

Innovative Cost-Effective Noninvasive Ultrasonic Testing for Utility Replacement

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Water utilities are faced with replacing aging infrastructure, while experiencing an ever-reducing repair and replacement budget. Finding cost-effective repair and replacement methods is an important objective for entities managing utility infrastructure. To accomplish this objective, South Seminole and North Orange County Wastewater Transmission Authority (Authority) explored cost-effective methods on aging pipeline infrastructure that resulted in substantial savings.

The Authority is an organization tasked with the funding, planning, operation, and maintenance of a wastewater transmission system serving five major local municipalities. This transmission system consists of transmission force mains, pump stations, and monitoring stations. The collected wastewater is conveyed to the Iron Bridge Regional Reclamation Facility, which is operated by the City of Orlando.

To continually maintain the integrity of the transmission system, the Authority re-evaluated its existing force main transmission system utilizing an innovative testing technology called noninvasive ultrasonic testing. The selected por-

tion of the transmission system had a ductile iron force main routed along a major state road (known as Aloma Avenue) that was experiencing significant corrosion ahead of its useful life, to the extent that replacement was recommended. In lieu of additional coupon testing done through a previous study (which is a destructive testing method) the Authority retained Reiss Engineering Inc. (REI) to implement non-destructive and noninvasive ultrasonic testing.

In order to determine the exact extent of the corrosion, locations were strategically identified based on evaluating those previous field testing results and pipeline profiles. At each test location, ultrasonic readings were conducted at the top of a pipe or along an array of angles located in a cross section of the pipe. These ultrasonic measurements of the pipe's wall thickness were compared to the original wall thickness to determine the extent of corrosion and associated remaining pipe wall thickness.

This technology narrowed the previously determined damage to a specific area along the force main, resulting in substantial savings to the Authority totaling approximately \$1.1 million. The success of the project persuaded the Authority to continue noninvasive ultrasonic testing on an annual basis to assess the rest of the infrastructure throughout the transmission system, which was

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completed in 2013, and in 2014, involving the same method of pipeline integrity testing.

Background

Ductile iron piping is subject to major corrosion, as shown in Figure 1. One of the primary factors of pipe corrosion in wastewater transmission systems is the production of hydrogen sulfide gas (H_2S). High points in the piping network can collect H_2S , making these areas more susceptible to corrosion. Air release valves (ARVs) are customarily located at the highest points in a force main piping system to avoid H_2S accumulation; yet, not every high point potentially vulnerable to air trapping contains an ARV. In addition, force mains do not always flow full, al-



Figure 1. Ductile Iron Pipe Corrosion

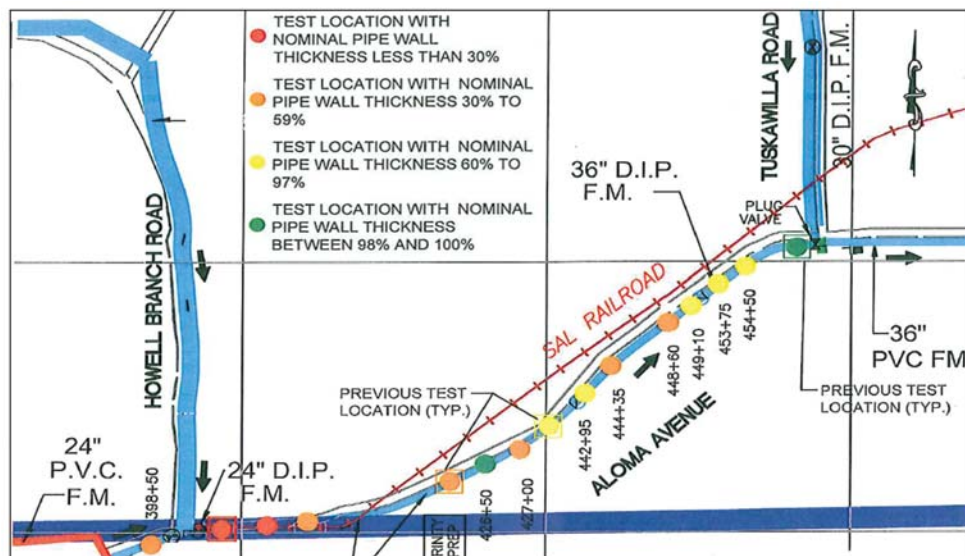


Figure 2. Previous Aloma Avenue Thickness Testing

lowing H₂S to accumulate in the open space and essentially coming in contact with the ductile iron force mains throughout the system. Hence, there is a periodic necessity to quantify corrosion levels and replace or rehabilitate pipelines.

In 2004 and 2007, previous studies were conducted to assess pipe integrity in a section of the transmission system owned by the Authority. The results, shown in Figure 2, indicated that the section of the force main located in the right of way (ROW) of Aloma Avenue, between Old Howell Branch Road and Tuskawilla Road, was severely corroded and needed to be replaced. The previous testing efforts did not provide any detail on methods used prior to and during the testing effort conducted on this force main section.

In lieu of destructive testing methods, the Authority retained REI to re-evaluate its existing force main transmission system utilizing a non-destructive ultrasonic testing. Initially, 13 testing locations along 6,800 lin ft of the 36-in. force main were completed using the noninvasive ultrasonic testing method. Unlike the results previously obtained through other studies, the ultrasonic tests showed that only one test location exhibited critical deterioration of the ductile iron pipe. Then, the Authority and REI decided to supplement the initial study with 11 additional ultrasonic tests in the region where replacement was deemed necessary in order to determine the exact extents of the corrosion.

Additional locations were strategically identified based on evaluating those previous field testing results and pipeline profiles. The following sections are going to explain how other utilities can utilize innovative noninvasive testing methods, associated field protocol, and testing results to determine the condition of their force mains that may result in cost savings and future planning for infrastructure replacement.

Methodology

In order to determine the extent of the corrosion, field investigations using noninvasive ultrasonic testing were performed where previous piping wall thickness was identified as thinning, and thus were areas of potential concern. In addition, the hydraulic grade line was reviewed to determine high and low portions of the force main. The high points were additional areas of focus, and the low points were assumed to be fully submerged with minimal corrosion.

The first 13 tests had six in the state road ROW, four under the asphalt, and three in existing manholes. The additional 11 tests had five in the state road ROW, one in an existing manhole, and five under the asphalt on the connector road. Many of the force main locations were stationed within Seminole County, Orange County, and Florida Department of Transportation (FDOT) limits; therefore, ROW use permits were required. The permits imposed restrictions on testing, timing, and penetrations of paved roadways and set requirements for restoration and maintenance of traffic (MOT).

Piping segments were identified by REI that were deemed areas of concern for corrosion from the previous study results to determine the segment for re-evaluation. Then, REI provided noninvasive ultrasonic testing technicians with the approximate station locations, the previous testing results, and as-built drawings. Certified technicians performed field investigations using their sensors and a software ground penetrating radar (GPR) machine to determine the high points of the force main sections within the previously tested limits. The high points of the force main were confirmed using the GPR method to field-verify as-built drawings provided for the Authority's entire system.

An advanced nondestructive ultrasonic gauge (Figure 3), was used to determine the integrity of the pipeline. This instrument can be used in pipes, tanks, and other metallic structures that have the potential for erosion and corrosion. Additionally, the device is able to measure true metal thickness using a "single backwall echo," even when the metallic structure is painted and/or coated.

The instrument calibration instructions provided by the testing device company representative were followed by REI. The same representative also met the project team onsite and demonstrated the calibration procedure. The instrument measures wall thickness by sending an ultrasonic wave through the metallic material and then calculates the velocity of that wave. Different types of materials will exhibit different velocities at the same length; therefore, it is essential to calibrate the instrument using the exact same material that will be measured in the field.

In order to obtain accurate readings, REI obtained coupons (Figure 4) that were removed from previously rehabilitated sections of the Authority's force mains. Those coupons were machined and measured to a tenth of an in., and then used to calibrate the instrument. The validity of the calibration was confirmed by measuring the sample coupons with the testing device and a digital caliper. The results obtained were equal; therefore, it was confirmed that the ultrasonic testing instrument was properly calibrated for field measurements.

The testing device requires a clean testing surface area; therefore, the sections of the force main that were tested had to be exposed, then air-blasted to clean off the surface dirt, followed by using a wire drill brush to gently scrape off any debris remaining on the outer surface of the piping. This field preparation of the pipe is ex-

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Figure 3. Noninvasive Ultrasonic Testing Device

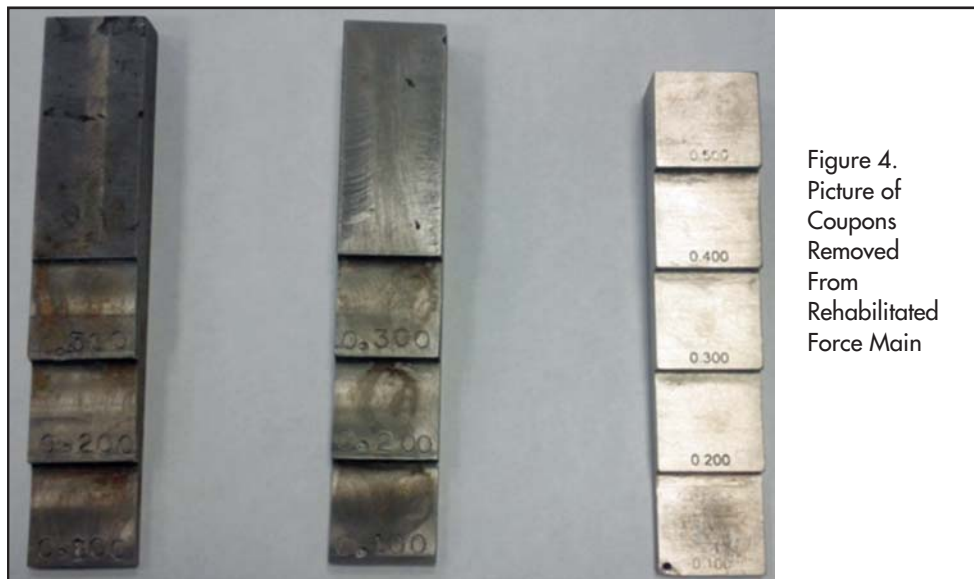


Figure 4. Picture of Coupons Removed From Rehabilitated Force Main

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tremely important to ensure the accuracy of the measurements.

The amount of measurements taken at each location ranged from top dead center of the pipeline, or 0 degrees, to angles measuring 45 degrees, 90 degrees, 270 degrees, and 315 degrees. These locations were chosen because corrosive gases tend to gravitate at the top of the pipeline. Multiple measurements were taken at 0 degrees in order to obtain an averaged result. Additionally, testing sites located under the asphalt were only tested at 0 degrees because FDOT restricted the core hole size to 14 in. in diameter.

To ensure that the same locations can be tested again in the future and results can be accurately tracked and compared, the following steps were performed initially:



Figure 5. Picture of Disk Marker

- ◆ Temporary stake markers were placed over the force main testing locations at the ground surface.
- ◆ The global positioning system (GPS) coordinates were taken at each testing location.
- ◆ A permanent disk marker (Figure 5) was installed perpendicular to the test location in concrete or asphalt as a means to locate the exact pipe segment tested in the future.

Results

The percentage wall thickness remaining was calculated for each tested location by dividing the minimum reading measured by the original wall thickness. The results obtained are displayed in Figure 6, with the original study results represented with circles and the new results represented by triangles. The original wall thickness of the 36-in. force main and the 30-in. force main were measured at 0.51 in. and 0.45 in., respectively. The minimum reading was used because it represents the worst-case scenario.

The results indicated that, unlike what was previously determined in other studies, the state road force main only needed to be replaced along a small portion of transmission main; all other locations yielded results above 70 percent, indicating that they were in good condition. This assessment drastically contradicted the previous study, which concluded that the entire section of the state road force main measuring 5,550 lin ft should be replaced. Additionally, the study confirmed that a connection between the new pipeline in the state road ROW and the existing connector road force main could be completed.

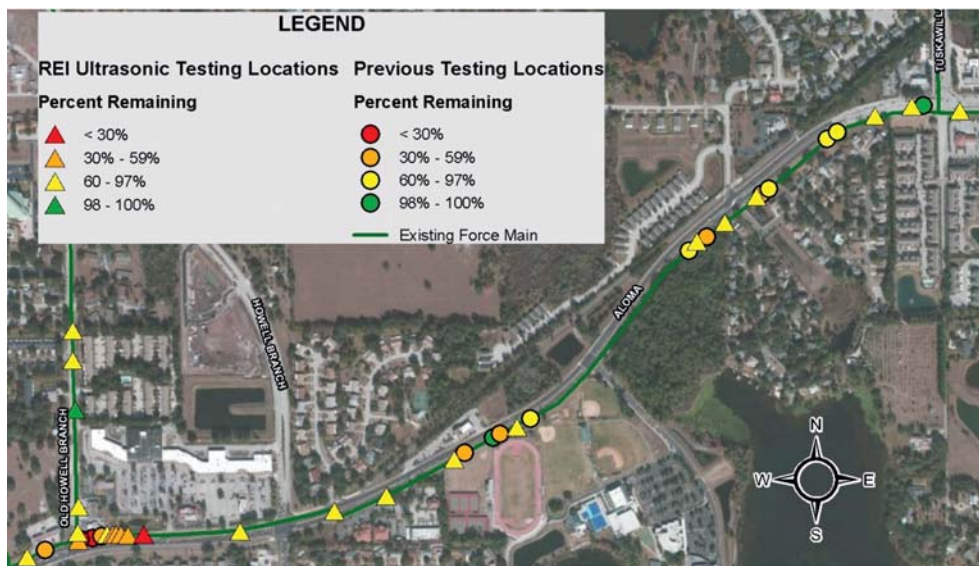


Figure 6. Comparison of REI and Previous Testing

Benefits

The quality, accuracy, and ease of application of the ultrasonic testing method contributed many advantages to the project. The ultrasonic tests performed by REI provided more accurate results than the tests previously performed. This increased the level of accuracy that was associated with the possibility of taking multiple readings of the same tested point without causing further structural damage to the pipeline with traditional destructive tests or increasing the difficulty level of the field effort. The instrument was also calibrated to coupons of the original pipe, which decreased errors significantly. The testing device reads the thickness of the material instantaneously *in situ*, eliminating the need for collecting samples for later measurement, and also saving time. Furthermore, the instrument is portable, little heavy machinery is required, and only small sections of pipe needed to be exposed in order to obtain accurate measurements.

Challenges and Considerations

The testing-device method cannot be performed if the pipeline is located under a water table, due to the fact that the velocity of the ultrasonic wave would be different under water, providing erroneous or inaccurate measurements.

Conclusion

There are differences noted during the current noninvasive ultrasonic testing results and the test results from previous studies on this transmission system. Current industry standard practices were implemented by REI for identifying high points within the transmission system, preparing the pipe for thickness testing, effectively calibrating the testing equipment, and using an independent company certified in the



Figure 7. Section of Removed Pipe

use of ultrasonic testing equipment. Additional verification of testing methods and procedures included coordination and feedback from the ultrasonic manufacturer's representative for calibration procedure review and confirmation, further calibrating the ultrasonic machine with large-diameter ductile iron piping coupons from the Authority's system, and measuring coupons with a digital caliper to compare to the ultrasonic testing readings.

The assessment revealed valuable information about the condition of the state road force main and allowed the project to be completed based on limiting the extents of the corroded sections. Noninvasive, ultrasonic testing also provided many advantages, including an increase in the accuracy of the results, a decrease in the time required for testing, and narrowing the previously determined corrosion to a specific area along the Aloma Avenue force main, which in turn saved the Authority approximate \$1.1 million in replacement costs.

The results of these tests were also confirmed with the completion of the state road force main construction with coupons and re-



Figure 8. Replaced 36-in. Force Main on Aloma Avenue

moved pipe confirming results from this study, as shown in Figure 7. The section of the replaced state road force main is shown in Figure 8.

Both REI and the Authority continued to work together on similar assessments in 2013

and 2014 to determine pipeline integrity using the noninvasive ultrasonic testing. Additionally, the Authority established an annual program to monitor its transmission system using ultrasonic testing.