

REINHOLD ENVIRONMENTAL[®]



2025 Reinhold/PCUG Round Table Presentation

Hosted by AEP and Buckeye Power

in The Hilton Columbus Polaris Hotel, Columbus, OH

on June 23-24, 2025

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Natural Gas Addition for Co-Firing

June 23, 2025 Presented By : Mike Johnson



 BabcockPower **ONE SOURCE. MANY SOLUTIONS.**

Agenda

- Introduction – Why Add Natural Gas Co-Firing?
- Engineering Approach
- Typical Boiler Performance Impacts
- Equipment Modifications
 - Gas Firing Equipment
 - Fan Evaluation
- Emissions Impacts
 - Changes to NO_x, CO, SO_x, PM, Hg...
 - Typical AQCS equipment

Introduction

Coal Power – Challenges Facing Electric Utilities

- Environmental
 - Carbon dioxide, coal ash, wastewater
 - Load cycling impact on emissions
- Fuel Economics
 - Variable coal cost - \$/ton, delivery & additives
 - Natural Gas sub - \$4/MMBtu
- Increased Cycling and Low Load Operation
 - Startup costs
 - Startup time
 - Reliability penalty



Environmental Drivers

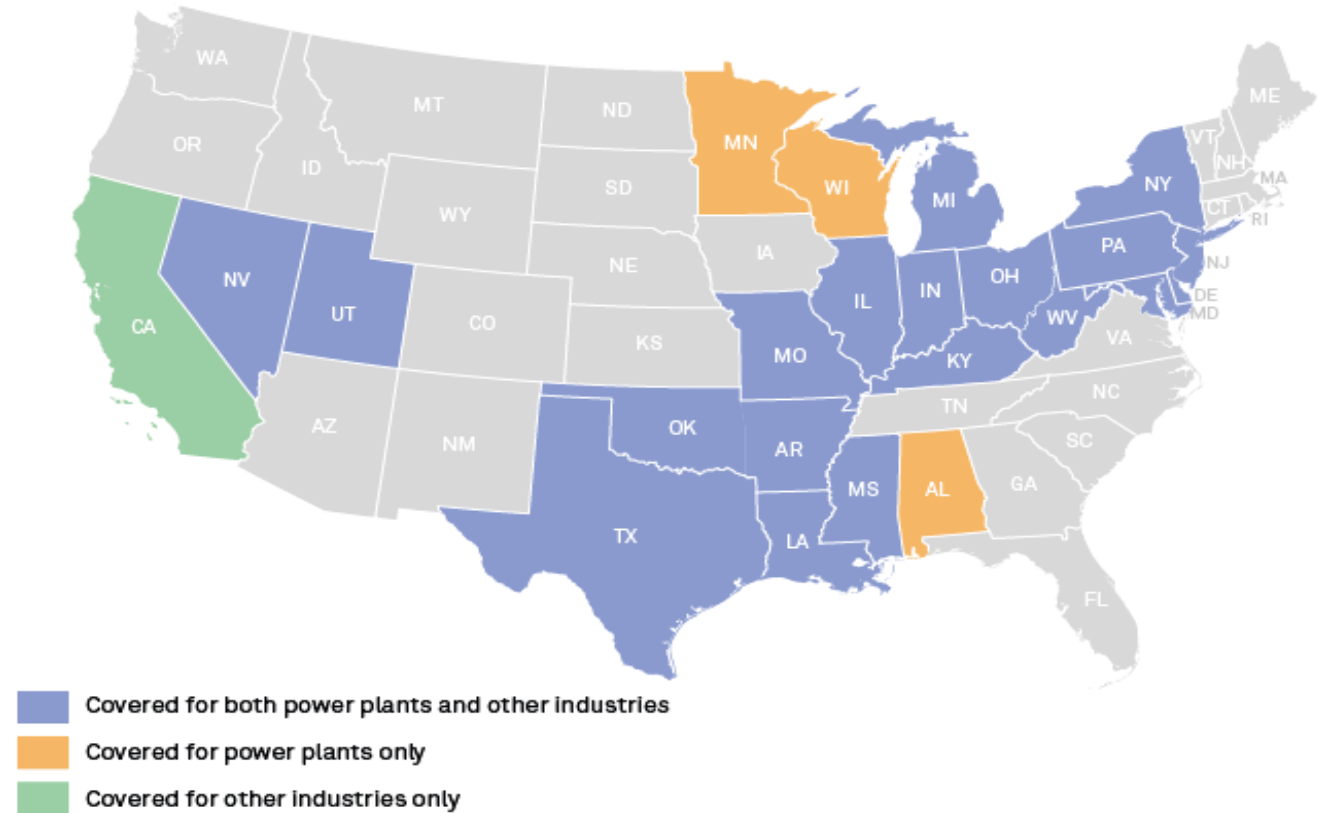
1. The Federal EPA has put forth a range of strict emission standards in recent years that aim to ensure cleaner air and reduce the impact of climate change.
2. Although these standards have seen a litany of legal challenges, many of which are still being fought in the court system, they have impacted the rate of natural gas replacing coal firing.
3. Efforts such as the Good Neighbor Plan, the Greenhouse Gas Standards and Guidelines for Fossil Fuel-Fired Power Plants, Mercury and Air Toxic Standards, and others have had a large impact on EGU operators.
4. Natural gas firing in lieu of coal is one of the least-cost and time-saving compliance pathways for current and proposed EPA and state regulations.

A recent example regulation

The Good Neighbor Plan Rule (aka, CSAPR 2.1):

- The EPA issued its final Good Neighbor Plan in March 2023.
- Intended to reduce NOx. Expected to eliminate 14 GW of coal generation by 2030
- Legal challenge posed by three states
- Plan currently stayed pending further litigation

US states covered by EPA cross-state ozone pollution rule



Data accessed Mar. 15, 2023.
Source: U.S. Environmental Protection Agency.
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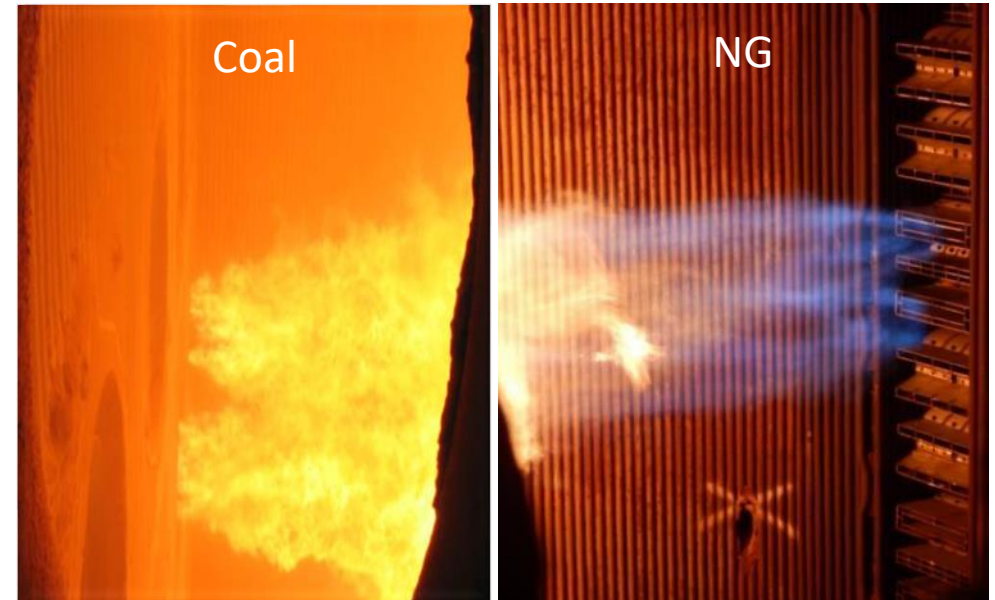
Current Legislation – New Source Performance Standards

As part of the new NSPS GHG standards, here are the choices:

- Coal-fired steam Energy Generating Units (EGUs) that plan to operate on or after January 01, 2032, must implement Best System of Emissions Reduction (**BSER***) by January 01, 2030.
 - * **The BSER for a coal fired steam EGU is co-firing with natural gas, at a level of 40% of the unit’s annual heat input.** The presumptive standard is a 16% reduction in the unit’s annual emissions rate.
- This still comes with a commitment to cease operations before January 01, 2039.

Natural Gas Firing Benefits

- Reduced environmental impacts
- Generally lower NO_x, CO and CO₂ emissions
- PM, SO_x, and Hg are generally non-existent in NG firing
 - Reduction or elimination of AQCS equipment
- Better burner turn-down and lower stable boiler load
- Improved boiler cleanliness (slagging & fouling)
- No ash to dispose of and/or store
- Reduced water usage
- Reduced boiler outages
- Reduced maintenance costs
- Increase unit availability and reliability
- Potential to fire hydrogen fuel
- Reduction or elimination of coal handling equipment



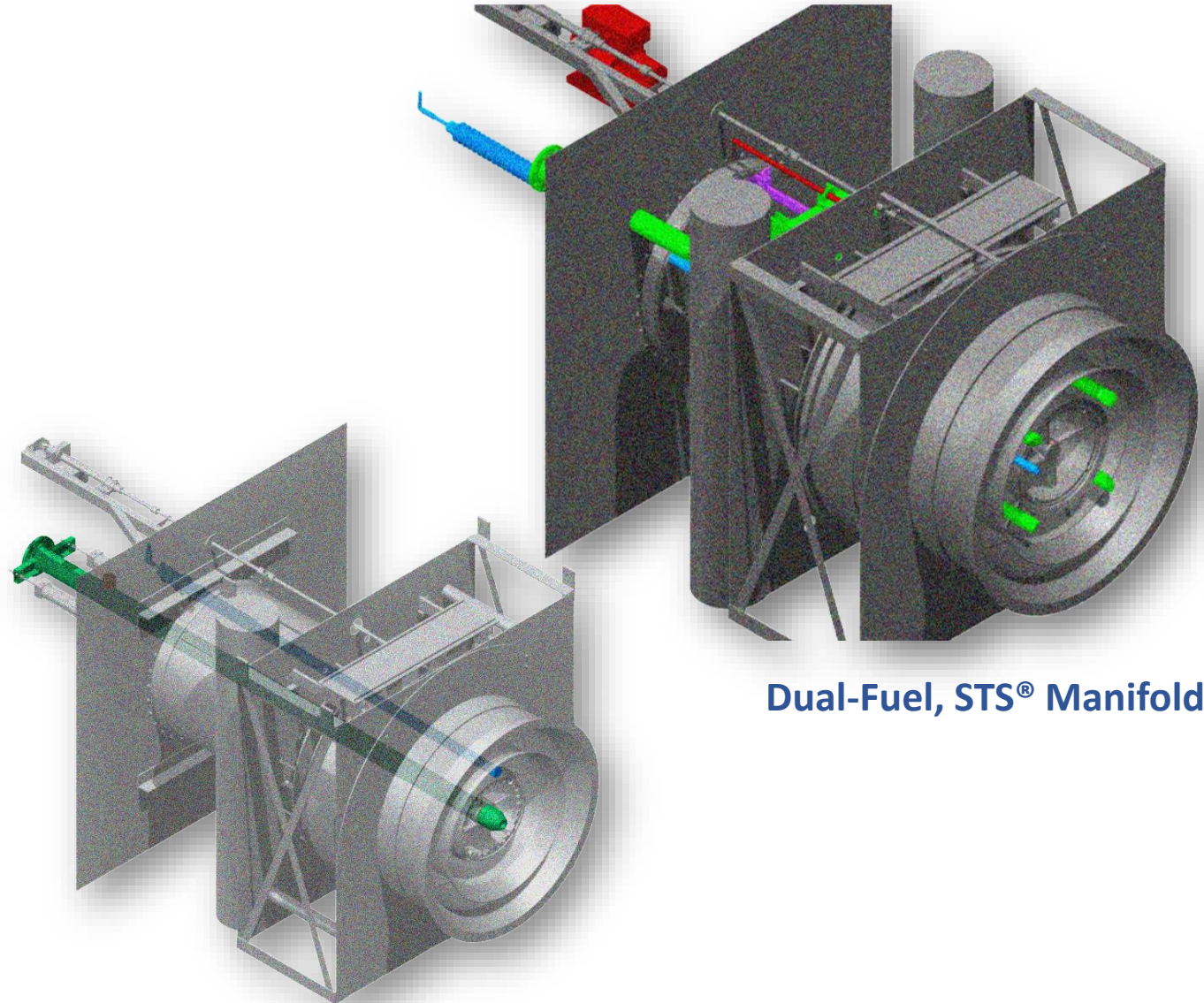
Gas Addition – Maximum Flexibility

Pros:

- Possibility of up to 100% MCR firing using either natural gas or coal.
- Can utilize existing coal-fired burners with gas retrofit, or new Riley Power Dual-Fuel VSII® burners with STS® gas technology
- Each burner can be fired on either coal or gas at any given time, allowing the ability to co-fire as well.

Cons:

- More complicated burners (more components in same space)
- Gas components subject to more wear
- Restrictions in burner performance based on utilizing existing burner construction



Dual-Fuel, STS® Manifold

Dual-Fuel, Center-Fired Gas

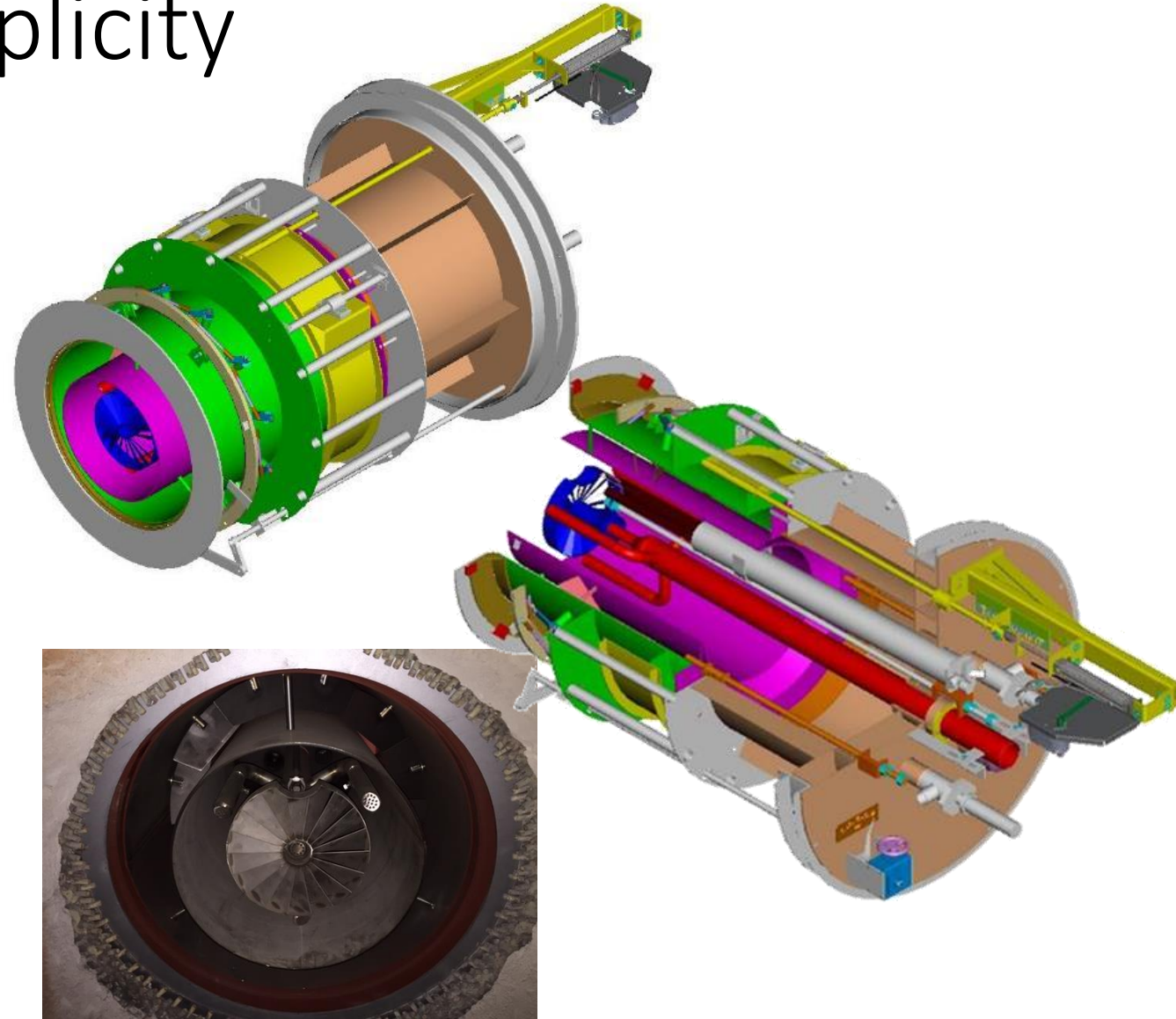
Gas Conversion - Simplicity

Pros:

- Reduced maintenance requirements
- Simplified combustion system operations
- Reduced backend environmental equipment
- Simplified Burner Front
- Lower aux power usage due to reduction in required equipment in operation

Cons:

- Loss of fuel flexibility



Performance Engineering Approach

Designing for Co-Firing

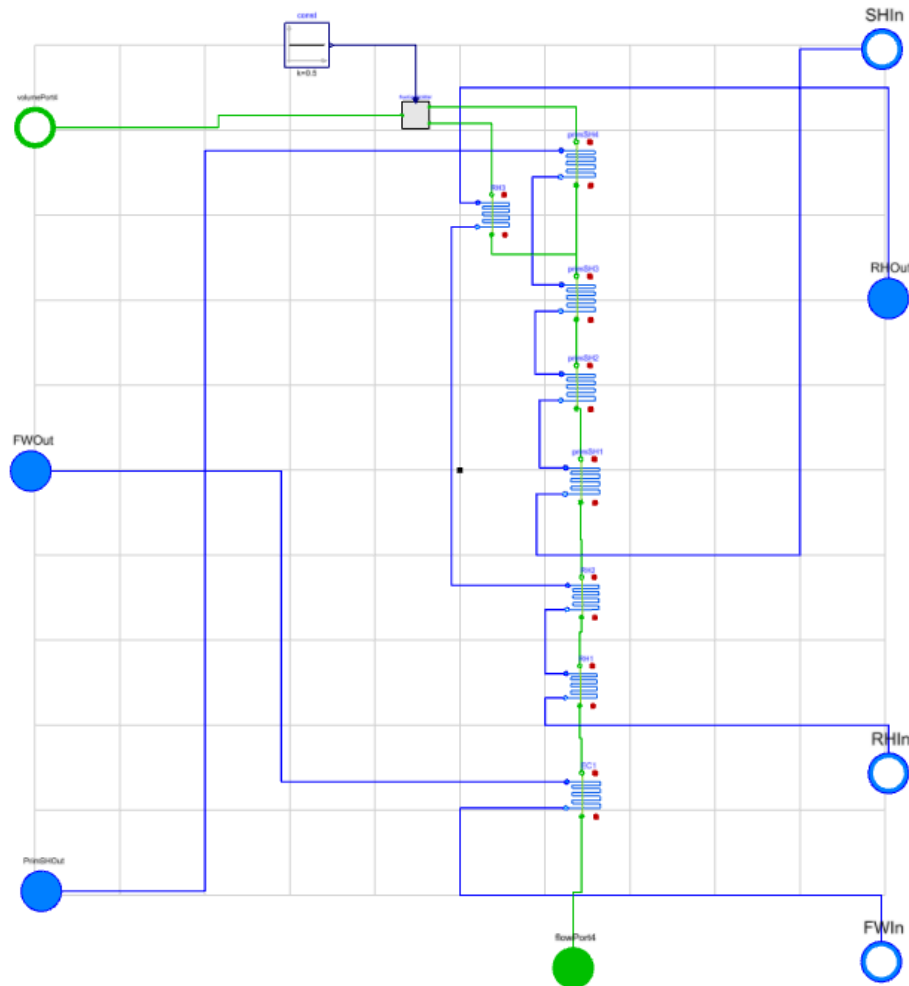
- Goals of Boiler Analysis
 - Evaluate fuel requirements
 - Evaluate air requirements
 - Determine impacts to boiler performance
 - Steam temperatures
 - Spray flows
 - Metal temperatures
- Two Methods Used for Analysis
 - Overall envelope calculations – “Basics”
 - Heat transfer models

Analysis Methods – Overall Energy Balance “Basics”

- Establish boiler efficiency (PTC 4.0 methodology)
- Calculates heat input required and subsequent fuel flows
- Calculate air flows based on fuel flows and excess air
- Approximate air preheater performance based on changes from base case

Heat input and fuel quantities based on:				PTC 4 Fuel Efficiency Basis		15,521.6	85.28%
						Input, Btu/lb fuel	Effic.
Gaseous fuel #4: 126,984 lb/hr				46,711	scfm @	0.04531	lb/ft ³ @ 60°F, 14.696 psia
Calculated Flow Rates, lb/hr							
Fuel	Total	lb/hr					
UBC	% in residue: 4.30%	996	Bitum coal	245,340			
Ash from fuel		22,154	PRB coal	0			
Ash residue, including UBC		23,151	India coal	0			
			Natural Gas	126,984			
						<i>based on bottom ash of: 20%</i>	
Total Combustion Air	lb/hr	5,108,436	Flue Gas From Combustion		5,457,609	<i>Flyash entrained specify distrib. in Resid sheet</i>	
AH air bypass, incl. TA, boiler infiltration		1,113,639	Flue Gas Recirculation, FGR		0	<i>lb/hr</i>	<i>lb / lb FG</i>
Hot air recirc, % of TCA	0.0%	0	Flue gas through surfaces		5,457,609	18,520	0.00339
AH air leak., % of FG in	25.00%	1,364,402	Additional air & moisture		0		
AH Air In	<i>see air heater section for individual stream details</i>	5,359,199	AH Flue Gas In		5,457,609	17,363	0.00318
AH Air Out		3,994,797	AH Flue Gas Out		6,822,012	16,205	0.00238
add'l downstream infiltr.	0%	0	FG w/ additional downstream infiltration		6,822,012	912,712	<i>CCO production</i>
boiler air infiltration (to furn, backpass)		0	FG from furn, w/o boiler air infiltration		5,457,609	16.724%	<i>by wt @ AH in</i>

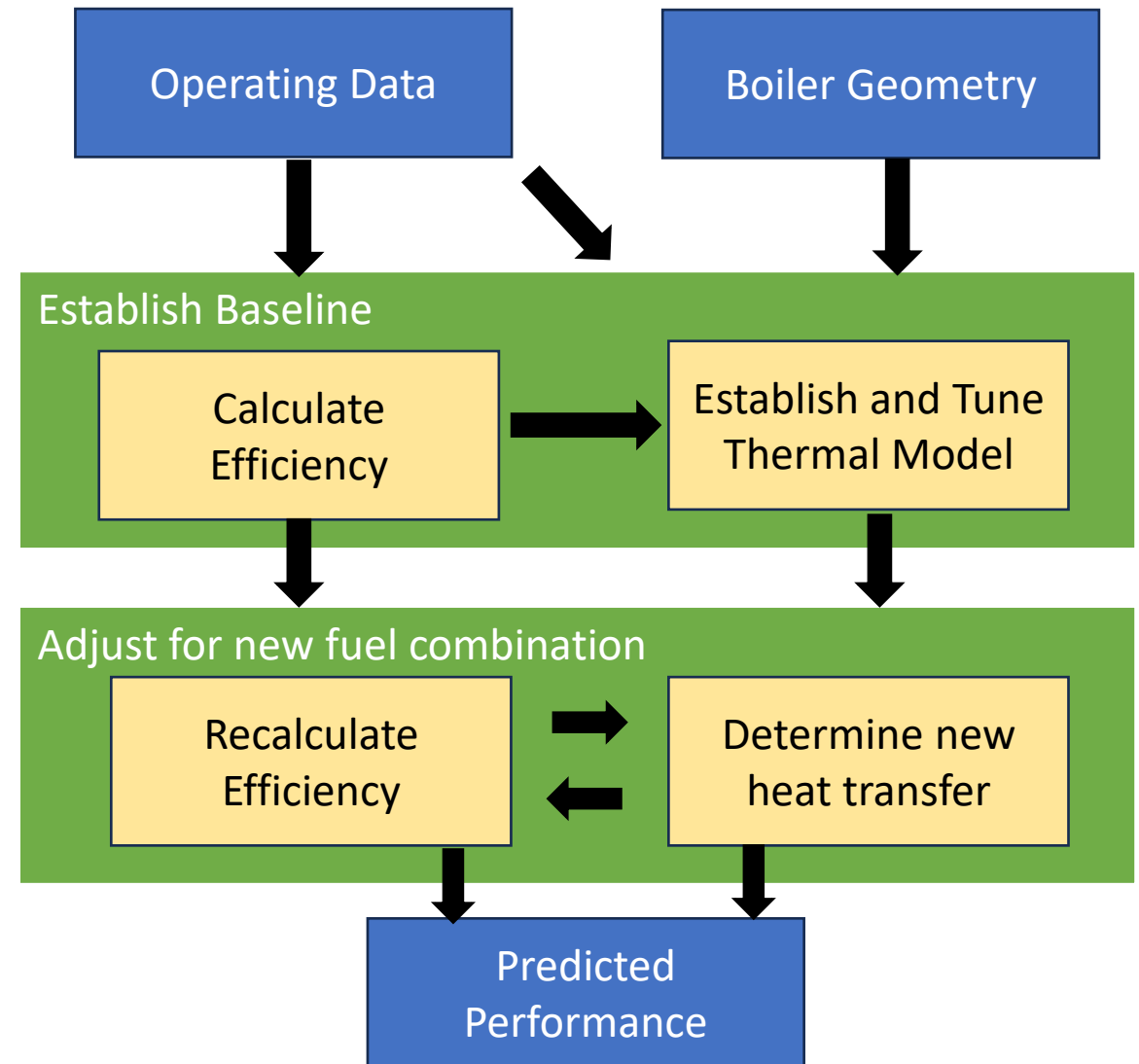
Analysis Methods – Heat Transfer Modeling



- Determine heat absorption by individual surfaces in the boiler
- Allows for calculations of metal temperatures, steam temperatures, and required spray flows
- Improves accuracy of overall efficiency calculations based on exit temperatures of steam and flue gas

Analysis Procedure

- Typically begins with operating data analysis to determine key parameters under coal operation
 - Steam Temps
 - Flue Gas Temps
 - Air Preheater Performance
 - Fuel Analysis
- “Basics” calculations are performed for loads of interest
- A thermal model is developed based on boiler geometry and its results tuned to match operating data
- Models and calculations then used to predict future cases

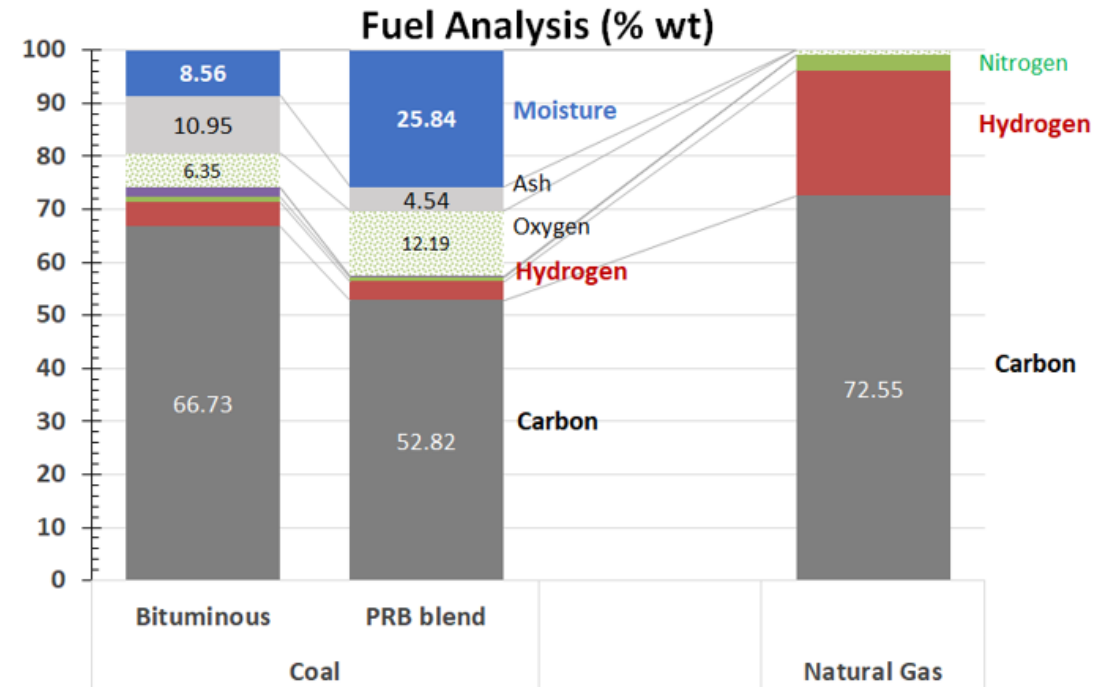
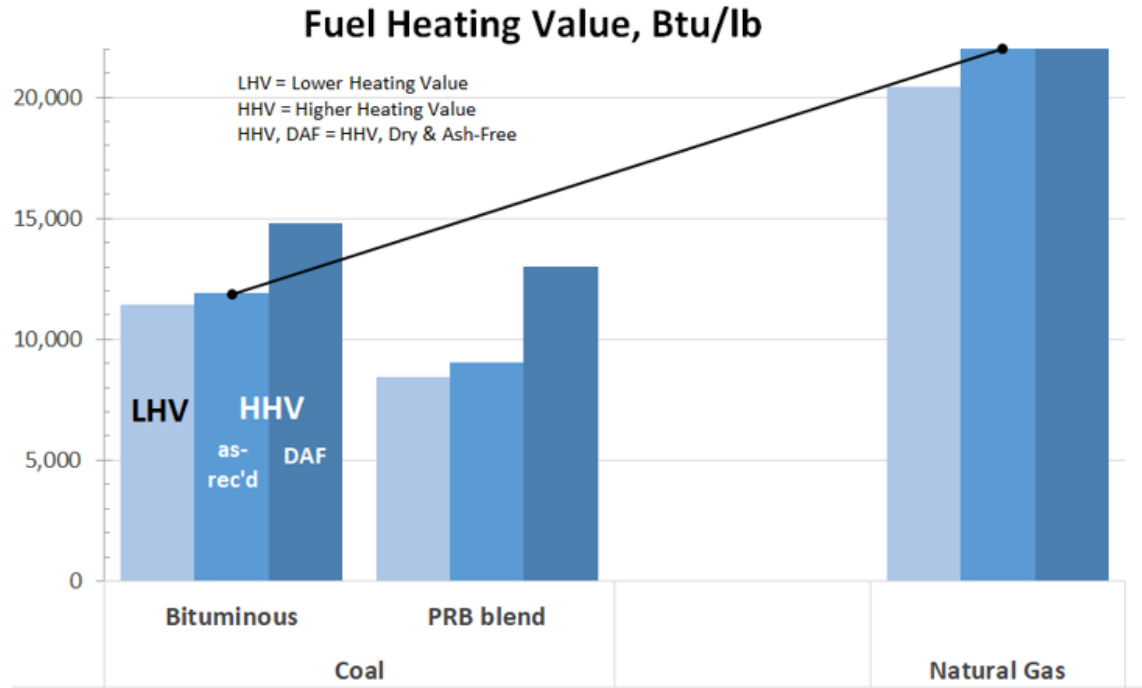


Typical Results – Fuel Comparison

- Natural Gas and Coal have very different compositions and combustion requirements
- Natural Gas generally requires less air for completion of stoichiometric combustion
- Natural gas has a much higher hydrogen content, which combusts to H₂O, increasing wet gas losses
- Water content in coal is highly variable depending on coal type, and impacts overall changes in efficiency
- Essentially no sulfur in natural gas
- No Ash in natural gas

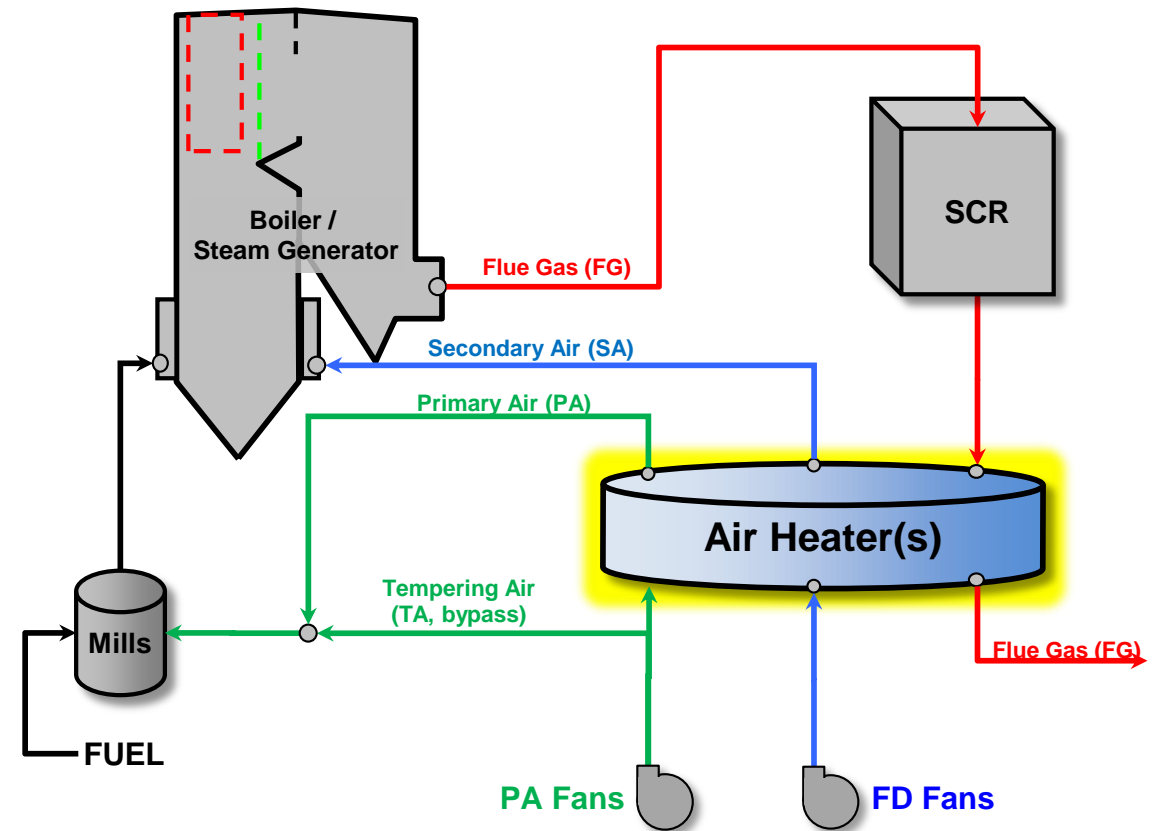
	%Wt (Wet)		Bit Coal	Natural Gas
Carbon	C	%	64.26	72.82
Hydrogen	H2	%	4.33	23.64
Nitrogen	N2	%	1.32	2.61
Sulfur	S	%	3.2	0
Chlorine	Cl	%	-	-
Ash	Ash	%	9.03	0.00
	H2			
Water	O	%	10.85	0.00
Oxygen	O2	%	7.01	0.93
Total		%	100	100
			1	
Air Requirement		lb dry air /MBtu	740	723
HHV		Btu/lb	11,778	22,755

Typical Results – Fuel Comparison



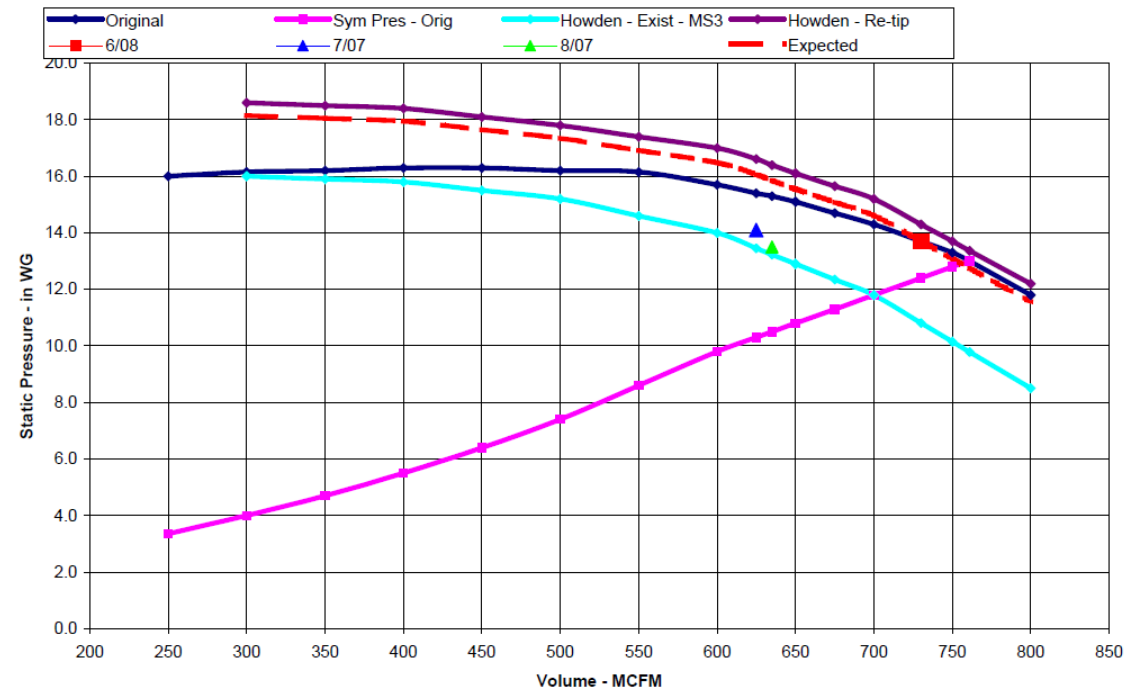
Typical Results – Combustion Air Distribution

- Excess air requirements vary depending on fuel.
- When switching from coal to gas, it is typical to reduce excess air from ~20% to ~10%
- When Co-Firing it is typical to match the coal excess air requirements. This limits any reductions in air flow that could normally be achieved with natural gas
- Reducing coal reduces primary air requirements proportionally, and increases secondary air accordingly
 - Primary and Secondary air fans need evaluation for co-firing due to changes in air distribution
- Excess air can be tuned to improve overall performance, both for steam temperatures, and emissions



Typical Results – Fan Evaluation

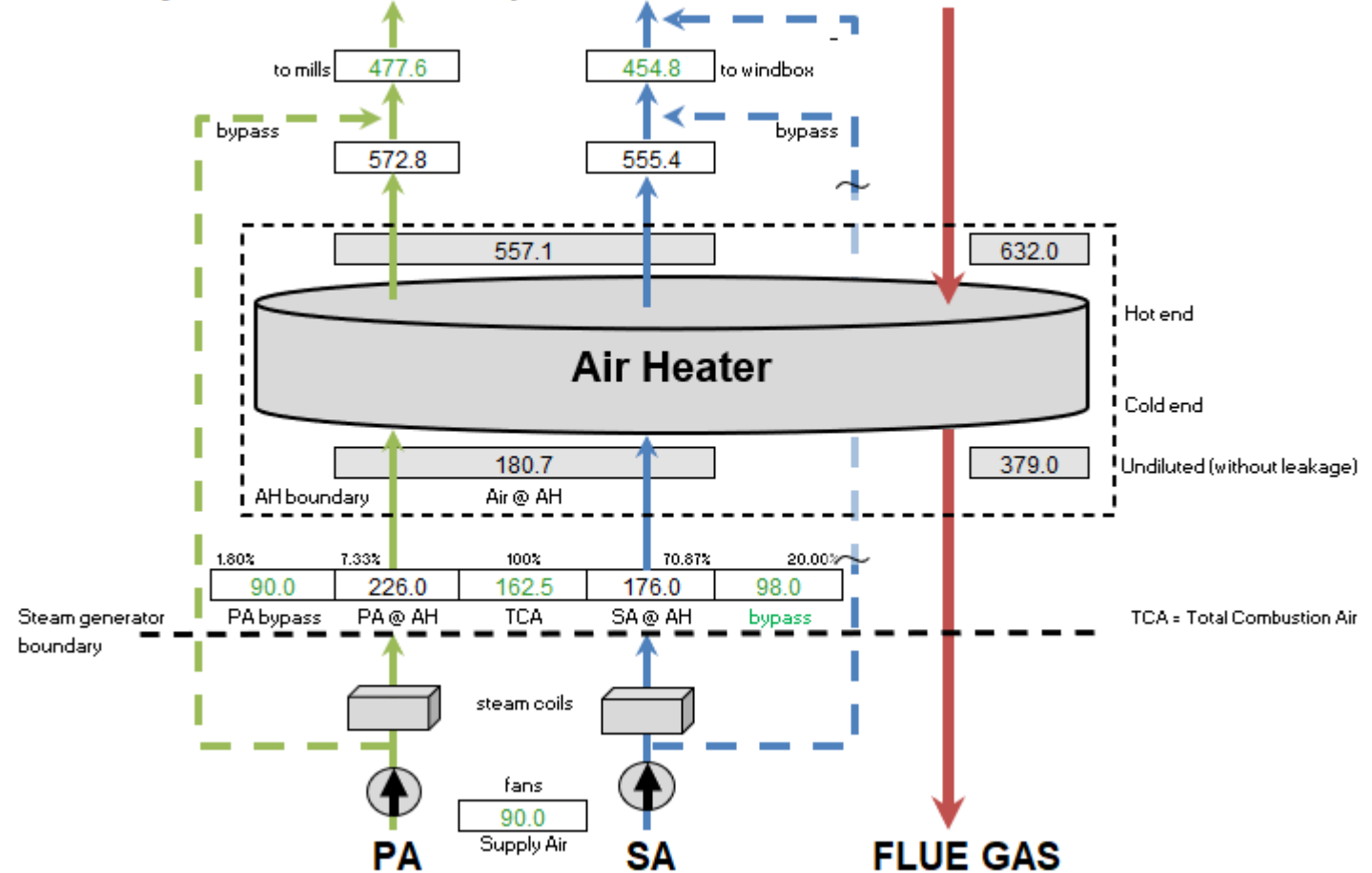
- With changing air requirements under co-firing it is important to confirm adequate fan capacity
- Existing fan curves are compared to new load points
- Modifications such as supplemental fans, fan replacement, fan tipping, or duct alterations may be needed



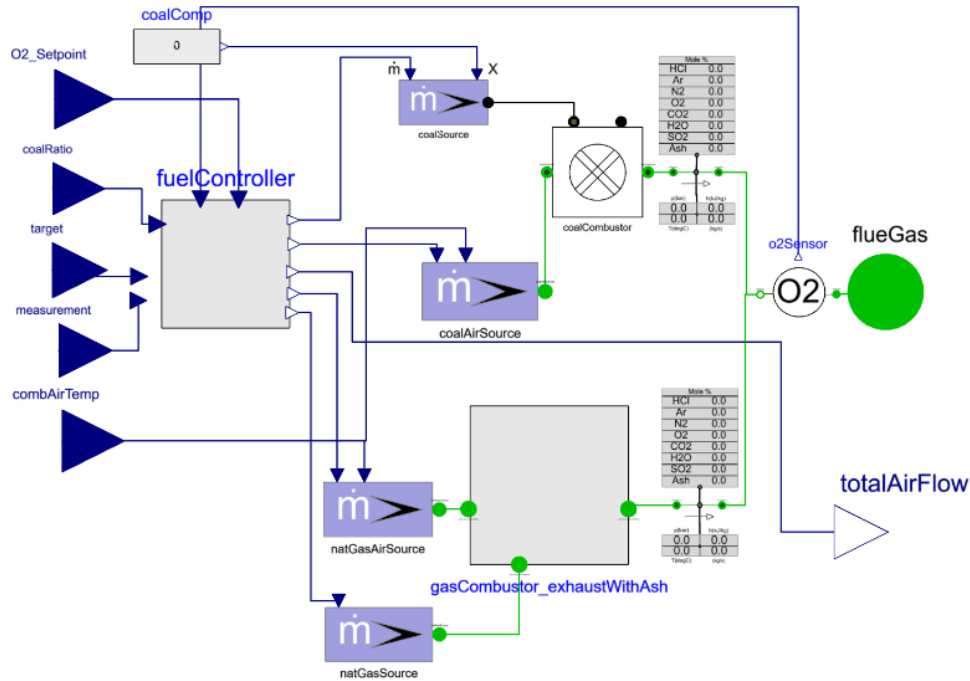
Typical Results – Air Preheaters

- Effect of co-firing on air preheaters depends on base configuration
- For trisector air preheaters there is minimal overall change in performance
- For separate primary and secondary air preheaters, dampers may be required to control flue gas distribution to match air distribution
- Air leakage through air preheaters may vary with changing air flow and may impact fans

Summary of Air and Gas Temperatures, °F



Typical Results – Flue Gas Adjustments



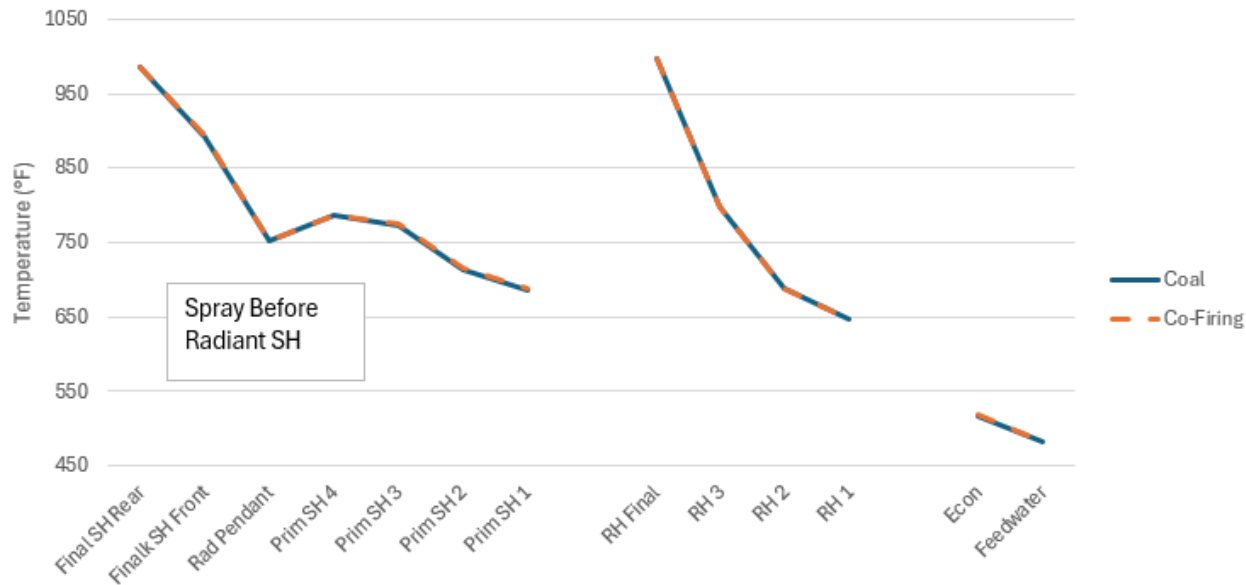
- Composition and amount of flue gas varies with fuel and excess air
- Hydrogen combustion when firing natural gas results in significant water vapor formation
- Co-Firing typically results in a small reduction in overall flue gas generation
- Minimal impact on ID fans, but may affect AQCS equipment

Excess Air	Coal			
	19.010 %			
	% volume		% weight	
	wet	dry	wet	dry
O2	3.101	3.423	3.351	3.555
N2	73.394	81.016	69.796	74.034
CO2	13.838	15.275	20.568	21.817
SO2	0.2589	0.2858	0.5602	0.5943
H2O	9.408	-	5.724	-
	<u>Air_wet</u>	<u>Air_dry</u>	<u>Gas_wet</u>	<u>Gas_dry</u>
lb/lb fuel:	10.5041	10.3461	11.4117	10.7585
lb/MBtu	892	878	969	913
Molec Wt	<i>lb/lbmol</i>		29.609	30.813
Density	<i>lb/ft3</i>		0.07764	0.08079

Excess Air	Co-firing 50/50			
	19.362 %			
	% volume		% weight	
	wet	dry	wet	dry
O2	3.101	3.589	3.461	3.784
N2	72.271	83.652	70.979	77.614
CO2	10.895	12.610	16.724	18.287
SO2	0.1286	0.1488	0.2874	0.3142
H2O	13.605	-	8.549	-
	<u>Air_wet</u>	<u>Air_dry</u>	<u>Gas_wet</u>	<u>Gas_dry</u>
lb/lb fuel:	13.7226	13.5162	14.6604	13.4071
lb/MBtu	884	871	945	864
Molec Wt	<i>lb/lbmol</i>		28.670	30.348
Density	<i>lb/ft3</i>		0.07517	0.07957

Typical Results – Steam Temperatures

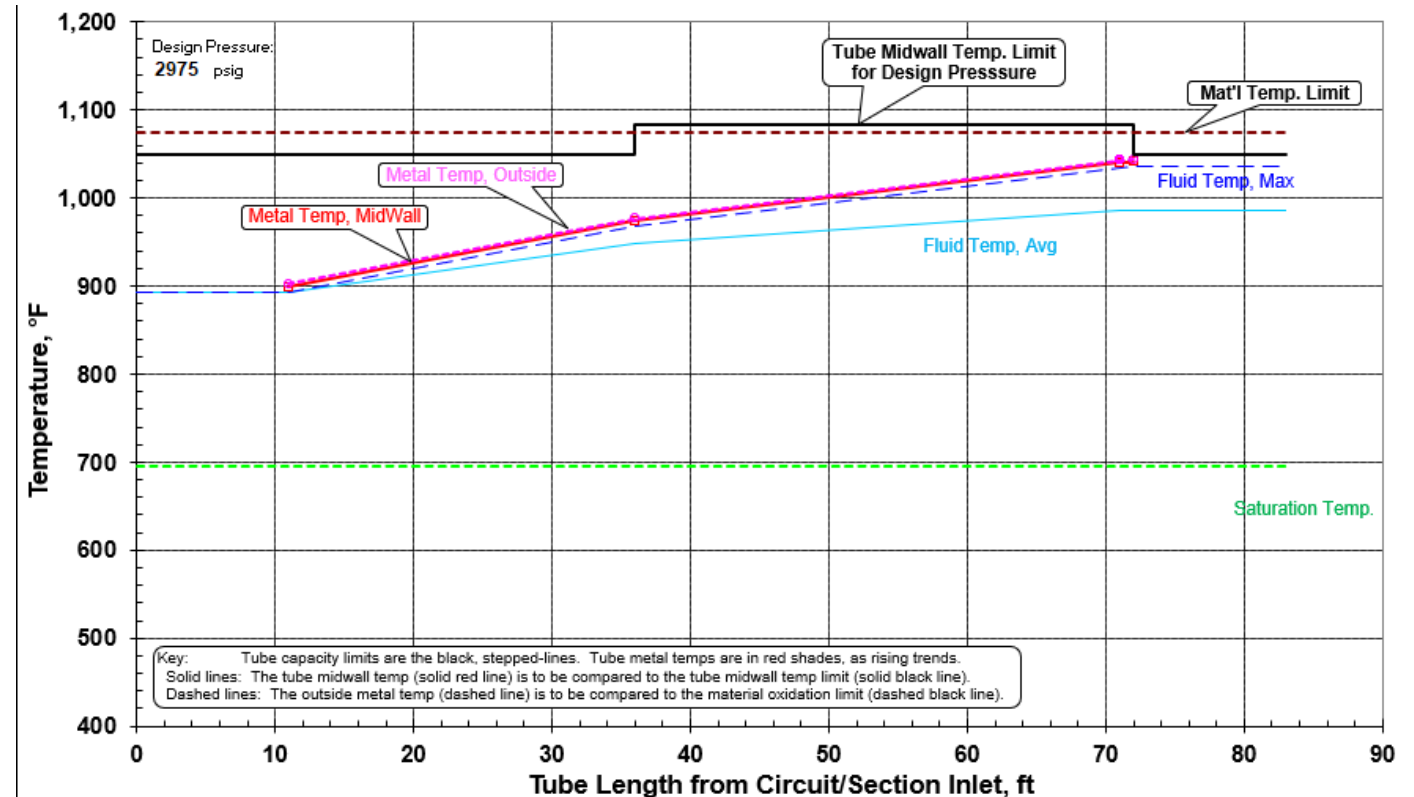
Steam Temp Comparison
Full Load



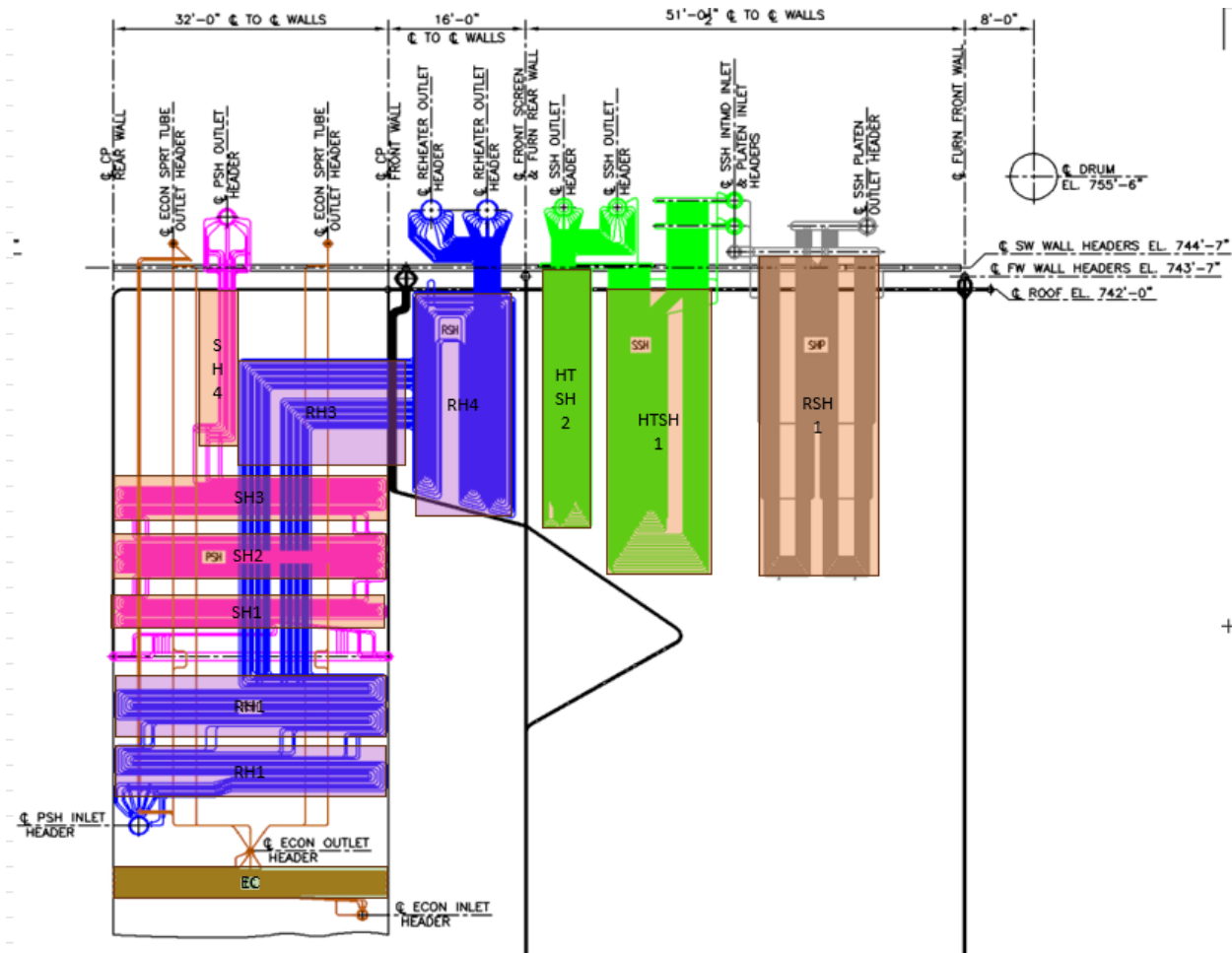
- When switching fuels from coal to natural gas, there are multiple items that may affect steam temperatures
- Changes to furnace absorption due to flame characteristics and emissivity change FEGT
- Reduction in excess air reduces total flue gas flow through the backpass reducing heat transfer
- Cleanliness of surfaces improves increasing heat transfer
- These factors generally balance out, resulting in small changes to overall steam temperature profiles
- When Co-Firing these effects are minimal, as excess air is not adjusted, and coal firing prevents improvements to surface cleanliness.
- Steam temperatures are normally similar to coal firing when co-firing at up to 50% natural gas

Typical Results – Metal Evaluation

- Metal evaluations are performed for all areas that may see higher temperatures when co-firing or firing on natural gas
- This evaluation calculates the mid wall temperature of the tubes, and compares this to the code values for material strength
- In rare cases, modifications may be required to surfaces to prevent tube failure.
 - This is more likely for full conversions, but still uncommon
 - If needed, recommended modification is upgrade of materials in specific areas or elements to allow for higher metal temperatures
- Evaluation assumes tubes are in good condition and not at end of typical wear cycle.



Typical Results – Surface Adjustments



- For co-firing, temps and sprays are generally unchanged as compared to coal firing.
 - Modelling can be done on excess air, burner tilts, etc. to optimize in many cases.
- If a unit is not meeting original design criteria when firing coal, surface redesign to adjust steam temperatures is possible and can be performed as part of an addition/conversion
- Surface may be added or removed for superheater, reheater, or economizer to improve performance
- In low temperature areas, extended surface may be applied to improve efficiency (more common for gas conversions where fouling no longer a concern)
- Air preheaters may be modified to improve energy recovery.

Typical Results – Boiler Efficiency

- Efficiency is calculated by PTC 4 which is a loss-based calculation method
- Boiler Efficiency: (HHV basis)
 - Co-firing is typically done near baseline excess air. Efficiency value often sees a small decrease
 - 100% gas firing: Efficiency value may reduce modestly.
 - The change depends on the baseline coal type (especially moisture content) and excess air being used for coal and gas.
 - This change in efficiency value has more to do with how HHV is quantified in lab; it does not mean combustion process is less efficient or that more heat is being lost.

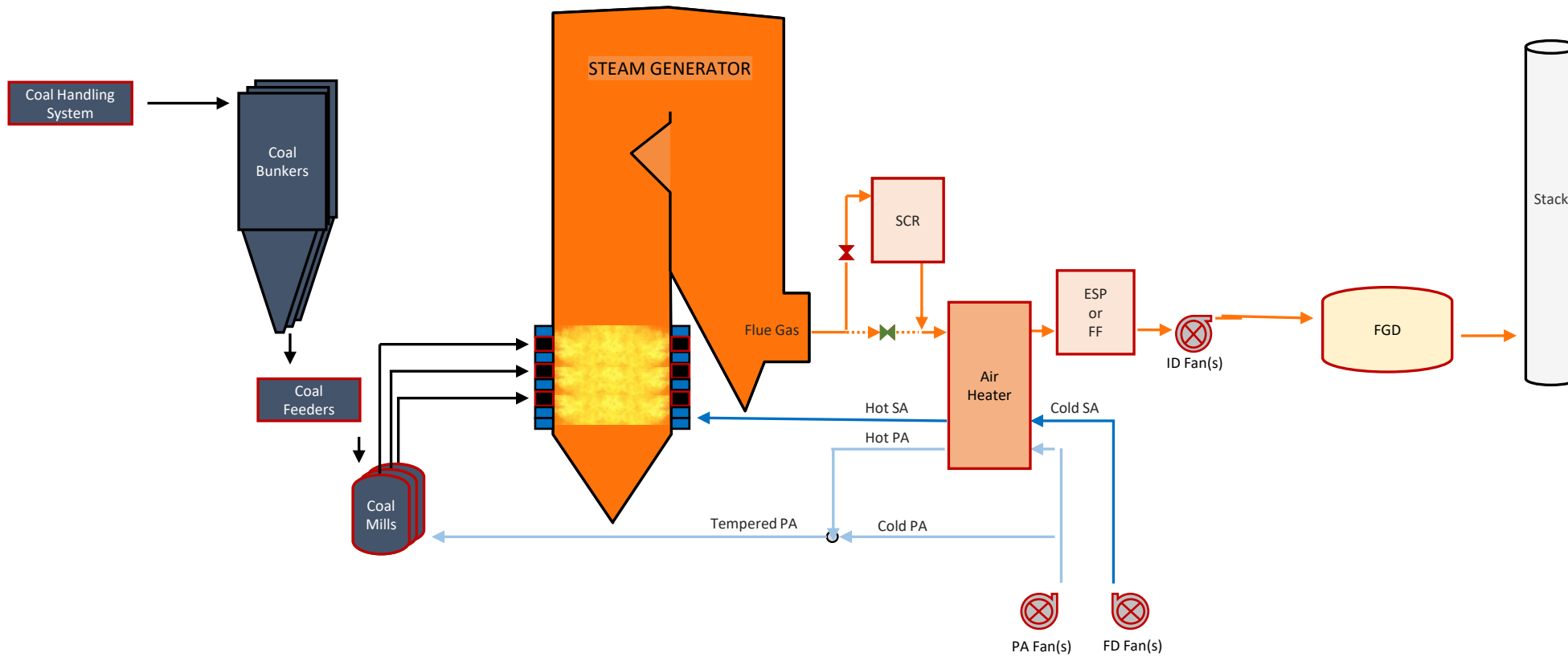
Fuel Equipment Selection

Gas Addition Equipment Overview

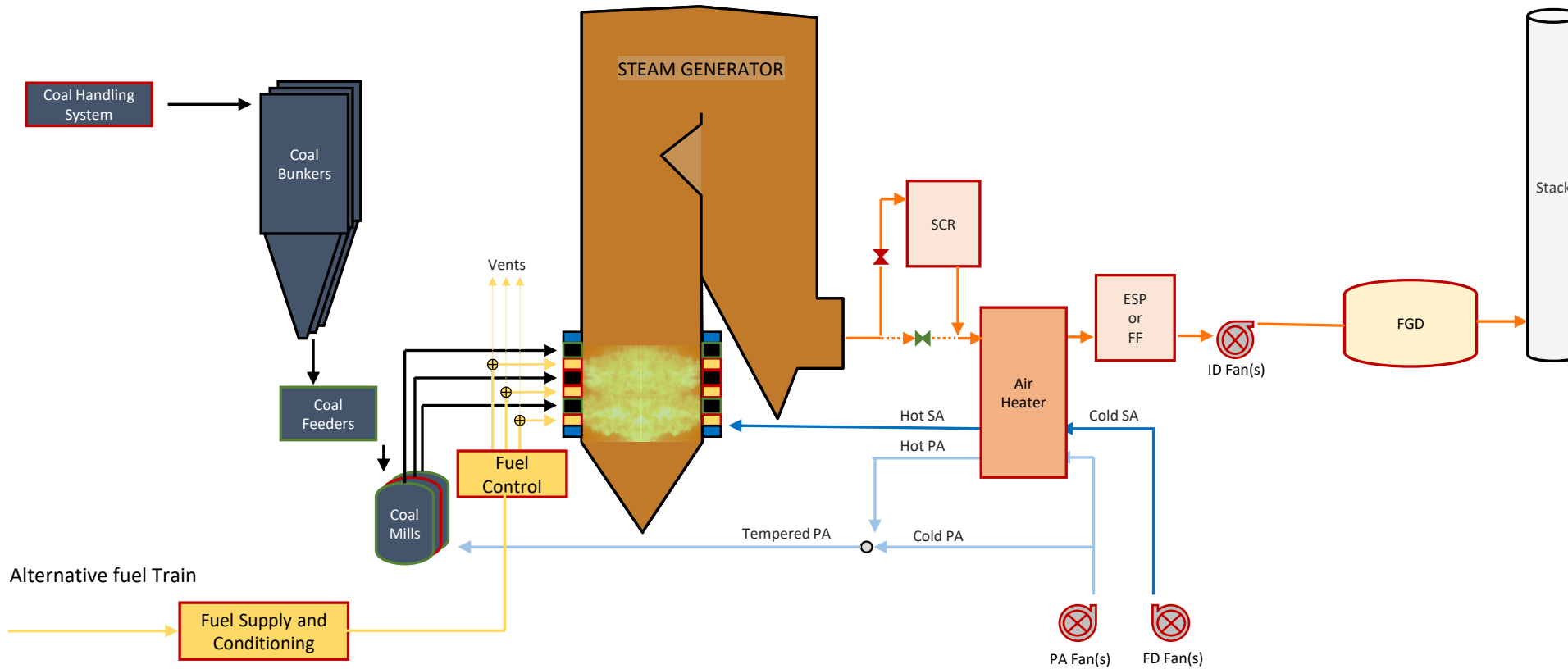
- Major components of a gas addition
 - Burners or Burner Modifications
 - Gas Skids
 - Gas Piping
 - Fuel Yard
- Safety Considerations
 - Risk Analysis
 - Hazardous Area Classification



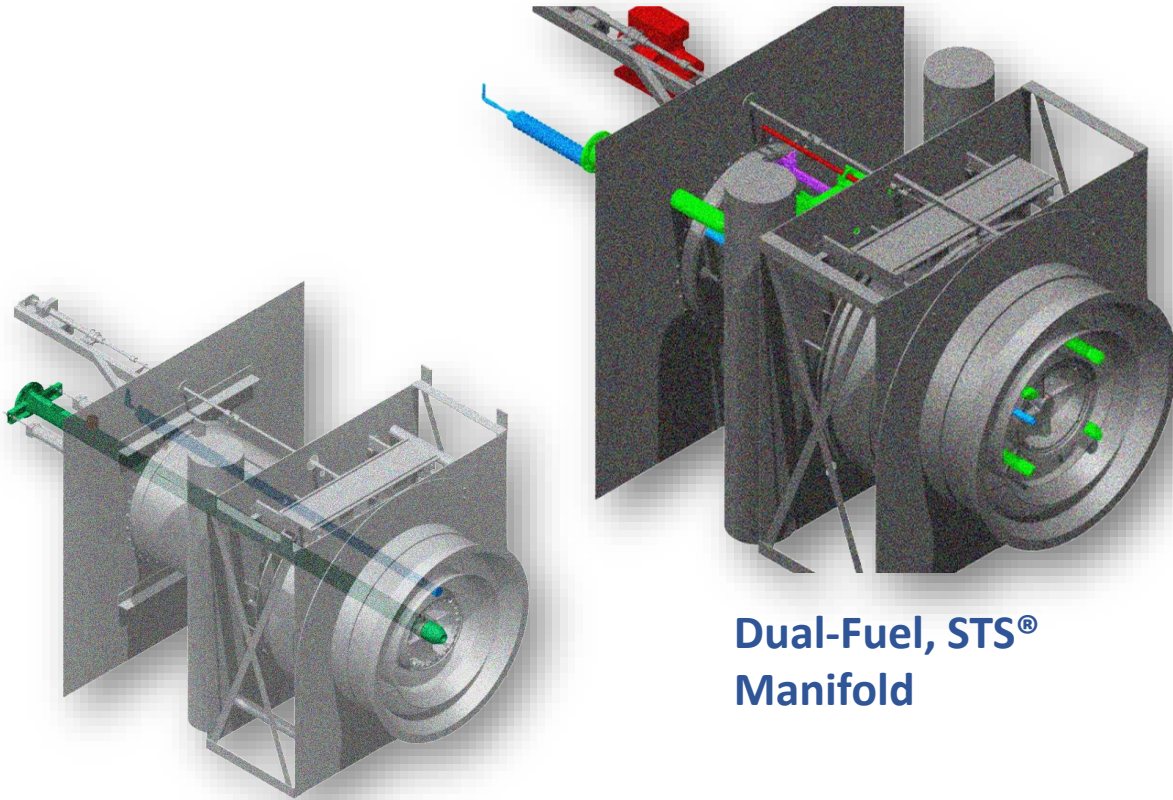
Typical Pulverized Coal Boiler



Dual-Fuel (Coal + Nat Gas)



Gas Equipment – Flat Wall Burners

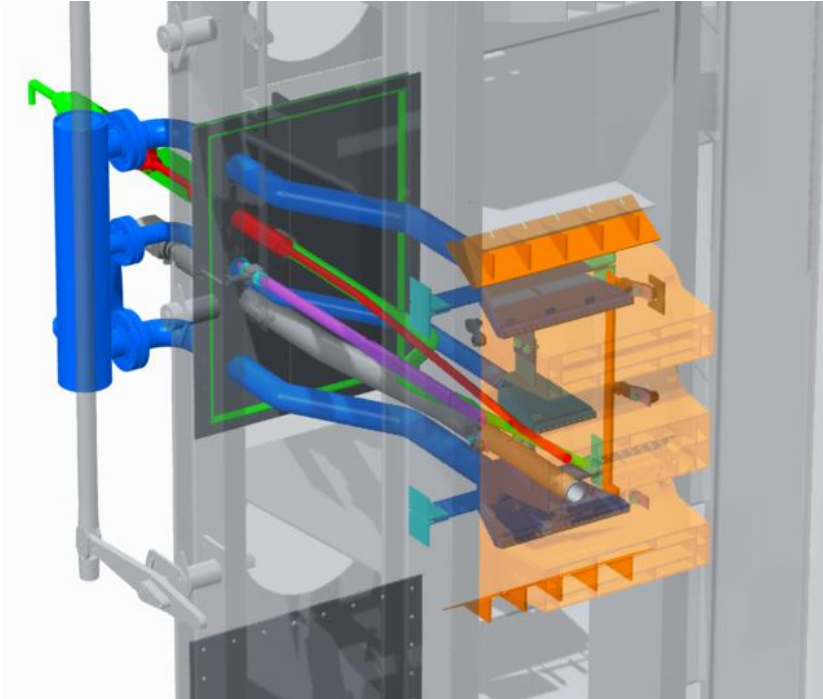


Dual-Fuel, Center-Fired Gas

**Dual-Fuel, STS®
Manifold**

- Wall fired dual fuel burners consist of a standard central coal pipe and either a central gas nozzle or multiple gas tips in the secondary air register
- Gas piping can be retrofit into many existing burner designs.
 - Burners must be in good condition to support this, and may require maintenance or replacement in some cases
- New burners may improve emissions performance in some cases

Gas Equipment – Tangential Burners



- Tangential burners consist of coal and air compartments
- Natural gas tips can be added to air compartments in between coal levels

Gas Equipment - Scanners

- As dual fuel burners can fire either coal or gas, they must be equipped with scanners appropriate to both fuels
- This can be accomplished by adding UV scanners, or replacing existing scanners with UV/IR options



**RapidEye IS Plus Series
UV/IR Scanner**

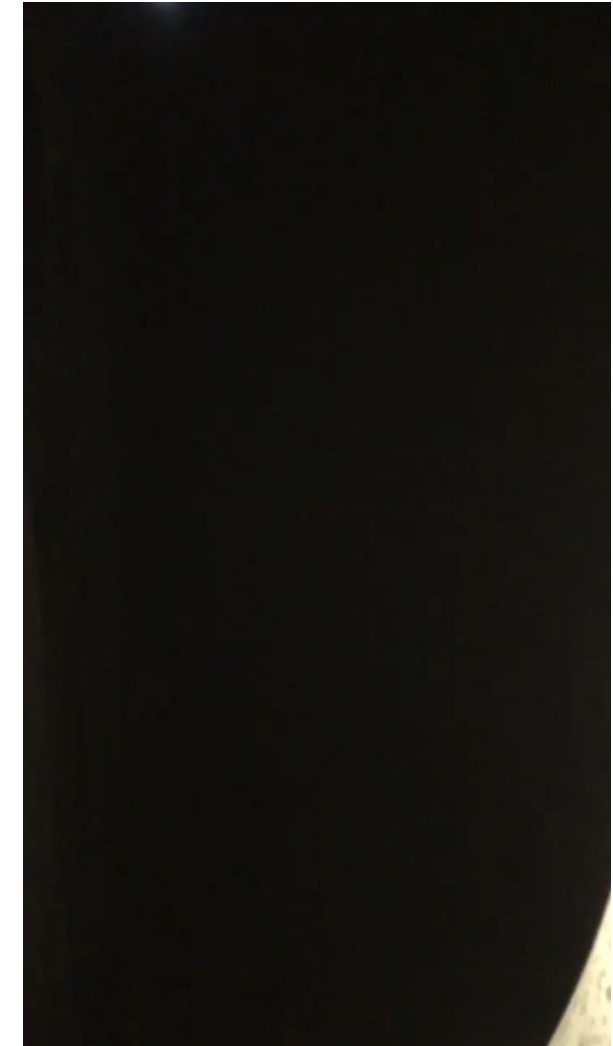
Gas Equipment - Ignitors



- With addition of natural gas to the burners, this fuel can be used as an ignition source
- This can replace existing oil ignitors, or be added as a supplemental option depending on plant preferences

Gas Equipment – Riley Power Direct Spark Ignition

- Class III – Special Ignitor
 - Main burner fuel is directly ignited using a retractable HESI (High Energy Spark Igniter)
- Large Cost Savings:
 - Eliminates equipment: igniter scanners, fuel trains, cooling air systems, etc.
 - Decreases maintenance & spares costs
- Ease of troubleshooting
- Riley Power burners are capable of high turndown
- Ease of boiler warmup
- Riley Power’s patented dual-fuel direct-spark technology allows a dual fuel unit to use the main gas burner as the ignition source for coal while also allowing up to 100% heat input on either fuel.



Gas Equipment – Control Skids



- Natural Gas fuel is supplied from the pipeline to the burners through control skids
- These skids can control the unit in multiple ways, depending on overall goals
 - Typical arrangements include elevation control, and unit control
- Additional block and bleed stations are placed at each burner as recommended by NFPA

Gas Equipment - Fuel Yard

- The Fuel yard may consist of the following components
 - High Pressure Gas Regulating Skid
 - Gas Heater(s)
 - Gas Filtration

Questions For Your Gas Supplier

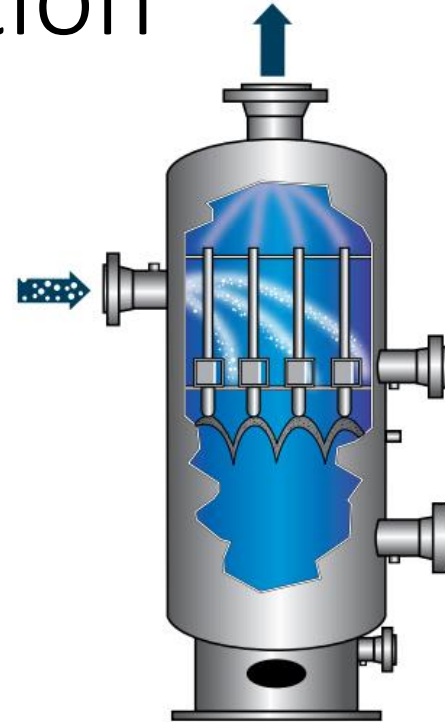
- What equipment will be provided at plant boundary
- What quality natural gas is guaranteed by your Tariff/Contract
- Location of tap/lateral on pipeline



Gas Equipment - Filtration

Cyclone / Knock Out Tank

- Maintenance Free
- Large Range of Flows
- Removal Efficiency
 - Solids:
 - 100% of 8 micron particles & larger
 - 99% of 6 – 8 micron particles
 - 90% of 4 – 6 micron particles
 - 85% of 2 to 4 micron particles
 - Liquids
 - 100% of all droplets 8 microns & larger



MULTI-CYCLONE SCRUBBER
FOR APPLICATIONS REQUIRING
EFFICIENT DUST AND LIQUID REMOVAL.



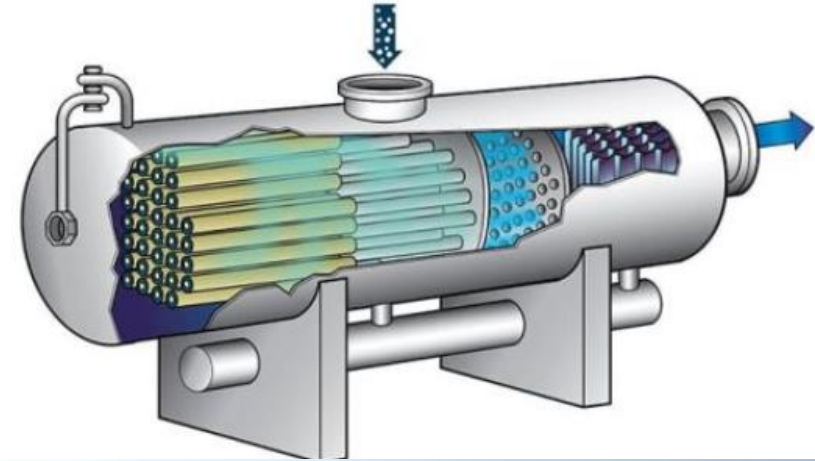
**Assembled Drain Tank &
Cyclone Scrubber**

ONE SOURCE. MANY SOLUTIONS.

Gas Equipment - Filtration

Coalescing Separators

- Requires Maintenance
- High Removal Efficiencies
- Removal Efficiency
 - Solids:
 - 100% of 1 micron particles & larger
 - 99.5% of 0.5 – 1 micron particles
 - Liquids
 - 100% of all droplets 8 microns & larger
 - 99.5% of 0.5 – 8 micron droplets



**Assembled 2x100% Coalescing Separators
& Drain Tanks**

Gas Equipment - Filtration

Filter Skid

- Ideal for plants where gas supplier has provided filtration at metering station
- Parallel runs of Y-Strainers
- Requires Maintenance
- Removal Efficiency
 - Solids:
 - 100% of 425 micron particles & larger
 - Liquid: N/A



Filter Skid

Gas Equipment - Heating

Questions For Your Gas Supplier

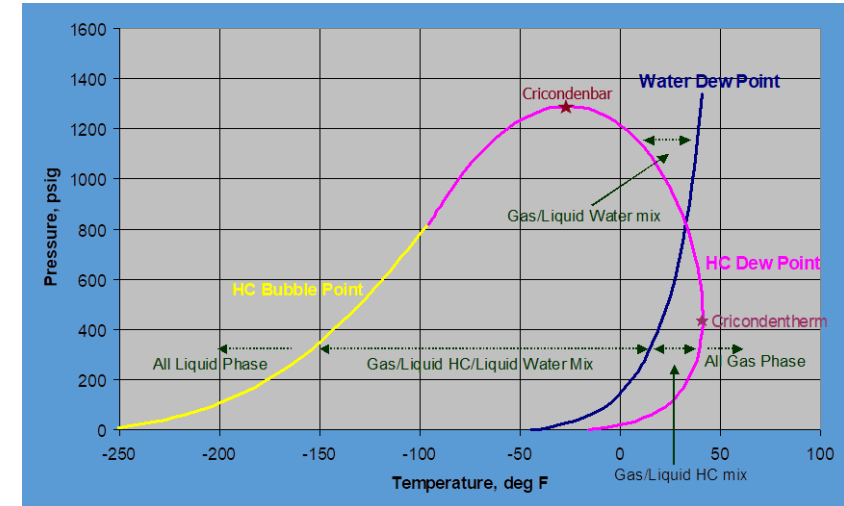
- What is the delivery pressure
- What is the hydrocarbon dewpoint

Why Heat Your Natural Gas

- Joule-Thomson Effect
 - Conservative Estimate: 7°F for every 100 PSIG of Pressure Drop
 - Modeling/Experience: 0.05 °F/PSIG
- Hydrocarbon dewpoint control
- Icing Control
 - Internal & External

Technology

- Water Bath
- Indirect Fired Thermal Fluid System



Fuel Equipment - Gas Heating

Water Bath Heater

- Pros:
 - Skidded assembly
 - Historic usage in plants
 - Simplicity
 - Low Maintenance
- Cons:
 - Low Thermal Efficiency: ~80%
 - Limited turndown
 - Governed by burner turndown & Bypass Flow Control Valve
 - Large glycol volume

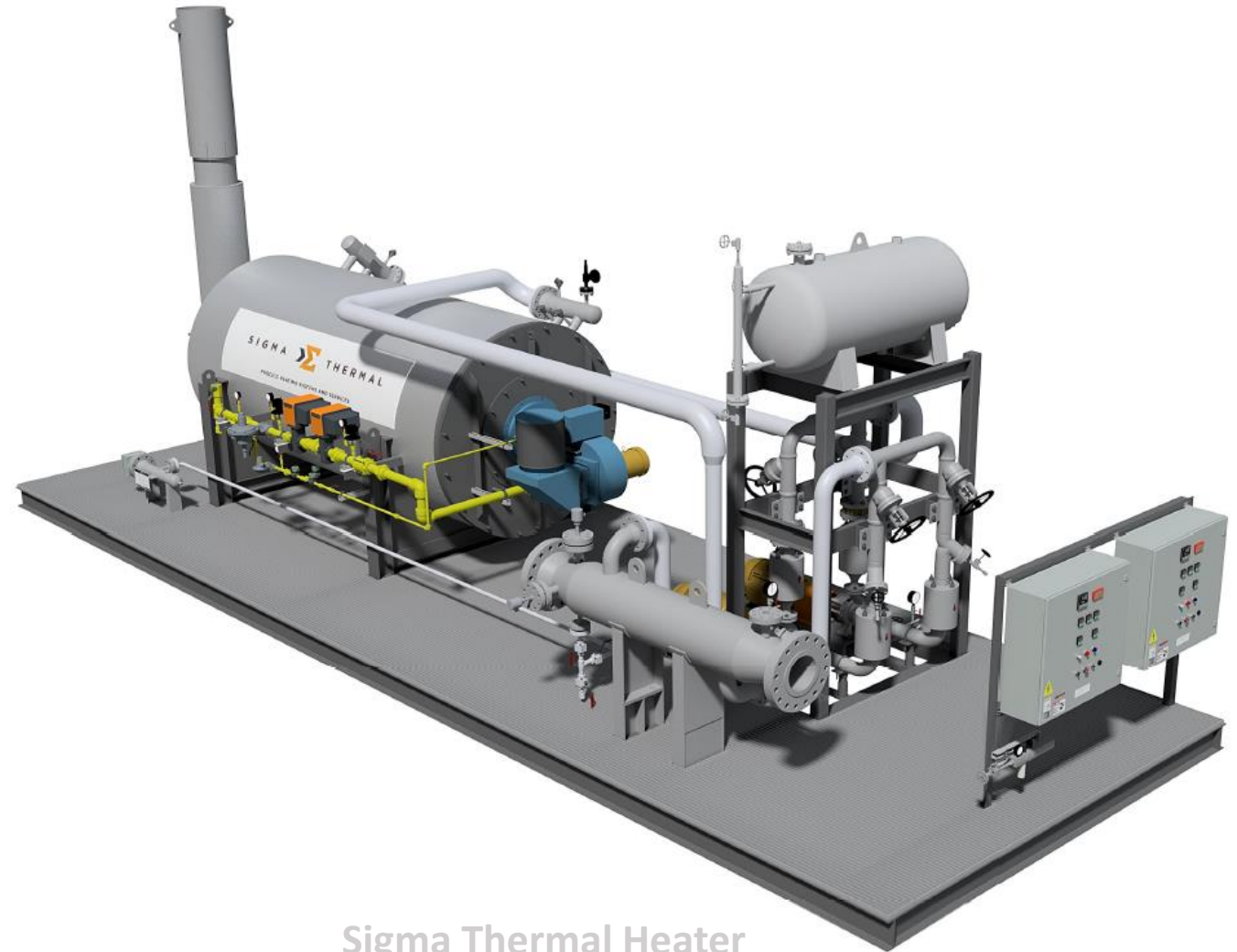


Sigma Thermal Heater

Fuel Equipment - Gas Heating

Indirect Fired Thermal Fluid System

- Pros:
 - Large turndown/Increased Flexibility
 - Burner Turndown, Glycol Temperature Setpoint, Glycol Flow Through HX
 - High Thermal Efficiency: ~87%
 - Only about ~4% of the required volume of glycol compared to Water Bath Heater
 - Skidded assembly
- Cons:
 - Increased equipment
 - Increase maintenance



Sigma Thermal Heater

Gas Equipment - Gas Regulation & Overpressure Protection

Questions For Your Gas Supplier

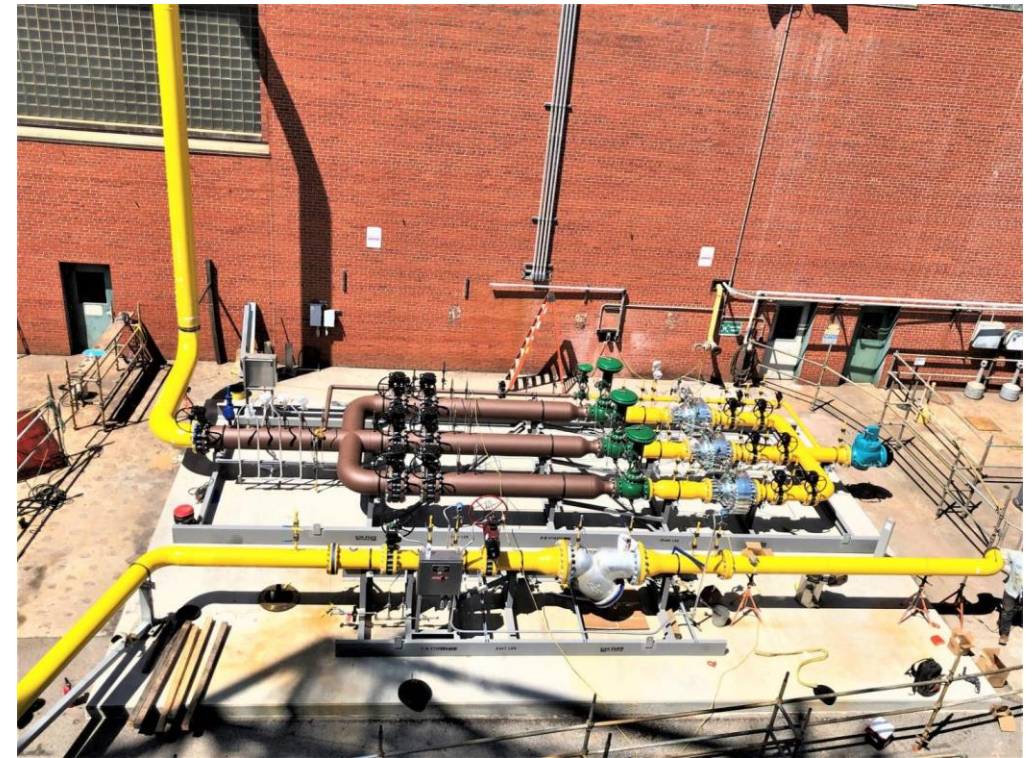
- What is the delivery pressure range
- What is the design pressure of the pipeline/lateral

Why Overpressure Protection

- ASME B31.1 122.8.1.D(1) requires overpressure protection anytime a pressure class change occurs in the piping system
- B31.1 Power Piping (in-plant) vs B31.8 (Gas Transmission and Distribution)

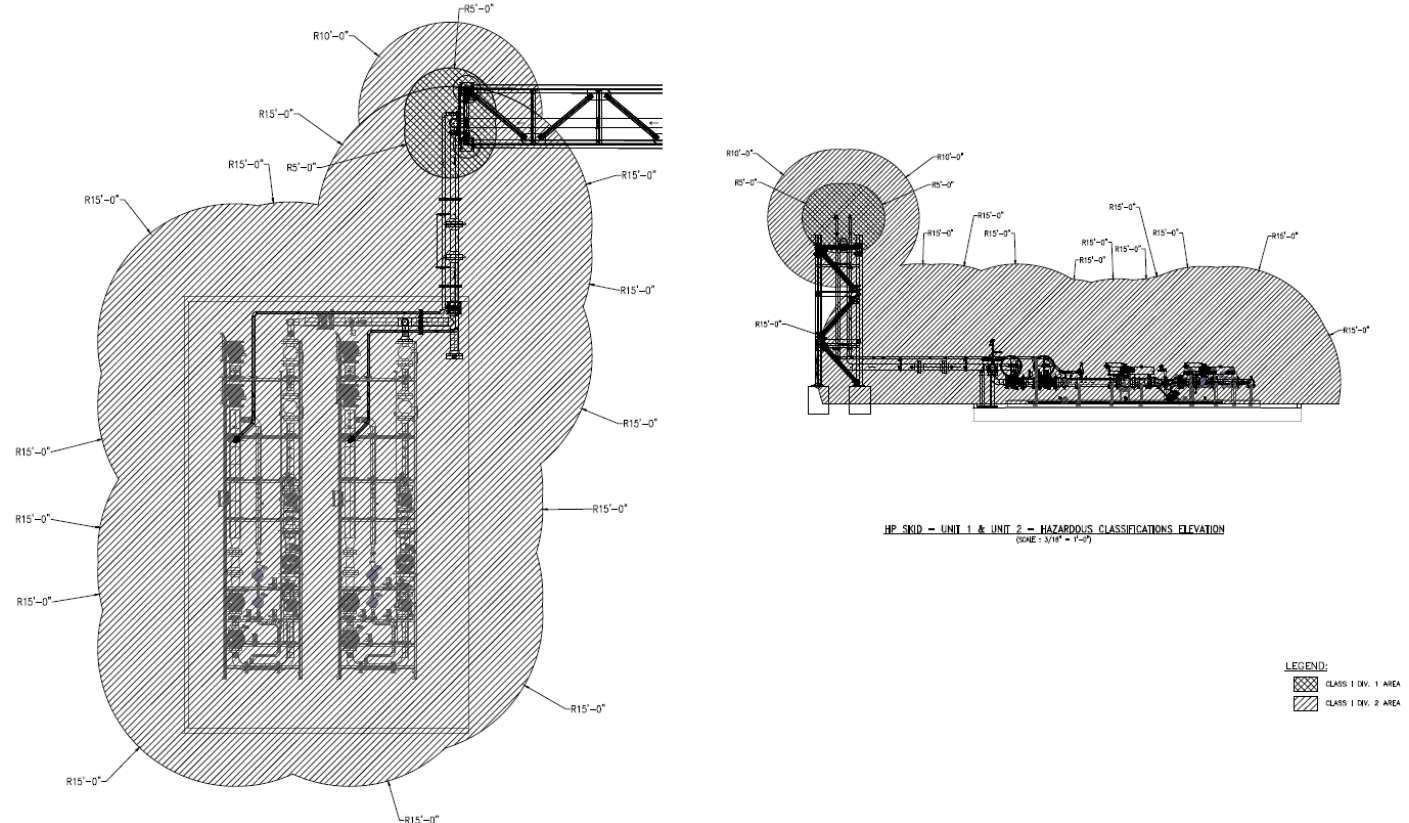
Why Pressure Regulation

- Isolates the boiler from fuel supply pressure variations caused by either the pipeline or other assets on the property
- Decrease pressure prior to entering the building (HAZOP and Hazardous Area Implications)



Safety Considerations – Hazardous Area Classifications

- Identify areas in the plant where hazardous area classification will change due to the introduction of natural gas piping
- Guiding Documents:
 - NFPA 497
 - API RP 500
- Activities
 - Ventilation Study
 - Hazardous Area Drawings
 - Hazardous Area Report
 - Gas Detector Location
 - Modification of Existing Equipment



Impact on Emissions

Co-Firing Emissions Overview

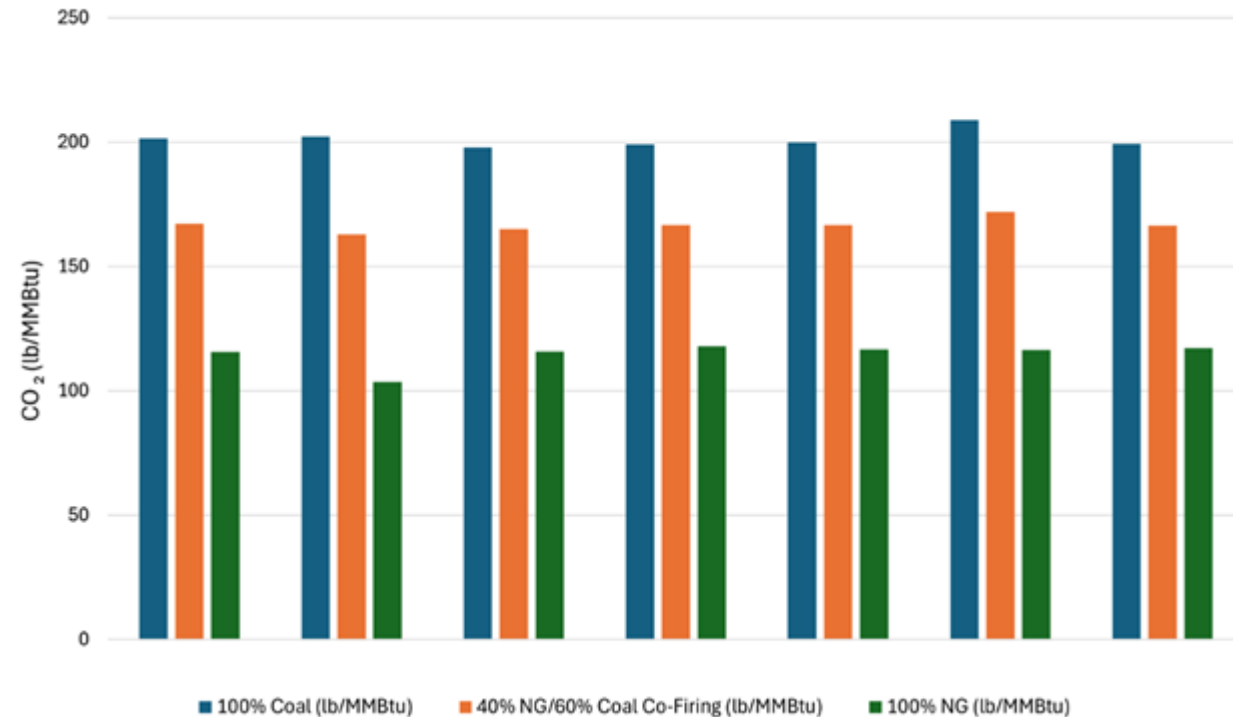


- Expected Emissions
 - CO₂
 - NO_x
 - SO_x, PM, Hg
- Adjustments to AQCS equipment?
 - SCR
 - FGD
- Aux Equipment Demand

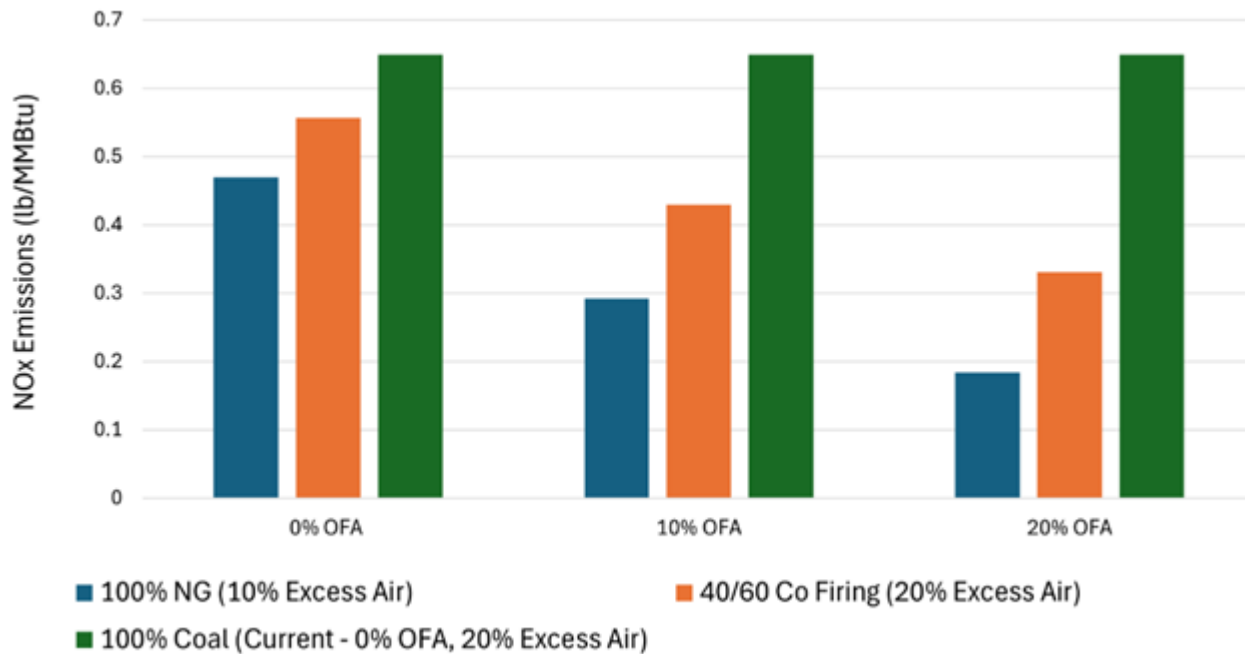
Emissions – CO₂

- CO₂ emissions are reduced when firing natural gas as compared to coal
- CO-firing natural gas with coal provides a proportional reduction in CO₂
- Gas addition is a low cost method to reduce overall CO₂ generation

CO₂ Comparison – Multiple Units



Emissions – NOx



- NOx generation is impacted by many factors
 - Excess air
 - Overfire air (OFA)
 - Combustion air temperature
 - Flue Gas Recirculation (FGR)
- Firing natural gas typically improves NOx generation
- Co-firing also improves NOx emissions, but to a lesser extent, impacted by air conditions

Emissions – SO_x, PM, Hg

- SO_x emissions are a function of the sulfur in the fuel. As a result they will be reduced proportional to the amount of natural gas burned as there is practically zero sulfur in natural gas
- The same is true of particular matter, with a direct and proportional reduction matching natural gas input
- Mercury is also a pass-through value based on the fuel content, and behaves similarly

Emissions – Impacts to SCR systems

Figure 7.5 - SCR Performance (Per Unit): NOx Removal - Candlestick Plot

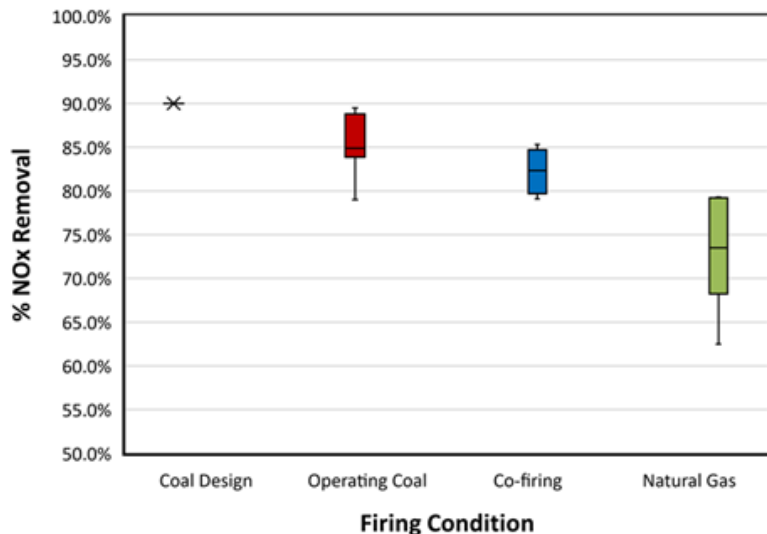
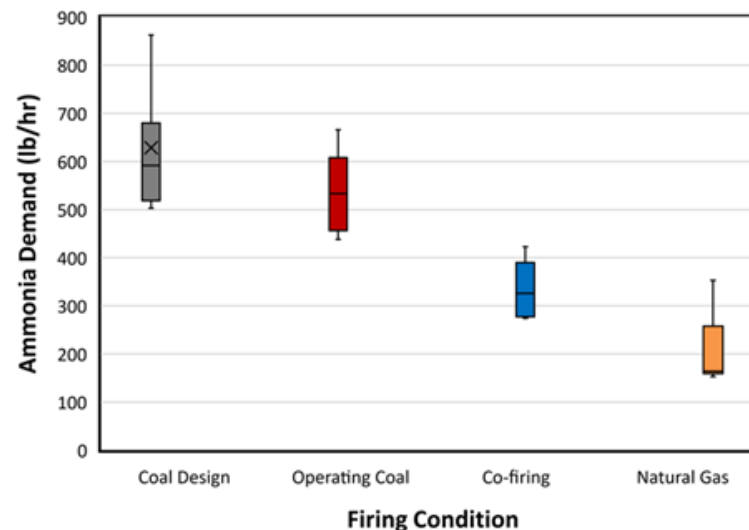


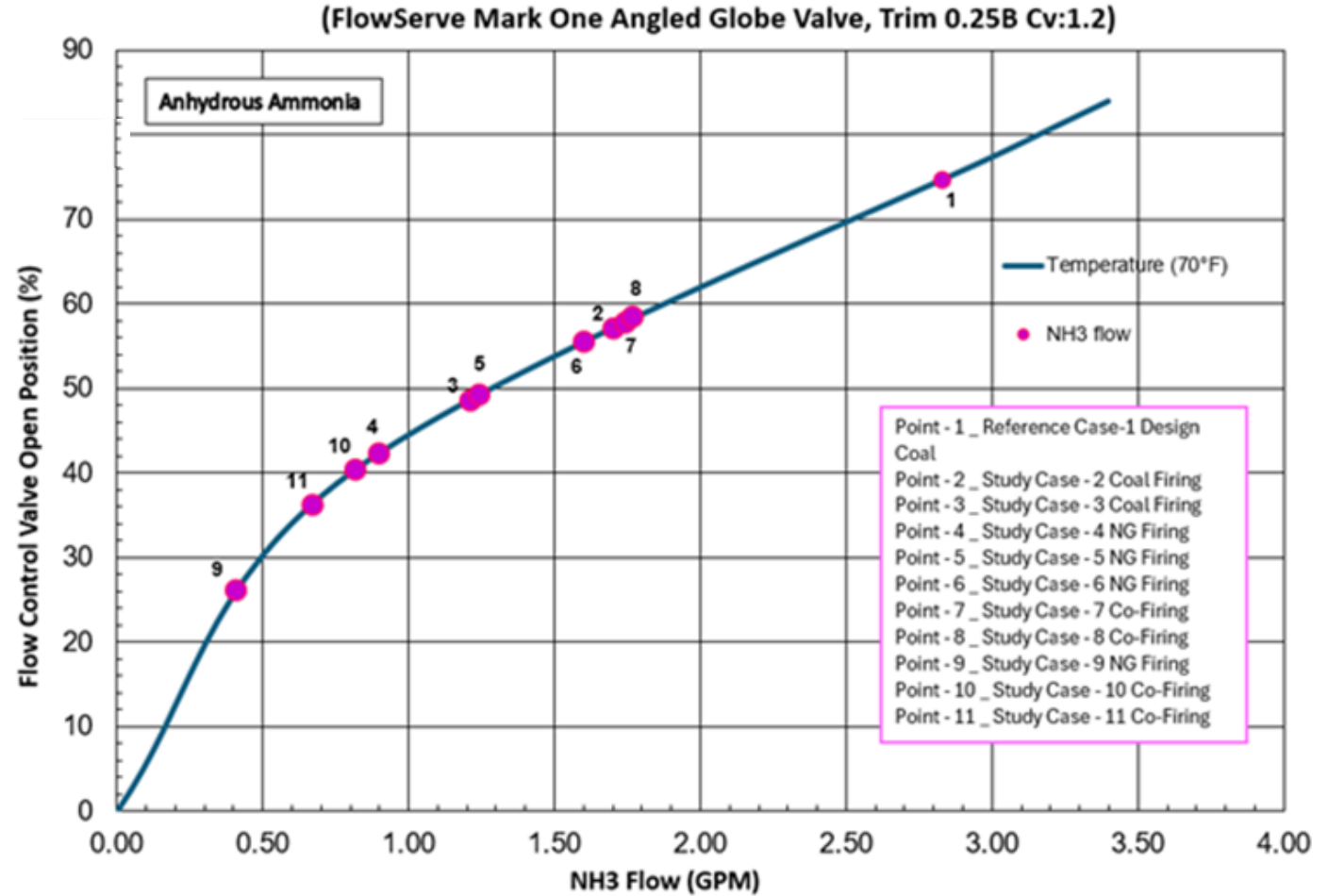
Figure 7.7 - SCR Performance (Per Unit): Ammonia Demand - Candlestick Plot



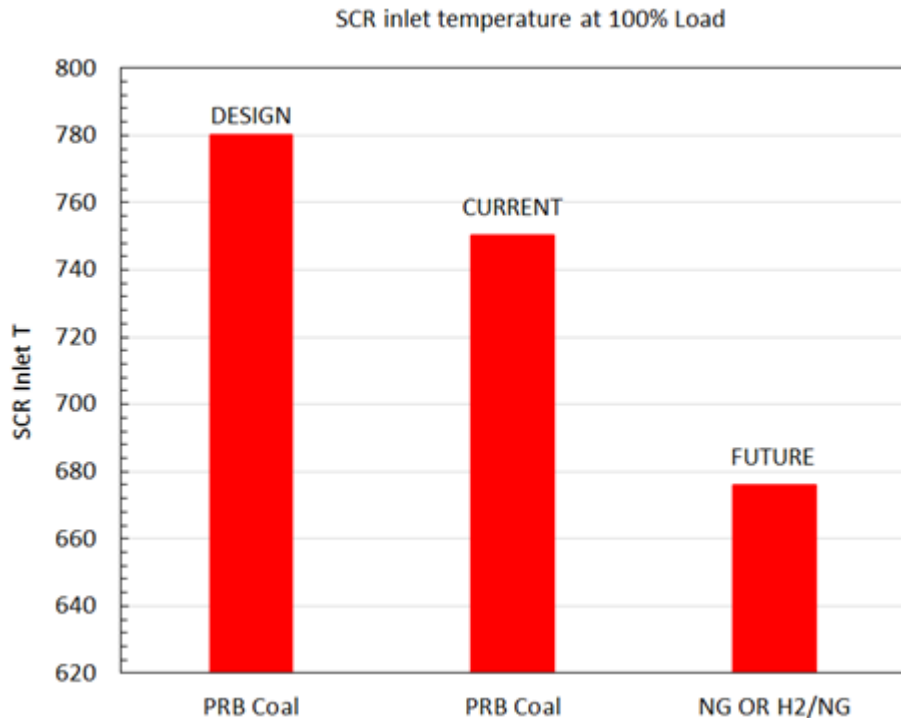
- Amount of NOx reduction required is reduced by lower inherent emissions when co-firing
- Operation of AQCS equipment is managed to meet permit requirements
 - If permit limits are reduced, SCR will operate with slight reductions in ammonia flow
 - If permit limit unchanged, significant reduction in reagent flows become possible

Emissions – Impacts to SCR systems

- With reduction in ammonia requirements, control system requires evaluation
- For lower turn down on ammonia system valves may require replacement
- Flow measurements may require evaluation for new range



Emissions – Impacts to SCR systems

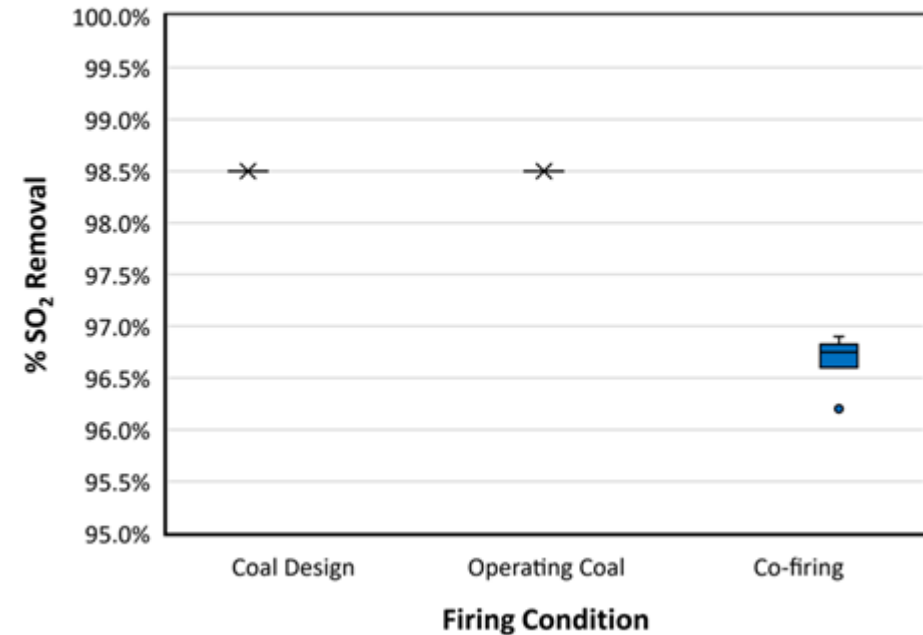


- Gas inlet temperatures are critical to proper catalyst operation
 - For high load co-firing cases, inlet temperatures are typically similar to base coal operation
 - At low loads, when firing natural gas only temperatures may be reduced further and impact SCR
 - Catalyst activity may be reduced at lower temperatures, but requirements are also reduced
- Catalyst life is extended when co-firing due to reduction of catalyst poisons (heavy metals, arsenic, calcium blinding, etc)

Emissions – FGD Impacts

- FGD systems remain in service for co-firing cases
- Reduced reagent demand based on required permit levels due to lower inherent emissions when co-firing
- Possible reductions in cooling water demand for low load or natural gas only cases

Figure 7.11 - WFGD Performance (Per Unit): SO₂ Removal - Candlestick Plot



Emissions – Aux Equipment

- Aux equipment loads are typically reduced for co-firing cases
 - Air compressors for instrument and service air
 - Service and process water supply systems
 - Steam and condensate handling
 - Waste water treatment
- Some of these items may be eliminated fully for 100% natural gas operation

Any Questions?

