In-pipe Ultrasonic Inspections of Mud and Tailing Lines: how to manage difficult to remove Scaling, provide quality and accurate Defect Assessments of steel and HDPE

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Abstract

Rio Tinto Yarwun Aluminium Refinery (RTY) is expanding its pipeline integrity assessment technologies. As part of this effort, RTY has been working with Intero Integrity Services (Intero) to introduce Intero's Pipeline Surveyor services, a free-swimming pipe inspection tool.

Rio Tinto is one of the world's largest mining companies, operating in 25 countries with a portfolio that includes iron ore, copper, aluminum, lithium, and other materials needed for everyday life. The Yarwun Aluminum Refinery located in Gladstone, Australia is operating since 2004. Australia is a country with very strict regulations and a tight social license to operate.

There is a need to provide it's owners with suitable technologies and methods to offer inspection technologies not only to detect pipeline defects, but also to evaluate the integrity and safety of their pipelines.

RTY has been working since 2019 to introduce Intero's Pipeline Surveyor as inspection technology for difficult-to-inspect mud, slurry, and caustic pipelines. In 2021 an inspection was carried out on an 8kms steel mud line of DN750.

This paper will provide an overview of the Pipeline Surveyor technology and information on the evaluation of inspections conducted for its application in Australia.

1. Introduction

RTY's has an in-house department for asset integrity with expertise in pipeline integrity assessment technologies. This chapter presents the background of this initiative and the technologies that RTY currently possessed.

1.1 Background

The total length of mud and slurry pipelines at Rio Tinto worldwide will be hundreds of kilometers. This can be broken down between steel and HDPE pipelines. All pipelines in Australia are constructed in accordance with AS2885 and take in consideration these lines can be in some very remote areas.

Due to asset aging, environmental changes, as well as government regulations, emphasis is beginning to be placed on pipeline maintenance and management, and interest in integrity assessment technologies is growing. In response to these changes, Rio Tinto has begun to expand integrity assessment technologies.

1.2 Integrity Assessment methodology of RTY

RTY has proprietary methodologies for pipeline maintenance and integrity assessment. RTY did not have a technology to assess the integrity of the pipe body. Therefore, this aspect needed to be expanded.

There are many mud and tailing pipelines in Australia. In addition, since there are many pipelines with complex alignments that weave through gaps in other infrastructure, there are many "unpiggable" pipelines in Australia. Therefore, RTY has been working with Intero since 2019 to apply Intero's free swimming, Pipeline Surveyor, in Australia.

1.3 Pipeline Surveyor

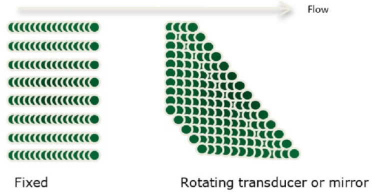
For maximum flexibility, the system applies a contact-free ultrasonic measuring head that is able to scan the full surface of the pipe wall. Dual diameter, mitered bends, full-bore unbarred tee pieces, and single-entry configurations are well within the capabilities of our system and can be inspected utilizing regular, high, and ultra-high resolutions. The pipeline Surveyor aims for unpiggable pipelines ranging from 2" to 64" and located from subsea offshore to remote areas anywhere in the world.

Matrix

- Multiple transducers evenly distributed over the tool's circumference
- High speed

Helix

- Rotating mirror covering entire pipe wall
- Flexibility to increase resolution and/or measurement grid



2. Preparation

Mud and tailing lines tend to have thick layers of scaling which requires a tailored cleaning program.

2.1 Selecting the right inspection method

Although the pipe characteristics allowed for a Magnetic Flux Leakage (MFL) inspection, the anticipated amount of scaling had the potential to result in a blockage. A combination of pipe geometry factors, such as back-to-back bends, multiple wall thicknesses, as well as a very tight receiving area too small to receive an MFL tool, resulted in Intero's Pipeline Surveyor being selected for the job. The biggest challenge using an UT ILI tool was getting the pipeline sufficiently clean.

2.2 Launching and receiving

For launching the permanent installed equipment was to be used. The launcher was, however, likely designed for MFL operations. To launch the single body Surveyor correctly a special push rod was designed to safely push it into position.

The mudlines are open ended during normal operations. A challenge was the receiving area which has very limited space, hence a tailored receiver was built for the job with sufficient capacity to release scaling.

Figure 1: A combined effort Rio Tinto, Contract Resources and Intero

Figure 2: Launcher location during launch of gauging bidi

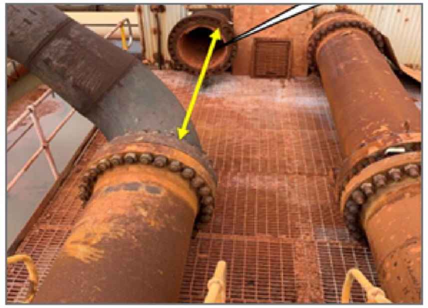


Figure 3: Tight receiver location

3. Execution

In September 2021 the pipeline inspection was executed. The overview and results of the inspection are presented in this chapter.

3.1 Purpose of the Inspection

RTY had indications, based on manual Ultrasonic Thickness Testing results, that areas of the pipeline were close to minimum allowable thickness. This was particularly the case around the 6 o'clock position due to erosion corrosion. Since the pipeline had underground sections a fit for purpose inspection was required which meant a full 100% coverage inspection was required.

Key pipeline characteristics:

Diameter: DN750

Length: 7945m

Wall Thicknesses: 9.5 mm, 12.7 mm and 15.9 mm

3.2 Cleaning

In consultation between RTY, Contract resources and Intero a progressive cleaning program was determined. The challenge was to remove the hard scaling, so it was clean enough for ultrasonic inspection and not too aggressive to damage the pipe wall.

After a flush, a few foam poly pig runs and a few brush pig total wire runs, the line was isolated from the supply tank. Since the cleaning runs were executed with an open-end pipeline there was hard scale noted on the inner wall, most notably at the 06:00 position in the last few meters of the pipeline. The scale on the other clock positions was notably softer. It took some force from a shovel to remove the scale. It was estimated to be 5-7mm thick in spots.

As a result of the initial assessment another 8 total wire cleaning runs were performed.

3.3 Bidi Results

The results of the cleaning runs were not entirely satisfactory as scaling remained visible. However, there was no guarantee this was the case over the entire pipeline. In consultation with all 3 parties, it was decided that more cleaning runs would not make a difference in achieving perfect cleanliness.

Figure 4: Scaling at 6 o'clock position

Figure 5: Scaling 5-7mm

The bidi run had another important role of obtaining valuable data to prepare for the ILI. The pipeline geometry, elevation differences and enormous pump capacity was a challenge to run an ILI tool in the 20m/min range.

The bidi run had two unexpected results. First one was that the receiver was seriously challenged to deal with a huge amount of scaling the bidi had removed and secondly because the bidi gauging plate was damaged beyond what would have been acceptable. The other challenge was that it was very difficult to control the speed of the tool.

The damage of the bidi was deemed to be a result of hitting an air pocket while navigating a section of back-to-back bends leading to an underground section. Consequently, based on the first run parameters it was decided to perform a second bidi run, with the aim to simulate the optimum for the ILI run. The results of the second bidi were within the set conditions with no damage to the gauge plate. With some minor changes at the launching, it was also possible to control the inspection speed. Finally, the amount of scaling was much less this second run.

3.4 Ultrasonic Results

With two bidi runs to prepare the ILI tool ran around the calculated optimum speed of 19m/min. At evaluation of the UT data, it showed there were still areas where no UT data was obtained, but mostly outside the critical 6 o'clock area.

The inspection data showed erosion was present at the 6 o'clock positions over a multitude of standard pipe lengths, however not gradual over the entire pipeline length.

Figure 6: Damaged gauging plate

3.5 RTY Remaining Life Assessment

A remaining life assessment was completed in-house by Rio Tinto engineers. The ILI data clearly showed internal erosion along the bottom of the pipeline, this is consistent with sliding bed erosion, which is typical in slurry pipelines. Although the pipelines were not fully cleaned, there was sufficient data to obtain a very good assessment of the bottom section along the entire length of the pipeline.

Continuous erosion along the bottom of the pipe in effect creates a continuous groove along the pipeline. From a pipe design point of view, this is very similar to a global erosion case, and the assessment was based on basic hoop stress calculations. It is noted previous assessments had been completed on the pipeline in relation to self-weight, seismic and wind. These all showed that pressure was the governing design case.

The ILI data had been provided in tabulated format, which included the minimum measured value in each pipe segment (approximately 12.5m lengths between each weld) and the chainage along the pipeline. This data was then overlayed with the pipeline elevation data.

In total following data was compiled and overlayed in a single chart which is shown in Figure 7:

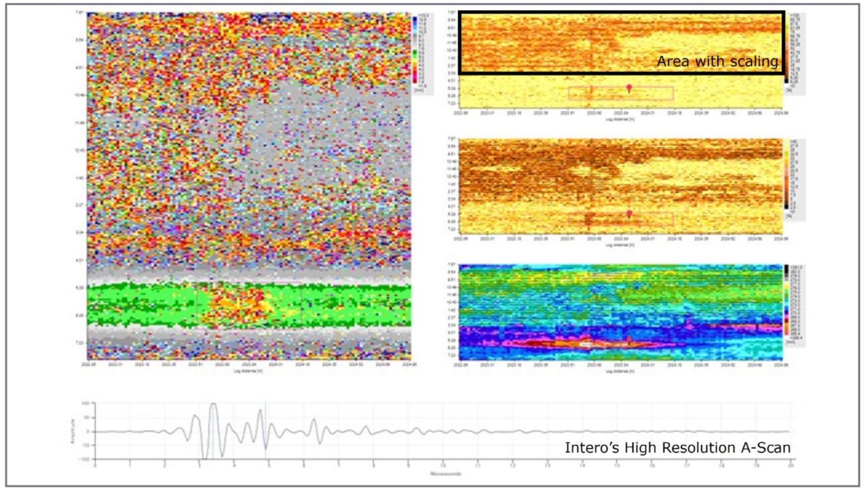


Figure 7: UT data presentation showing effect of scaling presence

- Pipeline elevation vs chainage
- Original nominal pipe thickness
- Measure thickness from ILI data
- 3x Required thickness lines (see below for explanation)
- Underground areas highlighted.

Note that the pipeline flows from left to right on the graph. Pumps are located on the left and pump the slurry about 100 meters vertically over the 9km length of pipeline.

The data showed significant loss of material along the entire pipeline. However, it also showed some areas with higher losses than others. These were in sections of higher "up-hill" gradient. It is unknown why the up-hill gradients show much higher material loss than similar downhill gradients. Ultimately given that it is not practical to change the pipeline gradient, no further investigation was conducted. The minimum required pipe thickness was calculated based on the original pipeline design standard B31.11. This is based on the basic hoop stress calculations provided in that standard. As discussed earlier the nature of the material loss results in this being a suitable assessment method. There is no need to perform a local area loss analysis. This calculation was completed 3 times with slight variations, the reason being to understand how sensitive the design is to some variable.

- T(mm) 3 pumps

This is a basic hoops stress calculation form B31.11, using a fixed elevation at the discharge of the pumps, which is almost the lowest elevation along the pipeline. This number is what was used to communicated to a wider audience when asked "what is the minimum required thickness". Is much easier to people to understand a single number, rather than having to refer to a graph every time.

- T(mm) 3 Pumps & Elevation

The same calculation was performed again, this time using the specific pipeline elevation to modify the pressure. As a result higher elevation sections of the pipeline have a lower required thickness. This is the "true" minimum required thickness for any section of the pipeline.

- T(mm) 3 Pumps & Elevation & Materials Certs

The material certificates for the pipeline were reviewed, and the material with the lowest yield stress was selected. A method specified in AS1210 (Australian standard for

pressure vessel design) adapted and then used to calculate a new SMYS for the pipeline. Refer AS1210 Appendix A. The same hoops stress calculations were completed using this revised material yield strength data. This line represents the "absolute lowest" minimum required thickness, and is provided to give a feeling of the sensitivity of the analysis. It was not used for formal decision making.

A second graph was produced based to show the "end of life" data along the pipeline. For each datapoint, the measured thickness was compared to the original thickness and a yearly wear rate determined based on linear trend. This was then used to calculated time to reach the required minimum thickness "t(mm) 3 Pumps + Elevation". A further calculation was conducted to determine the date at which this would occur. The results of this are shown in Figure 9.

The make the data a easier to comprehend, a line was manually drawn to the show the "lower bound life estimate" on the data (shown as red-dashed).

This graph is what was presented to the company management to allow for decisions to be made on a replacement / rectification schedule. The power of this approach is a simple graph shows at what date the given section of pipeline must be either rectified or removed from service. From a Pipeline Operators point of view this is the exact data they need to be able to make informed decisions.

- Rectification Strategy

The pipeline was re-designed in preparation for replaced using a much high corrosion allowance based on the expected life of the facility and the more recent design standard B31.4. This resulted in DN750 Schedule 30 pipe being specified, with a corrosion allowance of 10mm.

A combination of pipeline replacement and pipeline rotation is included in the rectification strategy, based on input from piping contractors of what is most feasible in each section of pipeline.

The overall timing of the rectification is staggered based on the End-of-Life graph. This allows cost of rectification to the spread over several years, without creating an increase in risk of pipeline failure.

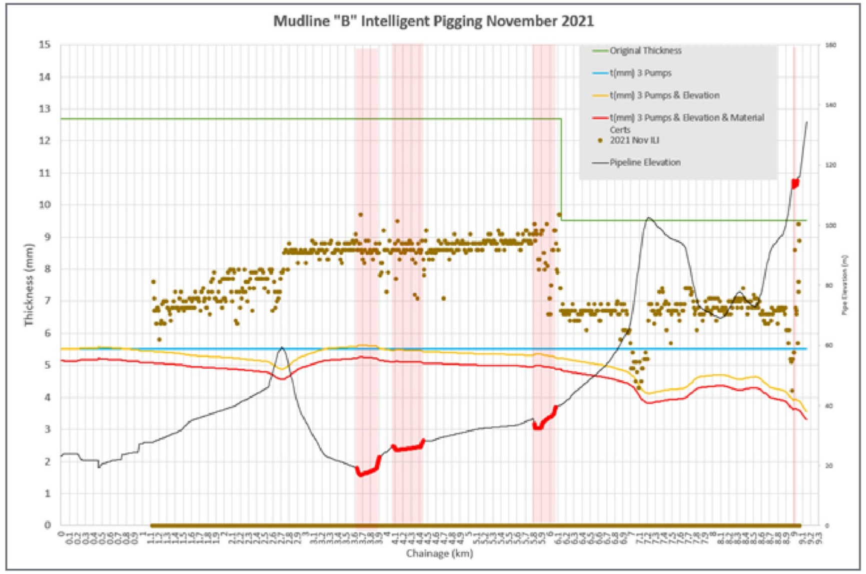


Figure 8: Graph with various overlay data showing minimum pipe thickness

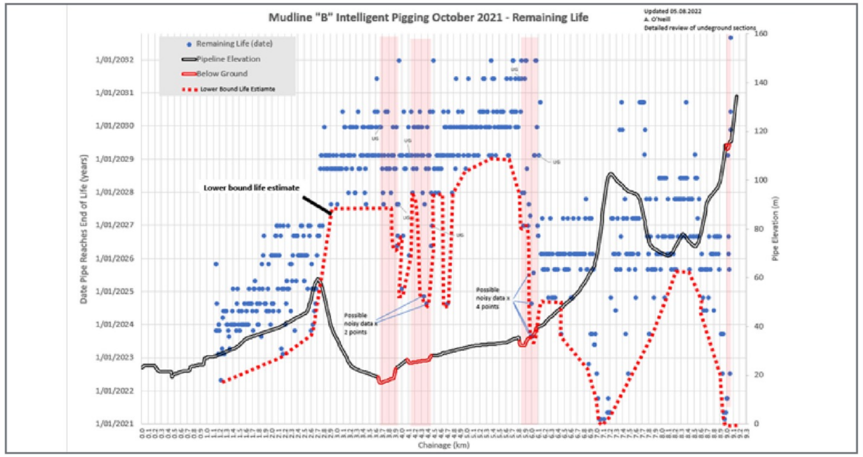


Figure 9: Graph showing "End of Life" date

4. Conclusion

Mud and tailing lines are critical assets for Rio Tinto. The inspection showed that although 100% cleanliness was not achieved the inspection data allowed Rio Tinto to make a well-informed assessment of the integrity of the pipeline.

As a result of the ILI inspection and remaining life assessment RTY was able to make informed decision to spread the rectification work over several years without increasing the risk of pipeline failure occurring. A key mechanism for this to occur was the presentation of the data in a simple graph that showed a prediction of when each section of the pipeline would reach End of Life.

RTY, Contract Resources and Intero will continue to work for the expansion of these inspection technologies for the integrity assessment of pipelines within the Rio Tinto organization.

References

1. B31.11 - Slurry Transportation Piping Systems
2. B31.4 – Pipeline Transportation Systems for Liquids and Slurries
3. AS1210 – Pressure Vessels

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