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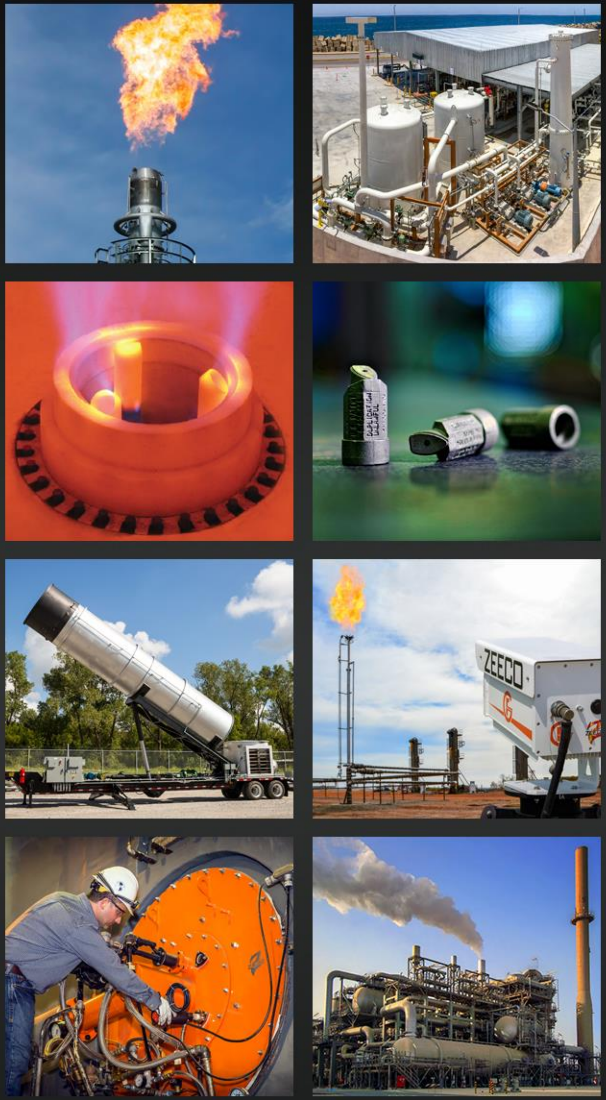
BURNERS FLARES THERMAL OXIDIZERS VAPOR CONTROL RENTALS AFTERMARKET



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Power/Steam Boiler Burner Systems

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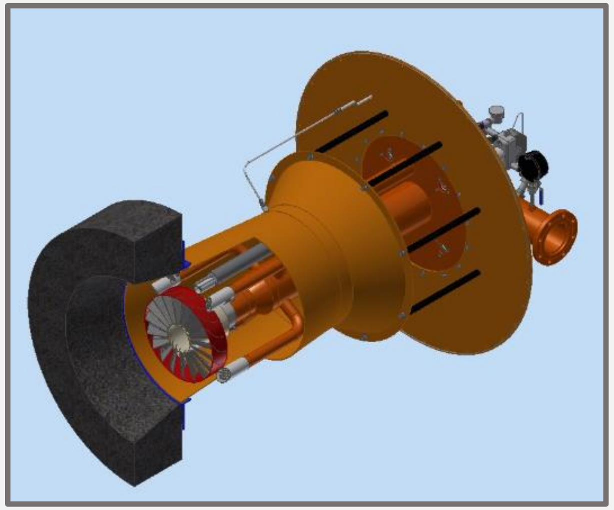
Topics to be Covered

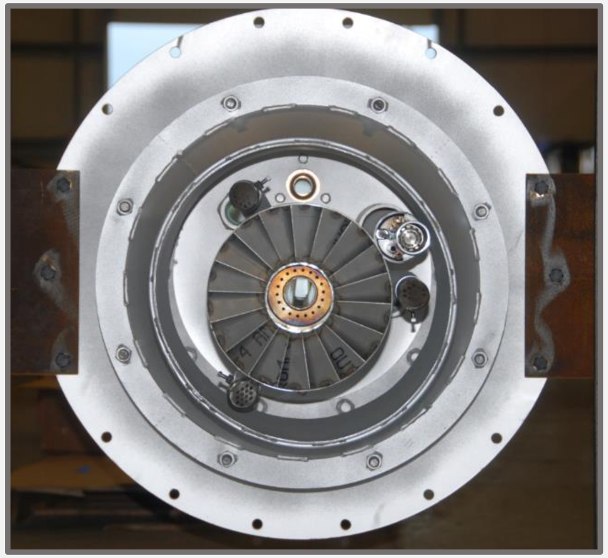
Power/Steam Boiler Burner Systems

- Power/Steam Emission Outlook
- Design & Operation of Low NOx Burners (LNB) & Ultra-Low NOx Burners (ULNB)
- Complex Multi-Fuel Configurations
- Design & Operation of Flue Gas Recirculation (FGR), Over-Fired Air (OFA)
- E-Style Burner Design
- Pilot, Ignitor and Scanner Designs

Market Outlook for Gas and Oil Systems

- Boiler Additions/Burner Replacements
- Emission Improvements
- Efficiency Improvements
- Fuel Conversions
- Change in Steam Requirements
- Reliability





Emission Conversion Chart

TO CONVERT		To: Multiply by									
	From		NO_x	SO_x	CO	lb/MMBtu			g/GJ		
		mg/Nm^3	ppm	ppm	ppm	$COAL_a$	OIL_b	GAS_c	$COAL_a$	OIL_b	GAS_c
	mg/Nm^3	1	0.487	0.350	0.800	6.65E-04	6.25E-04	5.92E-04	0.286	0.269	0.255
NO_x	ppm	2.053	1			1.36E-03	1.28E-03	1.21E-03	0.587	0.552	0.523
SO_x	ppm	2.858		1		1.90E-03	1.78E-03	1.69E-03	0.818	0.768	0.728
CO	ppm	1.250			1	8.30E-04	7.80E-04	7.39E-04	0.358	0.336	0.318
lb/MMBtu	$COAL_a$	1503	734	527	1205	1			429.95		
	OIL_b	1600	781	561	1283		1			429.95	
	GAS_c	1689	824	592	1353			1			429.95
g/GJ	$COAL_a$	3.495	1.702	1.223	2.797	2.33E-03			1		
	OIL_b	3.721	1.813	1.302	2.978		2.33E-03			1	
	GAS_c	3.928	1.913	1.374	3.143			2.33E-03			1

Notes:

a: COAL: Flue Gas dry 3% excess O_2; Assumes 263 dsm^3/GJ - 9780 dscf/MMBtu - Reference EPA 40CFR pt. 60, App. A, Meth. 19

b: OIL: Flue Gas dry 3% excess O_2; Assumes 247 dsm^3/GJ - 9190 dscf/MMBtu - Reference EPA 40CFR pt. 60, App. A, Meth. 19

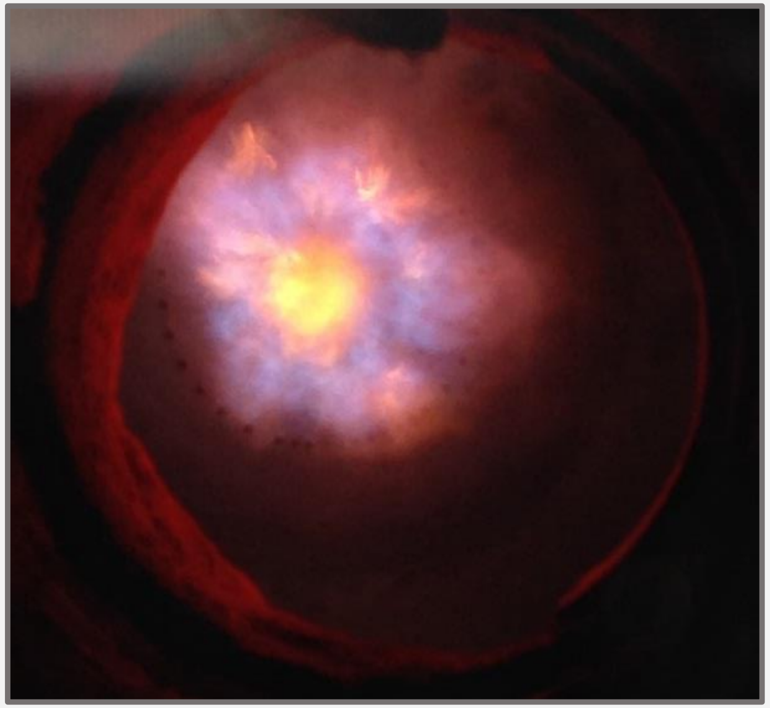
c: GAS: Flue Gas dry 3% excess O_2; Assumes 234 dsm^3/GJ - 8710 dscf/MMBtu - Reference EPA 40CFR pt. 60, App. A, Meth. 19

STANDARD CONDITIONS (IMPERIAL); 68°F, 1 atm.

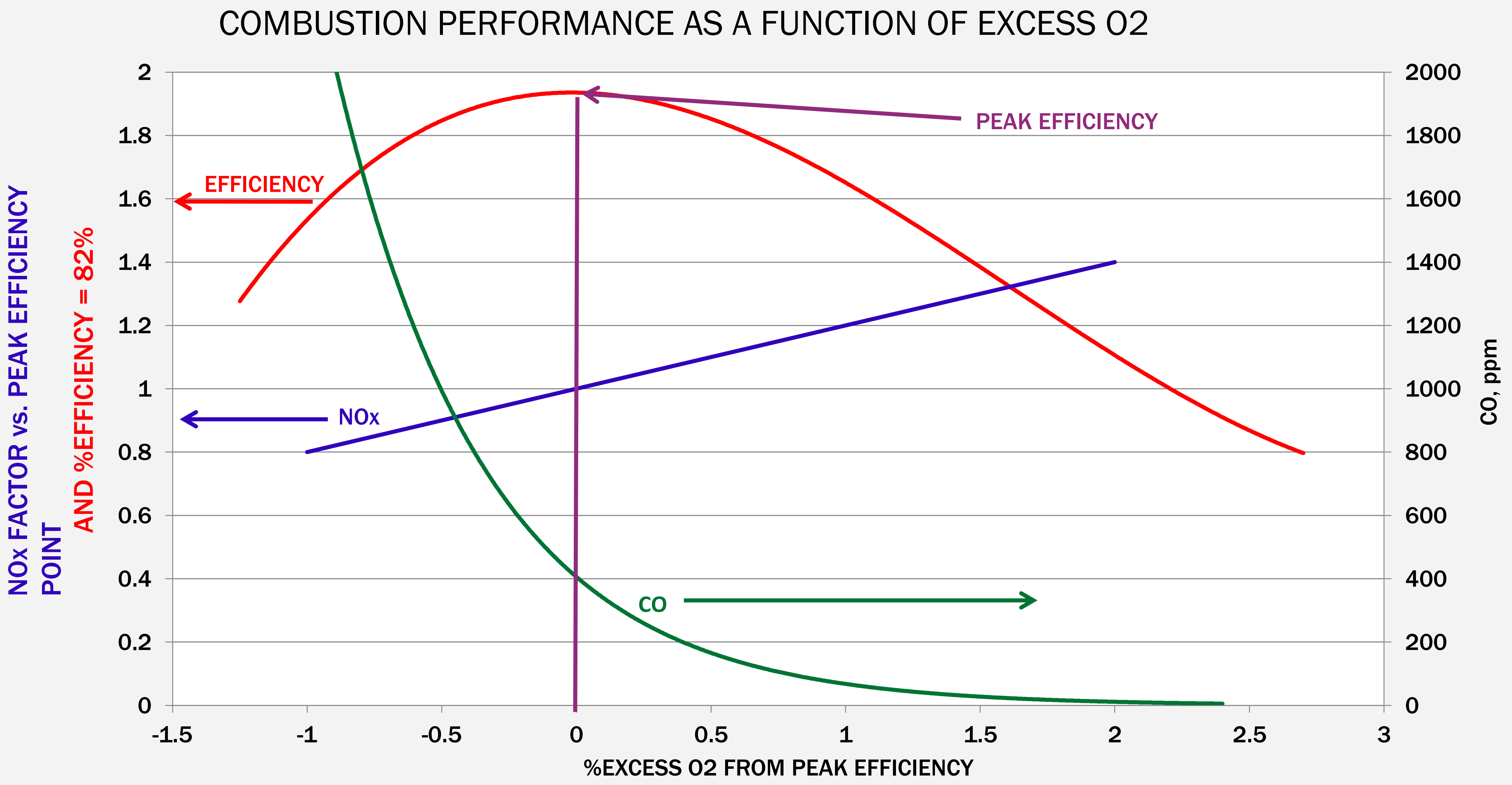
NORMAL CONDITIONS (SI); 32°F, 1 atm.

Achievable Burner Emissions

- Natural Gas Firing
  - Low NOx design: 50-80 ppm w/o FGR; 30 ppm w/15%; 100 ppm CO
  - Ultra low NOx design: 30 ppm NOx w/o FGR; 10 ppm w/ 15% FGR; 50-100 ppm CO
- Oil
  - #2 – 80-100 ppm NOx w/o FGR; 50-60 ppm w/ FGR; 100 ppm CO
  - #6 – 250 ppm NOx w/o FGR; 125 ppm w/ OFA & FGR; 100 ppm CO
- Hydrogen: Same NOx as NG but with higher FGR use
  - 10-30 ppm NOx w/ FGR; 0 ppm CO
- Low btu Fuels: Same as NG
  - 30-50 ppm NOx w/ FGR; 50-100 ppm CO
- Waste Fuels: Varies and depends on specific analysis
- Turndown: 10:1 gas   8:1 oil   4:1 emissions



NOx and CO Dance Together

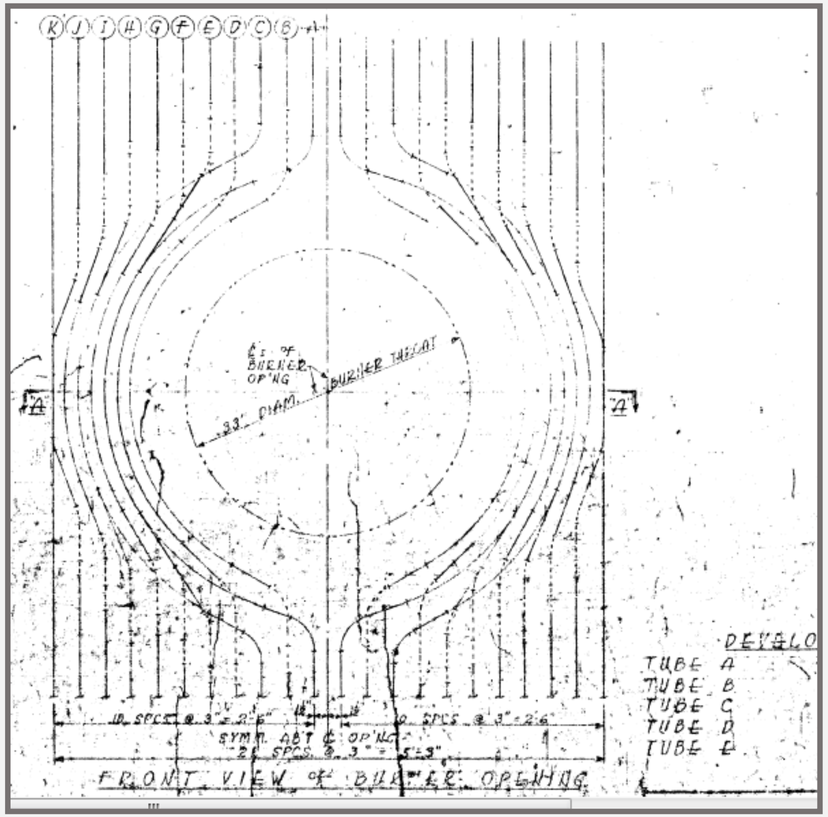


Defining Ultra Low NOx (from a combustion point of view)

- Ultra Low NOx = "Controlled Instability"
  - Operating at the very limits of combustion
- The significance of significant digits!
  - MACT requirement is 0.01 lb/MMBtu
  - 0.01 does not necessarily equal 0.010
  - 0.010 equals 8 ppm
  - 0.011 equals 9 ppm
  - 0.01 technically equals anything up to 0.0149 (12 ppm)
  - ***Don't paint yourself into a box by specifying 0.010 if it is not required!***

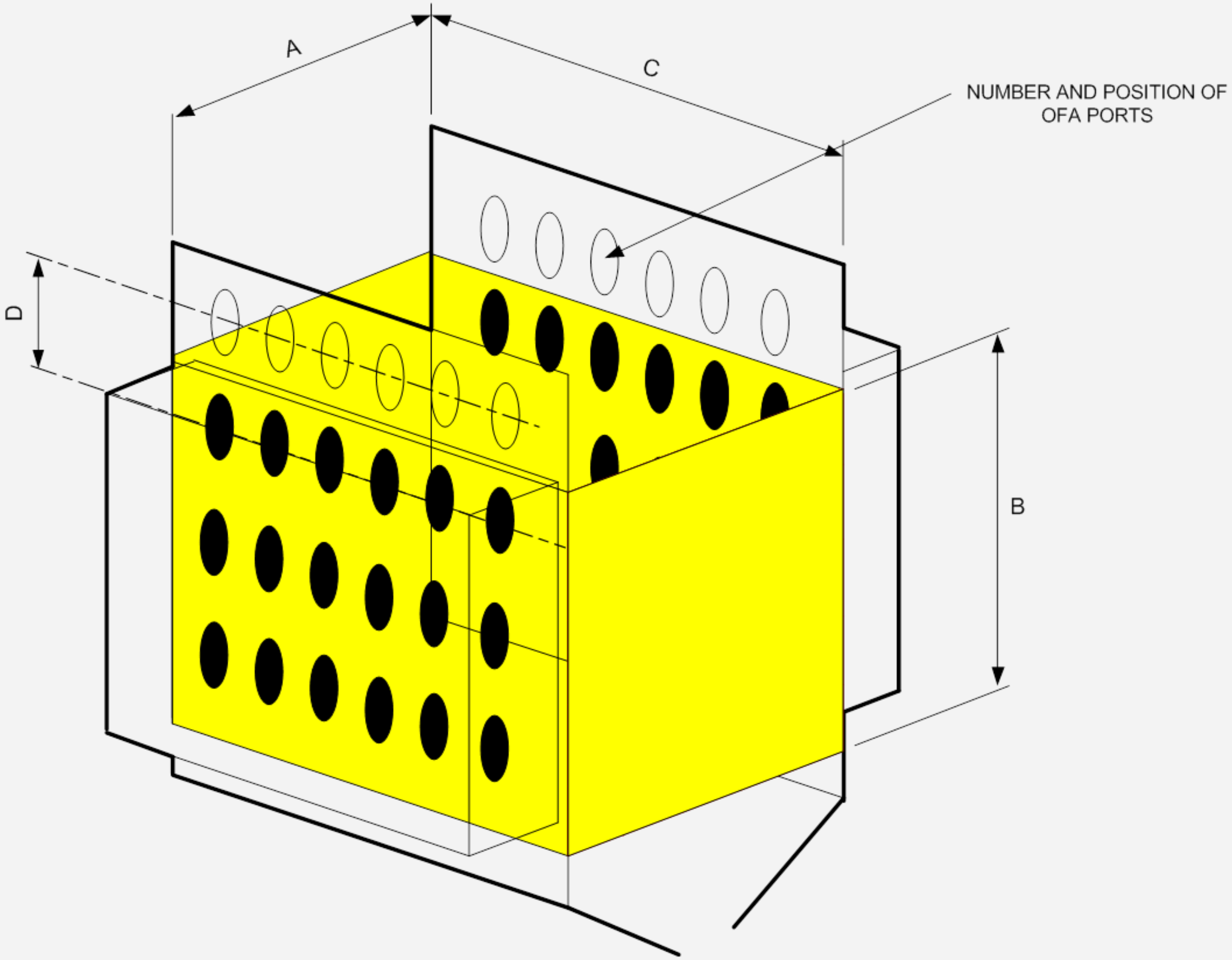
New Burner Design Requirements

- Boiler info required
  - Furnace dimensions (height, width, depth)
  - Boiler design, construction, tube configuration
  - Burner location/configuration
  - Boiler offset tube opening details for burner throats
  - Waterwall surface (refractory) & steam flow
  - O_2 control range (excess air)
  - Heat input & combustion air temp
- Type(s) of fuel(s) fired
  - Fuel analysis and pressures
- Emission requirements
  - NO_x, CO, SO_x, VOC, O_2, Opacity, Particulate



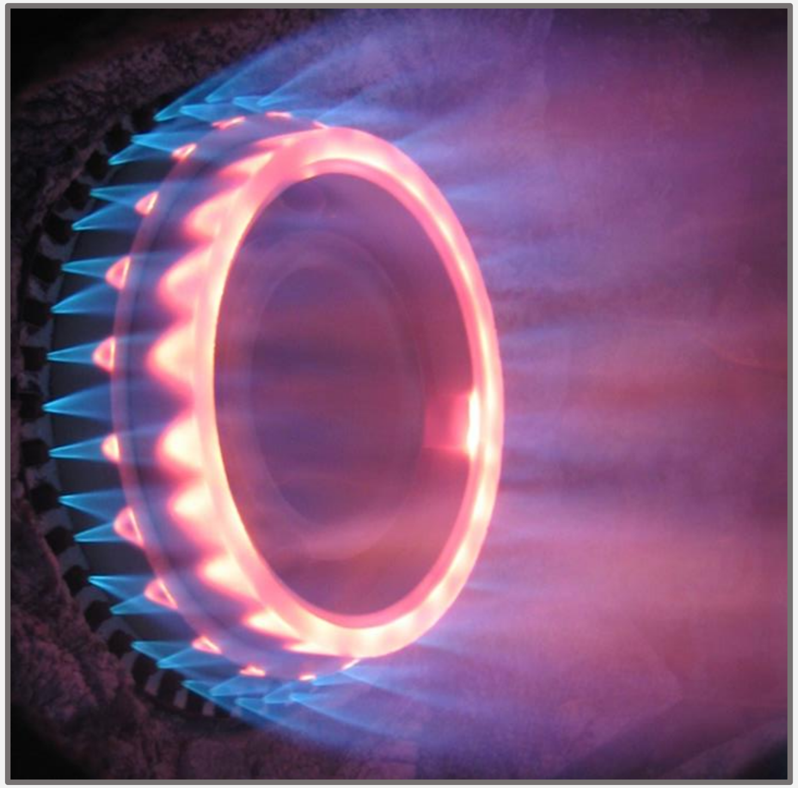
New Burner Design Requirements

- Furnace Design Analysis
  - What do we mean by burner zone heat release (BZHR)?
    - Available heating surface area compared to the heat input
    - Area inside of furnace

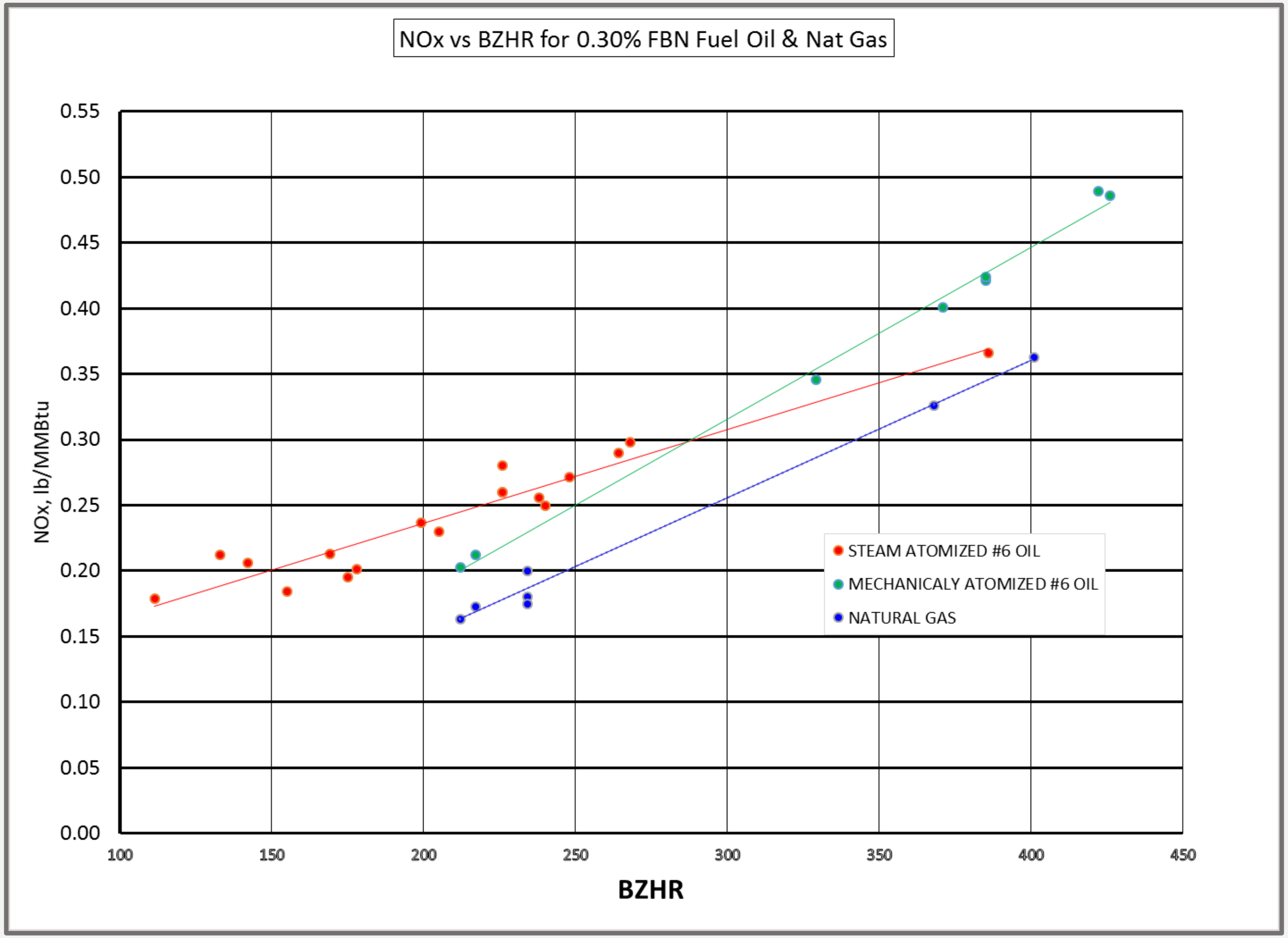


New Burner Design Requirements

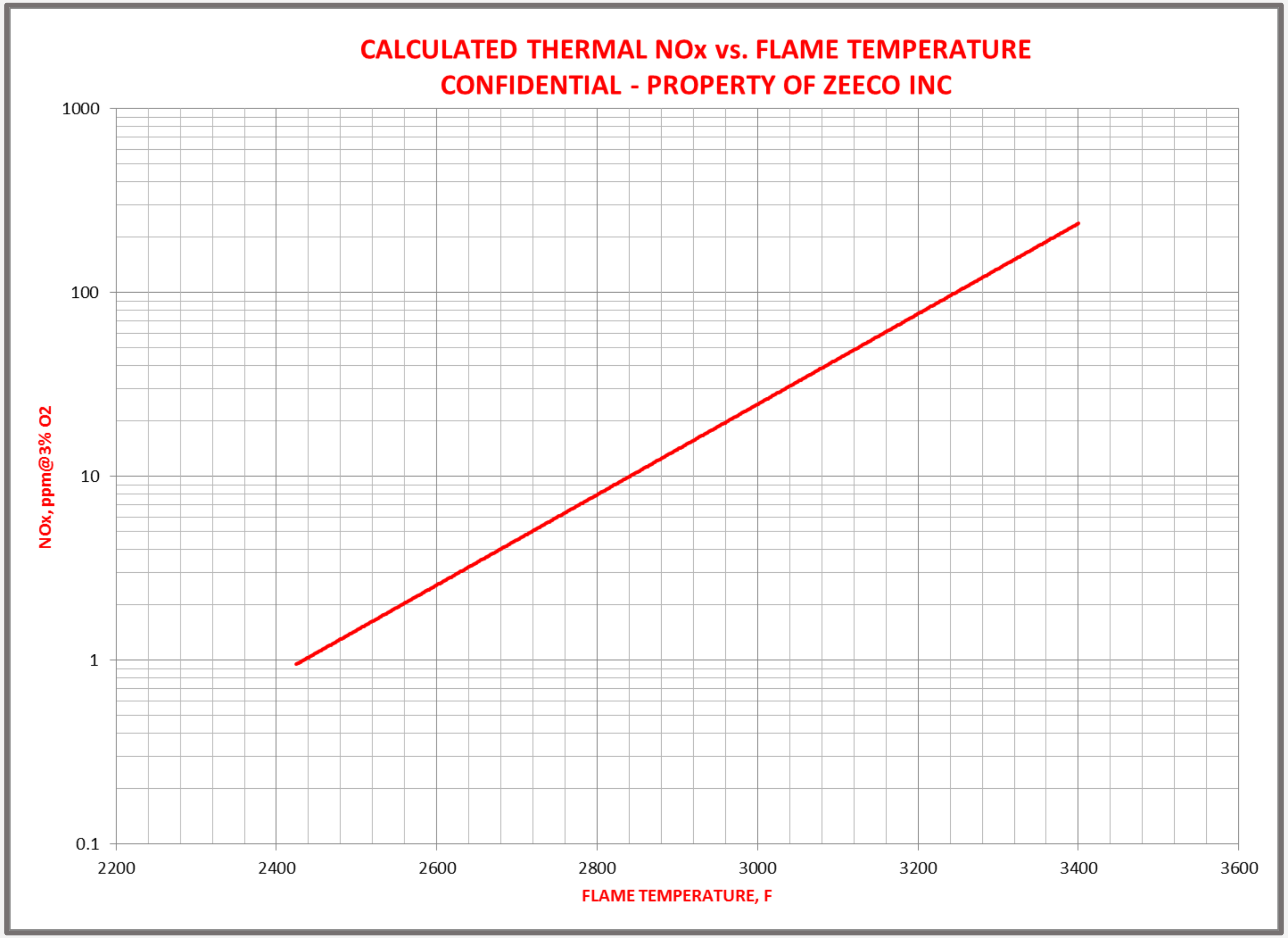
- Peripheral Equipment Information
  - Duct work details (for combustion airflow modeling)
  - Burner management system (BMS) and combustion control system (CCS) configuration/requirements
  - Site elevation
  - Stack height
  - Windbox pressure, furnace pressure, pressure drop duct losses
  - Fan curves



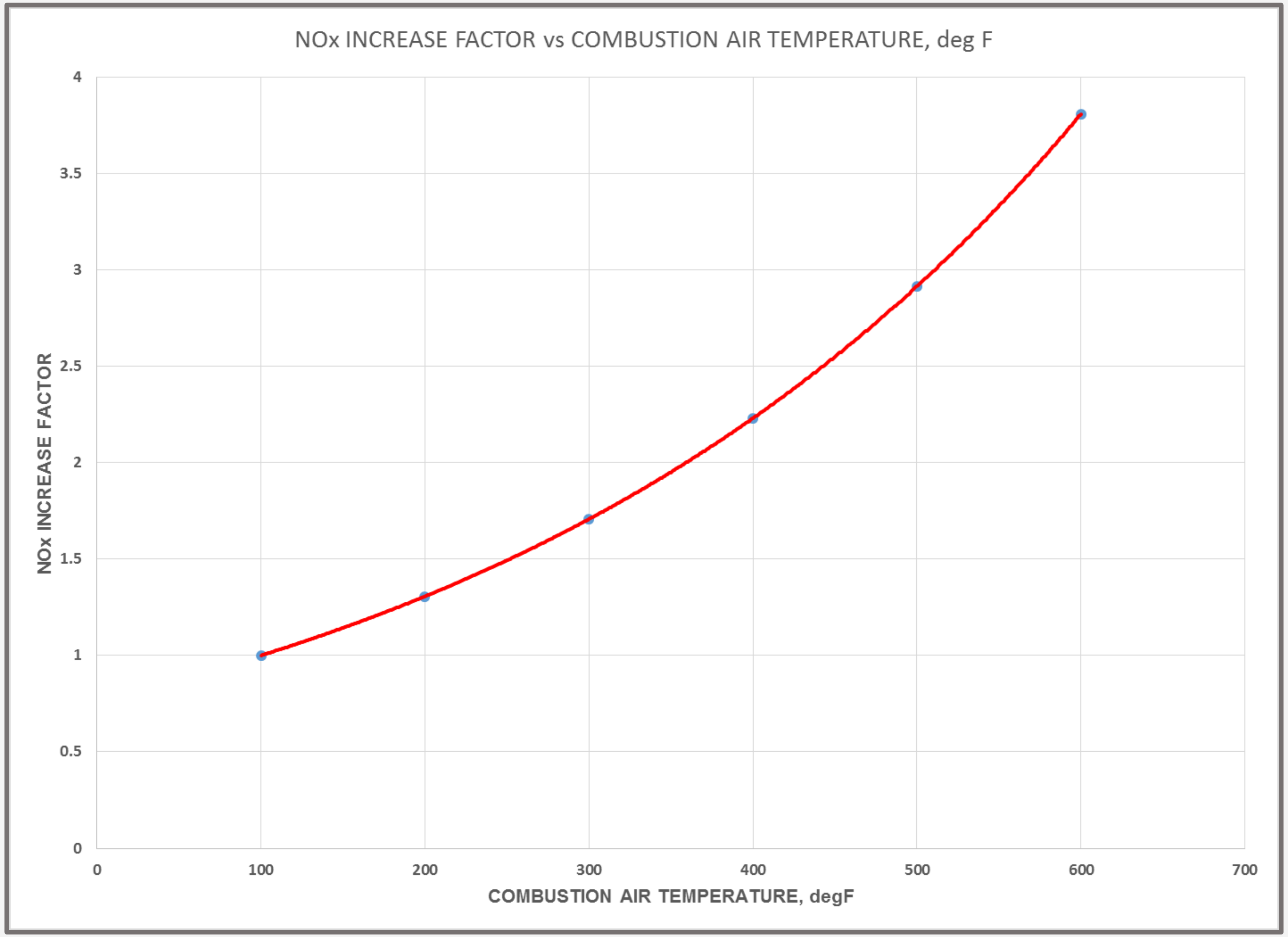
NOx vs. BZHR


NOx vs BZHR for 0.30% FBN Fuel Oil & Nat Gas
NOx, lb/MMBtu
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
100
150
200
250
300
350
400
450
BZHR
STEAM ATOMIZED #6 OIL
MECHANICALY ATOMIZED #6 OIL
NATURAL GAS

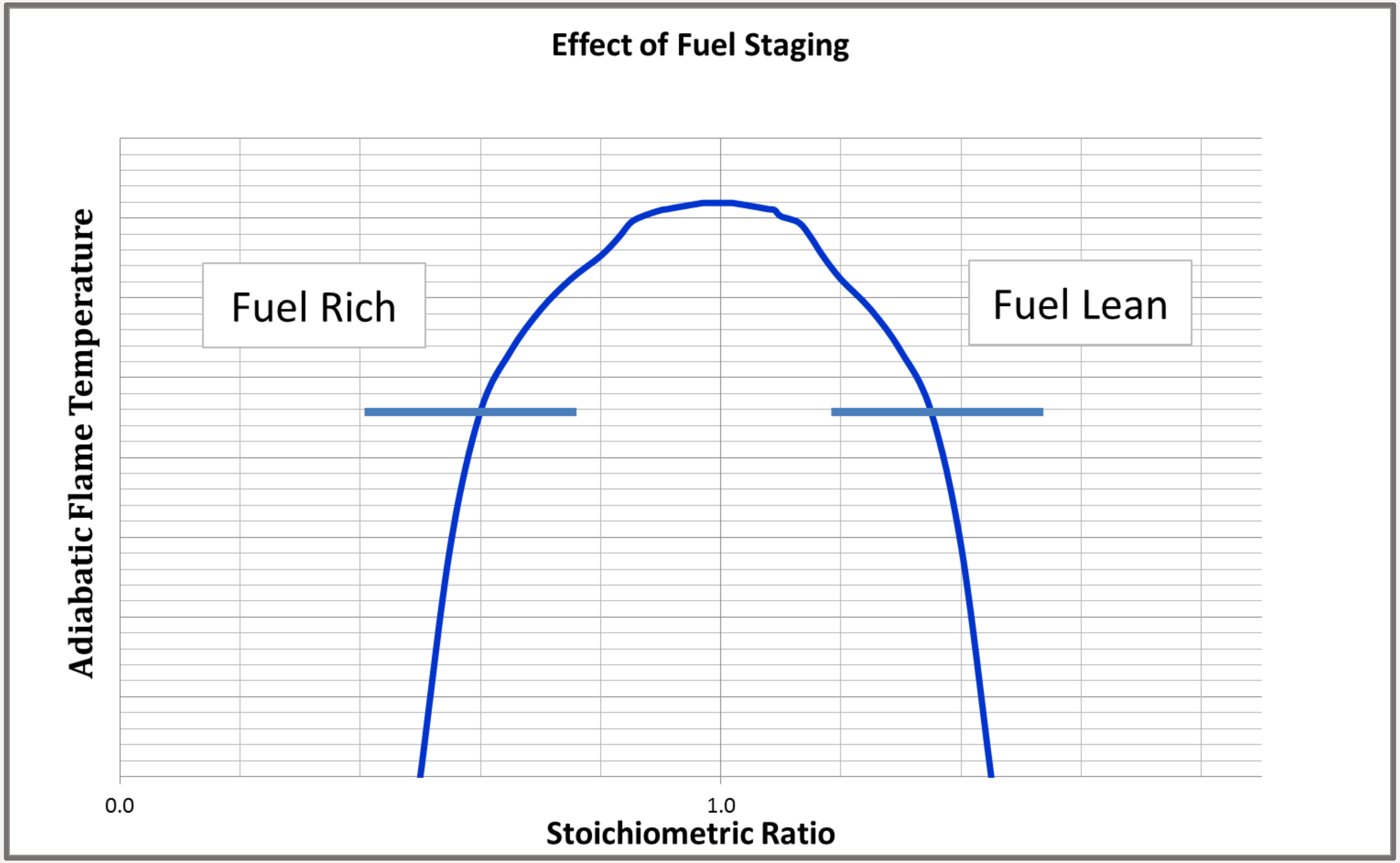
Effect of Flame Temperature on NOx



Effect of Combustion Air Temperature on NOx

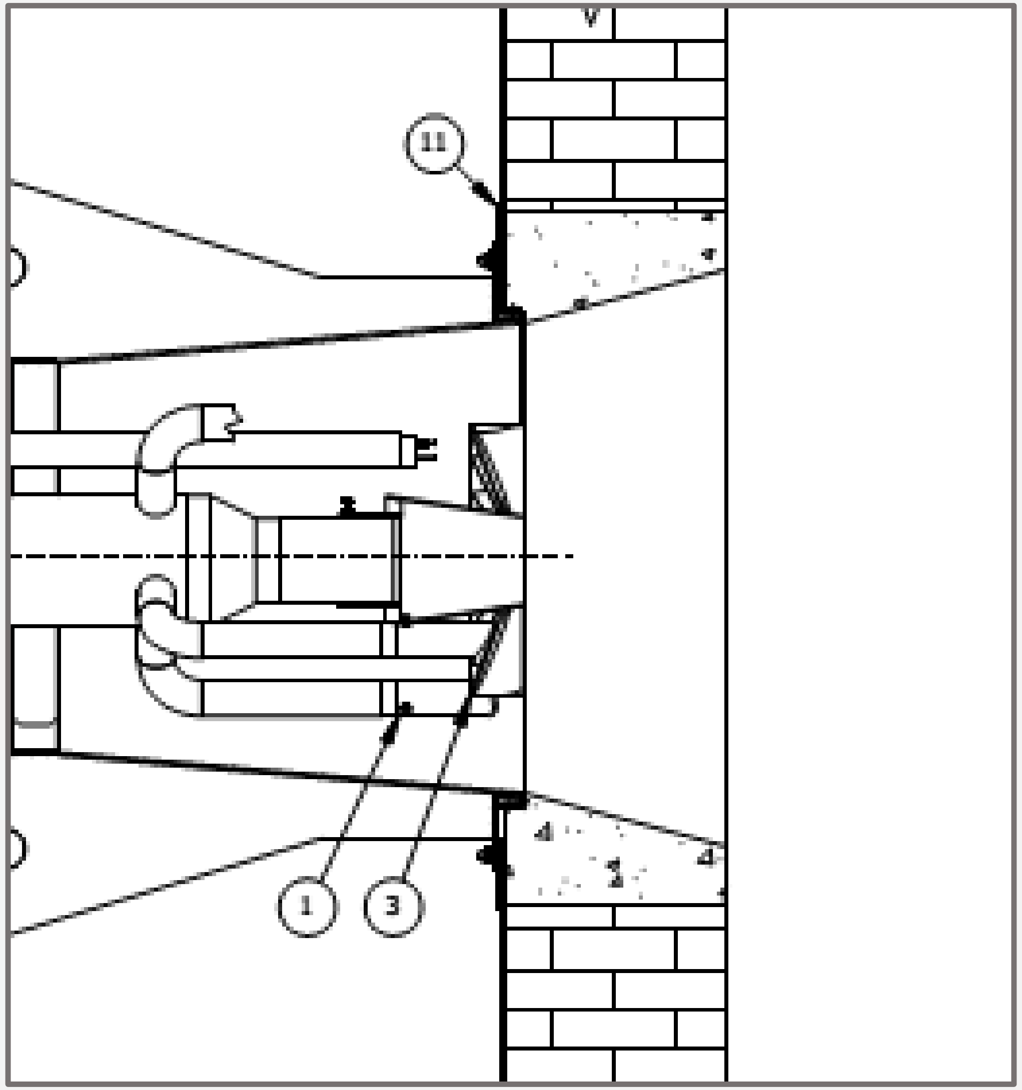


Effect of Fuel Staging



Low NOx Burner Design

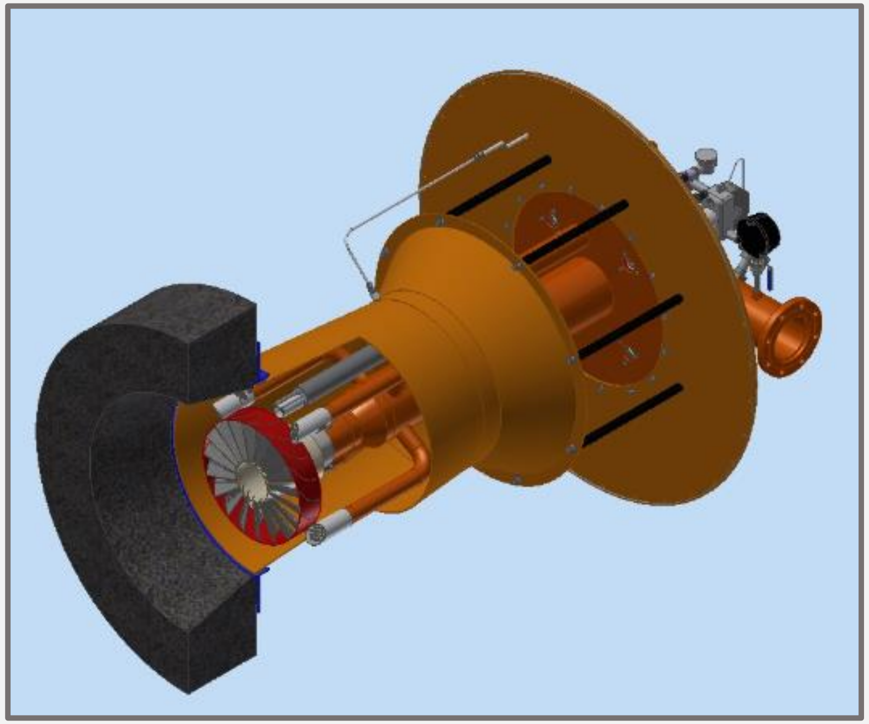
- Typical burners in operation
  - Zeeco GB
  - TODD Variflame and DLN
  - Coen DeltaNOx
  - MSC
  - DFL
- Emissions
  - NOx: 50-80 ppm w/o FGR; 30 ppm with 15% FGR; CO: 100 ppm
- Stages gas within throat for NOx reduction



Zeeco Low Nox GB Burner

GB Low NO_x Burner Technology

- Register design proven for 40+ years
- Staged gas/oil technology
- More compact flame fit versus competition – Smaller boiler w/ no flame impingement
- Multi-fuel firing capability
- Efficient – Lowest FGR and excess air in the industry
- Low CO2 footprint
- Multi applicability (fluid bed boilers, etc.)

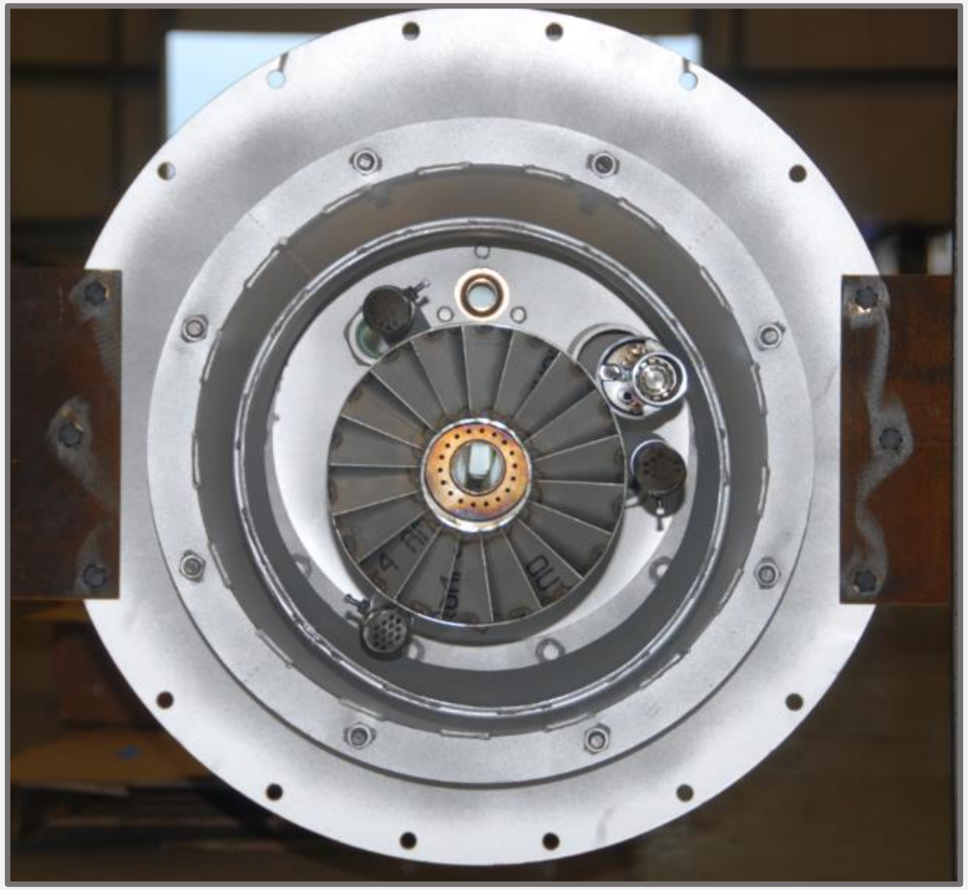


GB Low NO_x Burner Technology

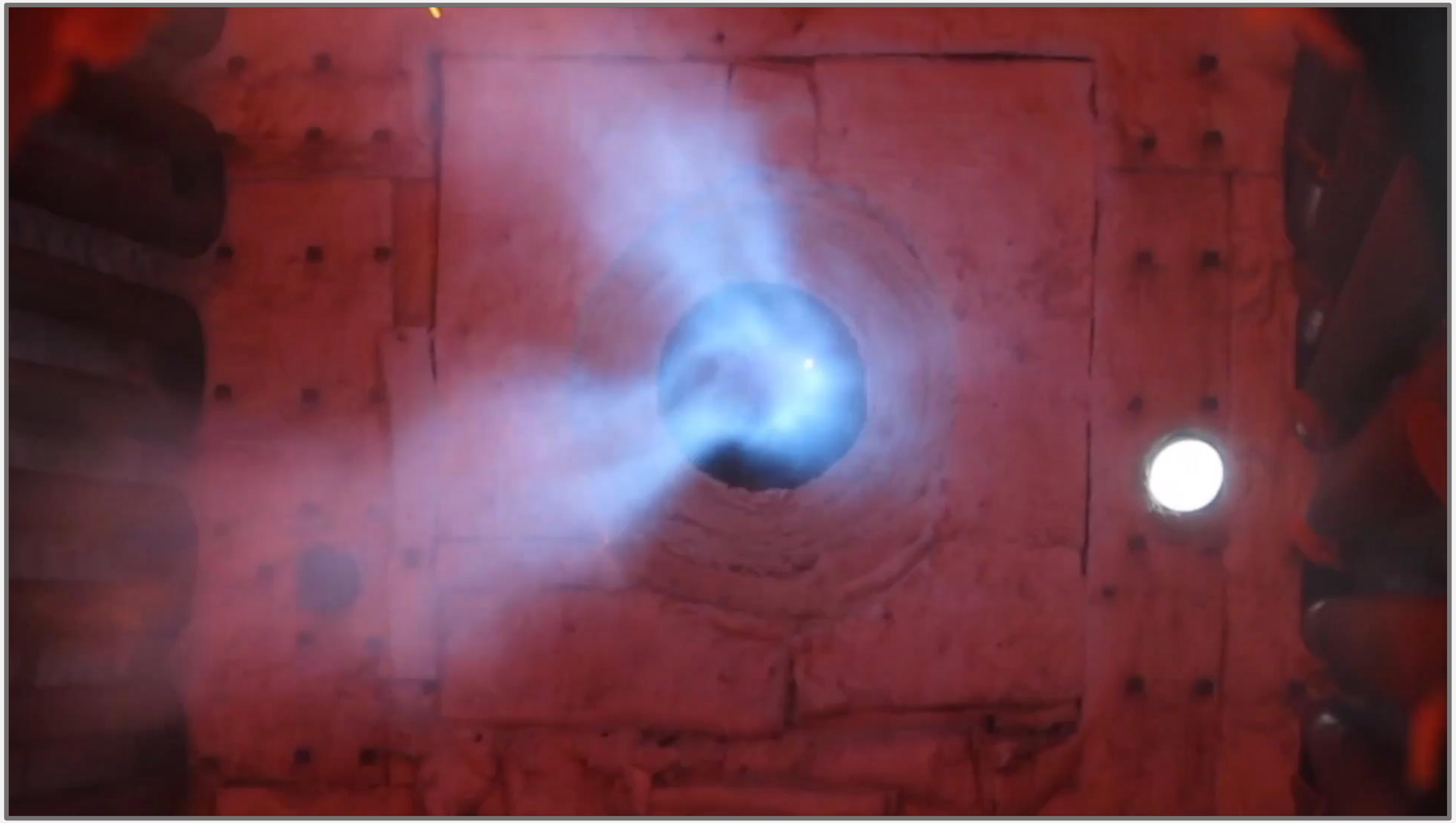
- Capacity: 15 – 430+ MMBtu/hr (single burner)
- Emissions:
  - NOx:
  - CO: 100 ppm

	PPM	
	No FGR	**15% FGR**
Nat. Gas	50	25
#2 Oil	80	50
#6 Oil	250	125

- Excess Air: 10%
- RDL: 5-12 in. w.c.
- Turndown:
  - 10:1 gas; 8:1 oil (operation)
  - 4:1 (emissions)



Firing Example (natural gas @ 100% load)

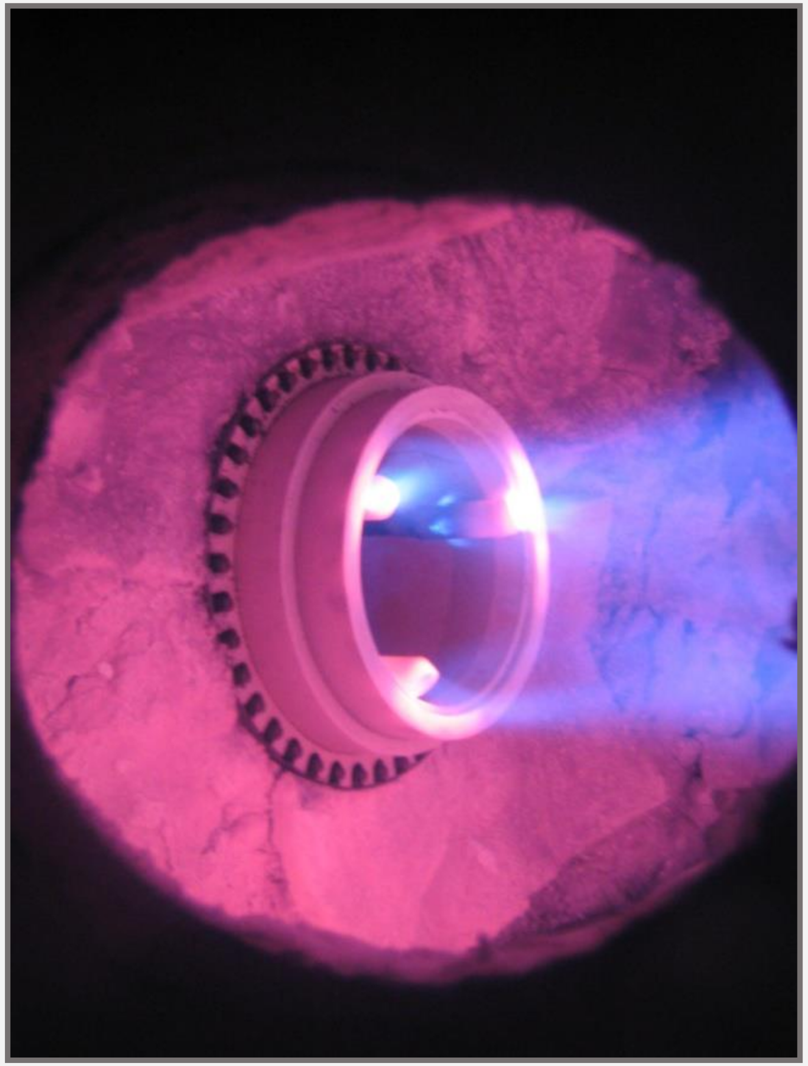


GB Burner Dual Fuel Packaged System

Multi GB Burners Installation

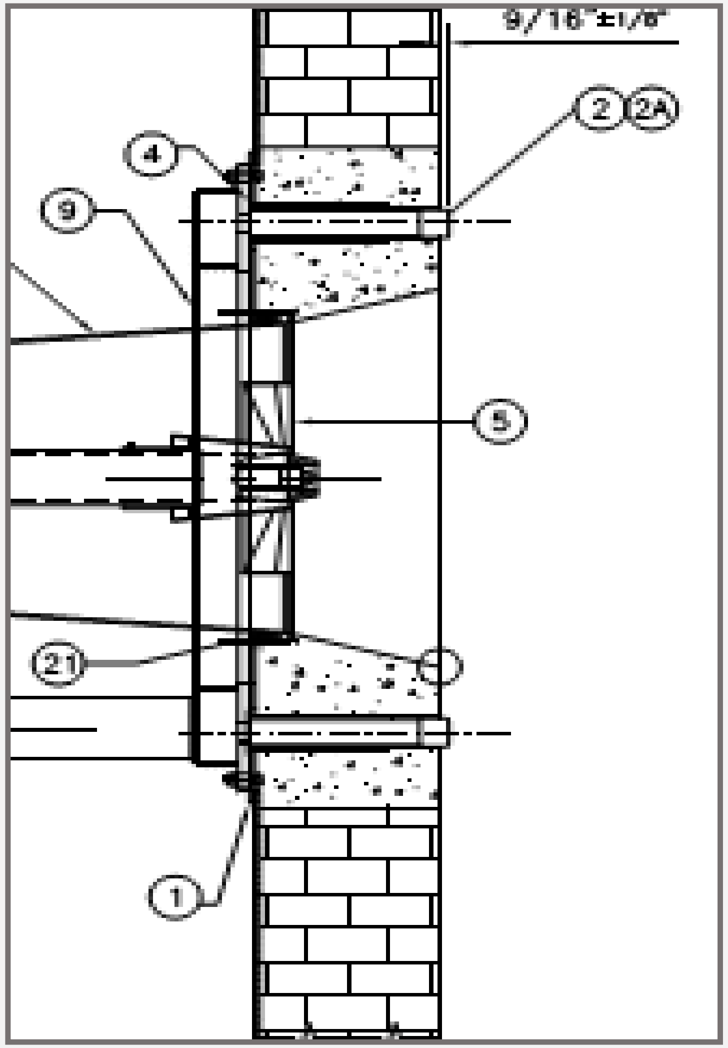
Ultra-Low NOx Emissions

- Next generation emissions (sub 10 ppm NOx) are achieved by gas mixing with the inert products of combustion in the furnace.
- The resulting composition burns at a lower peak flame temperature resulting in significantly lower thermal NOx production.
- Cooler combustion = Lower NOx!



Ultra-Low NOx Burner

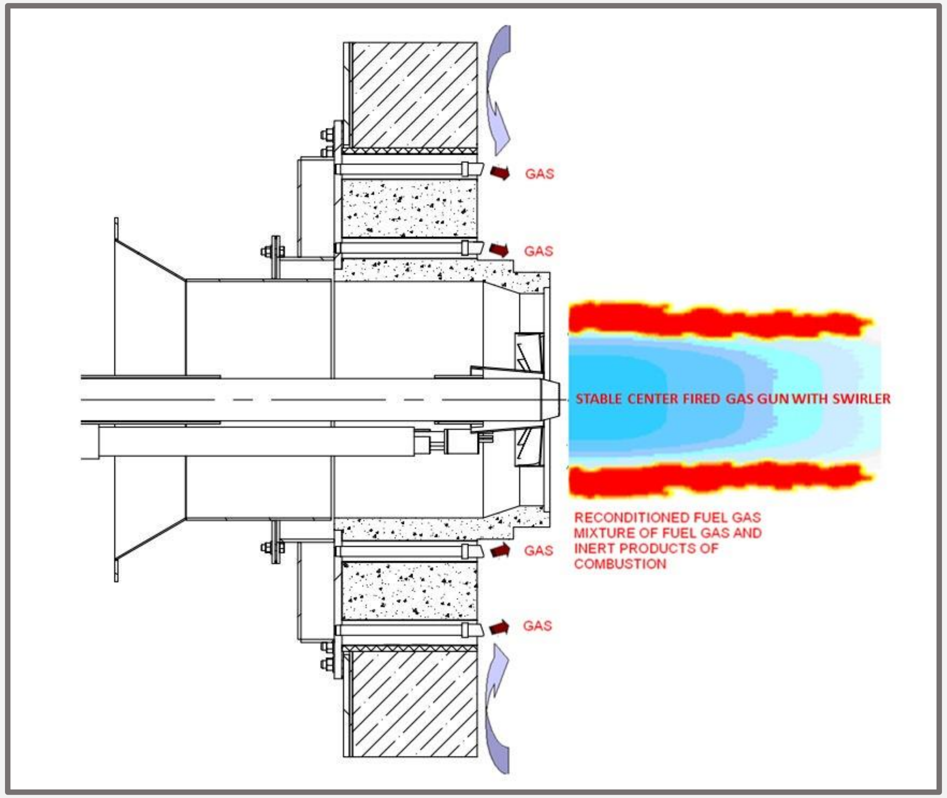
- Typical burners in operation
  - Zeeco FREE-JET
  - Coen QLN
  - TODD Variflame II and RMB
  - Peabody Ecojet
- Utilizes center fired gas for stability
- Stages outer gas for NOx reduction
- Stages fuel and air and uses furnace gases to dilute fuel
- Fuel gas is mixed with inert products of combustion before combustion occurs thus "reconditioning the fuel gas"



Zeeco Ultra-Low NOx FREE-JET Burner

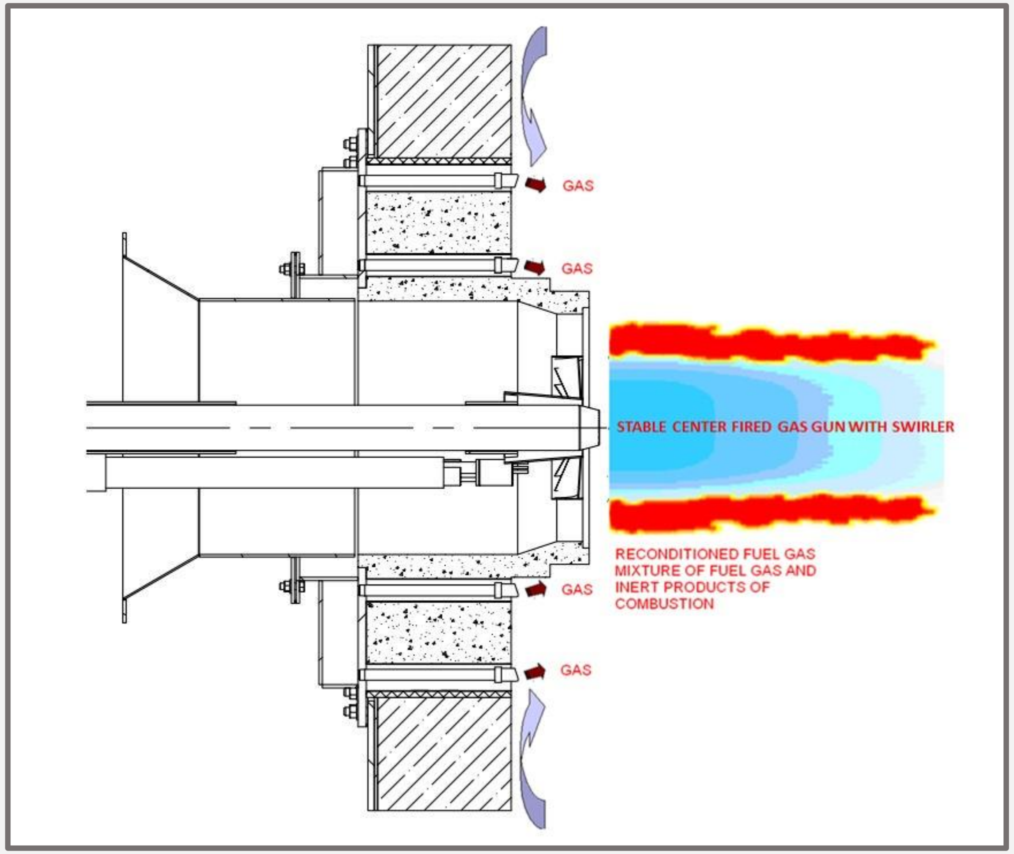
FREE-JET Ultra-Low NO_x Burner Technology

- Simple design for a complex problem
- Fuel gas is mixed with inert products of combustion before combustion occurs, thus “reconditioning the fuel gas” for lower thermal NOx
- Most efficient use of FGR (induced vs external)
- Multi-fuel firing capability (refinery gas, fuel oil…)
- Smaller fan(s) = less electricity, lower CO2 = “greener” project
- Less (or no) ductwork, hangers, expansion joints, etc.



FREE-JET Ultra-Low NO_x Burner Technology

- Advantages
  - Lowest FGR use (or no FGR needed)
  - Requires smaller fan(s):
    - Less electricity consumption
    - Lower CO2 = "Greener" project
  - Less (or no) ductwork, hangers, expansion joints, etc. required
  - Integral burner throat tile
    - No quarl forming required
    - Lowers installation cost
  - Quickest start-up/commissioning time

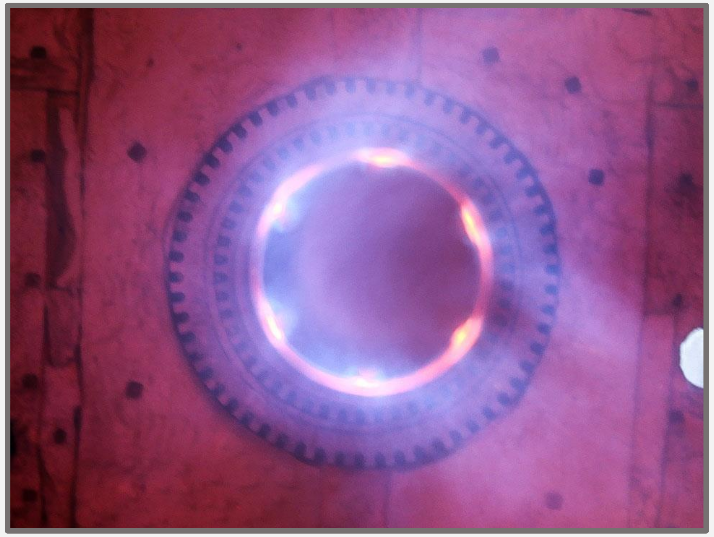


FREE-JET Ultra-Low NO_x Burner Technology

- Capacity: 15 – 430+ MMBtu/hr (single burner)
- Emissions:
- NOx:

	PPM	
	No FGR	15% FGR
Nat. Gas	30	9
#2 Oil	80	50
#6 Oil	250	125

- CO: 50 ppm
- Excess air: 15%
- RDL: 5-12 in. w.c.
- Turndown:
- 20:1 gas; 8:1 oil (operation)
- 4:1 (emissions)

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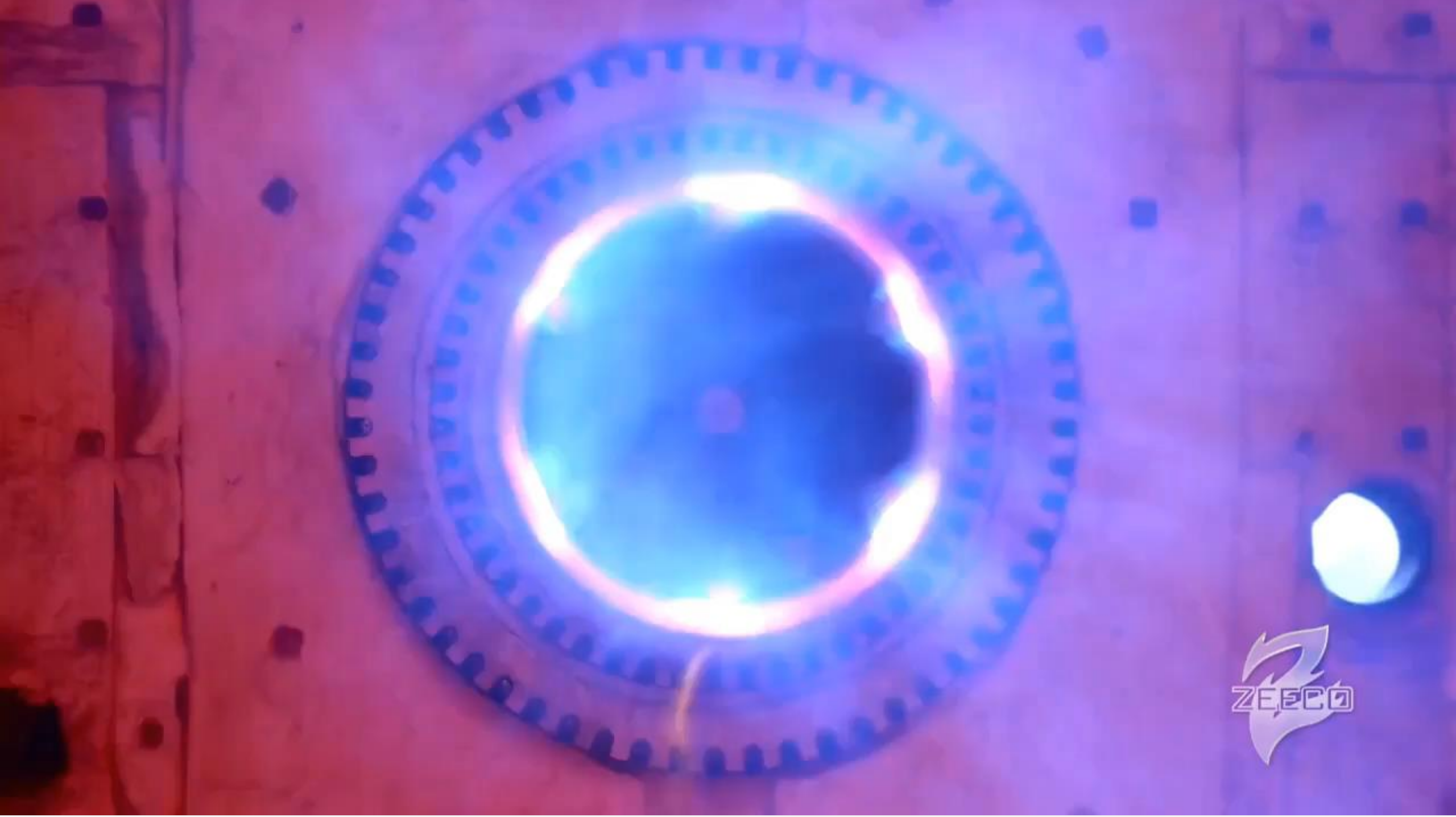
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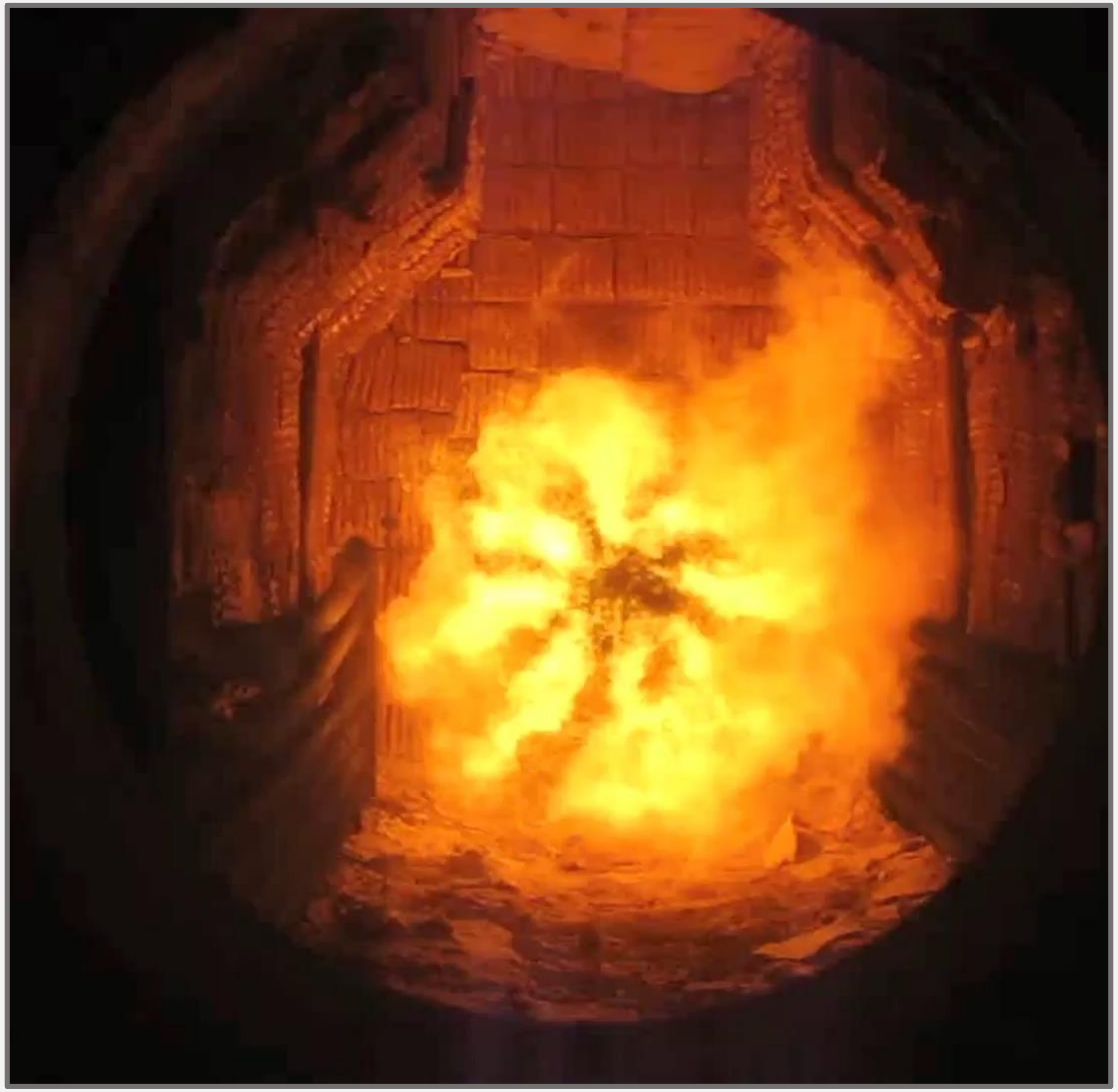
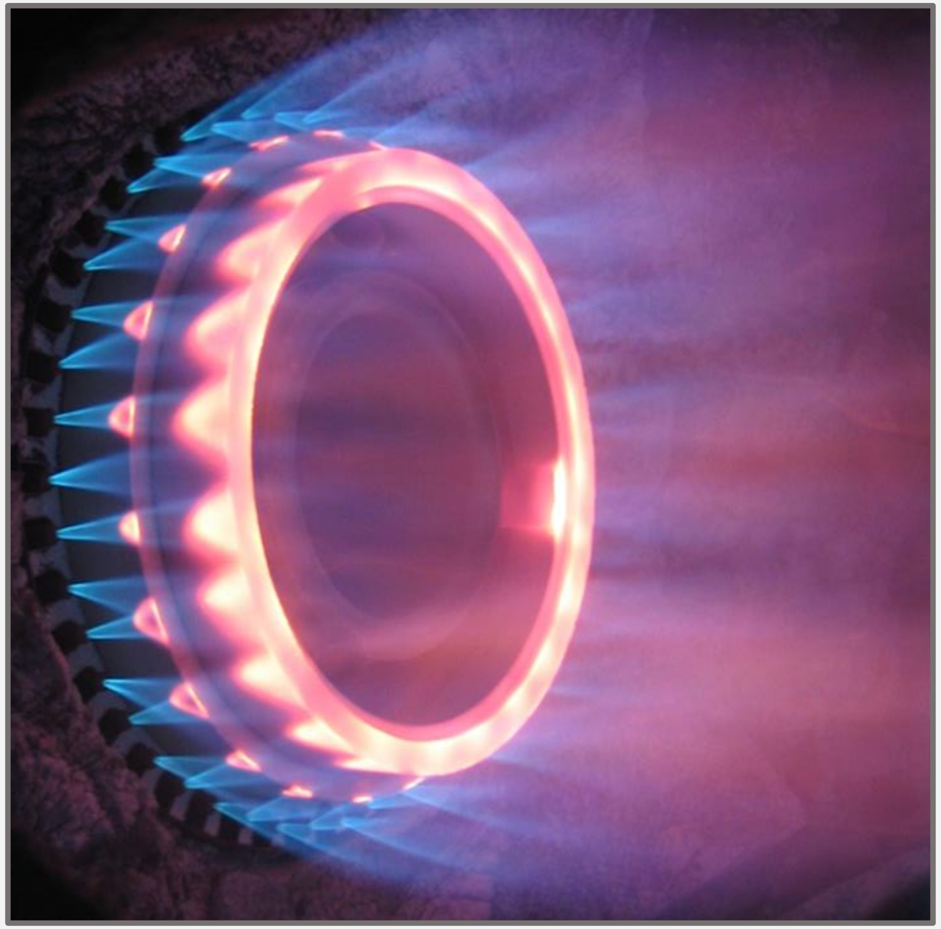
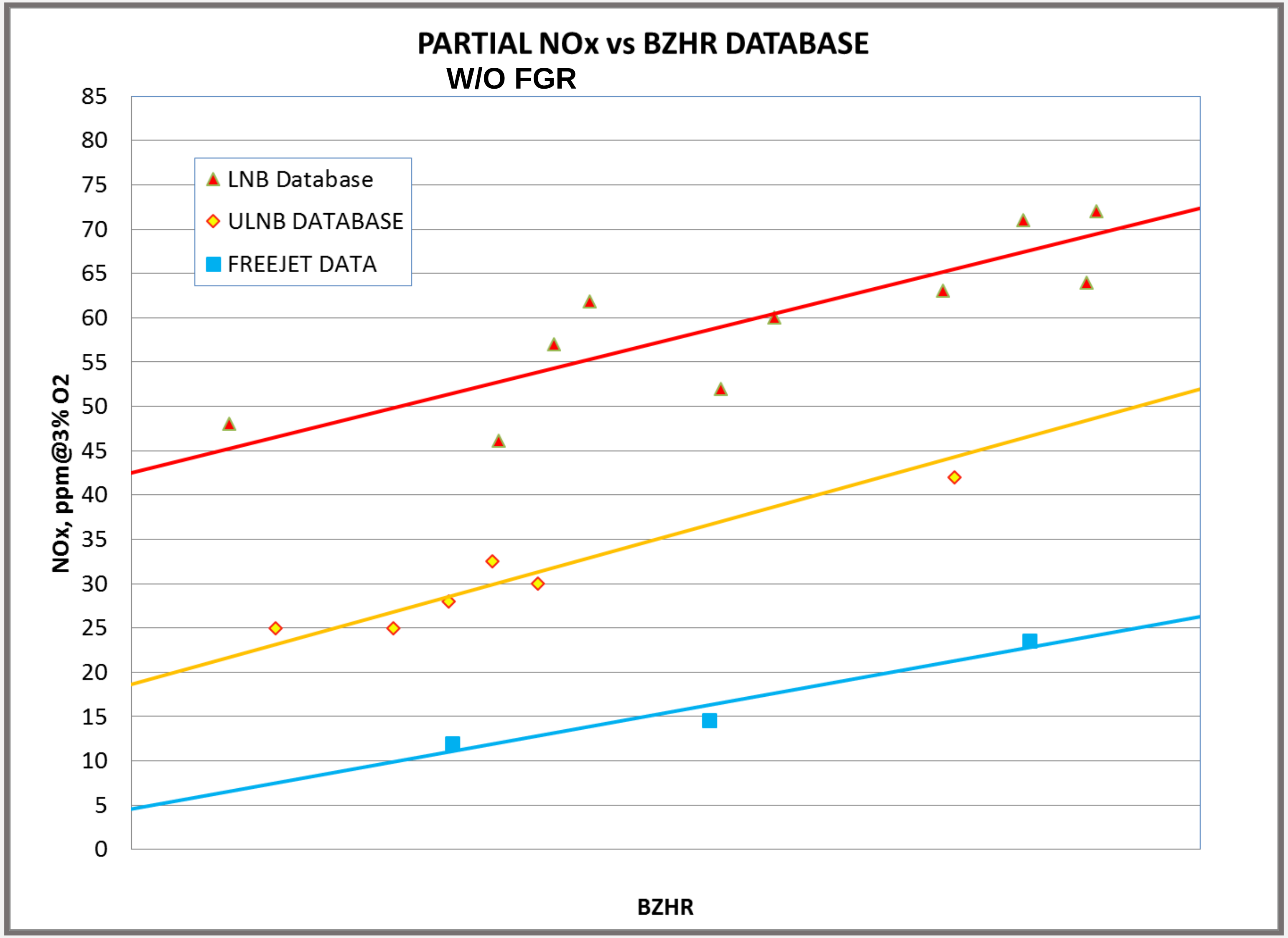
Fuel Oil Firing



FREE-JET Installation



How Does the FREE-JET Compare?



Zeeco FREE-JET Compared to Other Burner Manufacturers?

- Lean Premix & Rapid Mix Burner Designs
  - Have extremely high base temperature – Essentially adiabatic
  - Rely on copious amounts of diluents to reduce flame temperature
  - Lean premix requires 65-100% excess air for low NOx operation
  - Rapid mix requires 30+% FGR for low NOx operation
  - Higher horsepower fans required
  - Prone to harmonics and thermo-acoustic vibrations
  - Typically require lengthy start-up/commissioning times

Zeeco E-Style Burner Design

E-Style Burner – The Basics

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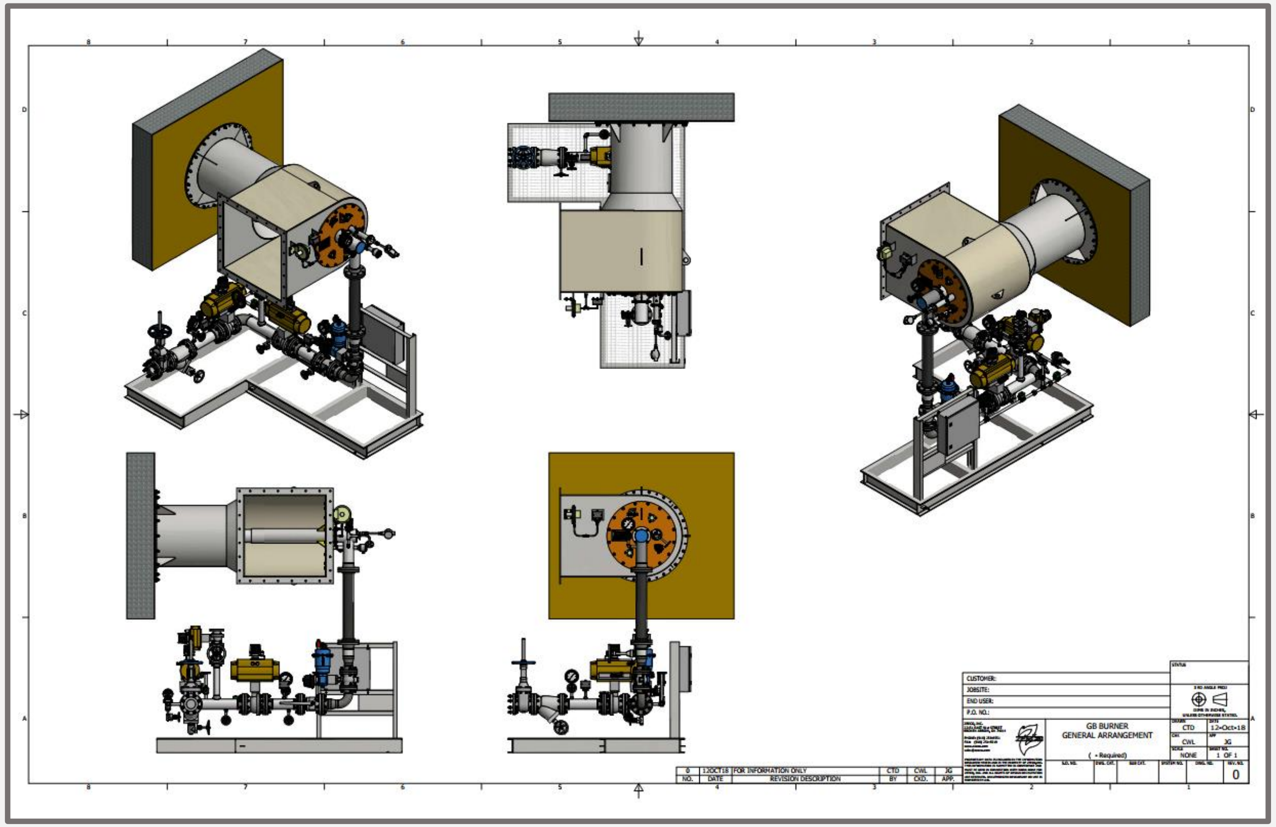
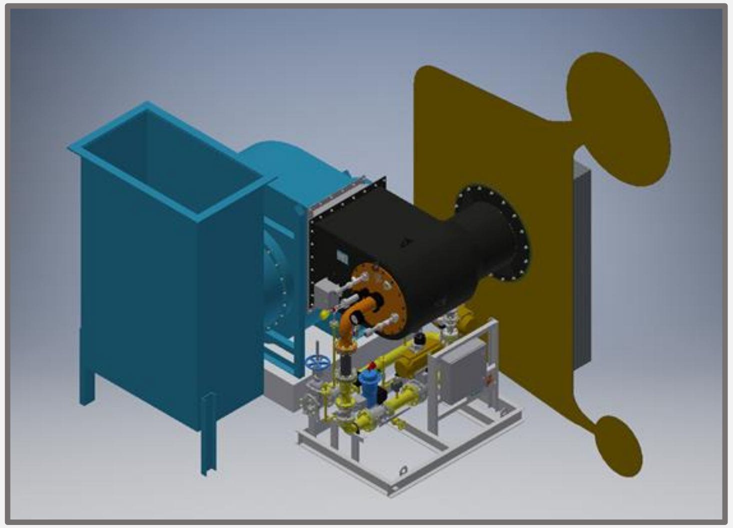
- Commonly used in overseas markets for many years
- Does not include a traditional square (or D-style) windbox
- The burner housing itself is the windbox plenum



E-Style Burner Advantages

- Lower cost
- Less weight due to smaller size and integral burner throat
- Inherent design allows for even air flow distribution to and around burner eliminating windbox baffles
- Compact design allows for extra space around burner and boiler front wall
- Much quicker and simpler installation onto boiler front wall – Bolts onto a windbox mounting plate
- No airslide required on multi burner configurations – Each burner has individual damper
- Valve train easily tucked underneath
- Same design can be applied to a GB or FreeJet burner

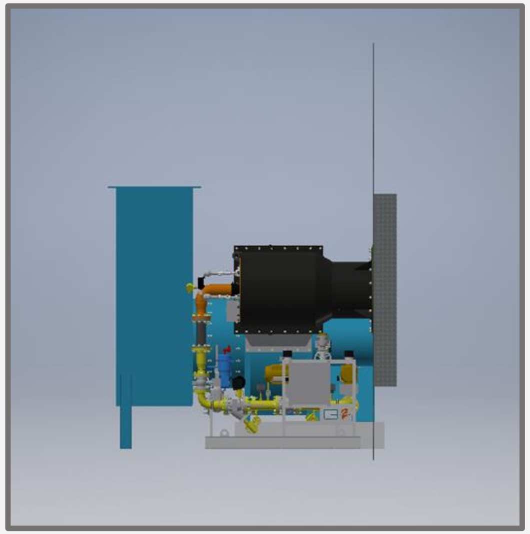


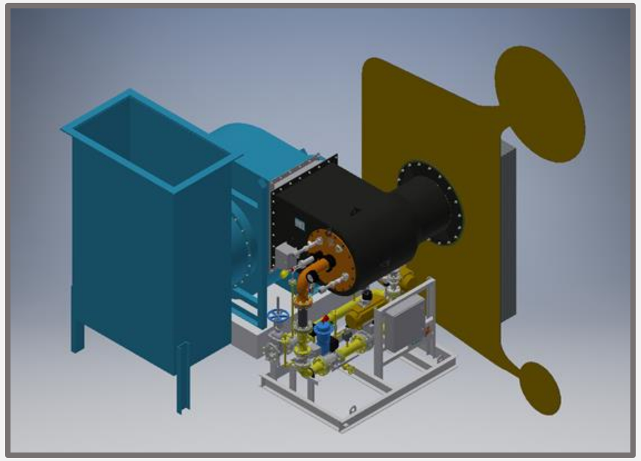
Money Saving Features

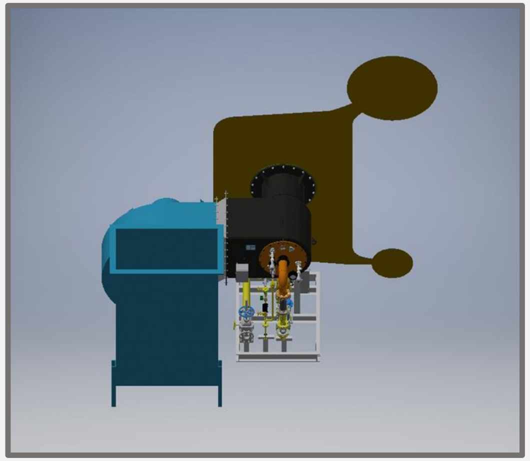
- Significantly less material and fabrication costs
- Burner shell is the air plenum:
- No windbox required
- Round shape requires few welds
- No airflow baffles required
- Reduced drafting time required
- Easier to transport/handle/lift due to much smaller footprint and lighter weight
- Fuel trains and controls can be skid mounted

Quantifiable Results!

- Requires less material and fabrication time
  - 5%+ capital cost savings per burner
- Quicker installation time
  - 10 less welding man hours per burner
- Smaller footprint/lighter weight reduces freight & handling costs
  - 1,000 lbs. less weight per burner







E-Style Burner Considerations

- Fan mounting will require additional support structure (can be skid mounted)
- Boiler front wall loading must be confirmed
- Existing ductwork arrangements might prevent use of this design

Various NOx Reduction Methods Effectiveness

	Fuels Fired	
Technology	**Gaseous**	**Liquid/Solid**
Over-Fired Air (OFA)	Moderate	Excellent
Flue Gas Recirculation (FGR)	Excellent	Moderate (LFO) / Poor (others)
Steam Injection	Excellent	Moderate (LFO) / Poor (others)
Combustion Air Temp Reduction	Excellent	Poor

Various NOx Reduction Methods Effectiveness

Technology	Fuels Fired	
	Gaseous	**Liquid**
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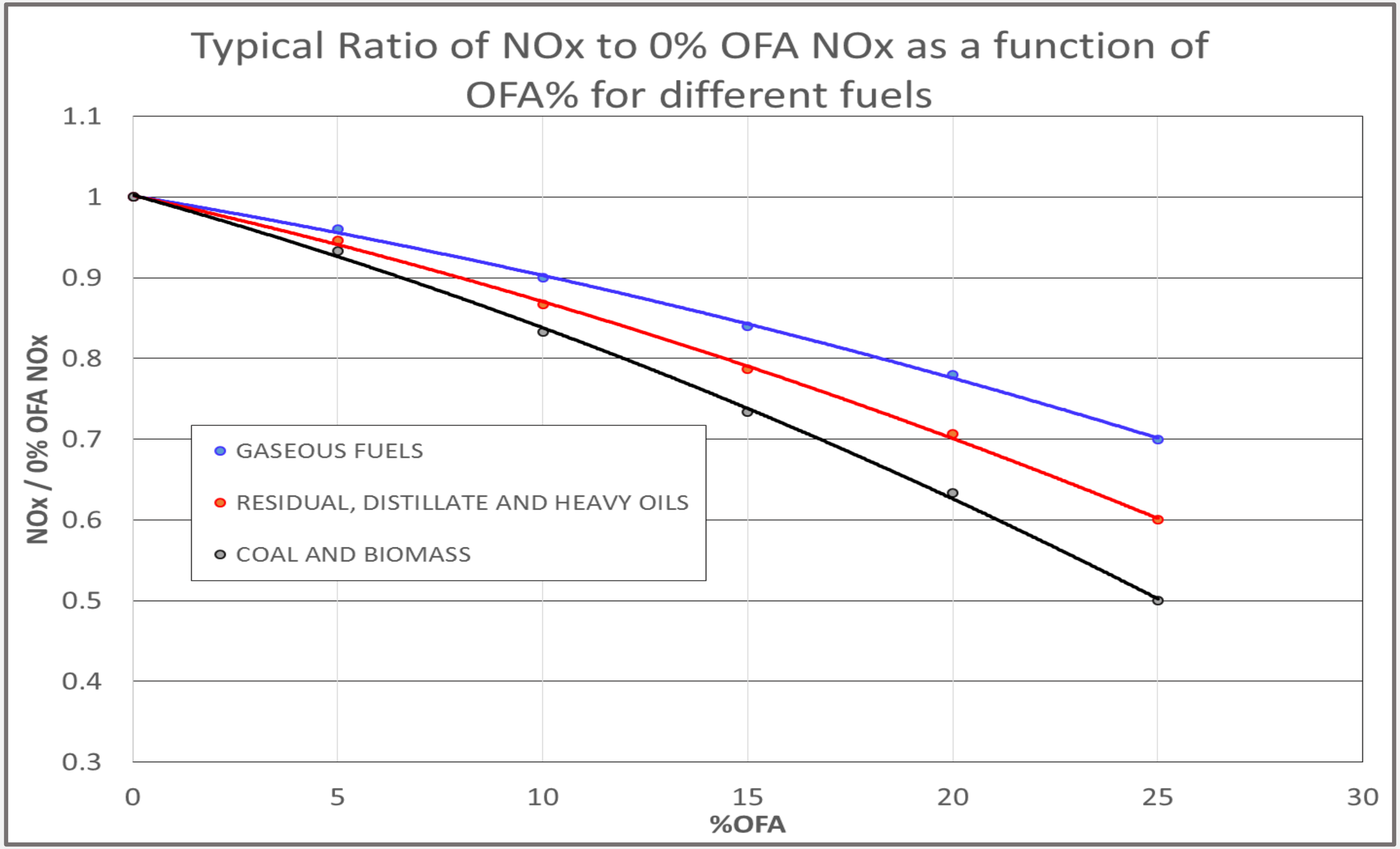
Steam Injection	Excellent	Moderate (LFO) / Poor (others)
Combustion Air Temp. Reduction	Excellent	Poor

Over-Fired Air (OFA) (and Fuel /Air Biasing)

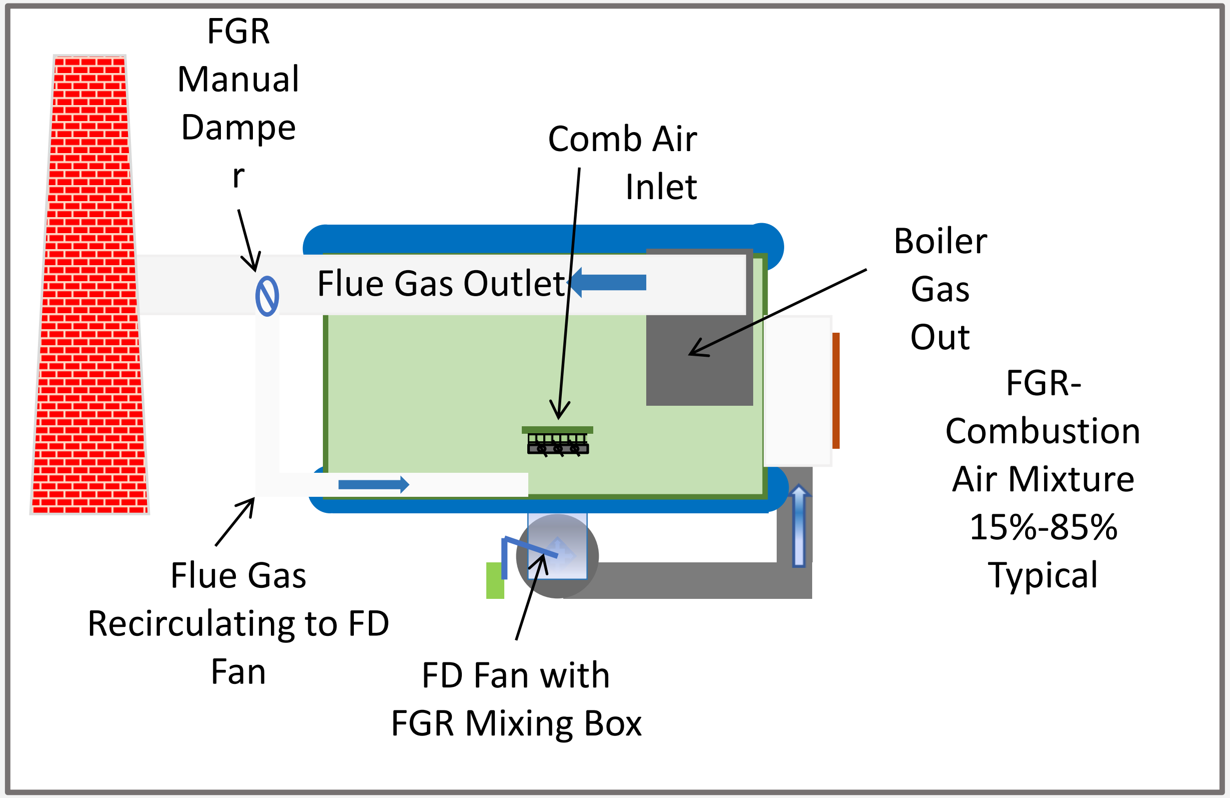
- Applied to field erected boilers with vertical gas path
- Has been unsuccessfully applied to package style / horizontal gas path boilers
- Typically designed for 15-30%
- Generally require 1-2 burner pitch (~ 6 - 16’) from top row of burners to OFA ports
- Minimum of 2 burner pitch (12-16’) from OFA port to nose

OFA vs. NOx

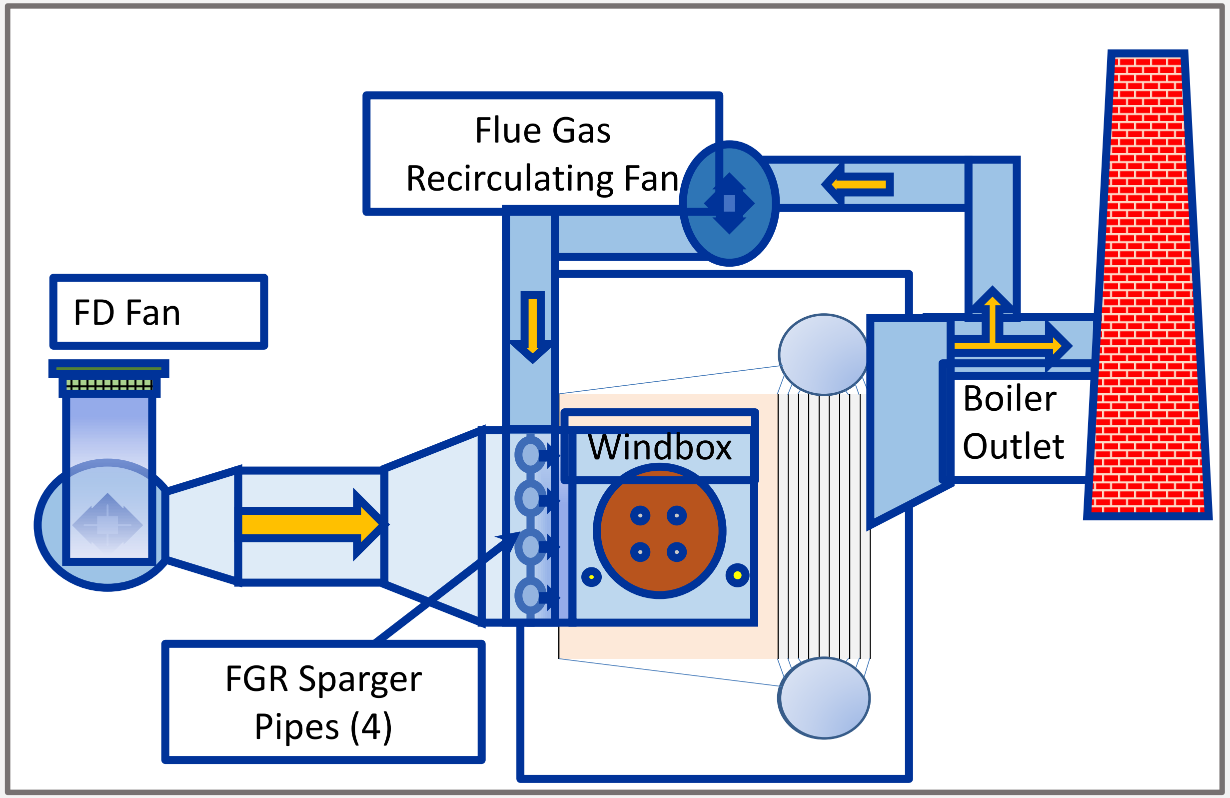

Typical Ratio of NOx to 0% OFA NOx as a function of OFA% for different fuels
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
NOx / 0% OFA NOx
0
5
10
15
20
25
30
%OFA
GASEOUS FUELS
RESIDUAL, DISTILLATE AND HEAVY OILS
COAL AND BIOMASS

Flue Gas Recirculation (FGR) Methods

Induced FGR System



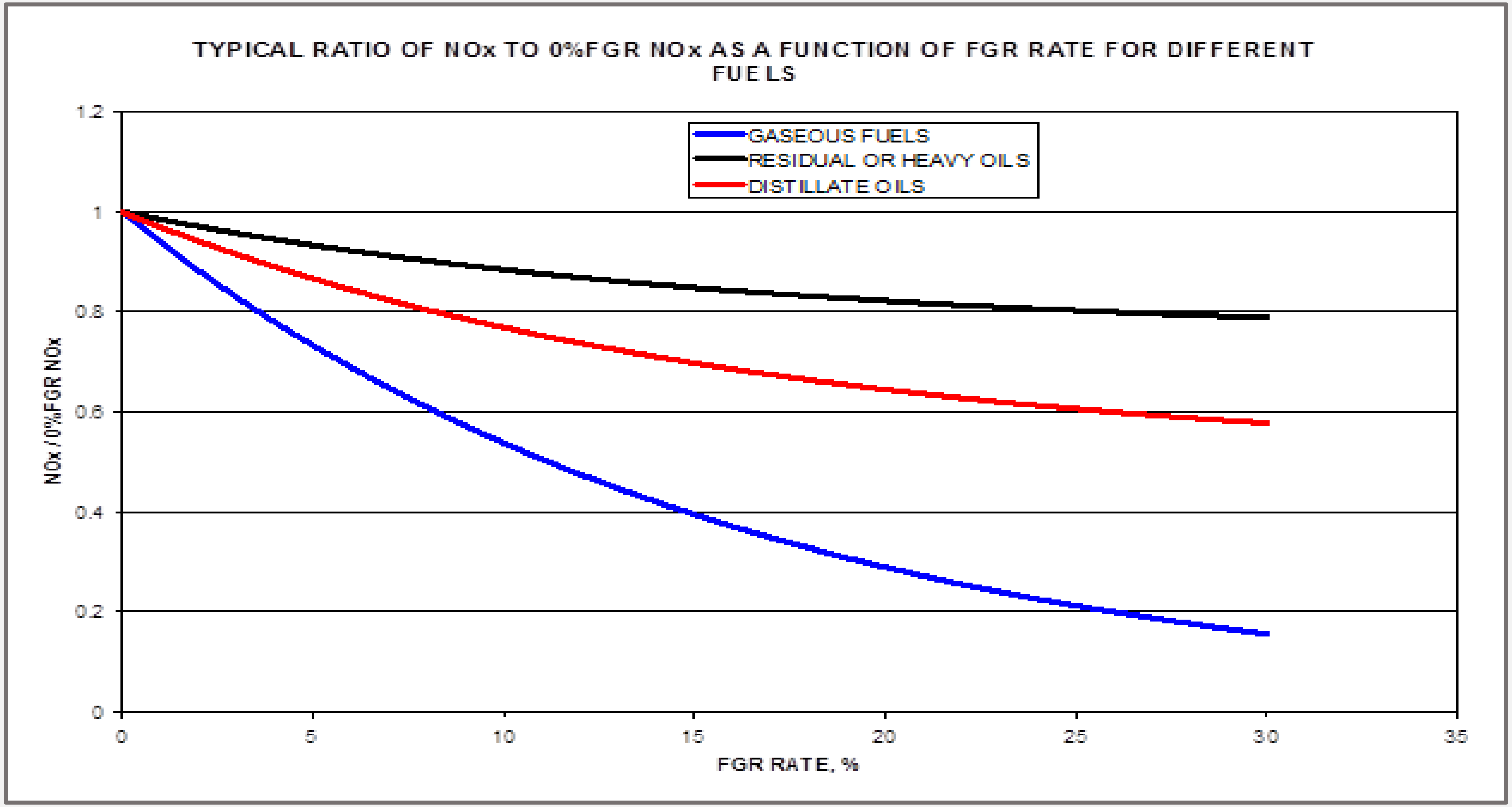
Forced FGR System



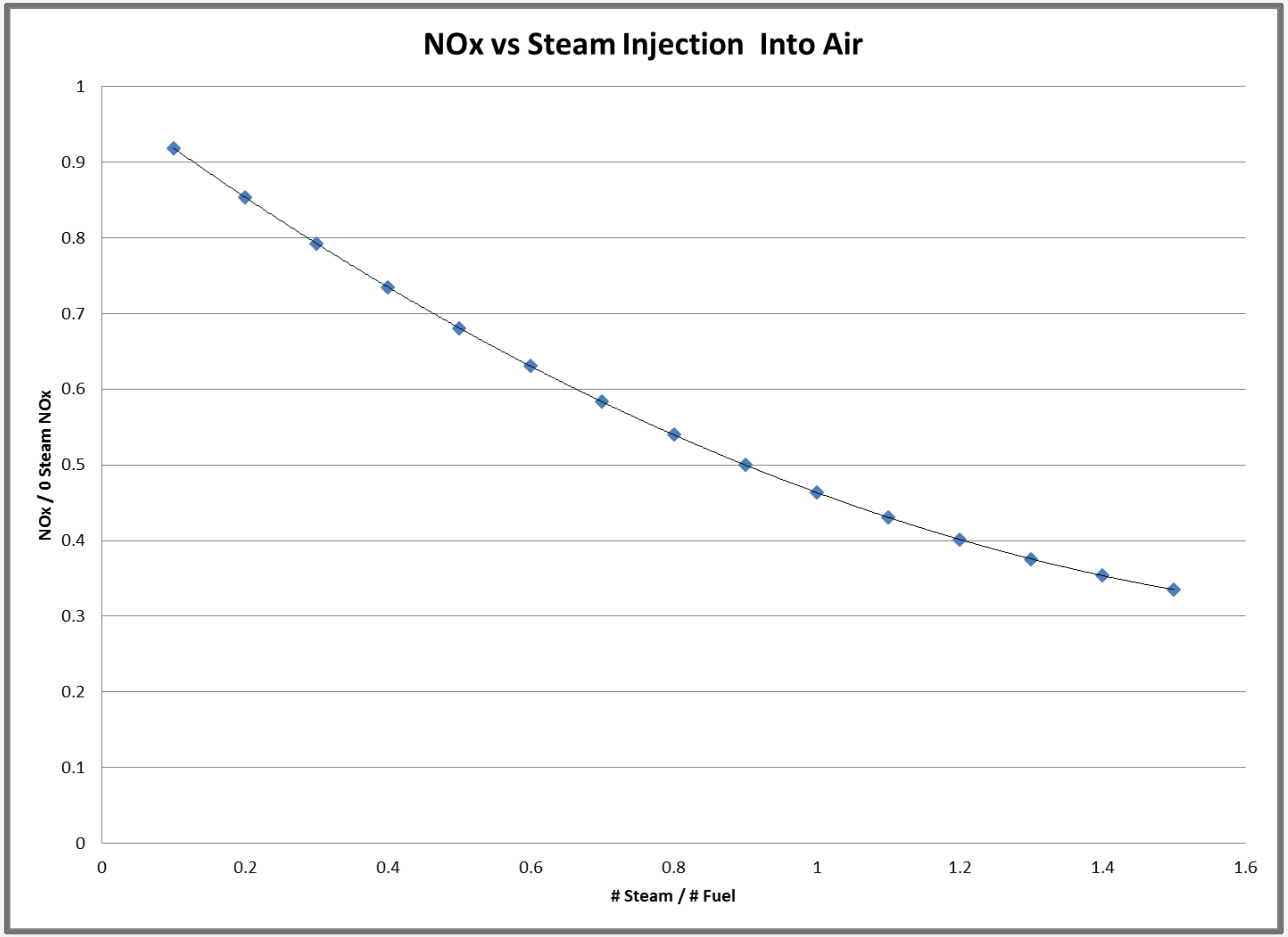
FGR - Lower Thermal NO_x

- **Forced FGR:**
  - Requires dedicated FGR fan and ductwork
  - Higher capital and maintenance costs
  - Added controls
  - Less efficient system
- **External FGR will impact balance of heat transfer**
  - Lower radiant furnace heat transfer and higher convective heat transfer
  - Lower furnace exit gas temperature out of furnace
  - More mass flow through convective bank
  - Adding more than 10% FGR requires boiler impact study

FGR Rates vs. NOx Emissions



Steam Injection

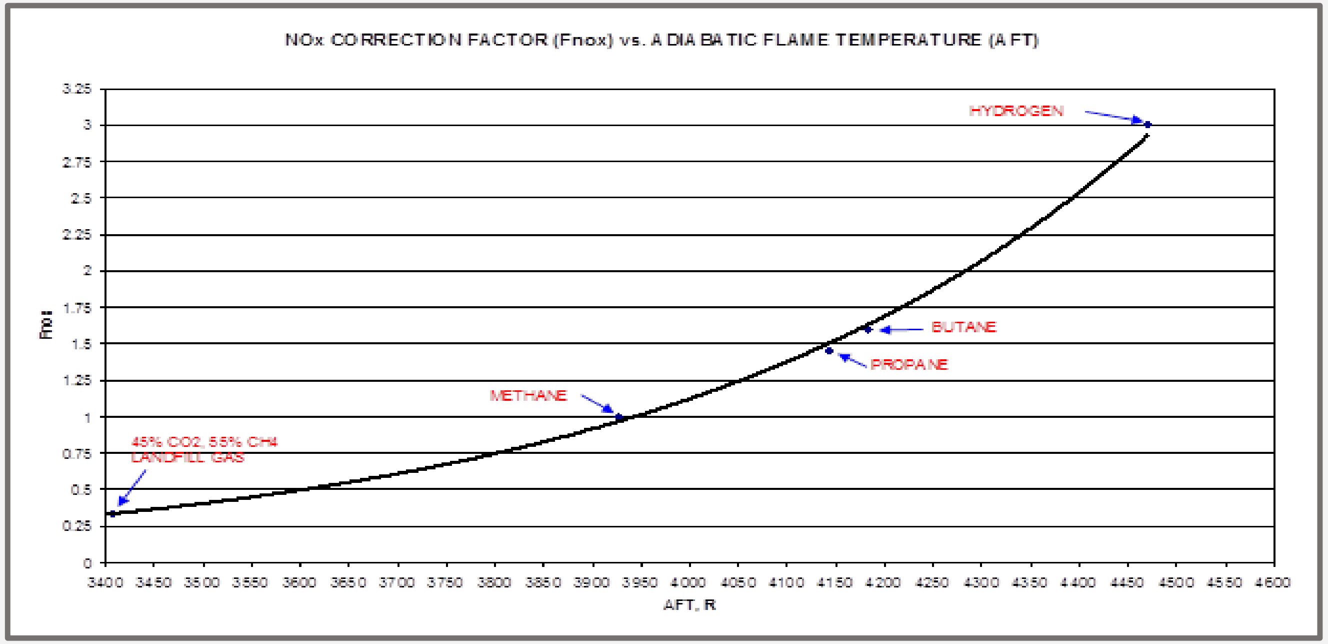


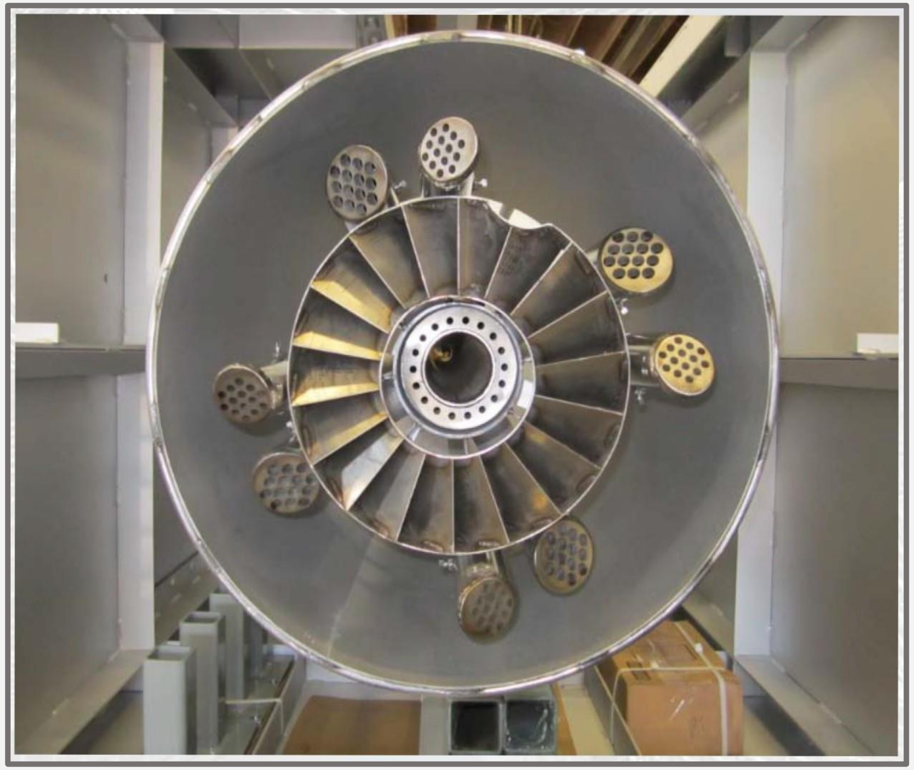
Other NOx Reduction Methods

- Replacing air preheater with economizer / Upgrade economizer
  - Good thing to look at when converting from coal to all gas
  - New economizer can improve efficiency and pay for project with fuel savings
  - Allows use of existing fans, even when adding FGR
  - Typically requires a burner change due to lower register draft loss
- Post combustion
  - SNCR / SCR
    - Requires catalyst
    - Can be utilized to achieve low emissions w/o an ultra low NOx burner

Multi-Fuel Gaseous Firing Designs

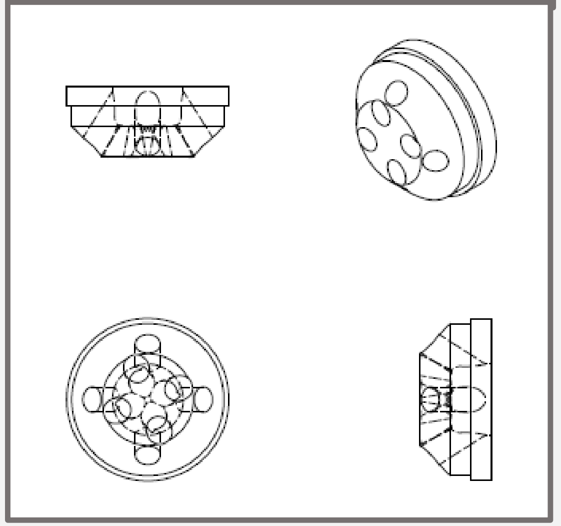
- Considerations for burning multiple gaseous fuels:
  - Fuel density, HHV, and available fuel pressure
  - Blend as many fuels upstream as possible
  - Fuel totalizer





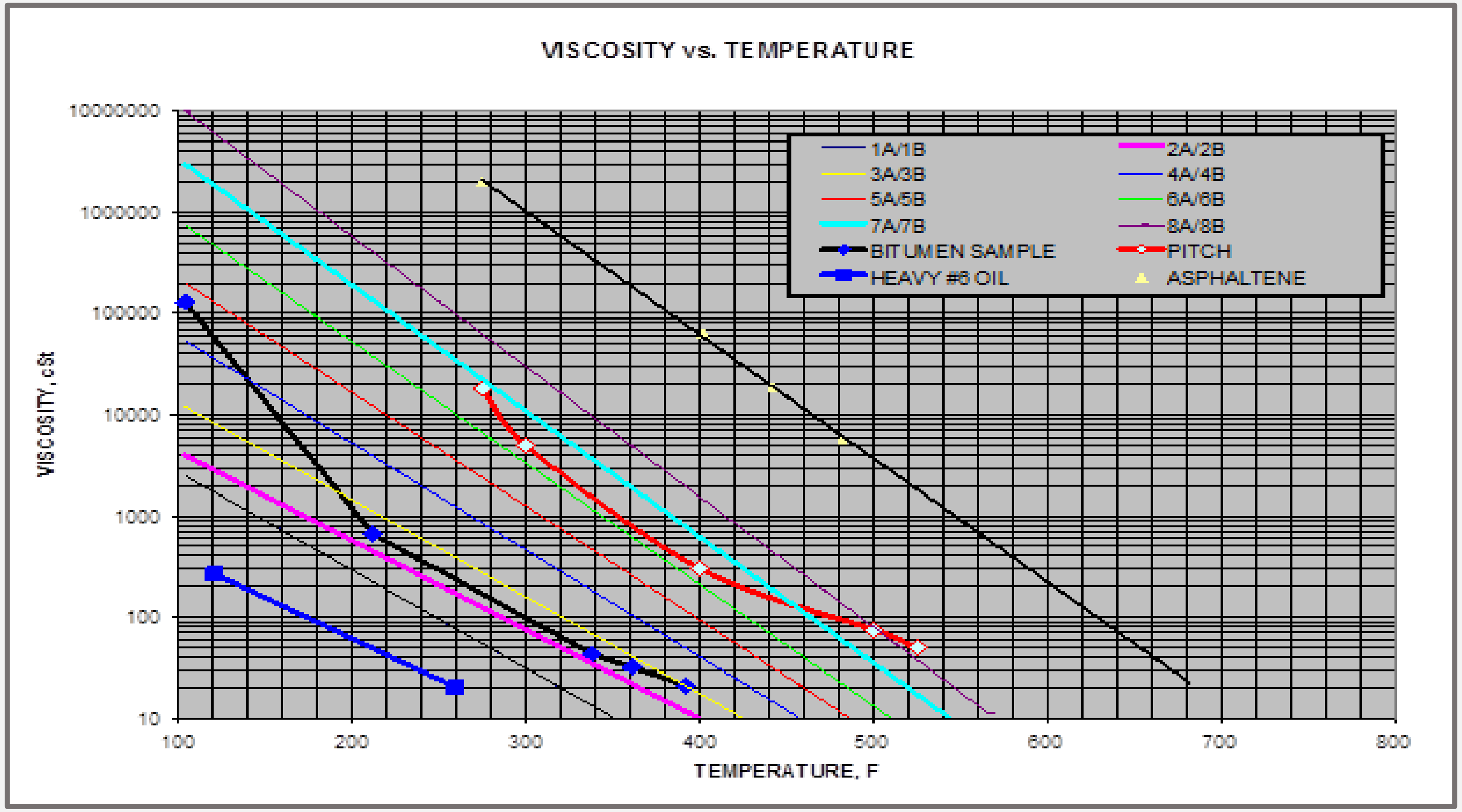
Oil Firing

- Issues when firing oil – smokey, sparklers, clinkers
  - Wet atomizing media
  - Improper viscosity
  - Improper pressures/worn tips
  - Poor tip design
- Utilizes steam or air atomization
- Constant pressure or constant differential systems
  - Very low steam usage on constant pressure steam
  - Multi-viscosity oils adaptability



Multi-Fuel Liquid Firing Designs

- Considerations need to be taken into account for burning multiple liquid fuels
  - To heat or not to heat?



ZEECO

BURNERS FLARES THERMAL OXIDIZERS VAPOR CONTROL RENTALS AFTERMARKET