

REINHOLD ENVIRONMENTAL Ltd.



**2012 Coal to Gas Conversion Round Table
& Expo Presentation**

October 23, 2012, Chattanooga, TN / Sponsored by TVA

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Natural Gas Conversion

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Oct 23, 2012

ALSTOM

Introduction

Converting Bituminous Coal Fired Units to Gas

Converting PRB Coal Fired Units to Gas

Natural Gas Emissions

Gas Firing Equipment & Auxiliaries

Reasons for Coal to Natural Gas Conversions

- Economics !!!!
 - Fuel Pricing – natural gas vs oil or coal
 - Eliminates the need for costly backend equipment
 - Reduces maintenance costs (no erosion, no corrosion, no coal handling equipment)
 - Reduced operational costs (coal handling equipment, conveyors, pulverizers, etc.)
- Politics !!!!
- Reduced Emissions

- 11 Engineering Studies have been performed
- 57 Inquiries currently in-house
- 3 Recent contracts

List of Alstom Gas Conversion Experience



| | Orig. Design Fuel | Fuel Conversion | Year of Conv. |
|---------|-------------------|-----------------|---------------|
| Plant A | Oil | Gas | 1996 |
| Plant B | Oil | Gas | 1993 |
| Plant C | Oil | Gas | 1993 |
| Plant D | Oil | Gas | 1993 |
| Plant E | Coal | Gas | 1996 |
| Plant F | Coal | Gas | 1994 |
| Plant G | Coal | Gas | 1996 |
| Plant H | Oil | Gas | 1991 |
| Plant I | Oil | Gas | 1995 |
| Plant J | Oil | Gas | 1995 |
| Plant K | Coal | Gas, GR | 1981 |
| Plant L | Coal | Gas, GR | 1981 |
| Plant M | Coal | Gas, GR | 1981 |
| Plant N | Coal | Gas, GR | 1981 |
| Plant P | Coal | 50% Gas | 1992 |
| Plant Q | Coal | 50% Gas | 1992 |
| Plant R | Oil | 30% Gas | 1985 |
| Plant S | Coal | 100% Gas | 1992 |
| Plant T | Coal | 100% NG | 1978 |
| Plant U | Coal | 100% NG | 1979 |
| Plant V | Coal | 50% NG | 1984 |
| Plant W | Coal | 60% NG | 1984 |
| Plant X | Coal | 50% NG | 1983 |
| Plant Y | Coal | 50% NG | 1984 |
| Plant Z | Oil | 100% NG | 2012 |

Introduction

Converting Bituminous Coal Fired Units to Gas

Converting PRB Coal Fired Units to Gas

Natural Gas Emissions

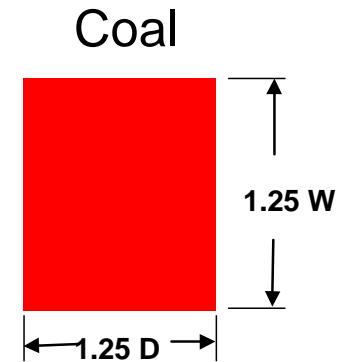
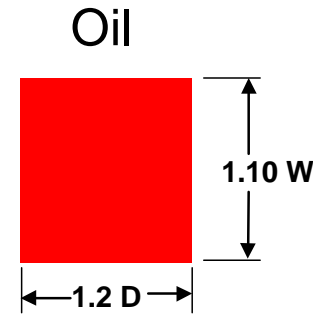
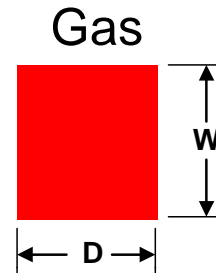
Gas Firing Equipment & Auxiliaries

Converting Bituminous Coal Fired Boiler to Gas Firing

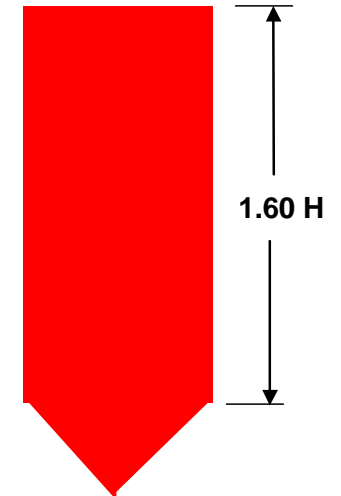
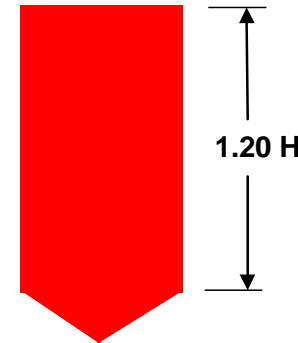
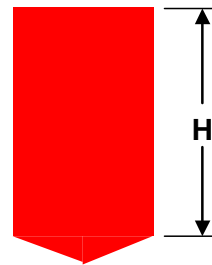
Normal Boiler Sizing



- Boilers are normally designed for a specific fuel.



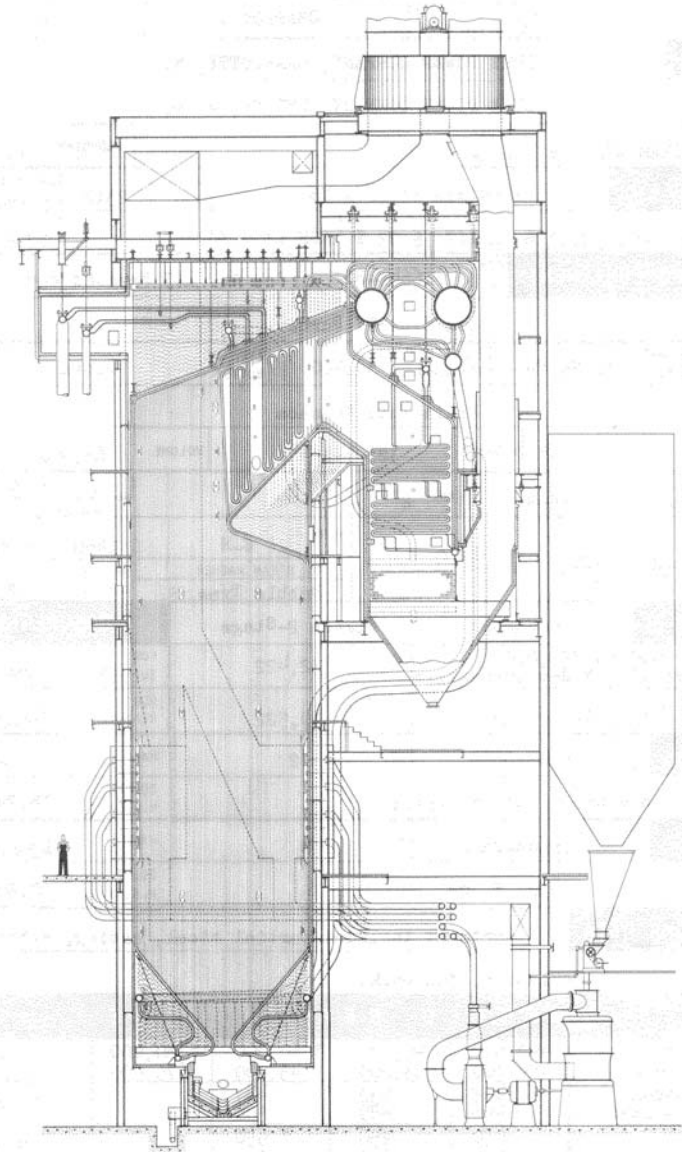
- Anytime a boiler has a change in fuel, there will be performance compromises.



Bituminous Coal Fired Boiler #1



| | | | | | | | |
|-------------------------------|-------------------------------|---|---------------------------------|--------------------------------|-----------------|--|-----------------|
| PROPOSED FUEL | | VIRGINIA BITUMINOUS | | ASH FUS. TEMP. F | 2310 | BTU PER LB AS FIRED | HARDGROVE GRIND |
| F.C. 47.84 % | VOL. 33.13 % | MOIST. 6.03 % | ASH 13.0 % | SUL. | | 12,450 | 55 |
| FUEL BURNING EQUIPMENT | | CONT. NO. | 16648-RB | 8 - No. 613 Raymond Bowl Mills | | | |
| and Type TV Burners | | | | | | | |
| FURNACE | CONT. NO. | 16648-PS | SQ.FT. H.S. PER FURN. | 38,480 | TYPE OF BOTTOM | Contant | |
| Plain Tube Furnace | | | | | | | |
| FRONT TO REAR | 24'-11-3/4" | WIDTH | 32'-7-1/4" | VOLUME | 63,000 | CU. FT. GROSS | |
| BOILER | CONT. NO. | 16648-BR | NO. | 2 | SQ.FT. H.S.EA. | - | |
| | | | | | PRESSURE | | |
| | | | | | DESIGN | OPERATING | |
| DESIGNATION | | 32'-7-1/4" 123-3 | | R | 54-60 | MFR. | C-E |
| | | 24'-11-3/4" 94-3 | | | 30 | 1450 | 1295 at S.O. |
| | | | | | STEAM WASHER | BOILER NUMBER | |
| | | | | | Bubble Type | 1 and 2 | |
| SUPERHEATER | CONT. NO. | 16648-SH | TYPE | Elesco 2-Stage | | DESUPERHEATER | |
| CONTROL RANGE | 490,000 to 780,000 | | by burner tilt & desuperheaters | | SQ.FT. H.S. | 32,422 | |
| | | | | | FOR SUPHT'R. | Spray Type | |
| REHEATER | TYPE | Interstage | | SQ.FT. H.S. | 10,522 | | |
| | | | | | FOR REHEATER | Spray Type | |
| ECONOMIZER | CONT. NO. | 16648-CONS | NO. | 2 | | MAKE C-E | |
| TYPE | CF-S 10H x 45W x 33'-6" Split | | | SQ.FT. H.S.EA. | 15,795 | | |
| AIR HEATER | CONT. NO. | 16648-CAHL | NO. | 4 | | MAKE Ljungstrom | |
| TYPE | 32 V 62 | | | SQ.FT. H.S.EA. | 90,800 | | |
| MISCELLANEOUS DATA | | Contract included partial steel, casing, setting, insulation, ductwork. | | | | | |
| EXPECTED PERFORMANCE | | | | | | | |
| LB STEAM PER HR-ACTUAL | Primary Reheat | 490,000 | 640,000 | *750,000 | **780,000 | *Guaranteed (Max.Cont.) **12 Hr. Peak | |
| | Econ. Boiler | 424,000 | 553,000 | 645,000 | 670,000 | | |
| FEEDWATER TEMP. TO | | 408 | 432 | 447 | | REHEATER DATA 645,000 lb steam/hr. Enter Temp. 690 F * Press. 431 PSI Leav. * 405 PSI | |
| | | 466 | 489 | 500 | | | |
| STEAM TEMP. Fat S.O. & R.O | | 950 | 950 | * 950 | | | |
| HEAT RELEASE BTU/CU.FT./HR. | | 10,600 | 13,600 | 15,600 | | | |
| TEMP. GAS FROM AIR HEATER | | 259 | 285 | 291 | | | |
| TEMP. AIR FROM AIR HEATER | | 578 | 610 | 619 | | | |
| OVERALL EFFICIENCY % | | 89.35 | 88.78 | *88.66 | | | |



Bituminous Coal Fired Boiler #1



| | | Original Design | Test Data Coal | Natural Gas | Natural Gas |
|---|---------|-----------------|----------------|-------------|-------------|
| Date | | | 2/16/2011 | | |
| Gross Load | MW | | 110 | | |
| Load | % | 104% MCR | 106% MCR | 106% MCR | 106% MCR |
| Main Steam Flow | lb/hr | 780,000 | 795,110 | 795,110 | 795,110 |
| Reheater Steam Flow | lb/hr | 670,000 | 689,093 | 697,292 | 702,476 |
| SH Spray Flow | lb/hr | 0 | 11,574 | 18,350 | 18,077 |
| RH Spray Flow | lb/hr | 0 | 0 | 8,199 | 13,383 |
| SH Outlet Steam Temperature | °F | 950 | 944 | 950 | 950 |
| RH Outlet Steam Temperature | °F | 950 | 961 | 962 | 950 |
| CRH Steam Temperature | °F | 697 | 692 | 697 | 697 |
| Economizer Water Inlet Temperature | °F | 450 | 442 | 442 | 442 |
| Economizer Water Outlet Temperature | °F | 502 | 478 | 477 | 477 |
| Drum Pressure | psig | 1,356 | 1,243 | 1,243 | 1,243 |
| SHO Pressure | psig | 1,295 | 1,200 | 1,200 | 1,200 |
| CRH Pressure | psig | 447 | 400 | 400 | 400 |
| Economizer Outlet Gas Temperature | °F | 720 | 687 | 691 | 691 |
| Air Heater Inlet Gas Temperature | °F | 720 | 628 | 691 | 691 |
| Air Heater Outlet Gas Temperature uncorr. | °F | 309 | 345 | 345 | 345 |
| Air Heater Outlet Gas Temperature corr. | °F | 290 | 325 | 324 | 324 |
| Air Heater Outlet Air Temperature | °F | 616 | 552 | 593 | 592 |
| Air Heater Inlet Air Temperature | °F | 80 | 108 | 108 | 108 |
| Boiler Efficiency | % | 88.59 | 88.60 | 84.08 | 84.08 |
| Heat Input | Mbtu/hr | 1,020 | 1,051 | 1,120 | 1,121 |
| Excess Air | % | 15 | 18 | 8 | 8 |
| Fuel Nozzle Tilt | degrees | Horiz | -8 | -12 | -12 |
| Fuel Elevations in Service | number | 4 | 4 | 3 | 3 |

Bituminous Coal Fired Boiler #1



| | | Original Design | Coal Data 2/16/2011 | Natural Gas |
|---------------------------|-------|-----------------|---------------------|-------------|
| Air Weight to FD Fan | lb/hr | 900,000 | 908,921 | 961,999 |
| Excess Air | % | 15 | 18 | 8 |
| Air Temperature to FD Fan | °F | 100 | 100 | 100 |
| Air Volume | ACFM | 211,500 | 219,989 | 232,163 |
| Air Volume per Fan | ACFM | 105,750 | 109,995 | 116,418 |
| 25% Tolerance @ 100°F | ACFM | 132,200 | | |
| Delta P | "w.g. | 9.30 | 9.03 | 9.60 |
| 25% Pressure Tolerance | "w.g. | 11.60 | | |



| | | Original Design | Coal Data 2/16/2011 | Natural Gas |
|---------------------------|-------|-----------------|---------------------|-------------|
| Gas Weight to ID Fan | lb/hr | 1,111,000 | 1,135,113 | 1,055,110 |
| Excess Air | % | 15 | 18 | 8 |
| Gas Temperature to ID Fan | °F | 302 | 325 | 324 |
| Gas Volume | ACFM | 356,000 | 393,341 | 365,152 |
| Gas Volume per Fan | ACFM | 178,000 | 196,670 | 182,576 |
| 21% Tolerance | ACFM | 215,000 | | |
| Delta P | "w.g. | 7.80 | 11.34 | 9.47 |
| 37% Pressure Tolerance | "w.g. | 10.70 | | |

Bituminous Coal Fired Boiler #1

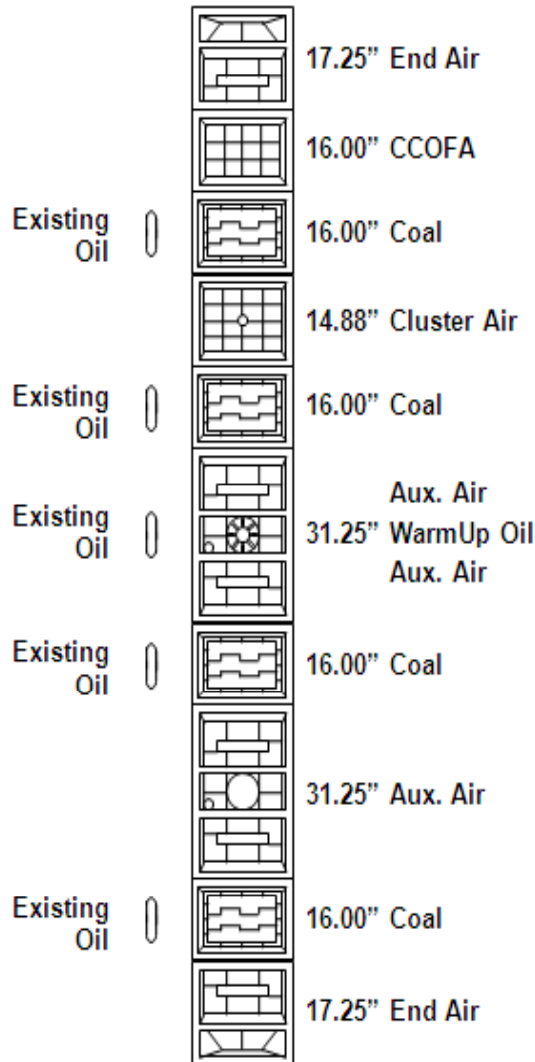


-
- Alstom performed a study to convert to 100% natural gas firing. For study purposes, the customer defined normal full load (NFL) at 107 MW (approximately 795 klb/hr steam flow). Coal firing will be eliminated.
 - To convert this unit to natural gas firing, the Company proposed three elevations of 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 bottom three coal elevations. 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.

Bituminous Coal Fired Boiler #1



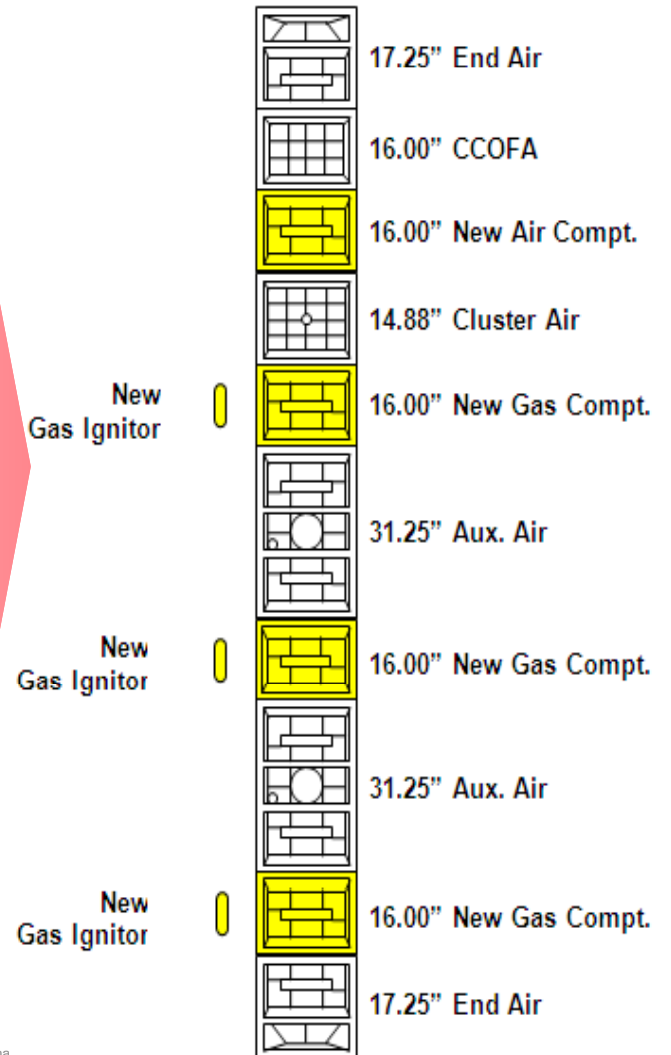
Existing 16" Wide Windbox



To convert Unit 1 to NG firing, Alstom proposed:

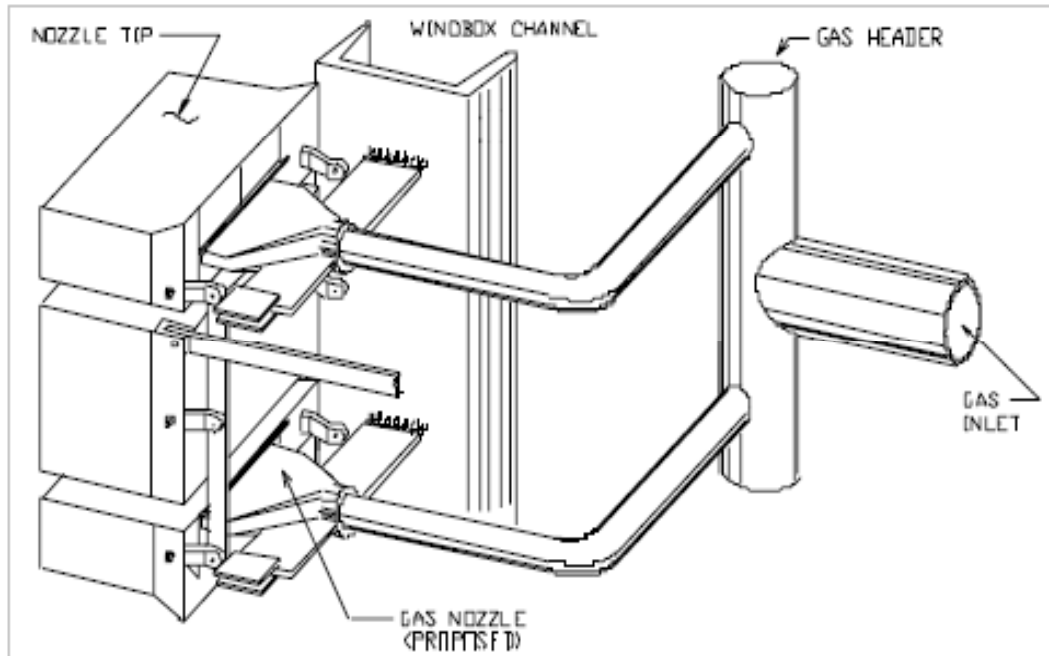
- Three elevations of load carrying gas guns, coupled with Class 1 gas ignitors
- Ignitors located adjacent to the gas guns and installed in bottom 3 coal elevations
- Class 1 ignitors eliminates need for flame scanners, although flame scanners may be used (if desired by Plant)
- Gas guns sized for full load capability *without* ignitors on

Proposed 16" Wide Windbox



Subject to change without notice. This drawing is strictly for informational purposes.

Bituminous Coal Fired Boiler #1 – Gas Firing Compartment Assembly



- Gas gun assemblies based on Alstom's standard gas gun arrangement
- Gas gun assembly sized for approx. 94×10^6 Btu/hr per compartment.
- 7:1 turndown capability with gas supply pressure of 25 psig to gas gun and minimum operating pressure of 1/2 psig above furnace pressure at burner spud

Bituminous Coal Fired Boiler #1



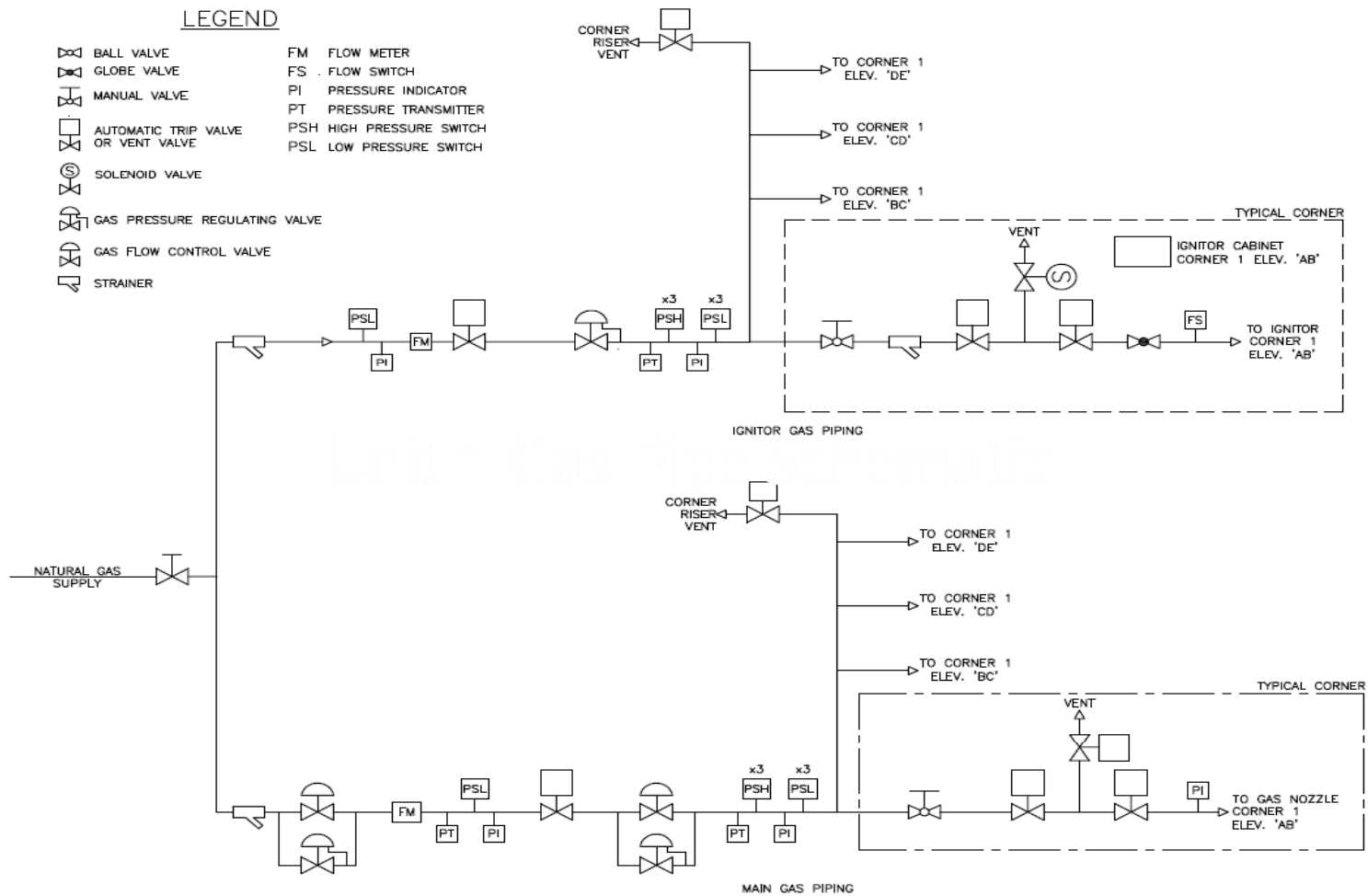
Ignitor Air System

- The existing 10,880 CFM ignitor air system is sufficient for the new ignitors (and any flame scanners, if the plant elects to install flame scanners).

SOFA Windbox

- No modifications are planned for the SOFA windbox. The Company expects the SOFA airflow required to meet NOx emission targets will be less than the current SOFA is designed for.

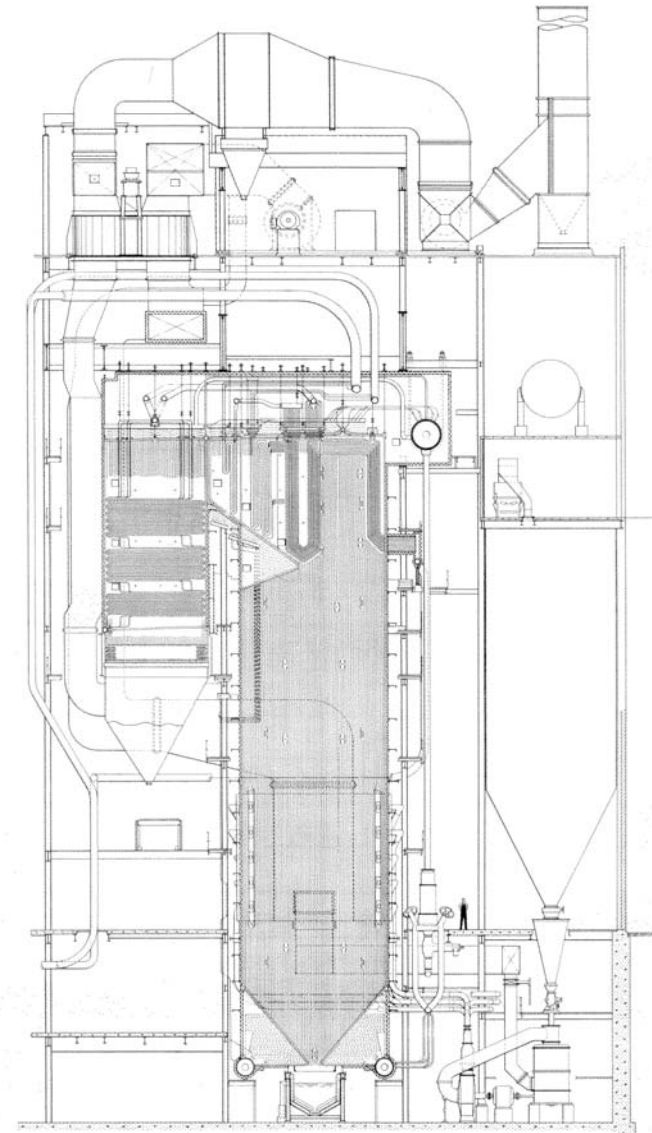
Bituminous Coal Fired Boiler #1 - Gas Pipe Schematic



Bituminous Coal Fired Boiler #2



| | | | | | | | |
|--|---|-------------------------------|--------------------------------|-------------------------|-------------------|---------------------------------|-----------------|
| 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 | | | |
| DESIGNATION | 40'-6 1/2" 28'-2" | 320-1 1/2 160-1 1/2 | 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 | | | | C O A L | | | |
| LB STEAM PER HR-ACTUAL | PRIMARY REHEAT | 660,000 | 1,100,000 | *1,160,000 | *1,200,000 | - 6 Hr. Peak - 18 Hr. Interval. | |
| | ECON. BOILER | 592,500 | 975,000 | 1,023,000 | | | |
| FEEDWATER TEMP. TO | | 420 | 467 | 470 | | | |
| | | 465 | 505 | 507 | | | |
| STEAM TEMP. at S.O. & R.O. | | 1050-1000 | 1050-1000 | *1050-1000 | | REHEAT DATA | |
| HEAT RELEASE BTU/CU. FT./HR. | | 8,150 | 12,850 | 13,450 | | 1,023,000 LB STEAM/HR. | |
| TEMP. GAS FROM AIR HEATER | | 245 | 280 | 282 | | Enter. Temp. 669 F | |
| TEMP. AIR FROM AIR HEATER | | 525 | 562 | 567 | | " Press. 507 Psi | |
| OVERALL EFFICIENCY % | | 89.71 | 88.99 | *68.95 | | Leav. Temp. 1000 F | |
| | | | | | | " Press. 474 Psi | |

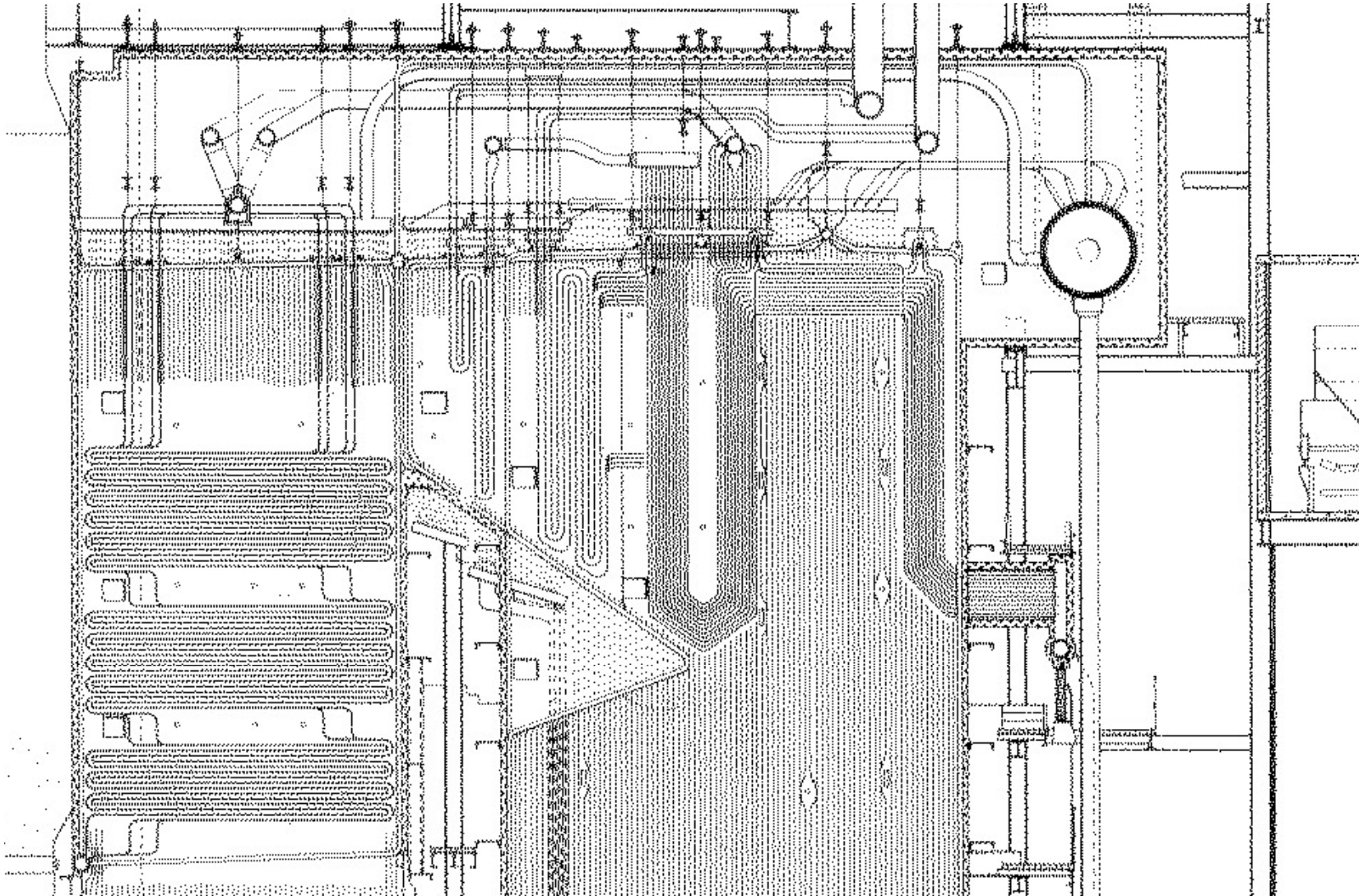


Bituminous Coal Fired Boiler #2

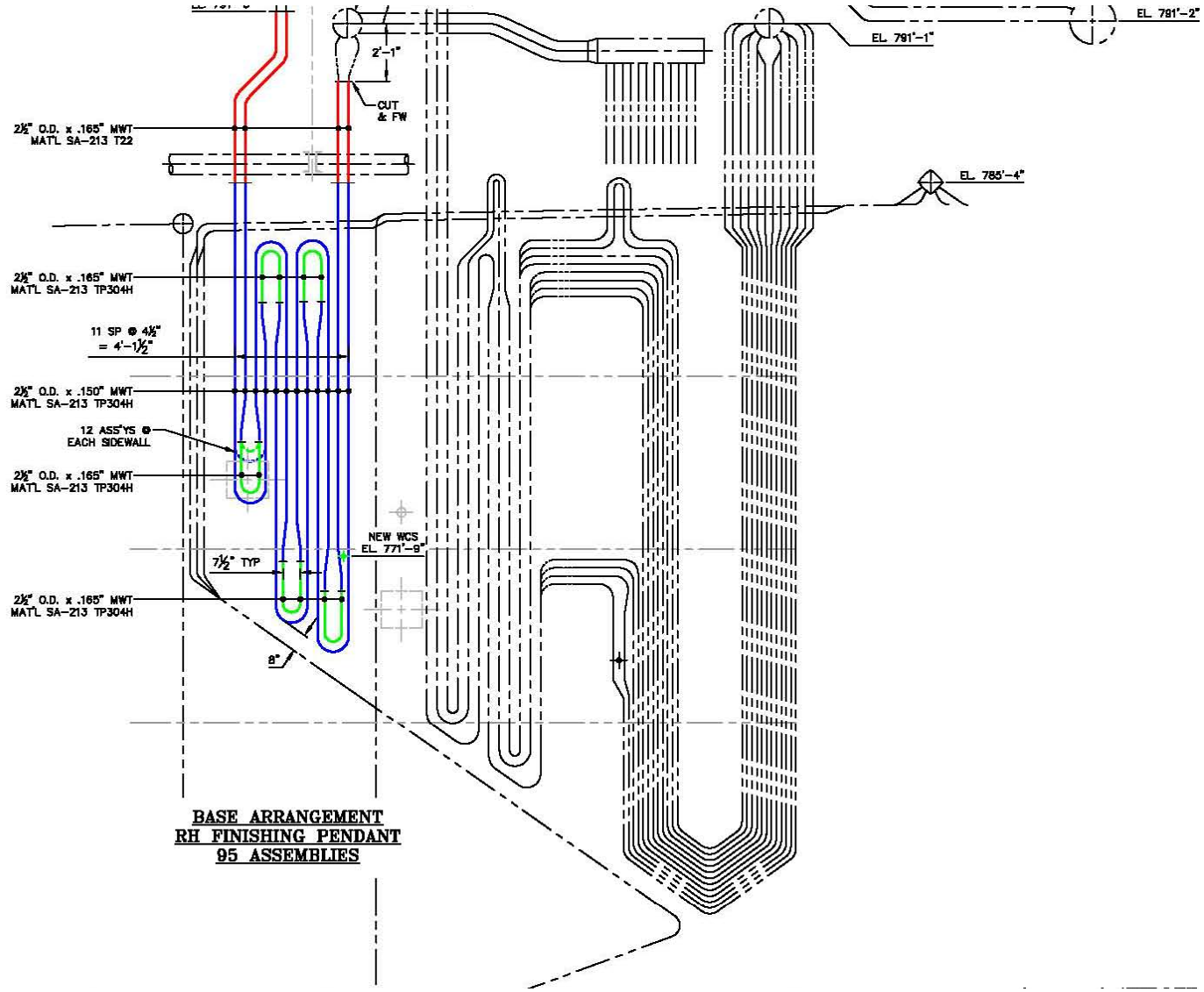


| | | Original Design | Test Data Coal | Natural Gas | Natural Gas | Natural Gas |
|---|---------|-------------------------|----------------|-------------|-----------------------------------|-----------------------|
| Date | | | 03/29/2 011 | | | |
| | | | | No Mods. | Add 31% more RH Finishing Surface | Add Gas Recirculation |
| Gross Load | MW | | 184 | | | |
| Load | % | 103.5% MCR 6Hr. Peak | 104.8% MCR | 104.8% MCR | 104.8% MCR | 104.8% MCR |
| 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 Tilt | degrees | Horiz. | -7 | +15 | +15 | +15 |
| Gas Recirculation | % | | | | | 20 |
| Fuel Elevations in Service | Number | 5 | 5 | 4 | 4 | 4 |

Bituminous Coal Fired Boiler #2



Bituminous Coal Fired Boiler #2



Bituminous Coal Fired Boiler #2



| | | Original Design | Coal Data | Natural Gas |
|---------------------------|-------|-----------------|-----------|---------------------------------------|
| | | | 2/16/2011 | With or Without Additional RH Surface |
| Air Weight to FD Fan | lb/hr | 1,418,000 | 1,367,521 | 1,578,988 |
| Excess Air | % | 15 | 16 | 20 |
| Air Temperature to FD Fan | °F | 100 | 100 | 100 |
| Air Volume | ACFM | 333,600 | 330,986 | 382,169 |
| Air Volume per Fan | ACFM | 166,800 | 165,493 | 191,085 |
| 27% Tolerance @ 140°F | ACFM | 212,000 | | |
| Delta P | "w.g. | 11.00 | 10.59 | 11.10 |
| 41% Pressure Tolerance | "w.g. | 15.50 | | |



| | | Original Design | Coal Data | Natural Gas |
|---------------------------|-------|-----------------|-----------|---------------------------------------|
| | | | 2/16/2011 | With or Without Additional RH Surface |
| Gas Weight to ID Fan | lb/hr | 1,684,000 | 1,685,711 | 1,733,470 |
| Excess Air | % | 15 | 16 | 20 |
| Gas Temperature to ID Fan | °F | 285 | 301 | 305 |
| Gas Volume | ACFM | 524,000 | 565,177 | 585,380 |
| Gas Volume per Fan | ACFM | 262,000 | 282,588 | 292,690 |
| 15% Tolerance | ACFM | 301,000 | | |
| Delta P | "w.g. | 16.00 | 11.41 | 10.92 |
| 26% Pressure Tolerance | "w.g. | 20.20 | | |



Bituminous Coal Fired Boiler #2

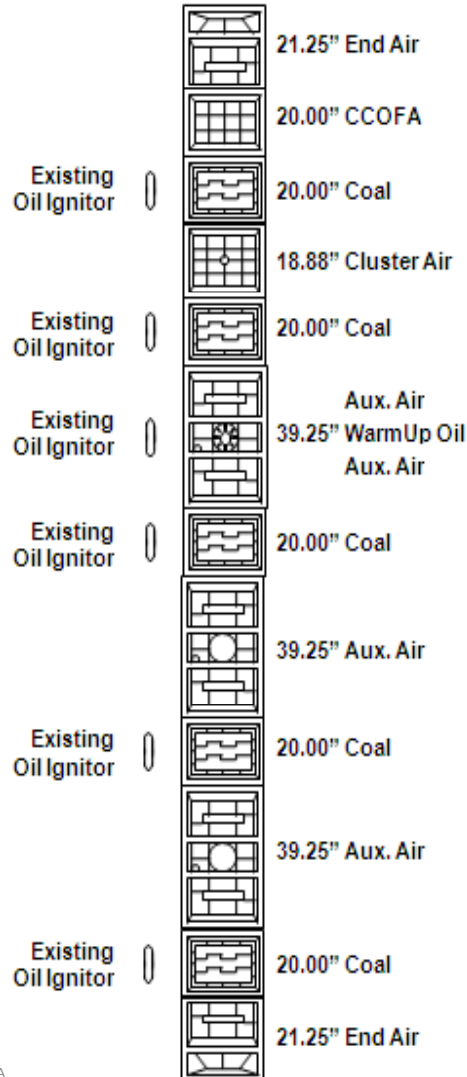


- Alstom performed a study to convert to 100% natural gas firing. For study purposes, customer has defined normal full load (NFL) at 185 MW. Coal firing will be eliminated.
- To convert the unit to natural gas firing, the Alstom will provide four elevations of load carrying gas guns, coupled with Class 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.

Bituminous Coal Fired Boiler #2



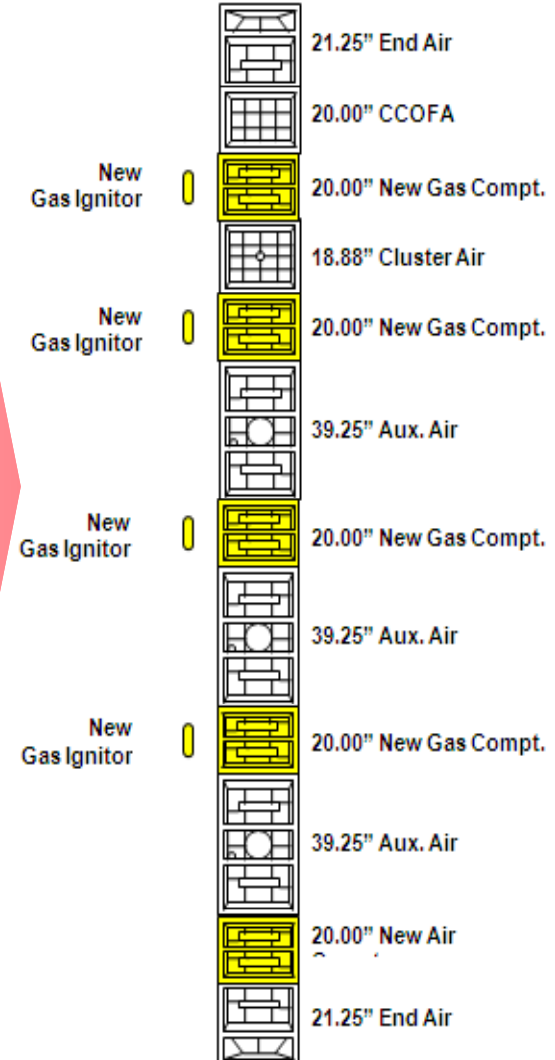
**Existing
16" Wide Windbox**



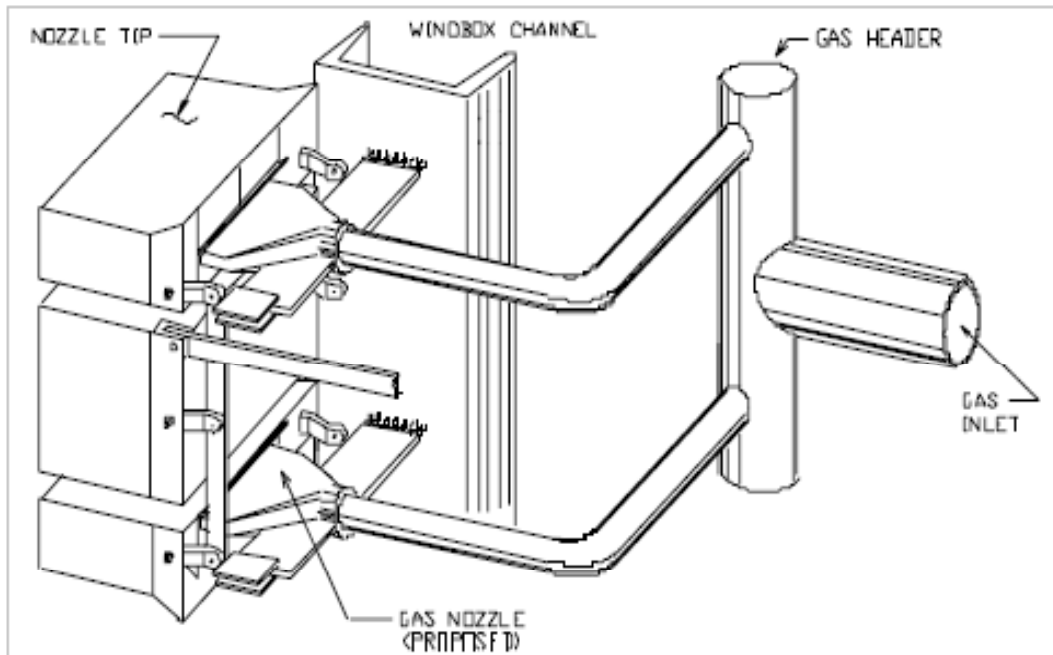
To convert Unit 2 to NG firing, Alstom proposed:

- 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

**Proposed
16" Wide Windbox**



Bituminous Coal Fired Boiler #2 – Gas Firing Compartment Assembly



- Gas gun assembly sized for approx. 111×10^6 Btu/hr per compartment.
- 7:1 turndown capability with gas supply pressure of 25 psig to gas gun and minimum operating pressure of 1/2 psig above furnace pressure at burner spud

Introduction

Converting Bituminous Coal Fired Units to Gas

Converting PRB Coal Fired Units to Gas

Natural Gas Emissions

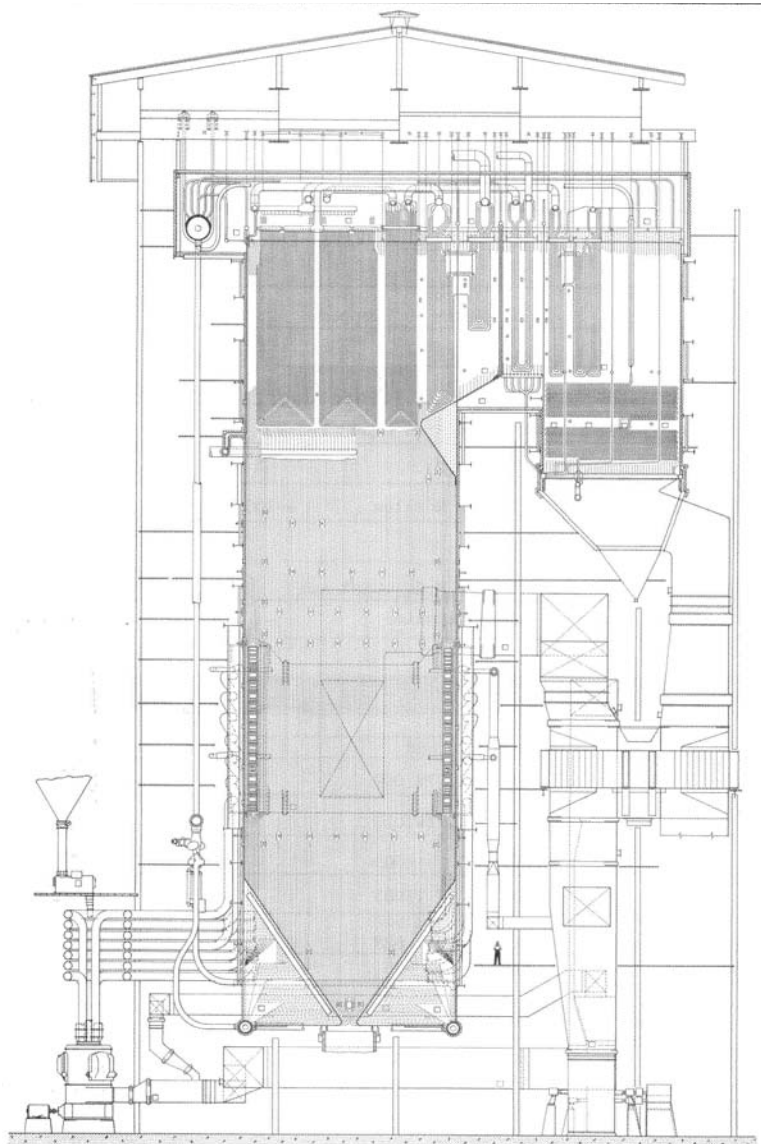
Gas Firing Equipment & Auxiliaries

Converting PRB Coal Fired Boiler to Gas Firing

PRB Coal Fired Boiler



| | | | | | | | | |
|----------------------------------|-----------------|--|--|-----------------|--------------------|--|------|------|
| BOILER | | Units #1 & #2 | SQ. FT. H.S. PER UNIT | 107,647 | DESIGN | 2990 | | |
| DESIGNATION | | 65' - 0" | 311 - 2" | CCRR | | OPER. | 2620 | |
| | | 52' - 7 15/16" | 234 - 2" | | | S.O. | | |
| | | | | | | TURBINE | 2520 | |
| FURNACE | | VOLUME CU. FT. TOTAL | 597,625 | TYPE OF BOTTOM | Hopper | WIDTH 65' - 0" | | |
| | | Fusion Welded Walls - Balanced Draft | | FRONT | | TO REAR 52' - 7 15/16" | | |
| SUPERHEATER | | TYPE | Multistage with Panels & Platens | REHEATER | TYPE | Multistage with Radiant Wall - Front & Sides | | |
| ECONOMIZER | | NO. 1 | TYPE Plain Tube - In Line 206 W x 48 H | | | | | |
| AIR HEATER | | NO. 2 | TYPE 31½ VI 84 (T) | | MAKE Ljungstrom | | | |
| FUEL BURNING EQUIPMENT | | TT Fuel Nozzles 6-1003 RP Mills* | | | | | | |
| FUEL | | East Decker Sub-Bituminous - C | | | ASH FUSION TEMP. F | GRIND-ABILITY | HHV | |
| | | 24.71% Moist. | 31.76% Vol | 39.23% F.C. | 43% Ash | 2190 | 50 | 9238 |
| | | (Future - Texas Lignite) | | | | | | |
| | | FOSSIL SERVICES | | | | | | |
| OPERATING CONDITIONS | | | | | | | | |
| | | CONTROL POINT | | MCR | | | | |
| LB STEAM PER HOUR ACTUAL | PRIMARY | 2,100,000 | 4,199,000 | | | | | |
| | REHEAT | 1,899,000 | 3,724,000 | | | | | |
| STEAM TEMP. F LEAVING | SUPERHEATER | 1005 | 1005 | | | | | |
| | REHEATER | 1005 | 1005 | | | | | |
| REHEAT DATA | ENTERING TEMP. | 572 | 648 | | | | | |
| | ENTERING PRESS. | 319 | 628 | | | | | |
| FEEDWATER TEMP. F | | 426 | 495.2 | | | | | |
| TEMP. AIR TO AIR HEATER | | 125 | 90 | | | | | |
| TEMP. GAS FROM AIR HEATER | | 256 | 290 (UNCORR.) | | | | | |
| OVERALL EFFICIENCY % *Guaranteed | | 87.49 | 86.56* | | | | | |
| SUPPLEMENTARY DATA | | *Provision made for 7th Mill for Lignite O.F.A.; Refractory: Insulation & Lagging; F.D. & P.A. Fans; Soot Blowing System; Steam Coil; Circ. System; Cold Precipitator by Customer. | | | | GENERATOR KW MFR. RATING | | |
| | | | | | | 600,000 | | |
| | | | | | | PLANT ELEV. | | |
| | | | | | | 376 FT. | | |



PUB. NO 1-2-62

PRB Coal Fired Boiler– Full Load



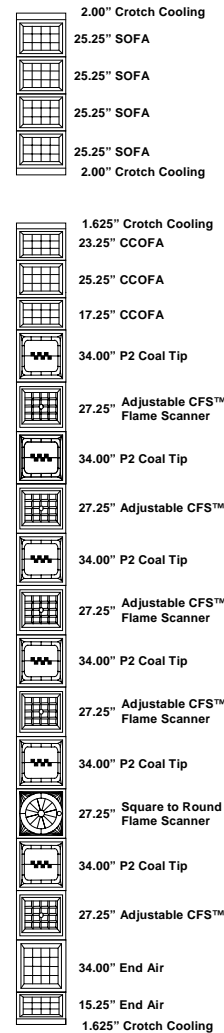
| | | | | | | | | |
|--------------------------------|------------------------|---------|---------|---------|---------|---------|---------|---------|
| SH Steam Flow | lb/hr | 4208428 | 4208428 | 4208428 | 4208428 | 4208428 | 4208428 | 4208428 |
| RH Steam Flow | lb/hr | 3926131 | 3848276 | 3899221 | 3814276 | 3814276 | 3839524 | 3814276 |
| SHO Temp | degF | 1004 | 990 | 1004 | 863 | 986 | 1004 | 978 |
| SH Desup Spray | % | 1.3 | 0.1 | 0.6 | 0 | 0 | 0 | 0 |
| RH Desup Spray | % | 2.9 | 0.9 | 2.2 | 0 | 0 | 0.7 | 0 |
| SHDesuperheater Spray | lb/hr | 56190 | 0 | 26563 | 0 | 0 | 625 | 0 |
| RHDesuperheater Spray | lb/hr | 111855 | 0 | 84945 | 0 | 0 | 25248 | 0 |
| RHO Temp | degF | 1005 | 1004 | 1005 | 789 | 988 | 1006 | 974 |
| RHDESUP OUT TMP | degF | 589 | 606 | 599 | 506 | 617 | 622 | 609 |
| Feedwater Temp | degF | 470 | 470 | 470 | 470 | 470 | 470 | 470 |
| Econ Exit Gas Temp | degF | 778 | 763 | 769 | 695 | 765 | 760 | 783 |
| AH TGO Uncorr | degF | 308 | 304 | 306 | 306 | 317 | 320 | 336 |
| Tilt | degree | -5 | -5 | 5 | 5 | 25 | 15 | 5 |
| Excess Air | % | 20 | 20 | 20 | 10 | 30 | 20 | 10 |
| Boiler Efficiency | % | 85.58 | 85.32 | 85.27 | 84.21 | 83.11 | 83.47 | 83.58 |
| Gas Recirculation | % | 0 | 0 | 0 | 0 | 0 | 0 | 35 |
| NHI/PA | Btu/hr-ft ² | 1.85 | 1.81 | 1.83 | 1.54 | 1.79 | 1.79 | 1.84 |
| Q FIRED | Btu/hr | 6052.8 | 5952 | 6037.9 | 5347.5 | 6017.8 | 6084.5 | 5940.5 |
| Gas Leaving AH | degF | 6524397 | 6317903 | 6400794 | 4889759 | 6347443 | 5967469 | 5403267 |
| Gas In Temp | degF | 2699 | 2642 | 2684 | 2454 | 2555 | 2687 | 2353 |
| Percent Coal | | 100 | 80 | 80 | 0 | 0 | 0 | 0 |
| Percent Gas | | 0 | 20 | 20 | 100 | 100 | 100 | 100 |
| Existing Windbox Configuration | | Yes | Yes | Yes | Yes | Yes | No | Yes |

PRB Coal Fired Boiler

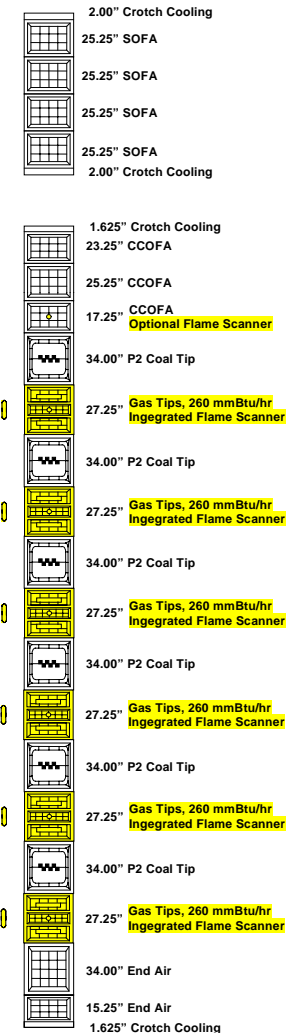


- Retaining coal firing capability
- Existing oil fired ignitors were eliminated that are adjacent to the coal compartments.
- New gas fired ignitors adjacent to the new gas compartments and coal will be ignited by the gas elevations.

Existing LNCFS™ Level 3 Low NOx System Windbox Arrangement



Natural Gas Modification to Existing LNCFS™ Level 3 Arrangement



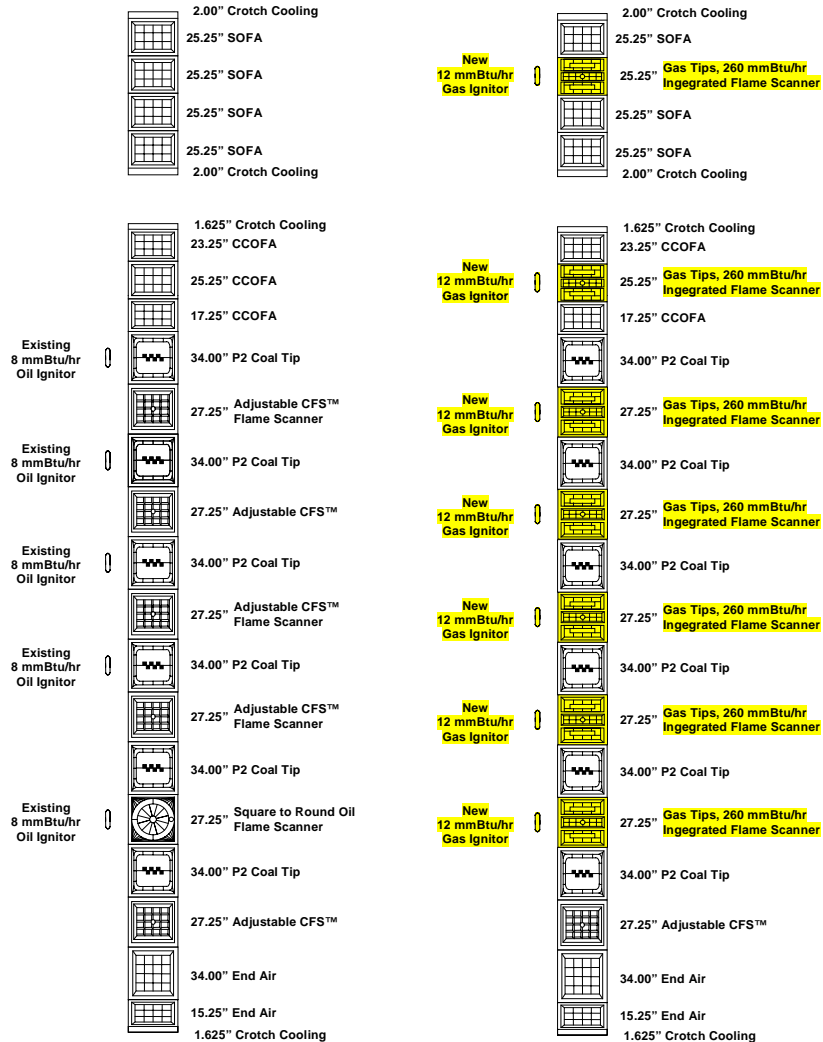
PRB Coal Fired Boiler



- Optional gas firing arrangement
- Install one elevation located in the SOFA to raise furnace outlet gas temperature so steam temperature can be achieved.

Existing LNCFS™ Level 3 Low NOx System Windbox Arrangement

Natural Gas Modification to Existing LNCFS™ Level 3 Arrangement

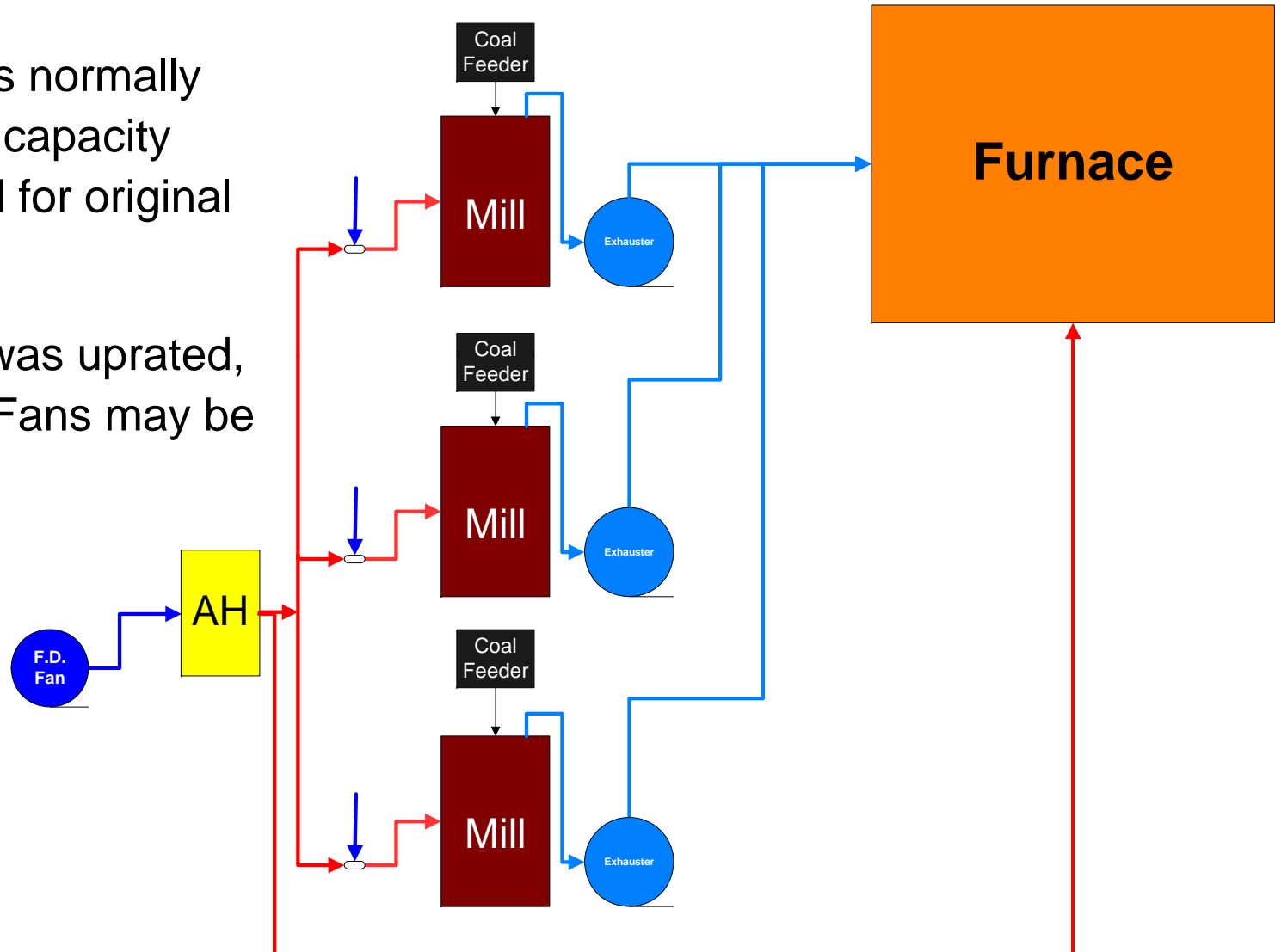


Pulverizer and Fan Systems

-
- How do we get the required combustion air flow to the windbox and furnace?
 - What operating or equipment modifications will be required?

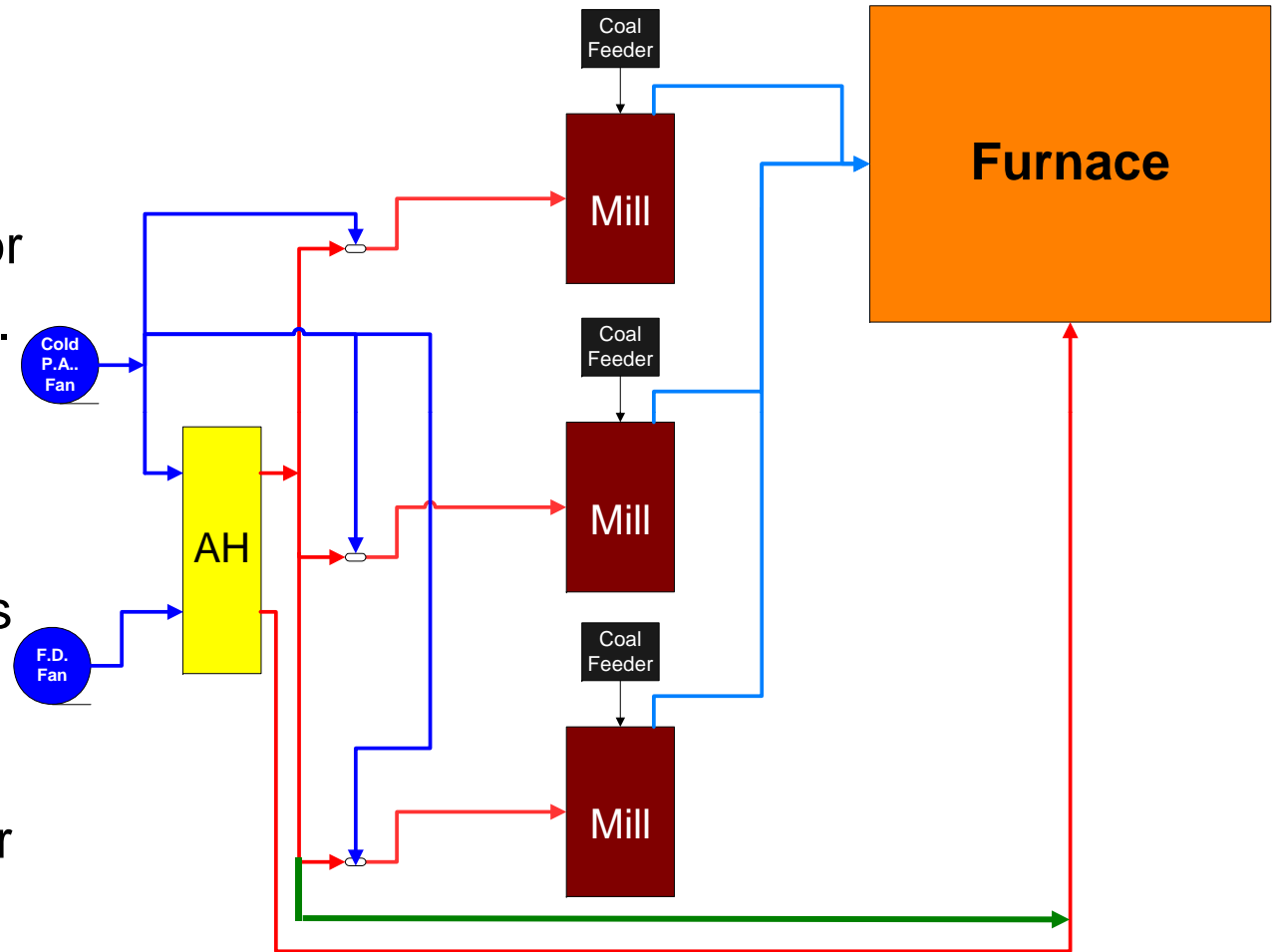
Pulverizer System with Exhausters

- F.D. Fans normally have the capacity and head for original full load.
- If Boiler was uprated, the F.D. Fans may be limited.



Cold Primary Air System with Bisector or Trisector AH

- F.D. Fans normally do not have the capacity and head for original full load only.
- The P.D. Fans will have to be modified.
 - Two speed motors if coal is retained.
 - If only NG, new lower speed motor and some rotor modifications.



Introduction

Converting Bituminous Coal Fired Units to Gas

Converting PRB Coal Fired Units to Gas

Natural Gas Emissions

Gas Firing Equipment & Auxiliaries

Gas Firing - Emissions

NOx is formed by two primary mechanisms:

- Thermal fixation of atmospheric nitrogen--
“thermal NOx”
- Fixation of nitrogen contained in the fuel--
“fuel NOx” (no fuel NOx in gas)

Parameters Influencing NOx Formation



- Boiler Operation
 - Unit Load
 - Tilt Position
 - Excess Air
 - WB Air Distribution
 - Fuel/Air Staging
- Boiler Design
 - Heat Release Rates
 - Air Inleakage
 - Firing Systems Design

- **Reduce Burner Zone Stoichiometry**
 - Low NOx Burners
 - Lower Excess Air
 - Overfire Air (OFA)
 - Flue Gas Recirculation

- **Lower Flame Temperature**
 - Reduce Secondary Air Temperature
 - Reduce Load
 - Steam/H₂O Injection
 - Flue Gas Recirculation
 - Spread Out the Heat Release

- **Flue Gas Recirculation**
 - Forced
 - Induced
 - Premixed

- **Reburn**

- **SNCR**

Low NOx Gas Fired Experience List



| Plant | Nominal MW's | FHI / PA | Pre NOx, lb/Mbtu | Post NOx, lb/Mbtu | Low NOx System |
|---------|--------------|----------|------------------|-------------------|--------------------|
| Plant A | 160 | 1.58 | 0.22 | 0.08 | SOFA & Hopper FGR |
| Plant B | 400 | 2.74 | 0.33 | 0.18 | CCOFA |
| Plant C | 400 | 2.74 | 0.33 | 0.18 | CCOFA |
| Plant D | 225 | 1.57 | 0.23 | N/A | CCOFA |
| Plant E | 235 | 1.69 | 0.42 | N/A | CCOFA |
| Plant F | 375 | 2.66 | 0.59 | N/A | CCOFA |
| Plant G | 365 | 1.97 | N/A | 0.14 | CCOFA |
| Plant H | 370 | 2.20 | | 0.15 | CCOFA & Hopper FGR |
| Plant I | 370 | 2.20 | | 0.15 | CCOFA & Hopper FGR |
| Plant J | 370 | 2.20 | | 0.11 | CCOFA & Hopper FGR |
| Plant K | 363 | 2.95 | | 0.11 | CCOFA |
| Plant L | 363 | 2.95 | | 0.10 | CCOFA |
| Plant M | 500 | 2.05 | 0.14 | N/A | SOFA |
| Plant N | 550 | 3.03 | 0.21 | N/A | VCCOFA |

N/A = Not Available

Generally, NOx is less than 0.15 lb/MBtu, and in many instances, can achieve less than 0.10 lb/MBtu with in-furnace technologies

- CO
 - Incomplete Combustion
 - Time, Temperature, Turbulence

Introduction

Converting Bituminous Coal Fired Units to Gas

Converting PRB Coal Fired Units to Gas

Natural Gas Emissions

Gas Firing Equipment & Auxiliaries

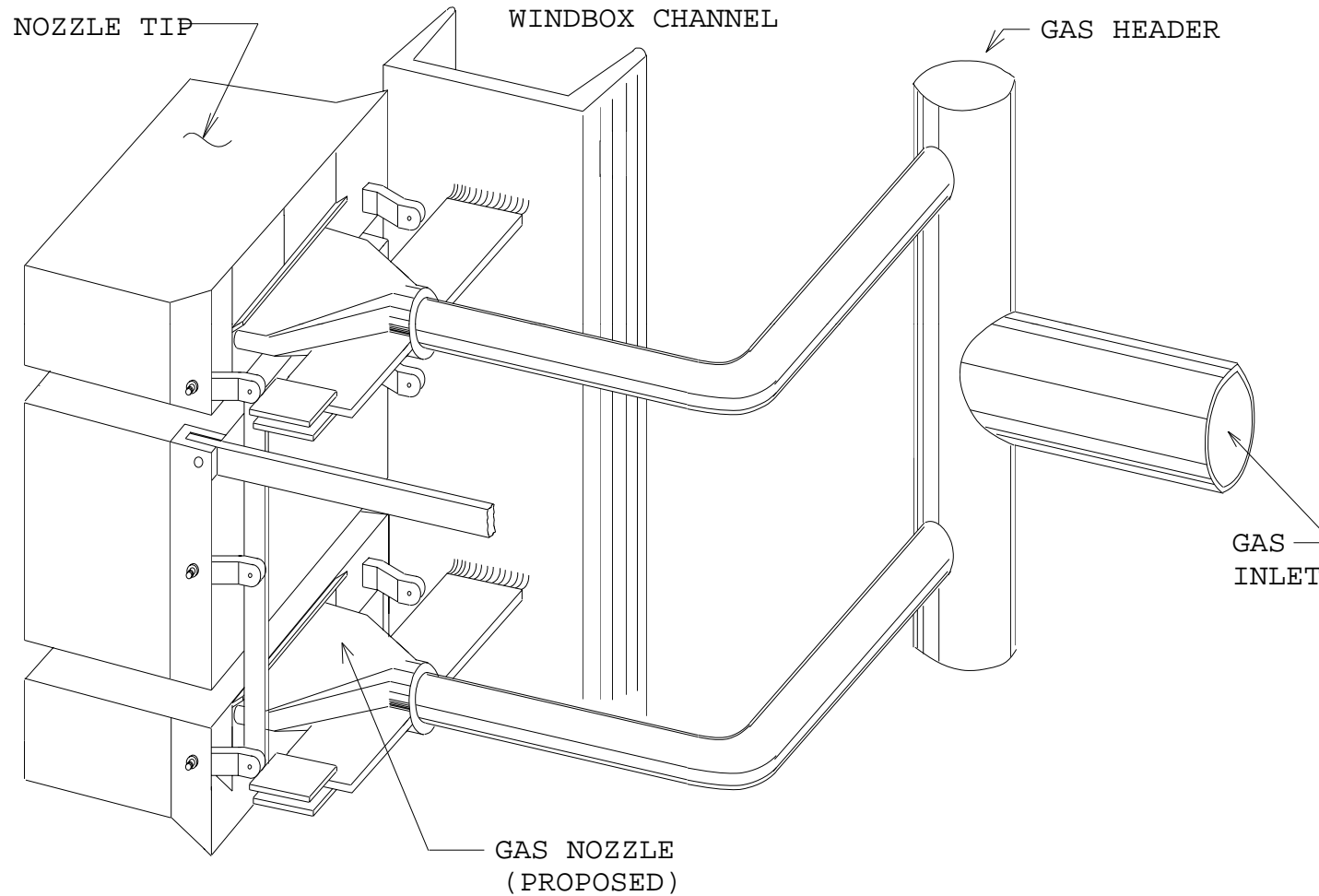
Gas Firing Equipment & Auxiliaries

Key Gas Design Criteria

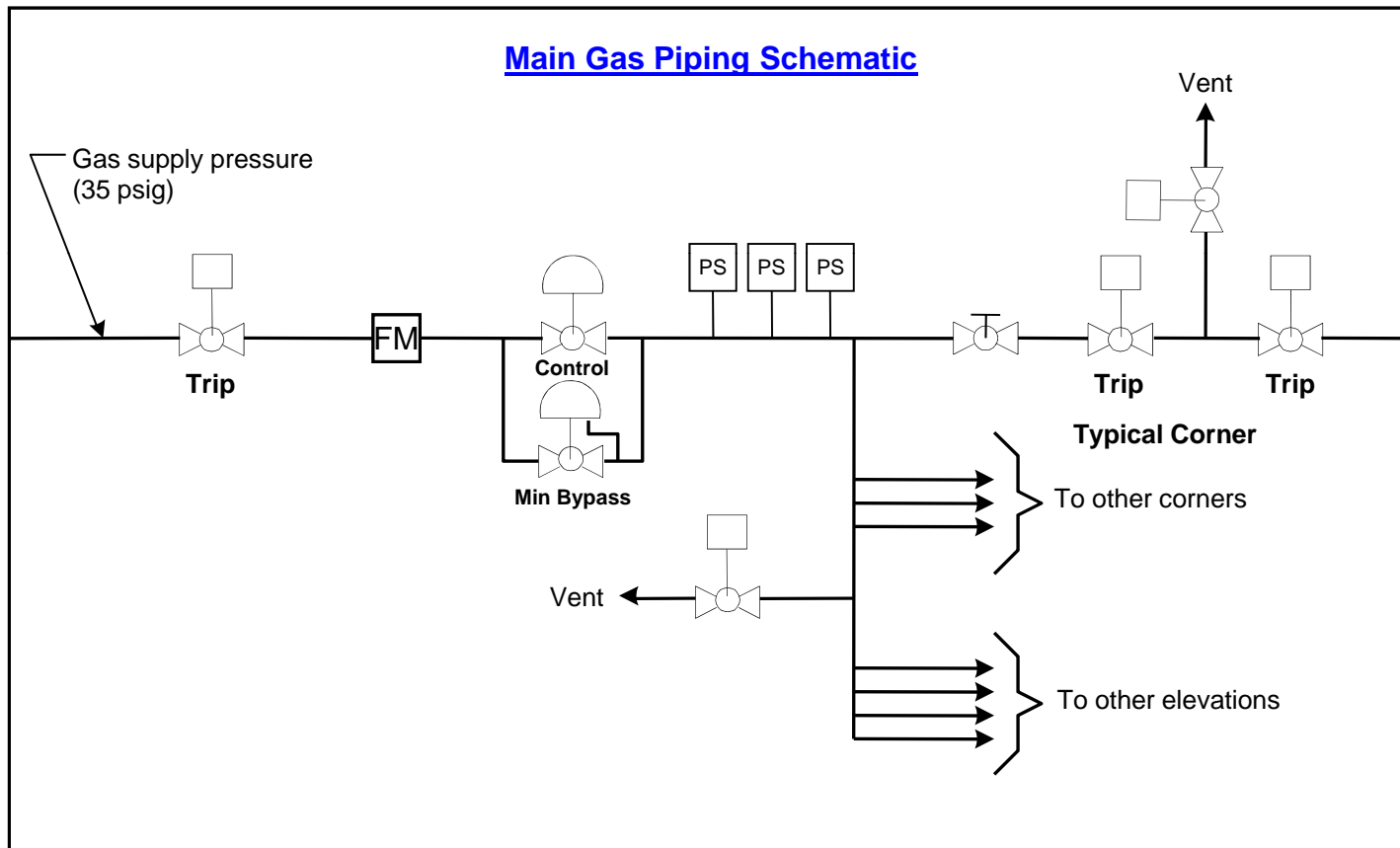


- Gas Composition
 - Flame Propagation Velocity
 - Heating Value
 - Specific Gravity
 - Hydrogen Content
- Adiabatic Flame Temperature
- Air Flow Requirements
 - Stoichiometric Airflow Requirements
 - Excess Air Levels
 - Mill Airflow Deficiency

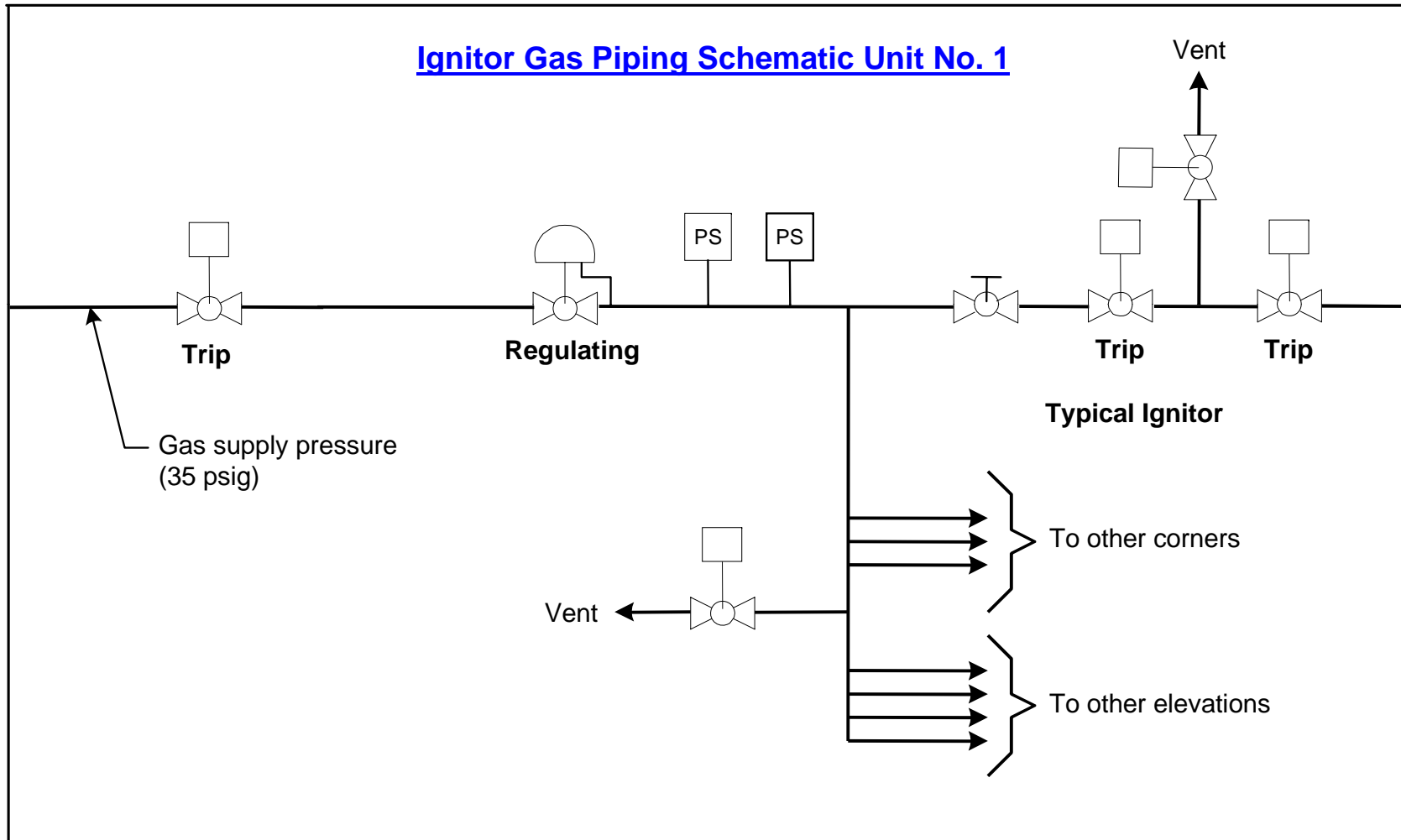
Typical T-Fired Gas Compartment



Typical Main Gas Piping Schematic



Typical Ignitor Gas Piping Schematic



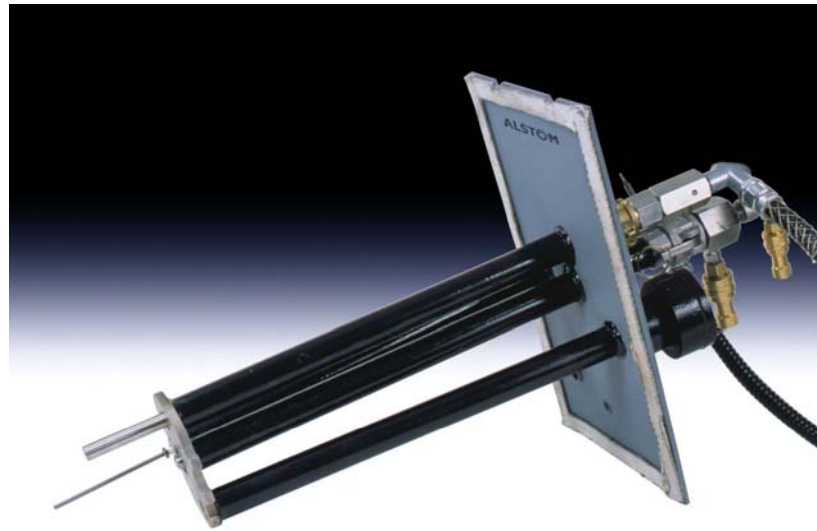
Main & Ignitor Gas Header Skid



Skid-Mounted Gas & Ignitor Pipe Trains



Side Pilot Gas Ignitors



- High Performance Natural Gas
- 6" Side Pilot Ignitor at 13MMBTU/hr



Gas Pipe Train

- Double Block and Vent Safety Shut-off Valves
- Gas Flow Regulating Valve
- Fuel strainer



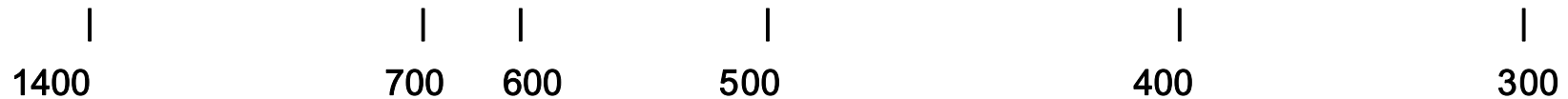
Flame Scanner Fundamentals



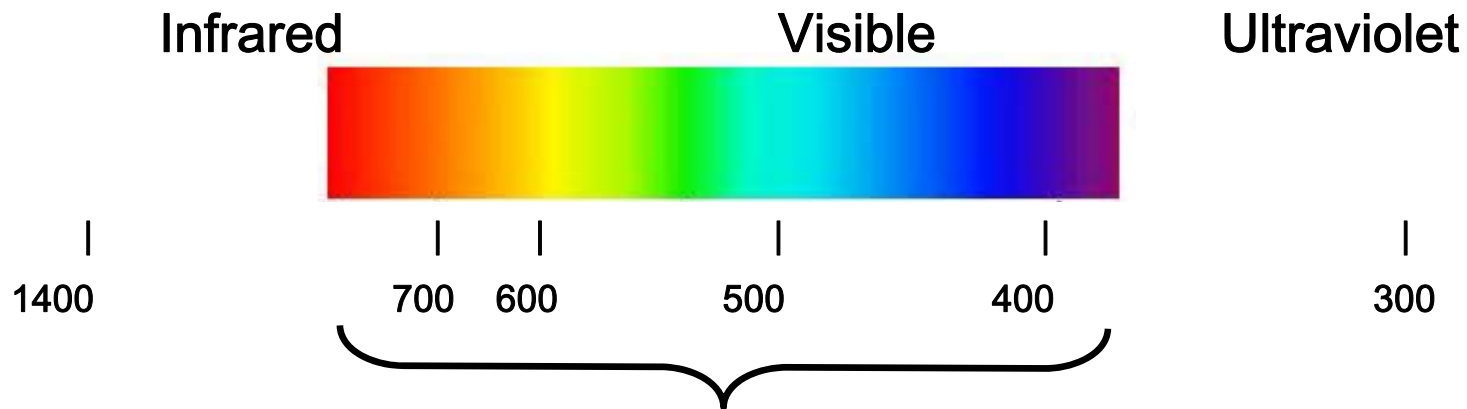
Infrared

Visible

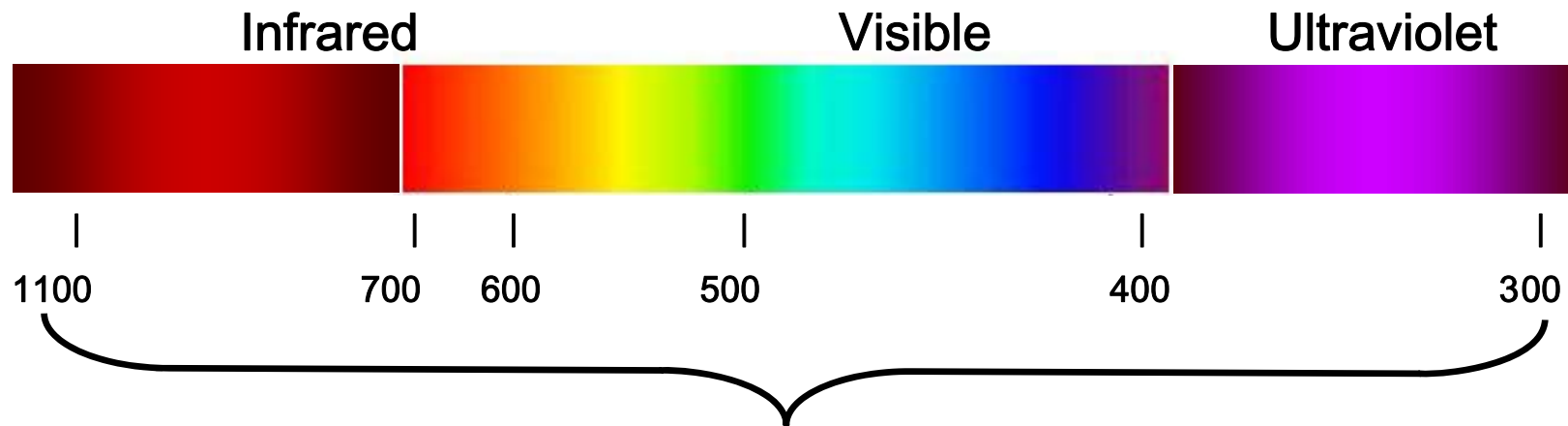
Ultraviolet



- **Alstom's first flame scanner (500 series) used a single sensor to examine ultraviolet light. These UV sensors proved to require extensive maintenance and were superceded by visible light flame scanning**



- **Safe Flame 1, 2 and DFS used a single photodiode sensing visible light to determine if flame is present. The technology was extended to allow under some circumstances, the ability to detect (discriminate) if the flame identified was oil or coal**



- **The latest generation LIMELIGHT, uses six sensors spread from Infrared to Ultraviolet to improve flame detection, improve the ability to distinguish one burner from another, and improve the ability to discriminate the type of fuel being burned.**



- **FS-100 Spectrometer**
- **Multiple Photodiodes**

- **One Piece Design**
- **Revolutionary Concept**
- **Seven (7) Discrete Sensors**
- **Covers Entire Light Spectrum –
UV to Visible Light to IR**
- **Improves Flame
Diagnostics**
- **Assess Burner
Performance**

LIMELIGHT™ Flame Scanner Features



- Newest Design Third Generation Scanner. Reliably detects flames in both T and Wall Fired Boilers
- Uses 6 discrete sensors for optimum ability to discriminate between support fuel flame, other burner flames and the flame to be monitored
- Straight-forward connection to Burner Management System with minimum wiring
- Part of ALSTOMs integrated approach to safe reliable operation

LIMELIGHT™ Flame Scanner

Benefits



- Integrated System with BMS proven in hundreds of Boilers with thousands of scanners
- High sensitivity for improved low load operation without unnecessary trips
- Configured to start-up without major adjustment.
- Network configuration reduces field wiring by 75%

Major Components



Converting Coal Fired Boilers to Gas Firing Summary

Possible Issues Include:

- An increase in SH desuperheater spray water flow
- An increase in RH desuperheater spray water flow
- An increase in forced draft fan volumetric flow
- SHO & RHO steam temperatures may not be achieved in some cases

These issues may or may not require capacity increases in their respective equipment

Bituminous Coal to Natural Gas Conversion

Possible Solutions:

- Increase the SH desuperheater spray water capacity
- “Tip” the forced draft fans to increase their volumetric flow capacity
- May require re-surfacing for improving steam temperature

Possible Issues Include:

- Inability to attain design SH steam outlet temperature
- Inability to attain design RH steam outlet temperature
- Insufficient forced draft fan volumetric capacity
- Insufficient forced draft fan motor size
- Exceeding steam turbine steam inlet temperature lower limits
- Exceeding steam turbine SH/RH steam inlet differential temperature limits

Possible Solutions:

- Raise the gas firing elevation in the furnace to increase furnace outlet temperature when firing natural gas
- Increases SH steam outlet temperature to design level
- Eliminates steam turbine steam temperature issues
- Customer may choose to let forced draft fan capacity determine MCR
- FD fan volumetric capacity may be increased by “tipping” the fan (may require motor HP increase)
- FD fan volumetric capacity may be augmented with the primary air fans
- Primary air system may need to be redesigned

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