INSPECTION OF RECOVERY BOILERS

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OUTLINE

- Purpose of inspections
- Inspection methods
- Scope and frequency of inspections
PURPOSE OF INSPECTIONS

- Verify that critical control and safety systems are operating properly
  - ESP test
  - Drum level and low solids trip tests
  - Safety valve tests
  - Instrument function tests
  - Instrument calibration tests

- Verify integrity of pressure parts and evaluate needs for maintenance and/or repair

TYPES OF INSPECTION

- Routine
  - e.g. walkthroughs

- Scheduled
  - Major inspections at planned shutdowns

- Opportunistic
  - When boiler becomes available for inspection for other reasons
AUDIT PROGRAMS USEFUL TO EVALUATE PERFORMANCE

- Operational performance
- Personnel organizations, progression, training
- Operator procedure checklists
- Boiler and auxiliary system inspections
- Corrosion inspections
- Rectification of non-compliant items
- Audit scope needs regular review
WHY DO WE NEED THESE EXPENSIVE CORROSION INSPECTIONS?

- Must prevent critical leaks
- Scheduled repairs much less expensive than unscheduled
- Cannot predict corrosion rates from boiler operation parameters

CAUSES OF CRITICAL LEAKS

- Attachment Welds 41%
- Corrosion Thinning 22%
- Ops & Maint. Problems 15%
- Butt Welds 10%
- Other 12%
INSPECTION METHODS (1)

- Inspect visually
  - To identify potential problems

- Measure tube thickness
  - To detect thinning problems

- Find fireside cracks
  - That could propagate into leaks

- Find waterside fissures
  - That could propagate into leaks

- Evaluate waterside deposits
  - That could cause overheating
INSPECTION METHODS (2)

- Visual inspection (every scheduled shutdown)
  - by plant workers
  - by outside experts
  - to focus NDT
  - particularly important with composite tubes – every port, every spout, every outage

- Don’t rely on journeyman NDT technicians to make visual inspections

INSPECTION METHODS (3)

- Measuring tube wall thickness (every scheduled shutdown)
  - Carbon steel tubes (total wall)
    - digital UT
    - oscilloscope UT
    - internal eddy current or UT in gen. bank tubes
    - automated UT for near-drum scanning
  - Composite tubes (protective stainless layer)
    - magnetic lift-off gauge
    - eddy current instrument
    - measure only at air ports, smelt spouts, smelt line, or if DWD very high
INSPECTION METHODS (4)

- Look for fireside cracks in areas subject to thermal shock, esp. on composite tubes, with PT
  - Surface preparation is critical (TIP 0402-30)
  - Measure crack depth by exploratory grinding (or shear wave UT)
  - Greater risks in air port tubes than in floor tubes

- Look for waterside SAC in susceptible areas with RT
  - Beam must aim down, not across, fissures

- Analyze waterside deposits

INTERPRETING INSPECTION DATA

- You will not find critical defects unless you look where they are and use a method that can find them

- Judge fitness for service (consequences of discovered defects) using jurisdictional and insurance rules
  - National Board Inspection Code (ASME in some states) skills in fracture mechanics
  - API/ASME FFS-1
MINIMIZING ERRORS IN TUBE THICKNESS MEASUREMENTS
– accuracy and precision

ERRORS IN TUBE THICKNESS MEASUREMENTS

- Standard error in precision  0.005 - 0.007”
- Standard error in accuracy  0.004 - 0.006”
- Combined standard error about 0.007”
  - so check unexpected readings
SINGLE POINT RATE CALCULATIONS ARE NOT ACCURATE

- Year 1 measured thickness: 0.200” +/- 0.007”
- Year 2 measured thickness: 0.197” +/- 0.007”

True Rate -0.003”/yr

+0.011”/yr?

-0.017”/yr?

TO MINIMIZE ERRORS IN TUBE THICKNESS MEASUREMENTS

- Use only technicians pre-qualified by TIP 0402-21
- Recalibrate UT instruments every 100 readings, or every 15 minutes - repeat measurements if calibration drifted
- Check unexpected measurements - use different technician, different instrument
SCOPE AND FREQUENCY OF RECOVERY BOILER INSPECTIONS

- Alert observation during normal operations
- Systematic inspection during outages:
  - Visual inspection and appropriate NDT to find critical defects
  - Thickness measurements to estimate remaining life
- No national standards for scope, methods, frequency
- Develop an individual inspection plan for each boiler (5-year)

Useful documents:

- AF & PA Recovery Boiler Manual, 1992
- NACE (composite tubes), 1992
- TAPPI (UT surveys), TIP 0402-18, 2001
  (Technician qualification), TIP 0402-21, 2002
- ASTM E543 (qualification of NDT contractors)
- ASNT TC-1A, current edition
- API/ASME FFS-1 Fitness-for-Service code (2007)
ESTABLISHING INSPECTION SCOPE AND FREQUENCY

Three approaches have been taken:
1. Thickness measurements at predetermined grid locations
2. Thickness measurements based on risk of critical leaks
3. Visual observations, damage-appropriate NDT and corrosion rate calculations

1. PREDETERMINED GRID LOCATIONS

- No established standards for grid size or frequency
  - wide diversity in practice
- Increasing number of thickness readings generally does not increase probability of detecting critical flaws
- Tailor inspection plans according to
  - historical behavior this unit
  - Problems found in similar boilers
1. PREDETERMINED GRID LOCATIONS

- Use grid readings to:
  - estimate average corrosion rates
  - estimate remaining life
  - “flag” thinned areas

- Supplement grid readings with smaller grids or scanning:
  - in areas known to be critical
  - in areas found to be thin

- Calculate number of readings required to establish thinning rate in different areas of the boiler

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1. PREDETERMINED GRID LOCATIONS

- Remember grid methods will **not** detect:
  - fireside cracking of composite tubes
  - air port balding of composite tubes
  - thinning caused by sootblowers
  - near-drum thinning of generating bank tubes
  - fireside cracking at attachment welds and at headers
1. PREDETERMINED GRID LOCATIONS

- Grid methods will also **not** detect:
  - thinning next to tube-to-tube membrane
  - localized thinning at ports and at the smelt line
  - cold-side corrosion of non-membrane water wall tubes
  - waterside corrosion fatigue cracking (SAC)
  - excessive waterside deposits
2. RISK OF CRITICAL LEAKS

- 32% in lower water wall,
  - + 8% in floor + 6% at spouts
- 15% in upper water wall
- 12% in furnace screen
- 18% in generating bank

Relative grid sizes:
- Floor: 4 x 4
- Lower water wall: 1 x 1
- Upper water wall: 2 x 2
- Generating bank: 2 x 2
- Roof: 2 ¼ x 2 ¼
- Furnace screen: 2 2/3 x 2 2/3
- Air port tubes: scan 100%

Why is this a bad approach?
2. RISK OF CRITICAL LEAKS

- Critical leaks show what careless inspectors have missed, not what careful inspectors have found.
- So, since most leaks occur at defects created when the boiler was built, use critical leak data for planning QA programs rather than for planning inspections.
3. CORROSION RATES

- Establish scope and frequency of grid measurements to obtain statistically significant estimates of corrosion rate in each part of the boiler.
- To estimate rates with fewest measurements, measure thickness at same exact locations.
- Typically at least 100 measurements must be repeated in each part of the boiler on at least 4 occasions.

3. CORROSION RATES

- Computer generated thickness maps show patterns of thinning useful to refine grid sizes.
- Computer programs can:
  - calculate thinning rates
  - estimate remaining life
  - indicate the probable accuracy of these predictions
- Don’t try to calculate corrosion rates at individual points.
<table>
<thead>
<tr>
<th>Generic Recovery Boiler</th>
<th>UTotal (C) 1980, 1991 by WESTMACO CORP.</th>
</tr>
</thead>
<tbody>
<tr>
<td>212 - 884 locations</td>
<td>Blips: 8 (+30), 8 (-30), 14 (-Last Pt)</td>
</tr>
<tr>
<td>78 79 80 81 82 83 84</td>
<td>85 86 87 88 89 90 91 92 93</td>
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<tr>
<td>8 6 6 6 6 6 8</td>
<td>8 9 11 10 12 12 14</td>
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</tbody>
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1970 to 1993
S: 2.4, f: 7.1
c: 3.3, r: 6.1

Rds/Pt:
5+: 80%
3: 9%
4: 6%

Rate of Thinning (MPY) Histogram

Remaining Years (est)
33% of Pts est (60 yrs)
58 ± 35 yrs
70% ± 142%

FURNACE WATERWALL TUBING AT PRIMARY AIR PORTS - FRONT WALL
Next: 13 "FURNACE WATERWALL TUBING AT PRIMARY AIR PO
SCOPE AND FREQUENCY
RECOMMENDATIONS

- Use expert visual inspectors to seek critical flaws
- Use grid measurements to estimate corrosion rates
- Do additional NDT in areas:
  - of concern from previous inspections
  - of concern to current inspectors
  - of concern because of findings elsewhere in the industry

KEYS TO SAFE, LOW MAINTENANCE OPERATION

- Quality assurance to avoid building in defects during design and construction
- Careful operation by well-trained operators
- Regular, systematic, and well-documented inspection
- Planners and Inspectors aware of new inspection technology and of problems found elsewhere (BLRBAC, TAPPI, NACE)
- Timely maintenance with accountability
CONCLUSIONS

- AF & PA manual contains useful inspection planning checklists
- Tailored NDT plans can find thinning, cracking and internal defects
- Use expert visual inspectors to direct the search for thinnest tubes and critical flaws
- Because of (0.007”) errors in individual thickness readings, use UT data (only) to establish corrosion patterns, project rates and schedule repairs/ rebuilds