Multi-Sensor Autonomous Inspection Device for Condition Assessment

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ABSTRACT

PICA provides a breadth of services to asset managers, and we built a Multi-Sensor Autonomous Inspection Device (MSAID) for low-resolution condition assessment. PICA used this device to help the municipality of Jasper, AB, CAN gather data on a fire water pipeline. The device was inserted and retrieved through fire hydrants connected to the line. The data collected by the device was used to determine a leak location. This allowed the municipality of Jasper, AB, to repair that specific section that had been causing a significant loss of water. Applications of technology are constantly evolving by becoming more efficient, resilient, and effective. Using a Multi-Sensor Autonomous Inspection Device allowed the Municipality of Jasper, AB to gain a low-resolution data set without interrupting service.

INTRODUCTION

PICA Corp. in collaboration with Russell NDE Systems introduces the Multi-Sensor Autonomous Inspection Device (MSAID), an end user-focused solution for evaluating the health of critical pressure pipe infrastructure. This minimally invasive, low-resolution tool addresses the complex challenges faced by asset managers in maintaining aging and intricate pipeline networks. MSAID overcomes logistical constraints, delivers rapid data acquisition and analysis, and empowers informed decision-making, providing a safeguard to vital water and wastewater systems.

With over two decades of experience in providing high-resolution tools for pipeline inspection, PICA stands at the forefront of innovation in infrastructure condition assessment. Leveraging our extensive experience with high-resolution tools, we have introduced a minimally invasive, low-resolution tool tailored to identify areas that could significantly benefit from the application of our high-resolution and more invasive tools.

Collecting accurate data to evaluate the state of critical pressure pipe infrastructure presents a myriad of challenges for asset managers. From the inability to take pipelines out of service for extended periods to inaccurate record-keeping, private property constraints, unreported repairs, and insufficient capital for full replacements. In response to these challenges, there is a crucial need for a low-resolution, minimally invasive tool that can efficiently establish a baseline dataset to help develop a comprehensive condition assessment plan for critical water and wastewater infrastructure. PICA Corp. sought to address some of the challenges and concerns presented in the AWWA State of the Water Industry yearly reports. (Years 2022 and 2023)

SOLUTION

PICA Corp. determined that to best provide a low-resolution, minimally invasive inspection combining the following sensors in an adjustable buoyancy sphere would meet the needs of asset managers.

A super-sensitive ultrasonic crystal is used to detect leaks and air pockets through acoustic anomalies. The ultrasonic crystal uses piezoelectric materials to detect ultrasonic noises which are recorded by internal electronics. The piezoelectric materials can detect sound up to 30 MHz and the human ear can detect sound up to 20 kHz. (Platte 1996) Leaks produce a sound that generates a sharp acoustic change from the baseline level of the acoustic spectrum. Air pockets produce an acoustic change that can be described as between the two extremes of baseline acoustic change. Figure 1 below shows the data from a leak and corresponding air pockets leading to the location of the leak.

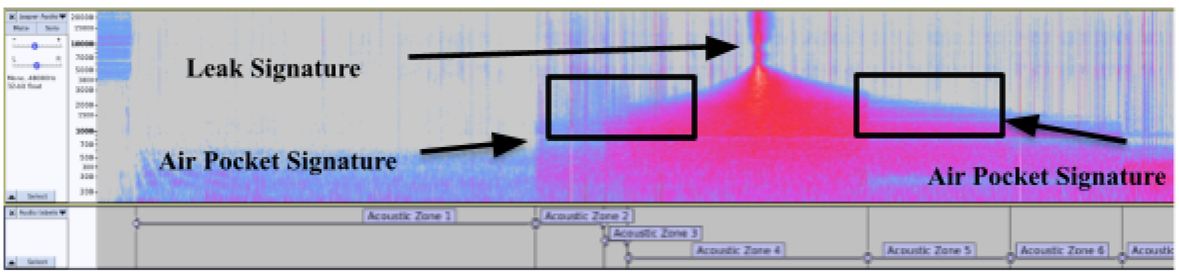

Figure SEQ Figure * ARABIC 1. Acoustic Leak Data

Using a magnetometer to collect data in a pipeline while underflow can provide an initial baseline of pipe magnetic data. In a nonmetallic pipeline, the magnetometer can detect metallic features along the pipeline path. In a metallic pipeline, a baseline measurement of magnetic flux resident in the pipe wall can provide a basis for comparison to future runs where the loss of wall through corrosion may have changed the magnetic properties of the pipe. For the application of MSAID and the challenges in the water and wastewater industry, the data collected by the magnetometer on an initial data collection inspection indicate that the results of magnetometer data should only be used in correlation with other data analysis methods. The limitations of historical qualitative data analysis, controlling the speed of the device, pipe wall magnetic saturation, etc. affect the accuracy of magnetometer data. (Shi, et al. 2015) The data gathered is useful in providing the data analyst with a more comprehensive picture of the condition assessment of the pipeline in question. Figure 2 reflects the magnetometer data collected around the leak detected for the Jasper, AB pipeline.

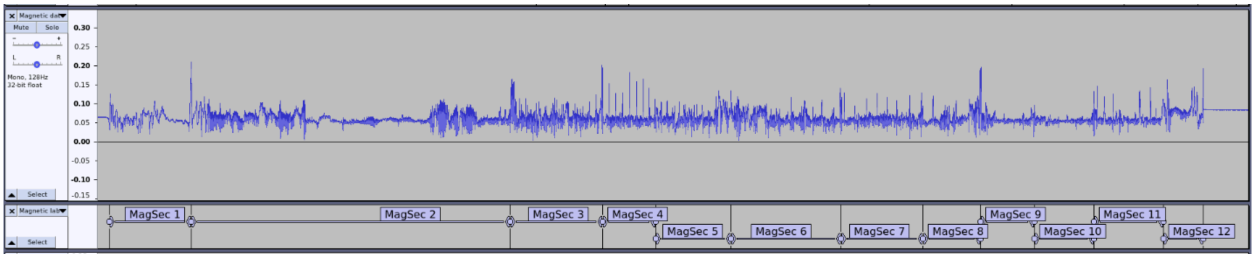

Figure SEQ Figure * ARABIC 2. Magnetic Features

The image above in Figure 2 provides a visual representation of magnetometer data from an initial data collection run of the pipeline. Patterns can be recognized, and varying levels of magnetic flux can be seen. Without knowledge of what the baseline conditions were when the pipeline was installed the data gathered should only be used to correlate the data collected by the other sensors. In the future, it would be beneficial to measure the data collected over periods to assist in providing an analysis of changes in magnetic flux over time.

A pressure sensor is contained in the device to measure changes in pressure along the pipeline path. A sudden variation in pressure can indicate a pipeline anomaly that could be a leak. Hydraulic head pressure changes help to indicate elevation changes on the pipeline path. The pressure reading can be correlated with existing plan and profile records to help asset managers determine the current condition of the pipeline. (Idachaba, Tomomewo 2022) The pressure reading from the area of the leak is shown in Figure 3 below.

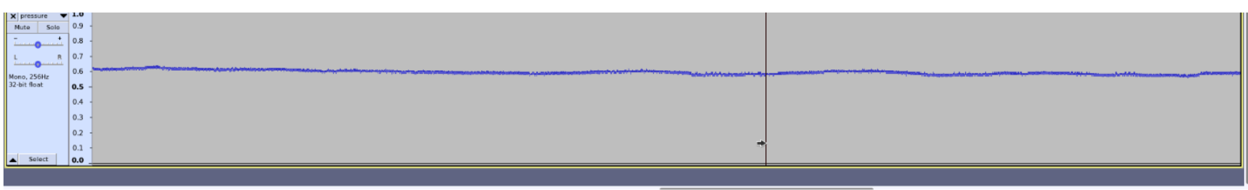

Figure SEQ Figure * ARABIC 3. Pressure Data

The MSAID also contains an accelerometer and inertial measurement unit (IMU) which allow the data analyst to further correlate the data collected. These sensors assist in providing information about the device's location in the pipe along the path during the inspection.

A significant challenge in ensuring that the device makes it through the entire pipeline path is the buoyancy of the device in the pipeline fluid. If the device is too buoyant then it could become obstructed by air release valves or other unknown blockages in the crown of the pipeline. If the device is not buoyant enough, then it can get lodged in deposits or other unknown blockages along the bottom of the pipeline. The device can have the weight altered on-site thus allowing the buoyancy of the device to change to field conditions to ensure a successful completion of the proposed pipeline path. The post and weights can be visualized in Figure 4 below.

Figure SEQ Figure * ARABIC 4. Buoyancy Weight Alteration Post

The timeliness of data analysis is critical to asset management, especially in the context of identifying a leak. PICA's autonomous inspection device is engineered for efficiency, allowing users to upload data as soon as an internet connection becomes available. This real-time data transfer enables our skilled data analysts to conduct a preliminary analysis within hours of completing successful field operations. The rapid turnaround time ensures that asset managers receive actionable insights promptly, facilitating swift decision-making and proactive infrastructure management.

The MSAID records data on a Micro-USB memory card that is easily accessed by the device user. Once the fieldwork is complete the Micro-USB memory card is removed, and the data is uploaded to the PICA data analyst. An initial analysis of the data can be completed within 3 business days depending on the length of the pipeline and a full report can be submitted in 10 business days.

Understanding the importance of convenience, PICA designed an autonomous inspection device with intuitive operations. The user has the flexibility to modify buoyancy before field operations, ensuring a seamless retrieval process. Additionally, the device's user-friendly interface facilitates easy data upload, providing asset managers with quick and hassle-free access to critical information about their infrastructure.

RESULT

The municipality of Jasper, AB, Canada, faced a suspected water line leak, prompting a swift response from PICA. From the initial contact to the completion of fieldwork, launched and retrieved from modified hydrants seen in Figure 5 and Figure 6 below, our team ensured a seamless process, deploying a field technician equipped with our advanced inspection device in under 45 days.

Figure SEQ Figure * ARABIC 5. Jasper Insertion Hydrant

PICA leveraged its extensive high-resolution inspection experience to develop a deployment method for inspecting pipelines. A field technician utilized a modified fire hydrant

to introduce the inspection device into the pipeline. A specially designed catch device was used to retrieve the device from another designated exit hydrant. This approach enabled swift and efficient inspection of the water line. One of the key innovations is the ability to use readily available fire hydrants, eliminating the need for creating complex insertion and retrieval points. The dedicated catch device ensures smooth retrieval, minimizing disruption and potential damage to the asset. This method streamlines the inspection process, saving time and resources.

Upon completing the fieldwork, the collected data was uploaded in hours, and our data analyst, utilizing the device's sensors and map files, determined on the same day that a leak had been detected. Leveraging the information gathered, PICA's analysis team provided an approximate location of the leak within a range of 10 meters. Figure 7 below shows the location of magnetic anomalies and the leak location that MSAID and our data analysis team detected.

Figure SEQ Figure * ARABIC 7. Map Overview of Jasper Anomalies

Following the precise leak location identified during fieldwork, the Jasper operations team mobilized to discover the leak. The leak identified was a lateral split on the underside of the pipe that encompassed almost 50 percent of the circumference. They were able to locate and repair the leak within days, demonstrating effective collaboration between PICA's data analysis, operations team, and the Municipality of Jasper. This prompt action minimized disruption to the community's fire water supply. An image of the leak is shown in Figure 8 below.

Figure SEQ Figure * ARABIC 8. Jasper Leak

The leak detection and repair in Jasper demonstrates the efficiency and precision of the methods employed with the MSAID. Combining innovative technologies with a dedicated operations team allowed for a swift response and successful resolution, minimizing disruption to the fire water supply. As advancements in infrastructure inspection continue, the focus remains on supporting communities in maintaining the resilience of their water networks.

CONCLUSION

PICA's autonomous inspection solution represents improved optionality in the assessment of critical water and wastewater infrastructure. By integrating multiple technologies, overcoming buoyancy challenges, and prioritizing timely data acquisition and analysis, our solution empowers asset managers with a tool that enhances the reliability, efficiency, and overall integrity of pipeline inspections. As we continue to push the boundaries of innovation, PICA remains dedicated to providing solutions that meet the evolving needs of the industry and pave the way for a more sustainable and resilient infrastructure future.

MSAID doesn't replace high-resolution inspection tools; it supplements them. By providing a preliminary assessment, MSAID identifies areas with the highest probability of requiring high-resolution examination. This targeted approach dramatically reduces inspection time and cost, optimizing resource allocation and ensuring the most impactful use of high-resolution technology. In the vast, intricate pipeline networks asset managers are responsible for MSAID acts as a reconnaissance tool, narrowing down potential trouble spots, and allowing high-resolution tools to focus their powerful capabilities on confirmed areas of concern, maximizing their effectiveness.

The success of Jasper, AB, is evidence of MSAID's versatility. Its modular design and internal sensors make it adaptable to diverse pipeline configurations and challenges. From aging cast-iron pipes to modern networks, MSAID navigates bends, traverses obstacles, and adapts to varying pipeline changes, ensuring successful deployment even in the most complex systems. This adaptability makes MSAID a truly global solution, applicable to a wide range of water and wastewater infrastructure across the world.

By prioritizing minimally invasive inspections, rapid data acquisition, and actionable insights, MSAID offers improved options in pipeline management. It empowers asset managers to:

- Extend the lifespan of critical infrastructure: Proactive maintenance driven by data insights prevents premature failures and costly replacements.
- Minimize service disruptions: Targeted inspections and rapid data analysis allow for swift interventions with minimal impact on water and wastewater services.
- Optimize resource allocation: Focusing resources on areas with the highest risk of failure maximizes cost-efficiency and ensures the most effective utilization of maintenance budgets.

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