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Hot Pipeline Condition Assessment Study

Nomination for:

Canadian Consulting Engineer Awards

BUILDINGS CATEGORY

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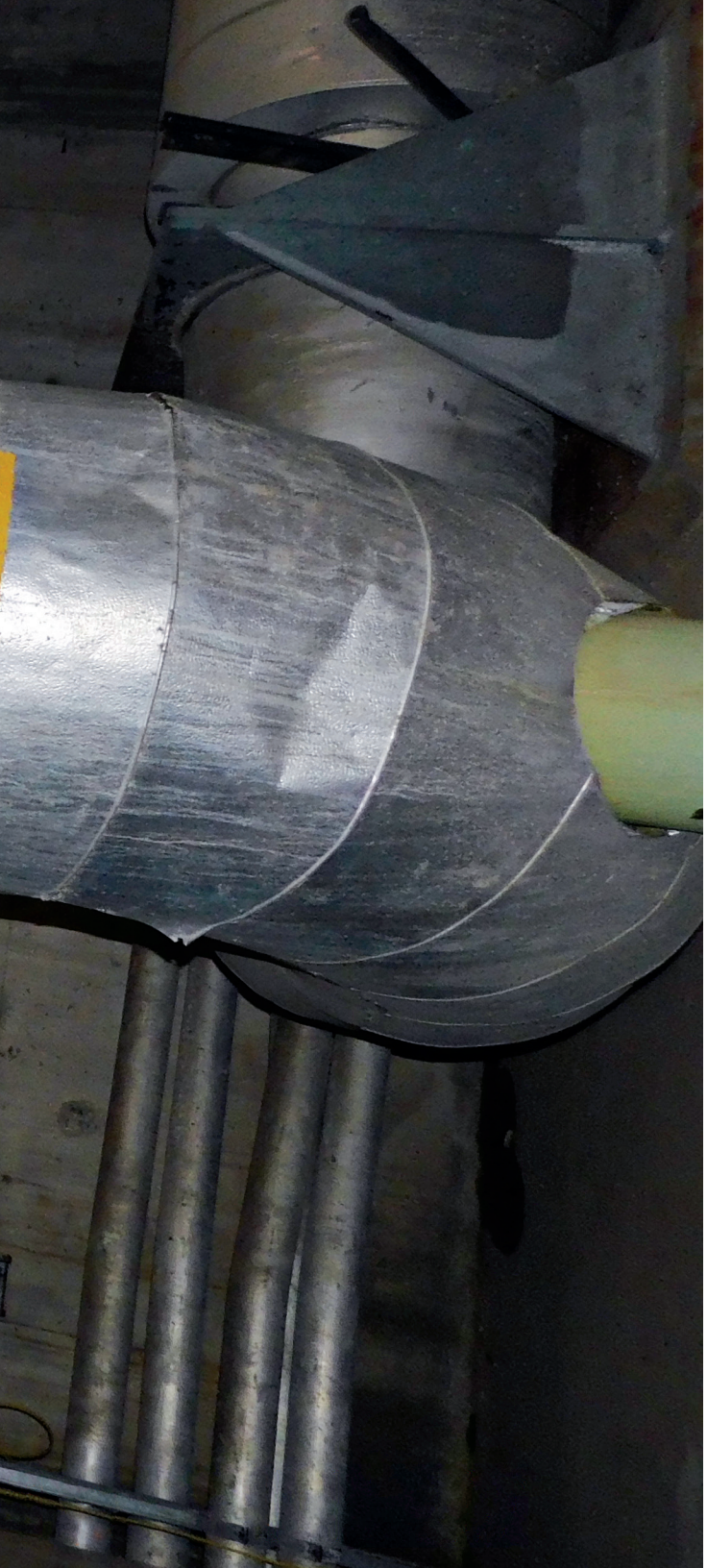
Summary

The Greater Toronto Airport Authority (GTAA) owns and operates a critical Hot Pipeline System that consists of Carbon Steel pipes operating at high temperatures. These pipelines must be assessed to ensure the continuous operation of the Toronto Pearson International Airport. GTAA engaged CIMA+ to develop a condition assessment solution to meet the GTAA's high inspection standards. Today, the GTAA is inspecting their entire hot water pipe population based on the results from this study.



Innovation

The GTAA's IOS55000 strategy for hot water assets adopts a proactive asset management approach to mitigate unexpected failure risks and ensure the continuous operation of the Toronto Pearson International Airport. Inspection findings will be interpreted into a POF score to rationalize investments in renewal capital plans based on a risk-based approach.

The GTAA engaged CIMA+ to develop an assessment method to assess the challenging pipeline systems (carrier inside a conduct), given the limitations and constraints resulting from system operating conditions (high temperature) and their limited tolerance for inspection risks (preferring external tool concept and non-invasive tool). Acoustic technology is a well-known technology employed in potable watermains and is suitable to inspect buried pipelines. However, it is limited to pipelines installed in a compacted backfill and not installed in a void like the hot pipeline installation setup. When a noise acoustic wave is introduced on the pipe's external wall surface, it will vibrate on a macroscopic level causing radial displacements that impact the sound wave velocity moving inside the hot water body. Since the pipe is not compacted in the backfill, the boundary conditions for equilibrium is not the pipe wall (pipe stiffness is much bigger than soil stiffness) but the void surrounding the carrier pipe. This issue will lead to a variety of acoustic wave measurement results that cannot be used to assess the wave velocity due to the high range of wave velocity outputs.

Innovation (continued)

To address the boundary conditions for equilibrium issues, we developed the introduction of the acoustic sound wave in two forms simultaneously. The first form introduces the sound wave outside the pipe, similar to regular acoustic technology, but using a constant frequency of tapping on the pipe's external wall surface. The other form introduces a wave using a high amplitude sonar wave measuring deformations from inside the pipe. Introducing these two waves (inside and outside the pipe wall) the acoustic measurements can be compared to a point when the frequencies correlate providing a conclusive result of wave velocity. Once the velocity is determined, the pipe's remaining wall thickness can be calculated using transient wave velocity formula.

This innovated idea allowed the use of modified acoustic technology to assess Hot Water Pipes while the pipes are in-service. With no operational changes, this solution replaces the use of invasive tools that cannot withstand the high operating temperatures if deployed while in-service or requires the system to be out-of-service.

Complexity

Two major problems required creative solutions. The first was securing funds to conduct a trial and validation of the proposed idea, and the second was implementing the idea of constant external noise and building such a sensor.

To address both issues, CIMA+ developed a multistage plan for the GTAA that involved four major steps. The first step included a presentation of the proposed acoustic modification idea supported by simulation modeling and a detailed budget to get GTAA buy-in. Once the GTAA approved the budget, we started with the second step and engaged an acoustic technology vendor to design and build the equipment. The proposed solution for constant external noise was developing a “shaker” sensor that vibrates on a different and known wide range of frequencies that can correlate with sonar waves introduced inside the pipe. The third stage included picking a testbed pipe and performing actual field measurements using the newly developed tools. Once results were provided with a range of accuracy, CIMA+ implemented that last stage and validated the results and accuracy by collecting a sample of the inspected pipe and conduct pit depth measurements at a third party specialist lab.

Complexity (continued)

Results came back with an average of 6% accuracy which exceeded the original expectation of 10% accuracy. However, this accuracy can be increased by assessing the air inside the pipe since trapped air inside a water body impacts the wave velocity that is being measured.

Social and/or Economic Benefits

Hot water systems are critical assets used mainly for heating facilities such as airport terminals, hospitals, schools, mining industry, malls, etc. These systems should be assessed regularly to avoid catastrophic failures that may influence the operation of these critical systems required for any society.

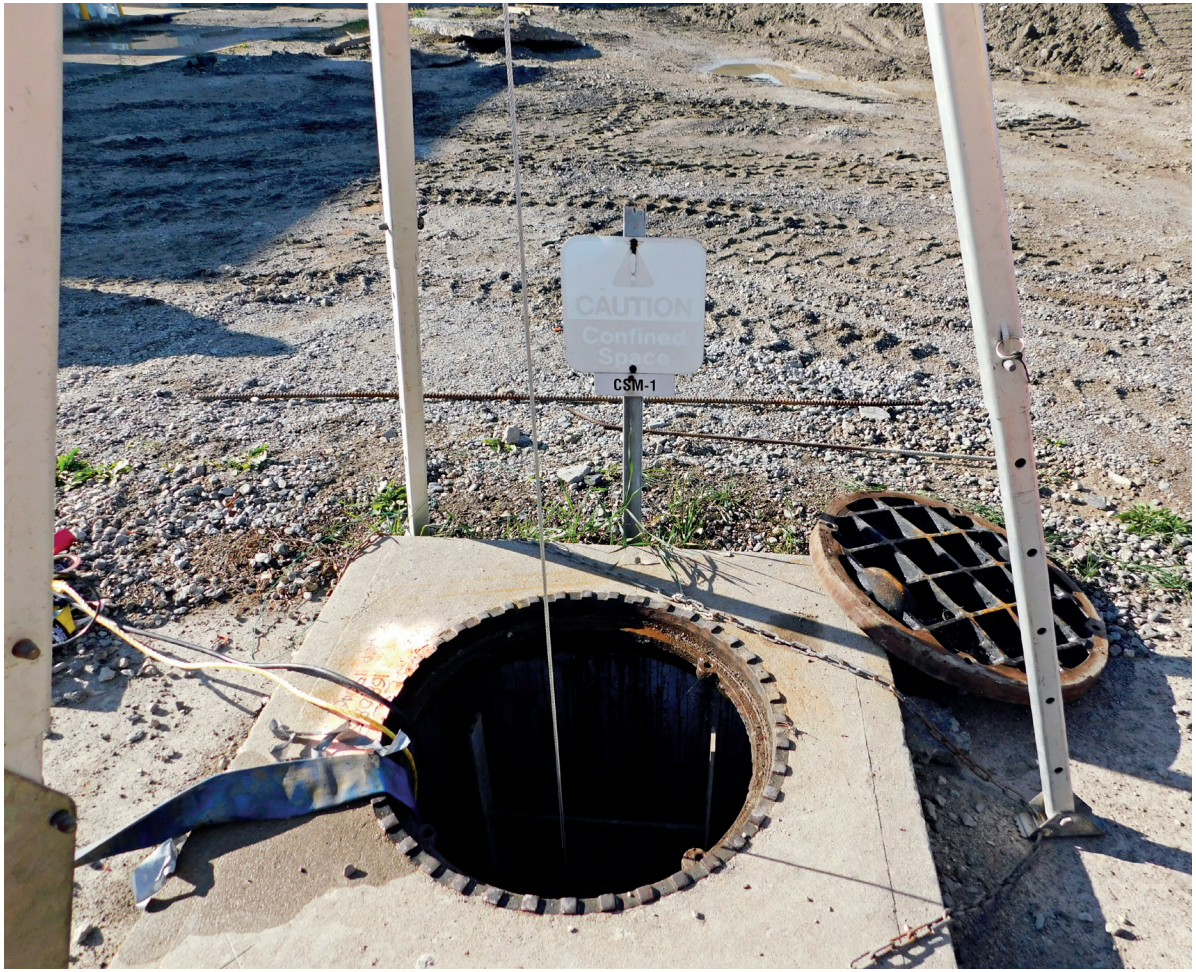
Also, failure in these systems may place a significant economic burden not only due to the direct cost of repairing hot water pipe breaks but also the cost associated with stopping the functionality of this system to conduct the repair. It is paramount to have a method capable to assess the hot water's physical condition at any time during the year to avoid unexpected failures during working seasons.

The findings of this study will be implemented this year (2021) by the GTAA, scaling the trial results to their entire hot water asset inventory. The GTAA is using the modified tool in this study to inspect their hot water pipe system while the system is in-service and fully operational. When the system is offline during summer, the GTAA can address repairs and replacement needs identified during the assessment that was conducted at the bigging of the year. This study allowed the GTAA to develop a seasonal maintenance cycle of assessing and renewing (as needed) during each year and increases the reliability of their hot water pipeline system.

Environmental Benefits

Hot water systems convey water fluids that contain chemicals designed to allow that water to run in high temperatures and provide a corrosion barrier for the internal surface of the pipeline. The hot water is designed in a closed-loop pipe system and any drainage is conducted within the closed-loop system using storage in boilers.

Therefore, any unexpected failures and main breaks will lead to hot water spills that may present a health and safety hazard due to high water temperatures and the chemicals inside the water may reach watercourses and/or combined sewer systems. The spilled water could eventually reach the treatment plants and cause significant issues to the treatment process due to high concentrated chemicals in the water. The Pearson Airport area includes major watercourses and combined sewer systems that require reliable hot water systems that should be assessed annually and repaired as needed in a controlled and planned environment to avoid any spills in addition to the sustainability of the terminal's operations.



Meeting Client's Needs

The GTAA's objectives of the study were to develop an assessment method suitable to assess hot water pipeline systems while the pipe remains in-service.

Also, the GTAA has limited tolerance for risky inspections that use free-swimming platforms and require a method that can be used during operation seasons to utilize the offline period for repairs previously identified by the assessment method and prevent future failures by implementing an annual assessment-maintenance lifecycle.

These research findings enabled the GTAA to adopt an assessment method based on external platform sensors that do not involve invasive tools inside the pipelines and can be deployed while the system is fully operational and in any season of the year. This allows the GTAA to plan inspections on an annual basis and ensure high reliability in their hot water system to avoid unnecessary shutdowns that may influence the continued operation of Canada's largest airport.