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# Early Deposition Profiling and Non-Intrusive Technology

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## Abstract
The maintenance of pipelines is a concern for operators, primarily due to the risks associated with deposit accumulation which lead to reduced operational efficiency, blockages, revenue losses due to continued shutdowns of pipelines. Traditional maintenance strategies rely on reactive measures that are implemented after a problem has manifested, by which time the solutions are not only less effective but also more expensive. This paper explores the advantages of implementing an early deposition profiling survey using non-intrusive technology as a proactive approach to maintenance. We delve into how such technologies can accurately quantify deposit levels within pipelines, thereby allowing operators to tailor chemical treatment strategies effectively. The core argument presented is that by understanding the exact nature and extent of deposits, operators can use the optimal quantity and type of chemicals to prevent blockages, avoiding the need for costly remediation measures and helping to ensure continuous production. Through commercial calculations and technical explanation, we demonstrate the potential cost savings and efficiency gains achievable using such approach, highlighting significance as a cost-effective alternative to traditional reactive maintenance strategies. The findings advocate for a paradigm shift in pipeline maintenance, emphasizing the importance of early detection and precise treatment to safeguard operational continuity and maximize profitability.

## Keywords
Non-intrusive; pipeline; maintenance

## Introduction
Oil and gas transportation systems such as pipelines and flowlines are crucial components of the oil and gas industry infrastructure as they are used to efficiently transport crude oil, natural gas and their associated by products from production facilities to refineries and other processing plants.
They are designed to optimize the efficiency of fluid transportation. The diameter and routing of pipelines are carefully planned so as to minimize frictional losses and maintain steady flow rates. Flow assurance measures, such as heating, insulation, and corrosion control, are implemented to prevent flow disruptions and maintain system efficiency. This not only helps to ensure safe, but also efficient transportation of fluids or gases from one point to another.
The consequences of neglecting pipeline integrity lead to issues such as deposit build up, corrosion and material loss, reduced efficiency, blockages and most importantly revenue losses. For this reason, proactive measures and regular maintenance practices are absolutely essential to preserving the integrity and lifespan of pipelines.
Most pipeline operators using mechanical pigging as a means to mitigate flow assurance issues such as the formation of hydrates, wax buildups or solids accumulations. By periodically running pigs through the pipeline, operators can break up such deposits and help maintain consistent flow conditions, helping to ensure uninterrupted production and transportation of fluids. Traditional maintenance strategies often rely on reactive approaches, where maintenance actions are taken in response to equipment failures, breakdowns, or performance degradation. While reactive maintenance may seem straightforward and cost-effective in the short term, it comes with several limitations and drawbacks:

- Unplanned Downtime: Reactive maintenance strategies often lead to unplanned downtime when equipment failures occur unexpectedly. This downtime can disrupt operations, production schedules, and customer deliveries, resulting in lost revenue and productivity.
- Higher Maintenance Costs: Repairing or replacing equipment after it fails can incur higher costs due to emergency repairs, rush orders for spare parts, and overtime labor expenses.
- Safety Risks: Equipment failures can pose safety hazards to personnel, the environment, and

surrounding communities. Reactive maintenance increases the likelihood of accidents, spills, leaks, and other incidents that can result in injuries, environmental damage, and regulatory fines.

- Reduced Equipment Lifespan: It does not address underlying issues or gradual deterioration of equipment over time. As a result, equipment may experience accelerated wear and tear, leading to premature failure and a shorter lifespan.
- Loss of Product Quality: Equipment failures can compromise product quality and consistency, particularly in manufacturing processes where precision and reliability are critical. This can impact product performance, customer satisfaction, and brand reputation.
- Missed Opportunities for Optimization: It prevents organizations from proactively identifying opportunities for process improvement, optimization, and cost reduction. By waiting for equipment failures to occur, organizations miss the chance to implement preventive measures and predictive analytics to optimize asset performance and reliability.
- Lack of Data-driven Decision-making: This approach often relies on intuition, experience, or trial-and-error rather than data-driven insights. Without access to real-time performance data and condition monitoring, organizations may struggle to make informed decisions about maintenance priorities, resource allocation, and asset management strategies.

While reactive maintenance may offer short-term benefits such as lower upfront costs and simplified maintenance procedures, its limitations can have significant long-term consequences for organizations. To overcome these limitations, organizations are increasingly adopting proactive maintenance strategies, such as preventive maintenance, predictive maintenance, and reliability-centred maintenance, to optimize asset performance, reduce downtime, and enhance safety and reliability.

Determining the timing and frequency of maintenance pigging runs can be challenging due to various factors, including changing environmental conditions, variations in production flow, and evolving operational requirements. Environmental factors such as temperature can affect the accumulation of deposits and the condition of the pipeline. Regular monitoring of these conditions can help identify patterns and trends that may influence the timing of maintenance pigging runs. The type and nature of the production flow can vary over time due to changes in production rates, product composition, and process conditions. Monitoring production parameters such as flow rates, viscosity, density, and chemical composition can help assess the need for maintenance pigging and determine the appropriate frequency.

Implementing advanced monitoring technologies such as non-intrusive diagnostics can provide continuous visibility into the condition of the pipeline and detect early warning signs of potential issues. Integrating this information into the maintenance planning processes enables proactive decision-making and timely intervention. This in turn prevents costs associated with downtime and expensive remediation treatments and even pipeline shutdown. In the next section, we will take a look at two cases where the lack of preventative maintenance measures led to the blockage and eventual abandonment of pipelines.

We will now take a look at two scenarios where pipelines could have benefitted from pro-active measures in order to avoid expensive remediation. We will also run through a cost comparison of proactive versus reactive maintenance measures for both cases.

Scenario 1 – A 10 inch 8 km long production pipeline in eastern hemisphere was subject to frequent paraffin buildups eventually got blocked due to a stuck pig. Several attempts were made to clear the blockage, using hot oil, chemicals and various pressurization techniques, but eventually the pipeline had to be abandoned. Even though the routine maintenance pigging operations were performed every few weeks, unfortunately the pig got stuck and was not retrievable. The assumption is that the stuck pig was caused due to a paraffin wax build-up. In order to put the line back into production after 3 years, various remediation strategies will need to be explored.

Scenario 2 – A 12 inch 11 km long production pipeline in the western hemisphere had a similar issue where a pig got stuck in the pipeline during routine annual maintenance pigging operations prior to running an ILI tool. Since the line was prone to paraffin build-ups, the assumption here too is that the pig got stuck due to the presence of paraffin deposits. In this case, no attempts were made to clear the pipeline. It was abandoned for 3 years but now the Client is actively pursuing solutions to unblock the line due to an increased production demand.

In both cases, traditional methods of maintenance led to blocked and abandoned pipelines.

## Pro-active maintenance strategies

In this section, we would like to discuss the advantages of using non-intrusive diagnostic technologies for creating a more robust and proactive maintenance strategy for pipelines that are prone to deposit buildup.

Early Deposition Profiling and Non-Intrusive Technology

The advent of non-intrusive technology for deposition profiling marks a significant advancement in pipeline maintenance. Unlike traditional methods, which often require operational shutdowns and physical entry into the pipeline, non-intrusive technology allows for real-time monitoring of deposition levels without disrupting pipeline operations. This technology quantifies internal deposits accurately. The precision of these methods provides operators with detailed insights into the quantity and distribution of deposits, enabling more informed decision-making. One of the primary advantages of this approach is its ability to facilitate proactive maintenance strategies. By identifying potential blockage threats before they manifest into operational issues, operators can schedule maintenance activities during optimal times, thereby minimizing production downtimes and associated revenue losses. Moreover, the data acquired from these surveys can be used to create predictive models of deposit formation, further enhancing the efficiency of maintenance planning.

**Effective Chemical Treatment**

The specificity of information provided by early deposition profiling enables the targeted use of chemical treatments. Traditional approaches often employ a one-size-fits-all strategy, applying standard chemical solutions regardless of the deposit's nature. This can lead to suboptimal outcomes, where either excessive chemicals are used, increasing costs and environmental risks, or insufficient treatment is applied, leading to the persistence of blockages.

In contrast, with detailed deposition data, operators can select the most appropriate chemical quantity and formulations tailored to the specific types of deposits detected. For instance, in cases where wax buildup is identified, operators can use specific paraffin inhibitors and dispersants that target wax molecules, helping to ensure their effective dissolution and removal. Similarly, for scale deposits, acid-based or chelating chemical treatments can be chosen based on the scale composition (e.g., calcium carbonate, barium sulphate).

The scenarios presented of the 2 pipelines illustrates the potential impact of this approach. In Eastern hemisphere, where wax build-up was suspected, the lack of precise deposition information led to a trial-and-error approach with various methods, including hot oil treatments and chemical injections, none of which were successful. An early deposition profiling could have identified the exact extent of the wax deposit, allowing for a more effective and less costly treatment strategy.

Similarly, in Western hemisphere, the stuck pig incident in a 12-inch pipeline could have been prevented by earlier detection of deposit formations. The abandonment of this pipeline for over three years represents a significant loss of revenue and a missed opportunity to employ more effective, targeted chemical treatments that could have maintained the pipeline's operational integrity.

**Economic Analysis**

The economic implications of adopting early deposition profiling and effective chemical treatment are profound. Traditional reactive maintenance strategies often result in significant direct costs associated with mechanical interventions, such as pipeline replacement or extensive cleaning operations, and indirect costs due to production shutdowns.

By conducting a cost-benefit analysis, it becomes evident that the initial investment in non-intrusive deposition profiling technology and the subsequent targeted chemical treatments can result in substantial savings. These savings are realized through reduced need for mechanical interventions, minimized production downtime, and extended pipeline lifespan. Moreover, the ability to maintain continuous production not only preserves revenue streams but also enhances the operational reliability and safety of the pipeline infrastructure.

In the context of the described 2 cases, a hypothetical analysis can illustrate the potential savings. Assuming that early intervention could have prevented the blockages, the costs associated with the abandoned pipelines, including lost production and several remediation options in first case, could have been significantly mitigated. Furthermore, the targeted chemical treatments, by maintaining pipeline integrity, would contribute to sustained production efficiency and profitability.

The tables below show calculations of the economical advantages of proactive approach using non-intrusive diagnostics plus targeted chemistry.

For both scenarios, we have considered the production of the oil pipeline as 750 barrels of oil per day (BOPD) which will be used in our calculations. To calculate the annual revenue loss due to a production shortfall of 750 BOPD using the approximated average oil prices [1], we will follow this formula for each year from 2020 to 2023:

Annual revenue loss = 750 BOPD x 365 days x Average annual oil price

All estimates are provided in million US dollars (M, $)

Table 1 - Scenario 1 Total deferred revenue due to the application of a traditional maintenance approach.

| Traditional reactive maintenance approach | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|
| Loss due to deferred revenue | 10,9 | 17,7 | 27,3 | 21,9 |
| Remediation spend - chemical treatments* | | 1,0 | | |
| Remediation spend – pressurization techniques | | | 1,5 | |

| | | | | |
|---|---|---|---|---|
| Remediation spend – mechanical pipeline intervention | | | | 5,0 |
| Total loss (M, $) | 10,9 | 18,7 | 28,8 | 26,9 |

*Chemical treatments on a blocked pipeline are usually ineffective because a complete blockage removes the flow path for chemical to reach the blockage location.

Table 2 - Potential Scenario 1 savings in case proactive maintenance approach applied.

| Proactive maintenance approach | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|
| Non-intrusive diagnostics | 0,5 | 0,5 | 0,5 | 0,5 |
| Chemical treatments* | 2,0 | 2,0 | 2,0 | 2,0 |
| Total costs | 2,5 | 2,5 | 2,5 | 2,5 |
| Cost savings (M,$) | 8,4 | 16,2 | 26,3 | 26,4 |

*Continuous injection as well as batch application of chemicals

Table 3 - Scenario 2 Total deferred revenue due to application of traditional maintenance approach Traditional reactive maintenance approach

| Traditional reactive maintenance approach | 2021 | 2022 | 2023 |
|---|---|---|---|
| Loss due to deferred revenue | 17,7 | 27,3 | 21,9 |
| Total loss (M, $) | 17,7 | 27,3 | 21,9 |

Table 4 – Potential Scenario 2 savings in case proactive maintenance approach applied.

| Proactive maintenance approach | 2021 | 2022 | 2023 |
|---|---|---|---|
| Non-intrusive diagnostics | 0,5 | 0,5 | 0,5 |
| Chemical treatment* | 2,0 | 2,0 | 2,0 |
| Total costs (M, $) | 2,5 | 2,5 | 2,5 |
| Cost savings (M, $) | 15,2 | 24,8 | 19,4 |

*Continuous injection as well as batch application of chemicals

## Results

Comparing the reactive and proactive approaches demonstrated that while the proactive approach required an initial investment in non-intrusive diagnostic technology and a consistent chemical injection strategy, the overall expenditure was significantly lower. Furthermore, the proactive approach resulted in continued production without the interruptions experienced by Scenario 1, reinforcing the economic benefits of this strategy.

The same analysis applied to a second case, Scenario 2 also revealed a stark contrast in economic outcomes. Traditional reactive maintenance led to considerable loss in revenue due to prolonged pipeline abandonment, whereas proactive maintenance showed potential savings. These savings, presented in Table 4, factored in the costs of diagnostics and chemical treatment, emphasizing the proactive approach's long-term financial benefits.

The data compiled in these tables provided concrete evidence supporting the switch from a reactive to a proactive pipeline maintenance approach. By incorporating advanced diagnostics and targeted chemical injections early, operators can significantly improve the financial efficiency of their assets and lifetime of pipeline infrastructure. These findings make a compelling case for the industry to revise current maintenance strategies in favour of more cost-effective and sustainable practices.

## Conclusions

The exploration and analysis presented in this paper underscore the transformative potential of early deposition profiling and precise chemical treatment in the realm of pipeline maintenance. Traditional, reactive approaches to pipeline management, as illustrated by the scenarios are not only fraught with operational risks but also carry significant economic repercussions. The blockages that led to the abandonment of pipelines in these cases highlight a critical vulnerability in the industry's standard maintenance protocols—a reliance on intervention after problems have arisen, which often results in costly, less effective remedies.

The adoption of non-intrusive technologies for early deposition profiling represents a paradigm shift towards a more proactive, preventive maintenance strategy. By allowing operators to identify and quantify deposition risks before they escalate into blockages, this approach facilitates timely, targeted interventions that can avert pipeline failures, enhance operational efficiency, and extend asset lifespan. Moreover, the ability to tailor chemical treatments to the specific characteristics of detected deposits not only improves the efficacy of these interventions but also optimizes chemical usage, thereby reducing both costs and environmental impact.

Economic analysis further bolsters the argument for this proactive approach. By comparing the costs associated with reactive maintenance strategies—such as pipeline replacement, extensive downtime, and lost production—with the investment required for early deposition profiling and targeted chemical treatments, a compelling case emerges for the latter. The potential savings, both direct and indirect, signify not just an economic advantage but also a strategic imperative for pipeline operators seeking to safeguard their assets and ensure operational continuity.

Furthermore, this discussion extends beyond the immediate financial implications, touching on broader themes of sustainability and environmental stewardship. In an era where the energy sector is increasingly under scrutiny for its environmental impact, the ability to minimize chemical usage through targeted treatments aligns with a growing mandate for more sustainable industrial practices.

In conclusion, the evidence presented advocates for a significant re-evaluation of pipeline maintenance strategies across the industry. The adoption of early deposition profiling and effective chemical treatment is not merely a technical enhancement—it is a strategic shift that promises to redefine the benchmarks for operational efficiency, economic resilience, and environmental responsibility in pipeline management. As the industry stands at this crossroads, the choice to embrace innovation and foresight could well determine the future landscape of pipeline operations, setting a new standard for excellence and sustainability.

## References


[1] The data is taken from web-site *Average Crude Oil Spot Price Monthly Insights: Commodity Markets Review* | *YCharts*)

[2] SPE-197262-MS, *Reducing Pipeline Maintenance Costs, Time, and Resources Through Nonintrusive Diagnostics*. G.Jack and N. Stewart, 2019


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