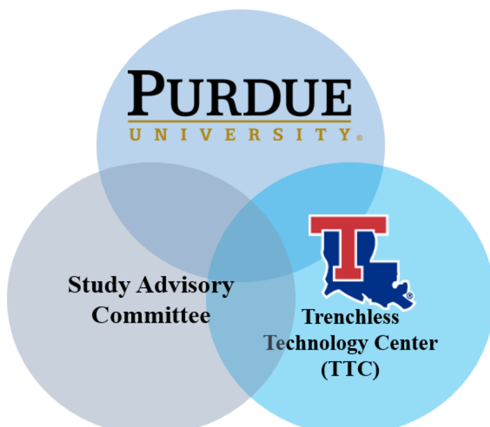
WaterRF 4661: Practical Condition Assessment and Failure Probability Analysis of Small Diameter Ductile Iron Pipes

Survey of Condition Assessment (CA) Technology Providers

Purdue University and Louisiana Tech University are partnering on a research project (WaterRF #4661) to develop a manual of practice (MOP), for the condition assessment of small diameter (12” and smaller) ductile iron pipes. This project aims to collect input from industry, utility and condition assessment practitioners, about identifying failures in small diameter ductile iron pipes, the technology capabilities and barriers to implementation of condition assessment technologies, and developing guidelines for condition assessment programs.

This survey is geared towards **Condition Assessment Technology Providers** and will take approximately **15 minutes** for completion. The information collected is confidential and will be used only for research purposes. Findings of the study will be aggregated and shared with the Water Research Foundation.



Abbreviations:

CA	Condition Assessment
DIP	Ductile Iron Pipe
ID	Internal Diameter
WDS	Water Distribution System

Terms:

Small DIP - Ductile iron pipe with an ID of 12 inch (30 cm) or less

1. Which of the following non-destructive non-invasive CA techniques do you provide for the CA of small diameter DIP? (You may select multiple boxes)

Condition Assessment (CA) Technique
☐ Acoustic propagation velocity measurement (APVM)
☐ Broadband Electro-Magnetics (BEM)
☐ CCTV inspection technology (CCTV)
☐ Magnetic Flux Leakage (MFL)
☐ Manual Pit Depth Measurement (MPDM)
☐ Remote Field Technology (RFT) (otherwise known as Remote Field Eddy Current)
☐ Soil Linear Polarization Resistance (SLPR)
☐ Ultrasonic—Automated, Handheld, Phased Array (UA, UH, UPA)
☐ Ultrasound C-scan (UCs)
☐ Acoustic leak detection (ALD)
☐ Others (Please specify)

2. Among the CA techniques that you selected in Question 1, please indicate on a scale of 1 – 5, the
    a. Speed of data collection. (1 being very quick, 5 being very time consuming)
    b. Speed of data interpretation. (1 being very quick, 5 being very time consuming)
    c. Ease of use in the field (1 being the very easy to use, 5 being the very difficult to use)
    d. Ease of data interpretation (1 being very easy to interpret, 5 being the very difficult to interpret)
    e. Level of operator training that is required (1 being minimal operator training required, 5 being extensive operator training required)

Condition Assessment (CA) Technique	**Speed of data collection**	**Speed of data interpretation**	**Ease of use in the field**	**Ease of data interpretation**	**Level of operator training required**	**Comments**
APVM						
BEM						
CCTV						
MFL						
MPDM						
RFT						
SLPR						
UA, UH, UPA						
UCs						
ALD						
Others						

3. Among the CA techniques that you selected in Question 1, please indicate on a scale of 1 to 5, the:
   a. Equipment cost (1 being very inexpensive, 5 being very expensive)
   b. Labor cost (1 being very inexpensive, 5 being very expensive)
   c. Reliability of the data collected (1 being very reliable, 5 being very unreliable

Condition Assessment (CA) Technique	**Equipment cost**	**Labor cost**	**Reliability of data collected**	**Comments**
APVM				
BEM				
CCTV				
MFL				
MPDM				
RFT				
SLPR				
UA, UH, UPA				
UCs				
ALD				
Others				

4. Among the CA techniques that you selected in Question 1, please rate their effectiveness in identifying:
   a. Internal flaws/irregularities (1 being very effective, 5 being very ineffective)
   b. Mid-wall flaws/irregularities (1 being very effective, 5 being very ineffective)
   c. External flaws/irregularities (1 being very effective, 5 being very ineffective)

Condition Assessment (CA) Technique	**Internal flaws/irregularities**	**Mid-wall flaws/irregularities**	**External flaws/irregularities**	**Comments**
APVM				
BEM				
CCTV				
MFL				
MPDM				
RFT				
SLPR				
UA, UH, UPA				
UCs				
ALD				
Others				

5. Among the CA techniques that you selected in Question 1, please specify the type of access to the pipeline that is required.

Condition Assessment (CA) Technique	**Type of access that is required**	**Comments**
APVM		
BEM		
CCTV		
MFL		
MPDM		
RFT		
SLPR		
UA, UH, UPA		
UCs		
ALD		
Others		

6. Which of the following condition monitoring techniques do you provide for small diameter DIP?

	Condition Monitoring Technique
☐	Corrosion rate sensor
☐	Acoustic emission sensor
☐	Magnetostrictive sensor
☐	Conformable and flexible eddy current array
☐	Flexible ultrasonic sensor
☐	Guided wave sensor
☐	Damage sensor
☐	Microwave back-scattering sensor
☐	Fiber optic sensor
☐	Others (Please specify)

7. For the condition monitoring techniques that you selected in Question 6, please indicate on a scale of 1 – 5, the:
    a. Reliability of data collected. (1 being very reliable, 5 being very unreliable)
    b. Ease of data interpretation (1 being very easy to interpret, 5 being the very difficult to interpret)
    c. Level of operator training that is required (1 being minimal operator training required, 5 being extensive operator training required)
    d. Overall cost (1 being inexpensive, 5 being expensive)

Condition monitoring technique	**Confidence in data collected**	**Ease of data interpretation**	**Level of operator training required**	**Overall cost**	**Comments**

If you are interested in engaging further with the research team on this project and for receiving a copy of the final results, please fill in the following information:

Name: ____

Organization/Agency/Company: ____

Role in organization/agency/company: __________________________________

Postal Address: ____

Email Address: ____

Phone number: ____

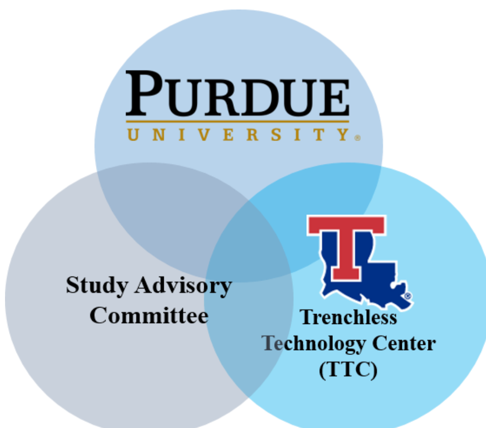
Please return the completed survey to Dulcy M. Abraham via email (dulcy@purdue.edu) or via postal mail to: Professor Dulcy M. Abraham. Lyles School of Civil Engineering, Purdue University, 550 Stadium Mall Drive, West Lafayette, IN 47907

WaterRF 4661: Practical Condition Assessment and Failure Probability Analysis of Small Diameter Ductile Iron Pipes

<u>Survey of DIP Manufacturers</u>

Purdue University and Louisiana Tech University are partnering on a research project (WaterRF #4661) to develop a manual of practice (MOP), for the condition assessment of small diameter (12" and smaller) ductile iron pipes. This project aims to collect input from industry, utility and condition assessment practitioners, about identifying failures in small diameter ductile iron pipes, the technology capabilities and barriers to implementation of condition assessment technologies, and developing guidelines for condition assessment programs.

This survey is geared towards **Ductile Iron Pipe Manufacturers** and will take approximately **15 minutes** for completion. The information collected is confidential and will be used only for research purposes. Findings of the study will be aggregated and shared with the Water Research Foundation.



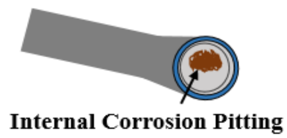
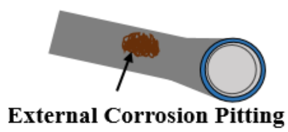
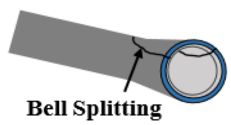
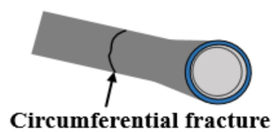
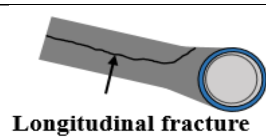
Abbreviations:

CA Condition Assessment
DIP Ductile Iron Pipe
ID Internal Diameter
WDS Water Distribution System

Terms:

Small DIP - Ductile iron pipe with an ID of 12 inch (30 cm) or less

Table 1. Small DIP failure modes

Failure Mode	Figure	Definition
Corrosion Pitting (Internal)		A localized form of corrosion, which manifests itself as pits on the pipe's internal surface.
Corrosion Pitting (External)		A localized form of corrosion, which manifests itself as pits on the pipe's external surface.
Blowout		Blowouts occur when corrosion or graphitisation has reduced the strength of the pipe wall in a local area, to a point where a pressure surge causes the wall to rupture.
Bell Splitting (Split pipe)		The crack terminates just below the bell of the pipe.
Circumferential Failure		Cracks propagate around the circumference of the pipe.
Longitudinal Failure		The pipe wall fractures parallel to the axis of the pipe.
Graphitization	**N/A**	A process which removes some of the iron in the pipe, but leaves behind a matrix of graphite flakes that is held together in part by iron oxide.
Joint Failure	**N/A**	As distinct from bell splitting or bell shearing which indicate fracture of the bell/socket, joint failure means that the joint is no longer watertight, resulting in leakage. This can undermine the pipe bedding and may produce heave forces in expansive clay soils.

<u>Questions related to failure modes, causes of failure, and condition assessment of small DIP</u>

1. Please rank the following external causes of failure for small diameter DIP, based on their frequency of occurrence? (Enter 1 for the most frequent cause of failure, 2 for the

second most frequent cause of failure, and so on. **Enter N/A if you have not experienced a particular cause of failure in small DIP**)

Cause of failure (External)	**Frequency** (1 – most frequent, 2 – second most frequent, and so on. N/A for no experience)	**Comments (Please indicate if this is the initial cause or the final trigger leading to failure)**
Additional loading to the system (truck loads, frost loads, changes in temperature, or changes in water pressure)		
Third-party damage		
Joint damage		
Manufacturing defects		
Corrosion pitting (external)		
Installation damages		
Others (please specify)		

2. Please rank the following internal causes of failure for small diameter DIP based on their frequency of occurrence? (Enter 1 for the most frequent cause of failure, 2 for the second most frequent cause of failure, and so on. **Enter N/A if you have not experienced a particular cause of failure in small DIP**)

Cause of failure (Internal)	**Frequency** (1 – most frequent, 2 – second most frequent, and so on. N/A for no experience)	**Comments (Please indicate if this is the initial cause or the final trigger leading to failure)**
Leakage (That results in pipe bedding being washed away)		
Transient loading		
Structural damage (During installation)		

Internal corrosion		
Manufacturing defects		
Others (please specify)		

3. Please rank the following failure modes, according to their frequency of occurrence? (Enter 1 for the most frequent failure mode, 2 for the second most frequent, and so on. **Enter N/A if you have not experienced a particular failure mode in small DIP**)

Failure Mode	**Frequency** (1 – most frequent, 2 – second most frequent, and so on. N/A for no experience)	**Comments**
Corrosion Pitting (Internal)		
Corrosion Pitting (External)		
Blowout Holes		
Bell Splitting (Split pipe)		
Circumferential Failure		
Longitudinal Failure		
Graphitization		
Joint Failure		
Others (please specify)		

4. Which of the following non-destructive non-invasive CA techniques do you recommend for the CA of small diameter DIP? (You may select multiple techniques)

Condition Assessment (CA) Technique	**Comments**
☐ Acoustic propagation velocity measurement (APVM)	

☐ Broadband Electro-Magnetics (BEM) ☐ CCTV inspection technology (CCTV) ☐ Magnetic Flux Leakage (MFL) ☐ Manual Pit Depth Measurement (MPDM) ☐ Remote Field Technology (RFT) (otherwise known as Remote Field Eddy Current) ☐ Soil Linear Polarization Resistance (SLPR) ☐ Ultrasonic—Automated, Handheld, Phased Array (UA, UH, UPA) ☐ Ultrasound C-scan (UCs) ☐ Acoustic leak detection (ALD) ☐ Others (Please specify)	

5. Which of the following condition monitoring techniques do you recommend for small diameter DIP?

	Condition Monitoring Technique
☐	Corrosion rate sensor
☐	Acoustic emission sensor
☐	Magnetostrictive sensor
☐	Conformable and flexible eddy current array
☐	Flexible ultrasonic sensor
☐	Guided wave sensor
☐	Damage sensor

☐	Microwave back-scattering sensor
☐	Fiber optic sensor
☐	Others (Please specify)

Questions related to manufacturing defects, handling instructions, and service life of small DIP

6. Please list the common manufacturing defects in your small DIP, and also indicate their frequency of occurrence on a scale of 1 to 5 (1 being infrequent and 5 being very frequent).

Manufacturing defect	Frequency of defect (1 – infrequent, 5 – very frequent)	Comments

7. What are the failure modes associated with the above manufacturing defects that you listed in Question 6?

Manufacturing defect	Failure mode(s) associated with manufacturing defect	Comments

8. Can the above mentioned manufacturing defects be detected by CA techniques? If Yes, please specify which CA techniques are capable of detecting these manufacturing defects?

Manufacturing defect	CA technique capable of detecting manufacturing defect	Comments

9. Do you have any specific hauling/handling requirements/instructions for small diameter DIP? If Yes, please specify what they are?

____
____

10. Is there a standard installation procedure for the small DIP that you manufacture? If Yes, please specify what it is?

____
____

11. Please list the Quality Control/Quality Assurance procedures for the small DIP that you manufacture?

____
____

12. Do you have estimates of the service life of small DIP? If yes, please provide us with that data?

____
____

13. Do you recommend any techniques for extending the life of small DIP? If yes, please elaborate on those techniques?

____
____

14. Do you recommend the following methods for small DIP? Please answer yes/no.
    a. Installation of corrosion test stations (CTS): ____________
    b. Collect/test pipe-to-soil potentials: ____________
    c. Performing soil analysis: ____________
    d. Stray current interference testing: ____________
    e. Using cathodic protection: ____________
    f. Installation of pipe joint bonds: ____________

g. Installation of polyethylene encasement: ____________
h. Relying on the asphaltic coatings: ____________
i. Operating until failure: ____________