Nondestructive tool developed for inline assessments of mortar-lined water pipelines

For many years water utilities had expressed the need for improved accuracy in pipeline condition assessment, particularly for large-diameter pipelines that are often old, yet critical to water delivery systems. Frequently the only alternative to doing nothing was to gather indirect data and try to make the best judgment of a pipeline’s condition and its need for repairs, rehabilitation, or replacement. To achieve a means for conducting accurate water pipe inspections for large-diameter, cement mortar-lined steel pipes, the Hetch Hetchy Water and Power (HHWP) division of the San Francisco Public Utilities Commission (SFPUC) (San Francisco, California) initiated the development of an inline inspection (ILI) system that features a magnetic flux leakage (MFL) tool to detect corrosion of the steel pipe wall.

In 2007, HHWP wanted to accurately assess the condition of the San Joaquin Valley water pipelines to determine their future reliability, as well as to minimize maintenance costs, says NACE International member Rod Jackson, corrosion engineer with CH2M Hill (Sacramento, California). These pipelines, built in 1932, 1953, and 1968, include ~120 miles (193 km) of pipe with a replacement value on the order of $1 billion. Substantial portions of the existing pipelines are constructed of cement mortar-lined steel pipe.

Like other water utilities, HHWP’s prior condition assessments of its buried water pipelines were based on traditional methods for data collection and analysis, such as review of maintenance records (reports on leaks, soil corrosivity, and coating condition) and excavation of the pipe for inspection. The quality and accuracy of the collected data affect the validity of engineering evaluations, and experience suggests that these traditional methods of condition assessment provide a moderate level of accuracy at best.

According to Jackson, Margaret Hanfford, division manager for HHWP, recognized the limitations of traditional assessment methods for water pipelines and determined that the most accurate method to assess the pipelines would be to use an ILI method—similar to the ILI technologies used to inspect oil and gas pipelines—that scans the full circumference and length of the pipeline for damage from corrosion and other sources. However, the cement mortar lining unique to water pipelines had prevented accurate assessment of the pipe wall by ILI. To overcome the limitations of ILI methodologies for water pipes, Hanfford led a team, which included Electro-mechanical Technologies, Inc. (EMTEK) as the ILI expert and CH2M Hill as the technical consultant, to pursue the development of an ILI system for mortar-lined water pipelines.

“She assembled the team, arranged financing, and led the project to success—
ful completion,” says Jackson. “This innovative inspection system would not exist without her vision and commitment. It will benefit the entire water pipeline industry as well as the San Francisco water system.”

Three possible ILI technologies—ultrasonic thickness gauging, remote field eddy current, and MFL—were initially evaluated based on the literature and state-of-the-art systems used in the oil and gas pipeline industry. MFL technology was ultimately selected based on the expected accuracy and practicality. Similar to ILI methods for oil and gas pipelines, the resulting inspection system works by passing the scanning device through the inside of the pipeline and interpreting the data it collects to identify anomalies that indicate metal loss from corrosion or other types of damage.

It uses MFL technology to accurately measure the depths and dimensions of areas with metal loss from corrosion, including pitting, thinning, galvanic action, and microbiologically influenced corrosion (MIC), and also identify the locations of these areas in the pipeline. Additionally, features such as joints, connections, welds, and third-party damage can be readily identified, as well as old repairs and modifications that may not have been fully documented in records, which is common for older pipelines. The system includes a MFL tool to inspect pipelines with diameters ranging from 56 to 80 in (1.4 to 2 m) and a cement mortar lining that is 0.5-in (13-mm) thick or more; a geometry (caliper) tool to verify the internal diameter of the pipeline in multiple locations to ensure the MFL would pass through it; and propulsion equipment to move the tool through the pipeline, which is taken out of service and drained prior to inspection. All power and data storage are housed in the tool. A computer-based system for data handling and interpretation was also developed.

MFL technology is relatively simple in concept, says Jackson. Permanent magnets are used to temporarily magnetize the steel pipe and the effect is observed. When there are no flaws in the wall of the pipe, the magnetic flux is uniform. If internal or external flaws are present, however, the magnetic flux is distorted, and this distortion or “leakage” can be measured by Hall Effect sensors. He notes that applying MFL as an ILI methodology for large-diameter, mortar-lined pipe posed several challenges. First, powerful magnet assemblies had to be designed and built to magnetize the thick steel pipe wall through the mortar. Then, precision electronics had to be designed and built to magnetize the thick steel pipe wall through the mortar. Then, precision electronics had to be configured to acquire and retain huge amounts of digital data. Also, computer software needed to be developed to retrieve the MFL signals and correctly interpret the data. In addition, all ILI equipment had to be designed so it could be placed unassembled into the pipeline through existing manholes, then assembled, operated,

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unassembled, and removed by the reverse process. “Existing large-diameter water pipelines rarely have pig launching facilities,” Jackson says.

Another challenge was to make the tool adaptable to a range of pipeline diameters. This was accomplished using a modular frame design for the carriage. The diameter of the tool is adjusted by changing certain parts of the frame while keeping the same tool configuration.

Lastly, a means to safely move the tool through the pipeline at the desired rate of travel needed to be developed. An electric vehicle propulsion system was designed for this purpose. The combined weight of the magnets, electronics, power supply, carriage, and propulsion system is several thousand pounds.

Development of the ILI system started in 2007 and occurred in several phases. Phase 1 included design and construction of prototype systems with bench-scale testing followed by full-scale field testing on six miles of pipeline. Phase 2 consisted of revisions to the previously constructed ILI systems and subsequent full-scale field testing on seven miles of pipeline. Phase 3 consisted of further improvements to the MFL tools, electronics, and software, with full-scale field testing on additional pipeline. Since June 2013, the ILI system has been used to inspect water pipelines operated by the SFPUC and the San Diego County Water Authority.

The ILI system overcomes the barriers to magnetic induction and field strength measurements that are created by thick cement mortar linings in steel pipe. In addition, the ILI system overcomes the marginal accuracy provided by traditional indirect forms of pipeline condition assessment. “There is no other proven ILI system that can accurately measure metal loss and other features in large-diameter steel pipe with a mortar lining,” says Jackson. All large-diameter, cement mortar-lined steel pipelines are candidates for evaluation by this MFL ILI system. The only requirements are that the pipelines must be temporarily taken out of service and drained, so they are safe for personnel to enter and will allow passage of the ILI system.

“Our innovative work was an amazing collaboration from start to finish,” says Hannaford. “Developing a more efficient approach to address an age-old problem has allowed us to better maximize and prioritize our limited project resources.”

In 2011, during the later stages of ILI system development, EMTEK was acquired by Pure Technologies, which took over the manufacturing and delivery of completed tools, electronics, software, and related items. Pure Technologies obtained rights to build similar tools and markets the inspection system as a commercially available service.

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