Challenging ILI for a Sour Gas Service Pipeline

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Abstract

A case study was conducted on a sour gas service pipeline with high H2S concentration. The aim of the study was to evaluate the current condition of the pipeline and to provide a solution to perform the In-line Inspection (ILI) base run. The sour gas service pipeline was constructed in 2012, has been operating since 2013, and has over 50 KM in length with a size of 20" in diameter.

As part the commissioning, a caliper run was conducted to assess the pipeline's internal diameter, which revealed that there were no restrictions or dents in the line. After the pipeline was commissioned, ILI runs were scheduled as per the standard requirements, to inspect the newly commissioned pipeline to ensure full integrity. A gauging run was conducted to assure pipeline mechanical readiness for the ILI run.

The gauging run resulted in an unsuccessful run due to considerable damages in the tool and huge amount of debris (more than 1000 kg). A following gauging run was conducted after assuring that all valves were fully opened, which resulted in an unsuccessful run with the same damage profile as the previous run.

Given the unsuccessful gauging runs, a caliper run was conducted to identify the obstacle. The caliper tool was retrieved with severe damages and was inconclusive with regards to the internal obstruction. A comprehensive assessment on the pipeline was conducted to evaluate the causes of the damages, which revealed that the damage was due to heavy debris within the pipeline as a consequence of improper chemical cleaning that was implement after the line was in-service.

The assessment recommended a cleaning campaign with specialized spring-loaded cleaning tools with magnets followed by a caliper tool. The cleaning campaign contained a minimum of thirty back-to-back aggressive cleaning runs. After completing the cleaning campaign, the caliper tool was conducted successfully and the internal restriction was negotiable by utilizing the 18/20" ILI tool, which was conducted successfully. This cleaning campaign resulted in a successful revalidation of the pipeline.

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Introduction

In-Line Inspection (ILI) runs are conducted to inspect pipelines to assess pipeline integrity. The performance of such inspection activities is heavily dependent on the pipeline's operational conditions. Achieving a successful ILI run involves securing optimal parameters for the ILI tool to inspect the pipeline. Pipelines with conditions such as low-pressure, high flowrate, excessive debris, H2S service, or difficult-to-negotiate mechanical obstacles pose significant challenges in achieving ILI run success. In this paper, a case study is presented on a Sour Gas pipeline with multiple challenges and the solutions implemented to achieve run success.

Pipeline overview

The Sour Gas pipeline was commissioned in 2013 with a length of 65 KM, and diameter of 20". The pipeline is FBE coated and the material grade is X60 Carbon Steel. The pipeline service is a sour gas service with high H2S concentration of around 20%. The below ***Table 1*** summarises the pipeline data.

Table 1. Pipeline Data

	Pipeline Details
Pipeline Diameter	20"
Service	Sour Gas
H2S concentration	20%
Commissioning Date	2013
Minimum Bend Radius D:	3
Pipeline Length	65 km

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Problem case

Pipeline inspection challenges

The pipeline inspection challenges became apparent after the pipeline was commissioned and was in-service for some time. The challenges are summarized below:

- Parameters: High Speed
- Single Carrier (No redundancy)
- High H2S concentration
- Pipeline Cleanliness: High debris and Mechanical restriction in the pipeline associated with heavy debris

The high speed posed difficulty in securing the optimal speeds for the gauging and ILI runs. Additionally, the pipeline was the sole supplier to the receiving plant and the main output of the upstream plant, thus, modifying the operational parameters would affect the both plants production. Moreover, the high H2S can damage the ILI tool for long duration runs.

Despite the previously mentioned challenges present in the pipeline, the main challenge in achieving a successful inspection came down to overcoming the high debris and the heavy debris in the pipeline, which reduced the Internal Diameter of the pipeline, resulting in a mechanical restriction. The source of the heavy debris that reduced the internal diameter of the pipeline and caused the tool damages in the inspection runs post-commissioning was determined to be due to injection of diesel-based corrosion inhibitor, which accumulated heavy debris after the pipeline was commissioned.

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1st Caliper run (Pre-Commissioning)

During the pre-commissioning stage, the internal diameter of the pipeline was inspected with a caliper tool. The following ***Table 2*** shows the 1st caliper tool's relevant tool specification and run details.

Table 2. 1st Caliper Tool Specification and Run details

	Tool Specification and Run Details
Tool's Maximum Velocity:	4.6 m/s
Average Run Velocity:	1.6 m/s
Tool's Minimum Bend Radius:	1.5D
Tool's Minimum Internal Diameter:	431 mm
Minimum Pipeline Internal Diameter During Run:	468 mm
Tool Length:	0.94 m

From the above table, the pipeline's minimum internal diameter was revealed to be 468 mm, which was assessed to be negotiable by the MFL tool. From the caliper result, the possibility of a mechanical restriction other than heavy debris can be excluded as an inspection challenge.

1st Gauging run

A gauging (dummy) run was conducted 6 months after the caliper run to assure the pipeline internal diameters before conducting the MFL run. The run results are summarized in the below ***Table 3***.

Table 3. 1st Gauging Run Results

	Gauging Run Results
Gauge Plate before the Run:	471 mm
Gauge Plate After Run:	426 mm
Debris Found:	1000 kg
Tool's Minimum Internal Diameter:	431 mm
Minimum Pipeline Internal Diameter During Run:	468 mm
Tool Length:	0.94 m

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The minimum gauge plate diameter found after the run and the excessive sludge debris retrieved was not acceptable to proceed with the MFL run. Additionally, the guide and sealing discs were damaged. The below ***Figure 1*** and ***Figure 2*** illustrate the damages.

Figure 1. 1st Gauging Run Gauge Plate

Figure 2. 1st Gauging Tool Condition

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2nd Gauging run

Following the last gauging run, it was assumed that the hit indication was due to valve misalignment. A second gauging run was conducted after ensuring proper alignment for the valves. The below ***Figure 3*** and ***Figure 4*** show the gauge plate condition after the run. The gauge plate experienced hits and the minimum bore identified was 397 mm along with 20 KG of debris.

Figure 3. 2nd Gauging run — Gauge plate after run

Figure 4. 2nd Gauging run — Gauge plate after run (Other Side View)

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3rd Gauging run

A few Bi-Di runs were conducted by the operational proponent as part of their regular pigging program, and capitalizing on this, a third gauging run was conducted with a 1.5D bend plate fitted on the tool. The below ***Figure 5*** and ***Figure 6*** show that the gauge plate and the bend plate were retrieved from the pipeline with hits. The minimum bore was 394 mm and the debris amount were 150 KG.

Figure 5. 3rd Gauging run gauge plate

Figure 6. 3rd Gauging run bend plate

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2nd Caliper run

Given the unusual mechanical restriction indicated from the previous gauging run, a caliper run was proposed to identify the internal restrictions in the pipeline post-commissioning. The main challenge faced at this stage was the high flowrate due to the operating capacity of the upstream plant and production demands. Nonetheless, a window was secured with a reduced flowrate to achieve an acceptable speed for the caliper tool. The caliper run was conducted and the tool was retrieved with severe damages as shown in ***Figure 7*** and ***Figure 8*** below.

Figure 7. 2nd Caliper tool condition (Front)

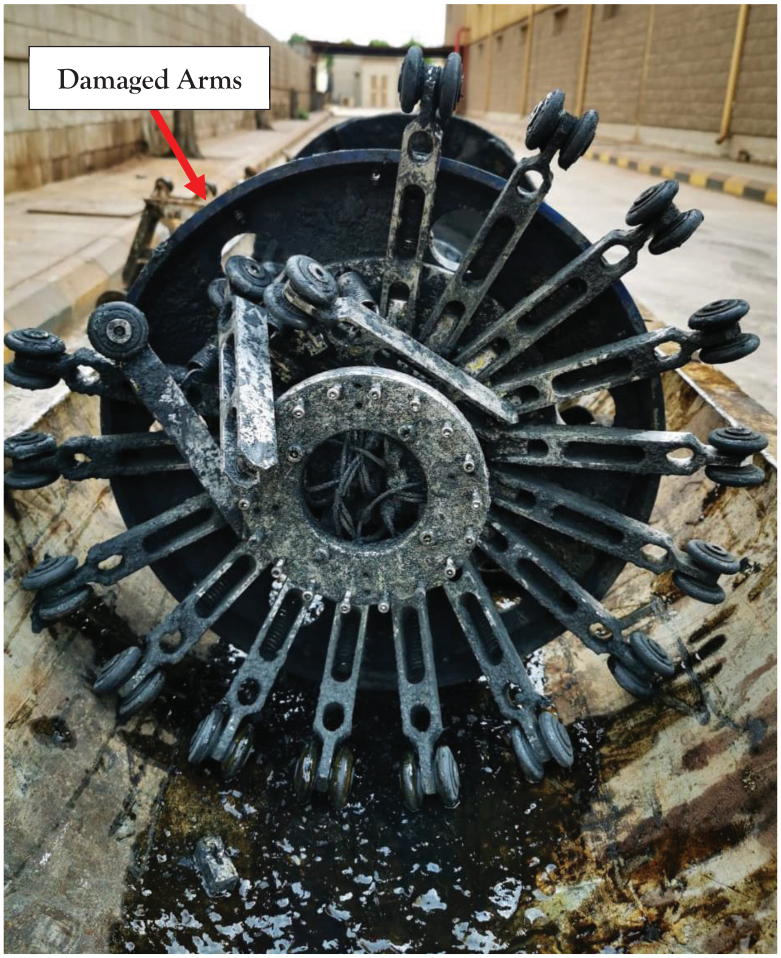

Figure 8. 2nd Caliper tool condition (Back)

As can be seen from the above tool images, the caliper experienced damages due to the high H2S in the pipeline and due to the heavy debris. Moreover, the tool was retrieved large amounts of sludge debris. The three caliper arms in ***Figure 8*** were damaged as retrieved from the pipeline. The average velocity during this run was 2.5 m/s, and the tool stalled in the line multiple times during the run, which allowed more time for the H2S to noticeably affect the tool. There were instances of significant sensor lift-off due to debris.

Nonetheless, the caliper tool measured the internal restrictions in the pipeline, and it was found that the minimum detected pipeline ID was 436.33 mm. It should be noted that the sizing of this internal diameter reduction could be exaggerated due to the debris present in the pipeline, but what can be concluded is that there is a major restriction in the pipeline from the heavy debris.

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Solution

As shown earlier, the major challenges faced in the previous runs were due to the pipeline cleanliness and the mechanical restriction from the heavy debris and sludge. Due to high demand on oil production, pipeline shutdown was not an option and only an in-service solution had to be achieved, and flowrate reduction was required to achieve an acceptable tool speed.
The pipeline had been in-service for some time without a baseline inspection which was risking the operation as this pipeline is a Single Point Of Failure (SPOF) for a major producing plant with unknown integrity conditions; especially with the observed pipeline cleanliness which questioned the pipeline internal corrosion.

In achieving a successful inspection run, an inspection procedure was designed and tailored for this pipeline considering the challenges and limitation as follows:

Pipeline Cleanliness
As stated earlier, pipeline cleanliness is the major challenge in the pipeline which is a risk to the ILI tool (sensor lift-off or tool damages), and, moreover, is a risk the operation if the pipeline flow is blocked. Operational safety and continuity were prioritized in the solution methodology. The inspection plan started with progressive cleaning campaign starting with a normal Bi-Di tool (without brushes) and progressively increasing the cleaning tool's cleaning aggressiveness (adding more cleaning elements) based on the cleaning results to avoid excessively accumulating the debris in front of the tool which might risk blocking the pipeline or stopping the tool under the isolation valve; especially with the sticky like debris material that might block the drains in addition to filtering system capability in the downstream facility.

Three cleaning tools were prepared — two tools with similar design and the third tool was prepared to be the next more aggressive design to maintain daily cleaning campaign. The target was to receive consistent amount of debris for two consecutive runs before deciding to go for the MFL ILI.

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Figure 9. First cleaning tool (After run)

Figure 9 above shows the first tool design used as cleaning after the run, which has a standard Bi-Di design. The tool was received with mechanical hit indication showing that mechanical restriction still exists in the pipeline.

Figure 10. Last cleaning tool (After run)

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Figure 10 above shows the last cleaning tool design after the run. As more cleaning runs were conducted, more aggressive cleaning elements were added (Stiffer disc material, ring brushes and spring-loaded arms).

Pipeline mechanical restrictions from heavy debris

Previously, it was mentioned that severe Internal Diameter (ID) reduction existed in the pipeline due to the heavy debris. By reviewing the pipeline history, a caliper run was conducted as part of the commissioning activities and no dents or ID reduction above than 2% was observed. This indicated that the ID reduction is probably caused by solidified debris. As a contingency a dual diameter tool 18/20" MFL tool was decided to be used to overcome the mechanical restriction issue.

After 18 consecutive cleaning runs a gauging run was conducted and the results shows an ID reduction to 406 mm. that indicated the need to conduct a caliper run to identify the restriction location and have more clarity of the restriction.

High speed

The pipeline was running on very high speed beyond the MFL tool capabilities. A flowrate reduction was required to have sufficient cleaning and secure the required parameters for the MFL tool. Since the pipeline transports associate gas and therefore crude reduction will be required which is complicated considering the supply demands. Since the reduction window will be available for limited time, the cleaning runs were conducted back-to-back to secure an acceptable cleaning condition in time for the MFL run date.

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Analysis of the cleaning results

Below is ***Table 4*** summarizing the cleaning, Gauging, Caliper and MFL runs since the starting of the cleaning campaign

Table 4. Cleaning Campaign and Inspection Runs

#	Run Type	Debris/Remarks
1.	Cleaning	25 kg of debris
2.	Cleaning	75 kg of debris
3.	Cleaning	20 kg of debris
4.	Cleaning	30 kg of debris
5.	Cleaning	250 kg of debris
6.	Cleaning	50 kg of debris
7.	Cleaning	25 kg of debris
8.	Cleaning	200 kg of debris
9.	Cleaning	50 kg of debris
10.	Cleaning	400 kg of debris
11.	Cleaning	200 kg of debris
12.	Cleaning	3 kg of debris
13.	Cleaning	200 kg of debris
14.	Cleaning	50 kg of debris
15.	Cleaning	100 kg of debris
16.	Cleaning	100 kg of debris
17.	Cleaning	100 kg of debris
18.	Cleaning	50 kg of debris
19.	Gauging	25 KG of Debris. Minimum bore of 406 mm
20.	Cleaning	50 kg of debris
21.	Cleaning	50 kg of debris
22.	Cleaning	25 kg of debris
23.	Cleaning	200 kg of debris
24.	Cleaning	100 kg of debris
25.	Cleaning	25 kg of debris
26.	Cleaning	50 kg of debris
27.	Caliper	Minimum bore 418
28.	Cleaning	30 kg of debris
29.	Cleaning	50 kg of debris
30.	Cleaning	50 kg of debris
31.	Cleaning	100 kg of debris
32.	Cleaning	100 kg of debris
33.	Gauging/cleaning	100 kg of debris (flow reduction was secured)
34.	MFL	200 kg of debris

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As shown in the above ***Table 4***, the amount of debris was increasing with the high scraping frequency and then started to stabilize. After that, the aggressiveness of the tool was increased until the received amount is consistent. One thing to note regarding Cleaning run# 12 was that this was an important run as it might had led to wrong decision if it was not evaluated properly. After further evaluation, it was found that the tool stayed under the lateral tee for several hours which might have washed the debris to the downstream facility. This is one of the reasons to have three consecutive runs with consistent debris amount as a real indication to take the best decision.

Gauging runs comparison

The below ***Table 5*** shows a summary and comparison of all conducted gauging run on this 20" pipeline.

Table 5. Gauging (Dummy) Runs Summary

Gauging#	Debris (KG)	Minimum Bore (mm)
Gauging 1	1000+	426
Gauging 2	20	397
Gauging 3	150	394
Gauging 4	25	406
Gauging 5	100	430

We can notice in the above table that the minimum bore was reducing until Gauging run # 3 then it was increased which indicated that the mechanical restriction was caused by solidified debris. This minimizes the possibility of the MFL tool to get stuck by mechanical restriction other than solidified debris.

Caliper runs comparison

The below ***Table 6*** shows a summary and comparison between the caliper runs conducted on the 20" pipeline.

Table 6. Caliper Runs Summary

Caliper Run	Minimum ID (mm)	Remarks
Caliper Run# 1	468	Conducted as part of the pre-commissioning activities
Caliper Run# 2	436.33	Inconclusive as some arms were broken which indicates more severe restrictions
Caliper Run# 3	418	The tool received in good condition

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We can see from the below speed charts of Caliper# 2 and Caliper# 3 (***Figure 11*** and ***Figure 12*** respectively) that the tool movement in Caliper Run# 3 has become more steady and has less excursion which indicates better cleanliness conditions. This proved the effectiveness of the cleaning campaign.

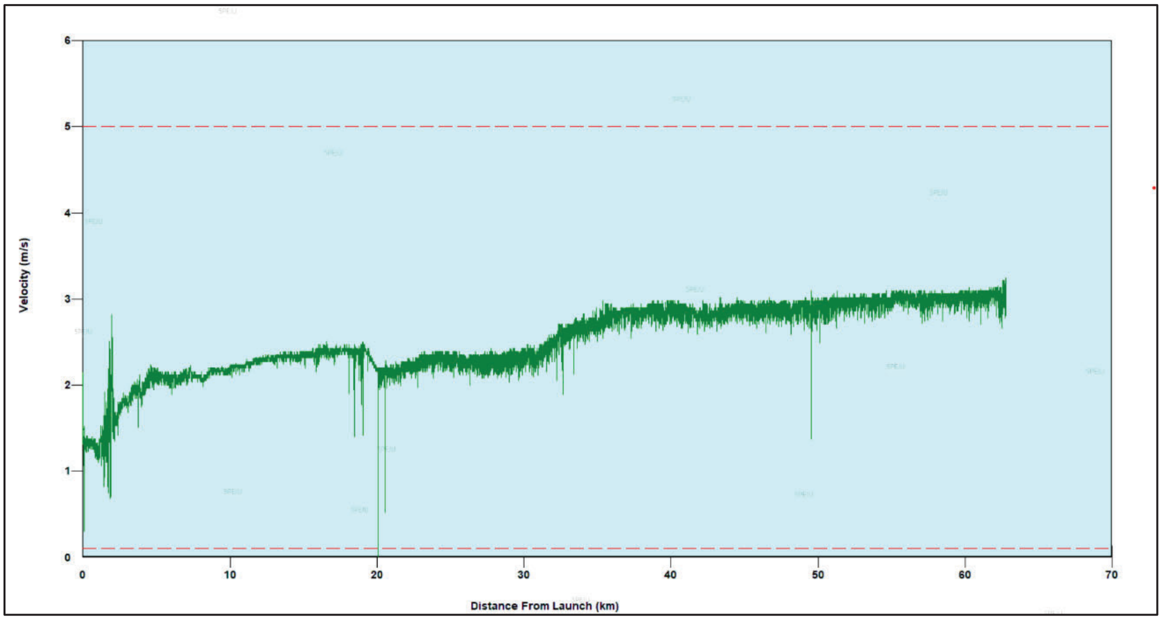

Figure 11. 2nd Caliper run speed chart

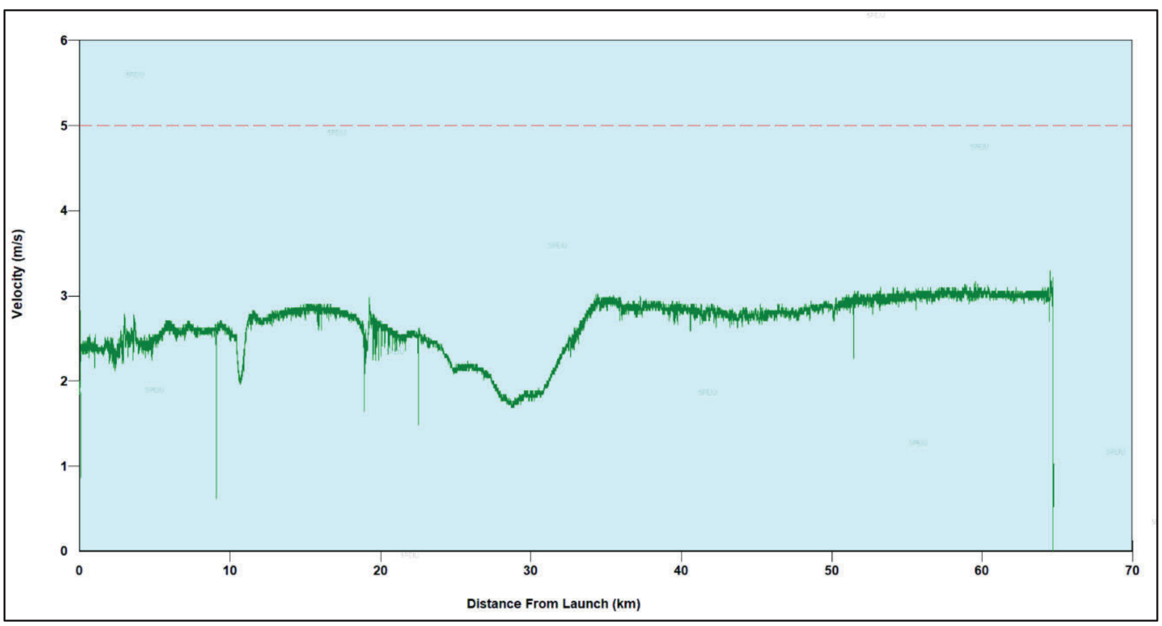

Figure 12. 3rd Caliper run speed chart

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Conclusion

Considering all abovementioned factors, it was decided to launch the MFL ILI tool after the flow reduction window was secured capitalizing on the effectiveness of the conducted aggressive cleaning campaign. In order to not affect the company's operation, hot-tap and stopple materials were prepared to be ready as a contingency plan in case if the tool got stuck and cut and replace if required. The MFL ILI run was conducted successfully with an average speed of 2.9 m/s for the MFL tool as per ***Figure 13*** below.

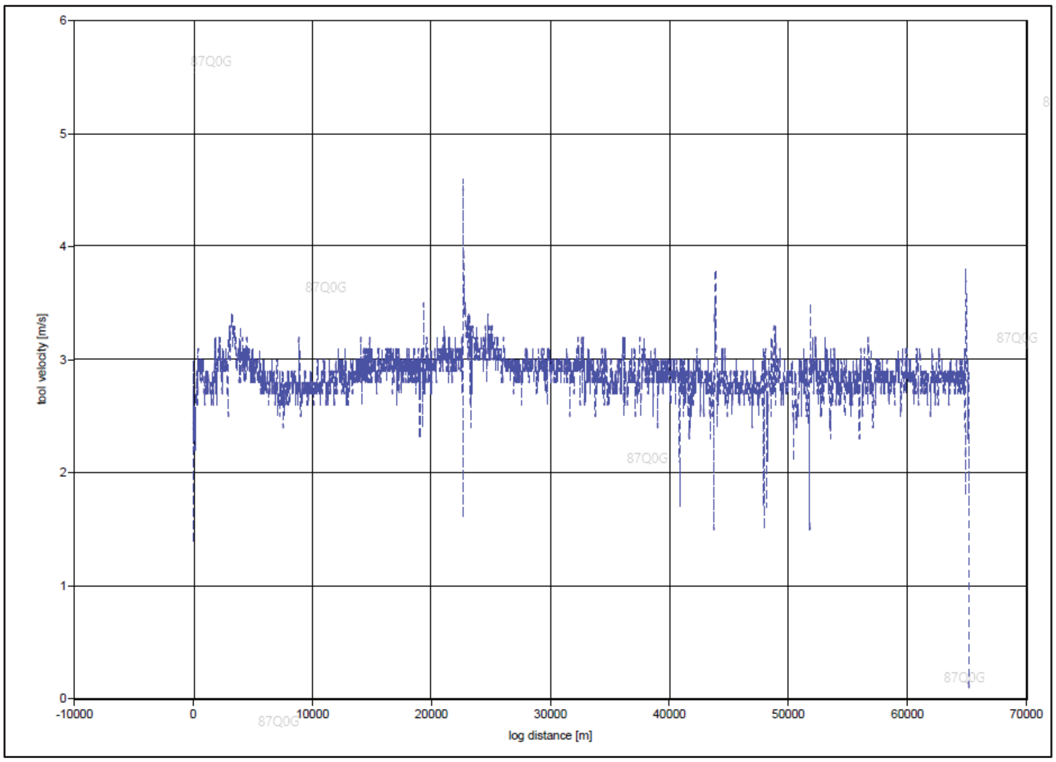

Figure 13. MFL ILI Speed Chart

Figure 14. MFL Tool After Run

The MFL inspection was successful and achieved acceptable data quality standards. The data quality assessment shows that no significant data loss was observed and that the magnetization level was within an acceptable range. Despite the debris on the tool show in the above ***Figure 14***, the debris did not affect the data quality, and thus, the cleaning campaign and the solution to the heavy debris present in the pipeline was successful and achieved a successful revalidation.

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