Summary of Field Experience for Acoustic Emission Monitoring of Seam-Welded High Energy Piping

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## Recent SH Link Piping Failures

<table>
<thead>
<tr>
<th>Company</th>
<th>Unit</th>
<th>Year</th>
<th>Type</th>
<th>Hours</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama Power (Southern Co)</td>
<td>Gaston Unit #2</td>
<td>1993</td>
<td>SH Link</td>
<td>156,000</td>
<td>Through-wall leak</td>
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<tr>
<td>Monongahela Power</td>
<td>Ft. Martin Unit #1</td>
<td>1995</td>
<td>SH Link</td>
<td>205,000</td>
<td>Through-wall leak</td>
</tr>
<tr>
<td>East Kentucky Power</td>
<td>Spurlock Unit #2</td>
<td>1996</td>
<td>SH Link</td>
<td>125,000</td>
<td>Through-wall leak</td>
</tr>
<tr>
<td>Virginia Power</td>
<td>Mt. Storm Unit #1</td>
<td>1996</td>
<td>SH Link</td>
<td>200,000</td>
<td>Catastrophic</td>
</tr>
<tr>
<td>Kansas City Power &amp; Light</td>
<td>Hawthorne Unit #5</td>
<td>1998</td>
<td>SH Link</td>
<td>225,000</td>
<td>Catastrophic</td>
</tr>
</tbody>
</table>

Mt Storm, June 1996

Hawthorne, Aug 1998
CREEP CRACKING IN LONG SEAM WELDS

Fine grain HAZ cracks at weld centerline (main steam link piping)

Interior weld metal defects or cracks

Fine grain HAZ (Type IV) (Mainly in main steam link piping)

Weld metal at fusion line (mainly hot reheat piping)

Base Metal

Cusp
Acoustic Emission

• Passive monitoring technology--energy comes from active sources
• High frequency---300-400 KHz in steam line applications
• Source location (time difference of arrival processing)
• Very sensitive to small amounts of defect growth
Purpose for AE Testing of HRH Seamed Piping

• Improve economics of inspection
  – Find active flaws during operational conditions
  – Direct additional NDE (ultrasonics, magnetic particle, radiography)
  – Reduce effort to evaluate inactive sources

• Provide global inspection
  – Detect active flaws in entire volume of piping
Key Elements of AE Testing

- Waveguides required for temperature isolation ---spacing 15-18 ft
- Sensor design and filtering to reduce influence of background (flow) noise
- Active linear source location to identify active emission sites
- Correlation with plant parameters to identify AE source behavior
Acoustic Emission
Instrumentation

AET 5500 Data Acquisition System

Stud-welded waveguide
AE MONITORING OF REHEAT LINES
Historical Perspective

• 1985, 86 Mohave and Monroe failures spur start of EPRI investigative program
• 1986-1990--Initial EPRI investigative program for AE (RP1893-4)
• 1990-1995--Joint investigative program with PG&E (RP1893-20)
  – Revised AE Guidelines for AE testing of seamed HRH piping (Nov ‘95)
  – Successful full scale test on PG&E Potrero HRH piping
• 1994-99--EPRI Guidelines testing of 38 HRH & SH lines shows good correlation with other NDE methods and advanced cryo-cracking metallography
EPRI AE GUIDELINES

ONLINE TESTING

• Normal Plant Operation
  – High Load Min. 25% (≥ 90% of peak pressure)
  – 2 Hr Min. at Peak Load (now prefer 4 hrs)
  – Pressure Reduction 25%
  – Five Load Cycles
  – Typical 3-5 days per line segment
• Creep and Thermal Fatigue Stimulation
• Best for Seam Weld Evaluation
AE Source Location Cluster Analysis
Normalized Event Density Ranking

NEDR = Cluster Events/Cluster Std Dev/Time
(units Events/Inch-Hr)
AE Guidelines Testing History

EPRI Acoustic Emission Guidelines Testing
HRH & SH Lines Showing Suspected Creep-Related Seam Weld Sources (1994-99)

- Creep-Related Seam Weld Sources
- No Seam Weld Sources

Operating Hours vs. # Lines
Kentucky Utilities Brown #3
SH Link Piping

• AE monitoring program
  – Startup and online Jun 1-9 ‘97 East and West SH
  – Online, cooldown Feb 25-Mar 6 ‘98 West SH only

• Both links replaced Spring ‘98 outage

• West SH link (6 ft segment) to EPRI
  – Inspected with phased array UT at EPRI NDE Center
  – 3” plug sample to M&M Engrg for cryocracking metallographic analysis
Example of Waveguide installation on SH link piping
Kentucky Utilities Brown #3
SH Link Piping--June 97 Startup

BROWN UNIT 3 SH EAST LEAD, FILE BR1601A, STARTUP 6/1/97
FILTERED: RDC>=25, FREQ>=30 KHz

BROWN 3 WEST SH LEAD, FILE BR1601A, STARTUP 6/1/97
FILTERED: RDC>=25, FREQ>=30 KHz

Kentucky Utilities Brown Unit #3
Superheat Link Piping
AE Located Clusters
Kentucky Utilities Brown #3
West SH Link--Mar 98 Online

AE location profile during online monitoring similar to June 97, but broadening

Sources show sensitivity to pressure during online conditions
Phased array automated UT scan finds scattered indications in weld centerline over 24” length of weld--matches AE location data.

3” plug sample is taken from suspect area for metallography.
Metallographic and cryo-cracking analysis by M&M Engrg (Austin, TX) finds evidence of early stage creep cavitation in weld centerline.

- **a** Fine grained intraweld zone 1/3 from OD
- **b** Fine grained intraweld zone at mid-wall
- **c** Weld center near ID and OD intersection
- **d** HAZ near ID/OD weld cusp
- **e** HAZ near mid-wall of pipe
- **f** HAZ near fusion line at mid-wall of pipe
- **g** Weld near fusion line at ID root pass

Kentucky Utilities Brown #3  
West SH Link--EPRI Evaluation
Peak Load:
~500 PSIG, 1000 F

Min Load:
~180 PSIG, 950 F

ASTM A-155 P-22 (2 1/4 Cr), seam-welded

Boiler/Turbine Leads 110 ft
28.75” OD x 1.406” MWT

Main HRH 440 ft
37.5” OD x 1.813” MWT
Baldwin Unit 1 HRH AE Test Program

Activity during online 4 days after 5/7/98 startup

- Clusters 4, 5 show pressure sensitivity
- Much reduced activity from startup condition
Intradose Weld LSW4I
53.5"
Extradose Weld LSW4E
110"
Girth Weld GS-11
Seam Weld LSW8
Spool HR8
Seam Weld LSW9
Girth Weld GF-10
Girth Weld LSW9
Spool HR9

Illinois Power
Baldwin Unit #1
Elev 553
Clamshell Elbow

24"
48-50"
48-50"
101-103"
24"

Focused Array UT Inspection

Centerline distance
WG #14 to WG #15 = 192"

WG #14
Spool HR8
Seam Weld LSW8
Girth Weld GF-10
Elbow HRF4
Intradose Weld LSW4I
53.5"

Extradose Weld LSW4E
110"

WG #15
Spool HR9
Seam Weld LSW9

CS Hanger
(U-bolt clamp)

Elev 553
Baldwin #1 HRH Elev 553 Elbow
UT Inspection Results

- No significant TOFD indications or FATS indications at elbow seam weld locations selected by SIA
- Significant TOFD indications in spool HR9 over 6’ section
  - FATS 0 & 45 deg inspections show this is due to plate laminations
  - Inconclusive results on presence of creep damage
- FATS indications of early stage creep damage in extradose elbow seam weld location selected by AEC
  - Isolated cavitation or disbonded inclusions near midwall cusp
- Material sampling recommended
- Cryo-cracking metallography only reliable method for early stage creep analysis
Illinois Power Baldwin #1 Elev. 553 Elbow
Midspan Extradose Weld Focused Array UT Scan
(48-50” downstream of GF-10)

FATS scan shows isolated cavitation or disbonding at midwall position on one side of the weld. Pattern is consistent with early stage creep damage.
Conclusions

- AE has reached field maturity
- Early detection of creep damage at cavitation stage
- Advanced UT and Metallographic techniques required for verification
  - FATS or Phased Array UT
  - Cryo-cracking SEM metallography
- EPRI Seam Welded Piping recommendations in review/revision