Boiler Efficiency Review 2012

Northern Ohio Chapter AEE

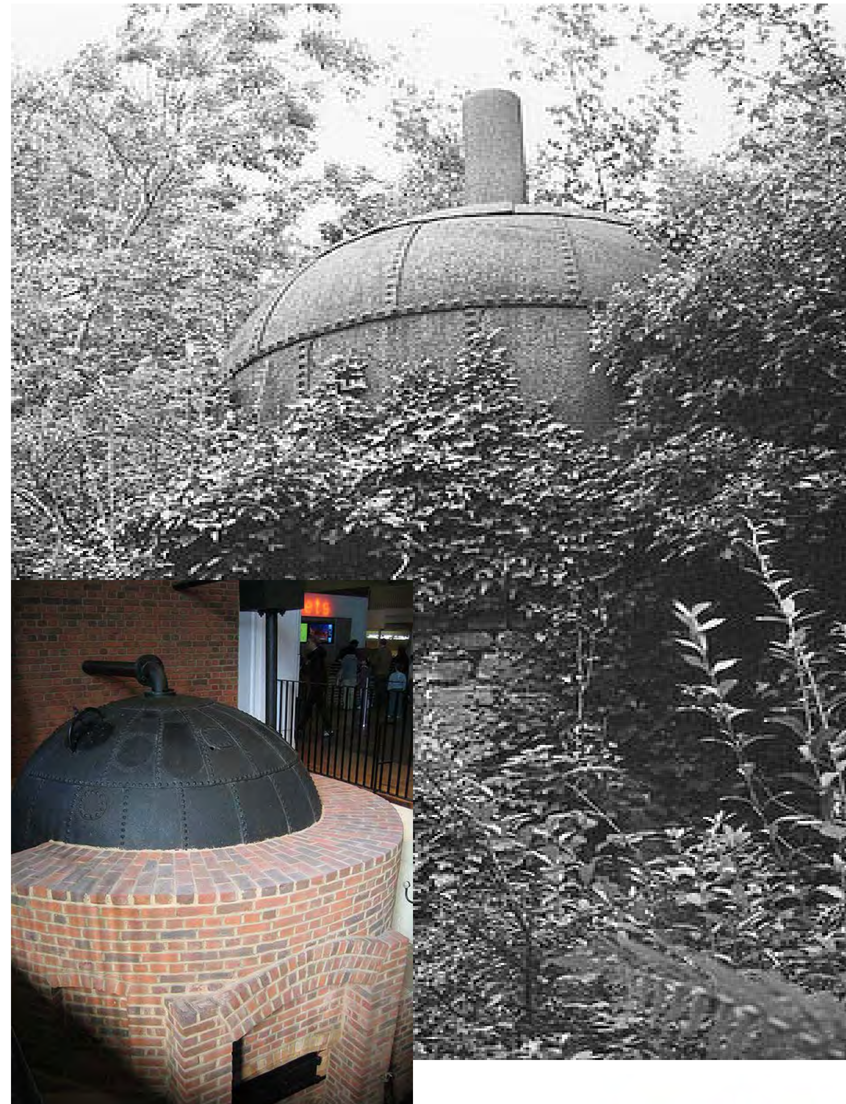
November 2012

Duane Rolkosky, Regional VP

Jeff Schoenberger, Energy Control,
Area Representative

Haystack Boiler, 1700's

- Process steam
- Heating
- Included a water level indicator



Steam Locomotive, 19th Century

- Powered industrialized America
- Weighed up to 200,000#
- Speeds to 100 MPH
- A boiler on wheels

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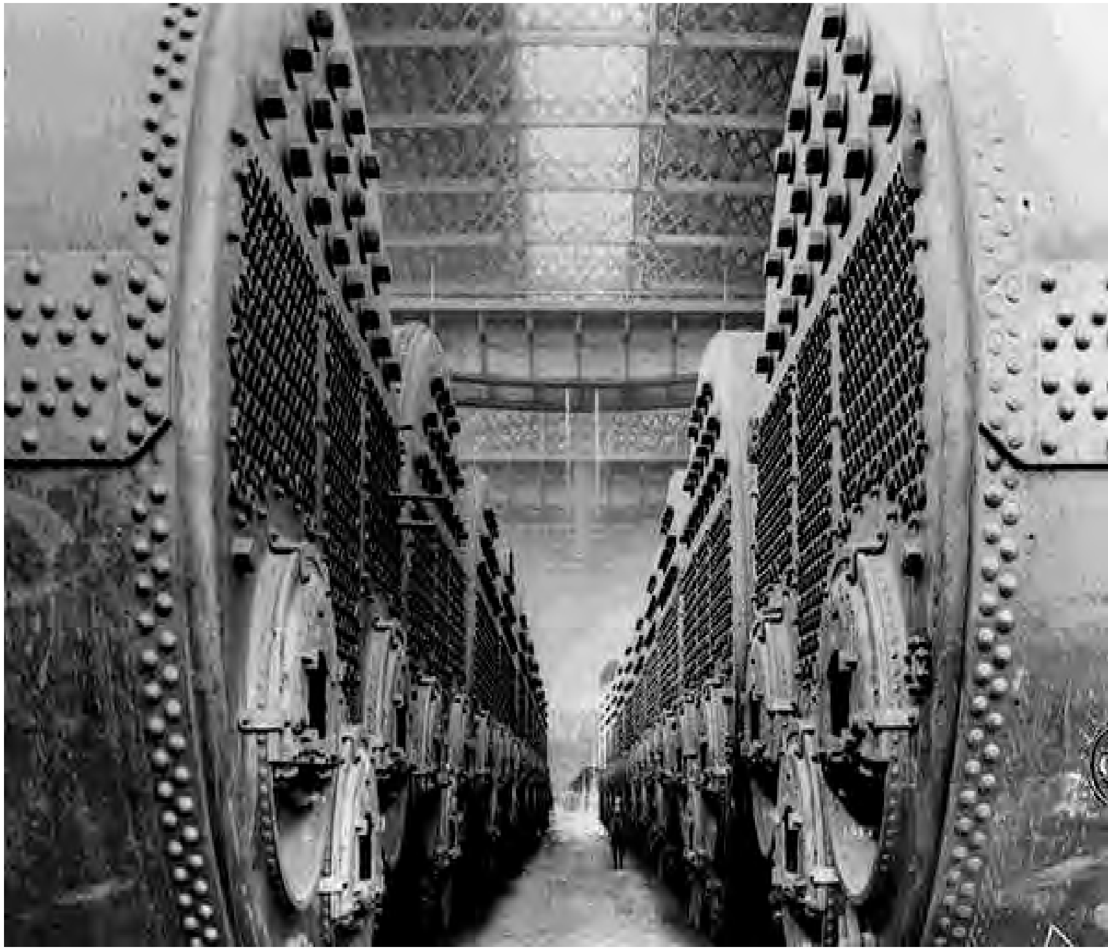
- April 14, 1912
- 46,328 Tons
- 60 feet from water line to boat deck
- Speed was 26 knots (30 MPH)
- 25 MPH when hitting the iceberg

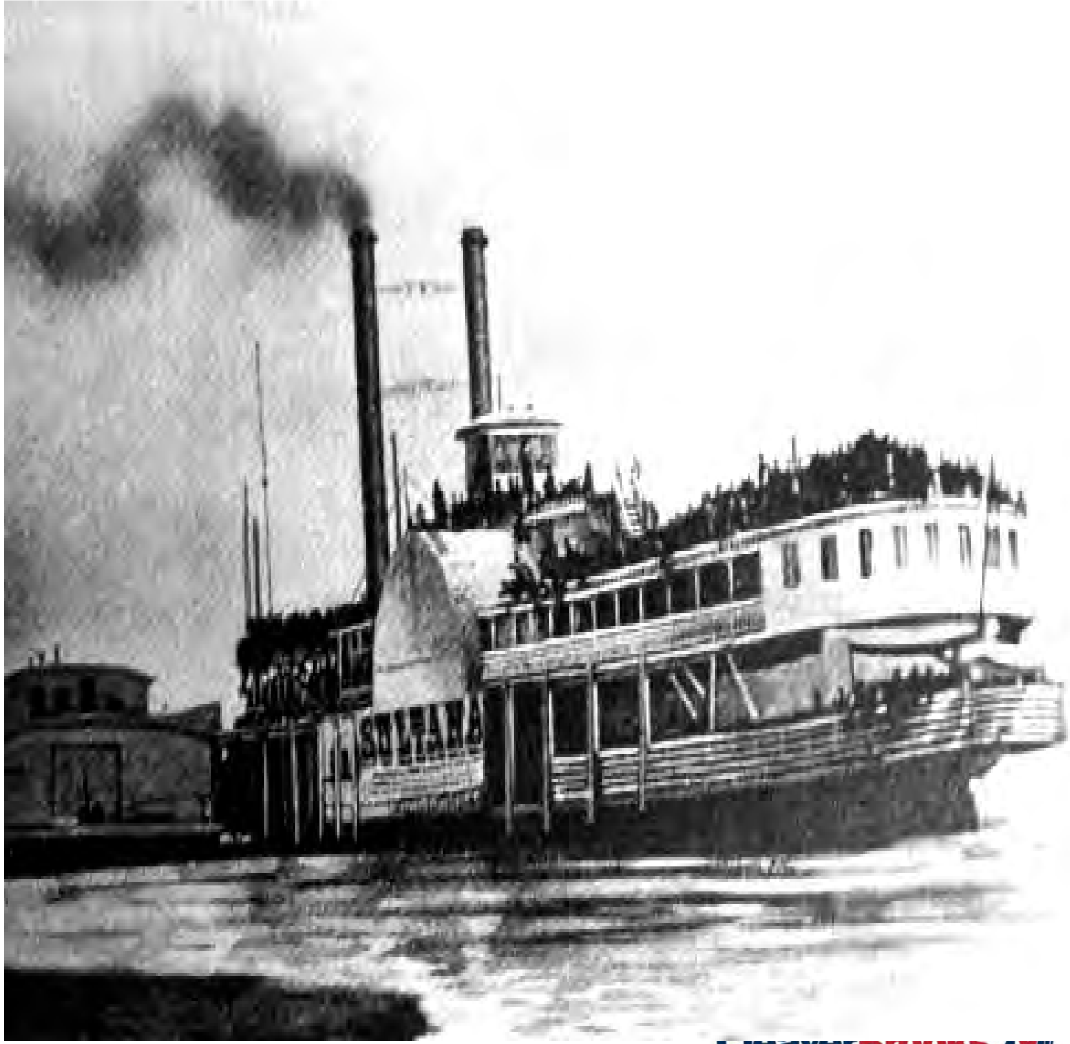
Titanic Boiler Room; Firetube Boilers

- 29 firetube boilers
- Multiple furnaces; 6 ea. in 24 of them; double ended
- 825 tons of coal per day
- 100 feet below the deck
- Operating approx. 215#
- Powered (2) engines and a generator for electricity



The Sultana Boiler Explosion Kills 1238 in April 27, 1865

- Commissioned Jan. 1863
- Boiler repaired a few days before the explosion.
- Events like this lead to safety regulations; stringent codes…



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Steam Locomotive Explosions…..Devastating

Photo: Martin F. Wintermute,
The [illegible] Railroad in Northwest New Jersey, Lowenthal/Greenberg, 1987

ASME Code

(American Society of Mechanical Engineering)

- Section I
  - High pressure - Steam boilers above 15 psi. Hot water boilers above 160 psi and/or 250^0 F. outlet temperature
- Section IV
  - Low pressure - Steam boilers less than 15 psi. Hot water boilers less than 160 psi and/or 250^0 F. outlet temperature
- National Board

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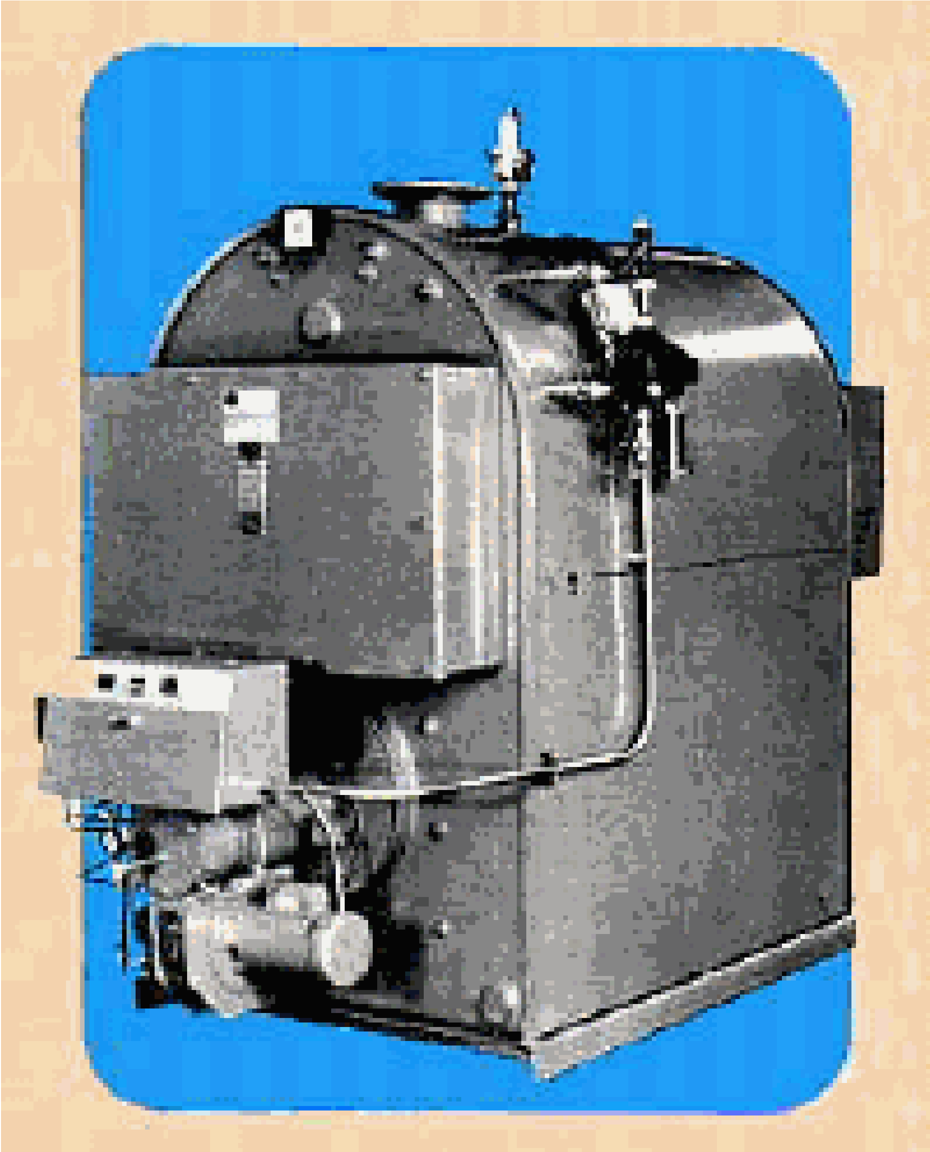
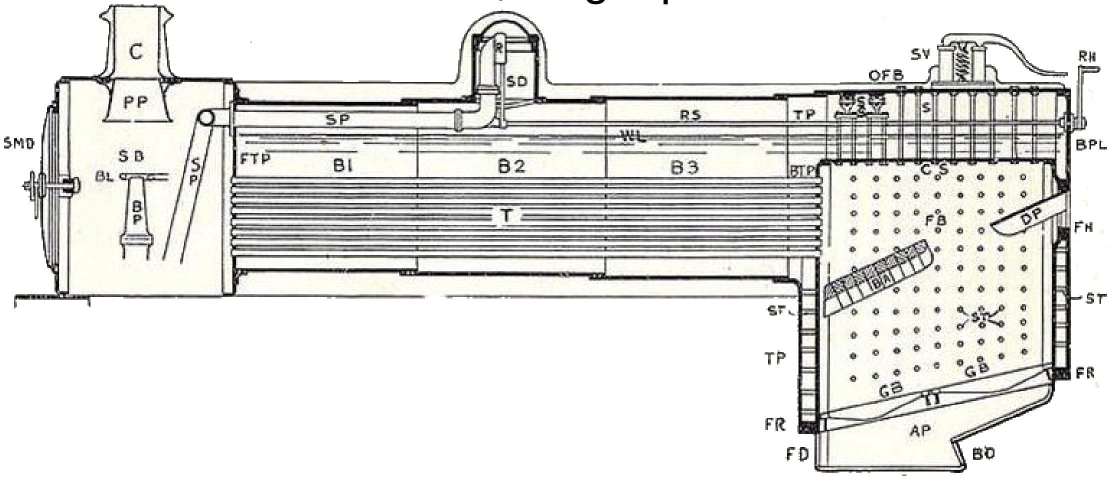
Firebox Boiler, Multiple Pass

- Low pressure steam and hot water for heating
- Primary oil firing
- Evolved from locomotive

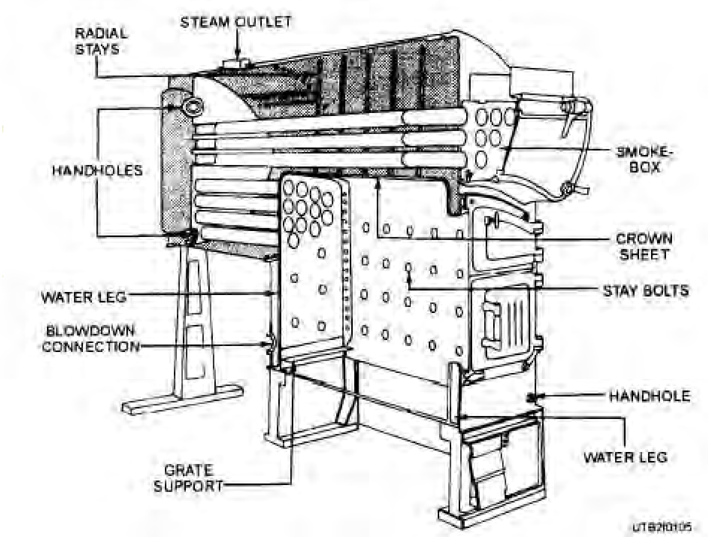


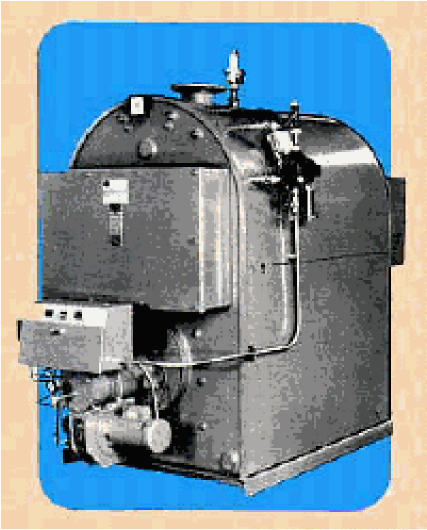
Locomotive & Firebox Boilers

Locomotive, single pass

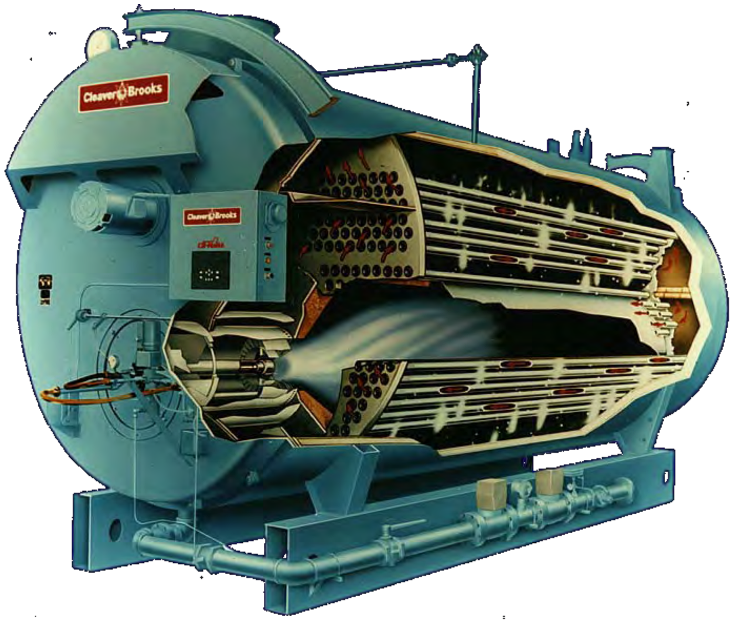


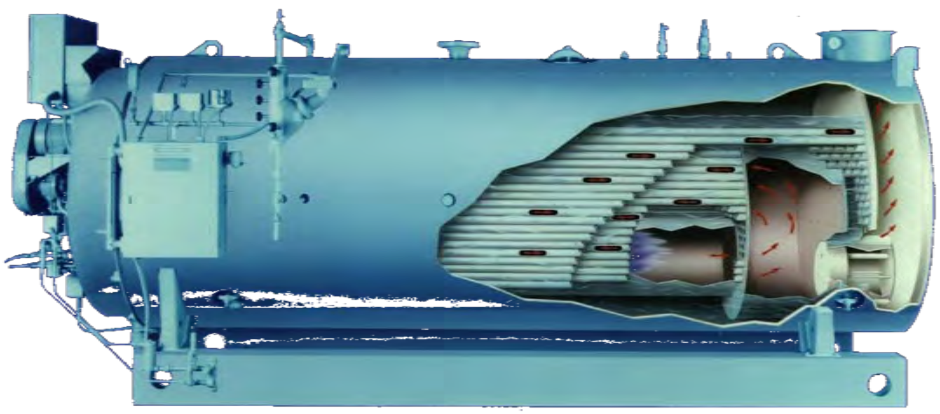
Firebox, 2 pass





- Gas becomes more available
- 1963 CAA
- November 1973-March 1974
- Same concept as firebox
- Smaller furnace
- No solid fuel unless pulverized
- Two tubesheets in the dryback
- Easy access to both ends of vessel





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Typical Industries

- Food
- Dairy
- Beverage
- Pharmaceutical
- Petro Chemical
- Textile
- Pulp & Paper
- Medical
- Automotive
- Computer Technology
- Government
- Schools
- Universities

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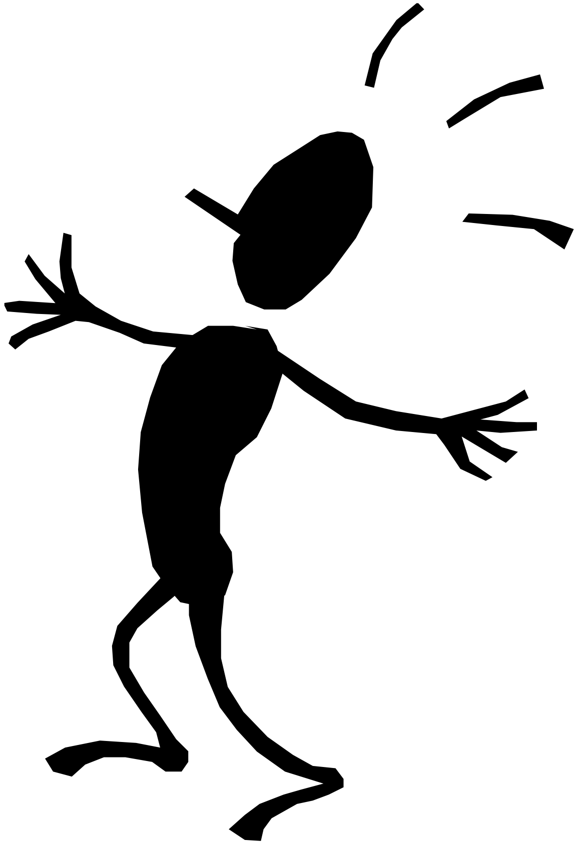
Boilers of the Late 20th and Early 21st Century

- 400,000 commercial/industrial boilers
- 60% over 20 years old (75% efficient)
- Consume 33 Quads/Yr.
- 25% of world's energy
- U.S. has 2% of the world's oil reserves
- 21 MM Brl's/day
- Importing over 60% or 13 MM Brls/day
- 5 MM Brls from OPEC
- Waste 400,000,000 brls @ 10%
- We burn less, we pollute less.
- What about the 5th fuel?



Large Commercial/Industrial Boilers

- 160,000 of the 400,000 boilers
- Process = 54,000 boilers
- 25,000 over 20 years old
- Average size 250-400 HP
- 400 HP @ 75% = 17,851,733 Btuh
- 179 therms
- @ $1.00 X 5000 hrs = **$895,000/yr**

- Energy conservation
- Environmental impact (Emissions)
- Reliability
- Safety
- Footprint

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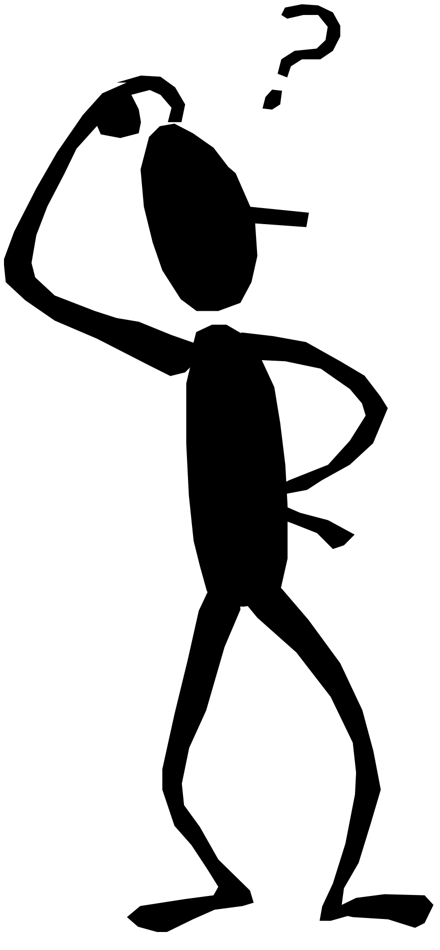
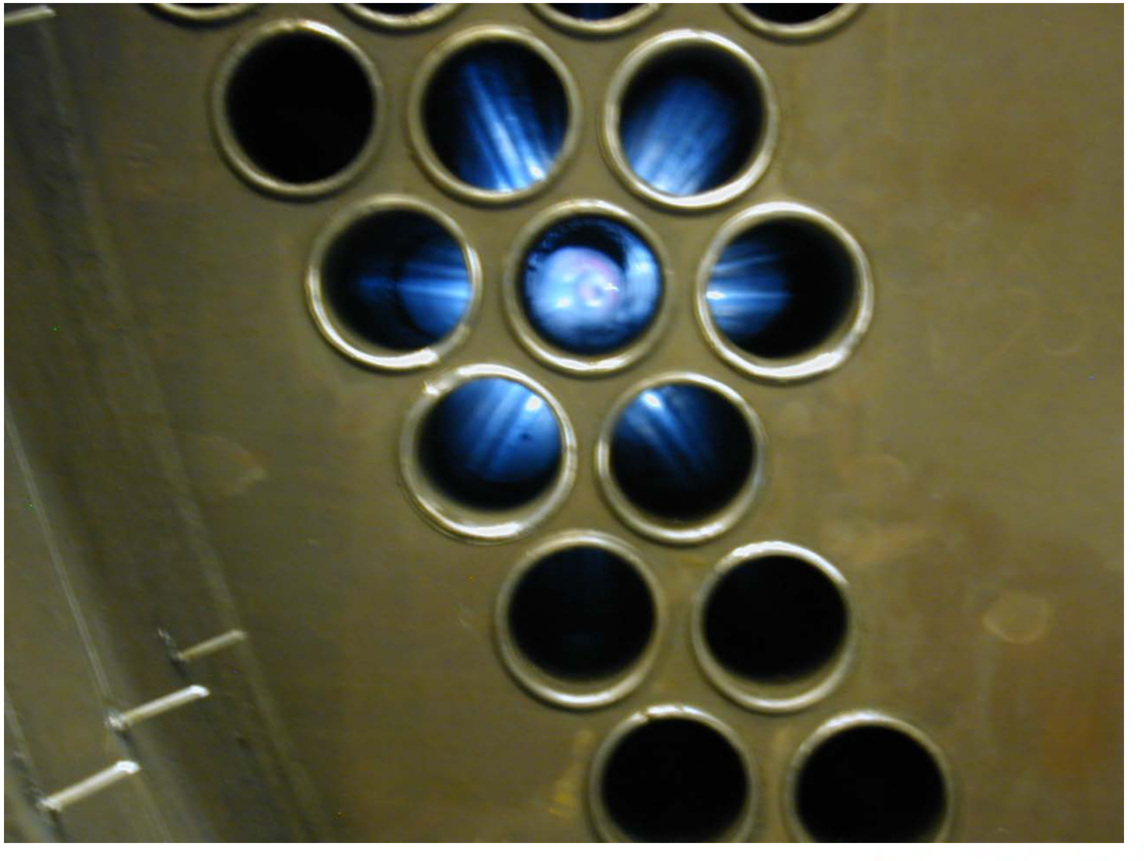
How can I make it more efficient?





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- Turbulence; Extended surfaces
- Increases heat transfer coefficient
- Must be part of packaged design
- Reduces heating surface requirement
- Reduces footprint

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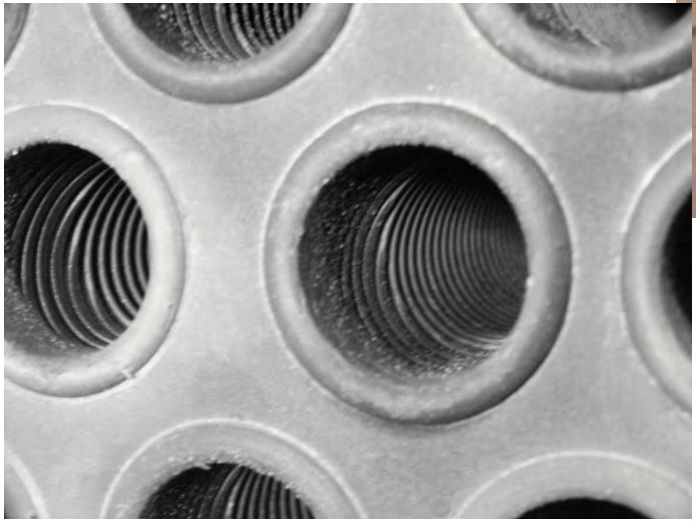
- Extended tube surfaces
- Less heating surface
- No compromise in efficiency or life



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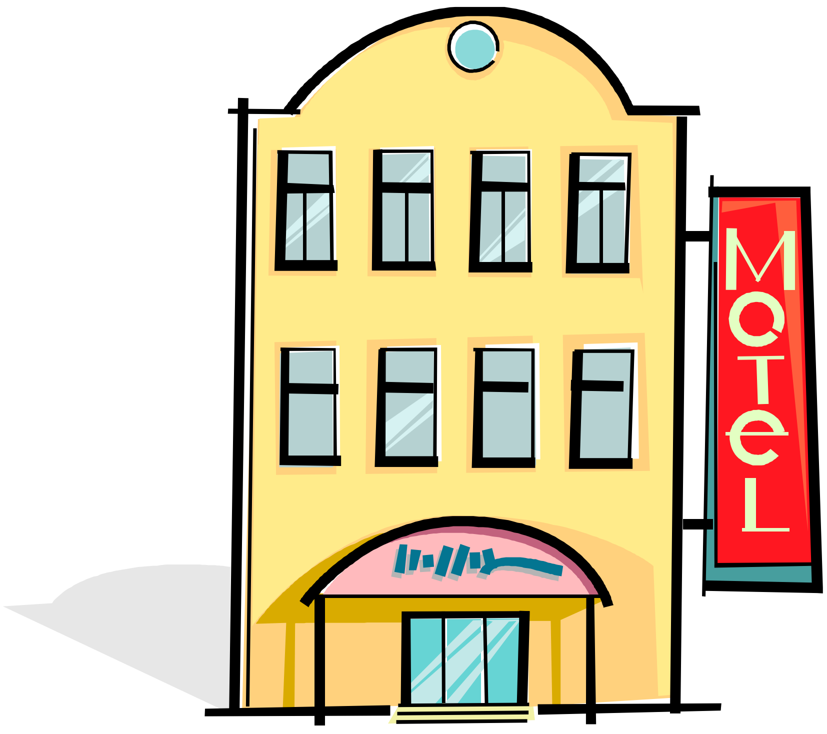
What's happening with hydronic Heating?

Large Commercial/Industrial Boilers

- 160,000 boilers (steam & hot water)
- Hydronic = 106,000 boilers
- 64,000 over 20 years old
- Average size 1,200,000 Btuh (36 BHP)
- @ 75% = 1,600,000 Btuh
- 16 Therms
- @ $1.00 X 6480 hrs = **$103,680/yr**



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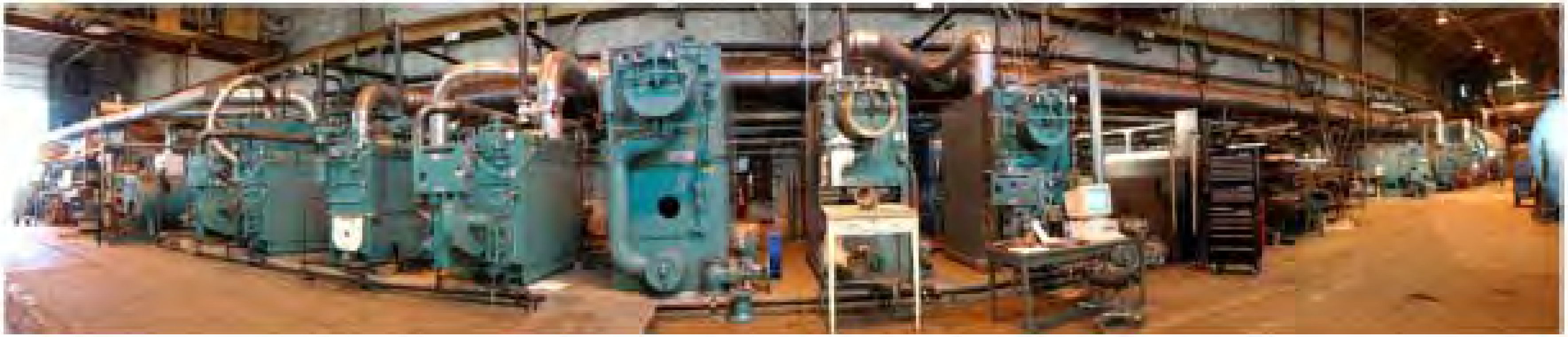
- Heightened awareness; first cost, energy cost & environment
- Buildings have gotten tighter
- Condensing vs. non-condensing boiler choices
- Some engineers are challenging the “old school” thinking and winning…

CB Product Development 2012



- Group of 15, includes Engineers, Designers and Technicians
- Test boiler sizes from 10 HP to 1500 HP(62 million input)
    - Steam and Hot Water boilers
    - Fuels – Natural gas, Propane, #2 oil, #6 oil
    - Emissions – Uncontrolled to 7 ppm NOx
    - Thermal and Combustion efficiency tests
    - Varying operating conditions
    - UL, CSA compliance testing
- Alternate fuel testing for customers
    - Bio diesel
    - Citrus oil
    - Wood chip oil
    - Waste oil
    - Glycerol
- Development and testing of controls
- Partnership with Honeywell, Fireye, Siemens ....to integrate their products with CB boiler-burner packages

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High Efficiency Boiler Designs

ClearFire Model CFC
[ClearFire Condensing]

- Range
- Construction
- Efficiency
- Venting
- Warranty
- Application

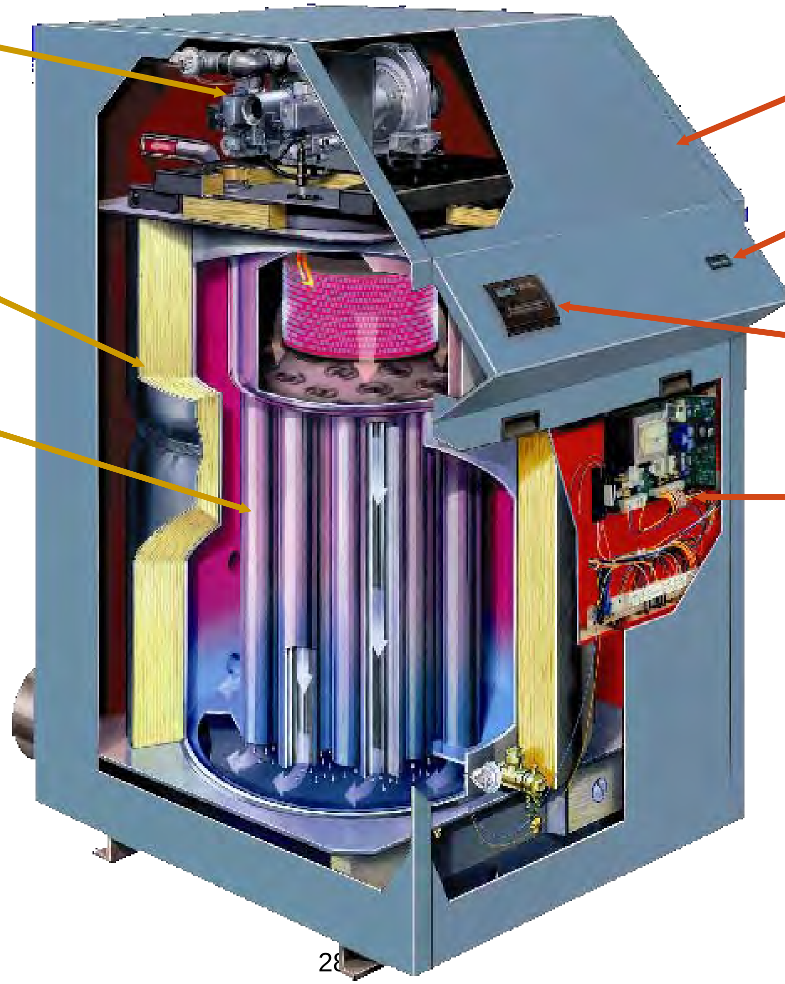
Model CFC

- Type: Vertical Alufer-tube Single Pass, Commercial Boiler.
- 7 Sizes: 500 through 3300 BTU.
- Design: 125 PSIG Hot Water
- Fuel: Natural Gas or LPG [No oil firing].
- Codes: ASME Section IV, UL, ASME CSD-1.

Model CFC

- UL listing
  - Available on all sizes
  - Natural gas or Propane have UL listing
- Dual Fuel UL listing
  - Separate Natural gas and Propane gas trains
  - Selector switch that energizes correct pressure switches
  - Falcon settings could be different
    - Lite-off speed
    - Max/min speeds
    - Turndown

Assembly



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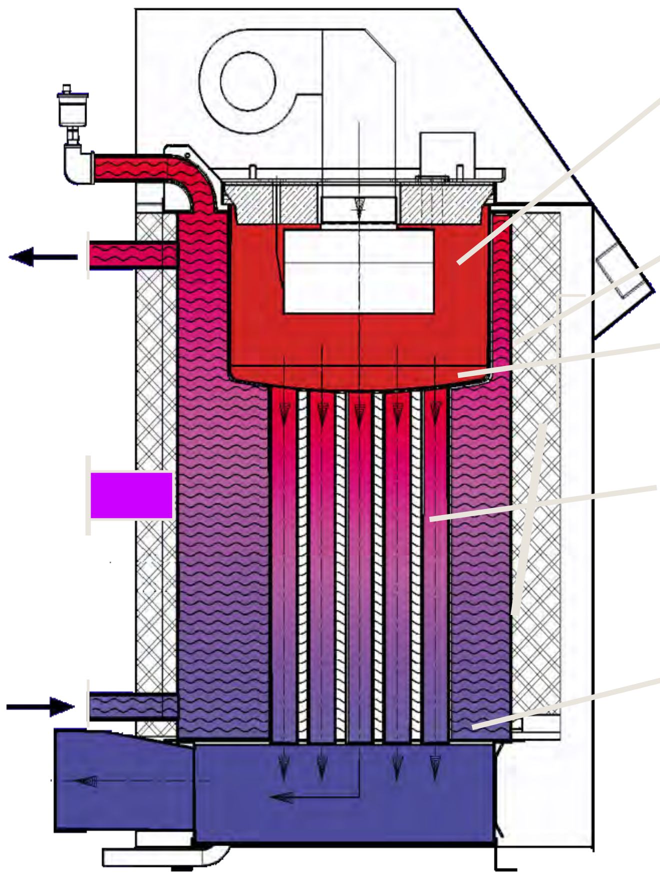
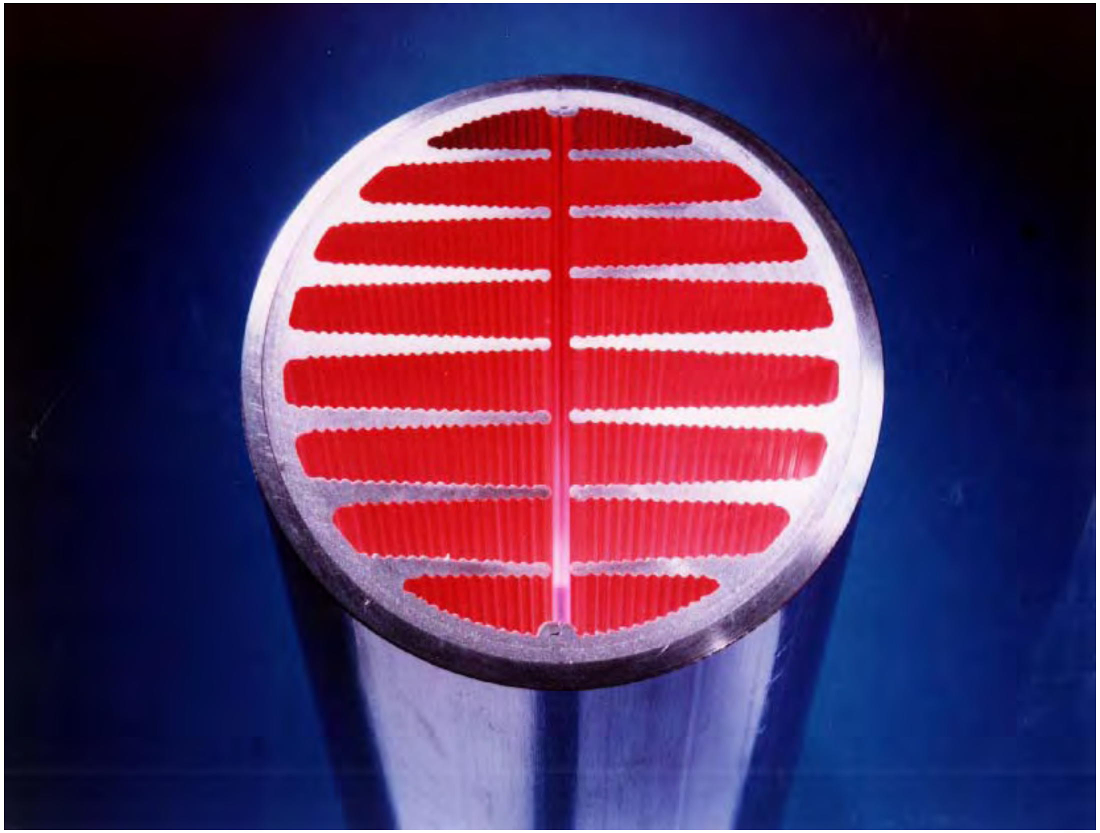
Pressure Vessel



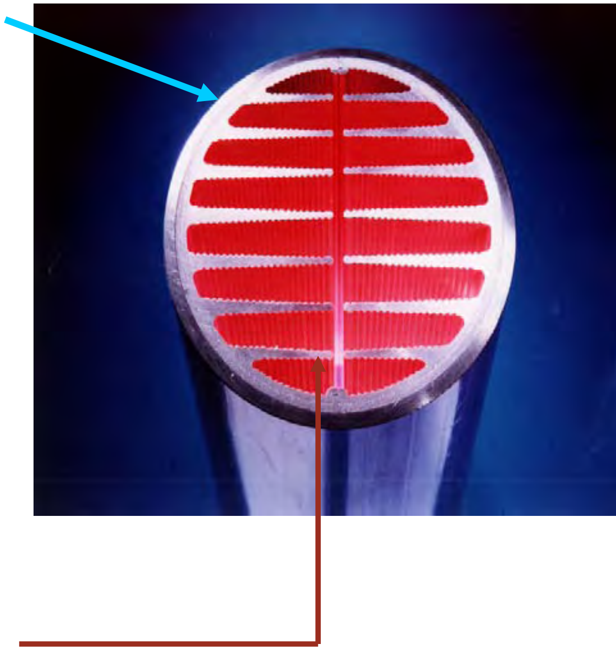
ALUFER® TUBE



Alufer® Tube

Tube Specification: 3” OD @ 0.157” Thickness.

- Model CFC Boiler tubes consist of an outer (Duplex) stainless steel envelope (waterside) and machined alloy metal profile on the flue gas side.
- This special alloy profiled tube interior with fins and micro structures, provides a large heat transfer surface.
- The heat conductivity of this alloy is ten times higher than stainless steel or carbon steel.
- Each boiler tube is divided into eight flow channels.
- As a result, turbulent flue gas flow is enhanced and a hot core stream is avoided. The vertical position of the tubes enables a self-cleaning effect and precludes a reduction in efficiency, due to deposits on the surface.



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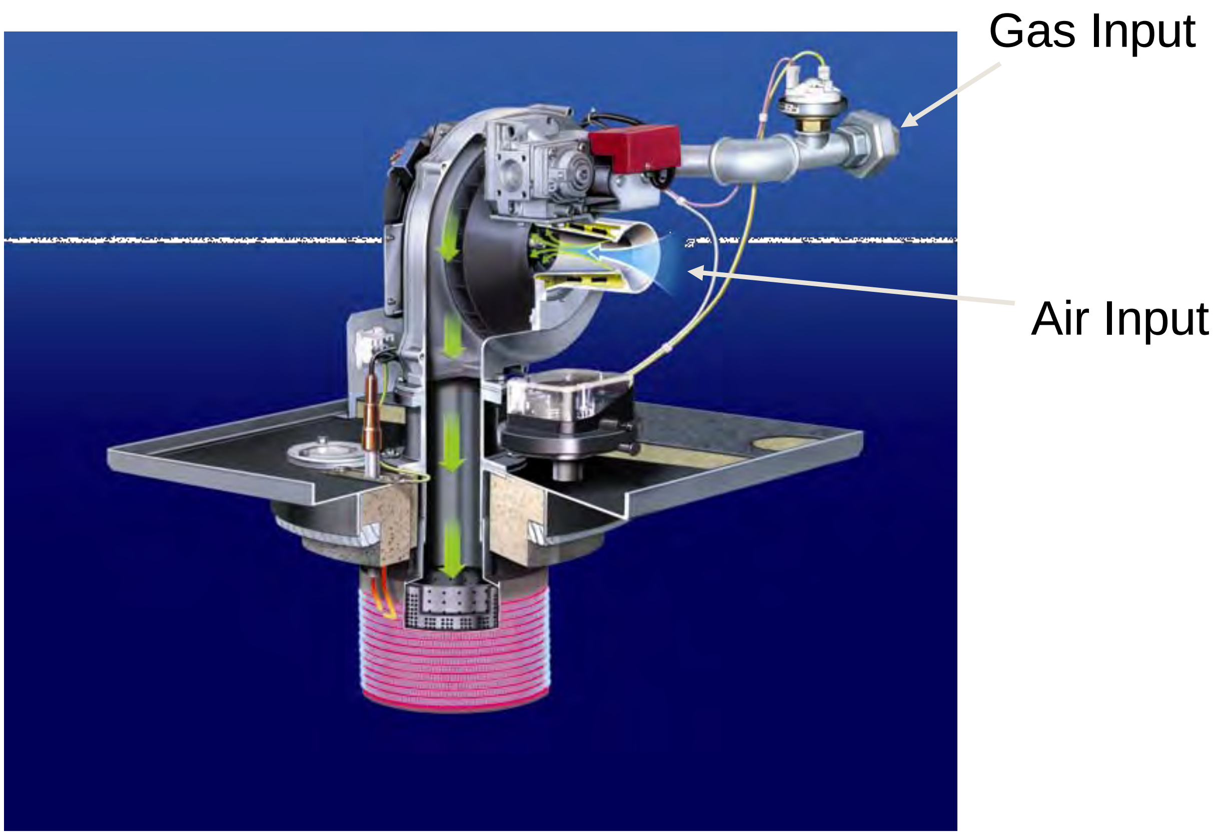
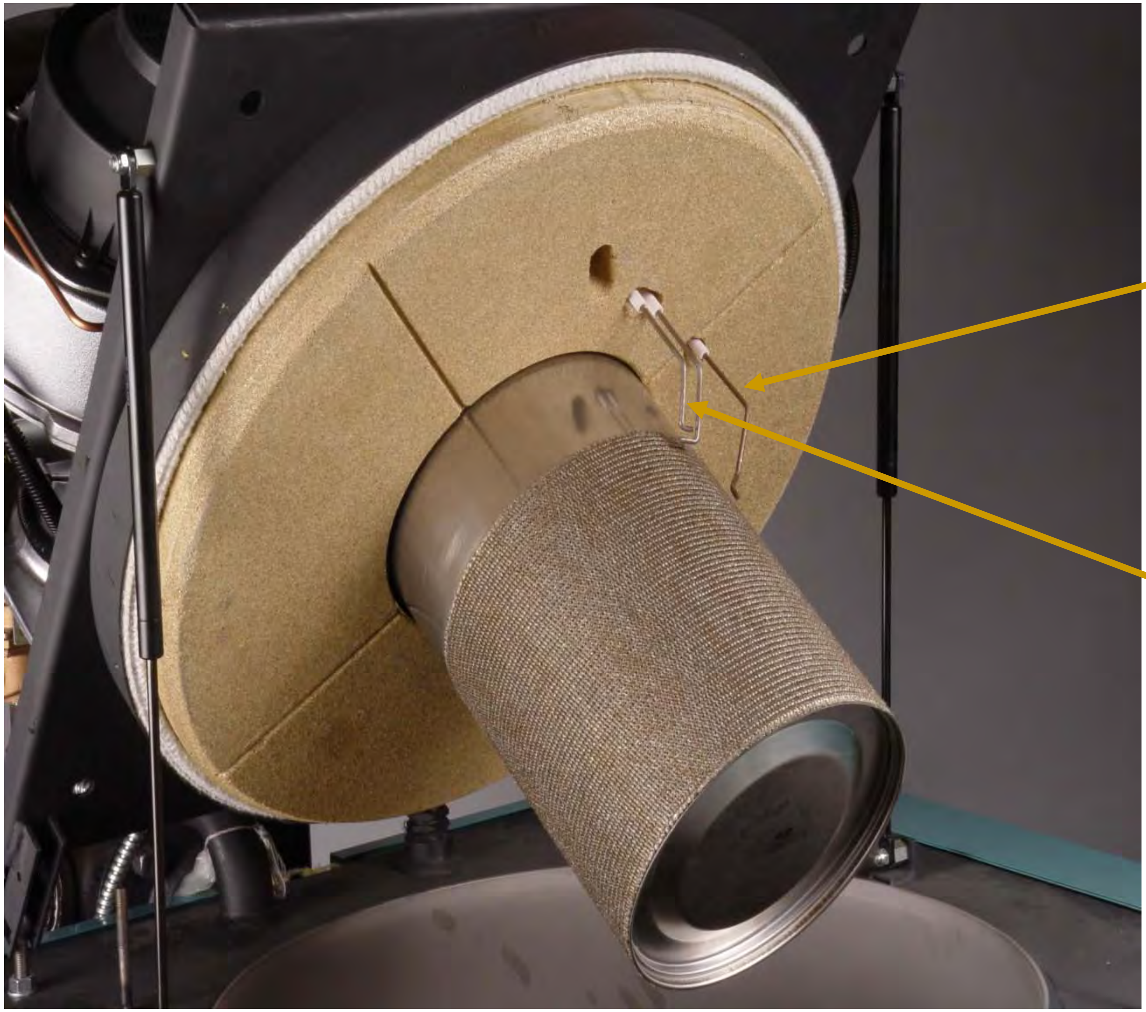
Premix Burner System



Electrodes/flame Rod

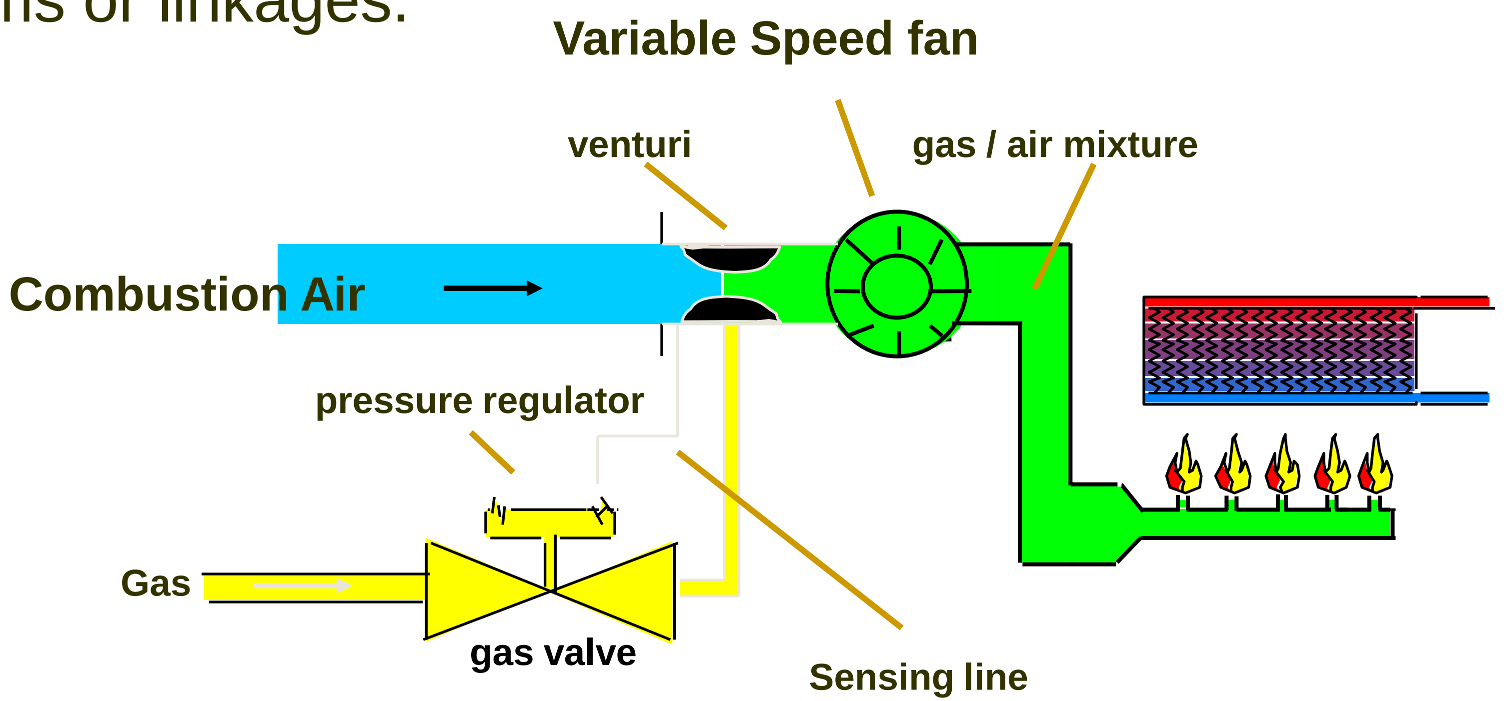


Flame Monitoring Electrode

Spark Electrodes

Premix Combustion

The 1:1 gas/pneumatic valve combined with an air venturi mixer reaches turn down ratios of 5:1 without cams or linkages.



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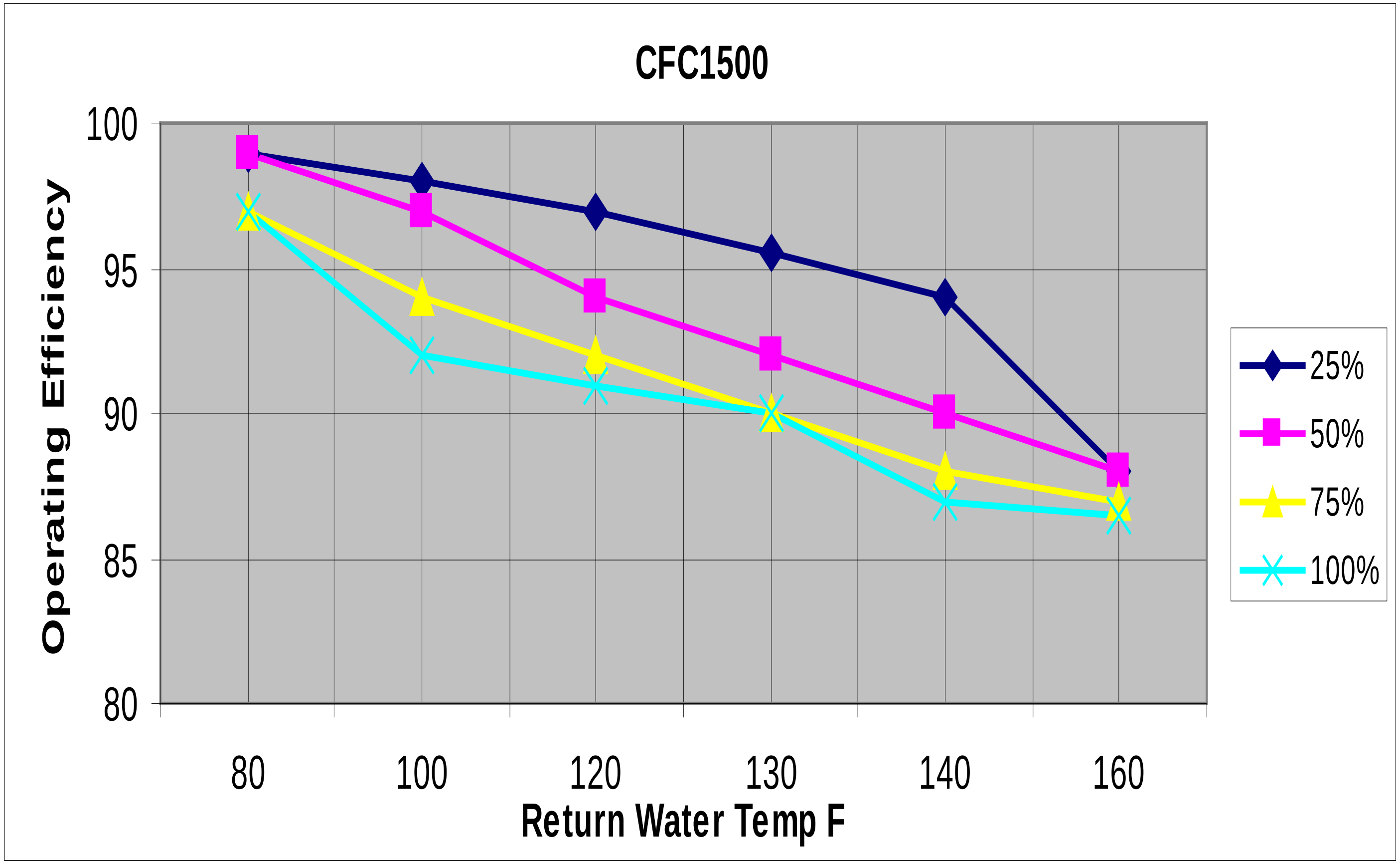
Basic Functions:

- Color touch-screen display providing user interface for monitoring and configuring the CB Falcon system.
- Individual and multiple boiler (up to 8) status, configuration, history, and trend analysis.
- Burner control sequence status, flame signal, diagnostic, historical files and faults.
- Locates all boilers attached to the network.
- Date/time stamping of Lockouts & Alerts.
- Tagging: boilers, limit strings inputs, annunciation points
- Four LED's
- Two communication ports
- 12 Vdc power supply

Efficiency

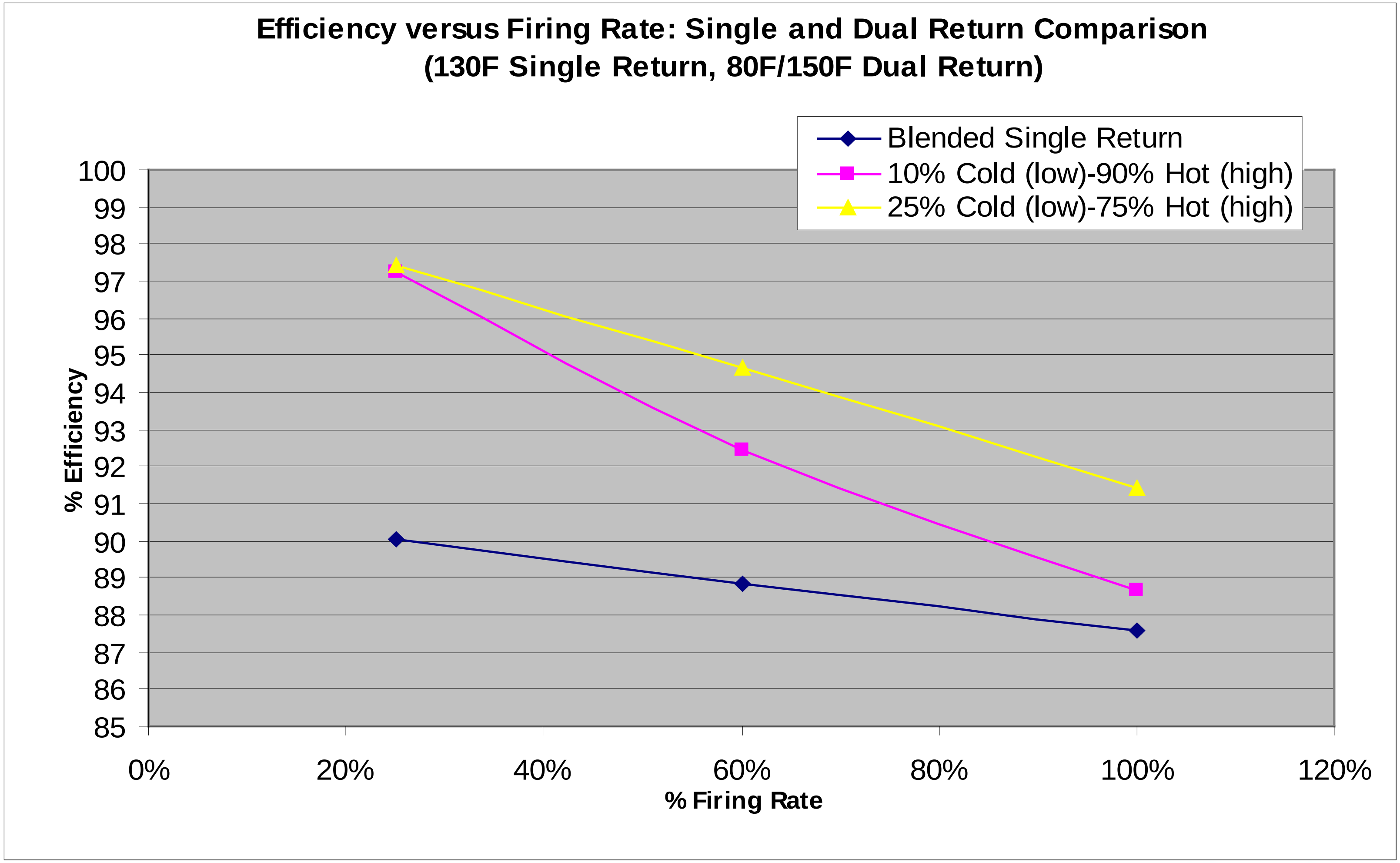


CFC1500
Operating Efficiency
100
95
90
85
80
80
100
120
130
140
160
Return Water Temp F
25%
50%
75%
100%

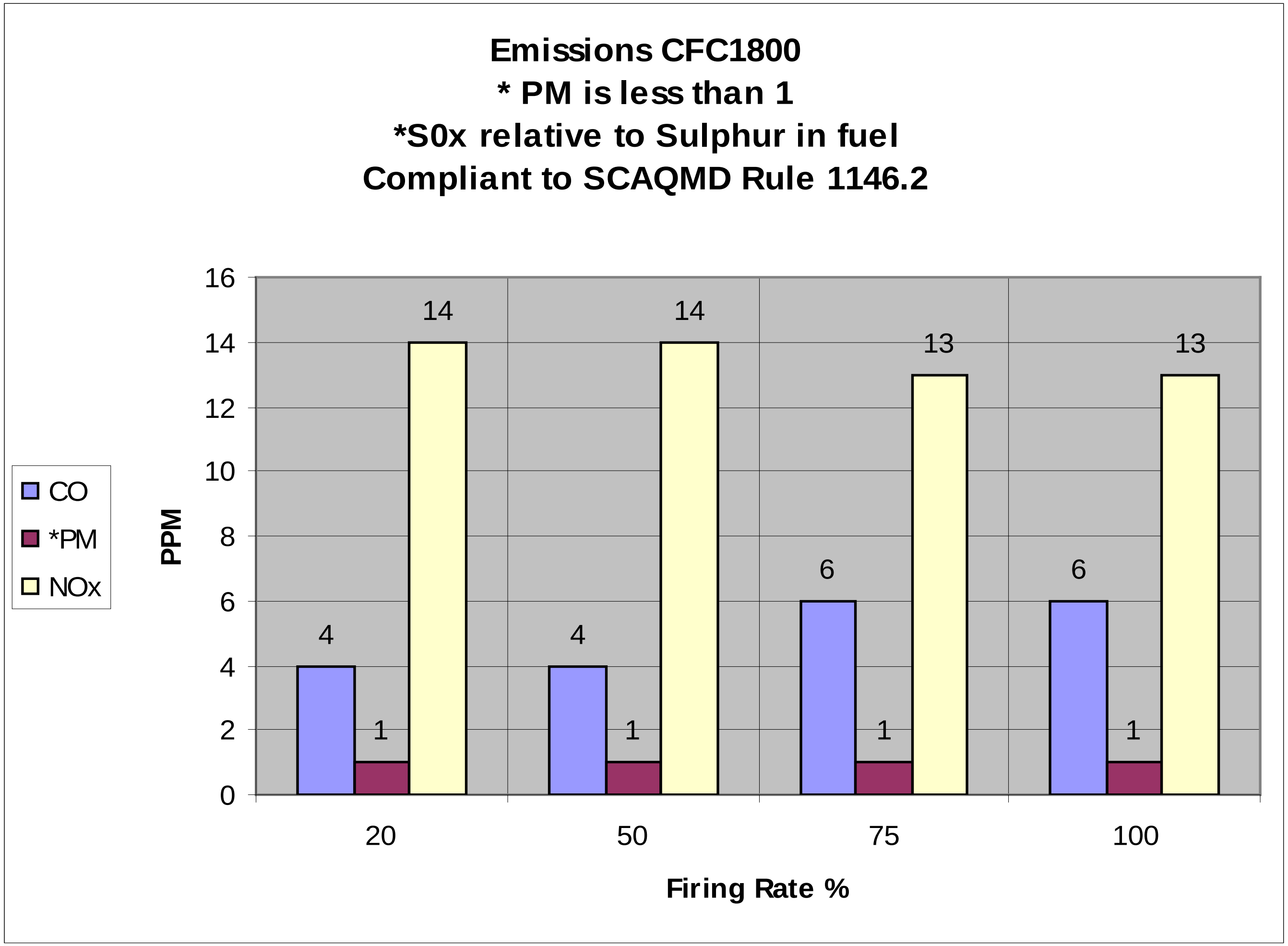
Dual Returns

- Dual Return
  - Available on all sizes
  - Increased efficiencies for a separate return (> 10% flow and < 130F)
    - Pool, snow melt, radiant floor
    - Best opportunity is from an oversized main coil in AHU
    - Will require a separate pump and piping loop

Effect of Dual Returns



Emissions



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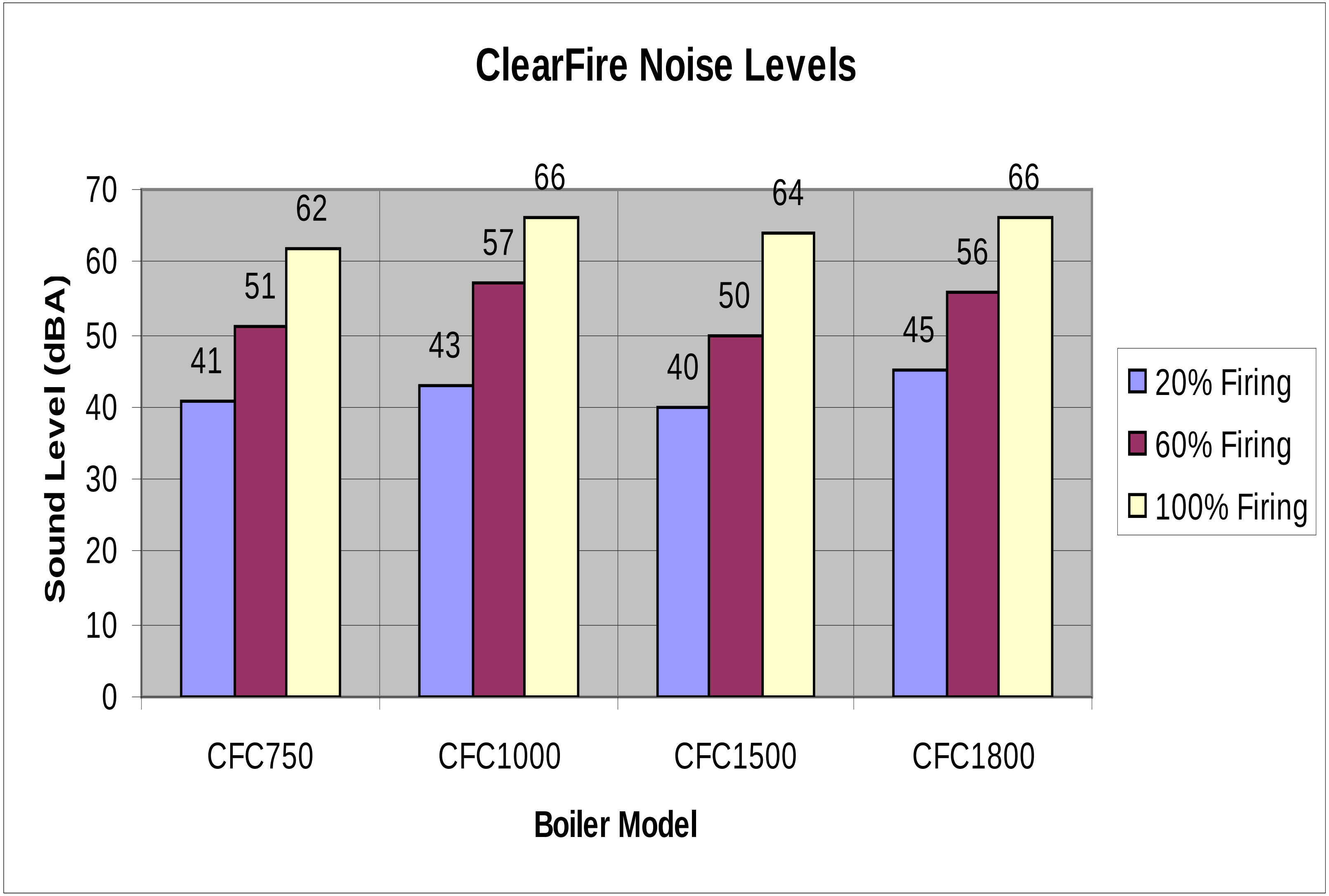
Sound Levels



Warranties

In addition to the standard warranty we provide:

- 20 years Thermal Shock Warranty
- 10 years Fireside Corrosion Warranty
- 5 years Burner Canister Warranty

Applications

LEED – Green Building Design
Heated Pavements - Snow Melting
Heat Pumps
Ventilation Coils
Low-temperature heating
Radiant floor heating
Pool-water Heating
Domestic Water Preheating
Natural Gas Heating @ Pressure Regulator Stations
Giant Aquarium heating

Model CFW

Model CFW

- Near-Condensing
  - Designed to provide a product for use in non-condensing applications
    - In place of CFC use in these applications
    - 86%
    - 4:1 to 5:1 turndown
  - Limited to 140F return water temperature

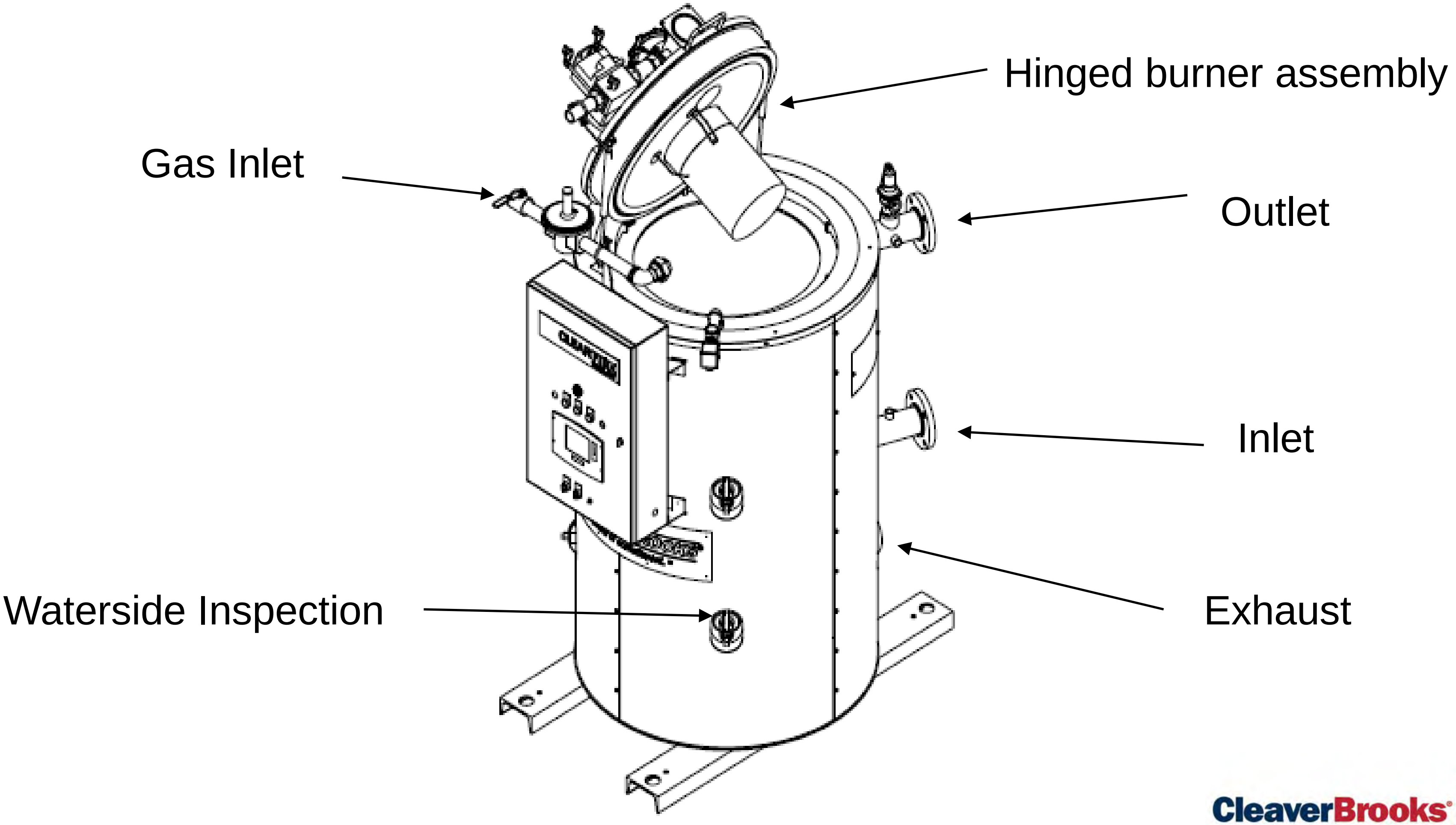
Model CFW

- Type: Vertical Alufer-tube Single Pass, Commercial Boiler.
- 7 Sizes: 400 through 2,400 MBH.
- Design: 125 PSIG.
- Fuel: Natural Gas or LPG [No oil firing].
- Codes: ASME Section IV, UL, ASME CSD-1.
- 88+% Fuel to Water

Overview


Single pass down fired heat exchanger
Low NOx fiber mesh burner
Touchscreen control with trending
ClearFire-W
Outlet
Inlet
Carbon steel tube with Alufer Insert
Water side inspection

Pressure Vessel



CFC TUBE

CFW TUBE

Model CFW

Applications:
- Schools
- Office Complex
- Healthcare Clinics
- Decentralized Plants

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CLEARFIRE
MODEL CFW
CLEAVER BROOKS
The power of commitment

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Intelligent Load Sharing

- **Control must understand what it is connected to…**
  - Number of boilers
  - Size
  - Modulating range
  - System dynamics (Flow Intelligence)
  - Selection capability for optimum efficiency

I'm Smart!

SYSTEMAX WIRING SCHEMATIC – HYBRID PRIMARY–SECONDARY HYDRONIC SYSTEM

*** SYSTEM PUMP CONTROL – ON/OFF AND/OR MODULATION

– BOILER PUMP CONTROL – ON/OFF AND/OR MODULATION

NOTES:

SYSTEM SHOWN MAY NOT REPRESENT ACTUAL INSTALLATION ARRANGEMENT.

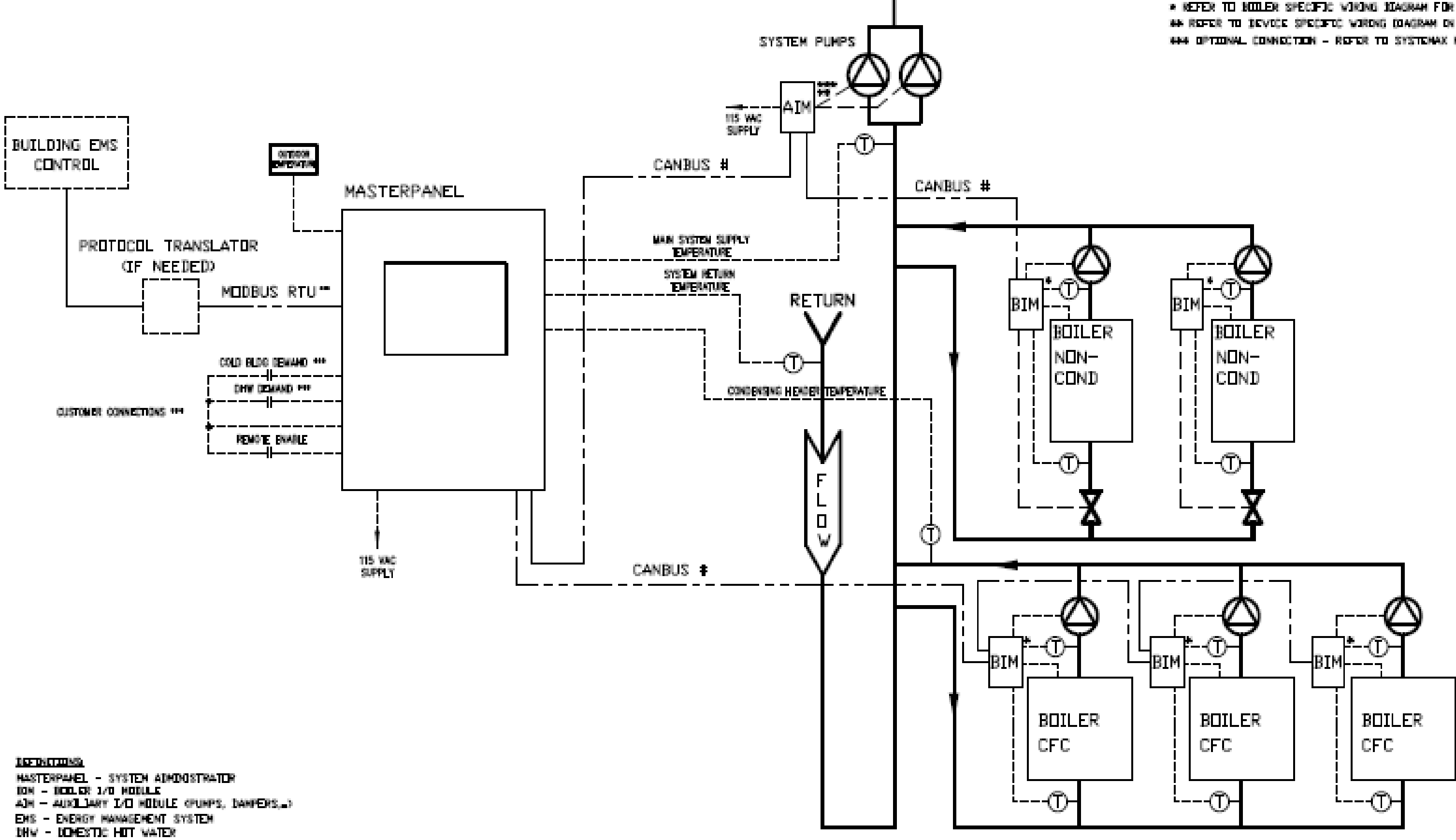
REFER TO SYSTEMAX 2.0 INSTALLATION & OPERATION FOR SYSTEM I/O WIRING CONNECTIONS TO MASTERPANEL

CANBUS NETWORK – 4C CABLE – DAISY CHAIN TOPOLOGY (REFER TO MANUAL FOR DETAILS)

* REFER TO BOILER SPECIFIC WIRING DIAGRAM FOR BOILER I/O MODULE INTERFACE CONNECTIONS

** REFER TO DEVICE SPECIFIC WIRING DIAGRAM IN MANUAL FOR AUX I/O MODULE INTERFACE CONNECTIONS

*** OPTIONAL CONNECTION – REFER TO SYSTEMAX MANUAL FOR DEVICE SPECIFIC WIRING DIAGRAM



DEFINITIONS:

MASTERPANEL – SYSTEM ADMINISTRATOR

BIM – BOILER I/O MODULE

AIM – AUXILIARY I/O MODULE (PUMPS, DAMPERS,…)

EMS – ENERGY MANAGEMENT SYSTEM

DHW – DOMESTIC HOT WATER

REVISIONS	OXXXX	SHT 01 OF 01	SCALE N.T.S. / DATE 11/15/10 / DRAWN BWH / SIZE B	CleaverBrooks® SYSTEMAX 3 HW SYSTEM CONTROL HYBRID PRIMARY–SECONDARY / DRWG. NO. 00

Hybrid System – Condensing and Non-Condensing.

Hybrid System – Condensing and Non-Condensing.

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Model CFH

CleaverBrooks

Model CFH

- Type: Horizontal Alufer-tube Single Pass, Commercial Boiler.
- 8 Sizes: 10 through 60 horsepower.
- Design: 15 PSIG Steam, 150 PSIG Steam.
- Fuel: Natural Gas or LPG [No oil firing].
- Codes: ASME Section I or IV, UL, ASME CSD-1.
- Qualifies for local utility rebates.

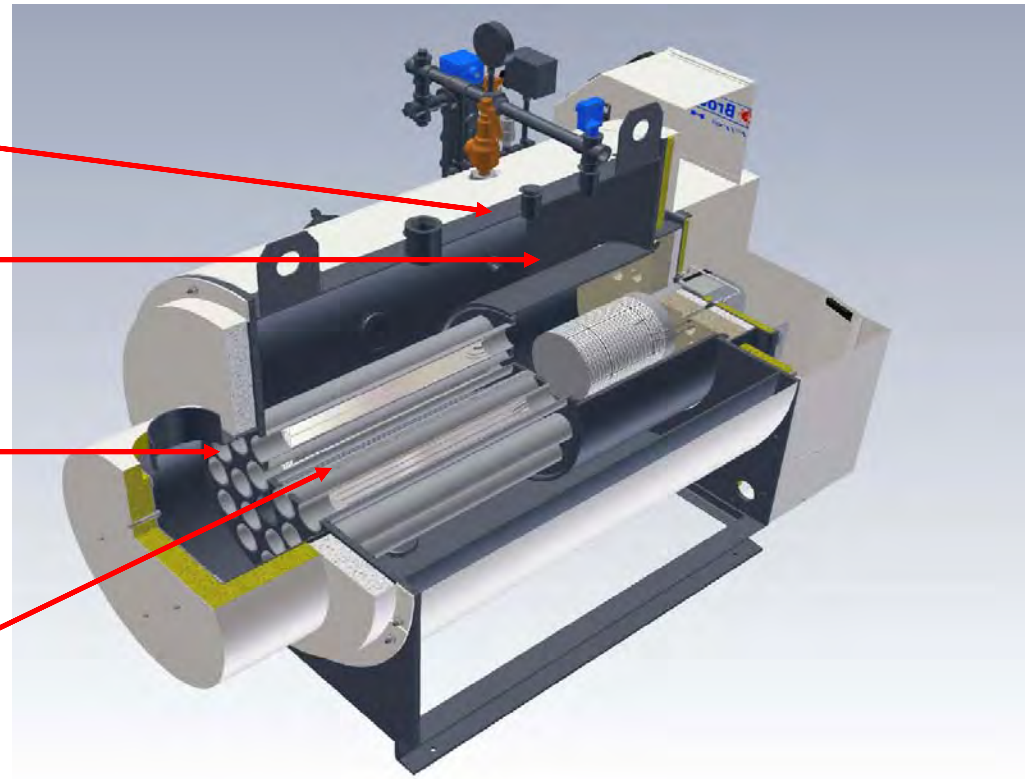
Heat Transfer non-condensing

Carbon Steel Shell

Carbon Steel Burner Housing

Carbon Steel Tubes and Tubesheets

Alufer Inserts



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CFC TUBE

CFH TUBE

Connections

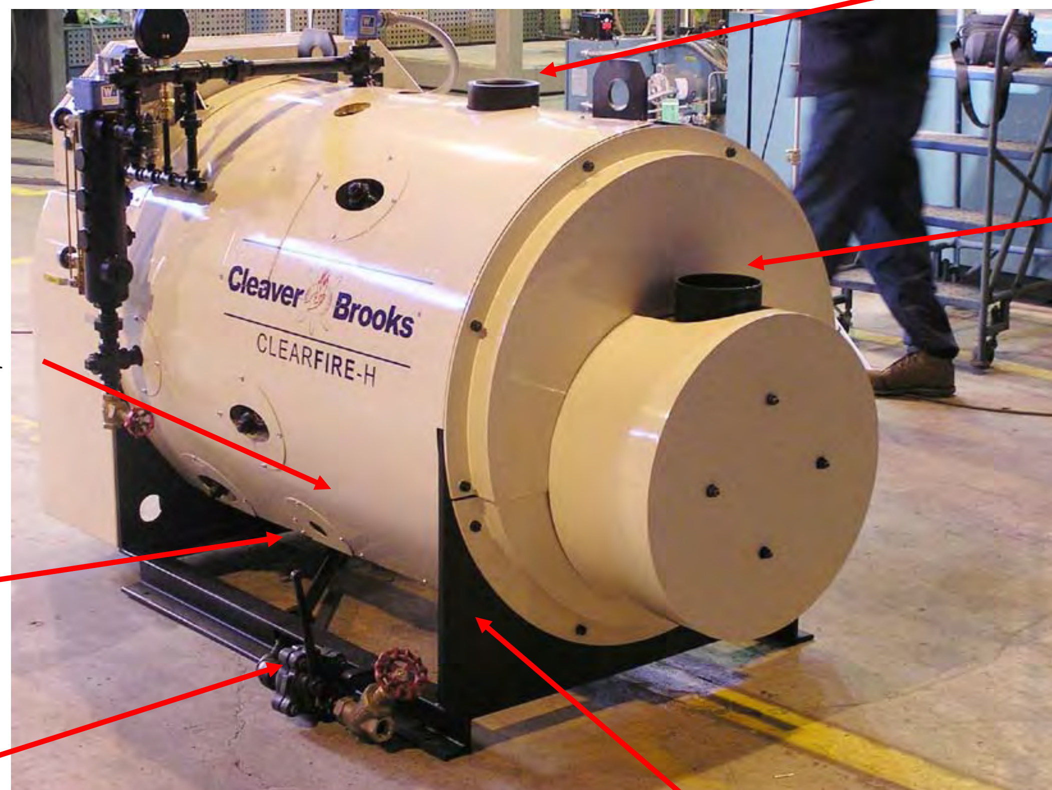
Steam

Stack

Chem Feed

Feedwater

Blowdown



Frame

Burner & gas train

Options

- Economizer [150#].
- Skid package w/feed system, Blowdown Separator, Chem Feed.
- Lead/lag Control: CB Falcon, up to 8 boilers.
- BMS Interface: CB Falcon

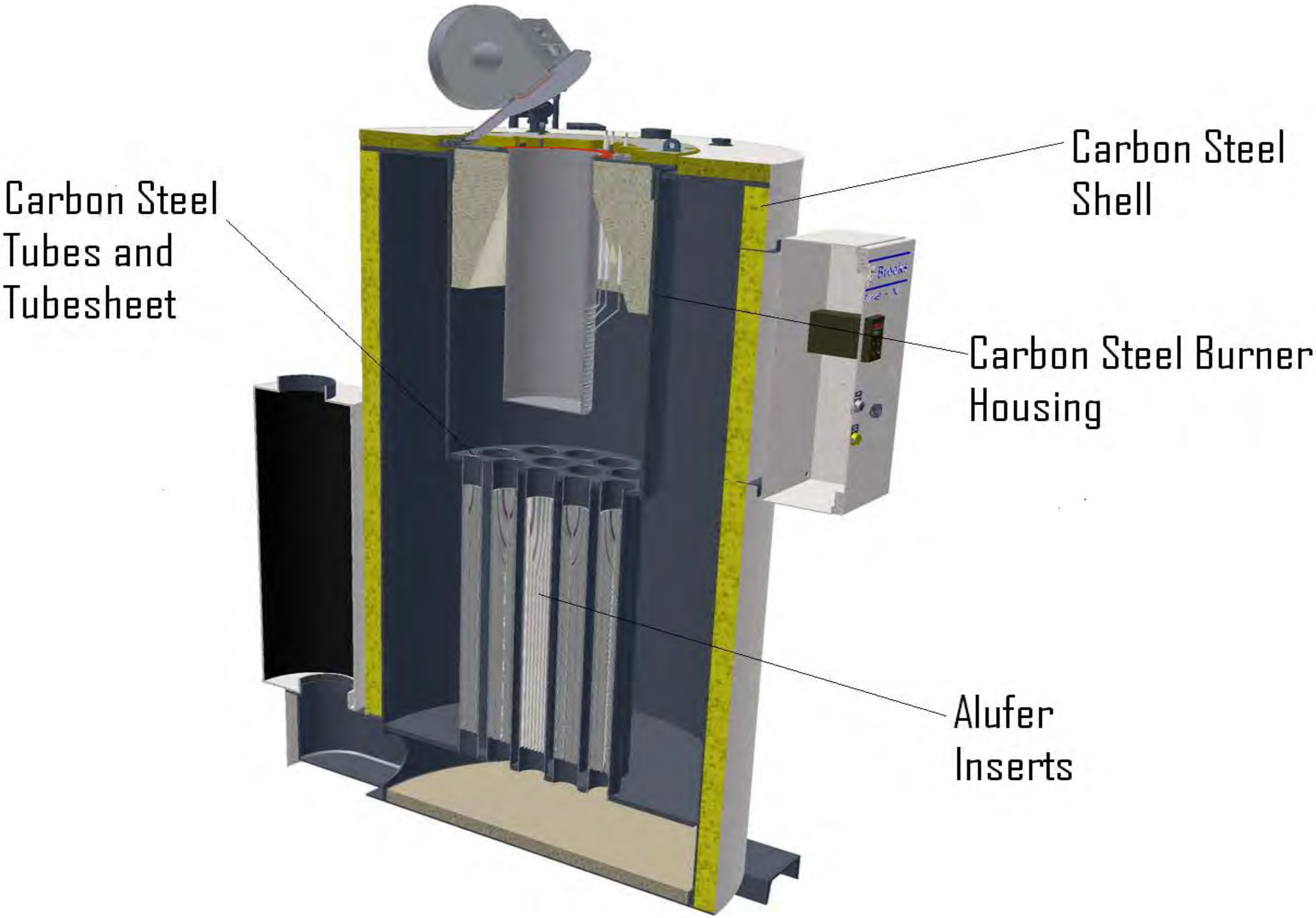
Skid Package

Model CFV

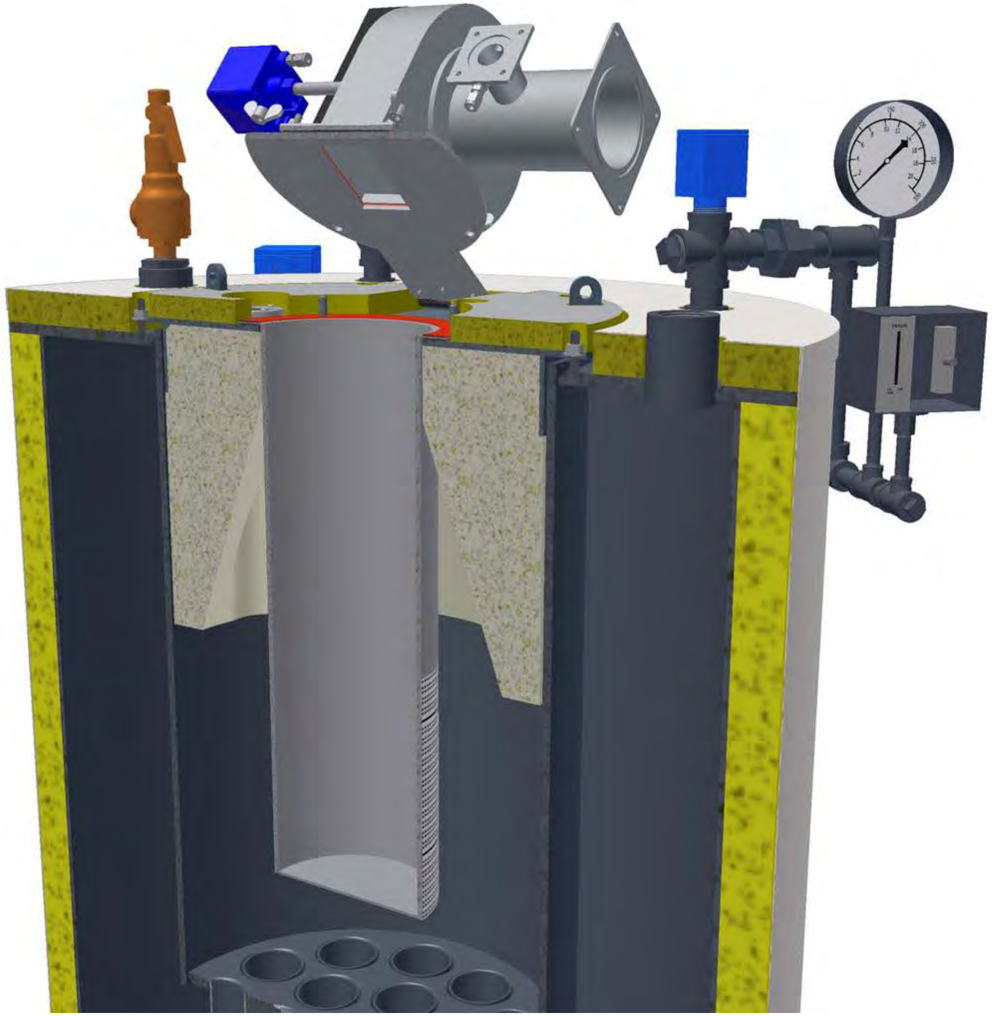
Model CFV

- Type: Vertical Alufer-tube Single Pass, Commercial Boiler.
- 8 Sizes: 10 through 60 horsepower.
- Design: 150 PSIG Steam.
- Fuel: Natural Gas or LPG [No oil firing].
- Codes: ASME Section I or IV, UL, ASME CSD-1.
- 81% Fuel to Steam

Pressure Vessel



Burner



Model CFV

Applications:
- Laundry
- Small Healthcare
- Process loads

Skid Package

CF "C"
- 500 MBH to 3,300 MBH
- Hot Water – Full Condensing

CF "V"
- 10 to 60 HP
- High Pressure Steam

CF "H"
- 10 to 60 HP
- Low Pressure Steam
- High Pressure Steam

CF "W"
- 400 MBH to 2,400 MBH
- Hot Water – Near Condensing

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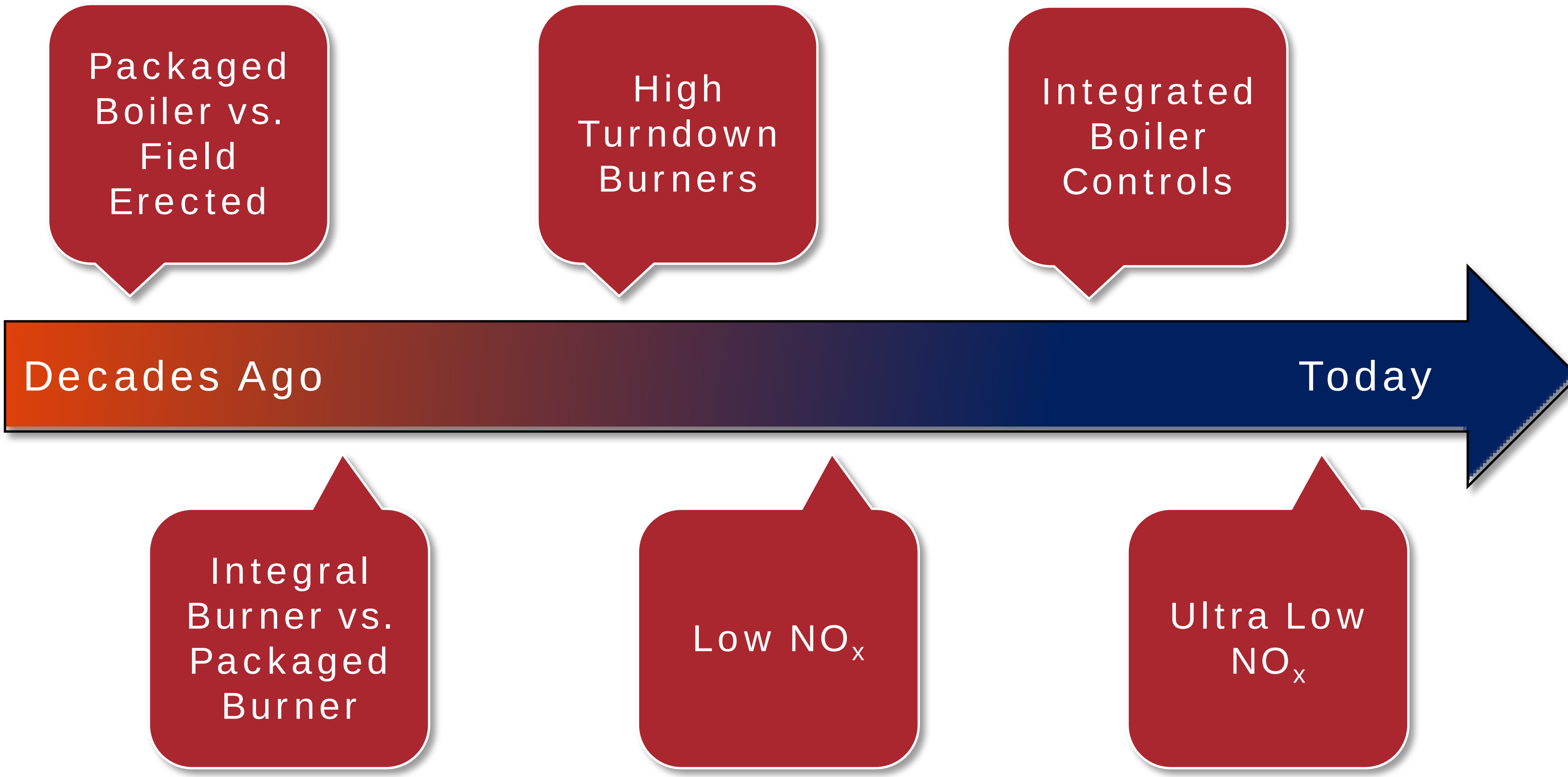
Advanced Firetube Design Breakthroughs

Cleaver-Brooks CBEX Firetube Boilers

Slow Development In Firetube Technology Breakthroughs



- "Rules Of Thumb" Philosophy
  - Five Square Foot Rule Of Heating Surface
  - Four- vs. Three- vs. Two-Pass
  - Dryback vs. Wetback
- Unavailable Sophisticated Modeling
  - Sophisticated modeling did not exist or was not financially feasible
  - Relied on trial and error from the field or R&D lab

Boilers

CleaverBrooks®

New Sophisticated Design Techniques

Computational Fluid Dynamic Modeling

- Computer software solves conservation equations
- Visualizations created showing distribution of key parameters
- Changes made to model, testing improvements
- Provides for design optimization

Finite Element Analysis

- Breakdown of complex engineering problems into finite elements
- Finite elements broken down to sets of linear equations
- Equations solved using matrix algebra
- Used for predictive performance and evaluating new concepts

Boilers

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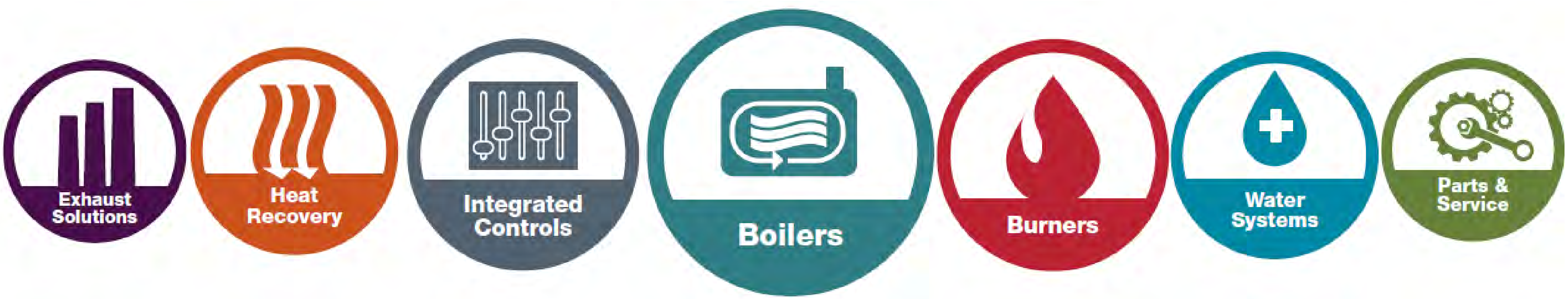
The Benefit Of Modeling Integrated Components

- By modeling the boiler, burner, heat recovery, and other components together, more accurate calculations for the values of velocity, temperature, chemical species, and other properties are determined from the boundary conditions



CBEX – The Most Advanced Firetube Ever Built

Primary

- Higher Efficiency
- Lowest Possible Emissions

Secondary

- Smaller Footprint / Less Weight
- Quicker Steam-Up
- Extended Pressure Vessel Life

Boilers

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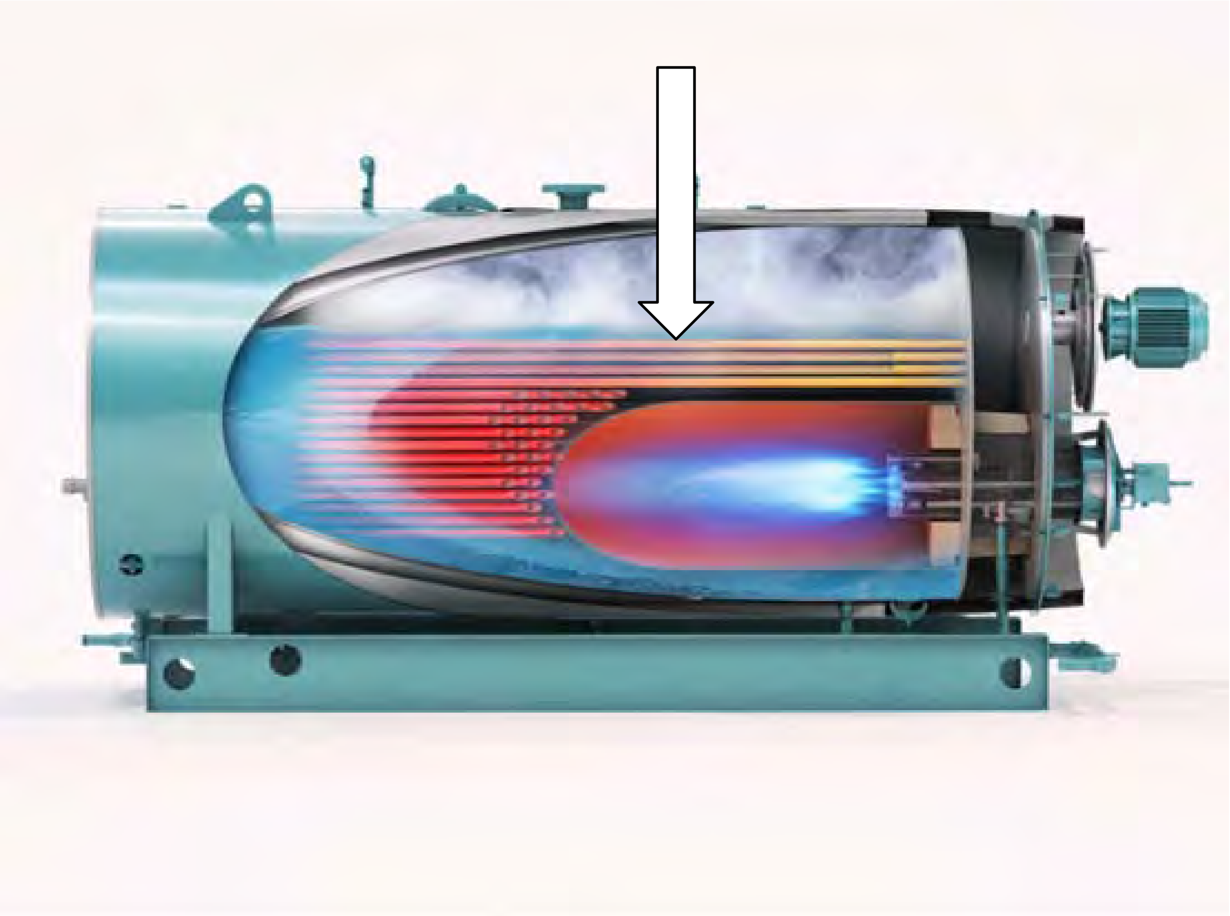
Cleaver-Brooks Uses New Technology To Advance Firetube Design

- Key elements of advancement to create the CBEX – the most advanced firetube design

Combustion Performance → Furnace Geometry → Heat Transfer Of The Tubes

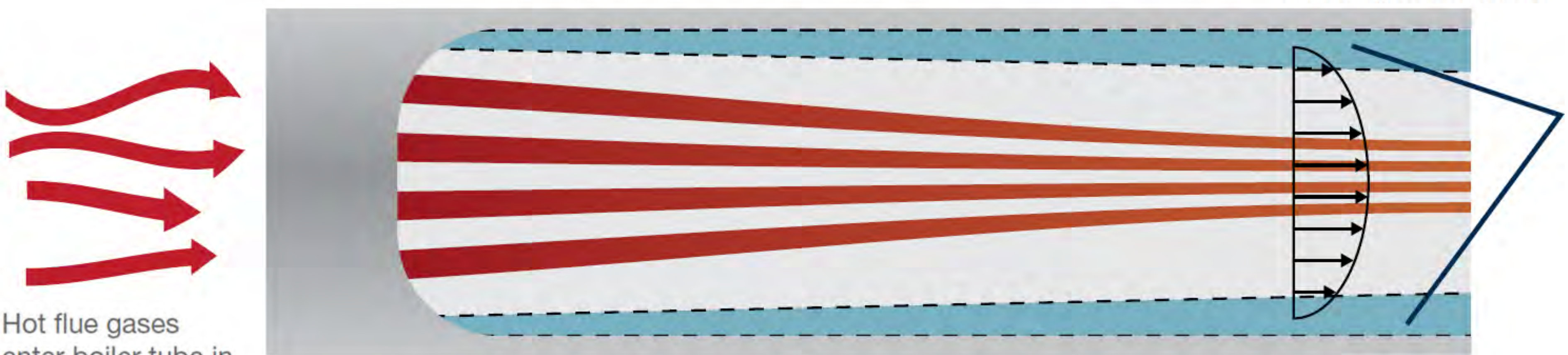
1. Heat Transfer Of The Tubes



1. Heat Transfer Of The Tubes
The Fundamentals

Typical Boiler Tube

Boundary layer forms along tube walls, retarding heat transfer



Hot flue gases enter boiler tube in turbulent pattern but quickly change to a laminar, or straight, flow

Boilers

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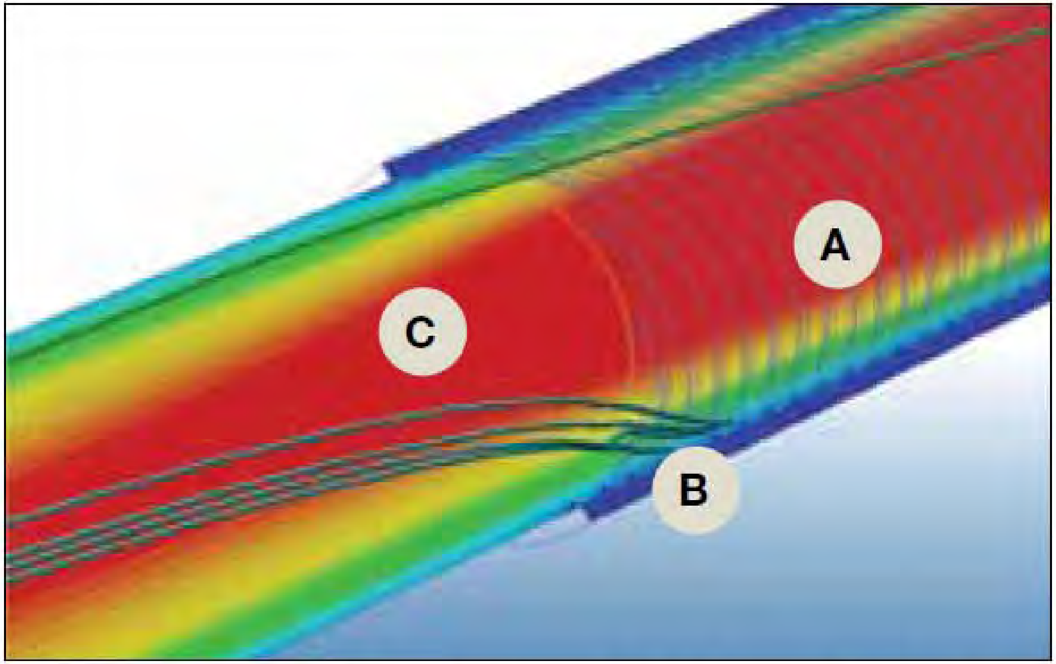
1. Heat Transfer Of The Tubes
Cleaver-Brooks Advanced Heat Transfer Tubes



CFD model of an advanced heat transfer tube.

A. The number of ribs, angle of the ribs, and height and width of the ribs have been optimized for peak tube performance.

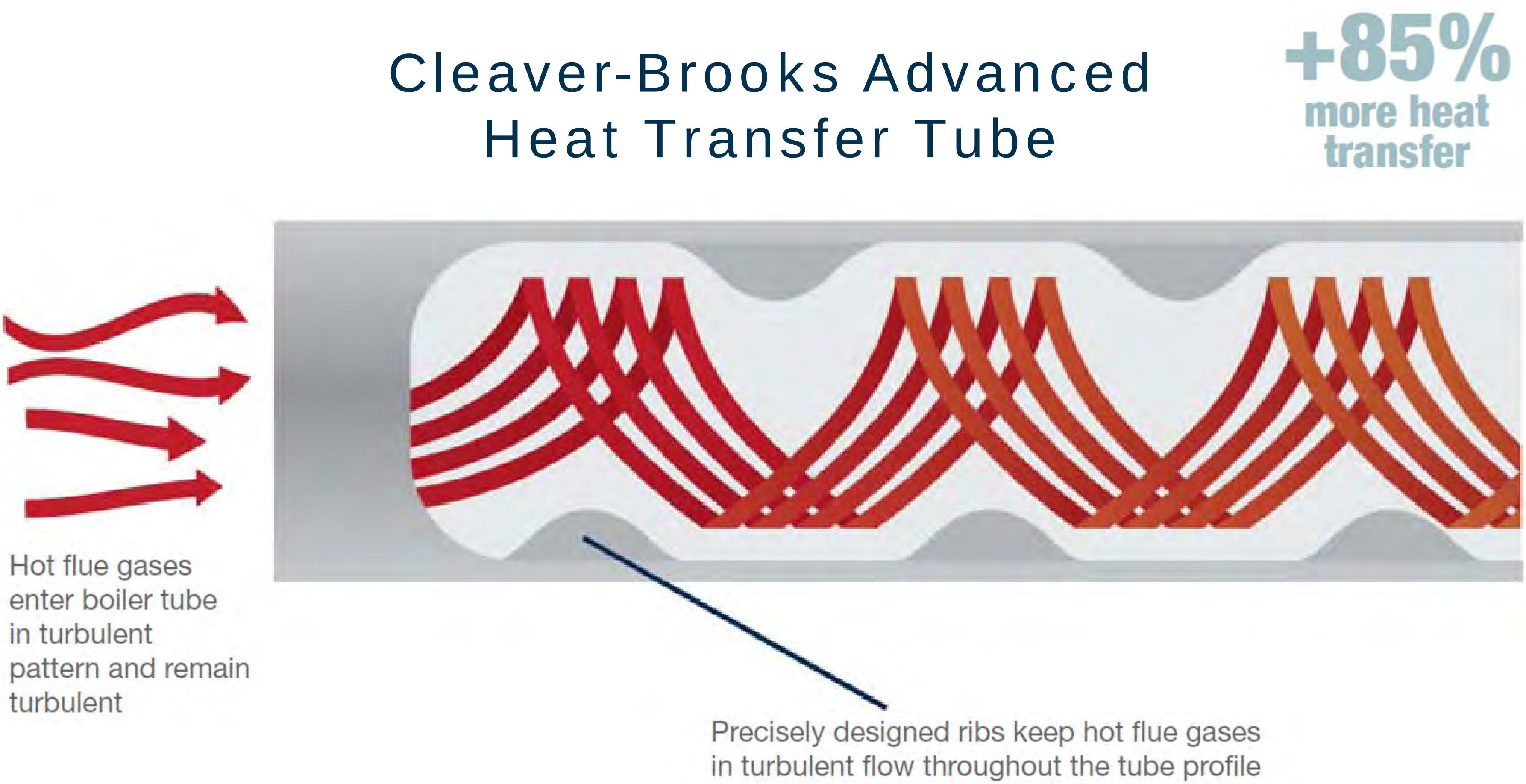
B. Improved tube profile utilizes 100% of the tube diameter for heat transfer.

C. Increased surface area and a complex boundary layer separation reattachment phenomenon result in better heat transfer.

1. Heat Transfer Of The Tubes

An Optimized Heat Transfer Tube

Cleaver-Brooks Advanced Heat Transfer Tube



Boilers

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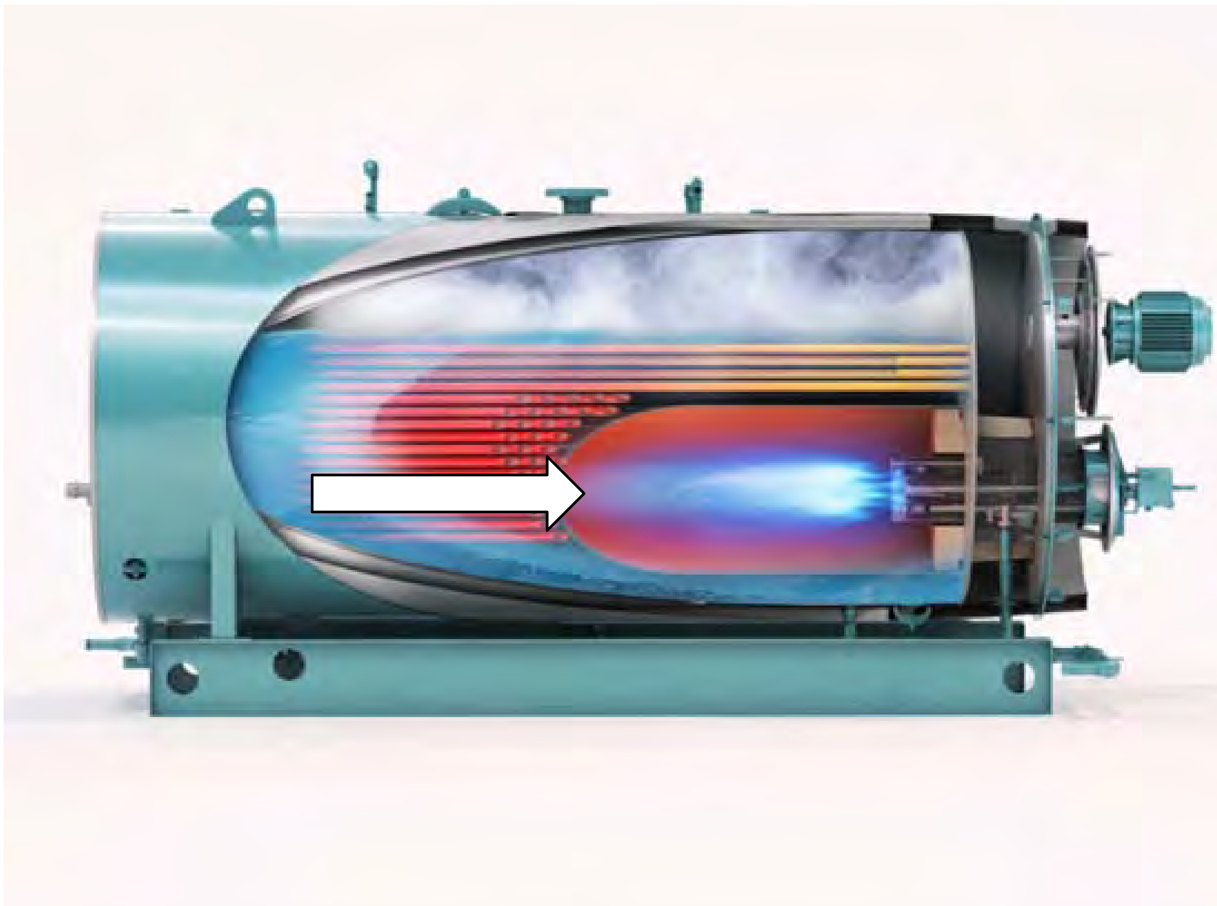
2. Furnace Geometry



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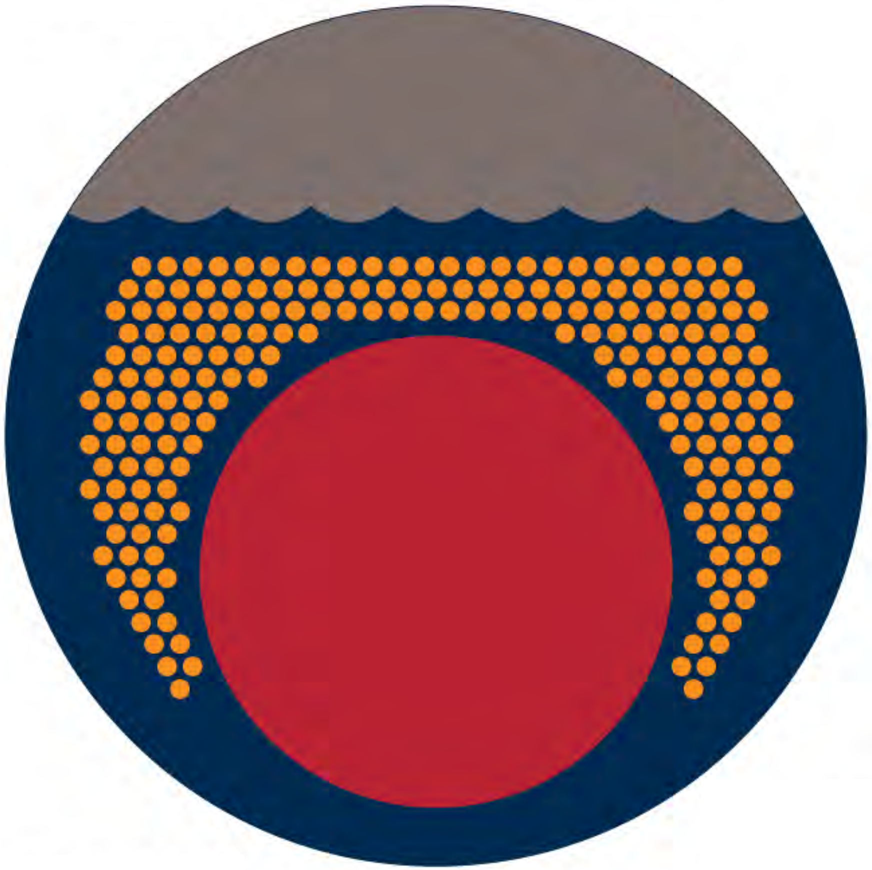
Important Considerations

- Optimized high heat transfer of the radiant zone
- Lower and more uniform flame temperature and flame stability in the furnace
- Reduce heat release rates of the furnace
    - Current firetube average is 150,000 BTU/hr/cubic feet

2. Furnace Geometry

Cleaver-Brooks Answer To Furnace Optimization



- Maximized the heat transfer with the lowest possible pressure drop
- Lower heat release rate enables a more uniform flame temperature
- Reduced furnace heat release rates to 125,000 BTU/hr/cubic feet

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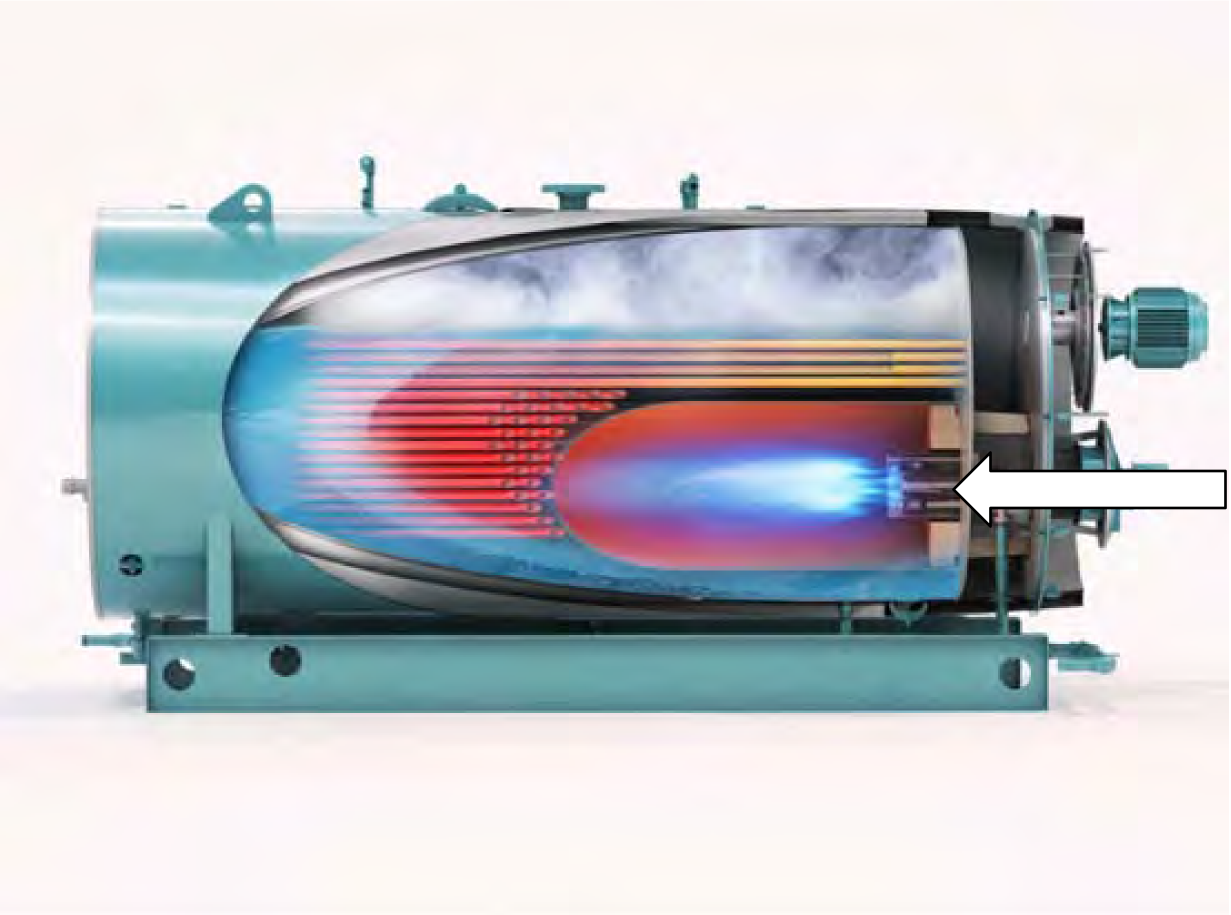
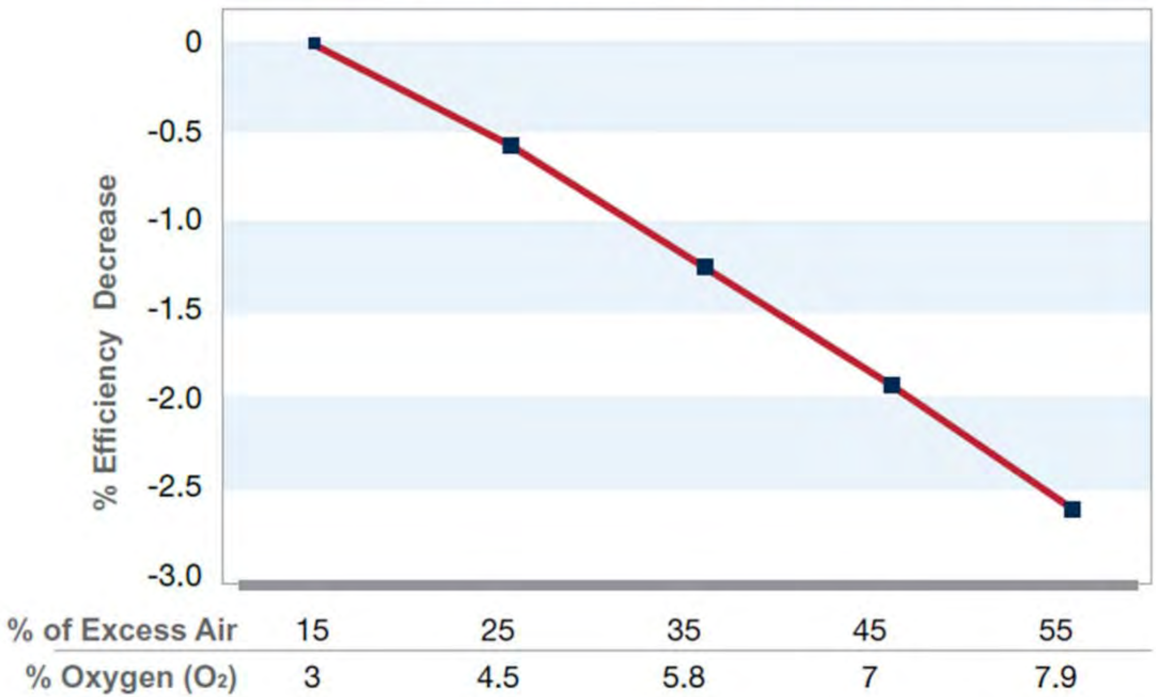


Excess Air Is An Important Factor

- Some excess air needed to reduce unwanted emissions and surface fouling
- Controlling excess air reduces flame instability
- Too much excess air causes a decrease in efficiency
- An ideal balance calls for a 15% excess air level

As Excess Air Increases, Efficiency Decreases

EXCESS AIR EFFECTS ON EFFICIENCY FOR NATURAL GAS



EXCESS AIR VS EXCESS OXYGEN (O_2)

The terms excess air and excess oxygen are commonly used to define combustion. They can be used synonymously but have different units of measurements. The percentage of excess air is the amount of air above the stoichiometric requirement for complete combustion. The excess oxygen is the amount of oxygen in the incoming air not used during combustion and is related to percentage excess air. For example, 15% excess air equals 3% oxygen while firing natural gas.

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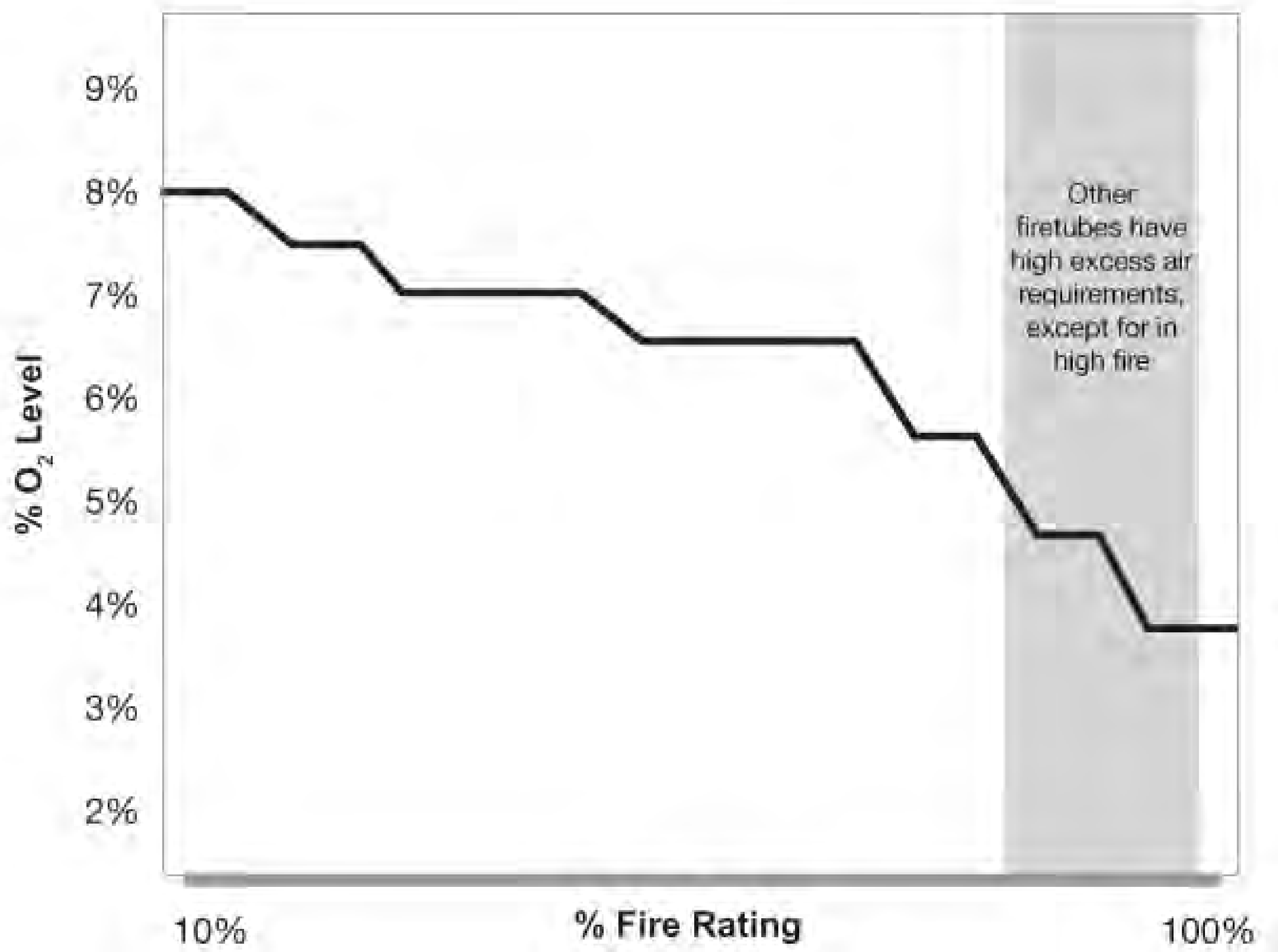
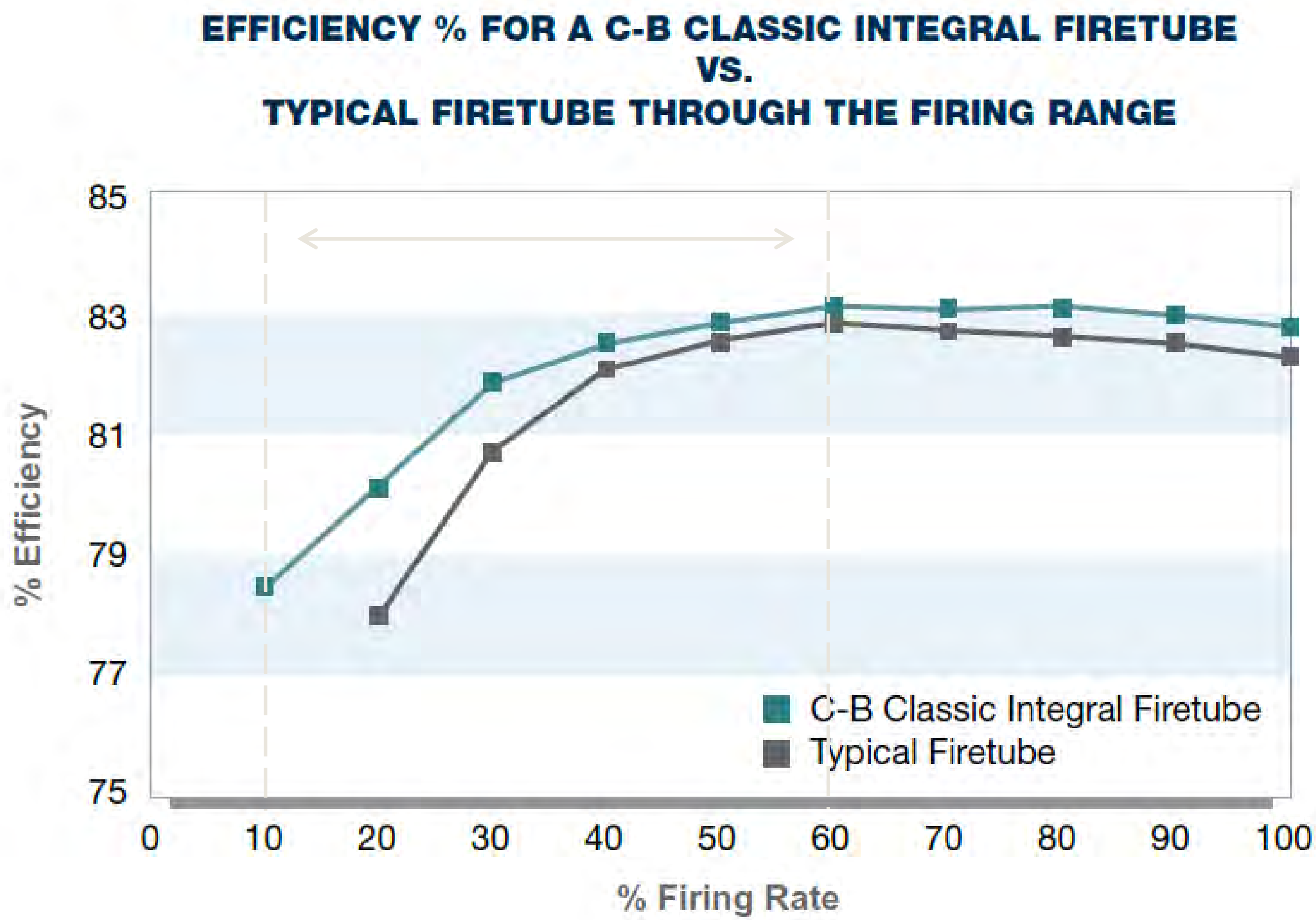
Excess Air Increases As The Firing Rate Decreases



3. Combustion Performance

Efficiency Drops Dramatically At Lower Firing Rates



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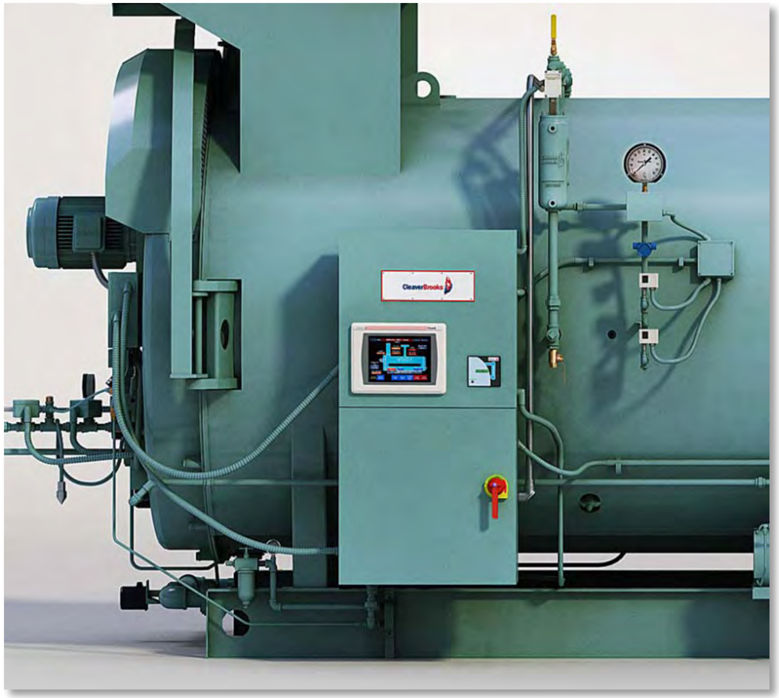
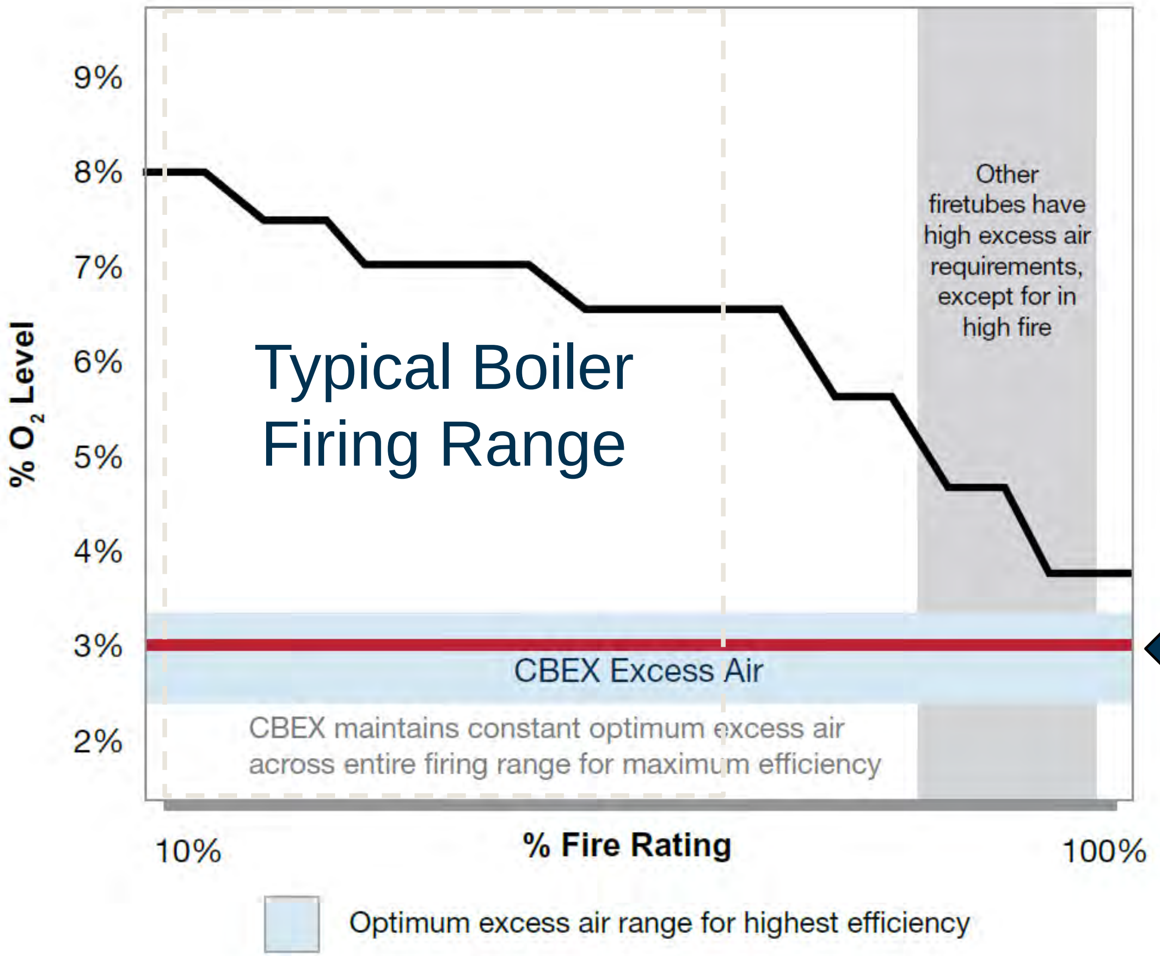
By integrating the burner and controls, combined with the optimization of the furnace, superior combustion can be achieved



The Highest Operating Efficiency Of Any Firetube



10:1 turndown while maintaining 3% O_2 across the firing range*

* CBEX Elite Boilers 250-800 HP

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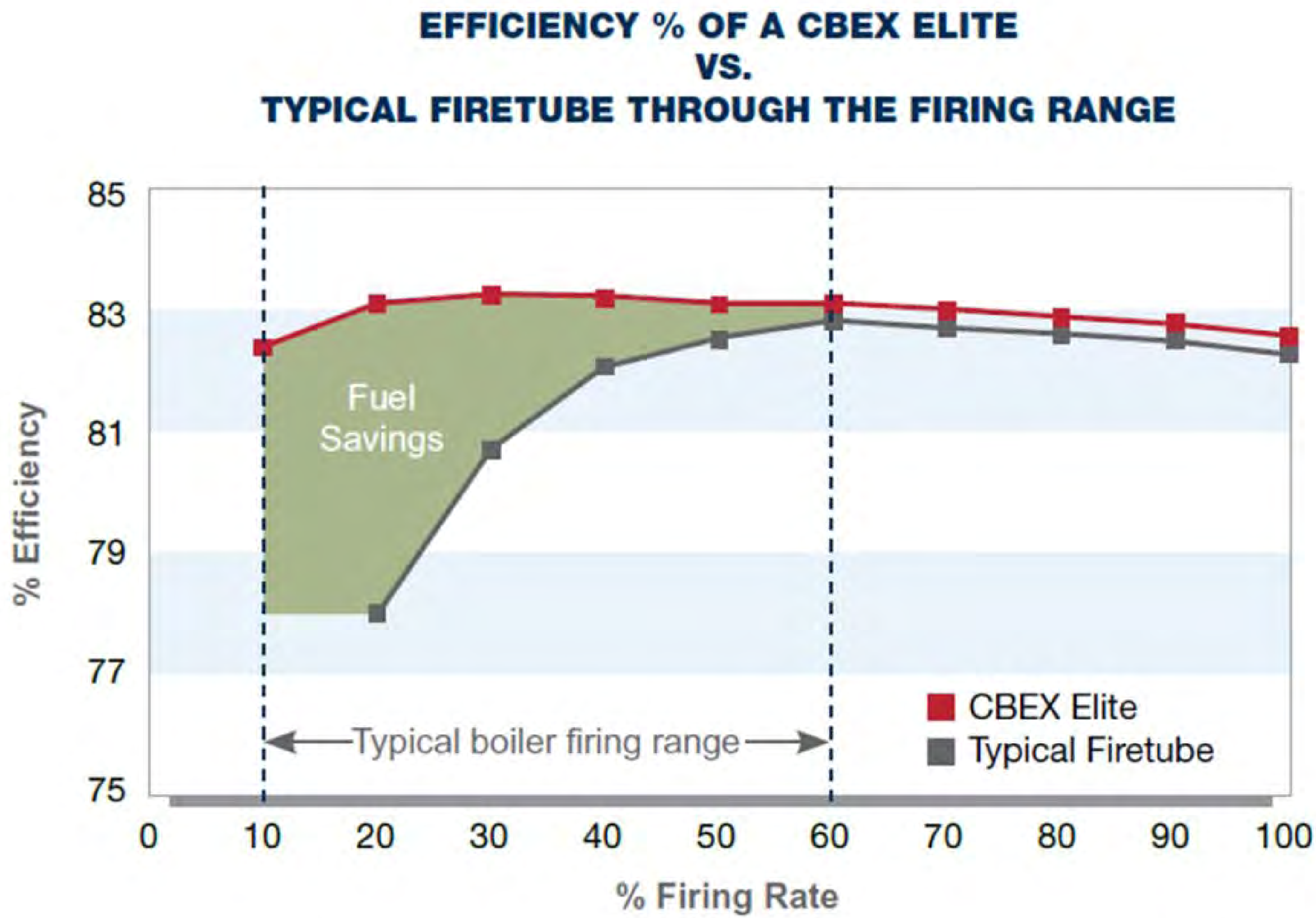
Higher Efficiency Over The Entire Firing Range



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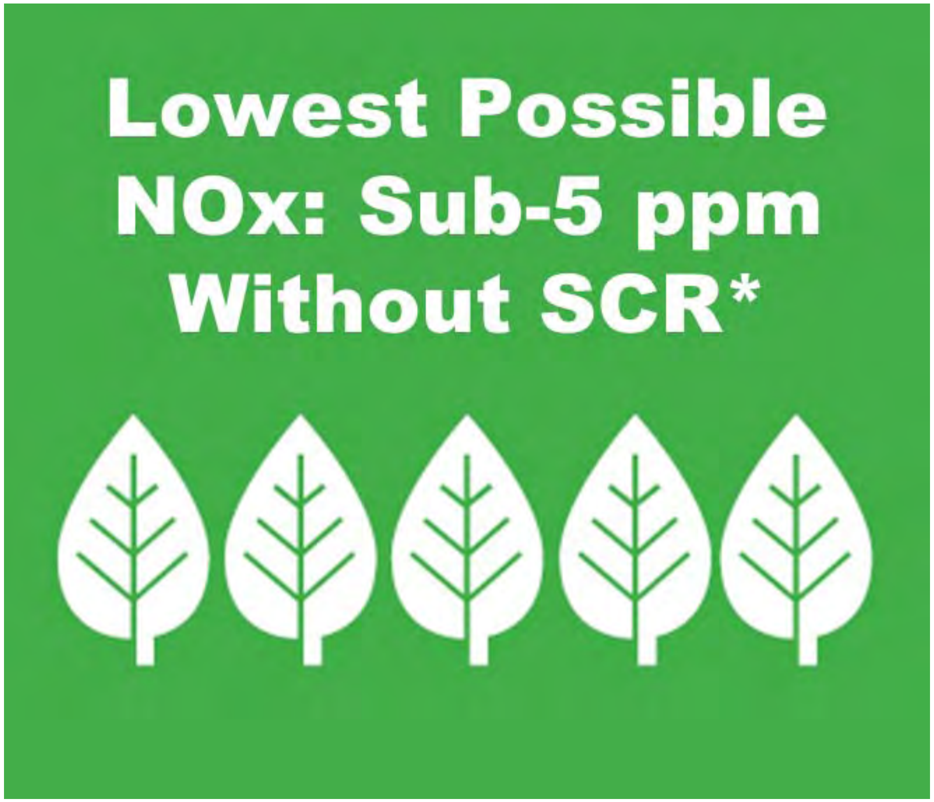
Optimized Combustion Results In Lower NOx



- Optimized furnace provides lower heat release and near-perfect combustion
- Combined with the Hawk, emissions are reduced to unprecedented levels
- Prior to the CBEX, sub-5 ppm NOx without SCR had never been achieved

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** Select models*

CleaverBrooks®

CBEX Firetube Boiler Line

Boilers

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CBEX Features

- Best operating efficiency of any firetube ever built
- Completely integrated boiler, burner, controls, and heat recovery system
- Minimum excess air across the operating range
- Ultra-low NOx emissions without SCR
- Can meet 10 ppm CO emissions requirements (at 30 ppm NOx)
- 15% reduction in footprint vs. traditional designs

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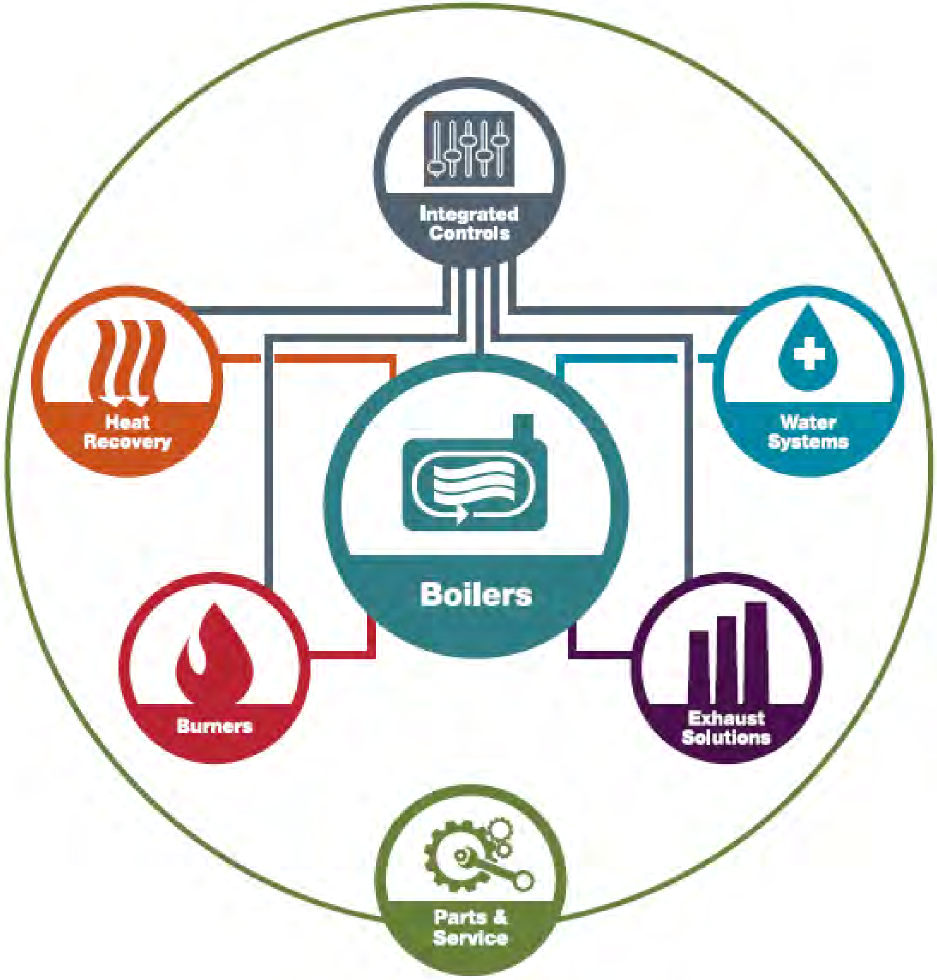
Total Integration Goes Far Beyond Boilers



For questions, please to contact:

Jeff Schoenberger, Energy Control
jschoen@econtrol.com

440-746-1205

Or
Duane Rolkosky, Cleaver-Brooks
drolkosky@cleaverbrooks.com

414-359-0600