Heat Balance Impacts of Wall Cleaning, Combustion Modifications, and Heat Transfer Surface Modifications

A Predictive Assessment in Coal Fired Boilers

For Energy and
Environmental
Solutions

REACTION ENGINEERING INTERNATIONAL

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Clearwater Coal Conference

Clearwater, FL   June 1-5, 2014

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746 East Winchester, Suite 120, Murray, Utah 84107
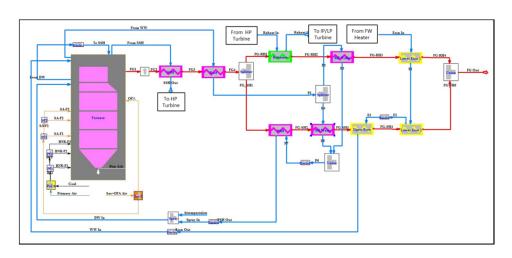
Presentation Overview

- Analytical Approach

  – Radiant furnace CFD modeling

  – Convective pass and boiler process model

- Summary of Results

  – Impacts of combustion modifications

  – Impacts of boiler cleaning equipment

  – Impacts of heat transfer surface modifications
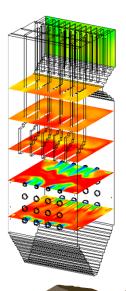
- Conclusions

Modeling Approach

Process Model

- Overall heat and mass balances for the boiler
- Couples together fireside and steam side heat transfer
- Predictions of heat transfer in convective section

CFD Model

- 3D multiphase, turbulent, reacting flow simulations in radiant section
- Thermo-chemical predictions are used within the radiant section of process model
- Emissions predictions
- Slagging predictions
- Impacts of heat transfer modifications and surface cleaning in radiant section

Advanced Model of Mineral Matter/Ash Behavior

- CCSEM, PCF, and bulk ash elemental analysis are used to characterize inorganically and organically associated elements

- The Partial Coalescence Model (Beer & Sarofim) is used for prediction of fly ash particle size and particle-size dependent composition

- A viscosity model (Senior and Srinvasachar) is used to calculate the viscosity of silicate glass particles as a function of both temperature and composition

- This model is then implemented within GLACIER

  – As coal particles interact with boiler surfaces, the fraction of particles that deposit is calculated as outlined by Walsh and co-workers

  – Local occurrence of slagging and extent of sintering are predicted as the deposit accumulates using a pseudo steady-state approach
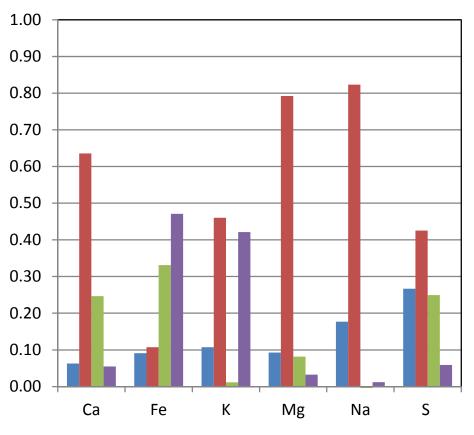
Coal Ash CCSEM

WEIGHT PERCENT ON A MINERAL BASIS

	1.0 TO 2.2	2.2 TO 4.6	4.6 TO 10.0	10.0 TO 22.0	22.0 TO 46.0	46.0 TO 400.0	TOTALS
QUARTZ	.3	.9	.9	1.2	2.0	4.0	9.1
IRON OXIDE	.0	.0	.0	.2	.3	.4	.8
PERICLASE	.0	.0	.0	.0	.0	.0	.0
RUTILE	.0	.0	.0	.0	.0	.0	.0
ALUMINA	.0	.0	.0	.0	.0	.0	.0
CALCITE	.0	.1	.0	.0	.3	.1	.5
DOLOMITE	.0	.1	.2	.4	1.0	.7	2.5
ANKERITE	.0	.0	.0	.2	.0	.0	.2
KAOLINITE	.6	2.5	2.0	1.8	4.4	3.9	15.3
MONTMORILLONITE	.1	.7	.5	1.0	.9	3.5	6.8
K AL-SILICATE	.8	3.2	2.6	3.3	4.6	9.5	24.0
FE AL-SILICATE	.1	.4	.3	.3	.4	.0	1.5
CA AL-SILICATE	.0	.0	.0	.0	.0	.0	.1
NA AL-SILICATE	.0	.1	.0	.0	.1	.1	.3
ALUMINOSILICATE	.1	.2	.2	.7	.5	.5	2.3
MIXED AL-SILICA	.2	.2	.2	.2	.2	.2	1.1
FE SILICATE	.0	.0	.0	.1	.0	.0	.1
CA SILICATE	.0	.0	.0	.0	.0	.0	.0
CA ALUMINATE	.0	.0	.0	.0	.0	.0	.0
PYRITE	.1	1.0	2.1	5.1	3.0	1.5	12.8
PYRRHOTITE	.0	.1	.0	.5	.2	.0	.8
OXIDIZED PYRRHO	.0	.0	.0	.1	.1	.0	.3
GYPSUM	.0	.0	.3	.4	.4	.6	1.7
BARITE	.0	.0	.0	.0	.0	.0	.0
APATITE	.0	.0	.0	.0	.1	.0	.1
CA AL-P	.0	.0	.0	.0	.0	.0	.0
KCL	.0	.0	.0	.0	.0	.0	.0
GYPSUM/BARITE	.0	.0	.0	.0	.0	.0	.0
GYPSUM/AL-SILIC	.0	.2	.1	.1	.2	.0	.6
SI-RICH	.1	.5	.3	.5	.6	1.7	3.5
CA-RICH	.0	.0	.2	.1	.1	.1	.5
CA-SI RICH	.0	.0	.0	.0	.0	.0	.0
UNKNOWN	.5	2.4	1.5	1.4	3.3	5.7	14.9
TOTALS	2.9	12.6	11.6	17.7	22.7	32.5	100.0

- Computer Controlled Scanning Electron Microscope (CCSEM)
- Included and Excluded Minerals
- Determination of distribution and size of minerals
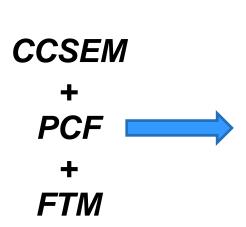
Partial Chemical Fractionation

- Extraction of inorganics by:
  - Water
  - Ammonium Acetate
  - Hydrochoric Acid
- Fraction extracted by ammonium acetate are "organically associated"
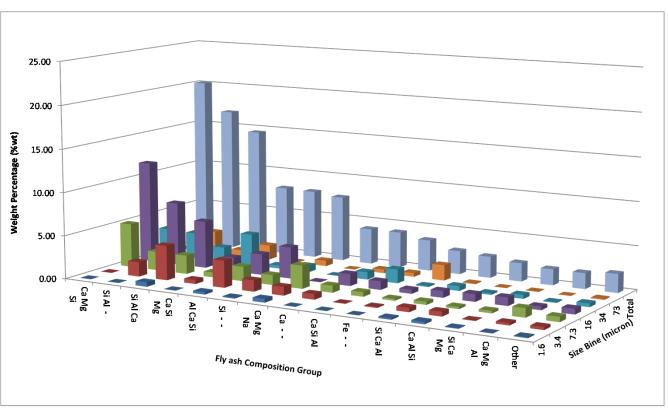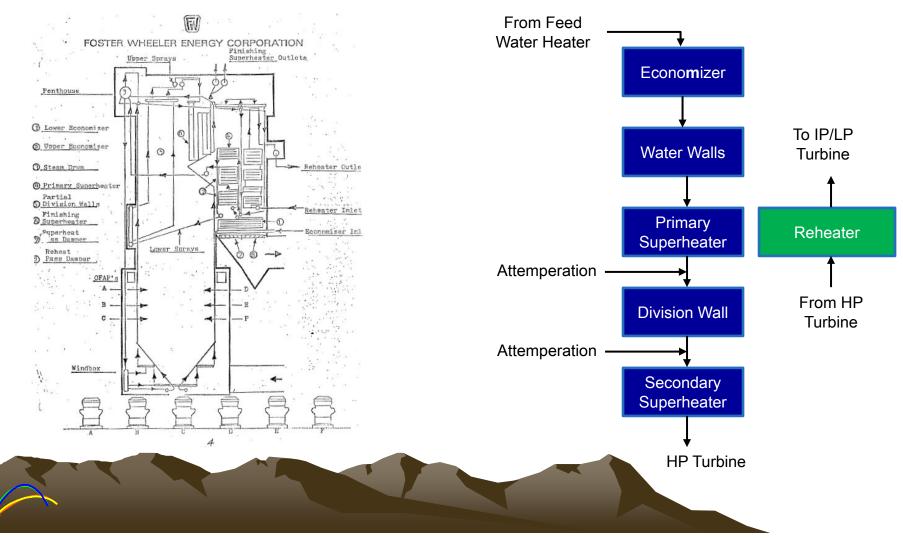
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Fly Ash Size and Composition

CCSEM = computer controlled scanning electron microscope
PCF = partial chemical fractionation
FTM = flyash transformation model

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  - As coal particles interact with boiler surfaces, the fraction of particles that deposit is calculated as outlined by Walsh and co-workers

  - Local occurrence of slagging and extent of sintering are predicted as the deposit accumulates using a pseudo transient approach

  - Thermal resistance of slag is function of composition and sintering

Case Study

- **Evaluate impacts of operational changes, wall cleaning, and changes to convective pass heat transfer surfaces in a 540 MW wall-fired coal boiler with a split back pass**

Solution Methodology

- Baseline model development for Baseline conditions
  - Tune thermal resistances and fouling factors to match measured duties
  - Local net heat flux is dependent on CFD predicted slagging
  - Compare predicted economizer exit gas temperature, NOx, FEGT with available data

- Apply model to parametric cases
  - Local net heat flux is dependent on CFD predicted deposition rates and on coverage areas of added wall cannons and remaining soot blowers
  - Heat input remains fixed, resulting in variable steam generation rates
  - Adjust waterwall steam generation based on CFD predicted heat transfer
  - Adjust backpass flue gas split to achieve 1005°F RH temperature and Baseline steam flow
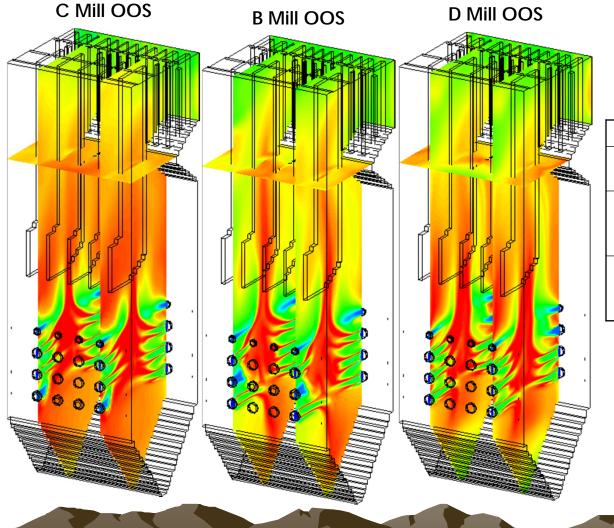 - Adjust attemperation flow to achieve 1005°F main steam temperature

IMPACT OF MILL CONFIGURATION

Gas Temperature
Effect of Mill Configuration

C Mill OOS

B Mill OOS

D Mill OOS

Gas Temperature (F)

3000
2500
2000
1500
1000
500

	Temperature (°F)		
	B Mill	C Mill	D Mill
Horiz. Nose Plane	2468	2572	2525
Vert. Exit Plane	2012	2066	2093

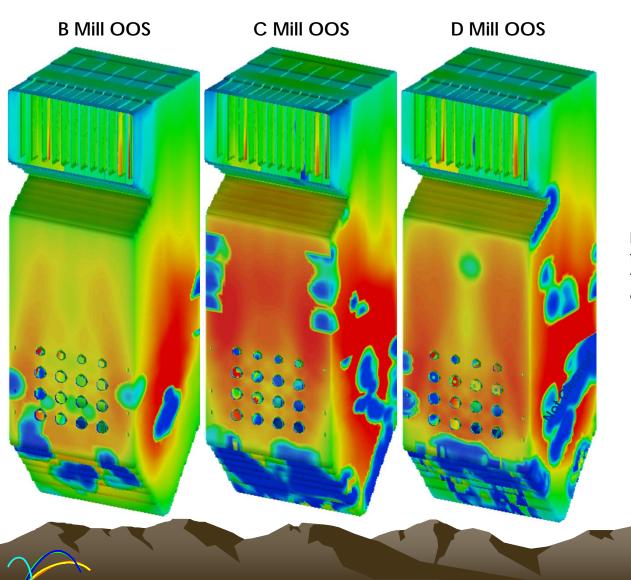*CFD graphics provided courtesy of Fieldview by Intelligent Light*

Coal Particle Trajectories

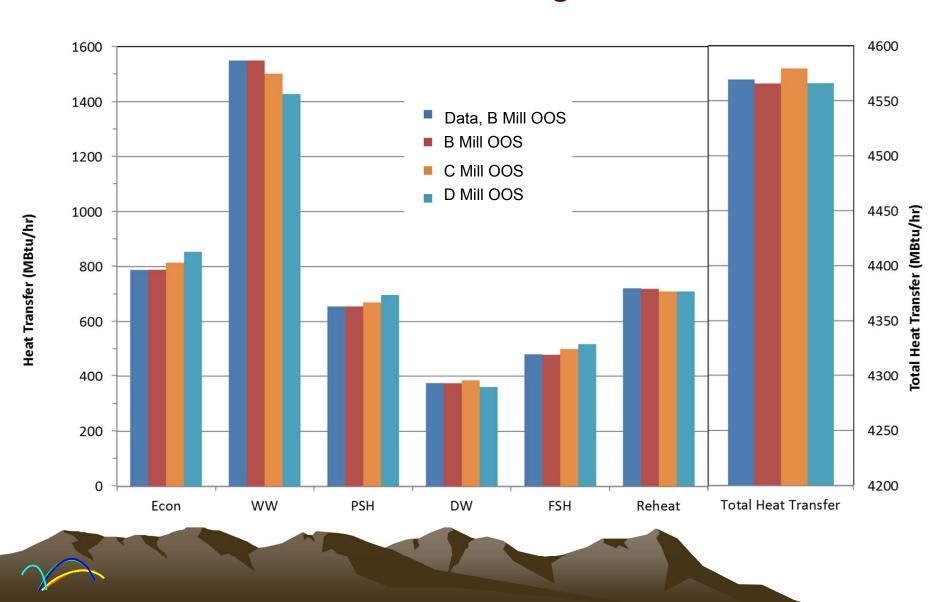## *Effects of C Mill OOS*

Net Heat Flux - WW
Effects of Mill Configuration

B Mill OOS   C Mill OOS   D Mill OOS

Heat Flux (Btu/h-ft²)

60000
48000
36000
24000
12000
0

Reduced total waterwall heat
transfer with C mill and D mill OOS is
the result of higher deposition rates
compared B mill OOS

*CFD graphics provided courtesy of
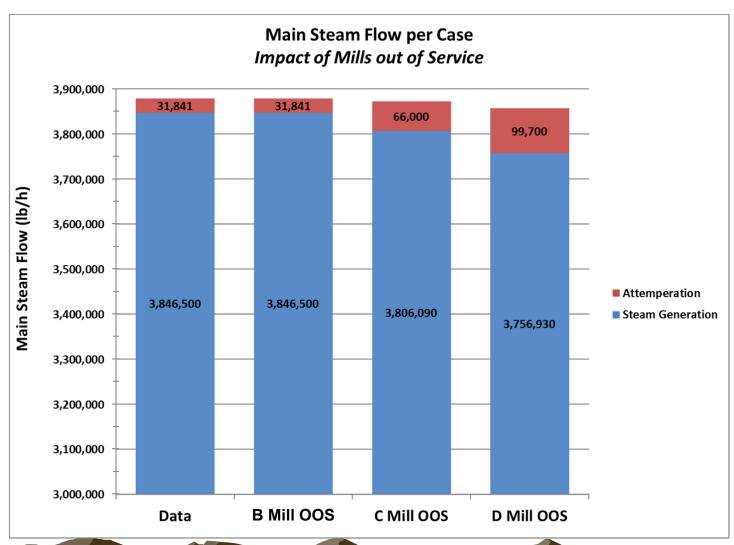Fieldview by Intelligent Light*

Heat Balance
Effects of Mill Configuration

Main Steam Flow
Effects of Mill Configuration

Main Steam Flow per Case
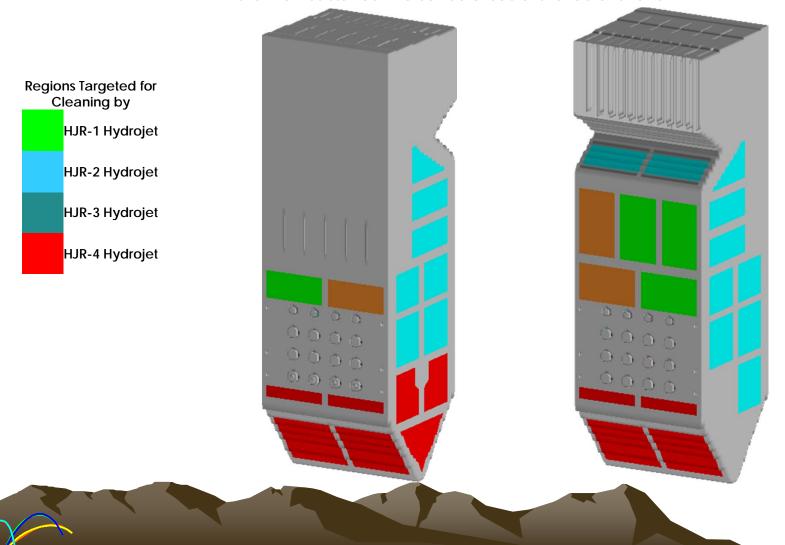*Impact of Mills out of Service*

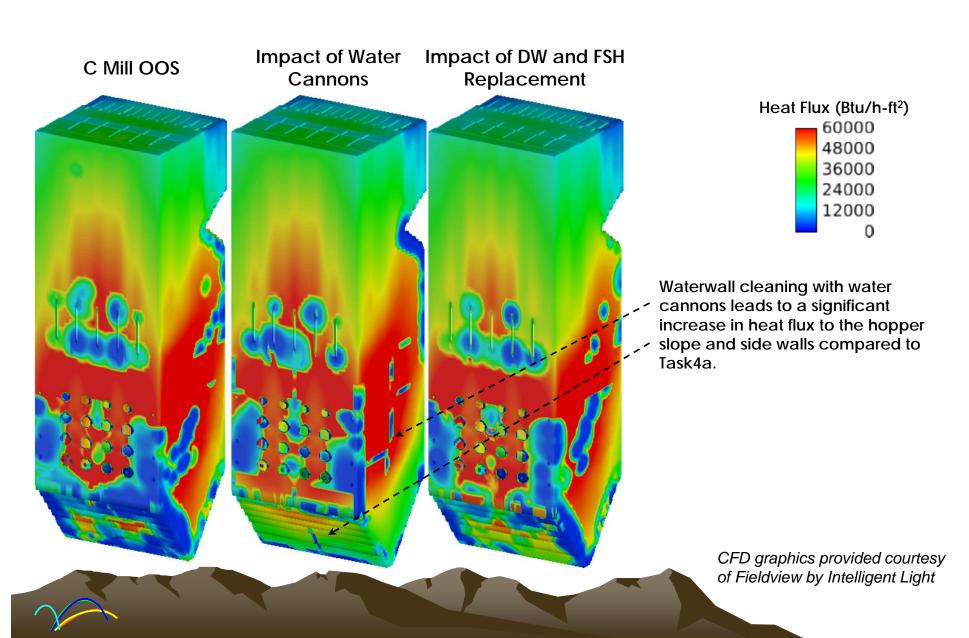# IMPACT OF WALL CLEANLINESS AND HT SURFACE MODIFICATIONS

Boiler Cleaning
Water Cannon Effective Cleaning Areas

Effect of boiler cleaning reflected as a change to
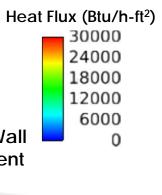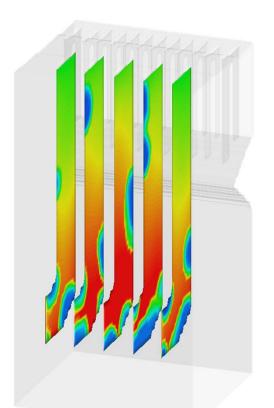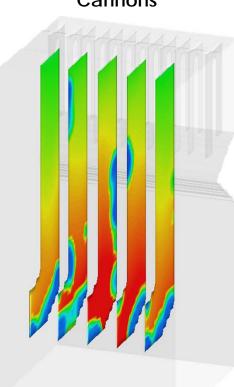thermal resistance in cleaned areas of the radiant zone

Regions Targeted for
Cleaning by

HJR-1 Hydrojet

HJR-2 Hydrojet

HJR-3 Hydrojet

HJR-4 Hydrojet

Net Heat Flux

C Mill OOS

Impact of Water Cannons

Impact of DW and FSH Replacement

Heat Flux (Btu/h-ft²)

60000
48000
36000
24000
12000
0

Waterwall cleaning with water cannons leads to a significant increase in heat flux to the hopper slope and side walls compared to Task4a.

CFD graphics provided courtesy of Fieldview by Intelligent Light

Net Heat Flux

Division Walls

Heat Flux (Btu/h-ft²)
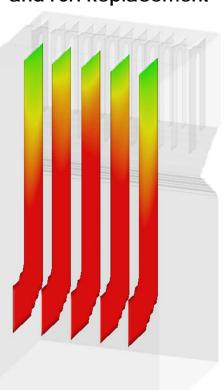
30000
24000
18000
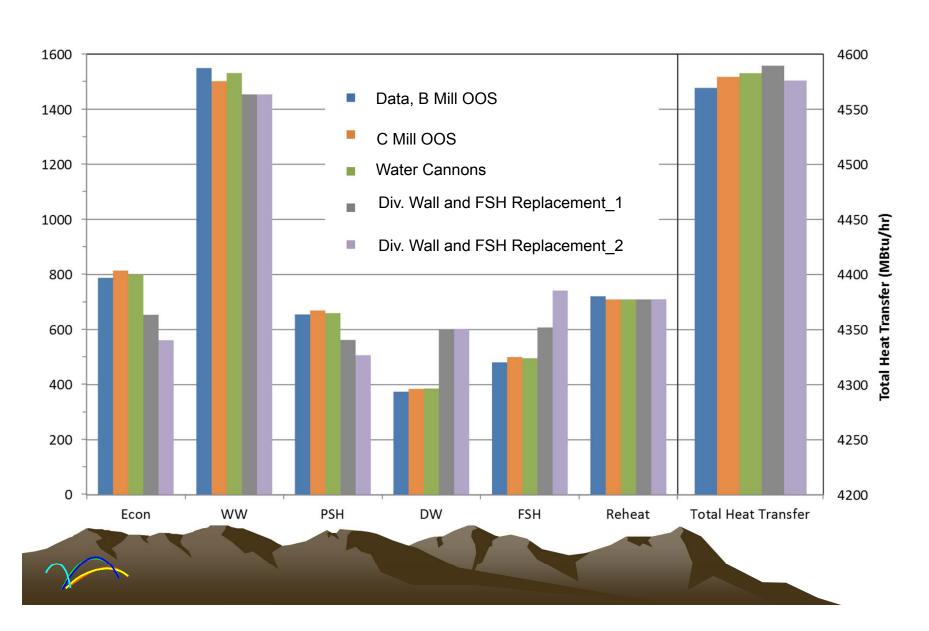12000
6000
0

C Mill OOS

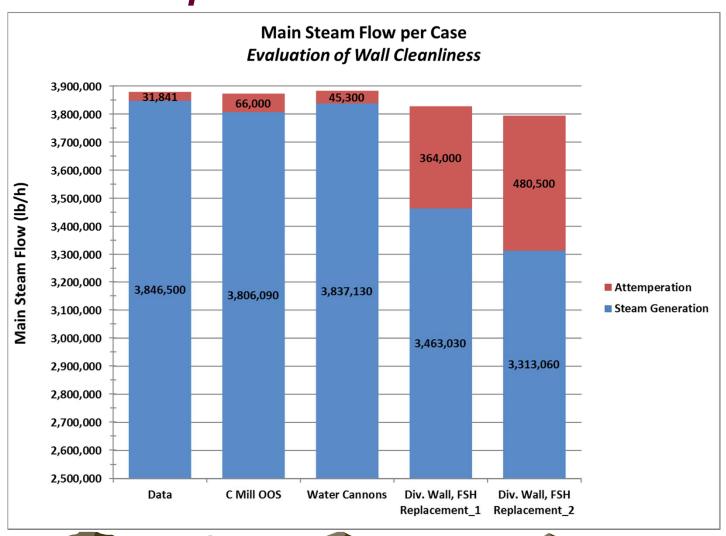**Impact of Water Cannons**

Impact of Division Wall and FSH Replacement
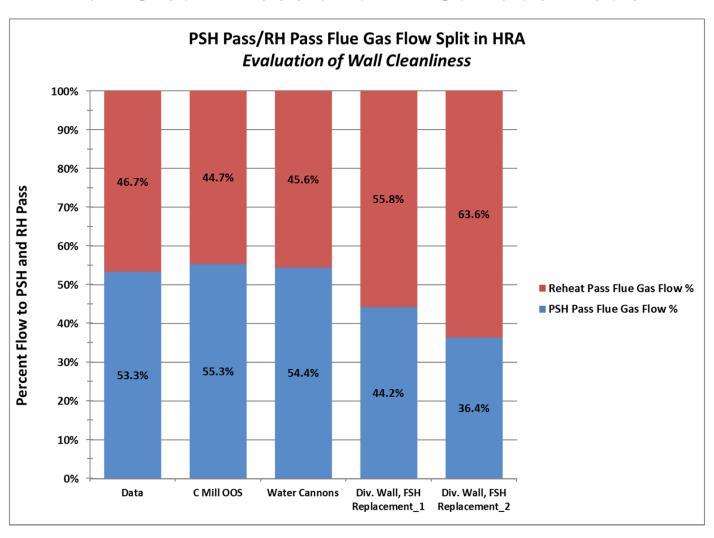
Heat Balance
Wall Cleanliness and HT Surface Mods.

Main Steam Flow
Impact of Wall Cleanliness

Main Steam Flow per Case
Evaluation of Wall Cleanliness

PSH/RH Flue Gas Flow Split
Wall Cleanliness and HT Surface Mods.

PSH Pass/RH Pass Flue Gas Flow Split in HRA
Evaluation of Wall Cleanliness

Conclusions

- The combined approach of CFD modeling with SGE process modeling provides a powerful, efficient methodology for evaluation of combustion mods and HT surface modifications on boiler performance

- CFD modeling of the radiant boiler provides robust predictions of combustion including emissions, and slagging, and radiant heat transfer effects

- SGE provides predictions of heat transfer impacts in convective section along with steam-side and fire-side coupling for entire boiler

- Simulation approach requires tuning of thermal boundary conditions based on baseline thermal data

- Application to a 540 MW opposed wall fired coal boiler showed:

  - Variation of SH attemperation between 0.8% and 2.6% due to variation in BOOS configuration

  - Increase of 2.0% in waterwall heat transfer through addition of water cannon cleaning

  - Largest impacts to heat balance predicted to be due to DW and FSH replacement, and improved WW cleaning is critical to limiting SH attemperator flows under this condition