Laboratory Examination of Smelt Spouts

2011 TAPPI PEERS CONFERENCE
Portland, Oregon

Craig Reid
Acuren Group Inc
BLRBAC Safe Firing

- Inspect spouts every scheduled outage
- Replace all spouts at least annually
- Cut up at least one removed spout to inspect the water side
- Field hydro test new spouts
- Never rebuild, repair, or modify a spout
- Clean and inspect head tank and collecting tank annually
- Periodically inspect cooling water piping
BLRBAC SAFE FIRING
compliance varies

- Spouts not changed annually
- Fireside inspection practice varies – (clean, dry, full access)
- Rebuilt spouts used
- Water side examination of sacrificial spout not documented
Materials

Carbon steel
- Bare
- Thermal sprayed
- Chromized
- Roll clad with stainless
- Roll clad with Alloy 825

Fabricated 304L stainless steel

50Cr/50 Ni Cast Dry spouts
Damage Mechanisms

- water side corrosion and/or deposition
- fireside corrosion by smelt
- fireside corrosion by condensed vapor
- fireside thermal fatigue
- fireside rodding damage
Water Side

Defined water passages

– the “CE” Spout
– water makes several longitudinal passages
– analogous to water flow through a tube

Not so defined water passages

– assorted designs
– water flow is more or less directly from inlet to outlet
“CE” Spout

Water inlet

Smelt inlet

Outlet from spout body

Inlet to spout body

Smelt outlet

Water outlet
water tube

- trough 1/4" thick
- water channel
- jacket - 1/8" thick
- stitch weld
- channel division bar
- plug weld
- tide line thinning
Summary

Damage Mechanisms

- water side deposition or corrosion not a factor in damage
- no overheating of either carbon steel or stainless steel
- corrosion of bare carbon steel
- corrosion of carbon steel exposed by loss of thermal spray and chromizing
- thermal fatigue cracking of carbon steel, stainless steel, roll clad plate, and 50 Cr/50 Ni dry spouts
- “mechanical” fatigue cracking of chromized spouts – after four years
Summary
Thermal fatigue

• not found with CE style spouts
• analogous to thermal fatigue of composite smelt spout opening tubes and primary air port tubes
• occurs without corrosion
• driven by smelt side heat flux variations (in dry and water cooled spouts)
• related to cooling water flow pattern in water cooled spouts with “not so defined cooling water passages”
Summary
Thermal fatigue

• No “easy” solution available to boiler operator
• Parallel with ORNL/Paprican research program on composite tube cracking
• Smelt side thermal flux variations inherent in operation
• Spout water passage design expertise resides with suppliers
• Spout water supply system design depends on suppliers
• Operator can monitor and trend cooling water parameters – e.g. flow rate and temperature
Summary

Inspection

• Observed damage occurs without significant water side corrosion or deposition
• Monitor water side by other means than spout sacrifice
• Keep spouts in service by visual inspection, UT thickness, MT or PT for cracking
• If significant damage is found or the type or pattern of damage changes then trigger a water side examination
• Always to a visual inspection with good lighting
• Surface preparation is essential for sensitive MT or PT
• “if you ain’t grindin/sandin then you ain’t findin”
• UT thickness must be a scan using a screen display – no point “doinking” by test robots
CHRONOLOGICAL BACKGROUND
<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>Harmac - average spout life 7 weeks</td>
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<tr>
<td>1982</td>
<td>Harmac - average spout life 11 months</td>
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<tr>
<td>1982</td>
<td>Harmac - cast Hastelloy C spout leaked in short service – due to casting defects</td>
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<tr>
<td>1985</td>
<td>Powell - “CE” bare - after boiler rebuild spout life decreased from 1 year to 6 months - tide line thinning</td>
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<tr>
<td>1985-1989</td>
<td>Powell – thermal spray used with mixed success</td>
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<tr>
<td>1990</td>
<td>Powell – 2 thermal spray and 2 chromized spouts installed. Thermal spray lost after 6 months.</td>
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<tr>
<td>1990-1995</td>
<td>Powell – “CE” chromized. Service up to 4 years with no deterioration</td>
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<tr>
<td>Year</td>
<td>Event</td>
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<tr>
<td>1995</td>
<td>Powell – 3 new “CE” chromized leaked after 6 months - a 4\textsuperscript{th} spout which had been in service for 2 years did not leak</td>
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<tr>
<td>1995</td>
<td>Powell – started changing chromized annually</td>
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<tr>
<td>1997</td>
<td>Swedish report of a smelt spout leaking incident due to start up overheat. Also mentioned thermal fatigue cracking as a common problem</td>
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<tr>
<td>2001</td>
<td>Mill N – “CE” bare - 2 boilers – no deterioration</td>
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<tr>
<td>Year</td>
<td>Mill</td>
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<tr>
<td>2002</td>
<td>Mill D</td>
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<tr>
<td>2002</td>
<td>Mill N</td>
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<td>2003</td>
<td>Mill G</td>
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<td>2003</td>
<td>Mill G</td>
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<td>2004</td>
<td>Mill E1</td>
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<tr>
<td>Year</td>
<td>Location</td>
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<tr>
<td>2004</td>
<td>Mill N</td>
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<tr>
<td>2006</td>
<td>Rebuilder</td>
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<tr>
<td>2006</td>
<td>Mill S1</td>
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<tr>
<td>2007</td>
<td>Mill N</td>
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<td>2007</td>
<td>Mill A</td>
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<td>2008</td>
<td>Mill E</td>
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<td>2008</td>
<td>Mill S2</td>
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<tr>
<td>Year</td>
<td>Description</td>
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<tr>
<td>2008</td>
<td>Mill C1 – solid 304L with weld overlay at inlet and discharge - thermal fatigue cracking to 50% of wall</td>
</tr>
<tr>
<td>2008</td>
<td>Mill D – bare carbon steel – thermal fatigue cracking to 75% of wall near discharge end on the two right side spouts - cracking coincided with cooling water discharge chamber. Left side spouts no cracking</td>
</tr>
<tr>
<td>2008</td>
<td>Mill H – “CE” thermal spray with 50Cr/50Ni – 1 year - widespread spray loss but no loss of exposed carbon steel - upper side of cooling tube thinned inside furnace similar to mills G and S – may not have been sprayed</td>
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<tr>
<td>2008</td>
<td>Rebuilder – 2 year examination of the 5 carbon steel spouts examined in 2006 – thermal fatigue at inlet, thinning at outlet end plate</td>
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<tr>
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<td>Mill C3</td>
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<td>Mill D</td>
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<tr>
<td>2009</td>
<td>Mill H – “CE” chromized – 11 months – 40% of chromized layer on outlet end cooling tube corroded at tide line. No exposed carbon steel.</td>
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<tr>
<td>2009</td>
<td>Mill T – carbon steel. Transverse thermal fatigue by in place PT. No lab exam.</td>
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<tr>
<td>2010</td>
<td>Mill C4 – “CE” bare – 2 years. Thinned. Max. loss 0.110” from 0.250” original. 87 – 99 grams/ft² DWD in high heat flux channels.</td>
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<tr>
<td>2010</td>
<td>Mill D – bare carbon steel – thermal fatigue cracking to 50% of wall near discharge end on the rightmost spout only - cracking coincided with cooling water discharge chamber.</td>
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<tr>
<td>2010</td>
<td>Mill S1 – “CE” bare – 13 months. No corrosion – 10 grams/ft² maximum DWD</td>
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<td>Mill Description</td>
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<tr>
<td>2010</td>
<td>Mill N – “CE” chromized – 4 years</td>
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<tr>
<td>2011</td>
<td>Mill D – bare carbon steel – thermal fatigue cracking</td>
</tr>
</tbody>
</table>
Mill D – 2002 – Bare “CE” – one year water leak at smelt outlet
Damage mode – General thinning

Smelt outlet end

Smelt inlet end

Smelt Flow
Mill G – 2003 – Bare “CE”
THERMAL SPRAYED SPOUTS
Mill H – one year
Chromizing
Chromizing

carbon steel

chromizing
Chromizing
Powell River – 1995 – 6 months
Suspected cause of failure was overheating – not accepted by mill
1997 Swedish Incident

- Subatmospheric cooling water
- Start up with low smelt and start up burners to maintain steaming
- Hot smelt corroded inside ends of spouts
- Smelt sucked into hole in one spout
- Internal explosion in spout - then new smelt sucked in and another explosion – explosions repeated several times a minute
- Cooling water ejected from spout into furnace
- Hot water ejected out over dissolving tank roof
• Furnace ESP’d
• Silver Lining:
  “no thermal fatigue cracks found in spout troughs which is a frequent trouble of spouts here in Sweden”
Chromizing

- Spouts left in service with annual PT
- Cooling water leaks found at four year inspection
- Suspected “mechanical fatigue”
- Three leaking spouts replaced
- Three non-leaking spouts left in place
Water leaking from cracks

DEFECTS ON ALL THREE (3) LEFT SIDE
SMELT SPOUTS WERE AT SIMILAR LOCATIONS

Water leaking from cracks
WATER SIDE EXAMINATION
DWD Measurement
Smelt Inlet End
Butt Weld in Trough
Weld Overlay at Smelt Outlet End
Cross Section of Crack Adjacent to Weld Overlay
Crack Tip
Crack Adjacent to Weld Overlay
Broken Open
Crack Surface
There are Clear Fatigue Striations
Mill C1 – 2009
Solid 304L – 9 Months
Trough at Smelt Outlet End
Mill D – 2008 – Bare carbon steel
Mill D – 2011 – Bare carbon steel
Mill A – 2007 – 304L Clad Plate
Mill A – 2009 – Alloy 825 Clad Plate
12 months
825/carbon steel interface
Mill E – 2008 – Dry Spout
Mill S2 – 2008 – Dry Spouts
Proverbs 3:5

Trust in suppliers with all thine heart and lean not unto thine own understanding