WhitePaper

Acoustic-Based Condition Assessment

Provides Accurate Remaining Pipe Wall Thickness Measurements for Columbus, Ohio

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The City of Columbus, Ohio's water infrastructure is quickly coming to the end of its life expectancy. As a result, the city is significantly increasing its budget for large-scale pipe replacement projects. Malcolm Pirnie, a Division of Arcadis, the engineering firm that is assisting Columbus with its water infrastructure improvement projects, approached Echologics to perform an acoustic-based assessment of the remaining wall thickness of selected 6–12 inch Ductile Iron and Cast Iron water pipes that run throughout the city.

Life expectancy and age alone are not accurate indications of pipe integrity. Many pipes have been found to have significant remaining service life even after the end of their theoretical design. Basing pipe replacement strictly on age will result in the unnecessary removal of healthy pipe, thus wasting money. A more efficient approach for utilities to determine whether or not a pipe needs to be replaced is acoustic-based pipe condition assessment. This method can help them to better understand the levels of pipe degradation in their water systems; such information helps utilities to effectively prioritize replacement and rehabilitation projects according to remaining wall thickness levels, not age.

Echologics' innovative pipe condition assessment can accurately measure the remaining wall thickness with little to no service interruption. This paper will outline Echologics' methods while comparing its condition assessment results involving 6, 8, and 12 inch Cast Iron and Ductile Iron pipes to samples of the same pipes that were collected following the surveys.

Echologics uses its Pipe Integrity Testing to accurately measure the remaining wall thickness of pipes. Echologics measures the speed of acoustical signals in the pipe. The speed of sound in a pipe is governed by the water hammer equation which is shown here in its simplified form:

Equation 1

$$v = v_o \cdot \sqrt{\frac{1}{\left[1 + \left(\frac{D_i}{t_r}\right) \cdot \left(\frac{K_l}{E}\right)\right]}}$$

v	Speed of Sound of filled pipe
v_o	Speed of Sound in water
D_i	Internal pipe diameter
K_l	Bulk Modulus of Elasticity of water
t_r	Pipe wall thickness
E	Young's Modulus of pipe material

D_i, K_l, E, and v_o are values that represent pipe and water properties. Echologics measures velocity(v). Wall thickness can now be solved with every other variable known.

In order to acquire an accurate speed of sound, Echologics introduces acoustic signals into the pipe. These signals are generated by physically tapping on a fitting, flowing water from a fire hydrant, or using vibro-mechanical shakers to induce noise into the pipe at specific frequencies. These signals are measured by acoustic sensors mounted on separate, easily accessible appurtenances such as existing inline valves or on the pipe itself. Echologics' equipment then measures the time it takes for the acoustic signal to reach each sensor. The velocity can then be calculated using that time delay and the sensor spacing. Echologics requires the pipe to be pressurized to perform these measurements, so there is no disruption to service.

Echologics can calculate the remaining wall thickness by accurately measuring the velocity and using the other known variables to solve the appropriate version of Equation 1.

Occasionally, however, dimensional or material data is not available and poses a problem. For example: Cast iron must be identified as either spun cast or pit cast, as each classification has a different modulus of elasticity, and sometimes the pipe's manufacturer or installation date is unknown. Equation 1 can no longer be solved if some of these variables are unknown. In such circumstances, Echologics cannot provide an absolute thickness. However, Echologics can reasonably assume pipe properties based on historical data and then rank the measured pipes by their comparative thicknesses. In this type of scenario, clients receive valuable data outlining the comparative degradation of the pipes.

Composite pipes, such as ductile iron pipe with concrete lining, require additional consideration in this calculation. Equation 1 will not indicate whether the thickness is lost in the pipe or the lining. Echologics treats the pipe as a composite structure and uses the concept of effective thickness to account for the lining and composites.

The concept of effective thickness is straight forward; because the lining and the host material provides stiffness to the pipe, Echologics can calculate the effective thickness of the lining. That is to say, if the lining was removed, how much host material must be added to return the pipe to the original stiffness? This extra material is the effective thickness of the lining.

The Pipe Integrity Testing method gives an average value of minimum wall thickness over the length of the pipe. Therefore, the method can recognize minor levels of uniform corrosion and major levels of isolated pitting corrosion, but a pipe with high levels of isolated degradation will appear to have minor loss overall. Any of the following descriptions will hold true for a pipe with 10% measured loss:

1. Uniform loss of 10% throughout the entire length around the entire circumference
2. Uniform loss of 20% throughout half of the length around the entire circumference
3. Uniform loss of 10% throughout the top half of the entire length of pipe

For simple pipes that consist of one material, Echologics can provide the average remaining wall thickness. For pipes of unknown origin or multiple materials, Echologics can rank the surveyed pipes from the healthiest to the most degraded.

In June 2010, Echologics surveyed 5.3 kilometers (3.33 miles) of pipe throughout the City of Columbus. Testing took place over three days, using the existing pipe fittings—without any disruption to service. Echologics split each site into multiple sections, roughly 150 meters (500 feet) in length. The City contracted the Corrosion Probe Institute (CPI) to verify the data. A sample from each section was sent to CPI for independent analysis. CPI measured the pitting and remaining wall thickness for each tested section. Echologics' and CPI's results are shown in Figure 1:

Figure 1

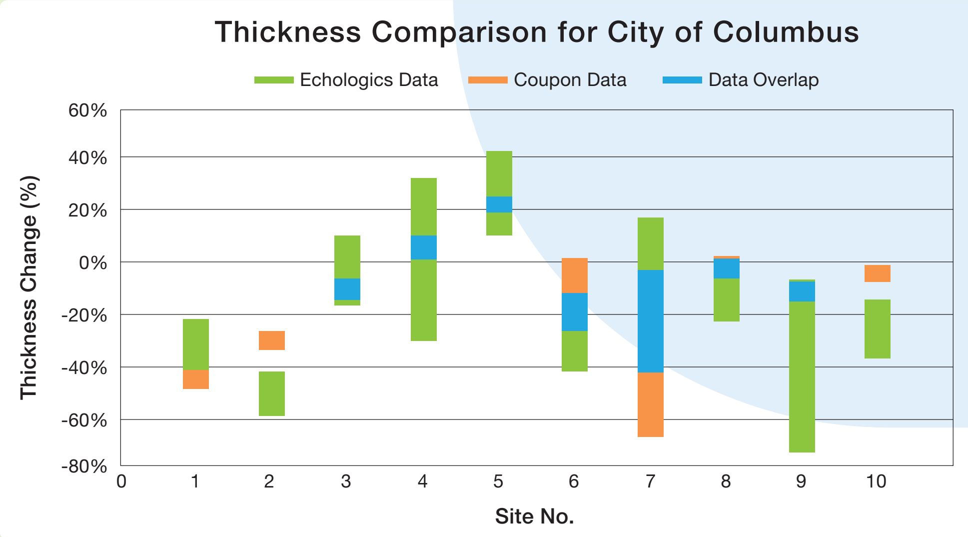

Figure 1 shows Echologics' measured thickness for each site (green); CPI's measured thickness for each corresponding coupon sample (orange); areas where measurement data from each company matched (blue). As illustrated in the chart, Echologics' measurements of remaining pipe wall thickness matched the measurements collected by CPI for seven of the 10 sites. Echologics measured thickness change and CPI's data were within 10% to 20% on Sites 1, 2 and 10. Figure 2 compares the thickness loss predicted by Echologics with the thickness loss measured from the samples.

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Figure 2

Site Number	Section Length (meters/feet)	Pipe wall thickness loss measured by Echologics	Pipe wall thickness loss measured from samples	Coupons Measured	Difference
1	442m/1451ft	-32.78%	-44.41%	3	11.63%
2	505m/1656ft	-50.67%	-30.37%	1	20.30%
3	413m/1354ft	-4.17%	-11.25%	1	7.08%
4	495m/1624ft	2.44%	5.37%	1	2.93%
5	373m/1223ft	-25.85%	-21.38%	1	4.47%
6	708m/2321ft	-24.84%	-13.95%	1	10.88%
7	693m/2274ft	-9.41%	-28.63%	2	19.22%
8	446m/1464ft	-11.27%	-2.37%	2	8.90%
9	493m/1618ft	-57.72%	-30.78%	1	26.94%
10	364m/1193ft	-25.56%	-4.31%	1	21.24%

Again it can be seen that Echologics' measurements were within 10 to 20 percent of the degradation measured from most of the samples. It is expected that if more samples were taken, data from the samples would converge with Echologics' results, as Echologics' condition assessment method gives an average value of minimum wall thickness over the length of the pipe. Coupon sampling is not an ideal method to verify the results provided by Echologics since sampling looks at discrete locations, and the coupons may not be indicative of the degradation over the length of the pipe. Unfortunately, exhuming a statistically significant number of coupons is cost-prohibitive.

Conclusion

Remaining pipe wall thickness measurements obtained through accurate, acoustic-based pipe condition assessment can help municipalities to effectively prioritize replacement and rehabilitation projects and spend their budgets more wisely, as this non-invasive method can help them to avoid needlessly replacing healthy pipe and instead focus on pipes that require immediate attention.

Echologics applied its innovative condition assessment technology to assess the remaining pipe wall thickness of cast iron and ductile iron pipes for the City of Columbus. Echologics surveyed 5.3 kilometers (3.33 miles) of pipe in three days, using existing pipe fittings, without any disruption to service. The City submitted pipe section samples to CPI, an independent company, to verify the results. CPI results show that the condition assessment performed by Echologics proved to be useful and accurate. The City was satisfied with the level of correlation between the measurements provided by Echologics and the thickness of the exhumed samples.

Cross section of extracted pipe sample from site #1

Cross section of extracted pipe sample from site #7

Cross section of extracted pipe sample from site #6