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VIBROACOUSTIC TECHNOLOGY: DESIGN AND DEPLOYMENT OF A PIPELINE INTEGRITY MONITORING TOOL

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ABSTRACT

Pipelines play a vital role in supporting everyday life, necessitating vigilant monitoring and safeguarding against potential failures, deliberate sabotage, and involuntary physical vulnerabilities.

Vibroacoustic Technology (VT) is an efficient and reliable monitoring tool, detecting leaks and precursor events like excavations through micro-vibrations, pressure, and sound. This study focuses on VT role in pipeline integrity, covering deployment, calibration, and its real-time event localization capability. The work provides insights into the design, hardware-software deployment, and calibration preceding VT integration into specific pipelines.

Keywords: Vibroacoustic Technology, Leak Detection, Third-Party Interference, Asset Integrity Monitoring

1. INTRODUCTION

Modern societies rely heavily on essential infrastructure networks such as fuel, gas, power and water to sustain daily life, public services and economic growth. Pipeline networks are an integral part of said infrastructure, and it is therefore crucial to safeguard them from potential failures, intentional or accidental physical and cyber threats.

Pipelines transporting fuel (e.g., refined petroleum products) are a common target of illegal tapping, i.e., the act or attempts to steal fluids by establishing unauthorized connections along a pipeline [1][2]. These incidents frequently lead to severe pipeline damage, production loss, environmental pollution and hazards for populated areas.

Leakages can arise from corrosion, not just illegal tapping, further emphasizing the need to protect and monitor pipeline networks. Various leak detection methods are accessible, utilizing distinct physical principles to promptly detect leaks and mitigate their consequences.

VT is a robust and reliable monitoring tool, encompassing not only leak detection, but also TPI, effectively identifying precursor events like excavations and impacts that often precede leakages. The VT systems deployed worldwide exploit vibroacoustic waves (micro-vibration, pressure and sound) generated by said events to detect and localize leakage and TPI events in real-time.

With the installation of vibroacoustic sensor blocks every few kilometers, this technology enables the identification and differentiation of leakages and TPI incidents. Engineered for efficiency, these sensor blocks are low bandwidth and power consumption. They capture vibroacoustic data created by leakages or TPI activities occurring along the pipeline. In a matter of minutes following a leakage or TPI event, the VT promptly emits an alarm, precisely pinpointing the event's location.

This work focuses on the VT role in pipeline integrity monitoring, outlining the installation process from deployment to calibration and release. The study describes the design phase, hardware and software deployment, and the fundamental calibration process preceding the release of VT into a specific pipeline.

2. MATERIALS AND METHODS

2.1 Vibroacoustic Technology Deployment

The design phase started with VT specialists assessing the detection needs to align with suitable detection methods. Subsequently, the available infrastructure was evaluated to optimize installation, reducing expenses and installation duration. The pipeline has a diameter of 10-inch and spans about 40 km, crossing urban zones and transports refined petroleum products.

Sensor blocks were powered with direct power grid links and solar panels. For telecommunication UMTS with double redundancy was used to ensure steady data flow to the core processors. Servers hosted distinct VT software core processors for leakage and TPI detection.

Sensor blocks were strategically positioned at approximately 5 km intervals to achieve TPI detection; for leakages, this range can extend to 50 km. In this configuration, once an event is identified, alarms are sent via email to select recipients and the web user interface.

2.1 Test Campaign

Following installation, a test campaign was organized to perform leakage and excavation tests (Figure 1), aiming to adequately calibrate the system before its official release. The tests were performed with and without flow.

FIGURE 1: Excavation (left) and Leakage Tests (right)

Specialized tools were employed to induce leaks with varying hole diameter size dimensions (0.1 - 0.2 - 0.25 in). The resulting fluid was collected in a dedicated tank and appropriately disposed of at the end of the test campaign. To minimize product leakage, the conducted leak tests were brief, resulting in only a few liters being spilled per test.

The excavation tests took place within a pipeline segment far from sensor blocks. A mechanical excavator was used, but also manual excavation tests were performed. The pipeline was buried at a depth of around 1.5 m, and the soil was carefully removed to access the pipeline without fully exposing it.

3. RESULTS AND DISCUSSION

All tests were executed as planned and concluded without any HSE incidents. In Table 1 we show the Key Performance Indicators (KPIs) used to analyze the test results. The leak detection method used is the Advanced Negative Pressure Wave. Other leak detection methods can be used based on the vibroacoustic data [3].

		Leakage	**TPI**
KPI	***Sensitivity [in]***	0.1" (no flow) 0.2" (flow)	Manual Excavation
	Response time [min]	5÷10	13÷21
	Localization precision [m]	25	25
	Propagation distance [km]	≈ 50 km	5÷10 km

TABLE 1: VT Performance - KPI

Additional information provided by the VT includes PIG tracking and valve sealing assessments [4]. The system's adaptability in design, retrofit , extensive event detection capabilities, and support for pipeline operations with minimal sensors is a strong feature. This adaptability extends to challenging environmental and remote scenarios, further solidifying its installation viability.

4. CONCLUSION

VT proves to be an efficient and cost-effective method for real-time detection of leakages and TPI incidents. Its adaptable design, wide event detection, and minimal sensors support pipeline operations, even in remote and challenging environments.

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