

# Understanding Graphitization Risk

Pennsylvania Public Utility Commission  
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Author and Presenter:  
James Datesh, WATTA Inc.  
Pittsburgh, PA  
With Special Thanks to:  
Mehrooz Zamanzadeh, PhD.  
Matco Services, Inc.



# Understanding Graphitization Risk

## Outline

Who needs to focus graphitization risk

What is graphitization

How to identify it

Assessing the Risk

Why this is important



# The Who Is Simple



# The Who

Whoever has **cast iron** pipes in their systems that are old or subject to corrosive conditions



# The Who

Prior to steel, **cast iron** was widely used for pipeline construction



# The Who

In 2012: 34,000 miles of **cast iron** main lines and  
15,000 miles of service lines



# The Who

**Cast iron** pipe now found mostly in:

NJ, NY, MA, PA, MI (main lines)

large cities (service lines)  
e.g., NYC, Boston, Washington, Philadelphia



# What Is Graphitization



# What Is Graphitization

Selective leaching of iron from **cast iron**

**Cast iron** is a combination of iron and graphite

When the iron exits, that leaves graphite behind



# What Is Graphitization

The result is a weakened and brittle pipe

But to the eye, the pipe may look unaffected



# What Is Graphitization

Maybe we should rename it, de-**iron**ification

Then it would be easier to understand



# What Is Graphitization

Other examples of selective leaching:

the de-**zinc**ification of brass

the de-**calc**ification of bones  
(better known as osteoporosis)



# How to Measure Graphitization



# How to Measure Graphitization



The HAMMER method

“Clang and Clunck”

# Sensing Graphitization Non-Destructively

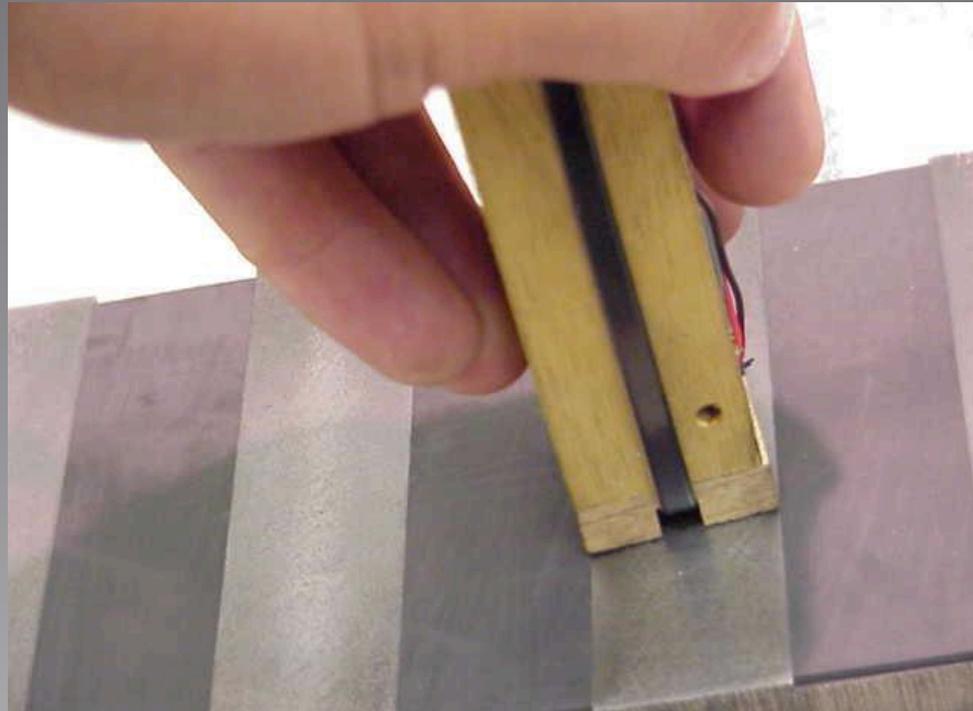
Localized leaching of iron during graphitization changes the magnetic permeability of the pipe

This can be used to detect graphitized areas



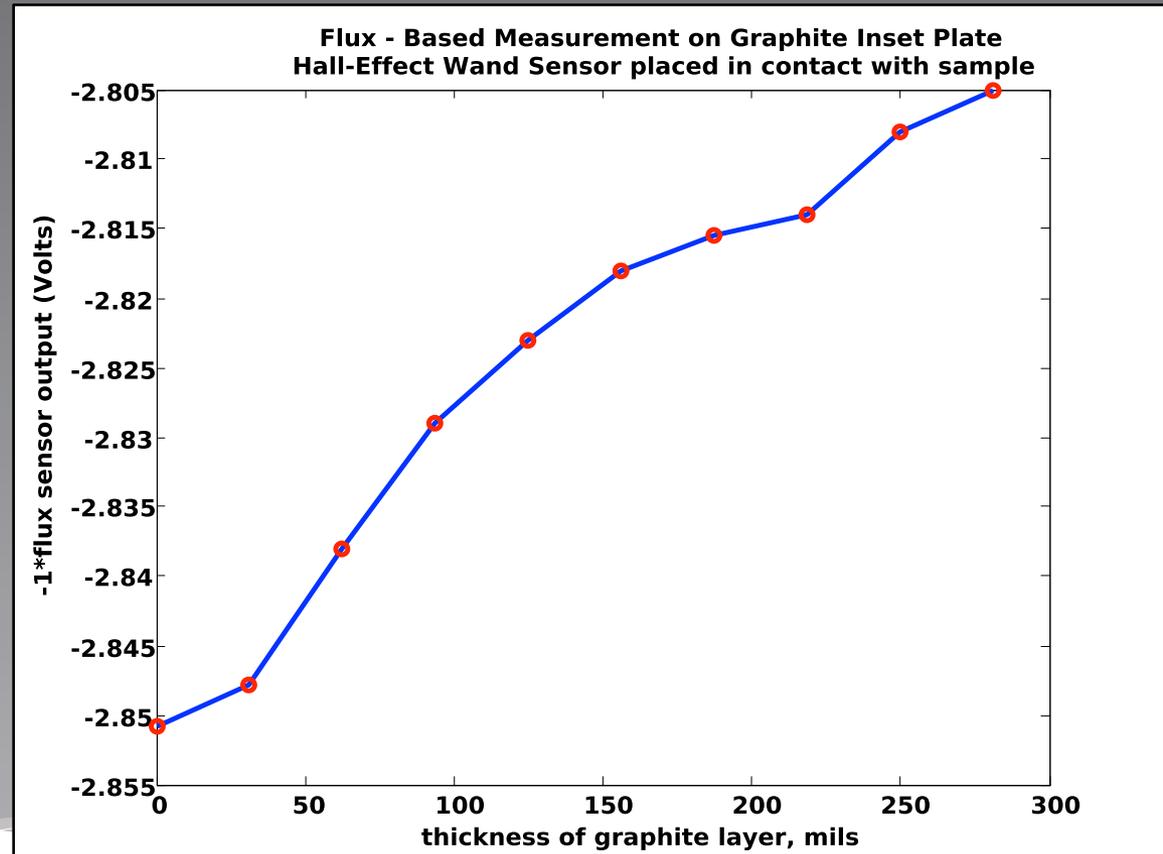
# The Method

Prototype sensor being used to measure the thickness of inset graphite patches



# The Output

Measured voltage varies as the graphite layer gets thicker



# Sensing Graphitization Non-Destructively

Dr. Zee's patent : US 7719266 B1

Pipes undergoing graphitization may  
appear sound.



# Sensing Graphitization Non-Destructively

Dr. Zee's patent : US 7719266 B1

Graphitized regions of pipe wall will be brittle and subject to failure under load as the result of temperature variation, heavy traffic, or shock.



# Sensing Graphitization Non-Destructively

Dr. Zee's patent : US 7719266 B1

A sensor measures the interaction of an applied magnetic field to a sample surface that includes magnetic materials to determine whether the samples surface has been corroded.



# How to Measure Graphitization

... when the pipe is underground ?



# What is Risk



# What is Risk

The nature of risk is **uncertainty**



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The nature of risk is *uncertainty*

Desired outcomes are inherently under threat of failure due to events that may occur during the asset life-cycles



# What is Risk

The nature of risk is *uncertainty*

Desired outcomes are inherently under threat of failure due to events that may occur during the asset life-cycles

Such events vary in their degree of probabilistic occurrence, magnitude of impact (severity), and manageability



# Key Risk Factors in Graphitization

Age

Soil chemistry

Soil resistivity (soil conductivity)

Stray current

Corrosion rate



# Key Risk Factors in Graphitization

## Age

Cast iron pipe has been in use in the U.S. for  
over 150 years

Ductile iron pipe could be up to 60 years



# Key Risk Factors in Graphitization

**Soil chemistry**

**Soil resistivity (soil conductivity)**

Chlorides, sulfates, sulfides

Low soil resistivity (high conductivity)

Acidity (low pH)

Wet-dry fluctuations

Differential aeration



# Key Risk Factors in Graphitization

Stray current

Corrosion rate



# Proactive Steps

Comprehensive surveys  
e.g., correlate by age, soil conditions, impact,  
priority test, access, history, electrical test

Cathodic protection

Pipe replacement

Risk-based inspection program



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# Why Is This Important

There are widely recognized risks associated with **cast iron** pipe in natural gas systems

Graphitization is a dominant factor



“About every other day over the past decade, a gas leak in the United States has destroyed property, hurt someone or killed someone”

“**cast-iron pipe** — some of it more than a century old — . . . is the chief suspect”

*(USA TODAY Network)*



A Notice by the PHMA on 03/23/2012

Pipeline Safety: **Cast Iron Pipe**  
(Supplementary Advisory Bulletin)



the need for continued safety improvements to  
**aging gas pipeline** systems

urges owners and operators to conduct a  
comprehensive review of  
their **cast iron** distribution pipelines  
and replacement programs

(PHMA)



# Summary

**Who** needs to focus graphitization risk

**What** is graphitization

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Assessing the **Risk**

**Why** this is important



# Conclusions

Graphitization introduces serious risk



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Non-destructive magnetic detection of  
graphitization is feasible



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Non-destructive magnetic detection of  
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Risk assessment should be applied



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# Question & Answer

