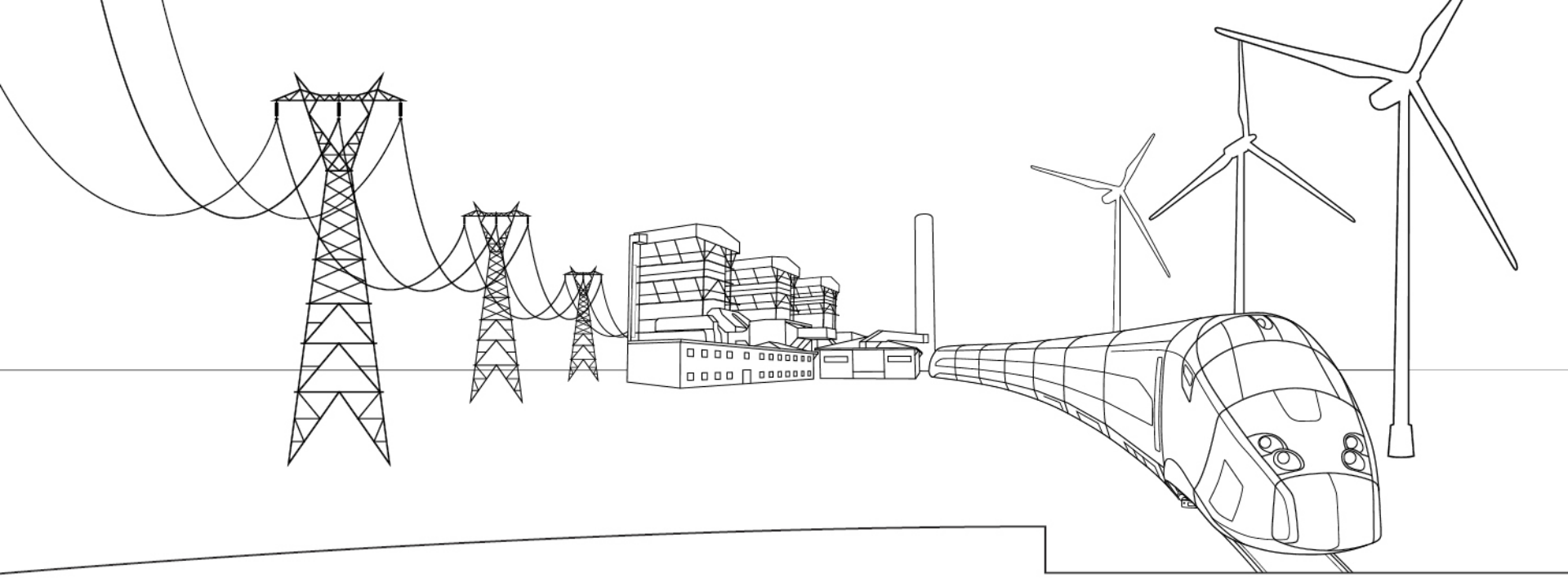
REINHOLD ENVIRONMENTAL Ltd.

2013 Coal to Gas Conversion Round Table & Expo Presentation

October 29, 2013, in Chattanooga, TN / Sponsored by Southern Company



Coal & Natural Gas Co-Firing Conversions

Danny Gelbar
Manager of Performance Design Engineering

Chattanooga, TN

10/29/13

ALSTOM
Shaping the future

Items Covered in this presentation

- **Background on Coal Fired Boilers**
- **Review of Converting Bituminous Coal Fired Boiler to Natural Gas Firing**
- **Coal & Natural Gas Co-Fired**
- **Coal & Natural Gas Co-Fired in a 600 MW Boiler Designed for PRB Coal**
- **Summary of Coal & Natural Gas Co-Firing**

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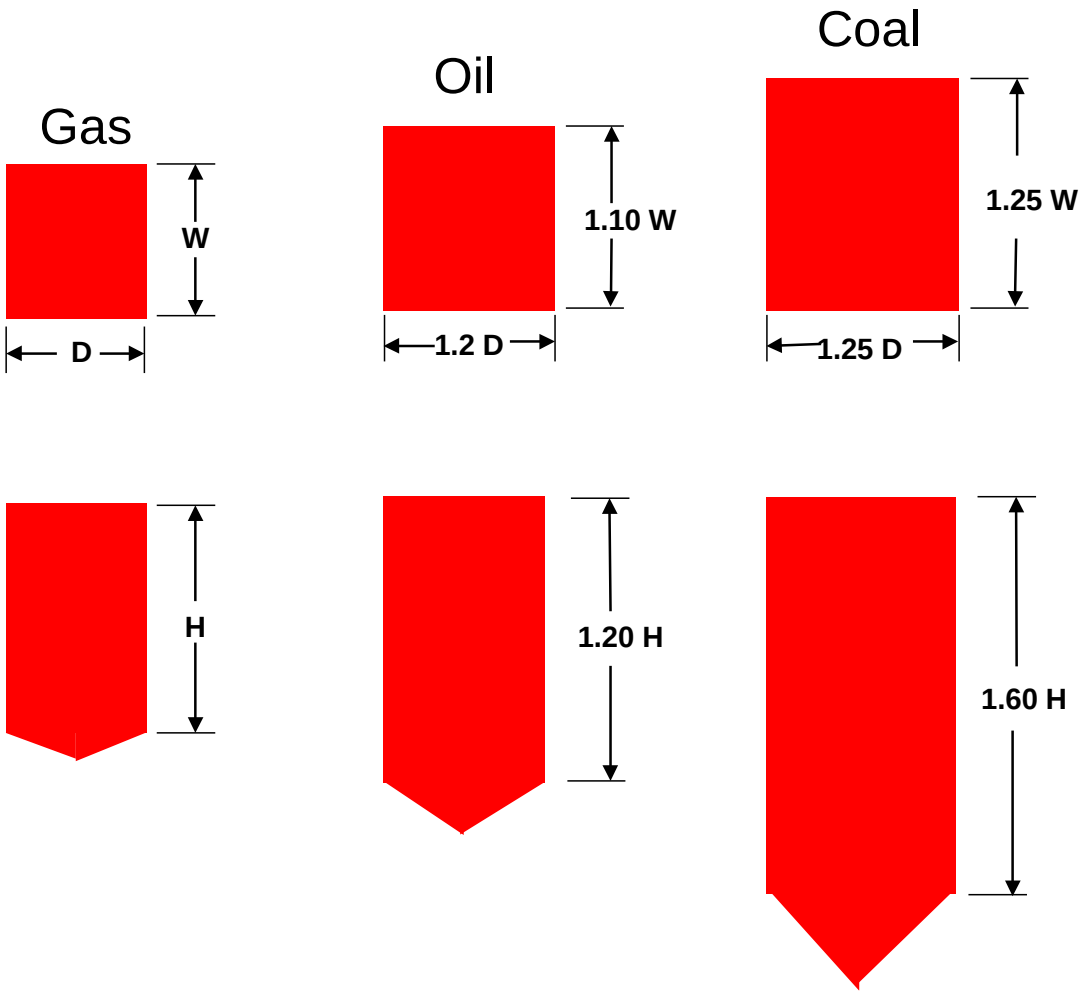
Background on Coal Fired Boilers

Normal Boiler Sizing

- Boilers are normally designed for a specific fuel.
- Anytime a boiler has a change in fuel, there will be performance compromises.



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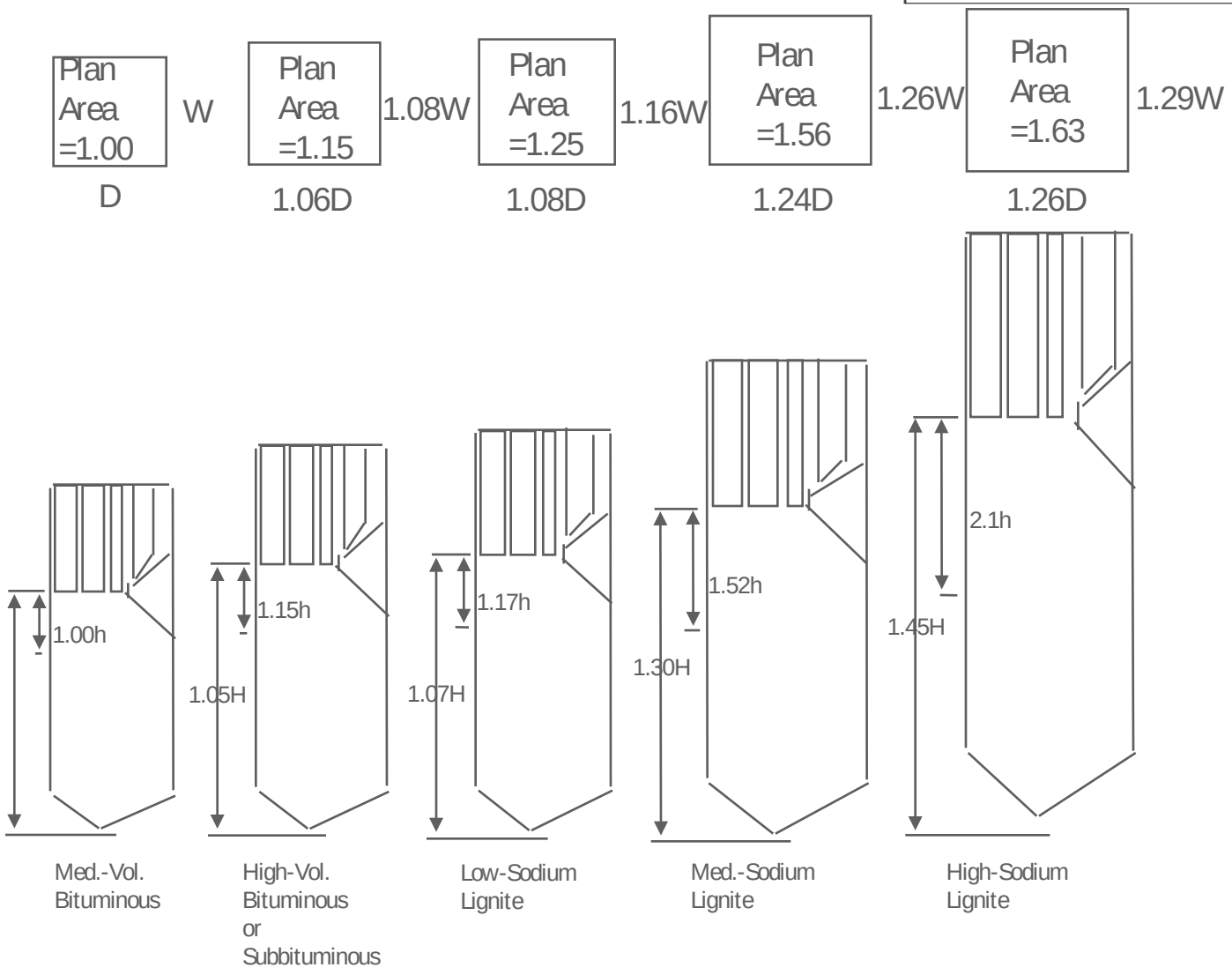
Coal Fired Boilers



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Review of Converting Bituminous Coal Fired Boiler to Natural Gas Firing

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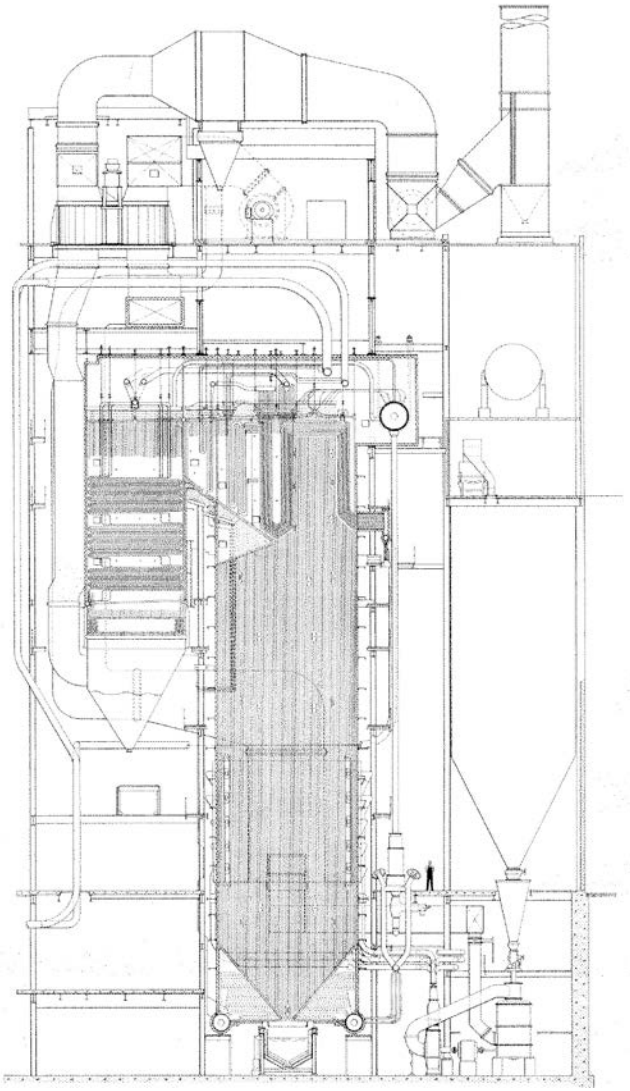
Bituminous Coal Fired Boiler

PROPOSED FUEL	EASTERN BITUMINOUS COAL			ASH FUS. TEMP. F		BTU PER LB AS FIRED	HARDGROVE GRIND
F.C. 55.8 %	VOL. 31.1 %	MOIST. 4.0 %	ASH 9.1 %	S. -		13,370	55
FUEL BURNING EQUIPMENT	CONT. SECT. RB	5 - No. 633 Raymond Bowl Mills and Tilting Tangential Burners					
FURNACE	CONT. SECT. PFSS	SQ.FT.H.S. PER FURN. 54,000	TYPE OF BOTTOM Basket				
Plain Tube Furnace							
FRONT TO REAR 28'-2"	WIDTH 40'-6-1/2"	VOLUME 116,500 CU.FT. GROSS					
BOILER	CONT. SECT. BCC	NO. 1	SQ.FT. H.S.EA. -	PRESSURE DESIGN	PRESSURE OPERATING		
DESIGNATION 40'-6½" / 28'-2" 320-1½ / 160-1½ CCRR 60 / 2-36			MFR. C-E	2700	2450 at S.O.		
			STEAM WASHER	BOILER NUMBER	3		
SUPERHEATER	CONT. SECT. SH	TYPE Multi-Stage with Channel		DESUPERHEATER			
CONTROL RANGE 660,000 to 1,200,000 with burner tilt & desuperheater		SQ.FT. H.S. 100,300		FOR SUPHT'R. Spray			
REHEATER	TYPE Interstage	SQ.FT. H.S. 15,200		FOR REHEATER Spray			
ECONOMIZER	CONT. SECT. CONS	NO. 1		MAKE C-E			
TYPE CF-S 8H x 76W x 40'-6" lg.				SQ.FT. H.S.EA. 26,575			
AIR HEATER	CONT. SECT. CAHL	NO. 2		MAKE Ljungstrom			
TYPE 24-1/2 H 54				SQ.FT. H.S.EA. 100,800			
MISCELLANEOUS DATA	Contract included steel-encased settings, insulation, duct-work, circulation pumps & piping, steam temp. controls.						

EXPECTED PERFORMANCE						GENERATOR KW
FUEL		COAL				1 - 165,000
LB STEAM PER HR-ACTUAL	PRIMARY	660,000	1,100,000	*1,160,000	*1,200,000	- 6 Hr. Peak - 18 Hr. Interval.
	REHEAT	592,500	975,000	1,023,000		
FEEDWATER TEMP. TO	ECON.	420	467	470		REHEAT DATA
	BOILER	465	505	507		1,023,000 LB STEAM/HR.
STEAM TEMP at S.O.& R.O.		1050-1000	1050-1000	*1050-1000		Enter. Temp. 669 F
HEAT RELEASE BTU/CU.FT./HR.		8,150	12,850	13,450		" Press. 507 Psi
TEMP. GAS FROM AIR HEATER		245	280	282		Leav. Temp. 1000 F
TEMP. AIR FROM AIR HEATER		525	562	567		" Press. 474 Psi
OVERALL EFFICIENCY %		89.71	88.99	*88.95		



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Bituminous Coal Fired Boiler

- Alstom performed a study to convert to 100% natural gas firing. For study purposes, customer has defined normal full load (NFL) at 185 MW. Coal firing will be eliminated.
- To convert the unit to natural gas firing, the Alstom will provide four elevations of load carrying gas guns, coupled with Class 1 gas-fired ignitors. The ignitors will be located adjacent to the gas guns, which will be installed in the top four coal compartments. Using Class 1 ignitors eliminates the need for flame scanners; however, they can be used if desired by the plant. The gas guns will be sized for full load capability *without* ignitors on, in case the plant installs flame scanners, now or in the future.

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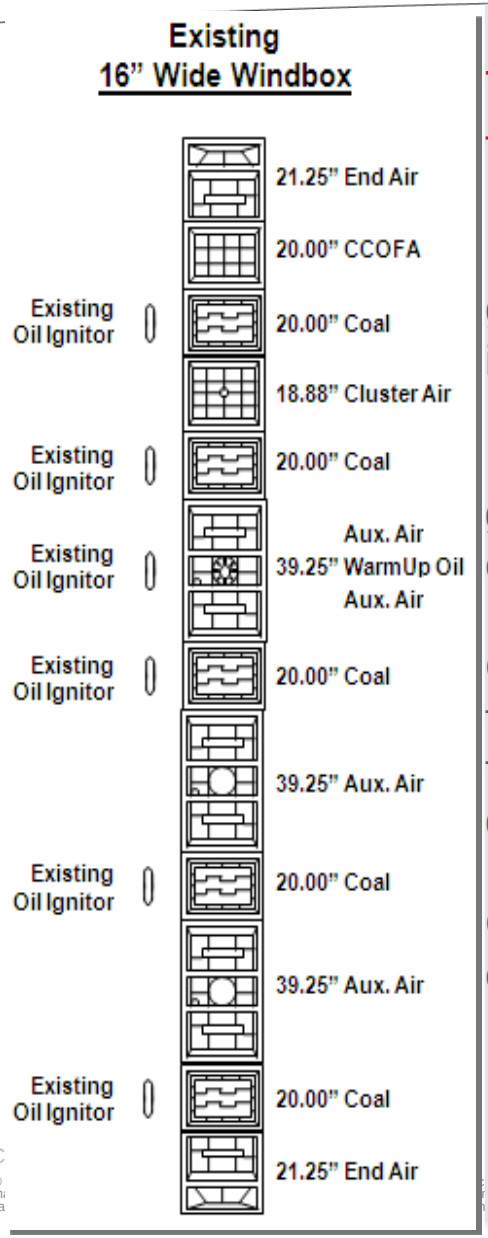
Bituminous Coal Fired Boiler



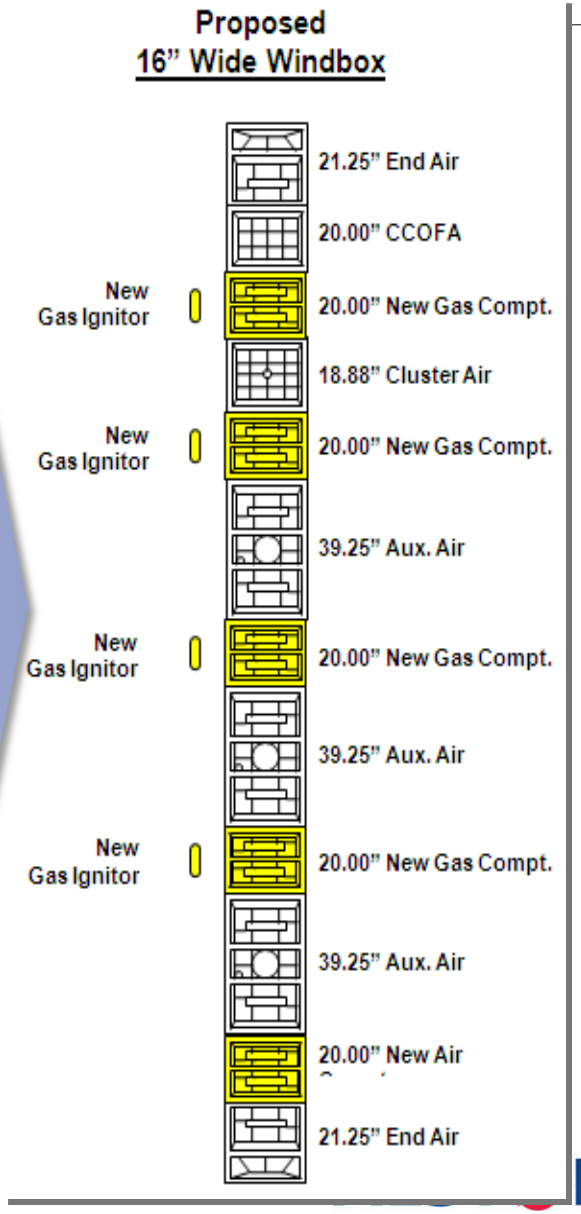
To convert this unit to NG firing, Alstom proposes:

Four elevations of load carrying gas guns, coupled with Class 1 gas ignitors.

Ignitors located adjacent to gas guns and installed in the *top four* coal compartments.

Class 1 ignitors eliminates need for flame scanners, although flame scanners may be used (if desired by Plant)

Gas guns sized for full load capability *without* ignitors on



Bituminous Coal Fired Boiler

		Original Design	Test Data Coal	Natural Gas	Natural Gas	Natural Gas
Date			03/29/2`011			
				No Mods.	Add 31% more RH Finishing Surface	Add Gas Recirculation
Gross Load	MW		184			
Load	%	103.5% MCR	104.8% MCR	104.8% MCR	104.8% MCR	104.8% MCR
		6Hr. Peak				
Main Steam Flow	lb/hr	1,200,000	1,216,118	1,216,118	1,216,118	1,216,118
Reheater Steam Flow	lb/hr	1,063,000	1,113,651	1,113,651	1,113,651	1,113,651
SH Spray Flow	lb/hr	0	51,558	11,804	7,062	85,317
RH Spray Flow	lb/hr	0	0	0	0	0
SH Outlet Steam Temperature	°F	1,050	1,050	1,050	1,050	1,050
RH Outlet Steam Temperature	°F	1,000	999	972	1,000	990
CRH Steam Temperature	°F	670	686	686	686	686
Economizer Water Inlet Temperature	°F	472	457	457	457	457
Economizer Water Outlet Temperature	°F	508	509	507	507	519
Drum Pressure	psig	2,568	2,386	2,386	2,386	2,386
SHO Pressure	psig	2,450	2,290	2,290	2,290	2,290
CRH Pressure	psig	524	494	494	494	494
Economizer Outlet Gas Temperature	°F	681	665	664	664	689
Air Heater Inlet Gas Temperature	°F	681	619	664	664	689
Air Heater Outlet Gas Temperature uncorr.	°F	290	310	314	314	323
Air Heater Outlet Gas Temperature corr.	°F	270	301	305	305	313
Air Heater Outlet Air Temperature	°F	570	512	532	531	556
Air Heater Inlet Air Temperature	°F	80	93	93	93	93
	%	88.94	88.76	83.98	83.98	84.08
Heat Input	Mbtu/hr	1,618	1,667	1,742	1,763	1752
Excess Air	%	15	16	20	20	12
Fuel Nozzle Tiilt	degrees	Horiz.	-7	+15	+15	+15
Gas Recirculation	%					20
Fuel Elevations in Service	Number	5	5	4	4	4

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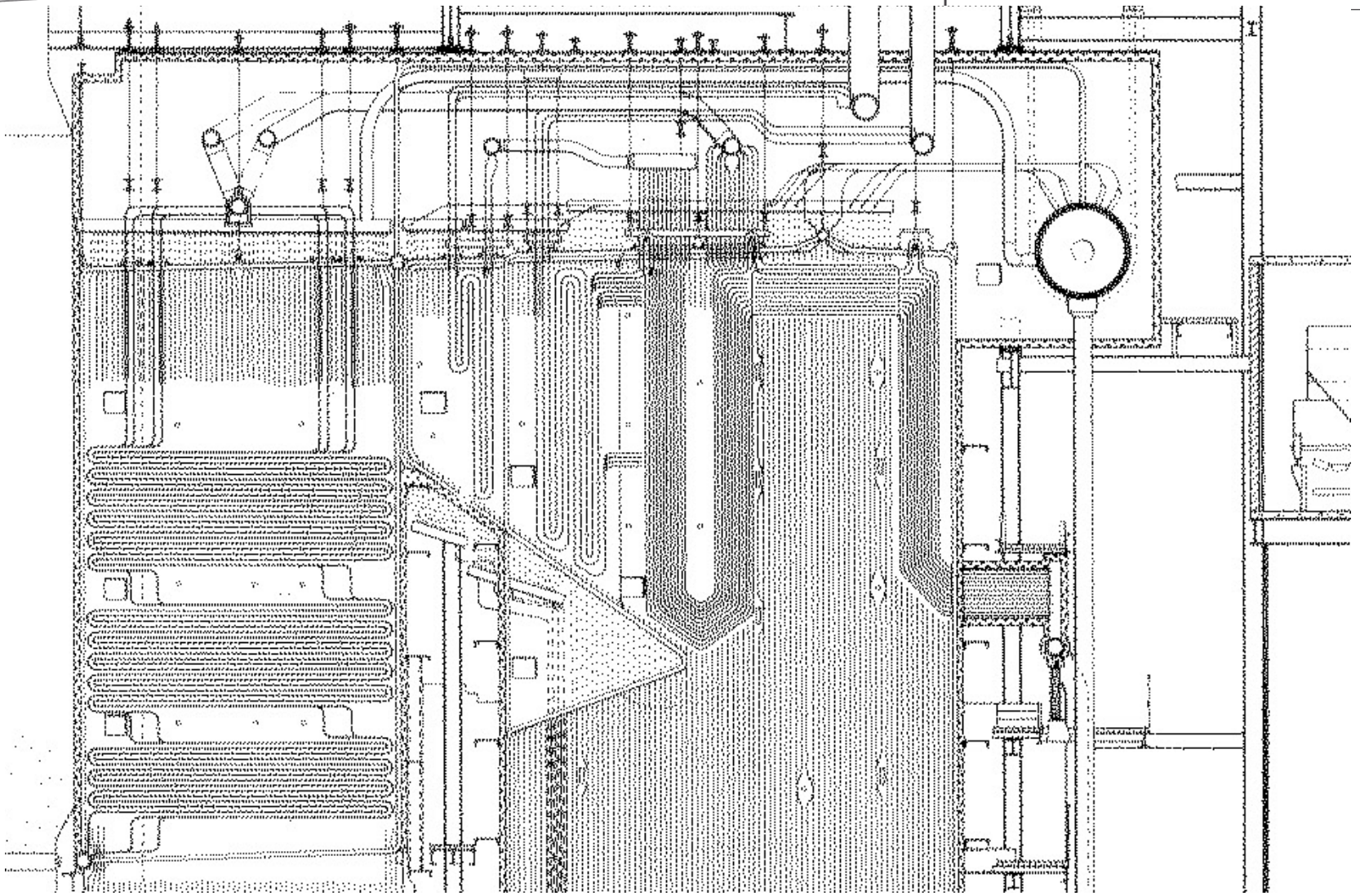
Bituminous Coal Fired Boiler



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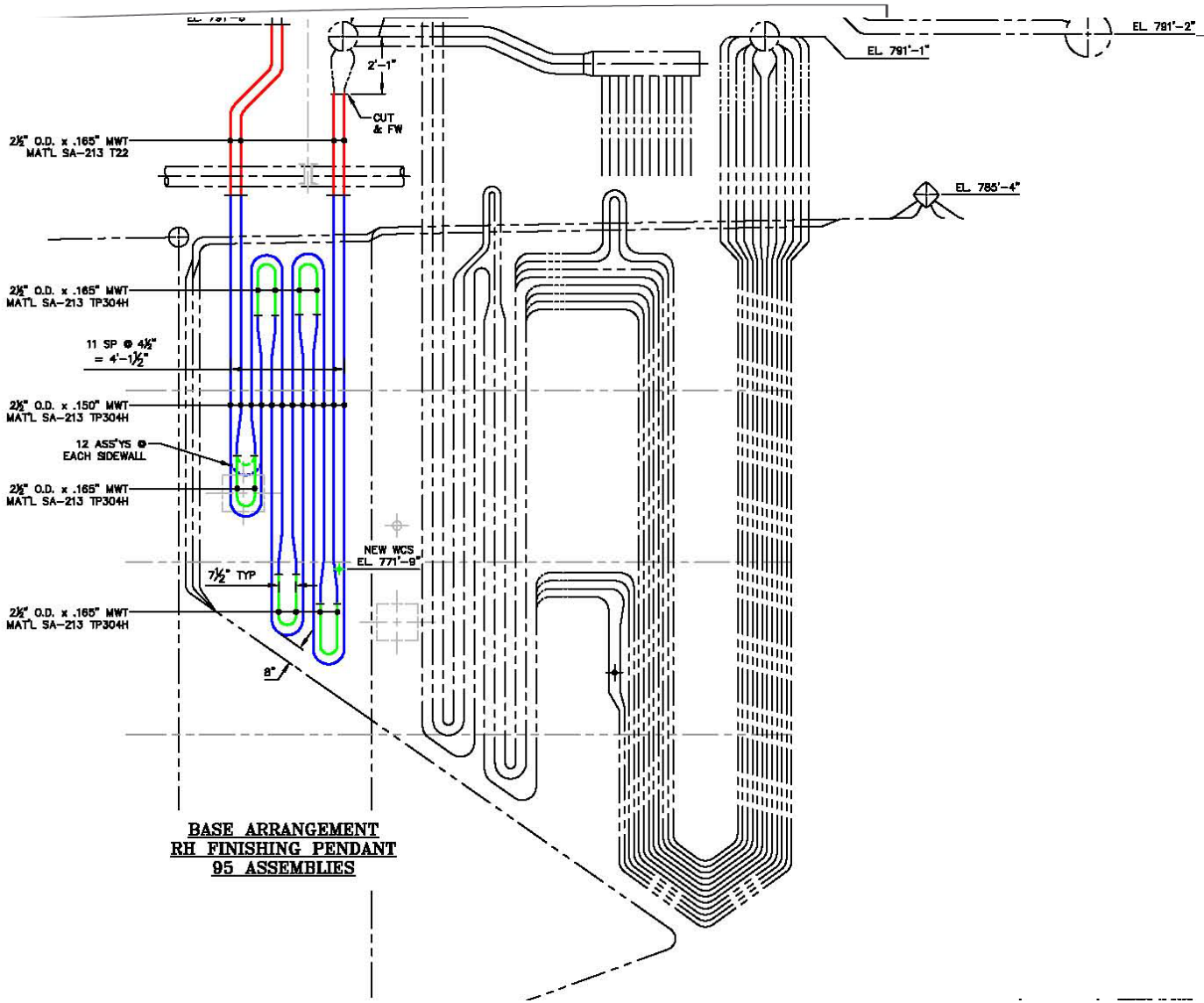
Bituminous Coal Fired Boiler



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Coal & Natural Gas Co-Fired

Coal & Natural Gas Co-firing

The Co-Firing of Coal & Natural Gas can be looked at in two ways:

- The switching back and forth from one fuel to another at 100% of each fuel is fired
- Firing both fuels at the same time with different quantities.

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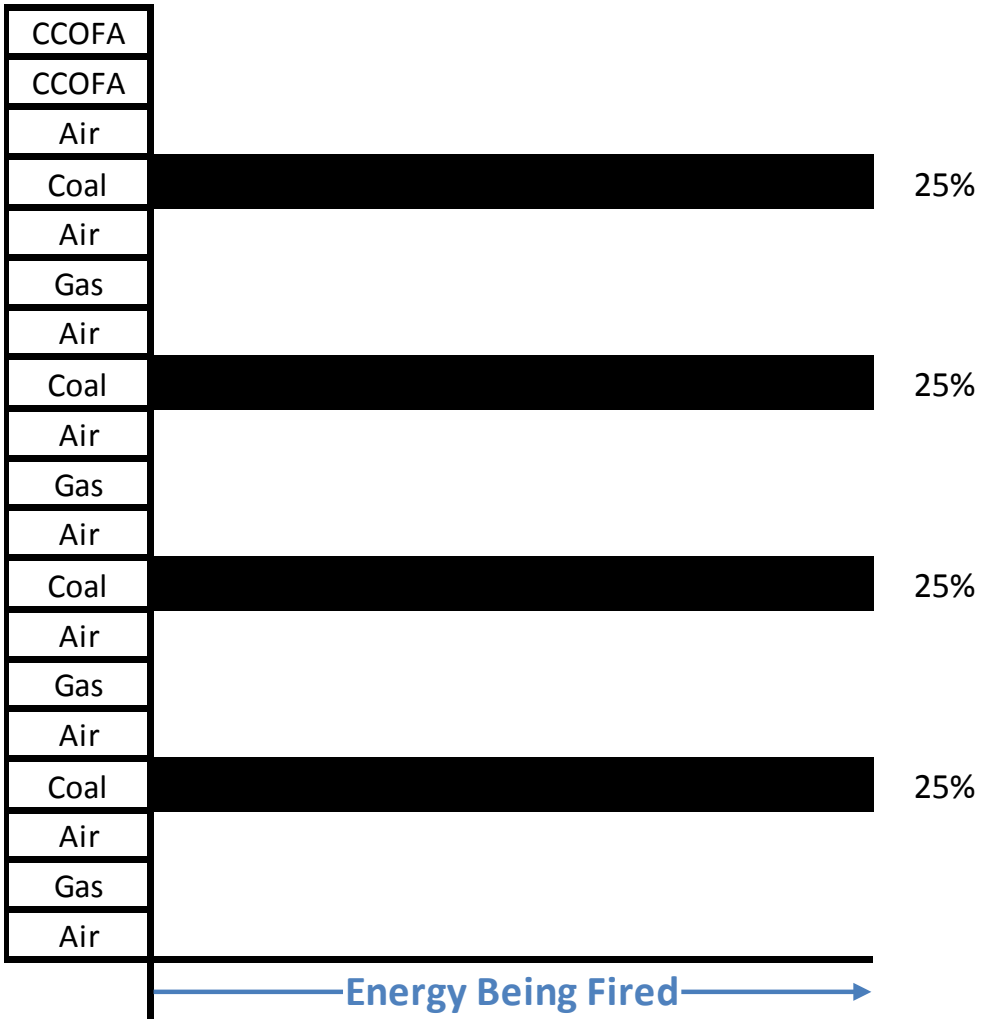
Normal 100% Coal Firing Configuration



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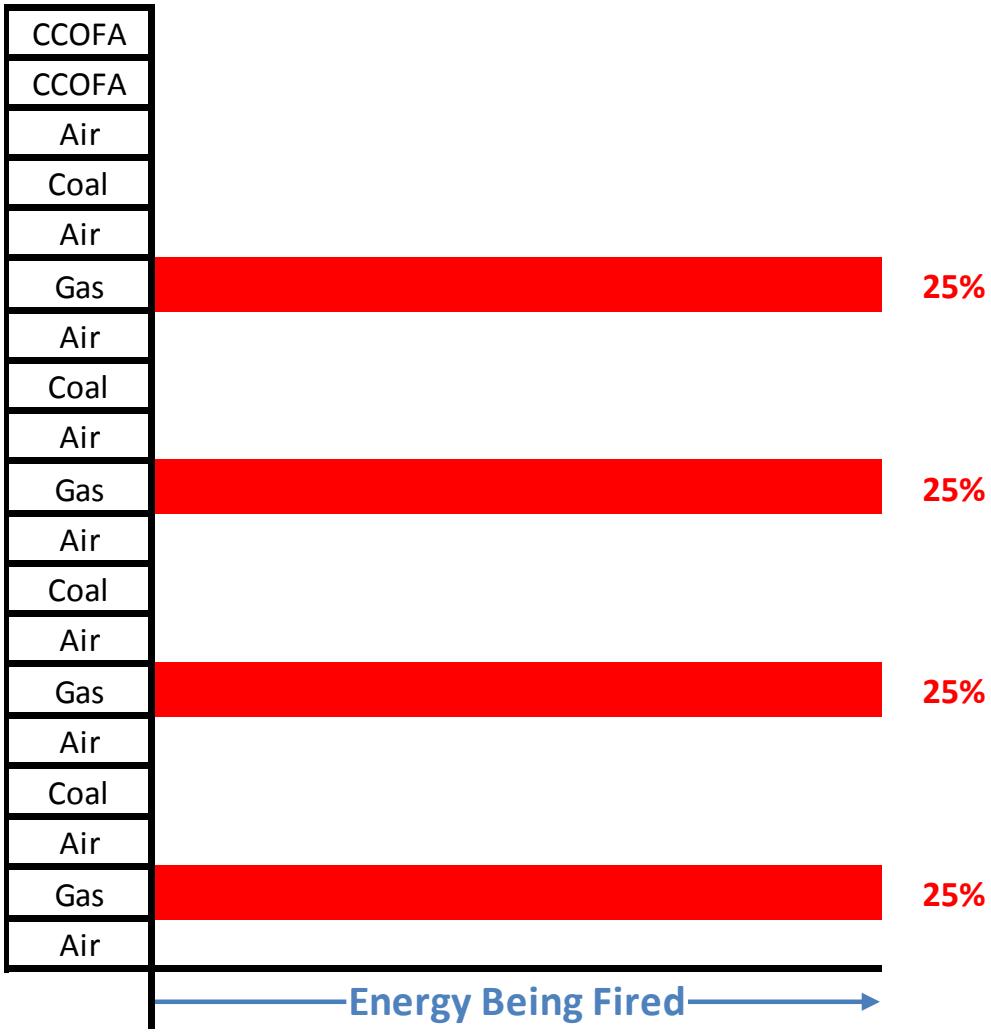
Normal 100% Natural Gas Firing Configuration



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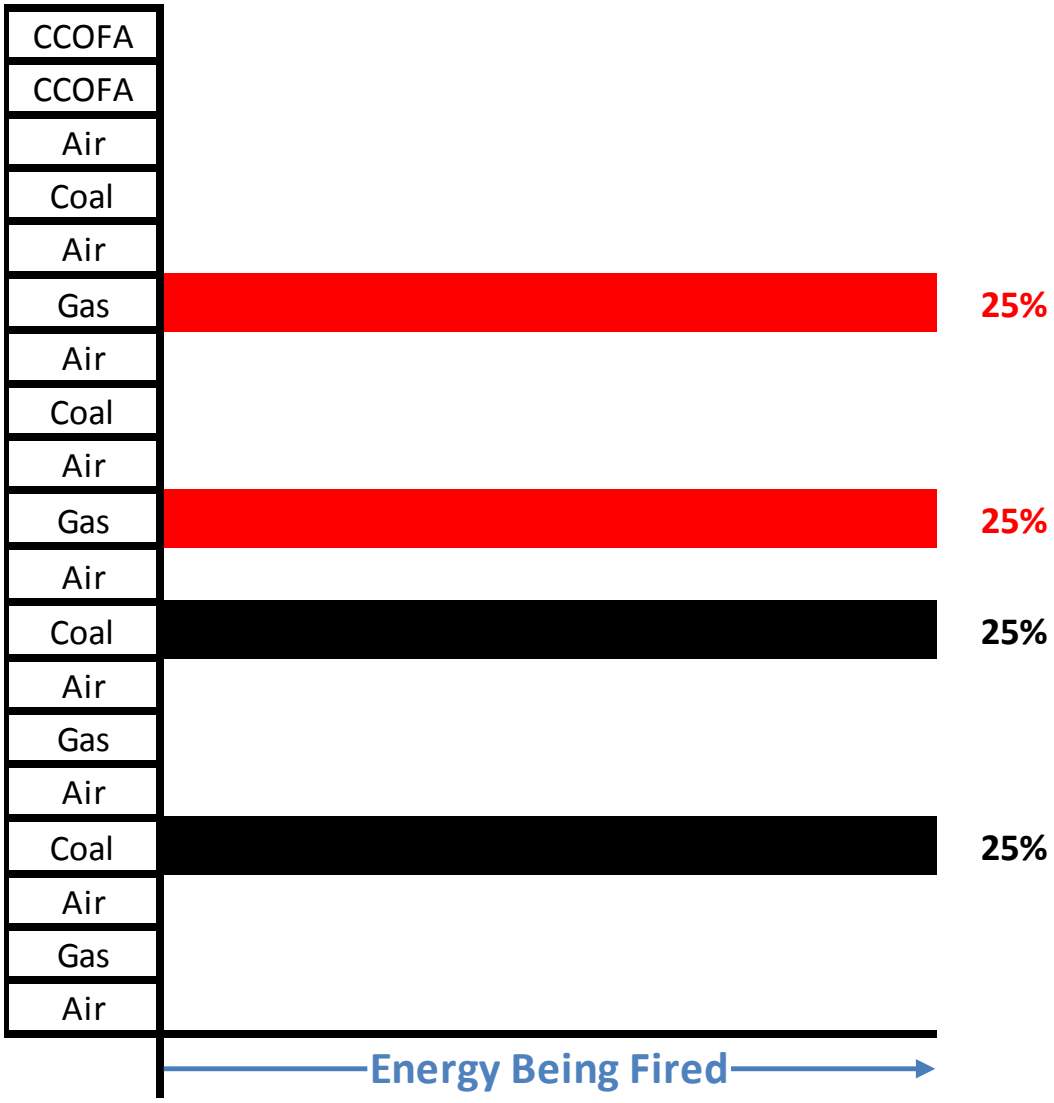
Typical 50% Coal & 50% Natural Gas Firing Configuration



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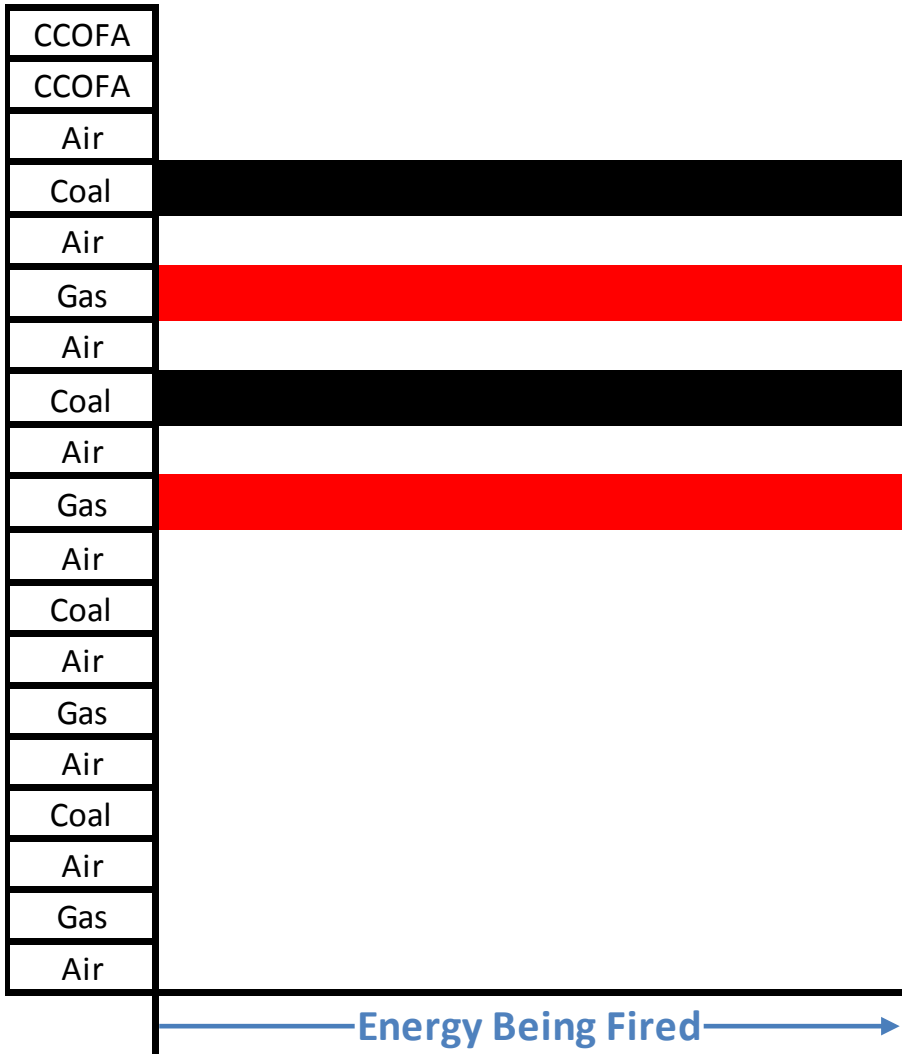
50% Coal & 50% Natural Gas Firing Configuration



25%

25%

25%

High Heat Input May Cause Overheating of the Windbox

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Coal & Natural Gas Co-Fired in a 600 MW Boiler Designed for PRB Coal

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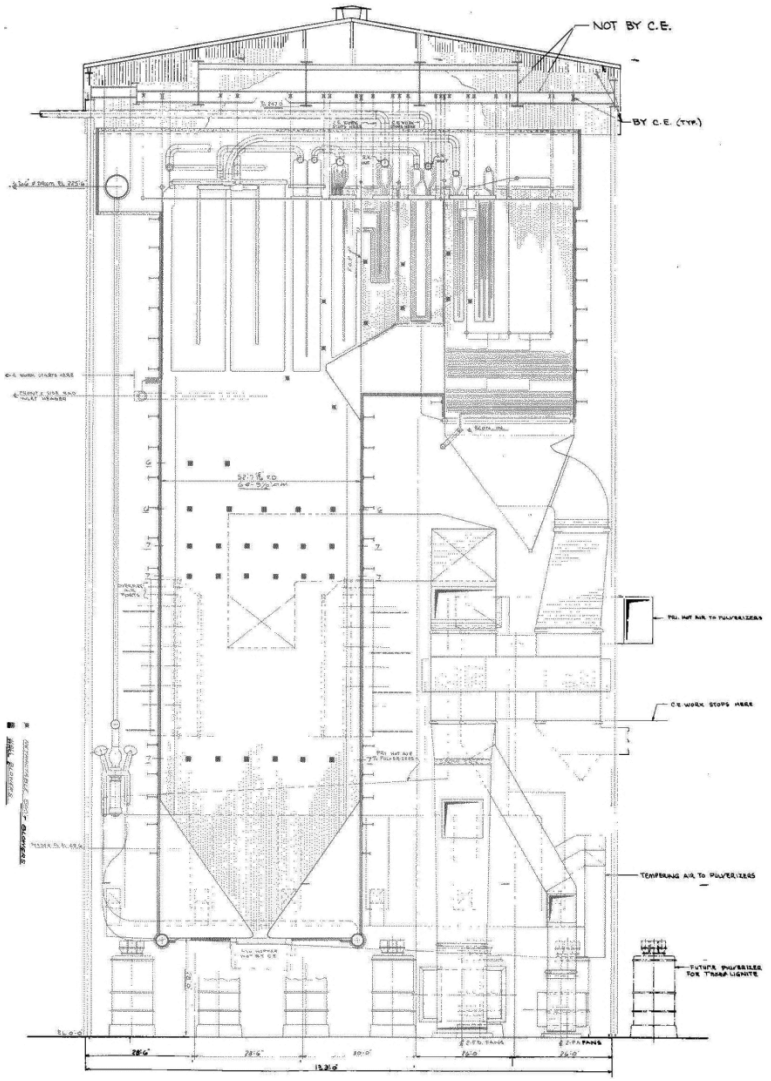
Side Elevation of 600MW Boiler

- Main Steam Flow = 4,199,000 lb/hr
- SHO Pressure = 2620 psig
- SHO & RHO Steam Temperatures = 1005°F
- Single Furnace – T-Fired
- Controlled Circulation Design
- Cold Primary Air System
- Tri-Sector Air Heaters
- PRB Coal



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Coal & Natural Gas Firing Performance

		100% Coal		100% Gas - Clean Furnace				
		Full	Low	Full	Full	Full	Full	Low
Run #		**1**	**3**	**4**	**5**	**6**	**7**	**12**
Steam Flows								
Main Steam Flow		4,220,986	2,402,371	4,220,986	4,220,986	4,220,986	4,220,986	2,402,371
% MCR Load		100.5%	57.2%	100.5%	100.5%	100.5%	100.5%	57.2%
Cold RH Flow		3,895,330	2,251,715	3,895,330	3,895,330	3,895,330	3,895,330	2,251,715
Fuel Fired								
Fuel	Type	Coal	Coal	Gas	Gas	Gas	Gas	Gas
Coal Fuel Heat Input	%	100	100	-	-	-	-	-
Natural Gas Fuel Heat Input	%	-	-	100	100	100	100	100
Coal Fuel Flow	lb/hr	661,590	383,429	-	-	-	-	-
Natural Gas Flow	lb/hr	-	-	229,181	250,174	254,843	254,988	149,407
Total Fuel Flow	lb/hr	661,590	383,429	229,181	250,174	254,843	254,988	149,407
Operating/ Performance Parameters								
Excess Air	%	17.7	30.6	12	25	21	25	30.0
Burner Tilt	Deg.	-16.0	-9	10	20	20	13	20
Mills in Service	-	B,C,D,E,F	B,C,D,E	-	-	-	-	-
Gas Burner Elevations in Service	-	-		1 - 5	1 - 5	2 - 7	2 - 7	5,6,7
Top OFA Gas Burner in Service	Y/N	N	N	N	N	Y	Y	Y
Boiler Efficiency	%	86.2	86.6	85.6	84.8	84.9	84.7	84.7
Steam and Water Temperatures								
SH Outlet Temp	deg. F	1,002	995	891	991	1,005	1,005	1,005
RH Outlet Temp	deg. F	1,007	963	861	983	1,005	1,005	989
SH DeSH Spray Flow	lb/hr	61,181	21,861	1,181	3,750	8,617	5,402	47,122
SH DeSH Spray Flow	%	1.4%	0.9%	0.0%	0.1%	0.2%	0.1%	2.0%
RH DeSH Spray Flow	lb/hr	57,230	0	0	0	45,069	38,936	0.00
RH DeSH Spray Flow	%	1.5%	0.0%	0.0%	0.0%	1.2%	1.0%	0.0%
Air and Flue Gas Temperatures								
AH Primary Air Outlet Temp	deg. F	741	637	704	748	751	755	649
AH Secondary Air Outlet Temp	deg. F	713	619	650	682	686	687	605
Furnace Outlet Temperature	deg. F	2628	2220	2475	2526	2611	2559	2296
Air Heater Exit Gas Temp (Unc)	deg. F	332	289	278	292	293	294	265
Air Heater Exit Gas Temp	deg. F	314	271	261	276	277	278	248

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Coal & Natural Gas Firing Performance

		100% Coal		75% FHI Gas		50% FHI Gas		25% FHI Gas	
		Full	Low	Full	Low	Full	Low	Full	Low
Run #		**1**	**3**	**9**	**13**	**8**	**11**	**10**	**14**
Steam Flows									
Main Steam Flow		4,220,986	2,402,371	4,220,986	2,402,371	4,220,986	2,402,371	4,220,986	2,402,371
% MCR Load		100.5%	57.2%	100.5%	57.2%	100.5%	57.2%	100.5%	57.2%
Cold RH Flow		3,895,330	2,251,715	3,895,330	2,251,715	3,895,330	2,251,715	3,895,330	2,251,715
Fuel Fired									
Fuel	Type	Coal	Coal	Coal/Gas	Coal/Gas	Coal/Gas	Coal/Gas	Coal/Gas	Coal/Gas
Coal Fuel Heat Input	%	100	100	25	25	50	50	75	75
Natural Gas Fuel Heat Input	%	-	-	75	75	50	50	25	25
Coal Fuel Flow	lb/hr	661,590	383,429	166,794	99,132	332,099	194,666	496,252	292,918
Natural Gas Flow	lb/hr	-	-	190,726	113,381	126,583	74,216	63,051	37,225
Total Fuel Flow	lb/hr	661,590	383,429	357,520	212,513	458,682	268,882	559,303	330,143
Operating/ Performance Parameters									
Excess Air	%	17.7	30.6	20.0	30.0	20	29	18	30
Burner Tilt	Deg.	-16.0	-9	14	20	4	20	-7	10
Mills in Service	-	B,C,D,E,F	B,C,D,E	B,C	D,E	B,C,D	D,E	B,C,D,E	C,D,E
Gas Burner Elevations in Service	-	-		4,5,6,7	5,6,7	5,6,7	6,7	6,7	6,7
Top OFA Gas Burner in Service	Y/N	N	N	Y	Y	Y	Y	Y	Y
Boiler Efficiency	%	86.2	86.6	84.9	85.0	85.3	85.8	85.8	86.2
Steam and Water Temperatures									
SH Outlet Temp	deg. F	1,002	995	1,005	1,005	1,005	1,005	1,005	1,005
RH Outlet Temp	deg. F	1,007	963	1,005	999	1,005	1,005	1,005	1,005
SH DeSH Spray Flow	lb/hr	61,181	21,861	3,093	78,329	143	80,623	6,368	0
SH DeSH Spray Flow	%	1.4%	0.9%	0.1%	3.3%	0.0%	3.4%	0.2%	0.0%
RH DeSH Spray Flow	lb/hr	57,230	0	34,220	0	37,288	0	46,212	64,278
RH DeSH Spray Flow	%	1.5%	0.0%	0.9%	0.0%	1.0%	0.0%	1.2%	2.9%
Air and Flue Gas Temperatures									
AH Primary Air Outlet Temp	deg. F	741	637	752	648	751	643	750	644
AH Secondary Air Outlet Temp	deg. F	713	619	706	621	711	619	716	624
Furnace Outlet Temperature	deg. F	2628	2220	2587	2370	2593	2353	2609	2306
Economizer Exit Gas Temp	deg. F	791	676	783	675	785	675	785	678
Air Heater Exit Gas Temp	deg. F	314	271	292	265	298	260	305	266

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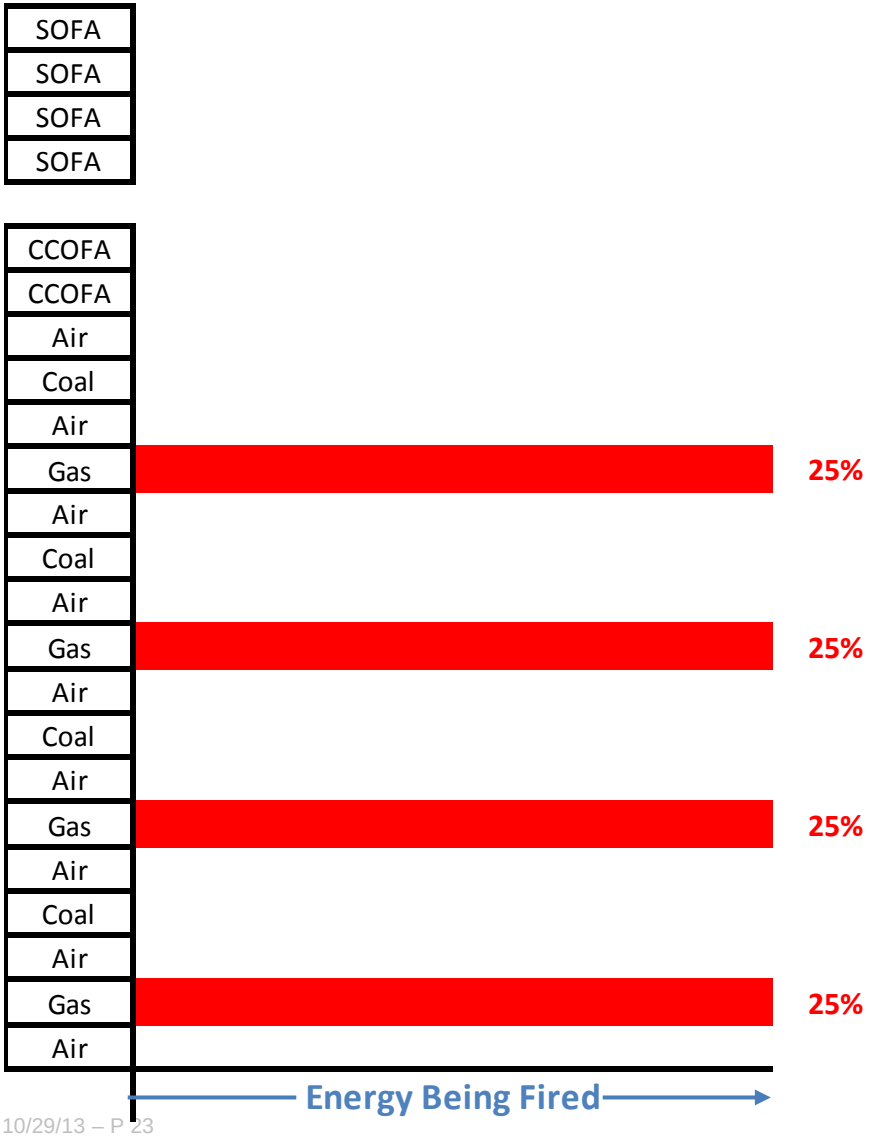
100% Natural Gas Firing Configuration with SOFA



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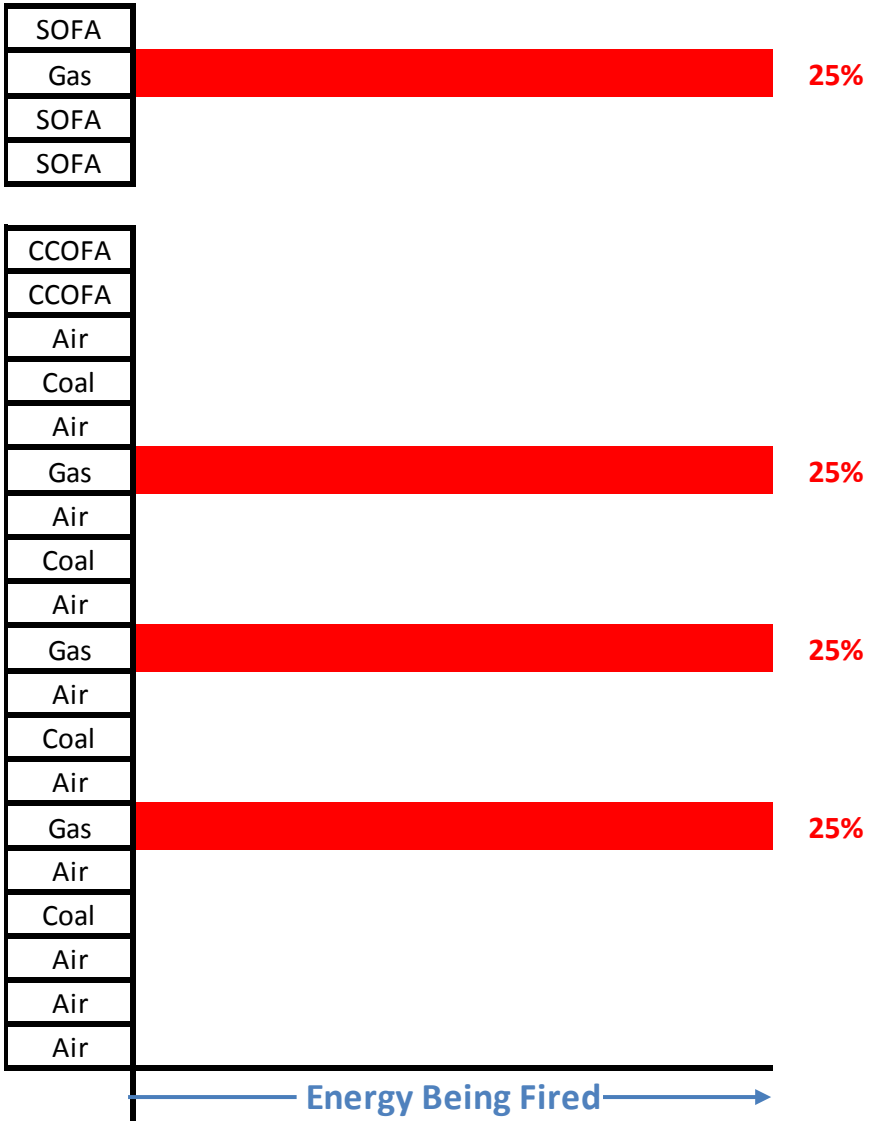
100 % Natural Gas Firing Configuration



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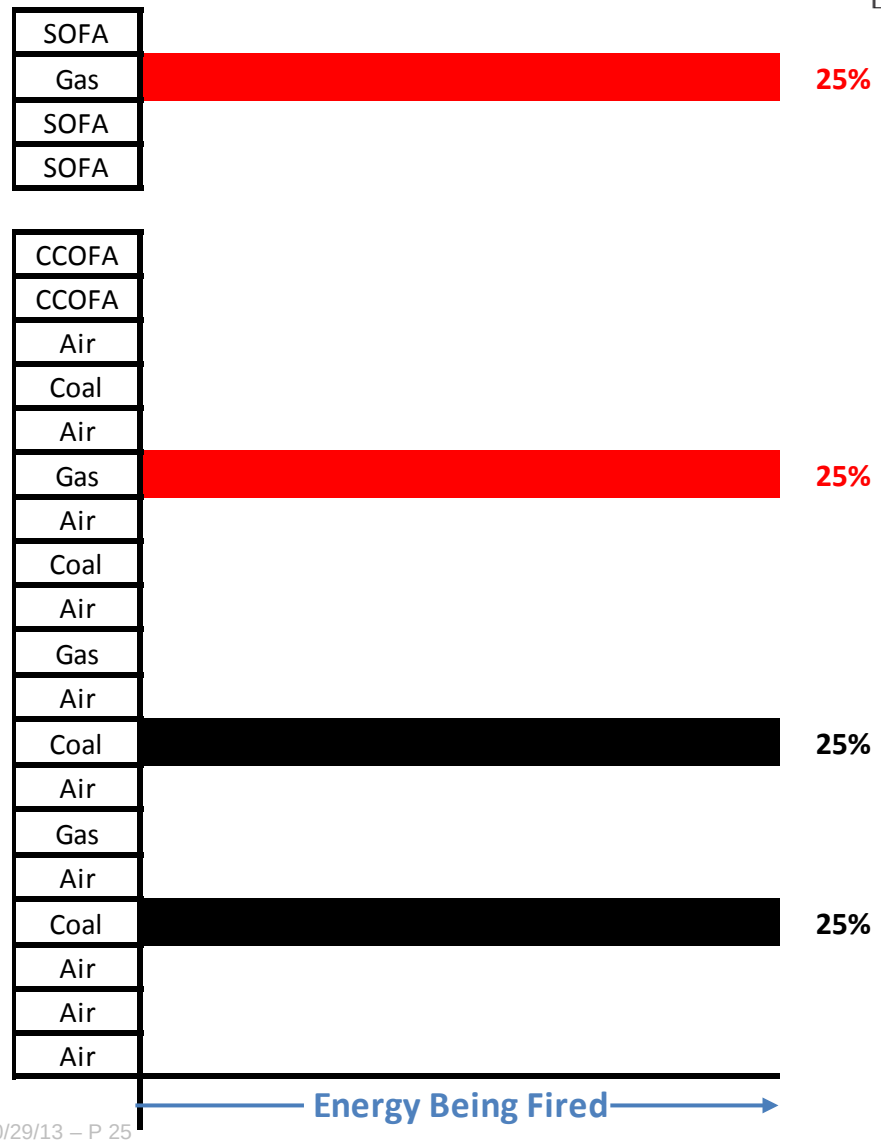
50% Coal & 50% Natural Gas Firing Configuration



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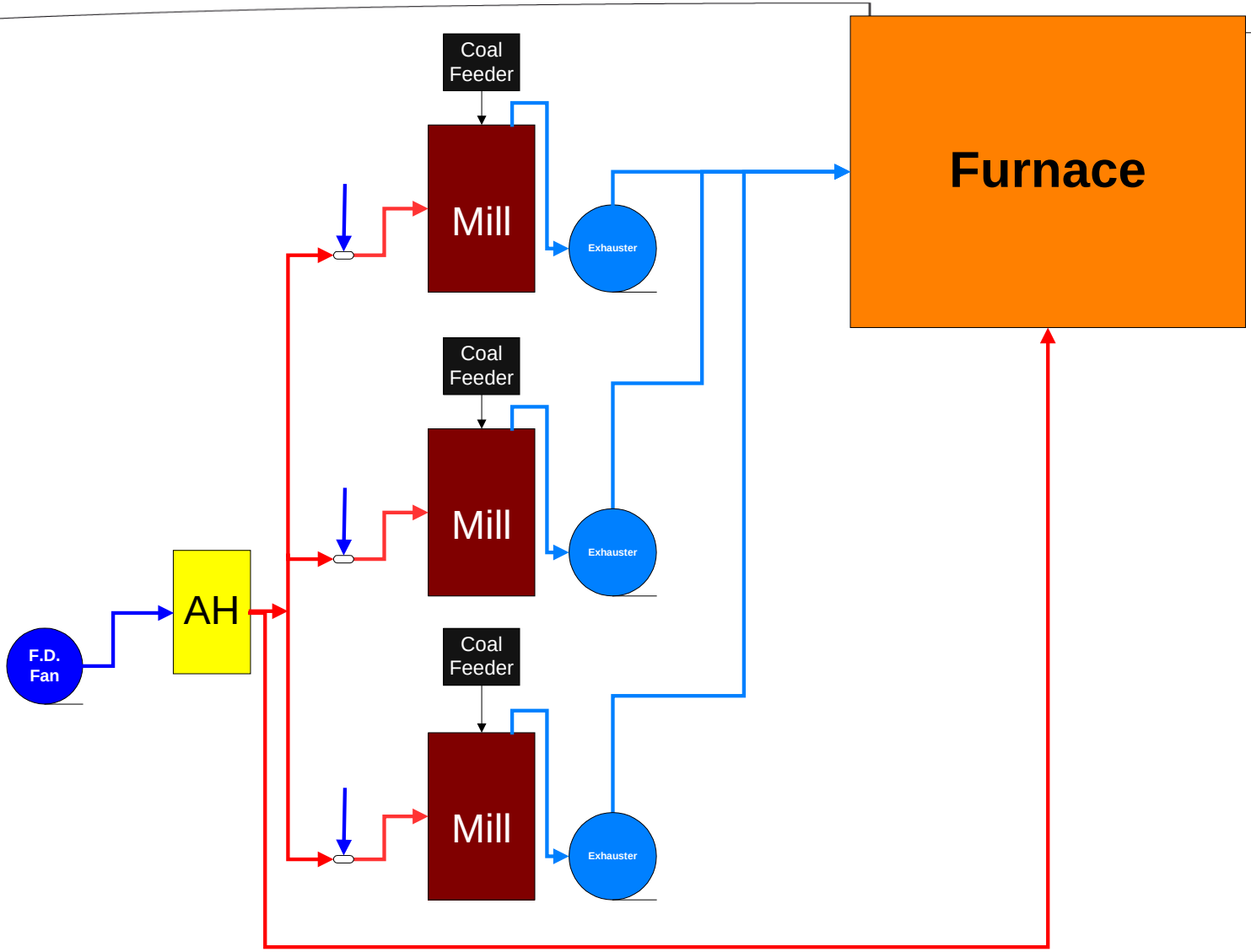
Pulverizer System with Exhausters



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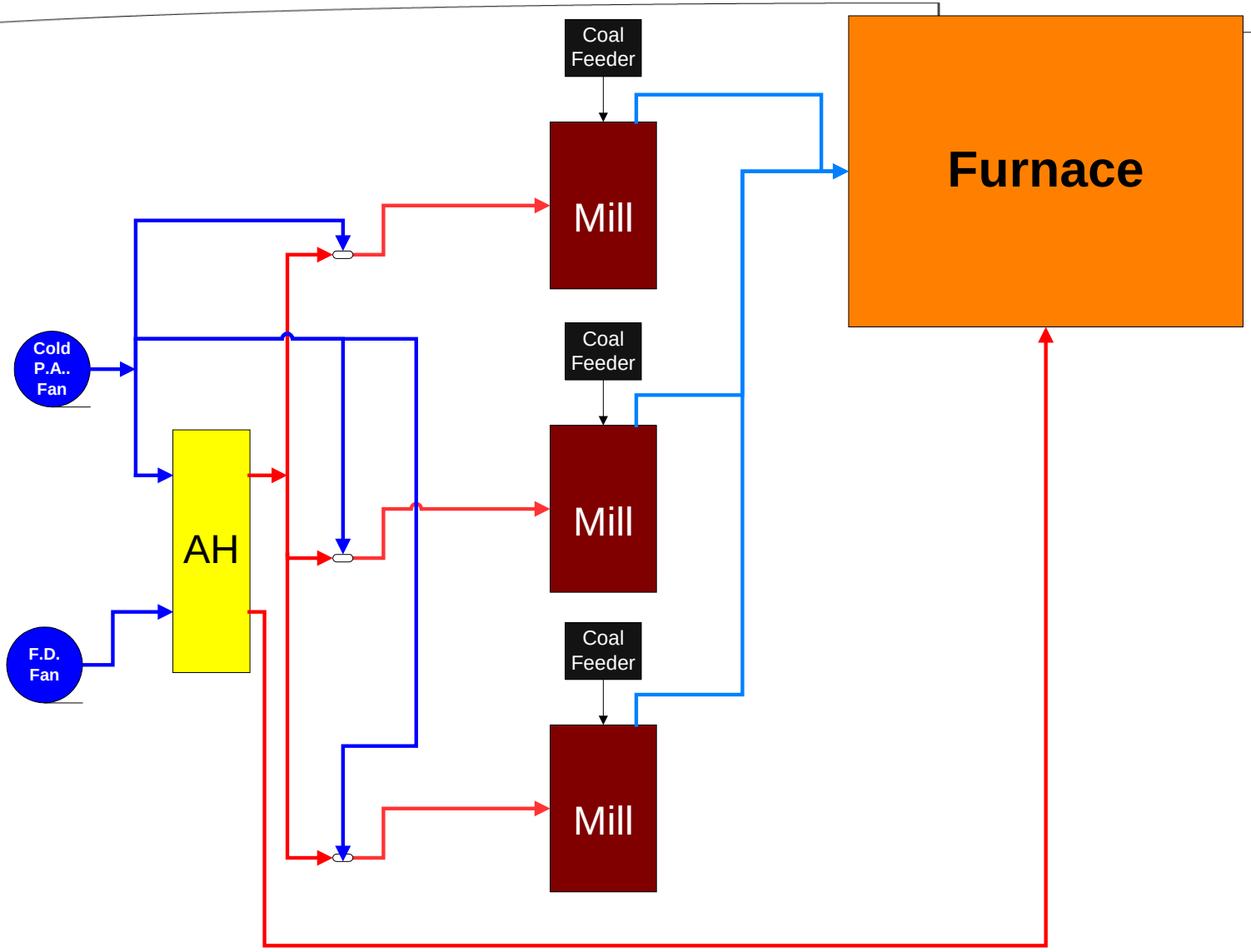
Cold Primary Air System



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Summary of Coal & Natural Gas Firing

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Summary of Coal & Natural Gas Co-Firing

- If the customer wants to only fire 25% or less of natural gas, almost any coal fired boiler can handle it.
- Once the amount of natural gas exceeds 25% then an evaluation study should be performed.
- 100% natural gas firing can cause problems with the pulverizer and air fans systems.
- If too much energy is released in a small region of the furnace, then overheating of the windbox may occur.

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Summary of Coal & Natural Gas Co-Firing

- It is easier to convert a boiler to natural gas when coal is being eliminated.
- Retaining coal firing makes the co-firing of natural gas much more difficult.
- With properly designed components, even PRB coal fired boilers can be converted to natural gas.
- Boiler originally designed to fire Mid-West Bit or Eastern Bit coals can normally fire 100% natural gas without major modifications.

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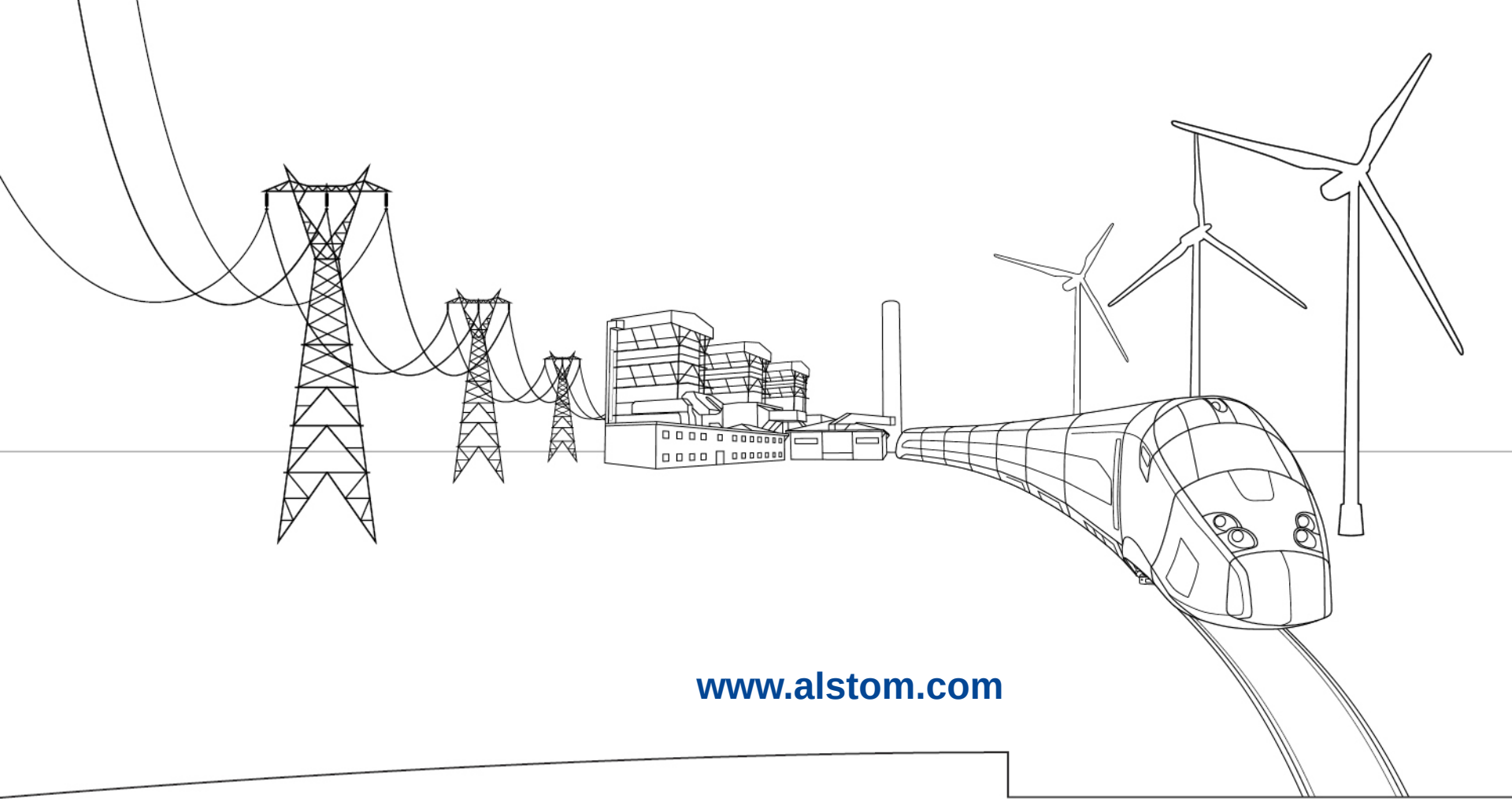

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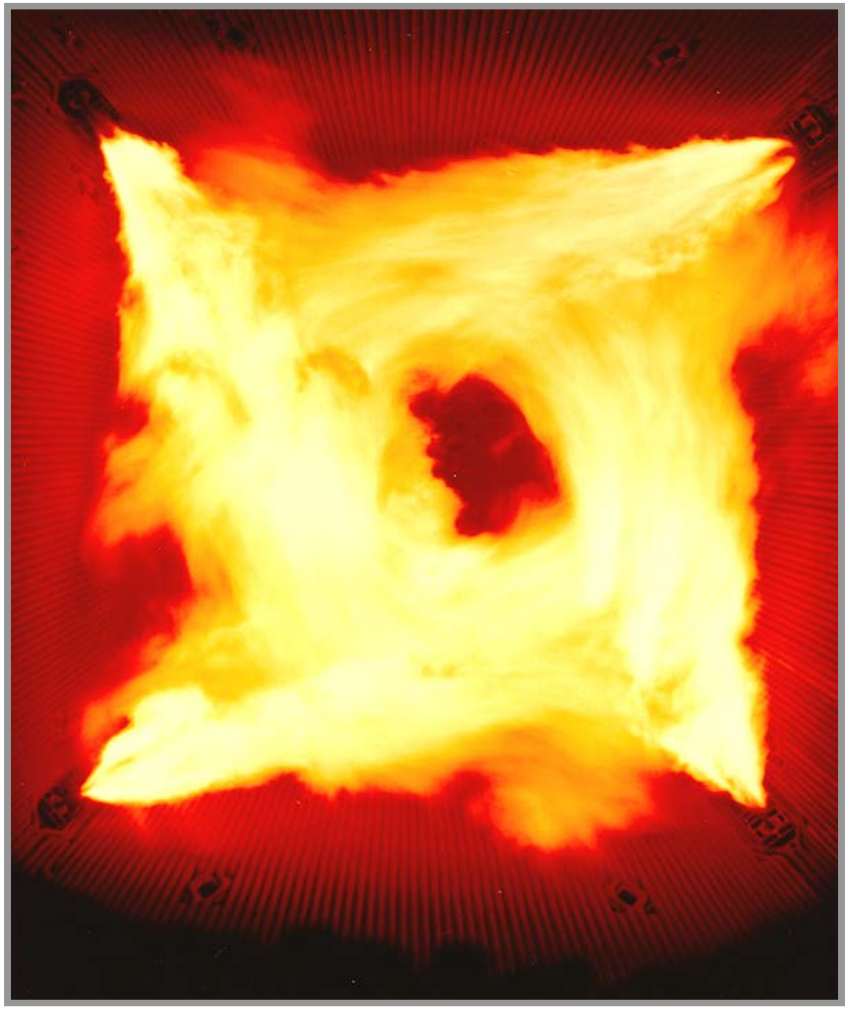
Shaping the future

Gas Firing Components

Tangential Firing System

- Flame Pattern of Tangential Firing System



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