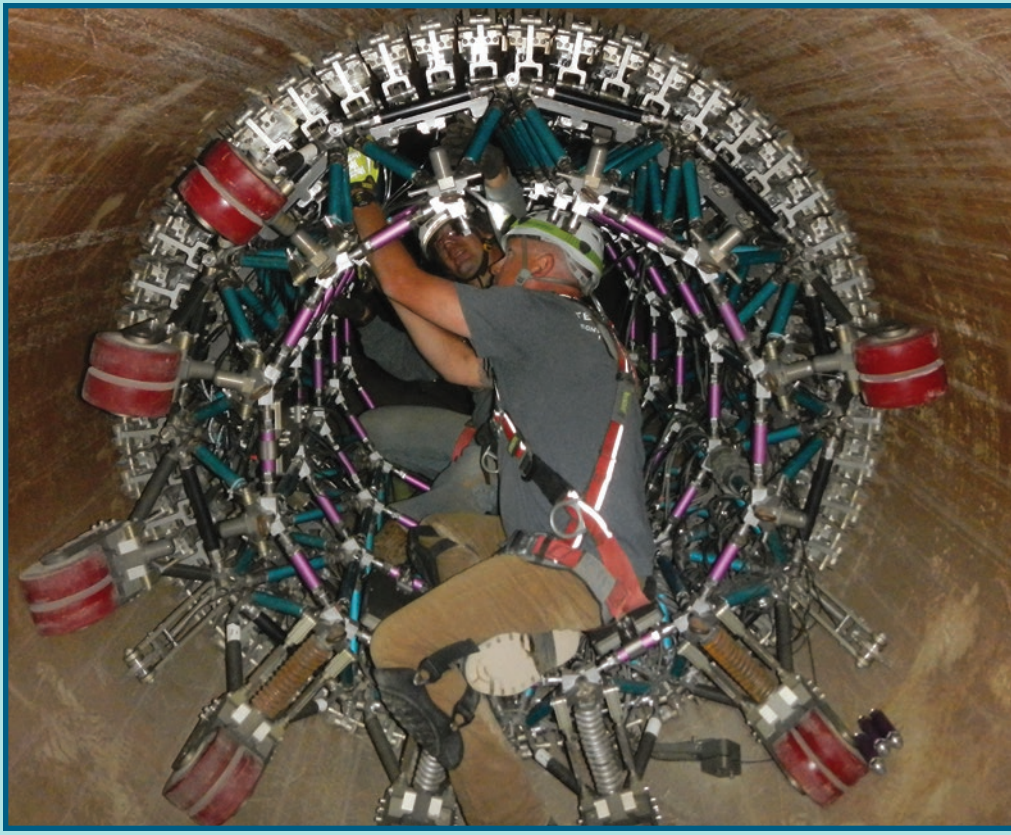
ASCE Manuals and Reports on Engineering Practice No. 134

Water Pipeline Condition Assessment



Prepared by the
Task Committee on Water Pipeline Condition Assessment

Edited by
George F. Ruchti Jr.

ASCE

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UTILITY ENGINEERING & SURVEYING INSTITUTE

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Sponsored by the
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A list of available Manuals of Practice can be found at http://www.asce.org/bookstore.

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PREFACE

This Manual of Practice provides an investigator with an appropriate path to adequately determine the structural status of an individual pipeline or pipeline system. The manual provides recommendations and information to assist in a detailed approach to prioritize a program and develop an accurate determination of the condition of the individual pipelines. With an understanding of the structure of such a program, understanding the nature of the materials to be evaluated, the tools available for the evaluation, and what information the findings should provide, the Water Pipeline Condition Assessment report can and should provide critical input to an asset management program.

The "Introduction" walks the reader through the steps to achieve this goal and provides the framework for this manual. The next chapters provide information on the type of reporting that utilities should be implementing and the planning that then goes into the structure of the condition assessment. Six chapters, written by experts in each material, discuss pipeline materials including cast iron, ductile iron, concrete (all variations), steel, fiberglass, PVC, and asbestos cement pipe. Although repair, rehabilitation, or replacement of the individual materials is not a function of the condition assessment, they are an important part of an asset management program; therefore, information on each product has been provided for assistance. "Pipe Inspection Tools" deals with the various tools available for the assessment, for which materials they can be used, and what they can and cannot accomplish. The Condition Assesment Report chapter provides an understanding of the results that should be expected, and the "Case Studies" provide guidance from actual projects covering the majority of the pipe products that have been available.

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ACKNOWLEDGMENTS

Task Committee on Water Pipeline Condition Assessment

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CHAPTER 1
INTRODUCTION

Various asset management programs can be employed to maximize the useful life of a water utility's infrastructure. An asset management program establishes a baseline to understand and anticipate present and future use of resources. In addition, the Government Accounting Standards Board (GASB) monitors and establishes reporting methods for state and local governments. Statement No. 34, also known as GASB34 provides two methods for reporting a water utility's assets:

1. Reporting of infrastructure assets is calculated by the historic cost less depreciation model.
2. Reporting is done by the infrastructure asset management system, also known as the Modified Approach, and is based upon the utility meeting the following requirements:
   a. Have an up-to-date inventory of eligible infrastructure assets.
   b. Perform condition assessments of the eligible infrastructure assets every three years and summarize the results using a measurement scale.
   c. Estimate each year the annual amount to maintain and preserve the eligible infrastructure assets at the condition level established and disclosed by the water utility.

Although more costly to provide, the Modified Approach offers tax incentives to a private water utility. This is a further incentive for a private utility to employ an asset management program.

This document will focus on the management of the transmission pipeline portion of a water utility's infrastructure, not the distribution system piping, as it is considered an ongoing maintenance issue. The condition assessment of a pipeline is an asset management tool that is

being employed by more utilities rather than wholesale replacement of troublesome pipelines. The guidelines presented in this document address the condition assessment of the pipeline itself. It does not address the assessment of pipeline appurtenances, such as control valves, blowoff valves, hydrants, air or vacuum valves, etc., unless they were determined to be at fault during the condition assessment and then such appurtenances should be duly noted. It is anticipated that these appurtenances will be exercised or inspected on a regular schedule and repaired or replaced as necessary.

1.1 CONDITION ASSESSMENT

The condition assessment of a pipeline is the evaluation of its current state and its associated components with respect to its ability to meet the defined needs of its owner. It may include an evaluation of its state of deterioration, its ability to withstand anticipated loads, its state of water tightness, and its level of hydraulic capacity. Condition assessment must also be time dependent; that is, it must address not only the present state of a pipeline but also make some determination of its remaining service life. There are few absolutes associated with a condition assessment program or the results of such a program, but there is one absolute in not pursuing a program, and that is the eventual loss of functionality of the system and increased risk to the public.

The service life of an asset is the time period the asset meets the defined needs of the owner. The current defined needs may be different from the original. Remaining life estimates usually result in very broad forecasts, such as

- The asset replacement or decommissioning is required as soon as possible;
- Over the next 20 years with normal maintenance, the asset is predicted to meet the owner's needs; or
- Major maintenance is required within the next 10 years for the asset to meet the owner's needs.

Deterioration may occur on the exterior surface, the interior surface, or both. It may take the form of oxidation of a metallic surface or a chemical attack. It may be that the product had a structural defect or sustained damage. The pipeline may currently be leaking or it may demonstrate a limiting term of continued water tightness and may even be in a state of structural distress or imminent failure. While oxidation or rusting of the interior surface of a metallic pipeline may or may not pose leakage issues, significant tuberculation hampers flow properties and reduces the pipeline's hydraulic capacity. Another concern, possibly to a lesser degree, is

when the water quality leaches cement or is detrimental to the aggregate in a cement mortar or concrete lining.

Condition assessment is an important tool for any asset management program. To effectively assess the condition of a pipeline or a system of pipelines, an inventory of the materials is critical to the success of the program. This inventory should include, but not be limited to pipe material, manufacturer, age, lining, coating, type of joint, maintenance history, failure history, construction history, design reports, inspection reports, and future expectations for the pipeline (i.e., does it meet the expected demand of the utility?). For the purposes of this document, a failure is considered to be a joint leak, a barrel leak, a rupture, or a collapse of a pipeline. To a lesser extent, as such information could be determined by the condition assessment team, it would be helpful to have data on soil corrosive properties and soil contamination and any known issues with stray currents from nearby or crossing pipelines, light rail tracks, high voltage power lines, or any other source of stray currents. While a failure is certainly not beneficial, if a pipeline should fail, the utility should take full advantage of any data that could be applied to other areas of the system to mitigate any failures in the future.

A buried water pipeline poses a considerable level of difficulty to determine the exact condition and how much service life remains. Uncovering portions of the pipeline only provides a snapshot of the line, and it may or may not be an accurate indicator of the entire pipeline's condition.

Companies have developed electromagnetic devices to investigate the structural integrity of certain prestressed concrete water pipeline materials. These devices, in conjunction with the more permanent incorporation of acoustic monitoring technology, can provide present and time dependent assessment of the pipeline's condition.

Tools have been developed by the oil and gas industry to evaluate the condition of buried metallic pipelines. However, these tools are not effective for assessing the condition of plastic or other nonmetallic pipeline materials employed by the water industry.

For many metallic pipelines, particularly those with bonded coatings, an over the line pipe-to-soil survey can be very effective in determining corrosive conditions that may then be quantified with some evaluation of time dependency. This procedure eliminates, or at least reduces, the impact of excavations. However, some types of installation pose greater levels of difficulty in detecting those areas of concern, such as under pavements and in congested areas.

Pipeline leakage is an indication of its condition and can now be evaluated by several means including hydraulic modeling and measurements and acoustic monitoring. With the advent of several acoustical mechanisms that are intrusive to the system, it is possible to detect leakage and approximate leak locations and leakage rates.

Most of the foregoing discussion regarding deterioration concerns metallic pipeline material. Fiberglass, asbestos, and plastic materials have a different set of concerns. Permeation of the wall, chemical attack, physical damage (cracks, scratches, and gouges), leaks, joint imperfections, age embrittlement, and nonelastic pipe deformation can pose concern for the long-term service of such pipelines.

Naturally, the more thorough and exhaustive the condition assessment, the more expensive it is. Pipeline owners do not have unlimited budgets. Compromise must therefore be made in developing the assessment program. The criticality of the pipeline, its failure history, its redundancy, the degree and depth of the investigation, etc., must be evaluated for maximizing cost effectiveness.

These guidelines are a result of the collaboration of a multitude of industry experts with a combined experience of more than 874 years. The assembled knowledge was acquired through material research and the implementation of previous condition assessment projects by various utilities. This information should be used to assist utilities with making informed decisions in initiating a comprehensive pipeline condition assessment program. These guidelines presented in 12 chapters, examine seven important topics:

- Introduction,
- Data collection and management,
- Planning,
- Pipe materials,
- Pipe inspection tools,
- Condition assessment report, and
- Case studies.

Important data collection and management records, which aid in completing water pipe condition assessments, are the routine reports completed after both an average water pipe leak repair and a critical or catastrophic failure. These reports provide a basis for evaluating the condition of water pipes. Suggested report data are provided for basic leak repairs, for advanced reporting, and for data provided by a utility administrator. Two sample forms are provided that highlight the suggested reporting data and format.

The "Planning" chapter presents ideas for managers to consider before initiating a pipe condition assessment. Also presented are two styles of condition assessment: function based and risk based. The chapter concludes by providing an example of general criteria for water line ranking.

Chapters 4 through 9 discuss six water pipe materials:

- Cast iron and ductile iron,
- Concrete,

- Steel,
- Reinforced fiberglass (also referred to as fiber-reinforced plastic),
- PVC, and
- Asbestos cement

Each of these chapters begins with a history of the pipe material before discussing the characteristics and circumstances that affect the condition of each particular pipe material. Techniques for completing condition assessments are presented along with the overall determination of the pipe condition. Each of these chapters concludes by discussing rehabilitation practices for each pipe material. This is not information to be incorporated in the final condition assessment report. Rather, rehabilitation and replacement have been included for information purposes only and are intended to provide an understanding of available options, particularly should a situation of eminent product failure be discovered during the assessment.

There are other pipe materials that are or have been used in water pipe service but providing a definitive condition assessment of their structural integrity or external surface condition is difficult, either because of their age and availability, primary installation applications, the extreme difficulty of assessing their condition, or because of their mode of failure.

The "Pipe Inspection Tools" chapter provides a list of 50 tests that can be used to evaluate the condition of water pipe, depending on the pipe material. These tests are listed in a joint Water Environment Research Foundation and Water Research Foundation report for condition assessments of water and wastewater utility assets. The list details the pipe materials for which each test is applicable.

The "Condition Assessment Report" chapter provides a discussion about what to do with the pipe testing results. Classification of these results allows the utility to evaluate the complete system of water pipes and determine where the pipes are in their life cycle and level of service. An example system is provided to illustrate a numerical value assignment that summarizes condition assessment results.

The final chapter presents case studies, summarizing condition assessment projects completed by the following utilities:

- Weber Basin Water Conservancy District in Utah,
- Miami-Dade Water and Sewer Department in Florida,
- Tarrant Regional Water District in Texas,
- San Diego County Water Authority in California,
- Pinellas County Utilities in Florida,
- Dallas Water Utilities in Texas, and
- City of Houston Department of Public Works and Engineering in Texas.

These case studies were completed on five different pipe materials. Details presented include planning, inspection strategies, tools and inspection methods used, condition assessment results, and recommendations.

One important note: Particular attention should be paid to avoid potential surges when refilling or repressurizing a line that has been shut down for any reason. Also, the owner should keep in mind the importance of future proper maintenance of their pipelines and appurtenances.

1.2 PERTINENT WEBSITES

American Petroleum Institute (API): http://www.api.org/
American Public Works Association (APWA): http://www.apwa.net/
American Society of Civil Engineers (ASCE): http://www.asce.org/
American Society of Mechanical Engineers (ASME): http://www.asme.org/
American Society for Testing and Materials (ASTM): http://www.astm.org/
American Water Works Association (AWWA): http://www.awwa.org/
Ductile Iron Pipe Research Association (DIPRA): http://www.dipra.org/
EPA Aging Water Infrastructure Research (AWI): http://www.epa.gov/awi/index.html
EPA National Service Center for Environmental Publications (NSCEP): http://www.epa.gov/nscep/index.html
Fiberglass Tank & Pipe Institute: www.fiberglasstankandpipe.com
Government Accounting Standards Board (GASB): http://www.gasb.org/
National Research Council (NRC): http://www.nationalacademies.org/nrc/index.html
National Research Council Canada (NRCC): http://www.nrc-cnrc.gc.ca/eng/index.html
National Sanitation Foundation (NSF): http://nsf.org/
Occupational Safety and Health Administration (OSHA): http://www.osha.gov/
Plastic Pipe Institute (PPI) / HDPE: http://plasticpipe.org/
PVC Pipe Association: http://www.uni-bell.org/
United States Army Corps of Engineers, Engineer Research and Development Center: http://www.erdc.usace.army.mil/
Water Environment Federation (WEF): http://wef.org/
Water Environment Research Foundation (WERF): http://www.werf.org/
Water Infrastructure Database: http://waterid.org/
Water Research Foundation (WRF): http://www.waterrf.org/Pages/WaterRFHome.aspx

West Virginia University, National Environmental Services Center (NESC): http://www.nesc.wvu.edu/
WRc: http://www.wrcplc.co.uk/home.aspx

1.3 RELATED DOCUMENTS

Aging Water Infrastructure Research Program (2004)
EPA/600/R-09/049: http://www.epa.gov/nrmrl/pubs/600r09055/600r09055.pdf
Water Research Foundation (2002)
Water Research Foundation (2008)

1.4 ACRONYMS

AC	asbestos cement
AE	acoustical emissions
AFO	acoustic fiber optic
AI	aggressive index
API	American Petroleum Institute
APWA	American Public Works Association
ARV	air release valve
ASME	American Society of Mechanical Engineers
AWI	aging water infrastructure
AWWA	American Water Works Association
BTEX	benzene, toluene, ethyl benzene, xylene
BWZ	broken wire zone
CA	condition assessment
CC	concrete cylinder
CCTV	closed-circuit television
CFRP	carbon fiber reinforced polymer
CI	cast iron
CIOD	cast iron outside diameter
CIP	capital improvement program
CMMS	computerized maintenance management system
CP	cathodic protection
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
DI	ductile iron
DIPRA	Ductile Iron Pipe Research Association
DSC	differential scanning calorimetry
DWU	Dallas Water Utilities
EC	embedded cylinder

EDS	energy dispersive spectroscopy
EM	electromagnetic
ESCR	environmental stress-cracking resistance
FRP	fiberglass-reinforced pipe
GASB	Government Accounting Standards Board
GIS	geographic information system
GRP	glass-reinforced plastic
HDPE	high-density polyethylene
LI	Langelier index
MCL	maximum contamination level
MFL	magnetic flux leakage
MSDS	Material Safety Data Sheet
NACE	National Association of Corrosion Engineers
NDE	nondestructive examination
NDT	nondestructive testing
NESC	National Environmental Services Center
NPS	National Pipe Standard
NRC	National Research Council
NRCC	National Research Council Canada
NSCEP	National Service Center for Environmental Publications
NSF	National Sanitation Foundation
OSHA	Occupational Safety and Health Administration
PCCP	prestressed concrete cylinder pipe
PE	polyethylene
PENT	polyethylene notch tensile test (ASTM 1473)
PPI	Plastic Pipe Institute
PPIC	Pressure Pipe Inspection Company
PPR	pipe penetrating radar
RC	reinforced concrete
RCP	rapid crack propagation
RCT	risk curves technology
RFEC	remote field eddy current
RPMP	reinforced polymer mortar pipe
RTRP	reinforced thermosetting resin pipe
SCG	slow crack growth
SDCWA	San Diego County Water Authority
SEM	scanning electron microscope
SFPUC	San Francisco Public Utilities Commission
SGH	Simpson, Gumpertz & Heger
SSDA	Second San Diego Aqueduct
TC	transformer coupling
TRWD	Tarrant Regional Water District
UKWIR	United Kingdom Water Industry Research
USACE	United States Army Corps of Engineers

UT	ultrasonic testing
WBWCD	Weber Basin Water Conservancy District
WEF	Water Environment Federation
WERF	Water Environment Research Foundation
WIRP	water infrastructure replacement prioritization
WRc	Water Research Centre
WRF	Water Research Foundation