor. The application procedure should be based on the specific operating conditions and line configuration, taking into account variables such as injection nozzle location and elevation.

   A typical train configuration in natural gas service consists of a batching pig, spray pig and foam wiper pig. The spray pig can be positioned either as the front or the back pig. It may be necessary to slow or stop flow during inhibitor injection since it is preferred to maintain the inhibitor as a single batch within the pig train.

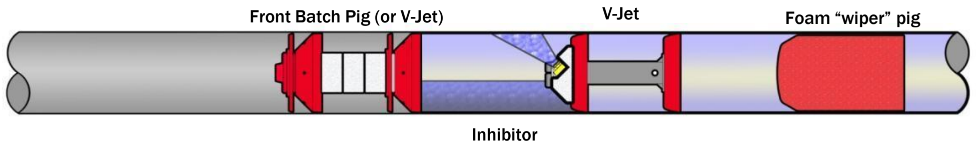

Figure 4. Batching in Gas Lines with V-Jet® Pig as Rear Pig

In liquid applications, the carrier liquid is used as a dispersant for the inhibitor, which is simply batched between two pigs with a foam wiper pig trailing. In this case, no spray pig is used. However, it is important that the batch size be restricted in length in order to ensure proper application.

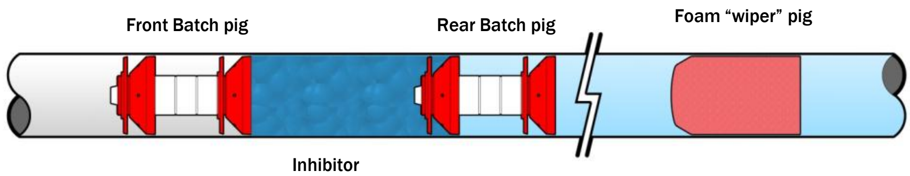

Figure 5. Batching in Liquid Lines. No V-Jet® Pig is Used

5) Results

The V-Jet® spray pig has been extensively tested to validate its effectiveness and performance in third party lab tests and TDW's test facilities and subjected to rigorous field exposure. The V-Jet® Pig is highly effective at controlling TLC in multiphase gathering lines. In one example, corrosion rates fell by an order of magnitude, from greater than 4 mils per year to a range of 0.2 to 0.42 mils per year [Ref.2]. More than 40 V-JET® Pigs have been sold to support customers in the USA and Asia mitigate TLC in their gas pipelines. The V-JET® Pig was found to be most effective and more efficient in terms of operating costs when run as a stand-alone dewatering pig as it effectively redistributes the inhibitor-containing liquids from the bottom of the line to the top of the pipe in a dense cloud form.

Quality Control

To gauge the effectiveness of an inhibitor run, it is necessary to know whether the inhibitor fluid has been successfully delivered to the pipe surface, and at the desired film thickness. For onshore pipelines, use of corrosion coupons and frequent, regular monitoring is a good way to validate success. Due to the lack of access to offshore pipelines, the best method for gauging the effectiveness of corrosion inhibition in subsea pipelines is through the use of inline inspection (ILI) tools. These tools are costly and infrequently run, typically after every couple of years. This inherent time gap between a chemical treatment and inspection creates a potential delay in detecting problems in inhibitor application. In light of this gap, a special V-Jet® Pig was equipped with an on-board data logger, incorporating some existing inline inspection technologies for data acquisition along the pipeline length, and run in some offshore pipelines to validate the tool's performance. The important parameters which were recorded during the pig run along the line length are as follows:

- **Rotational orientation.** In order to be effective, the spray pig must deliver inhibitor to the top of the pipe. The data acquired by the logger offered a complete profile of the pipeline throughout the run, including tool orientation (spray nozzle and port orientation). The pig sensors indicate whether the entire top of pipe had been properly sprayed or if and, from odometer data, where an improper orientation took place in the pipeline relative to expected or known corrosion areas.
- **Differential pressure.** The spray pig gauges pressure at both the front and back of the pig, allowing for the calculation of the differential pressure across the pig body. Pressure differential is of key importance to achieving proper jetting action, since bypass flow and differential pressure are the dynamics that create the Venturi effect which drives the spraying action.
- **Pig speed.** The spray pig should stay within speed limits to allow for proper contact time between the inhibitor and pipe wall. The pig's odometer generates the speed profile on the run as well as the accurate location of events. Inhibitor contact time for each specific

pipe segments of interest can be calculated, and can help establish future frequency of spray pig usage.

- **Acceleration.** Speed excursions are typical when pigging in gas lines but these are not conducive to consistent inhibitor application. Matching the data with the location obtained from the odometer provides a good overview of the overall jetting performance in a run.
- **Temperature.** Gauging line temperature throughout a run can highlight areas that may be most susceptible to corrosion, in particular TLC which is believed to occur in specific temperature ranges.

References

1. Powell, Daniel, 2008, "Integrity Management for Piggable and Non-Piggable Subsea Pipelines," Paper No. 08135, NACE Corrosion 2008 Conference & Expo.
2. Freeman, Eric N. and Williamson, George C., 2007, "New Technology Effective In Reducing Top-of-the-Line Corrosion Rate," Pipeline & Gas Journal, January 2007.
3. Payne, L.; Freeman, E.; and Wint, D. 2012, "Breakthrough in Inhibitor Science Fights Internal Corrosion," Pipeline & Gas Journal, June 2012.