REINHOLD ENVIRONMENTAL ®

2024 Reinhold/PCUG Round Table Presentation

Hosted by LG&E/KU and Co-hosted by Southern Co. and TVA

in The Marriott Resort Lexington Griffin Gate Hotel, Lexington, KY on June 24-25, 2024

Boiler Cleanliness to Maximize Boiler Efficiency and Operation

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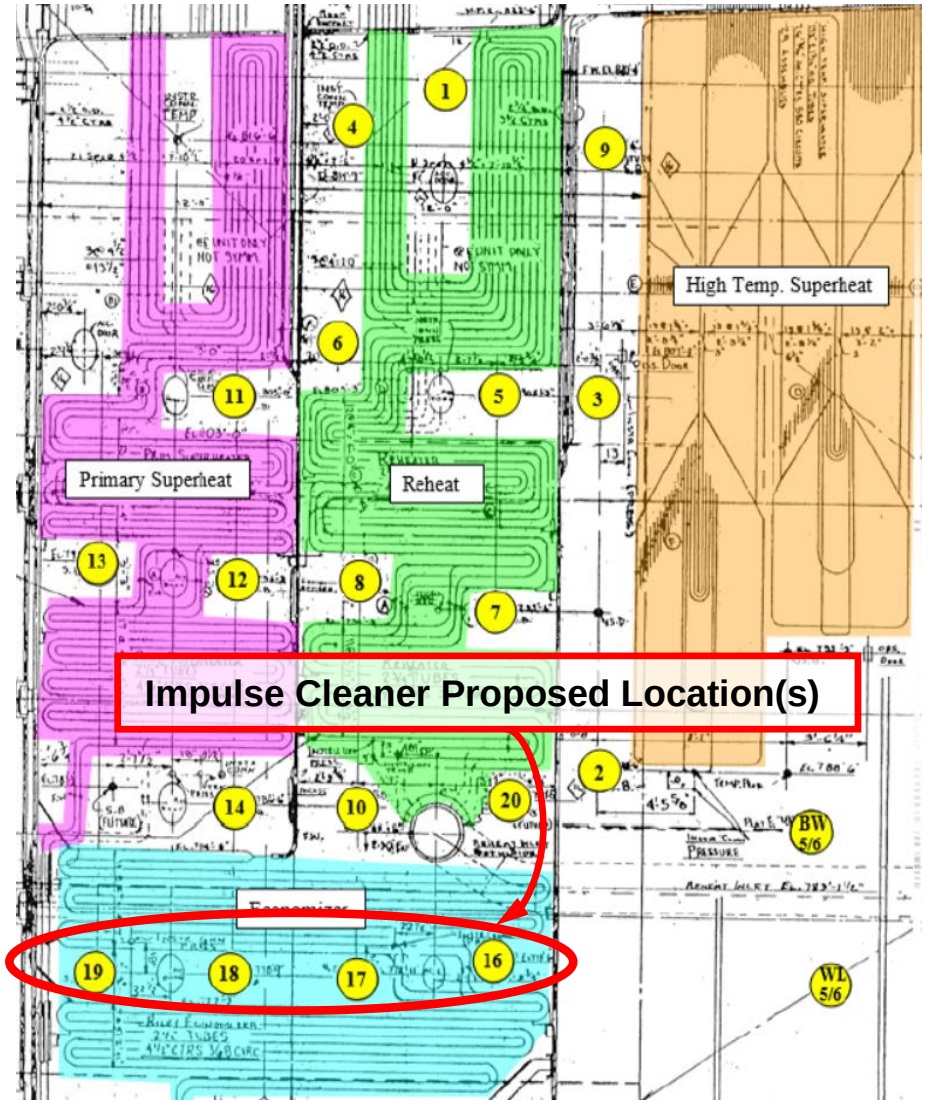
Storm Technologies, Inc.

Overview of the Importance of Boiler Cleanliness

- Impacts of Fouling and Boiler Cleanliness
  - Fuel Quality and Performance Optimization
- Boiler Cleaning Tools
  - Conventional Soot-Blowers
  - Water Cannons or Hydro Jets
  - Sonic Horns and/or Air Cannons
  - “Shock Wave” Impulse Cleaning Systems and Locations
- Cleaning Tool Locations (equipment varies with location)
  - Boiler Furnace
  - Convection Pass
  - APH’s and Backend Equipment
- Impacts on Boiler Efficiency/Heat-Rate and Operation
  - Excess Boiler Exit Temperatures
    - Metallurgical Limits
    - Boiler Efficiency
    - Back-End Equipment (i.e. SCR, Bag Houses, etc….)



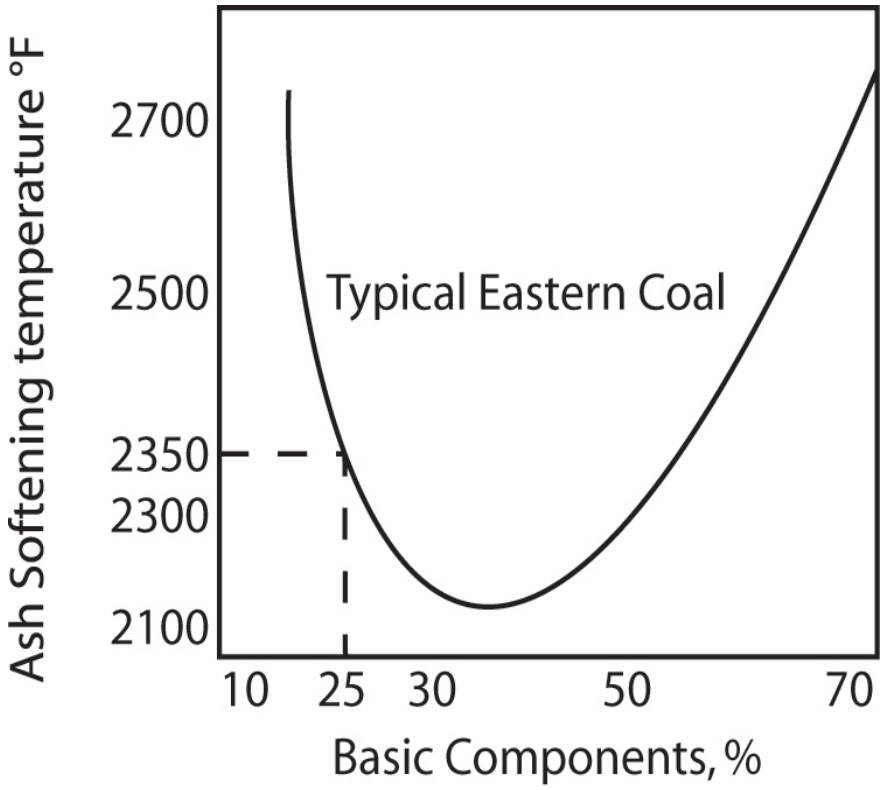
Fuel Qualities and Impact on Performance

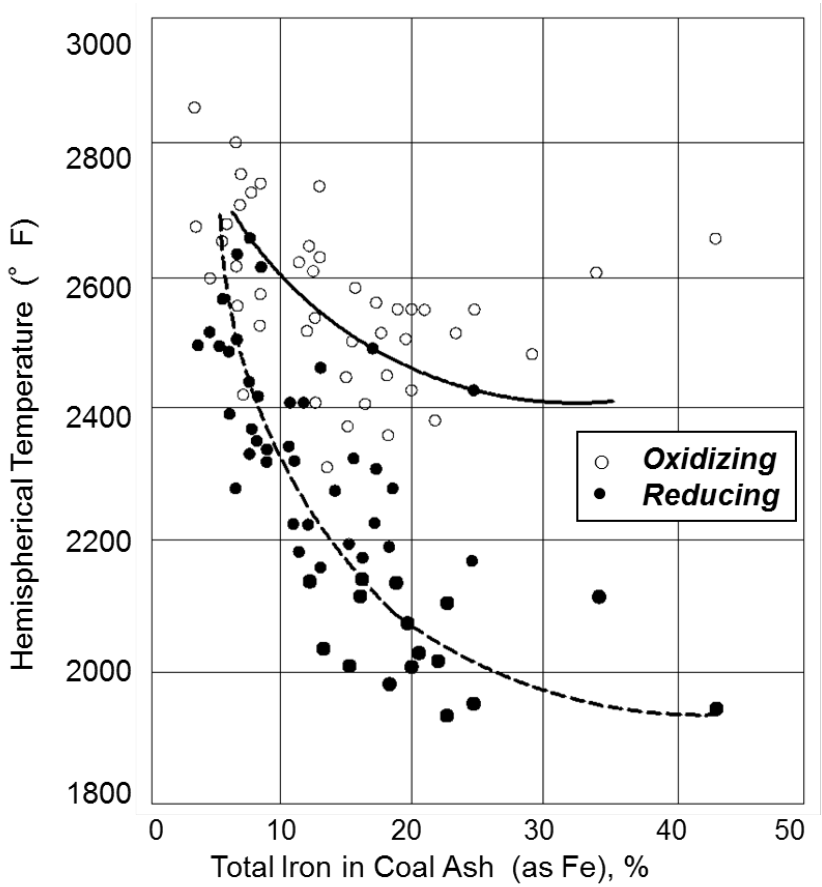
- General Equipment that will Impact Performance
  - Pulverizer Performance
  - Mechanical Tolerances of Burners/Dampers/Etc…
  - Air In-Leakage
- CAPP vs ILB Coals
  - Lower cost ILB – Illinois Basin coals that were purchased were extremely boiler unfriendly
    - Sulfur content increased 262%
    - Iron content increased 345%
    - Chlorine content is 0.16% - 0.19% on average
    - Reducing ash fusion temperatures are 500°F - 600°F lower
    - Free Swell Index (FSI) increased 6 pts
    - HGI increased 10 pts
    - HHV increased 1,000 Btu/lb

Description	Units	CAPP	ILB
Higher Heating Value	Btu/lb	11,525	12,287
Moisture	%	7.38	7.28
Ash	%	18.00	10.17
Sulfur	%	0.97	3.51
Volatile Matter	%	30.5	35.82
Ash Loading	lbm/MMBtu	13.96	8.28
SO_2	lbm/MMBtu	1.69	5.71
B/A Ratio		0.16	0.65
HGI		44	53
FSI		1	7.1
Oxidizing Atmosphere			
Initial Deform.	°F	XXXX	2,365
Softening	°F	XXXX	2,402
Hemisphere	°F	XXXX	2,461
Fluid	°F	XXXX	2,506
Reducing Atmosphere			
Initial Deform.	°F	2,500	1,964
Softening	°F	2,600	1,996
Hemisphere	°F	2,700+	2,064
Fluid	°F	2,700+	2,245

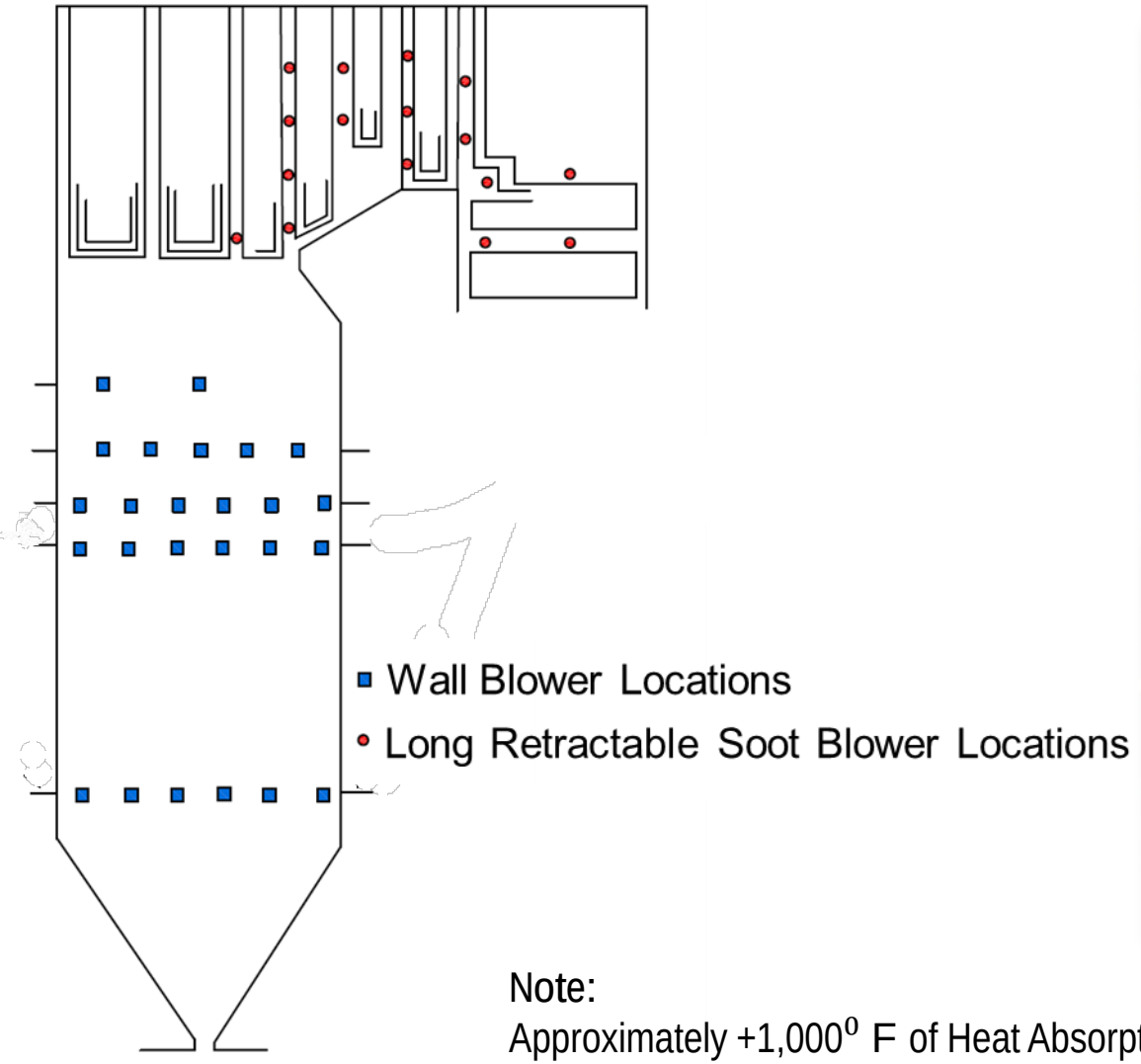
Fuel Qualities and Impact on Performance (Continued)

- Minerals in the coal they are a dynamic factor in the slagging characteristics in the boiler
  - Base/Acid Ratio
  - Iron content ranged from 25% - 30%





Soot Blower Performance



Ineffective Soot-blowing can often induce a "*Fireside & Steam Side Incompatibility*"

Note:
Approximately +1,000^{0} F of Heat Absorption is done in the Radiant Section of the Boiler.

Conventional Cleaning Methods

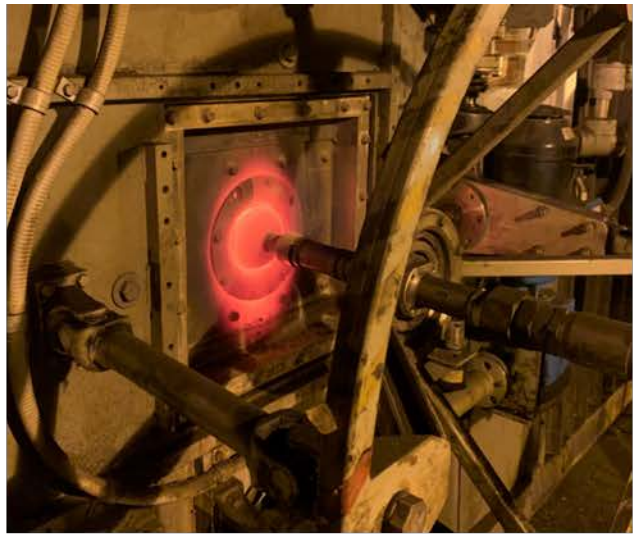
- Typically, these are either Air or Steam supplied cleaning devices
  - Either Wall Blowers (IR) or Long Retractable Blowers (IK)
    - Pressures and thermal drains must be properly set and all blowers operational

Conventional Cleaning Methods

- Sonic Horns, Water Cannon’s, APH Soot Blower Figures

Conventional Cleaning Method Operational Challenges

- Typically, we have found numerous blowers and/or Water Cannons/Hydro Jets are Out of Service



Notes:

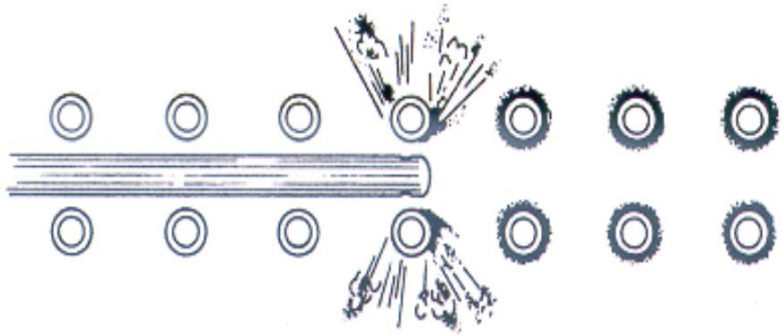
Out of Service Hydro-Jets and/or nearly 50% of IR and IK soot-blowers out of service

Soot Blower Erosion Challenges

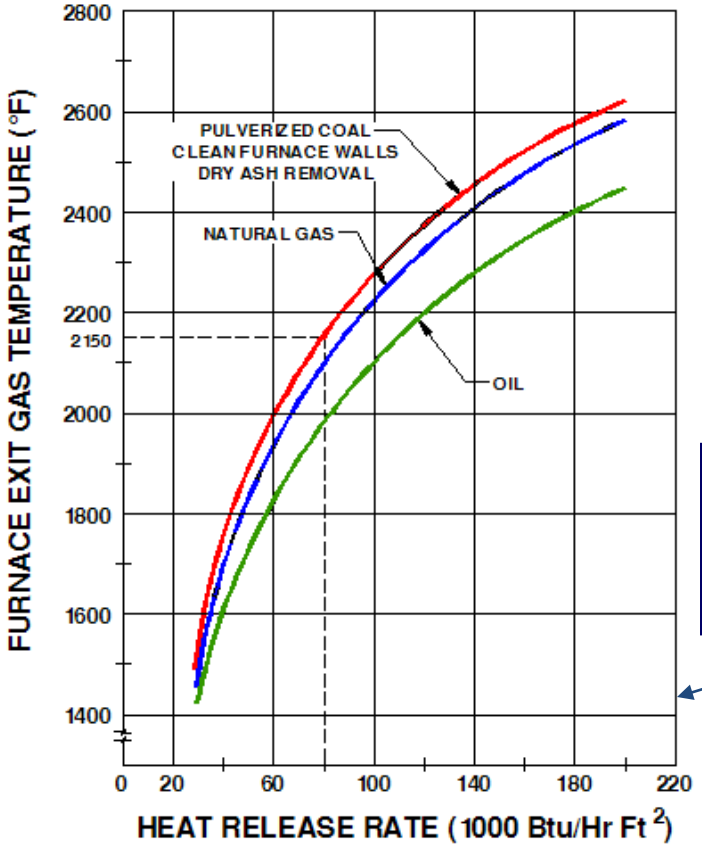
Steam Supply Pressure (600 PSI)

Steam Temperature (460 °F)

Steam Supply Pressure (600 psi) = saturation at 486 ˚ F. which is about 26 ˚ F below saturation. Soot blowing medium +50 ˚ F superheat or about 536 ˚ F was required in this case to prevent further tube erosion & failures/forced outages from condensate in the soot blowing system



Soot Blowing and Performance Impact on Performance



Result of High Furnace Exit Gas Temp.

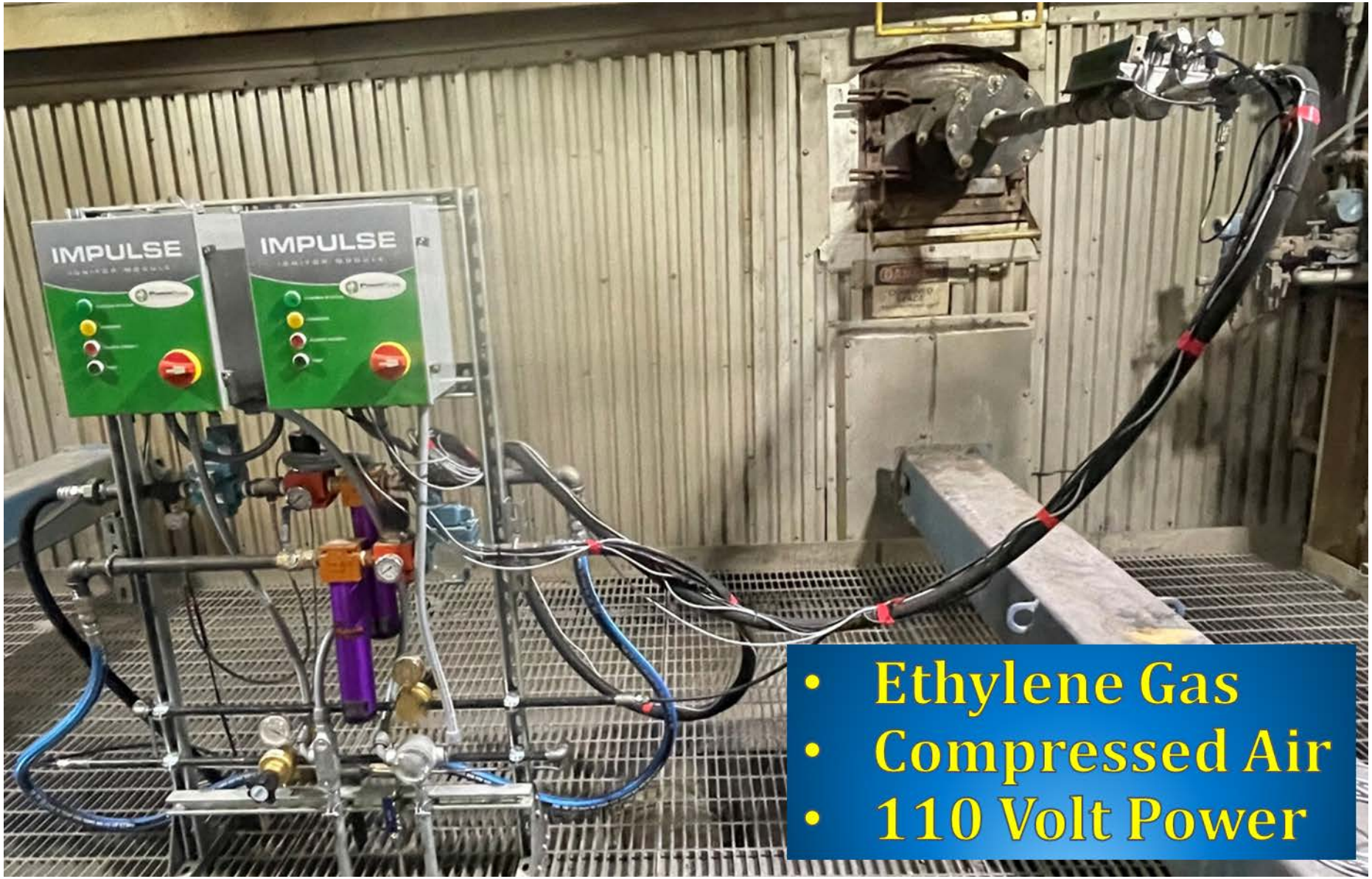
Proper Furnace Exit Gast Temperature

High furnace exit gas temperatures can contribute to overheated metals, such as these superheater alignment castings that only lasted 1 year due to greater than 2,500° F. furnace exit gas temperatures.

Soot Blowing Impact on Performance (Continued)

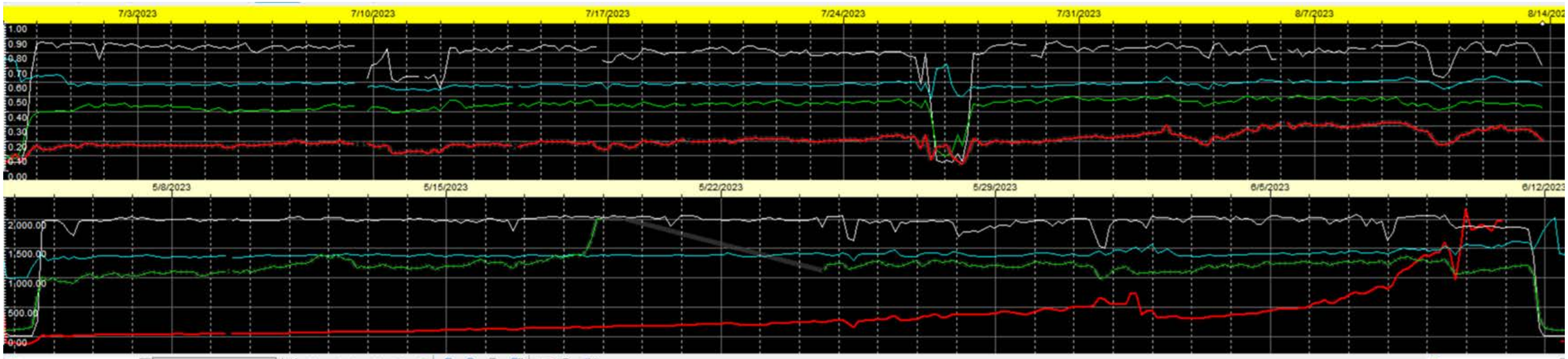
- Excessive soot blowing or improper settings on the soot blowers can result in significant damage to the heating elements.
- Soot blowing factors that can damage heating element
  - Soot blowing pressure
  - Soot blowing frequency
  - Moisture in the soot blowing medium
    - Soot blowing temperature and pressure
    - Soot blower drains

“Shock Wave” Impulse Cleaning Devices – Convection Pass



“Shock Wave” Impulse Cleaning Devices (Continued)

Why Consider “Shock Wave” Cleaning

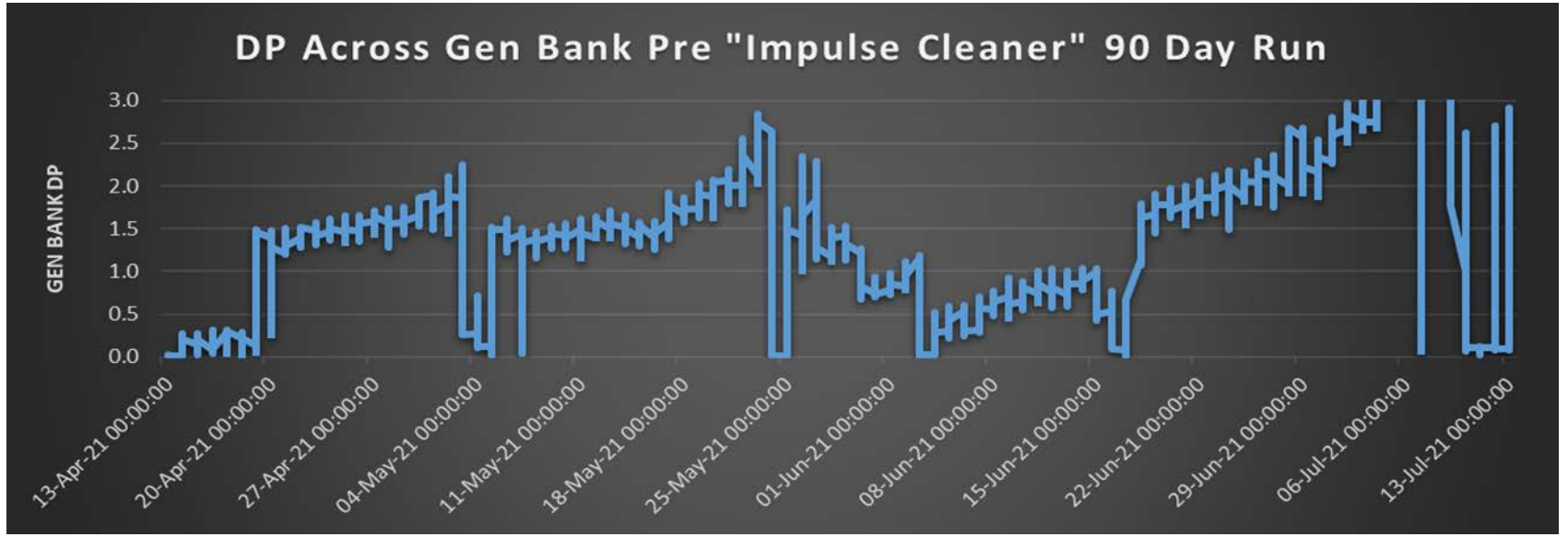


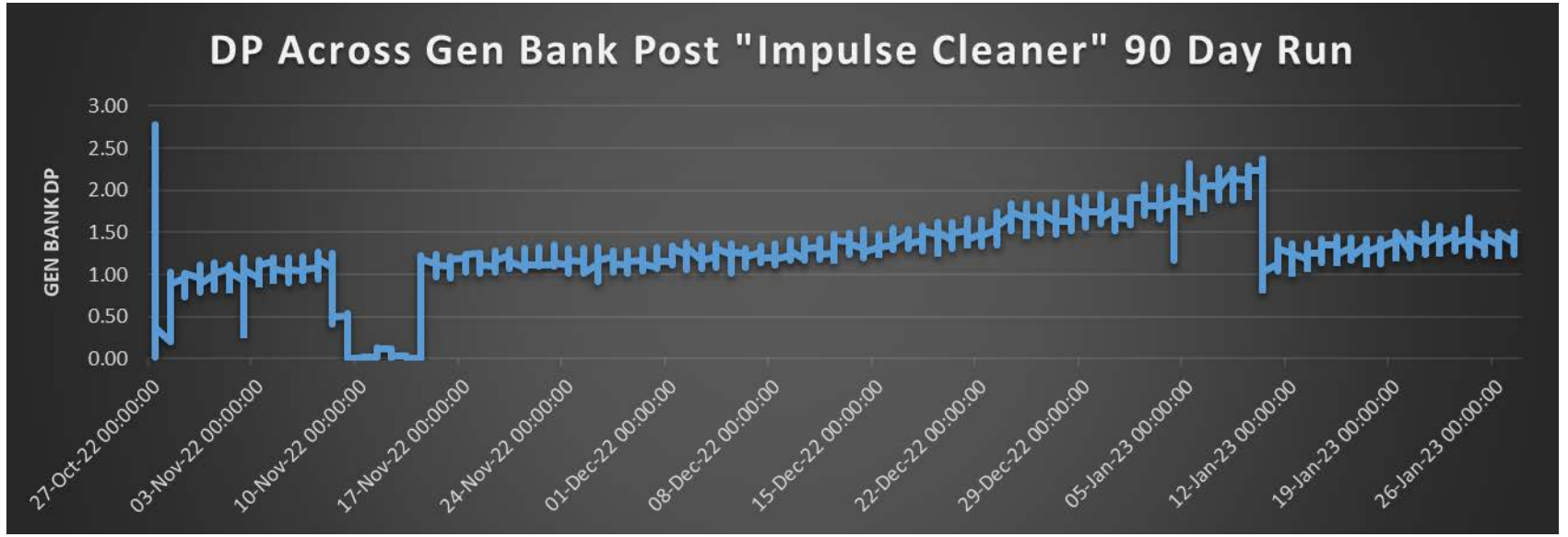
Object Tree	Scale	Engineering Units	Start Time	End Time	Duration	Tag	Minimum	Maximum	Average	Std Deviation	Cursor1	Cursor1 Time
Pane1												
B1 FURNACE DIFF PRESS	0.00 - 1.00	psig	6/29/2023	8/15/2023	6w 4d 16:24:13.812	HILDAS:hil_B1_PDIR_1575	0.0	0.3	0.2	0.1	0.2	7/26/2023
B1 CC Steamflow PV	-5.00 - 115.00	kpph	6/29/2023	8/15/2023	6w 4d 16:24:13.812	HILDAS:hi1_CC_Steamflow_PV	1.3	100.4	88.8	18.7	91.8	7/26/2023
B1 ID FAN MOTOR AMPS	-5.00 - 85.00	amps	6/29/2023	8/15/2023	6w 4d 16:24:13.812	HILDAS:hil_B1_IIR_1500	39.3	63.2	48.2	2.6	49.2	7/26/2023
B1 TEMP BEFORE FINAL SH	-125.00 - 2,375.00	degf	6/29/2023	8/15/2023	6w 4d 16:24:13.812	HILDAS:hil_B1_TIR_1582	85.3	1,148.8	974.8	167.0	1,049.5	7/26/2023
Pane2												
B1 FURNACE DIFF PRESS	0.00 - 5.00	psig	5/4/2023	6/13/2023	5w 5d 00:10:00	HILDAS:hil_B1_PDIR_1575	-0.0	4.6	1.0	0.8	0.9	5/27/2023
B1 CC Steamflow PV	-5.00 - 115.00	kpph	5/4/2023	6/13/2023	5w 5d 00:10:00	HILDAS:hi1_CC_Steamflow_PV	1.5	100.9	91.1	20.0	95.3	5/27/2023
B1 ID FAN MOTOR AMPS	-5.00 - 85.00	amps	5/4/2023	6/13/2023	5w 5d 00:10:00	HILDAS:hil_B1_IIR_1500	35.3	72.3	50.0	3.5	51.3	5/27/2023
B1 TEMP BEFORE FINAL SH	-125.00 - 2,375.00	degf	5/4/2023	6/13/2023	5w 5d 00:10:00	HILDAS:hil_B1_TIR_1582	92.0	2,015.2	1,208.7	273.6	1,218.4	5/27/2023

Notes:

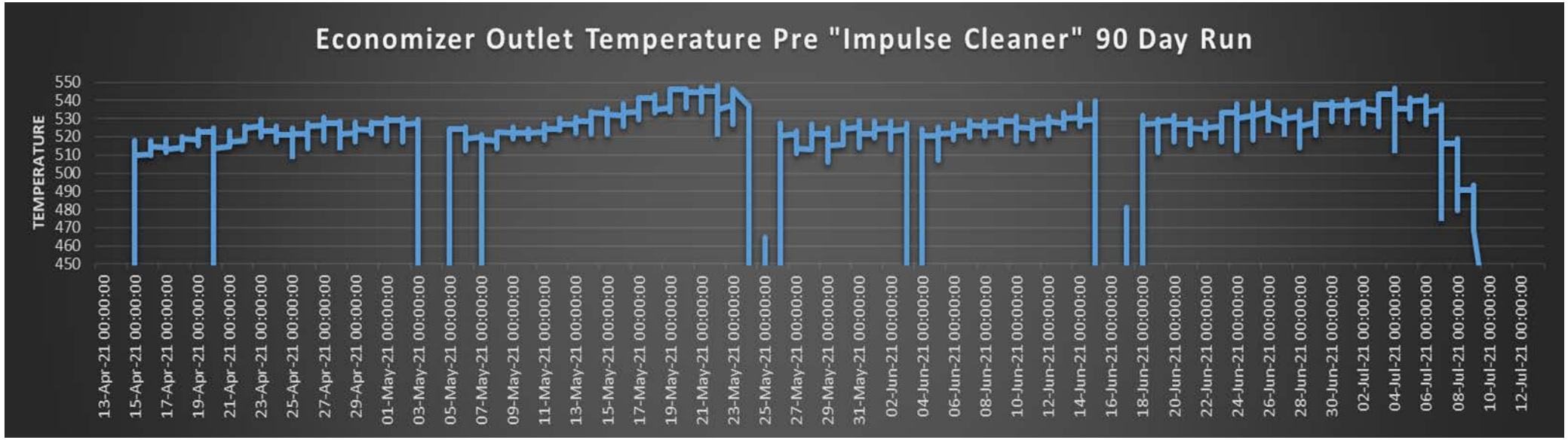
1. Top scale is with Impulse Cleaner and red line is DP with scale range of 0 - 1.0” w.c.
2. Bottom scale is without Impulse Cleaner and red line is DP with scale range of 0 - 5.0” w.c.
3. Duration Approx. 40-50 Days

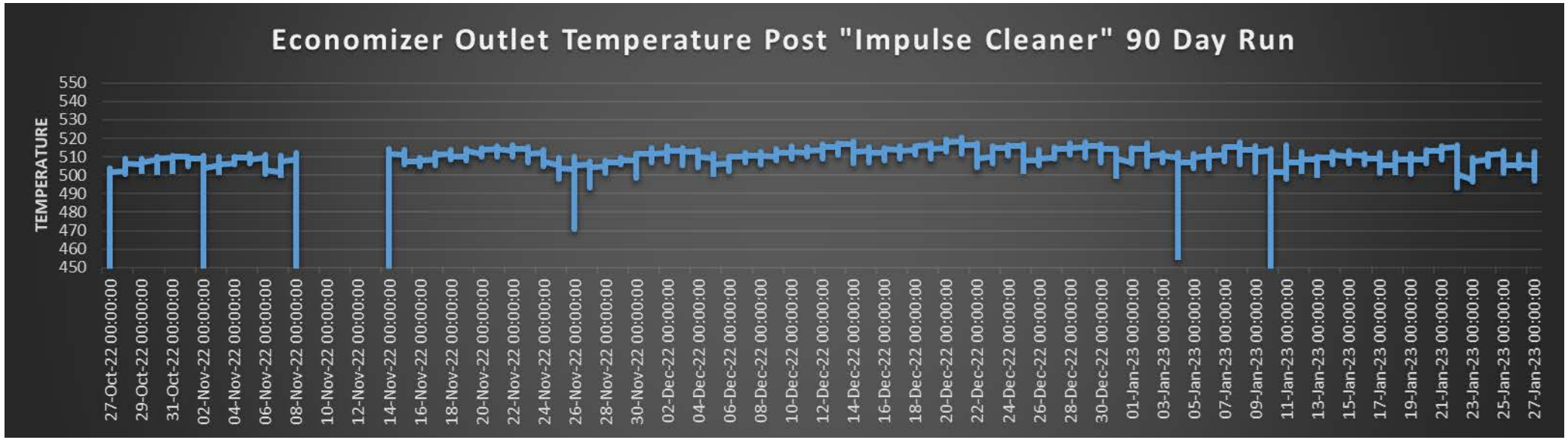
Why Consider “Shock Wave” Cleaning (Performance)





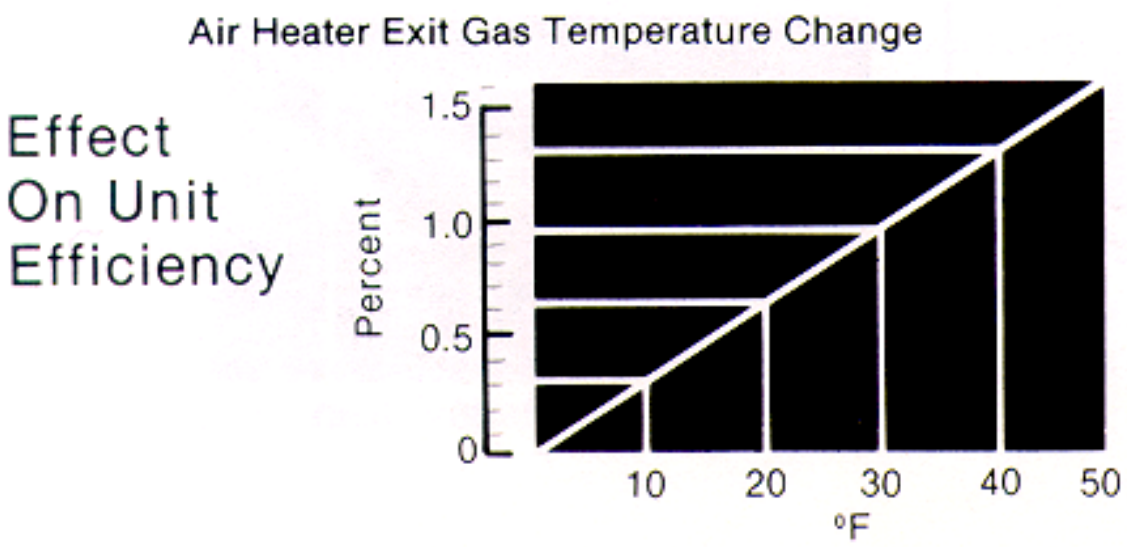
Why Consider “Shock Wave” Cleaning (Performance)





Impacts on Boiler Efficiency – Dry Gas Losses

- This loss is the totaling of the heat leaving through the stack that was not recovered and reintroduced into the system. The higher the stack gas temperature, the higher the dry gas loss.

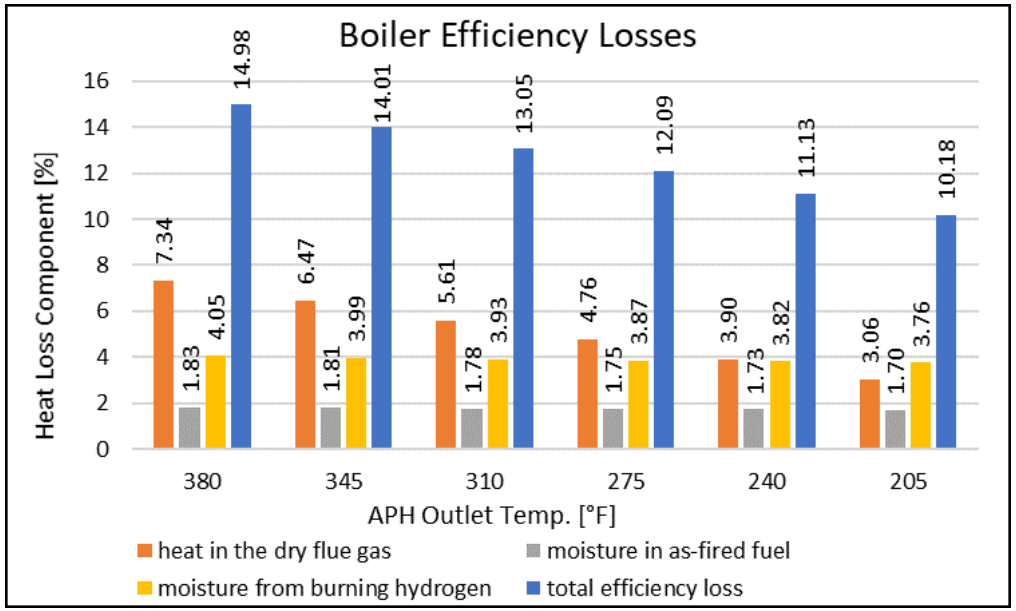


Impacts on Boiler Efficiency – Dry Gas Losses (Cont.)

- Indicated air heater gas outlet temperatures can be deceiving. When evaluating air heater performance and boiler efficiency gas outlet temperatures MUST but evaluated on a NO LEAKAGE basis.
- For every 35 deg. F change in temperature there is an approximately 1% impact on boiler efficiency.

- *Calculations based off:*
  - *ILB Coal*
  - *3% excess oxygen at the APH inlet*
  - *9% APH Leakage*
  - *700 deg. F inlet temp*

	APH Outlet Temp. [°F]					
Heat Loss Components [%]	380	345	310	275	240	205
Losses due to unburned carbon in total dry refuse	0.20	0.20	0.20	0.20	0.20	0.20
Losses due to heat in dry flue gas	7.34	6.47	5.61	4.76	3.90	3.06
Losses due to moisture in the "as-fired" fuel	1.83	1.81	1.78	1.75	1.73	1.70
Losses due to moisture from burning hydrogen	4.05	3.99	3.93	3.87	3.82	3.76
Losses due to moisture in air	0.16	0.14	0.12	0.10	0.08	0.07
Losses due to air infiltration	0.00	0.00	0.00	0.00	0.00	0.00
Unmeasured Losses to be assumed	1.40	1.40	1.40	1.40	1.40	1.40
Heat Credit Compontents [%]						
Credits due to heat from entering air	0.00	0.00	0.00	0.00	0.00	0.00
Boiler Efficency [%]	**85.02**	**85.99**	**86.95**	**87.91**	**88.87**	**89.82**
Δ Losses due to heat in dry flue gas		0.87	0.86	0.85	0.86	0.84
Δ Losses due to moisture in the "as-fired" fuel		0.02	0.03	0.03	0.02	0.03
Δ Losses due to moisture from burning hydrogen		0.06	0.06	0.06	0.05	0.06
Δ Losses due to moisture in air		0.02	0.02	0.02	0.02	0.01
Total Boiler Efficiency Increase [%]		**0.97**	**0.96**	**0.96**	**0.96**	**0.95**



Overview of “Shock Wave” Cleaning

- **“Shock Wave” Cleaning Technology Potentials for the following areas:**
  - Convection Pass Fouling (<1500^0 F temperature zone)
  - Potential APH Cleaning (Developmental Phase)
  - Potential SCR Cleaning (Developmental Phase)
  - Potential HRSG On-Line Cleaning (Developmental Phase)

- **“Shock Wave” Cleaning Benefits**
  - Help Reduce Boiler Exit Gas Temperatures (for SCR and/or metallurgical limits)
    - Deeper penetration and cleaning of the convection pass tube bundles
  - Help Reduce Convection Pass Drafts (for ID fan capacity limitations)
  - Help Reduce the need for conventional soot blower systems due to maintenance and operation of old systems
    - Minimize erosion and wear from conventional soot blower systems
  - Improve Overall Unit Efficiency by addressing the previous items

Video of “Shock Wave” Cleaning

Thank You!

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