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Deployment and Redeployment of IOT based Leak Detection Devices

Stephen Edmondson, Adrian Banica
Direct-C, Canada

Abstract

As operators become aware of potential threats to their pipeline, they often must consider conducting expensive direct assessments, either for explicit regulatory compliance or general integrity-related concerns. Occasionally, the operators find the dig-up campaign was not necessary or could be delayed because the pipeline "as found" condition is less critical than expected. Although this is a positive outcome it could potentially delay assessing locations that require more immediate attention, exposing operators to the risk of leaks.

This paper examines whether advanced mobile IOT systems can be used to monitor pipelines for leaks to reduce the risks from pipeline defects enabling a more structured approach to defect repair. The paper will also discuss how a response plan can be drawn up based on the output of a Risk Assessment of the Environmental impact due to a leak from a pipeline given the location of an anomaly. This leak detection technology can be deployed in targeted locations that are identified by algorithms designed to calculate the remaining life and time to inspection.

The sensors can then be re-deployed to other areas as those more severe defects are repaired. A large fleet of mobile leak detection sensors has been integrated by a US Pipeline operator into a rolling pipeline maintenance program.

These sensors are monitored via a cloud-based data and asset management system they provide data on the pipeline's condition and give the ability to detect a pipeline leak within 5 minutes of the liquid hydrocarbon contacting the sensor.

Key words: integrity management, corrosion, leak detection, condition monitoring, data analytics

Introduction

Oil and gas pipeline operators are required by regulation to maintain safe pipeline systems. They develop and perform detailed Integrity Management Programs (IMPs), typically involving hazard identification, inspection, direct assessment, and mitigation. These programs represent significant proportions of operating budgets. It is important from a business perspective that programs are executed both effectively and efficiently.

Many pipeline operators default to a standard "pig and dig" program. Inline inspection (ILI) tools are run on a regular basis. Inspection results are analyzed by integrity engineers, and the most severe flaws identified during the inspection selected for excavation and repair. For some of the smaller operators, the dig selection may be very rudimentary, based on simple failure pressure or flaw depth criteria. The larger operators typically have more data sets to leverage and can be more refined in their dig selections. However, either approach requires time and effort, and attention to detail.

Dig programs are expensive, not just in dollar value, but in time and resources. A lazy estimate of dig costs might be in the order of tens or hundreds of thousands of dollars, per location. A complex dig, involving a geohazard (slope or river) or near a highly populated area, may be millions of dollars. These estimates tend to focus on "out-of-pocket" expenses for the pipeline operator; contractor salaries, equipment rentals, travel and per diems. However, these lazy estimates do not encompass the true cost to the operator.

A more detailed review of the true costs of a dig program reveals a significant amount of time and resources spent by the operator internally, and potentially a significant amount of risk. Consider the internal resources used by the pipeline operator to manage the program; supply chain management, contractor management, quality oversight, health and safety, landowner management and others. In addition, there are intangible costs to some programs, such as logistical inefficiencies due to seasonal dig requirements, environmental or ecological difficulties, and disruption to local communities.

Dig program costs are exacerbated if ILI tools are found to overcall the severity of indications. A ten percent conservative bias in reported depths may double the cost of a dig program, or more. Unfortunately, these errors are often blamed on the ILI vendors. Operators sometimes lose sight of the fact that the accurate depth measurements they require are not made directly, but are inferred from magnetic flux leakage or ultrasound reflection in the steel pipe. The success of most ILI tools is impressive when all things are considered.

Bias in the ILI tool measurements are identified through the dig programs, but their analyses require several data points, and this can take several weeks or months to achieve. By the time an operator has acquired sufficient field data to statistically demonstrate an ILI measurement bias, the resources have been spent and the program may be too far along to achieve any real cost efficiency.

The problem of ILI bias and poor program efficiency is exacerbated by specific high-cost digs. And again, high cost should not be assumed to be just out-of-pocket dollar value expenses. Consider a dig program near a river, requiring travel with large machinery to a remote area, disruption to the local environment and ecology, and the increased risk of worker safety at site. Or consider a marginal flaw identified underneath a railway or highway cased crossing, and the extensive administrative costs of permitting and disruption to local transport. These types of digs can have a significant effect on program efficiency.

The goal of this work is to discuss opportunities for oil and gas pipeline operators to achieve better dig program efficiency through better dig prioritization and non-invasive threat mitigation techniques. This can be achieved through data analytics and machine learning. Data analytics may demonstrate some flaws are high risk and should be mitigated immediately. These would include deeper flaws in higher pressure pipelines, and rupture threats near high consequences areas, such as high population densities or environmentally sensitive areas. The flaws may require an immediate pressure reduction or urgent excavation and repair. Or data analytics may demonstrate some flaws are of marginal risk and can be mitigated less rigorously. These would include lower pressure pipelines, and leak threats in environmentally neutral locations. Operators can improve dig program efficiency by prioritizing flaw severity and potentially decreasing dig requirements if ILI results are shown to be biased. A detailed description of how these systems operates has already been presented elsewhere, this paper focuses on integration of some IOT systems into repair programs and data analytics.

One of the more cost-effective threat mitigation techniques available is the installation of internet-of-things (IOT) devices, such as pressure or leak detection sensors. Currently available leak detection sensors include a range of battery-powered fully mobile systems that can be deployed in a targeted approach to monitor specific areas of concern on liquid hydrocarbon pipelines and storage units. The systems can be installed by contractors (there is no need to have experienced technical staff on site) and commissioned in a few minutes. They automatically connect via cellular or satellite modems within the IOT device to a cloud-based data and asset management system which monitors for liquid hydrocarbon product contacting any one of the deployed sensors.

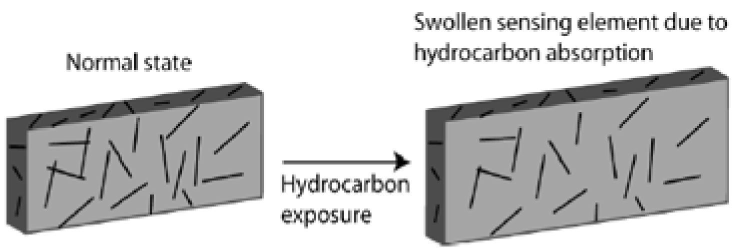
If a repair is planned for a particular pipeline location, the leak detection system can be left in place until repairs are carried out and then moved to another location once the repair is complete. In this way a fleet of leak detection systems can be incorporated into a planned maintenance program providing a high degree of focused risk mitigation over an entire remediation program. Units are simply leased for the duration of the monitoring program so no large CAPEX spend is required for the monitoring program, only an installation fee and covering the cost of any custom sensors.

IOT Based Leak Detection Sensors

The sensor systems all comprise a sensing element consisting of a silicone-based polymer embedded with conductive nanoparticles. This system was developed at the University of Calgary by Dr. Park and Dr. Parmar.

The polymer's characteristic of swelling in the presence of hydrocarbon molecules is exploited to detect hydrocarbon leaks. The polymer also provides the advantage of being hydrophobic and thus unaffected by water. The addition of nanoparticulates into the polymer matrix offers high electrical conductivity and reduces the concentration required to achieve the percolation threshold [2]. Thus, only a low concentration of nanoparticulates is required to achieve the same conductivity as other conductive particles, thereby reducing material costs. Moreover, the geometry of nanoparticulates facilitates elastic deformation (i.e. buckling rather than breaking), which leads to improvements in the robustness and stability of the nanoparticulates/polymer composites over time. This geometry also provides nanocomposite materials with high surface areas and exceptional electrical, thermal and chemical inertness, allowing them to have great potential as chemical detection sensors.

Figure 1. Effect of Hydrocarbon exposure on Polymer Nanocomposite

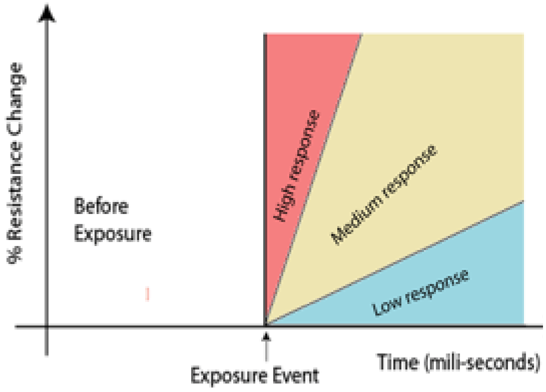


The silicone-based polymer swells upon physisorption of hydrocarbon molecules, causing increases in the distances between nanoparticulates and decreases in the nanoparticulate-nanoparticulate contacts, thereby increasing the resistance of the silicone-based polymer/nanoparticulate nanocomposite as shown in Fig. 1.

Table 1. Change in Resistance of the PNC coating on Exposure to liquid Hydrocarbons

Hydrocarbon	Instantaneous Slope (degrees)	Type of Response
Pentane	89.3	High
Octane	88.8	High
Diesel	73	Medium
Crude Oil	9	Low
Motor Oil	6	Low

Figure 2. Response of the Polymer Nanocomposite Coating



A Polymer Nanocomposite Coating was formulated for these applications which was not affected by methane (to eliminate any false positives caused by background methane), but rather was tuned to detect liquid C5 to C24 Hydrocarbons.

Since the detection method is based on the rate of change in resistance of the sensor, the type of hydrocarbon can be determined. This enables the detection, in a situation where several different hydrocarbons are being stored or transported close to a particular sensor, of which hydrocarbon has leaked.

Figure 3 illustrates some examples of leak detection sensor designs for various applications.

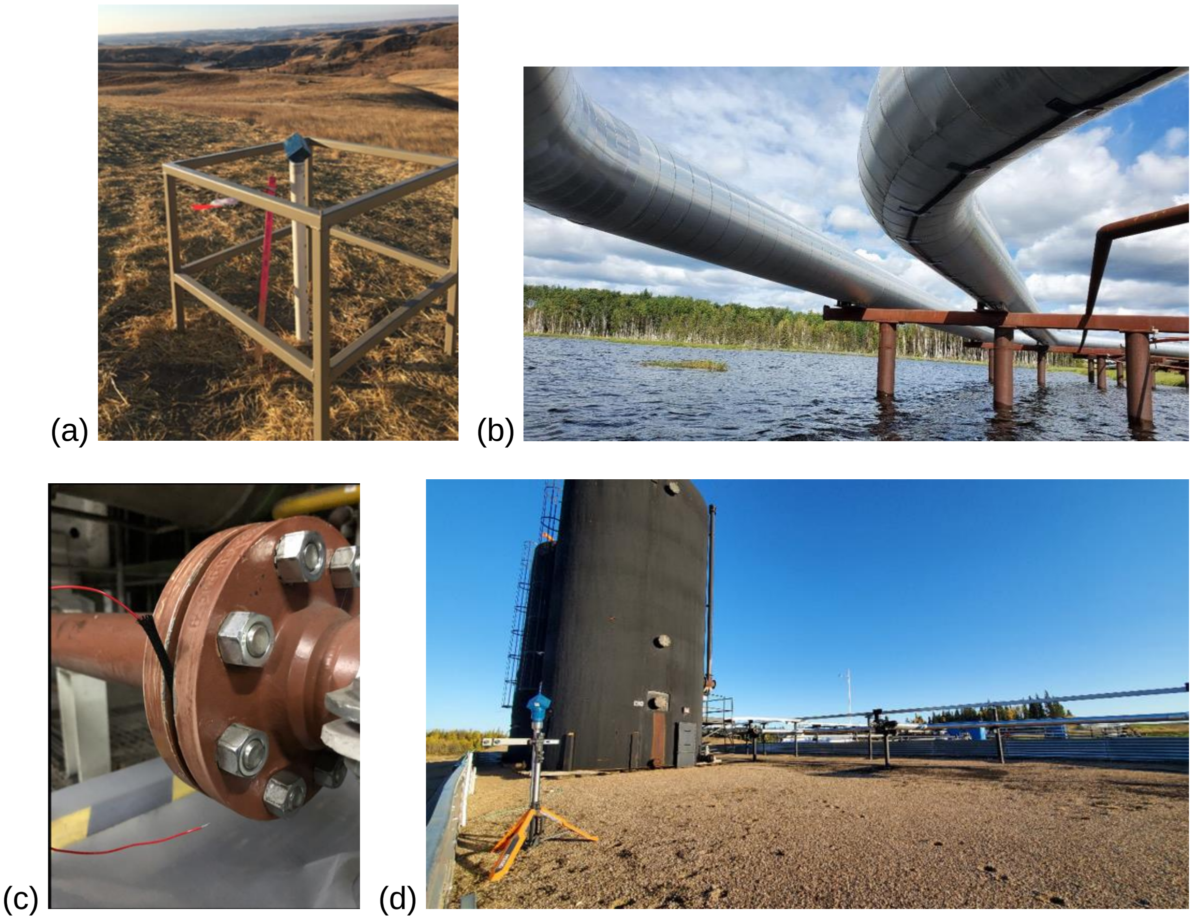


Figure 3. Leak detection systems for (a) ground probes near underground pipelines, (b) flexible sensor chains for aboveground pipelines with thermal insulation, (c) narrow and flexible sensors for flange fitting and tight gaps, and (d) mounted tripod sensors for aboveground and open locations.

Direct-C offers four standard leak detection deployment options: SubSense™ ground probe system, WrapSense™ flexible sensor chain, FlangeSense™ a narrow flexible sensor and BermSense™ and above ground system.

Of the four different configurations of the Leak Detection systems, the ground probe type has already been used as a fleet of 100 sensors, which were redeployed in different locations along the pipeline length. As pipeline defects were repaired, the sensors were redeployed to other locations in other States that were deemed to be the next in line for repairs.

IOT based Condition Monitoring Devices

The next generation of IOT based monitoring devices is currently being developed.

The aim is to add functionality to the leak detection system to enable the devices to generate useful data on the condition of the pipeline which can then be added to the data analytical systems.

Temperature Monitoring has been added to the WrapSense sensor by adding thermistors into the WrapSense chain. These thermistors are read in sequence with the Hydrocarbon sensors and have a special set of Alarms that enables either the detection of very high temperatures where a hot product is being monitored or very low temperatures where the pipeline is being heated and the loss of that heating needs being monitored.

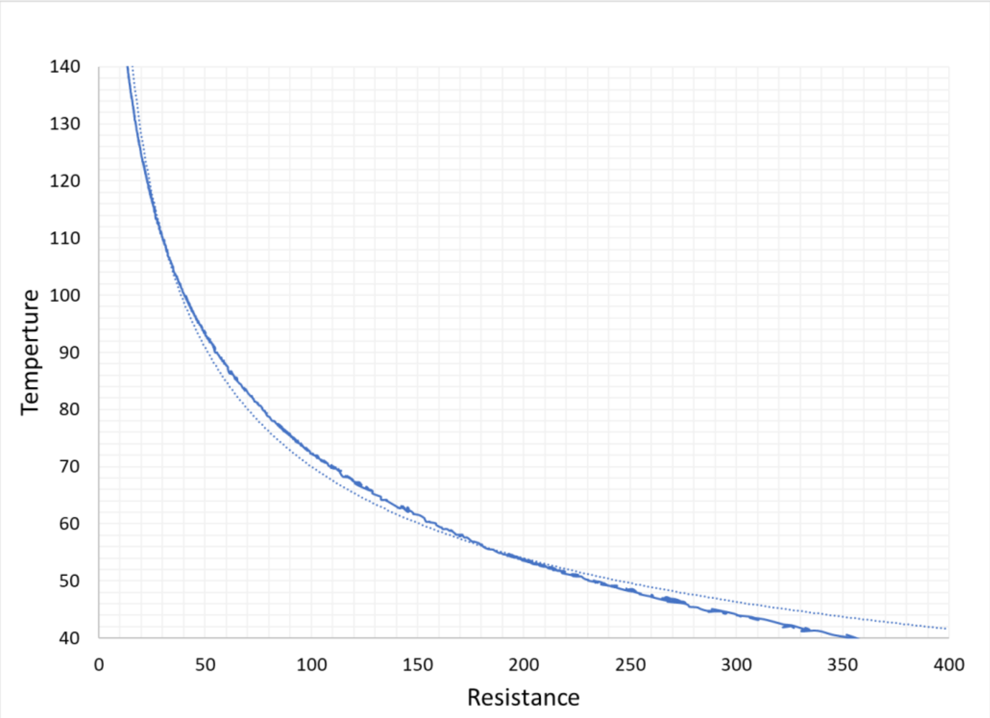


Figure 4 Thermistor Response graphs showing Temperature monitoring capability from + 40 ºC to + 140 ºC.

Conclusion

This work has demonstrated that advanced data analytics can be used to prioritize threats for either excavation and repair programs or less invasive threat mitigation techniques, such as IOT leak detection devices. This will have an influence on dig program efficiency for most operators. The most significant benefit is that the installation of IOT leak detection devices allows for more efficient dig programs without sacrificing pipeline safety. Modern IOT leak detection devices can be installed cost effectively to warn operators of leaks within minutes through cloud-based alarms. For large remediation programs, a fleet of mobile IOT Leak Detection devices can be deployed and then be redeployed to provide rolling leak detection coverage as defects are repaired.

Next generation IOT devices also have the capability of conducting condition monitoring on the pipeline infrastructure, for example thermistors can be added to an IOT based leak detection system so it can also monitor the temperature of insulated pipelines enabling the loss of heating of the pipeline to be rapidly detected.