where

pH_S = pH at which water is saturated with calcium carbonate
A = alkalinity (milligrams per liter of calcium carbonate)
H = hardness (milligrams per liter as calcium carbonate)

The relative aggressiveness of water is defined in Table 9-1.

Failure Patterns Many water utilities and recent studies have reported that after an AC failure had occurred at a particular location, subsequent failures had occurred in the same vicinity. These subsequent failures may be indicative that the pipe in a particular area is nearing the end of its service life. However, the subsequent failures could also be due to the additional hydraulic stresses from the initial failure or from disturbances from the repair and cleanup efforts. Testing in accordance with the ASTM C500 methods may help conclude the root causes and remaining useful life.

9.3 INSPECTION PROCEDURES

Most condition assessment techniques of AC pipe require excavating, exposing, and removing samples of the pipe. Testing and assessment methods focus on testing and examining the internal and external pipeline environment, i.e., aggressiveness of the soil and water surrounding the pipe and the aggressiveness of the water conveyed in the pipe. The tools and techniques used to perform these tests include, but are not limited to, mechanical tests, chemical tests, hardness tests, visual tests, and acoustic tests.

Soil and Groundwater Testing around Pipe For AC pipe, the primary mechanisms for potential chemical degradation from aggressive chemicals in the surrounding soil are sulfate deterioration, concrete carbonation, and acid attack. Testing will reveal potential problems related to leachable calcium, sodium, and sulfate ions in the surrounding soil and groundwater.

Table 9-1. Relative Aggressiveness of Water

	Aggressiveness		
Index	High	Moderate	Low
Langelier	<-2	-2 to 0	>0
Aggressive	<10	10 to 11.9	≤ 12

Conveyed Water Testing of Pipe The aggressiveness of the conveyed water can result in degradation of AC pipe. For example, soft water with very low carbonate and bicarbonate content could result in the leaching of free lime from the cement. Testing of the conveyed water in the pipe can indicate how aggressive the water is measured by using the AI. Internal and external waters are known to cause aggressive environments, and soluble sulfate contents of water and soils are considered separately even though they may exist in combination (ASTM C500/C500M).

Mechanical Testing of Pipe Pipe samples from failed pipe and coupons from in-service pipe can be mechanically tested. Commonly used mechanical tests include the hydrostatic pressure test, to measure the burst strength; the flexural test, to determine whether the pipe can withstand the loads stated in the specifications; the crushing test, to determine whether the pipe can withstand the crushing loads stated in the specifications; and Schmidt hammer tests, to measure the elastic properties or strength of the AC pipe (mainly surface hardness and penetration resistance). O-ring condition can be tested by applying a compression test (ASTM D395), a hardness test (ASTM D1415), and Fourier transform infrared (FTIR) spectroscopy.

Chemical Testing of Pipe and Gaskets Chemical tests can be performed on both the AC joint gasket and the pipe to identify degradation of AC pipe and gaskets. For example, the FTIR spectroscopy can be used to identify the purity and structure of rubber gaskets, indicating chemical loss or breakdown. Phenolphthalein can be used to identify the degradation of AC pipe due to leaching of calcium.

Electron Microscopes Scanning electron microscope (SEM) and energy dispersive spectroscopy (EDS) are two examples of microscopes that use a focused beam of electrons to analyze chemicals, e.g., AC pipe samples to determine pipe degradation (Fig. 9-6).

Phenolphthalein Dye Testing Phenolphthalein dye testing can be used to identify how much of the pipe cross section has degraded (carbonated). When phenolphthalein dye is injected or sprayed over the cross section of an AC coupon, the cross section will turn purple or pink where calcium is still available, whereas the white area may indicate the areas where calcium has leached from the pipe (Fig. 9-7).

Chemical Analysis Using EDS EDS with an electron microscope can be used to determine the chemical composition of AC pipe segments. Fig. 9-8 depicts the elemental distribution of multiple pipe segments. Careful analysis using EDS can help identify relationships between failed

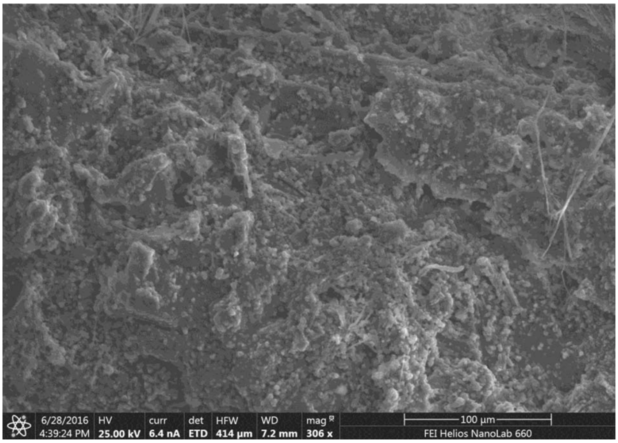

Fig. 9-6. Scanning electron microscope (SEM) of AC pipe sample
Source: Courtesy of Tucson Water

Fig. 9-7. Phenolphthalein dye test of asbestos cement pipe wall cross section
Source: Courtesy of Tucson Water

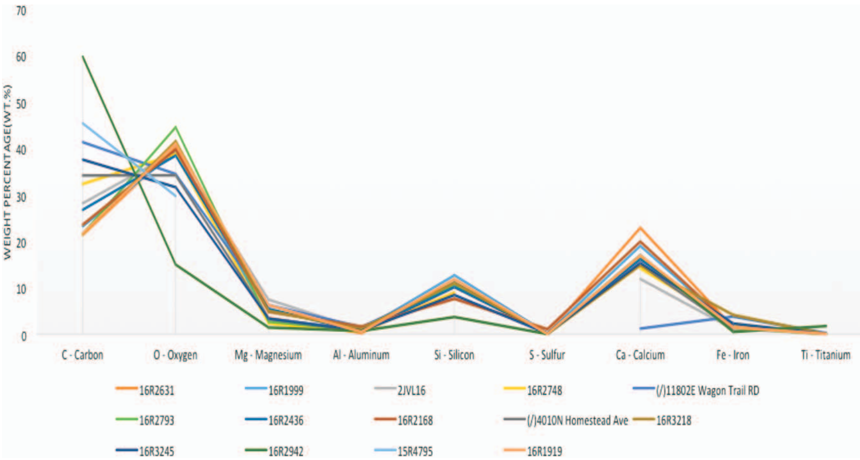

Fig. 9-8. Energy dispersive spectroscopy of multiple pipe samples
Source: Courtesy of Tucson Water

pipe and the failed pipe's elemental composition. This information can be helpful in predicting remaining service life of pipe cohorts of similar composition.

Sonic Inspection Sonic inspection entails sending a receiver through a pressurized pipeline and listening for acoustic events that may indicate leaks in the pipe wall or pipe joint. The level of the sound or frequency can help evaluate the size of the leak. The approximate location of the leak can also be determined by correlation methods and correlating equipment. However, leaks in AC pipe typically manifest themselves quickly as pressurized fluid erodes the pipe or coupling wall away.

Acoustic Pipe Wall Stiffness Assessment Acoustic signals can also be used to estimate remaining effective AC pipe wall thickness. An acoustic signal is transmitted through the pipe and measured to determine effective (nondeteriorated) wall thickness. Although this technology cannot be used to identify specific locations of severe degradation, it can be used to estimate the average minimum effective remaining wall thickness over the length the acoustic signal is measured (typically a couple of hundred feet). This technology can be performed by affixing acoustic sensors to the exterior of the pipe or by inserting equipment into the pipeline with a cable.

Petrographic Analysis Petrographic examination of the pipe may reveal sulfate-induced deterioration and acid attack on the pipeline wall in addition to other signs of failure.

Note: The following rehabilitation and replacement sections are provided for information purposes only. They are not a component of the condition assessment process but are integral to an asset management program, and they were therefore included for reference.

9.4 REHABILITATION PRACTICES AND REPAIR MECHANISMS

Asbestos cement pipe may be considered hazardous material once it is cut and becomes friable. While working with AC pipe, appropriate safety regulations and measures should be followed. For example, keeping the AC pipe wet before and during cutting with soil pipe cutters can prevent the release of airborne asbestos fibers. In addition, once the pipe has been removed from a trench, the ends of the broken pipe, cut pipe, or any damaged areas should be immediately painted to seal any potentially friable asbestos fiber. Lastly, the pipe pieces (less than 3 ft) should be double bagged before transporting. [See AWWA Opflow Handling Asbestos-Cement Pipe: A New Approach (Fullen 2012a), for an example of safe handling work practices].

9.4.1 Internal Surfaces

Slip Lining Slip lining is a process in which a fabric liner is installed in an existing pipeline to address failure modes of leaking joints and/or compromised pipe walls. This technology has proven successful for AC pipe. Two types of liners should be considered: one that is structurally independent of the host pipe, considering internal and external loading, and one that is reliant on the host pipe to withstand internal and external loading. Slip lining does, however, marginally reduce the effective pipe cross-sectional area and hydraulic capacity.

Pipe Bursting Pipe bursting is a *trenchless* method of replacing buried pipelines (such as sewer, water, or natural gas pipes) without the need for a traditional construction trench. *Launching* and *receiving pits* replace the trench needed by conventional pipe laying. Successful pipe bursting of AC pipe has been demonstrated; however, once AC pipe is burst it becomes a hazardous material. Many jurisdictions consider sites where AC pipe has been burst as hazardous waste sites. Knowledge of EPA and local regulations regarding AC pipe handling and disposal is prudent when deciding whether pipe bursting is a good option. During the writing of this manual, pipe bursting of AC pipe was being reviewed by the EPA.

9.4.2 Exterior Repair Types

Clamps Repair clamps are typically made of stainless steel, are of *full circle* design with a rubber liner, and are readily available for all diameters of AC. A single full circle repair clamp can be used by itself for repairing circumferential breaks, replacing a failed coupling, and repairing holes that have been tapped for service line connection or even holes that have been unintentionally drilled or punched through the pipe wall. When installing a repair clamp over a circumferential break or when replacing a failed AC coupling, both ends of the pipe must be in alignment with one another. When a repair clamp is used to repair damaged pipe that has occurred from an auger bit or a boring tool, or simply to cover a service tap hole after the service saddle has been removed, the hole must not have any fractures extending from the borehole itself.

Couplings Repair couplings, often referred to as flex couplings, are made of ductile iron and have a ring and rubber gasket on each end that when tightened against the end of the coupling barrel compresses a rubber gasket that seals around the surface of the host pipe. These couplings are typically used when replacing a damaged section of AC and are used to join the ends of a new piece of pipe to the existing pipe. These same couplings are often used in a planned mode for pipe modifications.

REFERENCES

ASTM. (2006). "Standard test methods for asbestos cement pipe." *ASTM C500-98*, West Conshohocken, PA.

ASTM. (2011). "Standard test methods for asbestos-cement pipe." *ASTM C500/C500M*, West Conshohocken, PA.

ASTM. (2012). "Standard test methods for rubber property—Compression set." *ASTM D1415*, West Conshohocken, PA.

ASTM. (2016). "Standard test methods for rubber property—Compression set." *ASTM D395*, West Conshohocken, PA.

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CHAPTER 10
PIPE INSPECTION TOOLS

Over the past decade, utilities have implemented asset management strategies that include condition assessment of pipelines. Condition assessment uses inspection data to assess the physical condition of an asset and provide an estimate of the remaining service life. When determining which inspection tool to use, risk is the most important factor to consider. For assets with a high consequence of failure, a detailed assessment is needed while lower risk assets may warrant a lower resolution screening technique.

Prior to implementing a condition assessment project or program, it is important to understand the anticipated failure modes for a given pipe material. Many of the tools that are currently available have been developed for specific pipe materials and detect defects associated with specific failure modes. As such, all the tools discussed in this chapter have limitations that should be clearly defined. Understanding the strengths and limitations of the tools and techniques will provide realistic expectations and improved understanding of the results.

This chapter provides an overview of several commonly used inspection tools and techniques that are currently available in the market. Due to the evolving nature of pipeline assessment, it is not practical to cover all of the tools or techniques that have been implemented. Rather, this chapter provides a sample of the more commonly used tools and techniques along with examples of the anticipated results.

10.1 INSPECTION TECHNIQUES FOR LOW RISK PIPELINES

Low risk pipelines, by definition, do not have a high consequence of failure or high likelihood of failure. As a result, significant investment in pipeline inspection is not always warranted. The inspection tools and techniques discussed in this section typically require lower financial or operational investment, are characterized as screening methods, and provide low resolution results.

10.1.1 Corrosion Surveys

- Material types: all
- Diameters: all

Corrosion surveys can be applied to all ferrous and concrete pipeline materials. They review a number of variables to evaluate the aggressivity of the environment surrounding the pipeline. These variables indicate that corrosion may be occurring on a pipeline. Some of the variables include

- Soil pH,
- Chloride content,
- Sulfate content,
- Resistivity,
- Drainage (wetting and drying),
- Redox potential, and
- Microbiological activity.

The American Water Works Association (AWWA) Standard C105 provides a 10-point scale to determine whether corrosion protection is necessary for cast iron (CI) or ductile iron (DI), based on soil corrosivity. Table 10-1 denotes the parameters scored under the system presented in AWWA C105. If the sum of the scores based on measurement of resistivity, soil pH, redox potential, sulfide content, and soil moisture equals 10 or more, then corrosion protection is recommended.

Tools and Techniques Available for Corrosion Surveys Corrosivity can be measured from the ground surface, above the pipeline alignment. A corrosion survey can detect and locate potentially corrosive environments surrounding the pipeline, providing a screening technique for the pipeline's condition. It should be noted that corrosivity surveys are low cost methods of identifying locations where corrosion *may* be occurring on the pipeline. They do not provide definitive results. A survey may miss areas of corrosion (i.e., false negatives) or may indicate corrosion when it is not occurring (i.e., false positives). This method of inspection should be viewed as a low cost, low resolution screening method, providing data that allow for an assessment of the pipeline's host environment.

Various survey methods include

- Pipe-to-soil potential,
- Cell-to-cell potential,
- Soil resistivity,

- Chemical analysis, and
- Linear polar resistivity.

Positives of Corrosion Surveys

- Low cost,
- Basic information on the environment surrounding a pipeline is provided,

Table 10-1. AWWA's 10-Point Scale for Soil Corrosivity

Soil Parameter	Score
Resistivity (ohm cm)	
<700	10
700–1,000	8
1,000–1,200	5
1,200–1,500	2
1,500–2,000	1
>2,000	0
Soil pH	
0–2	5
2–4	3
4–6.5	0
6.5–7.5	0
7.5–8.5	0
>8.5	3
Redox Potential (mV)	
>100	0
50–100	3.5
0–50	4
<0	5
Sulfide Content	
Positive	3.5
Trace	2
Negative	0
Soil Moisture	
Poor Drainage—Continuously wet	2
Fair Drainage—Generally moist	1
Good Drainage—Generally dry	0

Source: *Microcrystalline Wax and Petrolatum Tape Coating Systems for Steel Water Pipe and Fittings,* ANSI/AWWA C217. Copyright 2016 American Water Works Association. All Rights Reserved. Reproduced with permission.