Paper No.

02-1119

BUSINESS AS USUAL?
CORROSION IN A
CIRCULAR ECONOMY

In-line Inspection Experience with Lined Upstream Pipelines

Luc Simon
Shell Canada Limited
PO Box 1088
Pincher Creek, Alberta, T0K1W0
Canada

Neil Hay
Shell Canada Limited
400 – 4 Avenue SW
Calgary, Alberta, T2P0J4
Canada

Reg MacDonald
74 Gleneagles Close
Cochrane, Alberta, T4C1N8
Canada

ABSTRACT

An internal corrosion failure occurred in one of Shell Canada's (Shell) high density polyethylene (HDPE) lined sour gas pipelines in 2007. That failure led Shell to shut in all of its lined sour gas pipelines until the integrity of each could be verified and the internal corrosion mechanism was under control. The presence of a non-metallic liner within the pipelines made full in-line inspections (ILI) challenging. The removal and re-installation of liners had been the typical way to complete such ILI with magnetic flux leakage (MFL) smart pigs, but this was not practical in this case. Existing remote field testing (RFT) ILI tools were available and had been used by industry to inspect unlined pipelines, reinforced-concrete and cement mortar lined (CML) pipelines. It was this technology that was chosen to inspect the lined sour gas pipelines with the liners in place. The use of repeat RFT ILI since 2008 has provided verification of integrity and confirmed the pre-existing internal corrosion mechanism is now under control. The inspection success with HDPE lined pipelines led Shell to use the same technology to recently inspect a 28yr old CML produced water pipeline. External corrosion at disbonded coating locations was confirmed active on the pipeline. The RFT ILI allowed Shell to schedule repairs and continue use of the CML pipeline.

The ability to ILI existing lined pipelines without removing the liners is a tremendous advantage to Shell. RFT ILI of lined pipelines was novel in the past but is now considered a normal practice. This paper summarizes the experience and shares the learnings of the successful application of RFT ILI technology, which became an important part of Shell's pipeline integrity management program.

Key words: pipeline, inspection, in-line, RFT, verification, sour gas, liner, produced water, corrosion, CML, HDPE lined, cement lined, integrity management.

INTRODUCTION

Shell has been producing sour gas in Western Canada since the 1950's. It has used steel pipelines for the majority of its sour gas gathering systems. It often used HDPE lined sour gas pipelines in the few situations where elemental sulphur was probable in the raw production, and where pig and batch inhibitor application was restricted or difficult. A pipeline incident in 2007 led Shell to develop the ability to ILI its HDPE lined sour gas pipelines.

Shell also operates a few CML produced water disposal pipelines in some oil and gas field operations including one in the Waterton field. Since the water disposal pipelines are required to maintain oil and gas production in such producing fields, the water disposal pipeline integrity verification was imperative. Verifying the integrity of CML lined water disposal pipelines is not possible with conventional MFL ILI tools because of the sensor standoff that results from the cement liner. Shell's success with RFT ILI tools in the HDPE lined sour gas pipelines led to its use in the Waterton CML pipeline.

RFT ILI Technology

RFT is a pipeline inspection technology that does not require intimate contact with the metallic pipe wall (Ref. 1). The technique has been deployed in water pipelines since the mid 1990s. In most unlined metallic water mains, heavy internal scaling prevents direct contact with the pipe wall, again limiting the effectiveness of the traditional magnetic and ultrasonic inspection technologies. RFT inspection tools for water pipelines have typically been deployed by tether from a single access due to the lack of launch and receive stations. The tether is also used for providing power to the RFT inspection tool.

Given the relatively heavy thickness of HDPE liners and the need to prevent damage to the liner, RFT technology is particularly well suited to inspect HDPE lined pipe.

The RFT effect was first noted in the 1940's and was patented in 1951. In the late 1950s Tom Schmidt at Shell Development independently rediscovered the technique while developing a tool for the inspection of oil well casings. Schmidt spearheaded the development of the technique and branded it "Remote Field Eddy Current", in order to distinguish it from conventional Eddy Current Testing (ECT). The technique as used in industry is now commonly referred to as RFT, or "remote field testing". The name "Remote Field Technique" minimizes confusion with ECT and underlines the magnetic field interactions exhibited by RFT.

Remote Field Technology tools work by detecting changes in an AC electromagnetic field that is generated by the tool and interacts with the metal in the encompassing pipe. The field is generated by the exciter section of the tool and detected by an array of receivers. On board electronics measure the time delay (phase shift) and the signal strength (amplitude) of the AC electromagnetic signal. The receivers are positioned circumferentially so that they are sensitive to the many clock locations of the pipe circumference. A basic RFT ILI tool setup is shown in Figure 1.

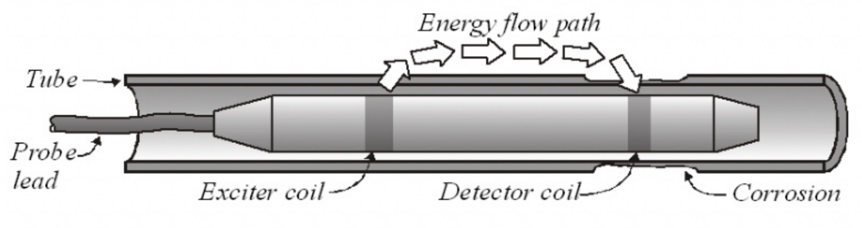


Figure 1: Basic RFT ILI Tool Configuration

An RFT ILI tool that is tuned to the electromagnetic coupling along the outside of the pipe can determine the thickness of the pipe wall – even if the tool is dimensionally smaller than the pipe internal diameter (ID). This through-transmission characteristic makes RFT an attractive technology for high lift-off inspections since the tools can be (significantly) undersized w.r.t. the ID of the pipe. Typical high-lift-off applications include scaled or lined pipelines, pipelines with more than one pipe size and pipelines with tight (small radius) elbows. Because RFT does not magnetically saturate the pipe wall, RFT ILI tools will detect magnetic permeability changes as well as changes in the wall thickness. It differentiates thickness increase from wall loss and in addition to wall loss, RFT measures the combined parameters:

- Wall thickness
- Electrical conductivity
- Magnetic permeability

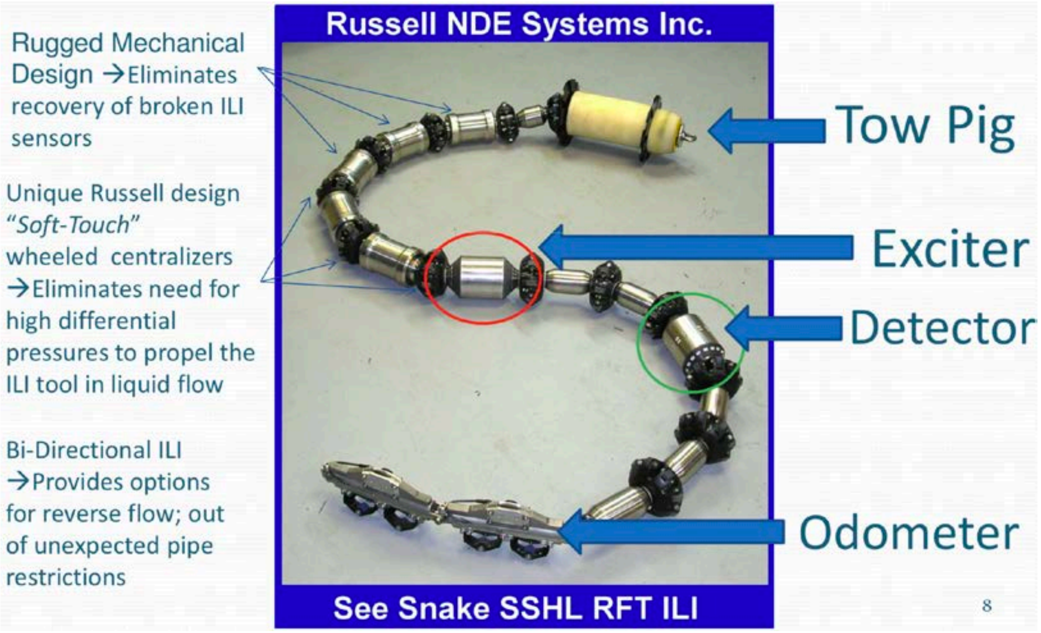
This allows RFT to identify:

- Stress (local and global)
- Bends (induction, cold-formed, etc.)
- Ferromagnetic objects nearby

For the successful inspection of HDPE lined pipe, the traditional RFT ILI tools had to be customized, i.e.; re-engineered. Some of the main additional design criteria that needed to be fulfilled:

1. Higher operating pressures (min 600 PSI).
2. On board rechargeable battery power to support Free Swimming Operation.
3. On board odometers and on board inertial measuring unit (IMU) to locate and help grade anomalies.
4. Matching the ID of HDPE lined pipe (which will be very different from the (standard) unlined steel pipe ID.
5. Ability to accommodate limited amounts of liner collapse.
6. Incorporate "soft-touch" materials on the outside of the tool to prevent damage to the internal liner.
7. Ability to accommodate oversize pipes. The lined pipe sections are occasionally interrupted by above ground risers that are unlined and can include valving and other ID changes. The tool must be able to bridge these internal upsets and transitions.

The tool shown in Figure 2 is the RFT ILI tool for 6-inch HDPE lined pipelines.



Russell NDE Systems Inc.

Rugged Mechanical Design →Eliminates recovery of broken ILI sensors

Unique Russell design *"Soft-Touch"* wheeled centralizers →Eliminates need for high differential pressures to propel the ILI tool in liquid flow

Bi-Directional ILI →Provides options for reverse flow; out of unexpected pipe restrictions

See Snake SSHL RFT ILI

Figure 2: RFT ILI Tool and Components

HDPE LINED SOUR GAS PIPELINES

In 2007 Shell experienced a lined sour gas pipeline failure in its Waterton field in southwestern Alberta. The cause of the failure was internal corrosion behind an intact HDPE liner, or corrosion behind liner (CBL). Subsequent to the pipeline failure, Shell shut in all lined sour gas pipelines until it could verify the integrity of the pipelines and understand the corrosion mechanism. Verifying the integrity of the pipelines with conventional MFL ILI tools was not practical. Partnering with an inspection company to develop an RFT ILI tool for these pipelines provided the verification of integrity for continued operation of its lined sour gas pipelines. The details of the incident and the initial ILI inspection results have been reported in the enclosed references (Ref. 2, 3, 4, 5, 7).

Shell's earlier work showed that the use of continuous methanol injection for hydrate control caused CBL and that lined pipelines with no continuous methanol injection experienced no CBL. The methanol in combination with the H2S and CO2 led to the CBL. The past work includes both a detailed corrosion study and the initial RFT ILI results to confirm the corrosion mechanism. Shell's 2009 restart required a change to its operating strategy to no longer allow continuous methanol injection for hydrate control in lined sour gas pipeline systems.

Shell partnered with Russell NDE Systems Inc. (Russell) to develop an RFT ILI tool for Shell's custom pipeline internal diameters of its lined NPS6 and NPS8 pipelines (Ref. 3). The thick HDPE liner precluded the use of other ILI techniques (Figure 3). MFL requires intimate contact of the sensors with the pipe wall and ultrasonic testing (UT) cannot measure through the liner. Removal of liners to allow MFL or UT inspection was not practical.

RFT ILI tools have been successfully used in other "high lift-off" applications and can have over 25mm separation between the pipe wall and sensor. Because plastic liners have no effect upon the field perturbations generated by wall loss indications this technology can inspect through HDPE liners. In fact, it can inspect through any internal coating or liner that is not ferromagnetic.

Figure 3: Lined Sour Gas Pipelines - ILI Technology Challenge

Calibration pipes were built to demonstrate the new ILI tools capability to detect the internal pits and grooves that were caused by the CBL in Shell's lined sour gas pipelines.

Calibration of the RFT tools established the threshold of detection (ToD) limits:

- Scans were conducted at different inspection frequencies for the Remote Field Excitation.
- Scans were performed at varying inspection velocities.
- Tool ToD at the nominal inspection velocity were established:
    - 20% x 1" diameter in 219mm (8in) pipe
    - 35% x 3/4" diameter* in 168mm (6in) pipe

In addition to calibration pipes, a section of NPS6 pipe from the 2007 failed pipeline that contained CBL damage was retained for the verification of inspection tools. The new NPS6 RFT ILI tool was pulled through this section of pipe and the results compared to automated ultrasonic testing (AUT) results. The pipe section with actual corrosion damage was helpful in demonstrating the tool's ability to detect actual CBL (Figure 4).

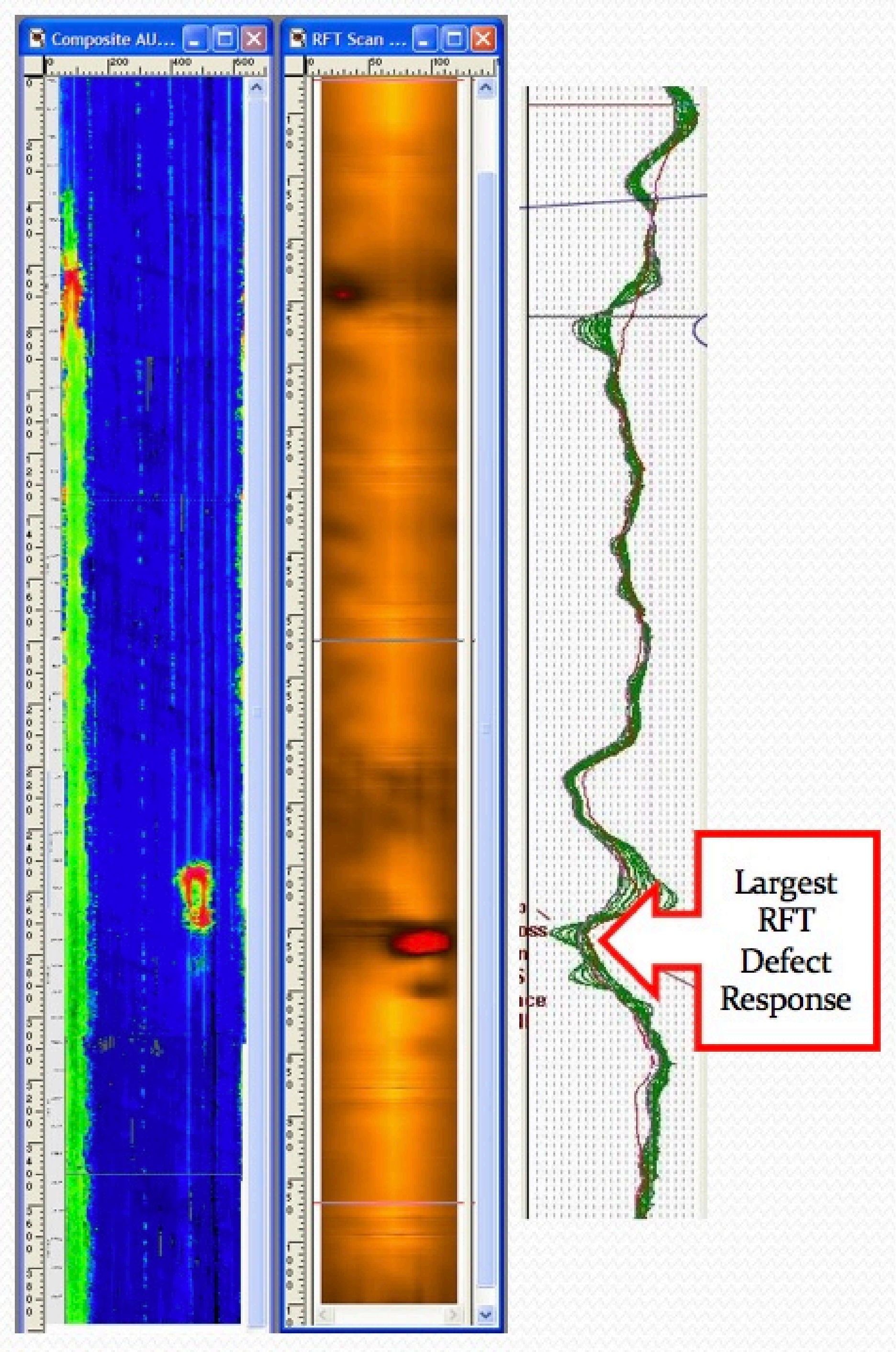


Figure 4: Corroded Section of NPS6 pipe from upstream of the 2007 failure
Left to Right: AUT scan; RFT scan; RFT signal response

RFT ILI Inspection Accuracy and Effectiveness

Shell's RFT ILI tool runs are completed by pumping the RFT ILI tool with water (or pulled as tethered tool in short pipelines) at speeds of approximately 3 m/min or 5 m/min dependent on selected tool frequency. Multiple runs with RFT ILI have been completed since 2008. Repeat inspections show excellent reproducibility between RFT ILI runs.

Verification digs were completed with conventional UT and radiographic testing (RT) results for integrity-based decisions on whether to repair the lined pipeline anomalies or not. Verification dig Thickness Measurement Locations (TML's) at risers and in permanent bell holes were routinely tracked to monitor the CBL rate.

The calibration pipes and subsequent inspection verification dig results were used to determine the RFT ILI tool's defect sizing accuracy for Shell's "thick walled" HDPE lined pipelines (Ref. 3, 5). Figure 5 compares the RFT ILI reported depth (vertical axis) to the measured (dig verification UT) depth (horizontal axis). Data in blue on the graph on the right is based on five years of calibration and dig verified data for defects above the ToD. Defects below the ToD are detected, conservatively sized, and monitored for change (as shown by the orange data points).

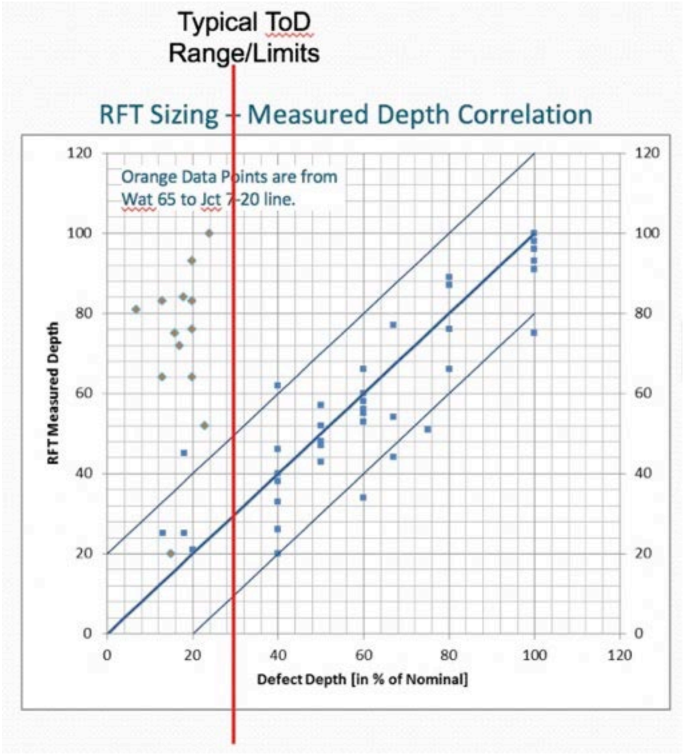


Figure 5: RFT Tool Defect Sizing Accuracy

The RFT ILI results demonstrated only a couple locations where continuing CBL occurred after pipeline restarts. The TML results confirmed that CBL was only experienced at a minor number of TML's being monitored and was only active intermittently. Inspection results show how the existing CBL pitting stopped subsequent to the removal of continuous methanol injection for hydrate control. In a few pipelines CBL was found to continue for a short time before stopping. It is expected that liner annulus fluids still contained methanol even when shut in. The pre-existing methanol isn't removed from the annulus fluids until the pipeline is operated at a higher temperature and annulus gas flow effectively vaporized and removed it, thus CBL would continue for some time after restart. The RFT ILI results also showed that external corrosion was not found to be a problem in any of the HDPE lined pipelines. In one particular case the RFT ILI reported a localized stress with possible wall loss. This was verified through a dig program and identified as a dent with an included linear crack indication.

One such location where the RFT ILI tool detected CBL activity for a short time after restart, demonstrated the ability of RFT ILI to detect wall loss defects. Figure 6 illustrates the RFT ILI data from before restart in 2008 and in 2010 when the inspection shows wall loss anomalies. The 2010 ILI report indicated 3 anomalies at 45%, 25% and 20% deep. Later Dig Verification NDE confirmed the depths to be below that, at 18%, 16% and 14%; demonstrating the ability of RFT ILI tool to detect anomalies below it's ToD.

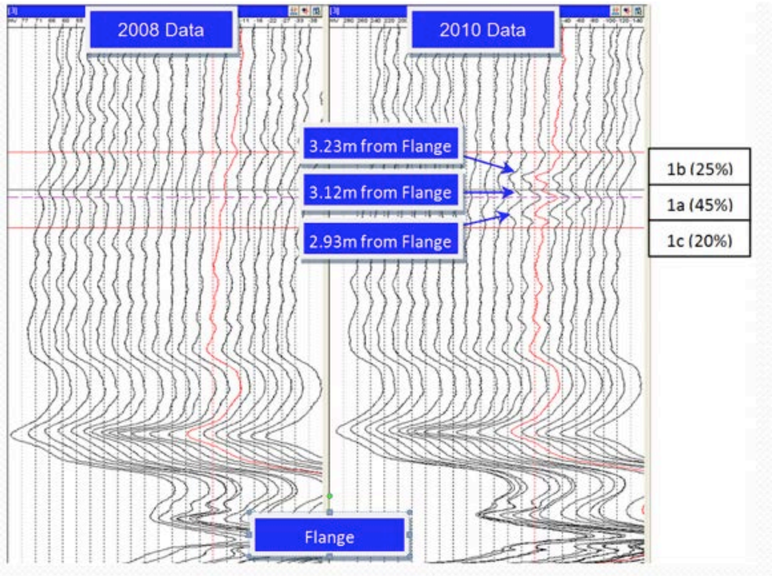


Figure 6: 2008/2010 RFT ILI Log Comparison – Corrosion Pitting Detection

Key Learnings from Multiple RFT ILI Tool Inspections

Shell had challenges arise and lessons learned during its completion of several RFT ILI tool inspections in HDPE lined pipelines that are considered helpful for others to be successful:

As part of most ILI projects in the planning stage, calibration runs are performed to define the ILI tool's ToD and aid in the analysis of the inspection data during future pipeline inspections. Calibration pipes must be the same diameter, grade, wall thickness and ideally from the same lot of pipe used in the original construction of the pipeline are recommended by Russell, and having the pipeline survey drawings helps quantify the results of the inspection. The use of rock-jacketed pipe consisting of reinforced concrete coating and/or pipe casings, will both introduce a different magnetic permeability from the pipe itself and cause changes with the data interpretation if its location isn't known. This is especially true if the pipeline was built in sections through intermittent rocky terrain or has unknown cased crossings.

Launcher and receiver pig barrels should be designed to accommodate the full length (~ 4m) of the RFT ILI tool and provide the ability to send or receive the tool from either end of the pipeline (i.e. bi-direction pig launchers). The ability to send pigs in either direction can help if cleaning pig, gauge/IMU pig or RFT ILI tool becomes stuck in the pipeline. In such cases, options are needed to push the pig or bi-directional tool backwards to the launch site.

Speed control is essential with the RFT ILI Tool, for good data quality and accuracy. In the Shell Waterton field the terrain is mountainous. In such hilly terrain the topography should be evaluated and if possible, plan the RFT ILI tool run in the predominant uphill direction, to avoid speed excursion. In most of Shell’s sour gas pipelines, it displaces the sour gas and runs the RFT ILI tool in a water filled pipeline to allow optimal tool speed control.

Due to slower travel speeds when compared to conventional MFL, the pressure pump trucks need to be sized accordingly in the range of 60-80 l/min pump rates and in addition care must be taken as to not overpressure the system due to the tool’s maximum recommended working pressure (3500 kPa). The effect of head pressure in mountainous terrain should be considered to avoid tool damage.

If there are steel risers or camel back risers in your pipeline, then ensuring a smooth transition of the ID from liner to steel riser is imperative for smooth passage and to avoid tool getting damaged or stuck. The tool hitting the smaller ID liner flange stub end could cause damage to the liner.

Conventional multi-diameter style pigs are not well suited for internally lined pipelines, but Russell’s dual density foam pigs have been used successfully to clean and dewater without damaging the HDPE liner (Figure 7).

Figure 7: Dual Density Foam Tow Pig

It’s important to include a gauge/IMU pig run prior to each RFT ILI tool run. The gauge/IMU pig (Figure 8) is run prior to the RFT ILI tool to ensure there are no excessive liner restrictions that would prevent safe ILI tool passage. The Gauge/IMU tool provides a record of the location and severity of any pipeline restrictions caused by partial liner collapse and/or swaging at the flanged liner stubs. It also records the locations of all major construction features including pipeline bends which helps in accurate positional location and interpretation of results.

Figure 8: Gauge/IMU Pig

HDPE lined flange pair restrictions have led to pigs becoming stuck during earlier ILI runs. Shell had unlined above-ground pipe spools with emergency shutdown valves that were temporarily replaced with pipe spools that had the same internal diameter as the lined pipe. This was done to allow the RFT ILI tool smooth passage through the full pipeline length with optimal speed control. The subsequent requirement to replace the liner flange retainer ring with a narrower ring after each ILI run (this is needed to ensure a seal on the liner flange face) led to increased ID restriction when completed. The restriction was identified as "cold flow" of the HDPE into the internal diameter adjacent to the flange face and led to blocking of the ILI tool and therefore had to be removed. United Pipelines Systems (with Shell's input) developed a procedure to mechanically remove the liner protrusion at all of the liner-to-bare-steel flange connections. A jig was built by United Pipeline Systems and modified by Shell to allow for both electric and air driven tools to remove the excess HDPE from the liner flange stub end ID. Shell later replaced line break valve spools with thicker pipe to allow ILI tool passage without the temporary pipe spool removal.

In some cases when making or breaking flange pairs damage, such as scratches or gouges to the liner flange faces can occur. The solution to this is often to pull out and then cut replace the liner flange stub end. Shell avoided this due to its concern for the effect of absorbed hydrocarbon liquids in the existing liner on the new stub end flange fusion. Shell chose to develop a procedure for an in-situ repair of gouges by melting new HDPE material into the gouge followed by machining or sanding the repair flush to the stub end flange face (Figure 9). By doing so, Shell avoided cutting the liner flange stub end off and the risk of having a poor HDPE fusion.

Figure 9: Left to Right; Damaged liner flange stub end, HDPE filler strips applied to fill areas of material loss and Finished stub end after sanding

Cathodic protection (CP) causes interference with the RFT ILI tool's remote field technology and must be turned off during the RFT tool ILI run.

At the time of this paper, the HDPE lined pipelines have been operating up to 9.5 years since restart. Shell has used RFT ILI tool runs repeatedly for 8 to 10 times per each operating lined sour gas pipeline during this time frame and inspection data has demonstrated the good repeatability of the RFT inspection technology (Figure 6 shows an example of this).

CML PRODUCED WATER PIPELINE INSPECTION

Shell has operated CML produced water pipelines in its Western Canada operations that were installed in the 1980's. The ability to ILI such pipelines was not part of the original design concept, yet after 28 years of operation, it was realized that the ability to ILI the CML pipelines was important to verify integrity and ensure ongoing safe operation.

Shell's in-line inspection experience with its HDPE lined sour gas pipelines was the basis for choosing RFT ILI technology for inspection of its 13.6km long NPS4 CML produced water pipeline in the Waterton sour gas field. The pipeline was designed with 20D field bends and no buried fittings between the risers. The design intent was to achieve a reliable internal CML pipeline without any problems in the cement lining. The pipeline was the only produced water disposal pipeline in the Waterton field and as such was business critical to the field's condensate liquids and natural gas production.

The original risers were internally bare steel with 45-degree fittings. Piping upstream and downstream of the pipeline was internally bare steel from design. Conventional inspection of the above ground piping over the pipeline's 28yrs of operation has shown insignificant internal corrosion. It is thought this result was due to a combination of the continuous corrosion inhibitor present in the produced water from the sour gas gathering system and its low operating pressure and temperature.

The main integrity concern was for external corrosion due to the older Yellow Jacket YJ1 coating system and experience with the sour gas pipelines with such coating systems.

RFT ILI Tool Run

In order to verify the integrity from end to end, the ability to use the RFT ILI tool would provide that. The original risers were replaced with sweep bend risers and permanent installation of a pig launcher and receiver. This allowed the scheduling of an RFT ILI run during an upcoming field/plant outage. During the outage, the 3.20in RFT ILI tool with a 42Hz frequency could be pumped through the CML pipeline with fresh water at the required speed (10 m/min) and allow for any significant anomalies to be repaired prior to restarting the pipeline.

Prior to launching the 3.20in RFT tool for inspection, multiple (8) pigging runs were performed using foam pigs, squeegee pigs, gauge pigs, grit ball pigs, polyurethane pigs and ribbed pigs of different sizes and durometers. These pigging runs were propelled with fresh water for the purpose of cleaning the pipeline and increasing its effective bore size. The initial pigging runs showed significant buildup of asphaltene/corrosion inhibitor sludge in the line. Subsequent pigging runs were able to reduce this buildup in the line.

An initial IMU/gauge pig run identified a minimum bore size smaller than the 3.2in RFT ILI tool. Subsequent IMU/reamer/gauge pig (Figure 10) runs were then performed at an approximate velocity of 30m/min in an attempt to remove the hard calcium carbonate deposits in the pipeline and to confirm the bore size of this pipeline. Although visible damage was observed on the centralizers of the IMU/gauge tool, the final gauge run concluded with deflections on the gauge plates recording a minimum bore restriction of 3.213in (81.610mm). Although this was 8.2% smaller than the tool design specification the line was considered borderline safe for passage of the 3.20in RFT tool.

The 3.20in RFT tool was launched from the gas plant where the tool travelled 475m before reaching a series of impassable bore restrictions in the line. The tool fortunately was designed to be bi-directional and was pumped backwards from the disposal well end towards the launch site and was successfully retrieved from the launch barrel. Visible abrasion marks on the tool's surface suggested a tight fit to the inner diameter of the line due to suspected high deposit buildups of calcium carbonate scale. It was apparent that more aggressive reaming and cleaning of the line would be required to increase its bore size to a level that would allow smooth passage of the 3.20in RFT tool. Due to the uncertainty and the variability of the bore size through the pipeline, the contingency plan of using a smaller diameter 2.39in RFT Tool was used in place of the original 3.20in RFT tool to complete the inspection. The 2.39in RFT tool was launched and it successfully navigated through the line and covered the complete 13.6km (average velocity of 9.9 m/min).

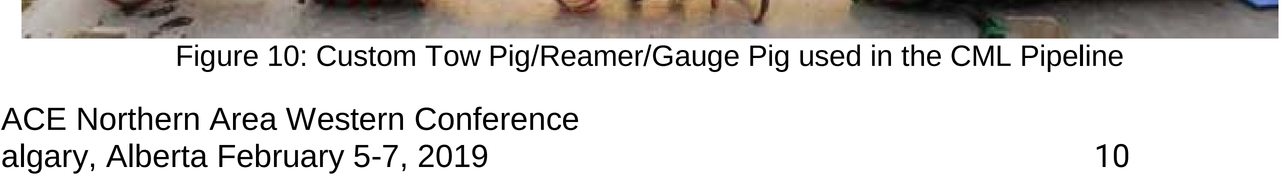


Figure 10: Custom Tow Pig/Reamer/Gauge Pig used in the CML Pipeline

Verification Digs to Validate ILI Tool Results

Two stages of dig verification were undertaken.

The first 4 dig verifications were restricted to “Imminent Threat Indications” that were verified during the Plant outage. Significant external corrosion was detected at each, with through-wall pits in three locations and 86% wall loss at the fourth location. The external coating had been damaged or disbonded. The cement lining was in good condition at the through-wall pits and withstood the low operating pressure to maintain the pipeline integrity without leaks. Eventually this corrosion mechanism would have resulted in a produced water spill. Figure 11 shows one of the through-wall pits. Coincidently these 4 primary sites happened to all occur within the 5.6mm WT pipeline segment (i.e. first 2500m of pipeline).

Figure 11: Through-Wall External Corrosion Pit from CML Pipeline.

After VT/RT/UT prove-up of the 4 primary sites a detailed analysis utilizing a secondary calibration for the 6.02mm WT pipe was performed to determine if any significant indications could be identified within this thicker pipe which accounted for an additional 10,963m of pipeline length.

These additional 7 dig verifications were selected to rule out the potential for lower confidence indications that were grouped into three specific indication categories:

1. Anomaly within girth weld.
2. Anomaly within cut-back area of Yellow Jacket both U/S & D/S of field tape wrap joints.
3. Mid-pipe anomaly away from field tape wrap joints.

Although these secondary indications could potentially size up to 85% WL it was understood that the 2.39in RFT ILI tool in the heavier 6.02mm WT pipe would have reduced resolution compared to the 5.6mm WT pipe. At the time we did not have a pipe specimen that would accurately determine the ToD for the 2.39in RFT ILI tool. These were exploratory digs used to refine the analysis of results in the 6.02mm NWT pipe. The results were used to confirm that the 6.02mm NWT segment of this 13.4km long pipeline was in good condition.

The ability to run RFT ILI on this CML pipeline was of great value to Shell. New risers, pig barrels, inspection, verification and repair work represented less than 20% the cost of total pipeline replacement. In addition, the inspection and timely repair prevented a potential future failure that could lead to production restrictions, produced water trucking/disposal cost and spill cleanup cost. It also identified that a section of pipeline had reduced WT which helps to improve the integrity management plan going forward.

Installing risers, pig traps, and running an ILI tool was a much lower cost than replacement of the water disposal pipeline.

INSPECTION IS PART OF LINED PIPELINE SYSTEM INTEGRITY MANAGEMENT PROGRAM

Alike internally bare steel pipelines, RFT ILI tool use in lined pipelines should be used in conjunction with other inspection, monitoring and sampling activities during operation. The multiple monitoring methods provide for timely notification of any changes that can alter the internal or external corrosion rate on the pipeline system. We recommend the following activities in addition to RFT ILI and CP monitoring/maintenance:

<u>HDPE lined pipelines:</u>

- Annulus vent samples – liquid and solids analyses.
- Annulus vs line pack pressure monitoring to verify liner integrity (i.e.; no liner breach exists).
- Select TML’s where UT can be used to determine corrosion activity and measure actual corrosion rates behind the liner.
- Profile RT at above ground risers.

It has been proven that internal CBL in lined sour gas pipelines has become insignificant since we’ve revised our operating procedures to prevent continuous injection of methanol for hydrate prevention. “Real-time” corrosion monitoring devices were used for 8 years following pipeline restarts and also confirmed that the CBL became very low. External corrosion has yet to become a significant threat in these pipelines, but future ILI will be used to verify this.

<u>CML lined pipelines:</u>

- Check screens at disposal wellhead to check for pieces of cement and/or plastic coating.
- Check orifice plates and other fittings for evidence of sludge which can indicate chemical incompatibilities.
- Select spool inspection by RT, UT and/or visual means.

External corrosion is the main corrosion threat on this CML produced water pipeline and infrequent ILI’s can be used to verify condition of mitigation going forward. RFT ILI of lined pipelines is currently available and can be used successfully to maintain safe operation over long term.

CONCLUSIONS

Lined pipelines have performed well at preventing internal corrosion in Shell’s sour gas pipelines and water disposal pipelines. The risk of external corrosion and potential internal corrosion on HDPE lined pipelines warrants the periodic inspection of Shell’s lined pipelines.

RFT ILI technology allowed Shell to:

1. Verify the integrity of its HDPE lined sour gas pipelines and help to confirm it’s change in operating practice in 2009 was successful in reducing the internal corrosion threat and,
2. Verify the condition of its 28yr old CML water disposal pipeline and to remove 4 significant external corrosion pitted areas prior to a pipeline leak.

With the high lift-off application in our HDPE lined sour gas pipelines and CML water disposal pipelines, RFT can detect defects below its ToD and conservatively size wall loss defects. Shell was able to be confident in the pipeline system integrity with this ILI capability.

The successful use of RFT ILI tools requires the Operator and the inspection company to understand and run the ILI job within the limits of the technology and to work as a team. The application of this inspection technology required Shell and Russell to re-calibrate more than once and to adapt based on dig verification learnings. The learnings allowed improvements to be made with both the ILI tool and the run practices so future inspections were more successful.

The ability to in-line inspect and repair the existing lined pipelines was of tremendous advantage to Shell. Shell has subsequently designed new lined pipelines to be capable of running RFT ILI tools. To be successful, lined pipelines shall be designed with full opening valves, appropriately sized pig barrels, sweep risers and bends to accommodate ILI tool passage. Sharing the learnings in this paper will hopefully assist other operators to be successful with their inspection plans.

ACKNOWLEDGEMENTS

Special thanks for the technical and execution of this application of RFT ILI tools as provided by Daniel Lingnau, Ad Shatat and the many staff of Russell NDE Systems Inc. who are responsible for successful pipeline inspections.

REFERENCES

1. A. Shatat, M. Korz, D. Russell, Inspection of Lined Pipelines with In-line Inspection Tools, Gas&Oil Expo & Conference 2011, Calgary, AB
2. 04703 Shell Canada Limited Sour Gas Pipeline Failure, Licence No. 23800, Line No. 61, November 19, 2007, ERCB Investigation Report - October 7, 2008
3. L. Simon, R. MacDonald, K. Goerz, "Corrosion Failure in a Lined Sour Gas Pipeline – Part 1: Case History of Incident", Feb. 2010, NACE Northern Area Western Conference
4. R. MacDonald, L. Simon, K. Goerz, "Corrosion Failure in a Lined Sour Gas Pipeline – Part 2: Role of Methanol in Corrosion Behind Liner", Feb. 2010, NACE Northern Area Western Conference
5. M. Bonis, M Girgis, K Goerz, R MacDonald, Corrosion/06, paper n° 06122, "Weight loss corrosion with H2S: Using past operations for designing future facilities", (NACE International, Houston, TX), 2006
6. "In-Line Inspections of Shell Canada Energy's HDPE Lined Pipelines Using Remote Field Testing (RFT) In-Line Inspection (ILI) Tools", Russell NDE Systems Inc., January 31, 2013, Waterton 68 Hearing Submission
7. M. Bonis, R. MacDonald, Corrosion/15, paper no 2015-5718, "H2S + CO2 Corrosion: Additional Learnings from Field Experience", (NACE International, Houston, TX), 2015