Quantitative Acoustic Emission (QAE)

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Margan
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Objectives

• Why inspect High Energy Pipe (HEP)?
• What is QAE Technology?
  - A Non-Destructive Inspection (NDI) screening & monitoring tool
• How does QAE work?
  - The phenomenon of acoustic emission
Objectives

• What is the QAE process?
  - Equipment / Installation / Testing / Analysis

• Applicability
  - P22 and P91

• Case studies
  - Effectiveness, advantages, and cost savings

• Summary
Why Inspect HEP?

Comprehensive Inspection Program

Protect Physical Assets and Employees

- Aging Plants
- Reduced Safety Factors
- P21 / P91 Uncertainty
- Operation
What Is QAE

• A passive system
  - Converts released flaw development energy into acoustic signature
  - Does not induce seismic or sonic energy into the HEP

• On-line system
  - Sensing devices are installed while on-line
  - Data is collected while on line
What Is QAE

- A Predictive Maintenance (PdM) tool for your Reliability Centered Maintenance (RCM) tool kit
  - Flexible coverage
    - 100% or can be limited to high risk zones

- Can move traditional NDE from time based to conditioned based inspections
What Is QAE

- A monitoring process
  - Continuous real time or period based
  - Entails trending data
  - Provides early alert to developing issues
What Is QAE

- A strategic screening tool
  - Optimizes knowledge of HEP integrity over time
    - Provides visual map
  - Assists in prioritizing NDE inspection efforts
    - UT, MT, LPA, replication
  - Reduces uncertainty
    - Provides sense of urgency
  - Facilitates outage planning
What Is QAE

• A strategic - screening tool
  - Helps improves budget process
  - Enables cost reductions
  - Helps defer or avoid unnecessary NDE
  - Reduces need for
    • Scaffolding
    • Insulation removal
QAE Limitations

- Indication must be active
  - Emit or resonate when placed under stress
- Does not “precisely” locate indication along linear length
  - +/- 10% (or approximately 1 foot)
- Does not differentiate between surface and subsurface location
- Does not provide size of indication
QAE Limitations

- Sensitive to background noise fluctuation and magnitude
- Can be overly sensitive
  - Small but very active indications
- Multiple flaws near same location cannot be differentiated
How Does QAE Work?

Fracture or deformation processes in differing materials have different signatures.
How Does QAE Work?

Fracture or deformation processes in differing materials have different signatures.
How Does QAE Work?

QAE System Collects and Converts

**Acoustic Emission** is a phenomenon of sound and ultrasound wave radiation in materials that undergo deformation and fracture processes.
**How Does QAE Work?**

**Burst AE** is a qualitative description of the discrete signal's related to individual emission events occurring within the material.

**Continuous AE** is a qualitative description of the sustained signal produced by time-overlapping signals.
What Can QAE Detect?

Flaw accumulation and development
- Micro / macro-cracking
- Fracturing and de-bonding of hard inclusions
- Creep development

Mechanical impacts and friction
- Hanger impacts and knocks
- Friction at side supports
- Dynamic overstressing
- Shock waves due to steam pulsation

Leaks, malfunctioning valves, and steam fluctuations
- Leaks
- Malfunctioning valves
- Steam fluctuations due to control problems
Examples of AE Sources

Type I – Flaw Suspected activity
Type II – Impact and friction

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Examples of AE Sources

Valve Leaks

Malfunctioning Valves

Leaks

Leak

Valve Leaks
What Is Margan’s QAE Process?

Equipment

System Design & Installation

Data Acquisition

Data Analysis

Report

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Equipment

- **P22 Waveguide**
  - Provides signal pass & dissipates heat before sensor
  - \(\frac{1}{4}\)” Stainless steel with an aluminum flux ball
  - Ceramic sensor converts pulse to electrical signal
Equipment

- **P91 Waveguide**
  - P91 material welding attachment standards require
    - Capacitor welding method
    - A specific waveguide
Equipment

- **Other**
  - Cable
  - Preamplifier
  - BNC Cable Connectors
  - Resonance Sensor
  - Integrated Pre-amplifier
  - AE PCI 4 Cards
  - Software
Design

- **Sensors strategically spaced**
  - Sensor spacing is function of sensor sensitivity, background noise, piping accessories, attenuation, etc.
  - **EPRI guidelines**
    - 15 to 18 feet in low background noise
    - 10 to 13 feet in high background noise
  - **Margan procedure**
    - 12 feet maximum
      - Increased sensitivity and reliability
    - <3 feet from piping accessories
      - Wye blocks, attempterators, hangers, etc.
    - Install on same circumferential side of pipe
Installation

Minimal Insulation Removal

Terminal Point

Welding Waveguide

No Scaffolds - Rope Access

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Data Acquisition

- Margan uses 3 calibration protocols
  1) Sensor response to a preset noise level
  2) Acoustic emission energy distribution
  3) Sensor attenuation vs distance to sensor
- Calibration is critical stage for accuracy
# Data Acquisition

<table>
<thead>
<tr>
<th>Margan Procedures</th>
<th>EPRI Guidelines</th>
</tr>
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<tbody>
<tr>
<td>Most of the inspection is performed under stable load conditions of plant operation. During baseline, it is recommended to perform low and variable load measurements (see below)</td>
<td>Stress method should not excessively stress the piping. Piping should be monitored under normal stable conditions.</td>
</tr>
<tr>
<td>Variable load measurement- the load swings between 90% to 100% of full load back and forth. This is done to monitor dormant flaws, which emit under changes in stress.</td>
<td>The load swing should include a pressure change of at least 25% of the piping operating pressure range.</td>
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<td>Low load measurement- the load is lowered to 70% of full load. This is done especially to monitor piping with high noise background, which will assist in filtering it.</td>
<td></td>
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Data Analysis

a

b

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Electric Generation
ISSUES, TRENDS, and PRACTICAL SOLUTIONS
Data Analysis
Applicability To P22

- Bench test P22 correlation strain vs AE vs time
  - Transition point occurs at ½ life
  - Transition correlates to 1st QAE increase
  - Strong correlation
Applicability To P22
Applicability

- For both P91 and P22
  - QAE can detect and accumulate energy trend
    - Anticipate failure and location of failure
    - Highlights use as a PdM tool to reduce risk
- P91 reacts differently to strain than P22
  - More sudden failure
    - Supports even a greater need for use on P91
Applicability

Creep Damage Accumulation Diagram

AE Is Emitted As Creep Accumulates

* Under normal background noise conditions
Case Studies

• Case study 1 MS line
  - System installed on MS line IN 2004
  - No special events reported until 2009
    • Inspection reported abnormal activity in section leading to turbine leads
  - During 2011 outage, client performed NDE
    • Cracks and creep were found
Case Studies

Case study 1 MS line
Case Studies

Case study 1 MS line

February 2006 and 2007

January 2009
Case Studies

Case study 1 MS line

UT, MT and replica in 2011
Case Studies

Case study 2 CRH line: thermal shock / fatigue

TMI - Trend monitoring Inspection
MC - Micro-Cracking
MT - Magnetic Particles Inspection
LPA - Linear Phased Array
NRI - No Reportable Indications

Fatigue Crack

- Baseline QAE MC: Feb 2003
- 1st TMI QAE Increased Activity: Oct 2003
- MT LPA NRI: Feb 2005
- 2nd TMI QAE Increased Activity: July 2006
- Leak in weld 14: 2 days later
- 2x40” Thermal Fatigue cracks

Crack identified by LPA in 2006

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Case Studies

Case study 2 CRH line: thermal shock / fatigue


Fatigue Crack

Crack identified by LPA in 2006

Feb 2003
Feb 2005
Feb 2008 After line repair
2004 - Two areas were recommended by QAE NDI to be inspected by localized NDE methods due to indications of micro-cracking and creep development.

2005 - Top area: creep class 3 was revealed by replica several indications were revealed by UT. Surface cracks were revealed by MT and grind out.

Bottom area: creep class 4 was verified by replica investigation.

Linear Phased Array Ultrasonic Examination revealed accumulation of multiple processing indications.
Case Studies

Case studies 3A and 3B HRH line

Replica investigation at girth welds located at zones between AE points 44-45-50 and 51-52.

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<th>Zone</th>
<th>Company 1</th>
<th>Company 2</th>
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<tr>
<td>Zone 1</td>
<td>Class 3 creep 2/2*</td>
<td>Class 1 creep 7/12, Class 2 creep 5/12</td>
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<tr>
<td>Zone 2</td>
<td>Class 4 creep 2/2</td>
<td>Class 1 creep 3/12, Class 2 creep 9/12</td>
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<tr>
<td>Recommend</td>
<td>Repair in six months to one year time period.</td>
<td>Re-inspect in 8-10 years.</td>
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Case Studies

Case studies 3A and 3B HRH line

Company 1; creep class 4

Company 2; creep class 2

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Case Studies

- **Case study 4 hanger assessment**
  - In 2000 Unusual AE Activity Noted
  - Activity Increased 6-Months Later
  - Visual Inspection
    - Rigid Hangers
    - Hanger Repaired

Margan Provides Hanger Assessment With Each Report
Case Studies

- Case study 5 thermal shock
  - Thermal shock zone is increasing
  - With time and as more
  - Attemperation is applied

January 2009

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<td>30-40</td>
<td>AE points 6-16</td>
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<tr>
<td>&gt;40</td>
<td>AE points 1-19</td>
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Case Studies

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January 2010

Start of intensive AE activity when attemperator opening is above 20%.
Case Studies

- Case study 6 new install economics
  - Probability of failure <1%, but consequences very high
  - After 10 years only about 21% of the HEP inspected
    - QAE would provide 100% coverage more frequently
  - Cost from traditional NDE on 100% of MS, CHR, and hrhline equaled ~$1.9 million / unit (excluding any asbestos)

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Case Studies

• Case study 6 new install economics
  - Unit had to be off line to complete traditional NDE
    • Replacement power could add to $1.9 million cost
  - QAE capital had <3 year payback
    • Would provide 100% coverage every 2 to 3 years
    • Would help prioritize NDE on higher risk areas
    • Required less scaffolding and insulation removal
Summary

• **QAE NDI is:**
  - A PdM monitoring and trending program and
  - A RCM diagnostic and screening tool

• **QAE is a part of a comprehensive HEP inspection program**

• **QAE can differentiate between various acoustic signatures**
Summary

- QAE works on both P22 and P91
- QAE reduces overall risk
- QAE helps to target and prioritize higher risk areas
- QAE supplements traditional NDE
- QAE is cost effective
  - QAE facilitates outage planning and budget process
Objective

When To Use QAE?

How And Where Does QAE Work?

Why Use QAE As Part Of A Comprehensive Inspection Program?

What Is QAE?