Solid Fuel to Natural Gas Conversions for Existing Boiler Applications

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COMBUSTION AND ENVIRONMENTAL SOLUTIONS.
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BURNERS


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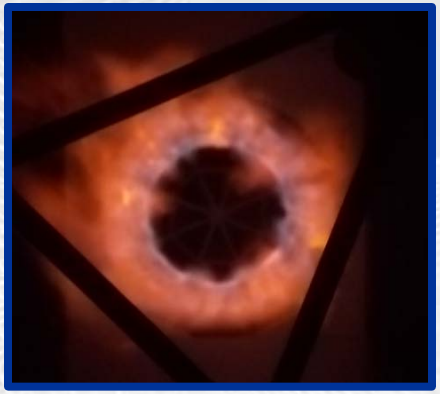
Free-Jet Conversion Project



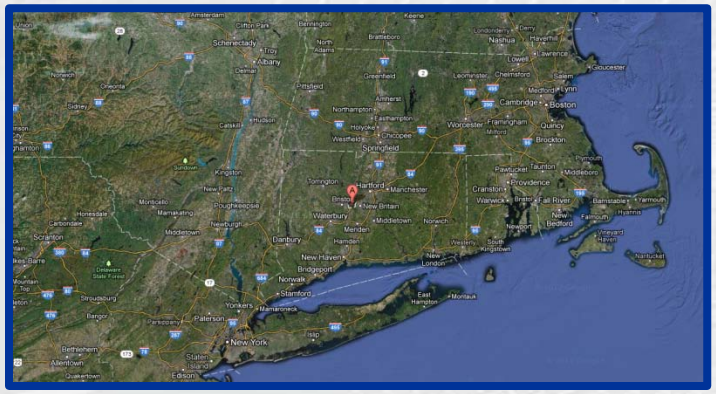
- Circulating Fluidized Bed Boiler (CFB)
- Solid Fuel Conversion to Natural Gas – Low NOx
- ~1,200 kPPH CFB – 1,500 MMBtu/hr
- 8 Low NOx Zeeco Free Jets – 177 MMBtu/hr each
- New engineering and intern training

Topics:

- Zeeco Power Overview
- Free-Jet Technology Development
- The CFB
- Challenges
- Solutions
- Implementation
- Data/Conclusion-Validation

Zeeco Power

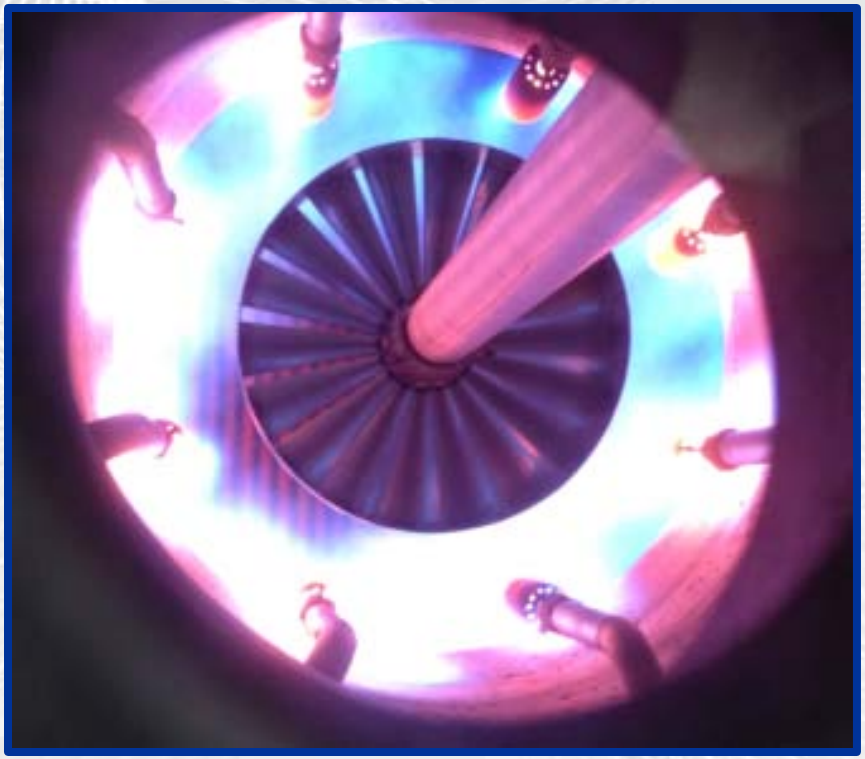
- Over 120 global personnel in Zeeco's Burner Division
- Global HQ for Power Division Located in Plainville, CT
- Sales, Applications, Project Management, Engineering, Design, Technical, Services, Turnkey
- 35 People in the CT office:
  - 29 report through CT office
  - 6 remote (Oklahoma, California and Minnesota)



Technology Development

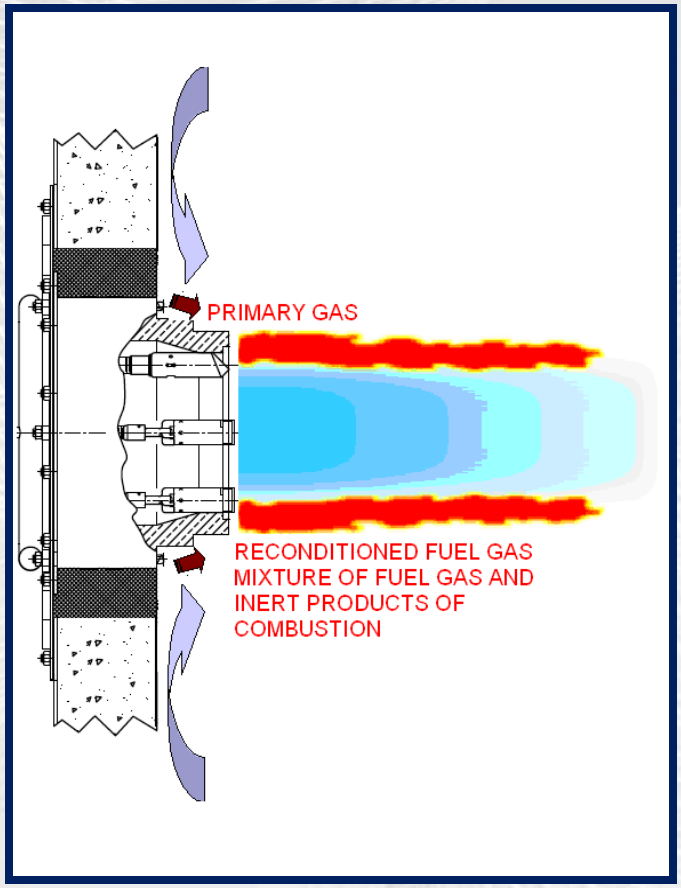
Solutions Driven Technology for over 18 years:

- Empirically-based foundation
- Several hundred applications in service
- Several thousand burners in service
- Good basis for Power applications



Practical application for Zeeco Free-Jet Fuel Reconditioning for Lower Thermal NOx

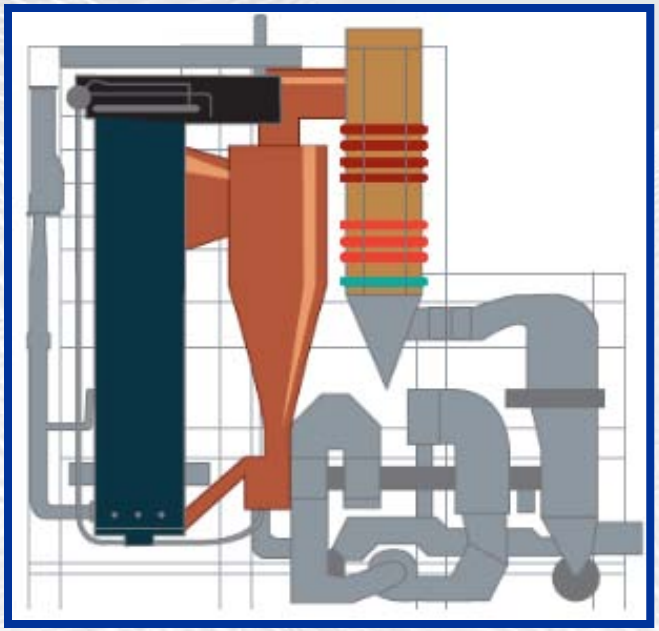
- Simple design for a complex problem
- The fuel gas is mixed with inert products of combustion before combustion occurs, thus “reconditioning the fuel gas”



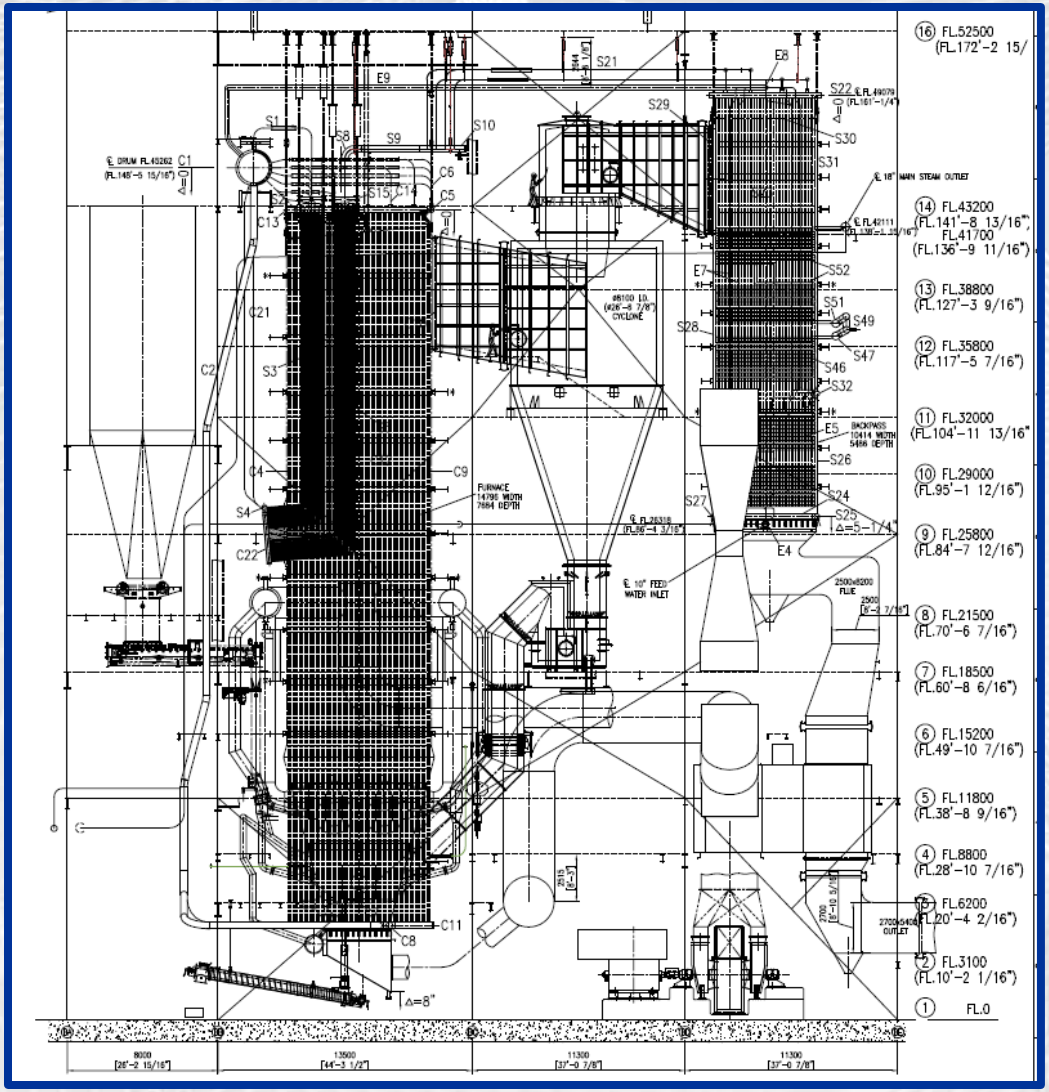
Inert Products of Combustion

Topics

- The CFB:
  - Designed for Petcoke – solids recirculation
  - Heat transfer (water and steam circuits) for Petcoke firing
  - CFB plant in service for under 1.5 years in total before decision
    - After initial engineering, plant wanted to keep potential for returning to petcoke
  - One key point – if a CFB can be converted, so can your boiler (whether solid, liquid, gas)

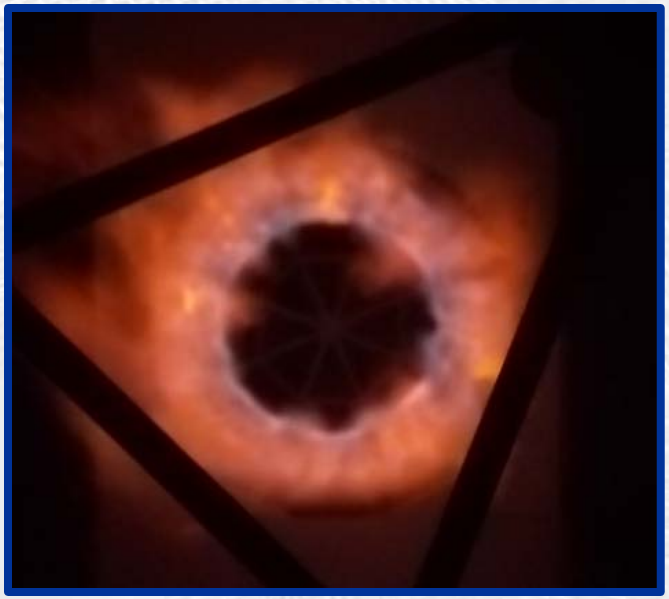


CFB Fuel Conversion

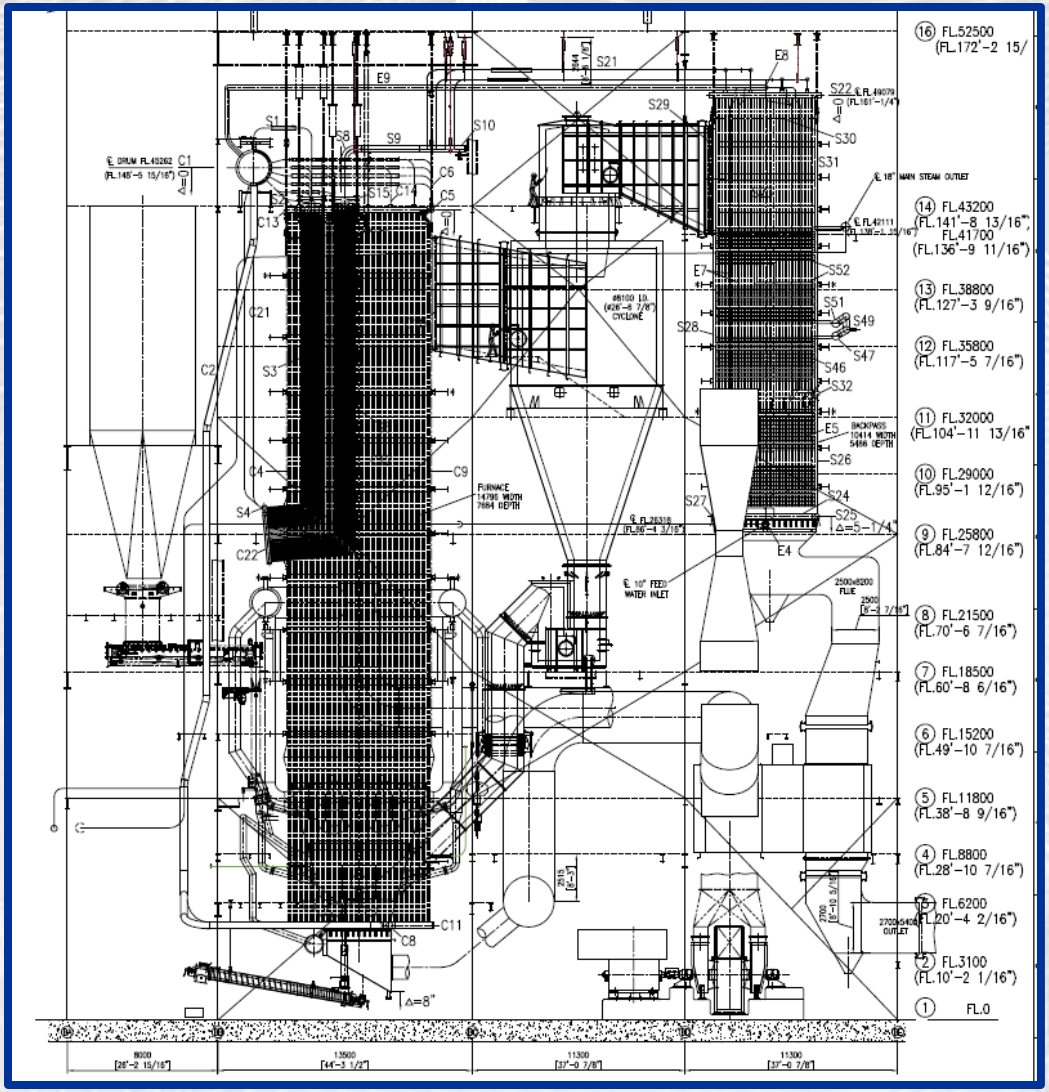


Topics

- Challenges to overcome:
  - Meet current permit NOx limits – 0.07lbs/MMBtu
  - No EFGR (convective impacts)
  - Ensure no degradation/derate on steam production
  - Solids return systems– cyclone
  - Ancillary equipment
  - Fluidization system

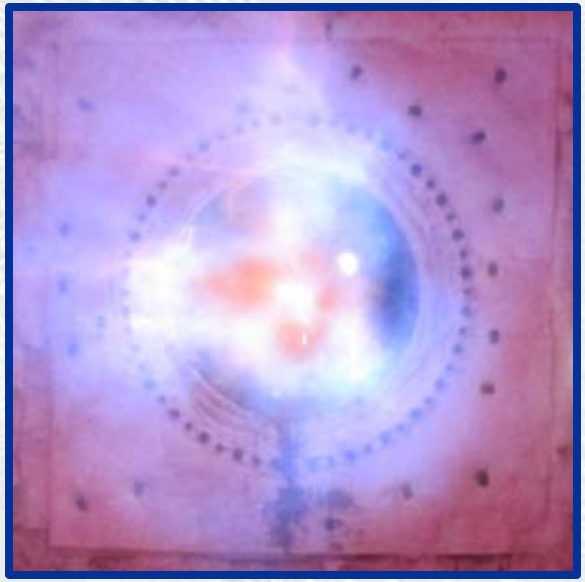


CFB Fuel Conversion



Topics

- Solutions:
  - Thermal performance analysis (boiler) cases run with various firing system solutions
  - Very important to water and steam circuits
  - Firing system cases – chosen one was dual elevation (runs with thermal boiler performance)
  - Performance runs are critical for waterwall protection system (circulation ratio) and reliable steam production post-retrofit



Boiler Thermal Analysis

Gas Firing Feasibility Study - Final Report Runs

Run No. 2 Run Type

Run 02: Natural Gas Firing, 100% MCR, 1,102,310 lb/hr Steam Flow, 1006°F Superheat Outlet Temp., 20% Excess Air, 1% Blowdown, 0% Spray After LTSH, No Bed.

FURNACE SH PANELS

Fluid In	642.2 deg. F
Fluid Out	692.7 deg. F
Gas In	1857 deg. F
Gas Out	1688 deg. F
SEF	1.17

SH FINISH UPPER

Fluid In	852.5 deg. F
Fluid Out	1006.0 deg. F
Gas In	1632 deg. F
Gas Out	1340 deg. F
SEF	1.01

SH FINISH LOWER

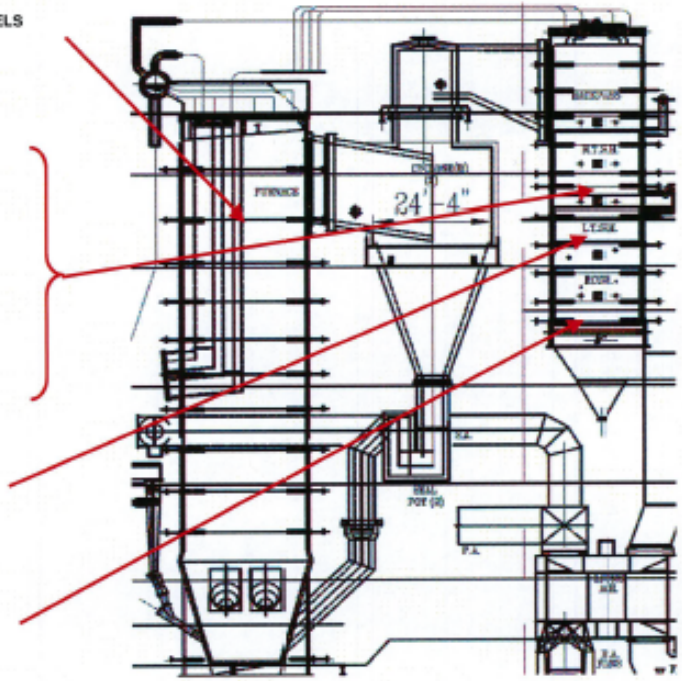
Fluid In	765.9 deg. F
Fluid Out	852.5 deg. F
Gas In	1340 deg. F
Gas Out	1135 deg. F
SEF	1.01

LTSH

Fluid In	701.2 deg. F
Fluid Out	765.7 deg. F
Gas In	1135 deg. F
Gas Out	926 deg. F
SEF	1.35

ECONOMIZER

Fluid In	426.0 deg. F
Fluid Out	526.3 deg. F
Gas In	926 deg. F
Gas Out	586 deg. F
SEF	0.93



Other Performance Data

Boiler Load	100 % MCR
Main Steam Flow	1,102,310 lb/hr
Main Steam Temp.	1,006 °F
DeSH Spray Flow	0 lb/hr
Boiler Efficiency	84.4 %
Fuel Fired	1412.5 Mbtu/hr
Fuel Flow	62,269 lb/hr
Excess Air	20 %
Combustion Air	1,033,963 lb/hr
+ Excess Air	206,793 lb/hr
= Total Air	1,240,756 lb/hr
Total Air	1,240,756 lb/hr
- BP Leakage Air	18,611 lb/hr
= Air To Burners	1,222,145 lb/hr

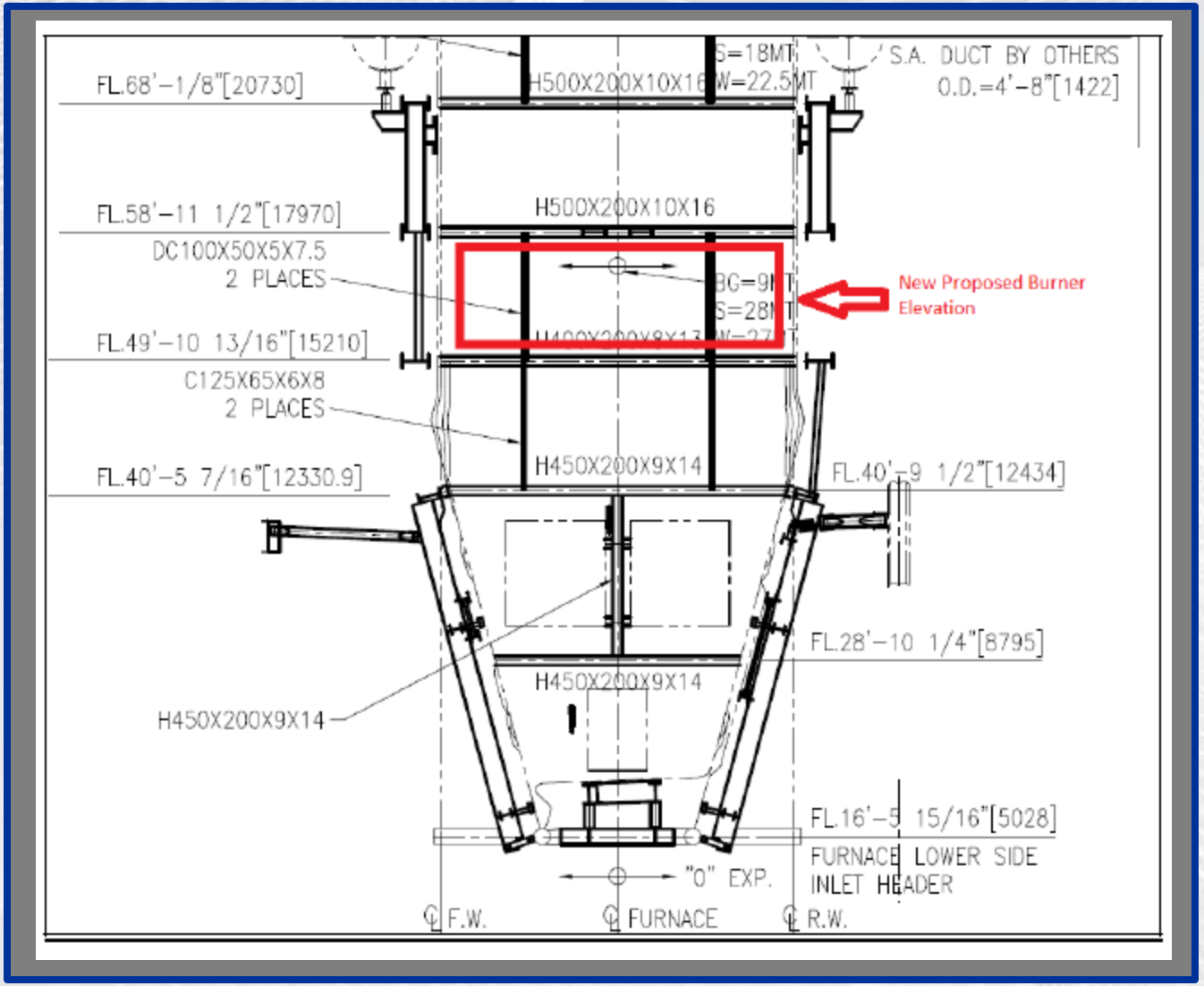
Air Heater Performance Data

PA In	653,822 lb/hr
PA Out	611,072 lb/hr
SA In	651,822 lb/hr
SA Out	611,072 lb/hr
Gas In	1,303,048 lb/hr
Gas Out	1,386,548 lb/hr
Air to Gas Leakage	83,500 lb/hr
Air to Gas Leakage	6.41 %
PA In	116 °F
PA Out	416 °F
SA In	116 °F
SA Out	458 °F
Gas In	586 °F
Uncorrected Gas Out	314 °F
Corrected Gas Out	303 °F

Input File Run 02.in
Output File Run 02.out

* Uncorrected = theoretical air temperature with zero air heater leakage (used for boiler efficiency calculations)
** Corrected = actual measured gas temperature, including the effects of internal air preheater leakage

Firing System Selection



Topics

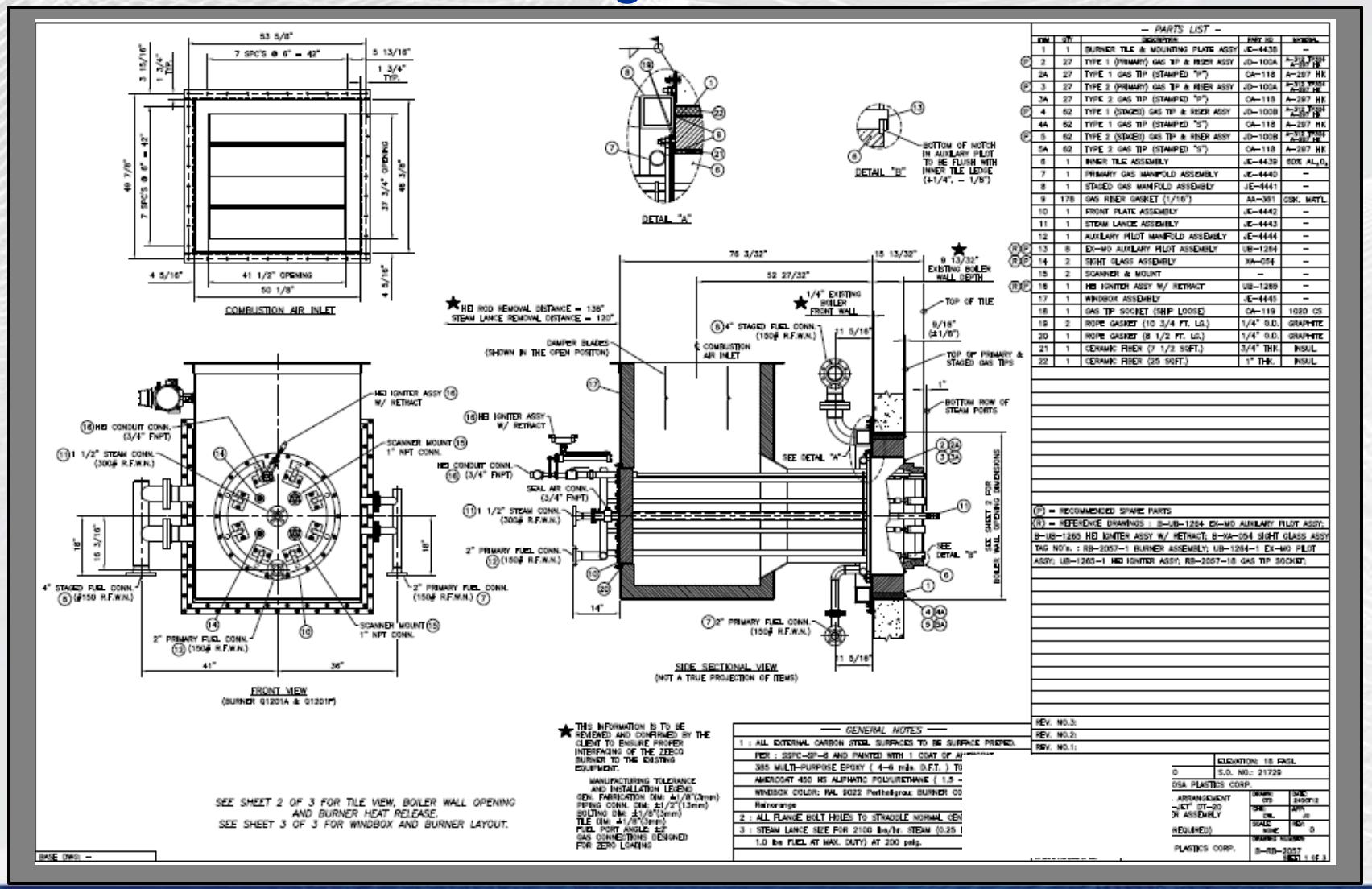
- Implementation and engineering:
  - Engineering commenced in September 2012, with a resultant delivery in February 2013. Zeeco was awarded the contract for the second boiler, with commissioning beginning mid-2014.
  - System implementation was performed over an 6 week outage
    - Ancillary systems (not affecting boiler operation) were installed off-outage
    - New offset burner throats installed during outage for new burner elevation
  - Commissioning – 3 weeks from first fire to “handshake”
  - Layup of all ancillary equipment (ash handling, limestone, solids recirculation (cyclone / seal pot, etc.), all performed by end-user with advisement from Zeeco

Project Overview, Continued

- Zeeco's scope:
  - New Low NOx Gas fired burners – eight per boilers
  - 177 MMBtu/hr capacity
  - Complete header and local valve trains
  - Redundant BMS
  - Controls Logic and Boolean
  - Installation assistance
  - Fixed Price Start up
  - Complete new combustion air system
  - KEY GOAL – maintain 80% of original solid fuel firing equipment for future potential for conversion back to solid fuel

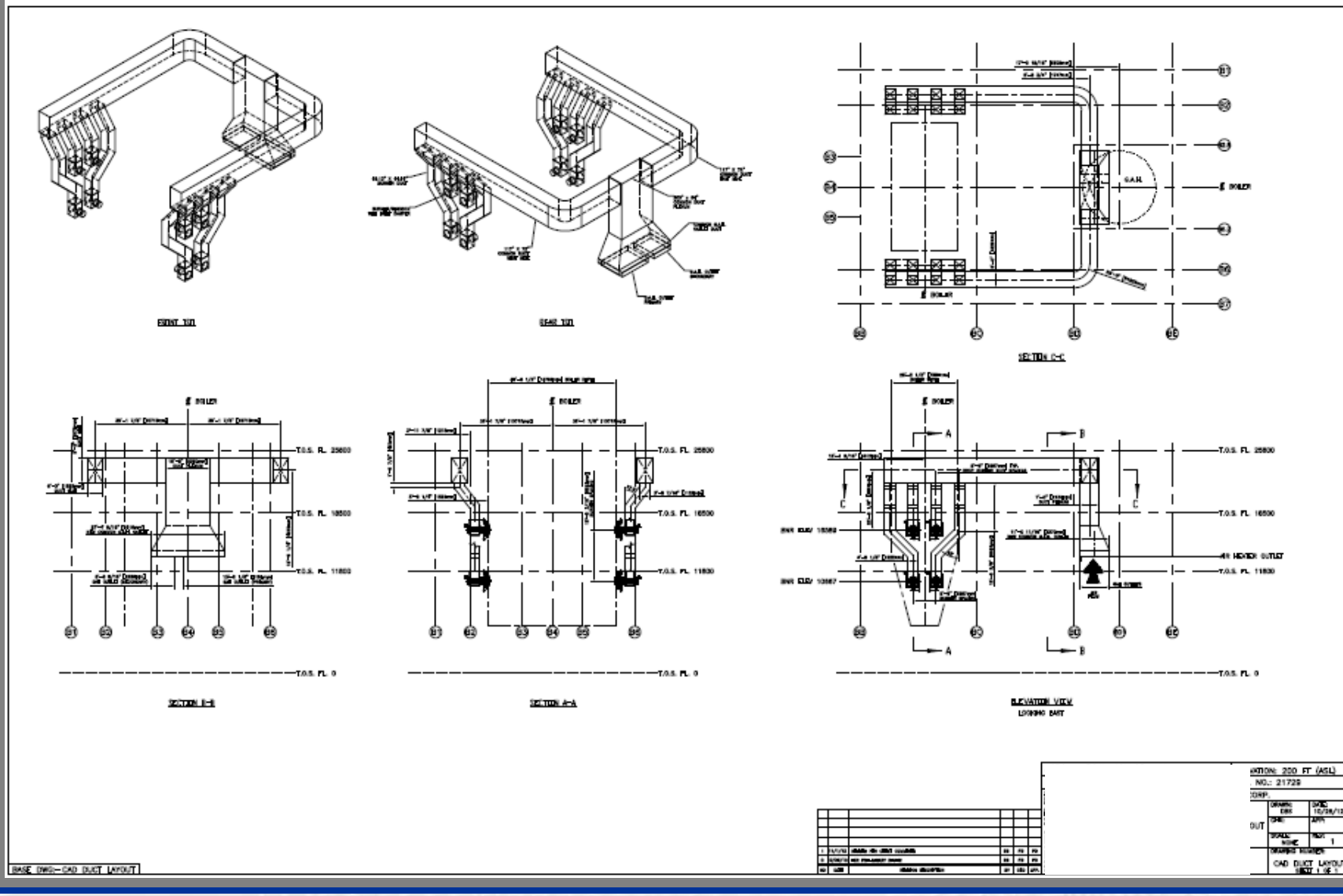
Burner/Windbox Assembly

Recent Contract for CFB Gas Conversion Burner General Arrangement



Local Fuel Racks

Complete Redesign of Air System



Complete Redesign of Air System

CFB Conversion Model

CFB Conversion Model

Topics

- Data, Validation, Conclusion
  - Physical flow modeling
    - All burners within ~1% airflow distribution
  - NOx – 0.07 lbs/MMBtu (25-100% boiler load)
  - CO – less than 50 ppm
  - Steam production as designed and modeled (and required for steam turbine performance)
  - Temperature duties in the water and steam cycle as modeled
  - Lastly – full conversion from a solid fuel fluid bed process to a natural gas fired boiler – all within 12 months

Questions?

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