Demonstration of Clyde Bergemann Water Cannons at Miller Unit 1

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Background

- **Alabama Power Miller Unit 1**
  - 660 MW, Commercial operation October 1978
  - B&W opposed wall-fired furnace
    - B&W DRB low NOx burners (56), B&W MPS 89 mills (7)
    - Compartmentalized windbox
    - Tube material: SA-210-A1 (medium carbon steel)

- **Started using PRB coal in mid-1990s (Unit 1 - 1999)**
  - Change in furnace slagging characteristics
    - Installed water lances for water wall cleaning (Diamond Power)
      - Furnace walls - 20 IK-4M-WL and IK-4M-PA
      - Upper rear wall - 2 IK-545 Selective Pattern
      - Furnace division walls - 6 Selective Pattern (3 per side)
    - Continuous water wall cleaning (~ three hour cycle time)
    - Decreased water wall life due to quench cracking
    - Increased condensate makeup water requirements
Quench Cracking

- Quench cracking dependent on
  - Velocity of water stream used to clean surface (pressure)
  - Progression velocity of water stream
  - Cross-sectional area of water stream (nozzle diameter)
  - Slagging condition at time of cleaning (clean / dirty)
  - Tube material (carbon-steel vs. low-chromium alloy)
  - Cleaning cycles
    - Can have multiple temperature cycles per cleaning cycle

Refs:
Water Blowing of Fireside Deposits in Coal-Fired Utility Boilers (EPRI CS-4914)
Quench Cracking

Circumferential crack leading to steam leak

tube at nose arch
2.75" OD x 0.290" MWT, SA210 A-1 cleaned by water lance

crazing pattern on the surface

cracks in progress
Primary Goals

- Extend life of water wall sections by mitigating quench cracking
- Reduce plant condensate makeup requirements by using filtered water instead of condensate for cleaning

Possible other benefits
- Improved boiler efficiency
- Reduced NOx Emissions
Program Schedule

- Installation - Nov. 2001 - Feb. 2002
- CBI conducted testing - Feb. 2002
- Reporting - Mar. 2003
Installation Summary

- Late October 2001 project approval
- Installation during previously scheduled outage
  - Mechanical ~ 3 weeks / 6 days week / 10 hour days
    - 4 water cannon bent tube openings (~18’ x 50’, 8 tubes)
    - 24 heat flux tube sections
  - Unit back on-line late December 2001
- Electrical ~ 4 weeks; most with unit online
- Operating in program (manual) mode week of Feb. 8
- Operating in auto (feedback) mode week of Feb. 18
- Continue optimization and debugging of system
- Installation of auto-tuning modules (3 Qtr 2002)
Cleaning Zones

Outside
Front Wall

Outside Rear Wall

Outside Left Side Wall

Existing Sootblowers

Water Cannon

Heat Flux Sensor

Outside Right Side Wall

Outside Front Wall

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Operations / Reliability to Date

- Running mostly in auto mode since February 18
- Very little operator interaction required
- Some sections being cleaned too often → adjustment of targeted heat flux levels
- Failure of supply line to cannon(s)
- Failure of data acquisition panel (1 of 2)
- Adjustment of jet progression velocity and pressure to limit tube temperature rise
Testing and Assessing Benefits

- Testing mostly passive - unit runs as normal
- Track water consumption of lances / cannons
  - Frequency / duration of cleaning cycles
  - Peak use / annual use
- Cracking of waterwall tubes
  - Visible inspection of waterwall tubes in area of previous damage
  - Tube samples in area of previous damage
  - Use of CBI fast data & faster sampling of waterwall temperatures
  - Use of tube failure models
Testing and Assessing Benefits

- Furnace Heat Absorption and Efficiency
  - Gas temperatures (furnace / economizer exit)
  - Spray flows
  - Boiler steaming capacity
  - Steam temperatures (superheat / reheat)
  - Boiler efficiency

- Generation Capacity / Unit Availability

- Emissions
  - Flue gas characteristics
    - NOx, temperature
Clyde Bergemann
Performance Testing

- Conducted Feb. 18-21, 2002
- Elements
  - Temperature and gaseous composition ($\text{NO}_x$, CO, $\text{O}_2$) at nose of furnace
  - Data logging through DCS/PI and CBI system
  - Furnace wall emissivity
- Unit full load during entire period
- Several modes of operation tested
Findings

- Improvement in heat transfer distribution (more consistent)
- Slight reduction in FEGT → greater overall energy transfer in waterwalls
- Reduction in NOx emissions (10%) as measured at nose of furnace
- No observable change in boiler efficiency
Testing Nov. 22, 2002

- **Goal**
  - Verify CBI collected temperatures
  - Faster sampling (~15 ms vs. 200 ms)
  - Higher precision

- Used spare thermocouples on CBI heat flux sensors
- Sampling system was Agilent 34970A
- Four runs to date
Run 1
Comparison of Surface Temperatures

Zone 415
Channel A09 / 9
Water Cannon # 4
West furnace wall

Data logger trend shifted in time and biased
Run 1
Surface vs. Subsurface Temperature

Zone 415
Channel A09 / 9
Water Cannon # 4
West furnace wall

TC1 - Surface
TC2 - Subsurface

Run 1 / Nov. 22, 2002

Temperature (Deg F)
Time (Seconds)
Run 2
Surface vs. Subsurface Temperature

Zone 410
Channel A10 / 10
Water Lance IK WL 09
West furnace wall

TC1 - Surface
TC2 - Subsurface
Run 3
Surface vs. Subsurface Temperature

Zone 308
Channel B09 / 21
Water Lance IK WL 20
East furnace wall

TC1 - Surface
TC2 - Subsurface
Run 4
Surface vs. Subsurface Temperature

Zone 303
Channel B10 / 22
Water Cannon #3
East furnace wall

TC1 - Surface
TC2 - Subsurface
Long-Term Data

Data sources

- Plant DCS / PI system
  - Normal plant data such as excess $O_2$, load, gas temperature

- CBI daily log files
  - Few plant parameters plus water cannon flow information such as flow, pressure, cannon, zone, heat flux, surface temperature, etc.
  - 30 second sample

- CBI fast data files
  - Waterwall surface temperatures (only when cleaning that zone)
  - Nominally 200 millisecond sample
Typical Surface Temperature Profile Over 24 Hours

Source: Daily log file for December 1, 2002
Example of Surface Temperatures During Cleaning

Source: fast data file for December 1, 2002
Distribution of Temperature Droop and Gain (April 2002 - November 2002)

Source: fast data files April 2002 – November 2002
Distribution of Cleaning Cycle Events
Temperature Droop > 0°F, < 50°F
(April 2002 - November 2002)

Source: fast data files April 2002 – November 2002
Distribution of Cleaning Cycle Events
Temperature Droop > 100°F, > 200°F
(April 2002 - November 2002)

Source: fast data files April 2002 – November 2002
Boiler Tube Life

- Failure = Cracking = $f(T_{\text{Initial}}, T_{\text{Droop}}, \text{material}, \text{frequency})$
- Statistical approach
  - Identify temperature transients - worst, best, typical
  - Determine historical (12 months) use of water cannons
  - Compare to water lance induced transients
- Identify tube failure model(s)
  - Direct calculation (non-FEM)
  - Determine sootblowing impacts on quench cracking
- Run temperature data through models
Summary

- Installation
  - No major problems / should have done more with unit online

- Operations / Reliability to Date
  - Relatively few problems
  - Plant staff have positive impression and are installing on other units
  - Little training to date, more required for operations, I&C

- Performance
  - Balanced heat flux in furnace
  - Still open questions on NOx and efficiency
  - Many cleaning events have temperature drop greater than 100°F
  - Some zones cleaned considerably more than other zones