AMERICAN SOCIETY OF GAS ENGINEERS

NATIONAL TECHNICAL CONFERENCE
JUNE 5TH, 2012

BOILER NOx EMISSIONS
POLITICS & TECHNOLOGIES

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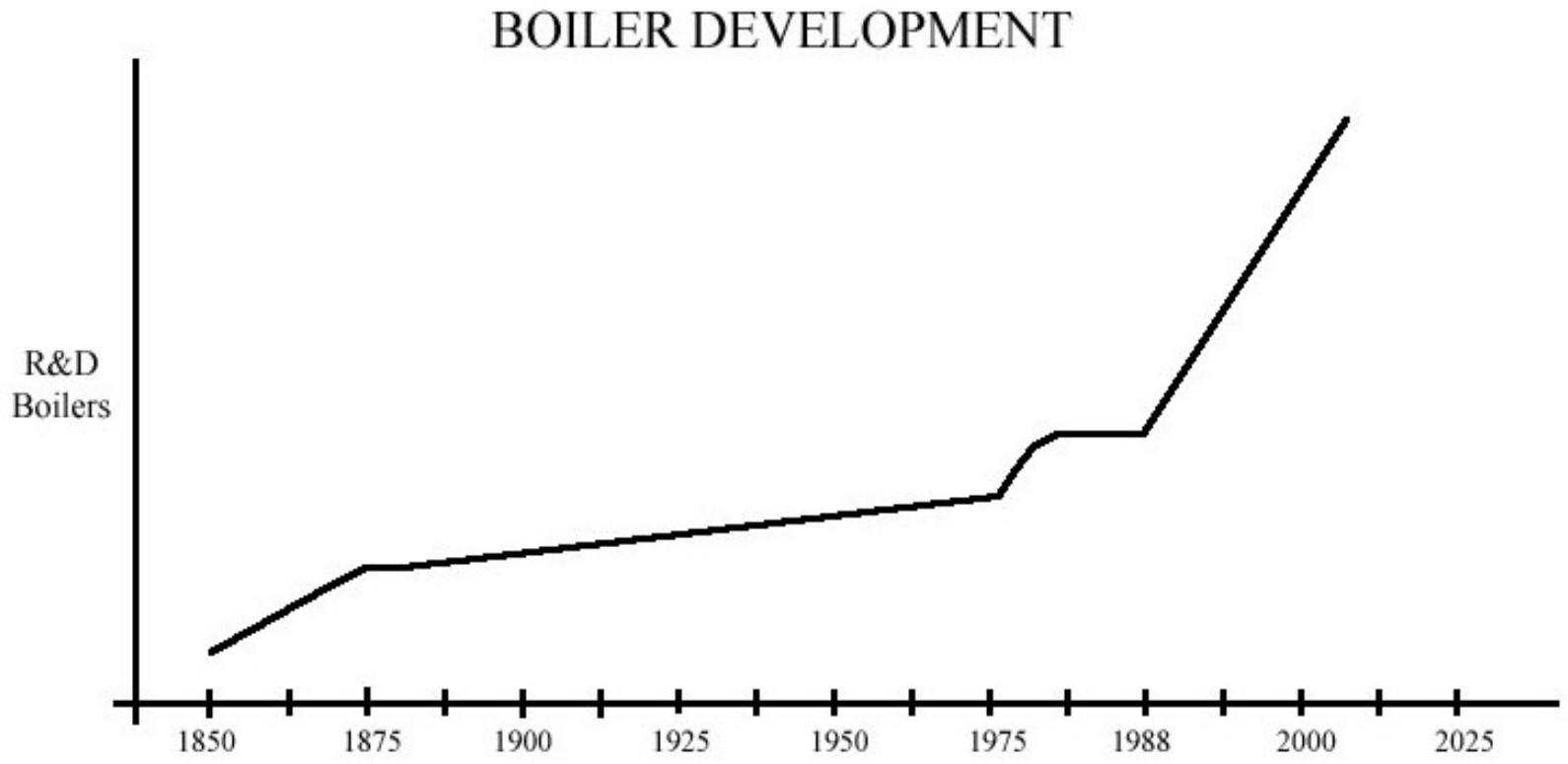
PARKER BOILER CO.

PRESENTATION ON BOILER NOx EMISSION POLITICS & TECHNOLOGIES

I. THE POLITICS OF NOx EMISSIONS
II. COMBUSTION PROCESS
III. NOx CONTROL TECHNIQUES
IV. ENERGY EFFICIENCY
V. WHAT'S NEXT



- **IN 1988, SCAQMD RULE 219 CHANGED PERMIT REQUIREMENTS FOR BOILERS**
- **PERMIT THRESHOLD WENT FROM 20MM BTUH TO 2MM BTUH**

THE KEY WORDS & RULES GOVERING BOILER DECISIONS ARE:

1. BACT (Best Available Control Technology). For AQMD
2. LAER (Lowest Achievable Emission Rate).
3. 219 (Permitting Rule, New & Existing Boilers).
4. Rule 1146 (Retrofit Rule) Boiler $\leq$ 5 Million BTUH.
5. 1146.1 (Retrofit Rules) Boilers 2 $\leq$ 5 Million BTUH.
6. 1146.2 (New & Retrofit) Boilers 75,000 - 2.0 Million BTUH.
7. Rule 1121 Water Heaters 0 - 75,000 BTUH.
8. Tune-Up
9. Source Test
10. Boiler Monitoring
11. Fees
12. Clean Fuels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Siskiyou
Modoc
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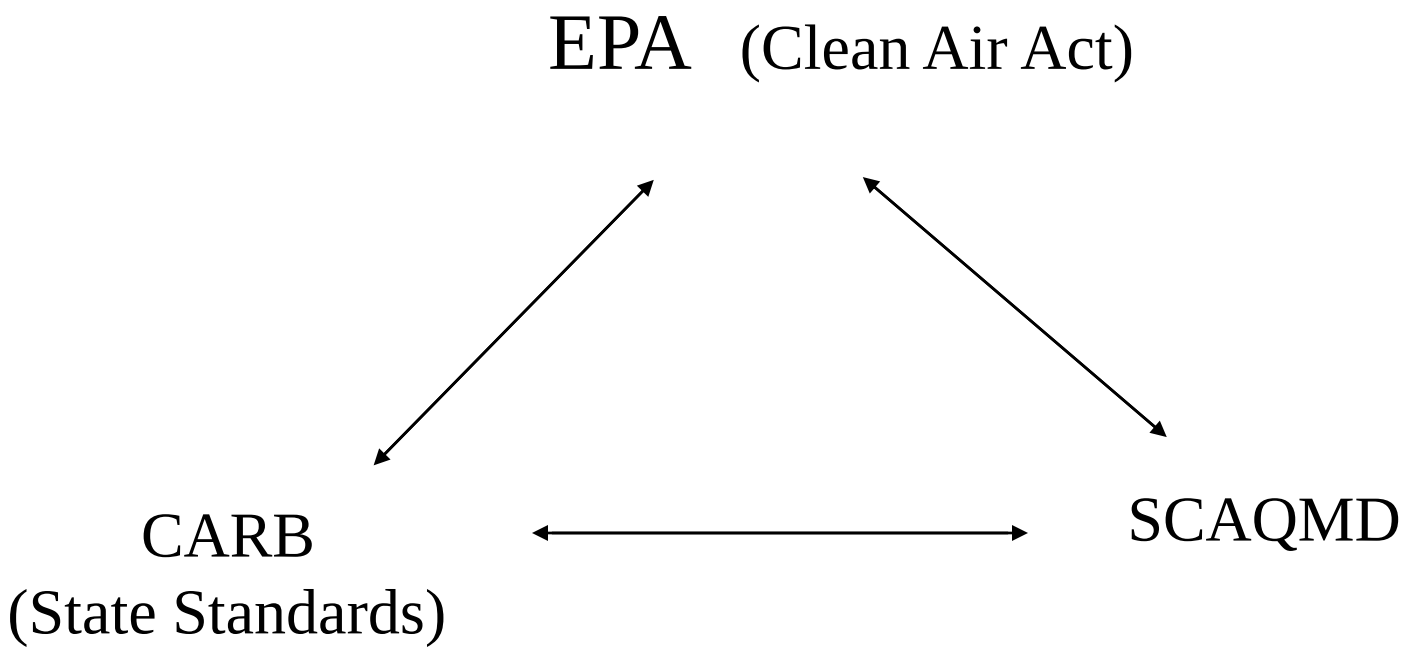
Sacramento Metro
El Dorado
Yolo Solano
Amador
Northern Sonoma
Calaveras
Tuolumne
San Francisco Bay Area
Mariposa
Great Basin Unified
San Joaquin Valley Unified
Monterey Bay Unified
San Luis Obispo
Kern
Mojave Desert
Santa Barbara
Antelope Valley
Ventura
South Coast
San Diego
Imperial
Reno
Texas
Las Vegas

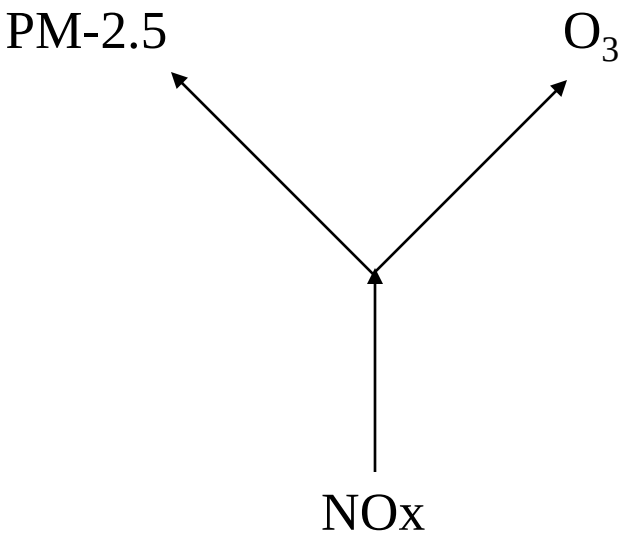
County	District /Area	Rule #	Date	New Boiler/ Retrofit Rule	Gas Permit Threshold	Oil Permit Threshold	NOx & CO - Gas @ 3% O_2	NOx & CO - Oil @ 3% O_2	Exemptions & Notes
Placer County	Placer APCD	231.5	1994	New & Retrofit	5,000,000	5,000,000	30/400	40/400	BACT required if > 10 lbs/day of NOx
Sacramento Metro	SMAQMD			New Boiler	1- 5,000,000	1,000,000	70/400	70/400	BACT required if > 10 lbs/day of NOX **NOTE:** Boilers 1-5,000,000 require evaluation
				New Boiler	5,000,000+	5,000,000	30/400	40/400	
			8/96	Retrofit	5,000,000	5,000,000	30/?	40/400	
San Diego	SDAPCD	11		New Boiler	5,000,000	1,000,000	30/400	?	
		69.2		Retrofit	5,000,000	1,000,000	30/400	30/400	Exemption - Less than 220,000 Therms use with fuel use data and tune ups.
San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare and Kern	San Joaquin APCD	4351		Retrofit	5,000,000	5,000,000	30/400	40/400	Exemption - Less than 90,000 Therms use with fuel use data and tune ups.
				New boiler	5,000,000	?	30/400	?	Exemption - Check with District
San Luis Obispo County	San Luis Obispo APCD	201	1991		2,000,000		30/400		Some Agricultural exemptions apply.
Santa Barbara	Santa Barbara APCD			New Boiler	5,000,000	All Units	30/400	30/400	
			1/21/92	Retrofit	5,000,000	5,000,000	30/400	30/400	Exemption - Less than 90,000 Therms use with fuel use data and tune ups.
Shasta County	Shasta APCD	2.1	1992	New Boiler	1,000,000	1,000,000	70/400	70/400	BACT required if > 25 lbs/day of NOx
		301	1992	Retrofit	5,000,000	5,000,000	70/400	115/400	
Siskiyou County	Siskiyou APCD								
LA, Orange, Riverside and portions of San Bernandino	SCAQMD	219	1988	New Boiler	2,000,000	All Units	(7/9) (50/100)	?	*(CO)50 PPM fire tube 100 PPM water tube
		1146	1989	Retrofit	5,000,000	5,000,000	40/400	40/400	Exemption - Less than 90,000 Therms use with fuel use data and tune ups.
		1146.1	1994	Retrofit	2- 4,999,000	2- 4,999,000	30/400	30/400	Exemption - Less than 18,000 Therms use with fuel use data and tune ups.
		1146.2	Jan. 1, 2000	New	>.4-2.0 MM/ Type 2 Unit		30/400		Manufacturers Certification required.
		1146.2	Jan. 1, 2001	New	>.075-.4 MM/ Type 1 Unit		***55/400		Manufacturers Certification Required ***55 PPM or 40 nanograms per joule NOx generation, test per Rule Test Protocol.
		1146.2	July 1, 2002	Retrofit****	>1-2.0 MM/ Type 2 Unit		30/400		Units manufactured prior to 1992. Exemption: Fuel use < 9000 Therms / year.
		1146.2	Jan. 1, 2005	Retrofit****	>1-2.0 MM/ Type 2 Unit		30/400		Units manufactured 1992 to 1999. Exemption: Fuel use < 9000 Therms / year.
		1146.2	Jan. 1, 2006	Retrofit****	>.4-1.0 MM/ Type 2 Unit		30/400		Exemption: Fuel use < 9000 Therms / year.
Tehama County	Tehama APCD								
Tuolumne County	Tuolumne APCD								

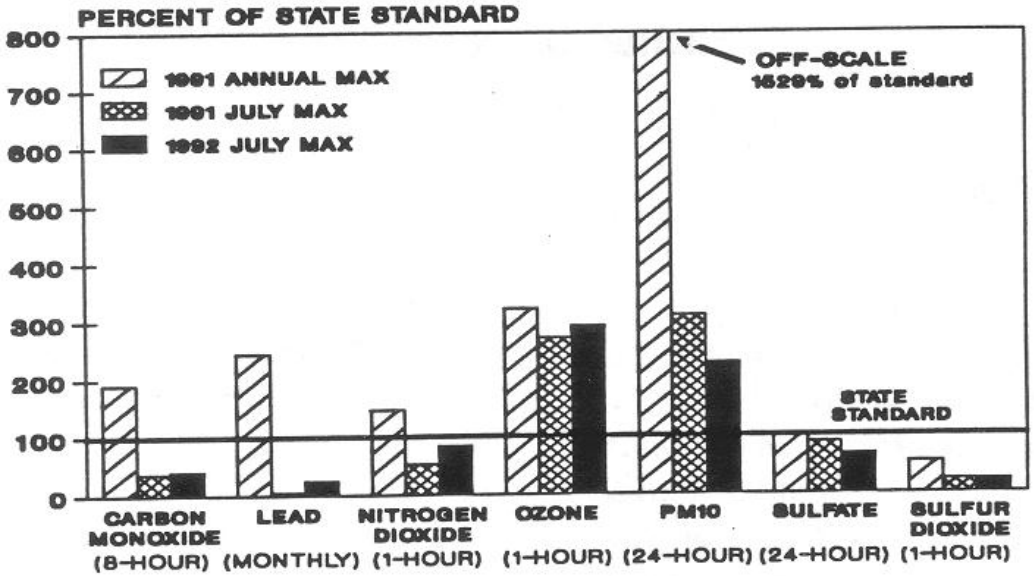

EPA (Clean Air Act)
CARB
(State Standards)
SCAQMD

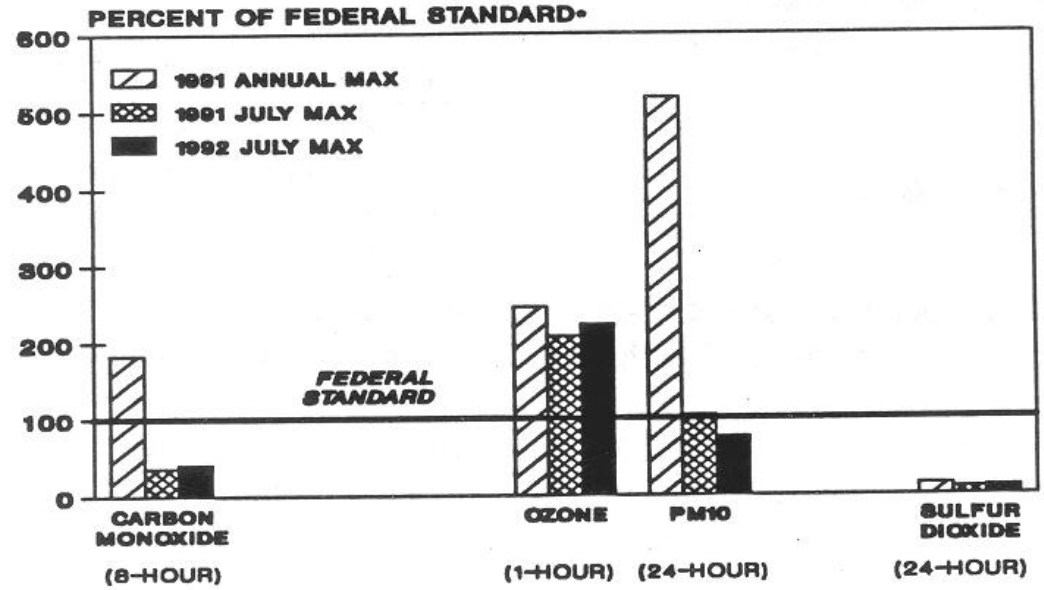
WHY NOx

1) NOx (NO & NO_2) is a precursor to Ozone (O_3)

2) NOx is a precursor to Nitrate Aerosol which is 40% of the mass of PM 2.5




PERCENT OF STATE STANDARD
800
700
600
500
400
300
200
100
0
1991 ANNUAL MAX
1991 JULY MAX
1992 JULY MAX
OFF-SCALE
1529% of standard
STATE STANDARD
CARBON MONOXIDE (8-HOUR)
LEAD (MONTHLY)
NITROGEN DIOXIDE (1-HOUR)
OZONE (1-HOUR)
PM10 (24-HOUR)
SULFATE (24-HOUR)
SULFUR DIOXIDE (1-HOUR)


PERCENT OF FEDERAL STANDARD*
600
500
400
300
200
100
0
1991 ANNUAL MAX
1991 JULY MAX
1992 JULY MAX
FEDERAL STANDARD
CARBON MONOXIDE (8-HOUR)
OZONE (1-HOUR)
PM10 (24-HOUR)
SULFUR DIOXIDE (24-HOUR)

SCAQMD NOx EMISSION SUMMARY
AQMP

NOx

Total NOx emitted per day = 1,194 tons

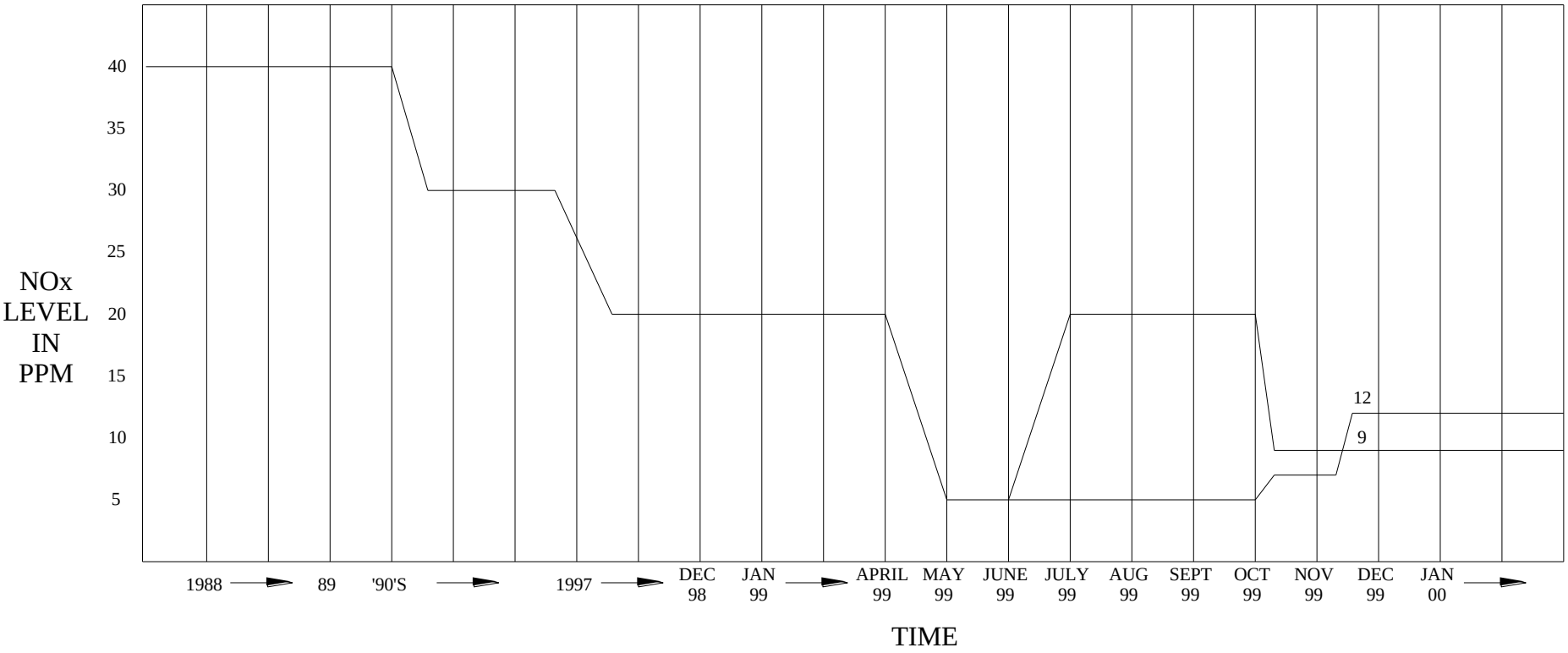
Total from Mobile Sources = 1,040 tons

Total from Stationary Sources = 154 tons

Estimated Emissions from Boiler
less than 2,000,000 BTU = 14.9 tons (1.2%)

Estimated Emissions from Boilers
greater that 2,000,000 BTU = 50-75 tons (6.2%)

ALLOWABLE NOx LEVEL IN BOILERS
PER SCAQMD 1999 (BACT)
For Boilers over 2,000,000 BTU



AQMD

South Coast Air Quality Management District

Rule 1110.2 Portable Analyzer Operator Training

1146 Unit Monitoring New Requirement

- As of July 1, 2009
- Monitor at least monthly or 750 hours whichever occurs later
- If passes 3 times then quarterly or 2,000 hours whichever occurs later
- 3 years source test
- No tuning prior to test or during
- Monitor must be certified

Requirements Both Rules

- Monitor must be certified by AQMD on Rule and Procedures
- Monitor test is 15 minutes run time plus response time
- Data log at 15 seconds intervals
- Certified Analyzer
- Pre-Calibration (within 10 days)
- Post-Calibration (must be within spec)
- Record a failed test
- Cannot derate below 2.0MM BTU

The Case of Shasta County

II. THE COMBUSTION PROCESS

A. Combustion
B. Factors & Key Words
C. Formation of NOx
D. Atmospheric combustion
E. Power Burners
F. NOx corrected to 3% O_2
G. Typical report (Flue Gas Analysis)

COMBUSTION

$C + O_2 = CO_2 + HEAT$

$2H_2 + O_2 = 2H_2O + HEAT$

AIR = 20.9% OXYGEN + 79.1% NITROGEN

$CH_4 + 2O_2 + 8N_2 = CO_2 + 2H_2O + 8N_2 + HEAT$

PERFECT COMBUSTION= 10 CU. FT. AIR/ 1 CU. FT. GAS

FLUE GAS

DRAFT

COMBUSTION

CARBON DIOXIDE

EFFECTS OF EXCESS AIR

CARBON MONOXIDE (CO)
(LESS THAN 400 PPM @ 3% O_2

EFFECTS OF CO

CAUSES OF CO

NOx EMISSIONS

1. NOx is formed in all combustion processes known as “Thermal NOx” and/or “ Fuel NOx”.

2. Fuel NOx is associated with fuels containing bound Nitrogen (Fuel, Oils, Coal).

3. NOx consists of 80 to 95% NO the remainder in NO_2.

4. Formed more with increased exposure at high temperatures.

SMOG

1. NOx reacts with sunlight to produce Ozone & Photochemical smog.

ATMOSPHERIC BOILER DRAFT HOOD

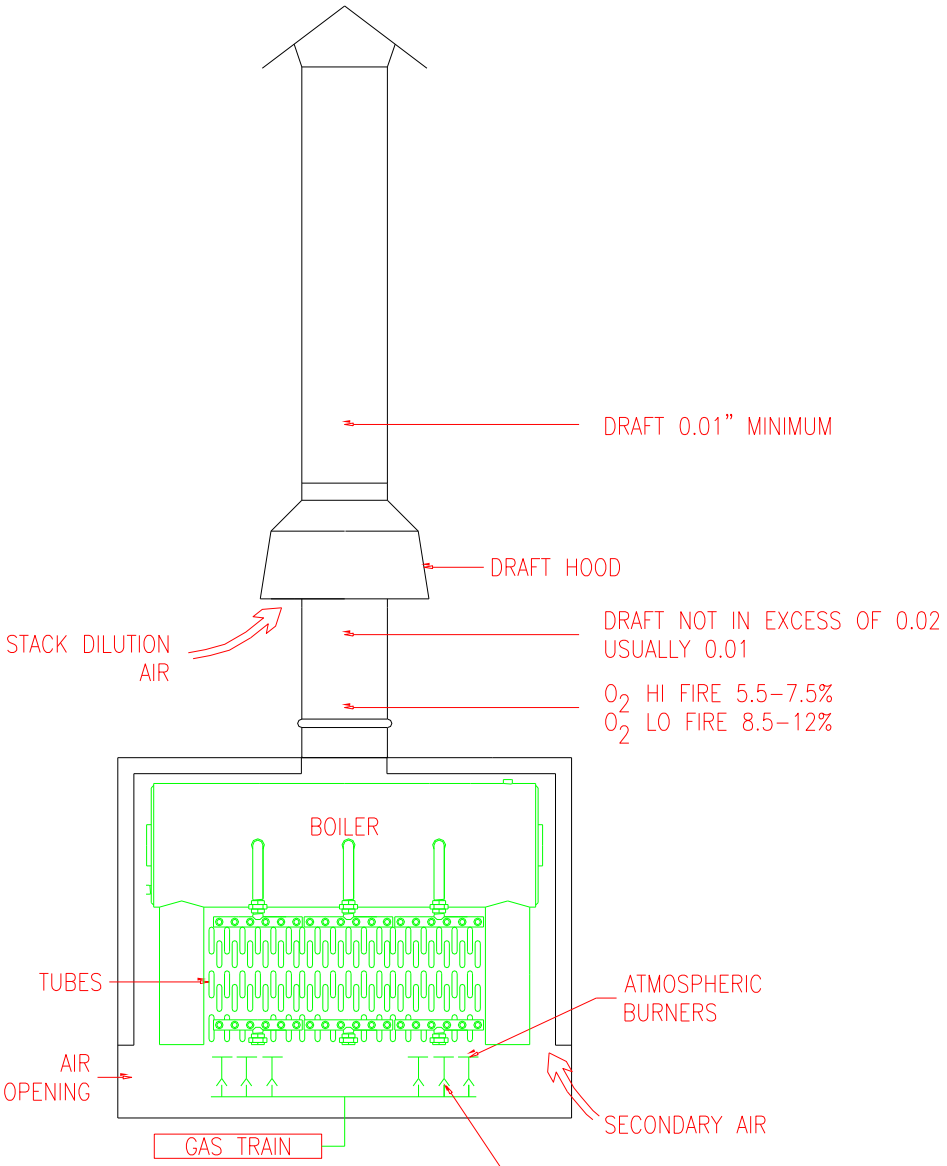
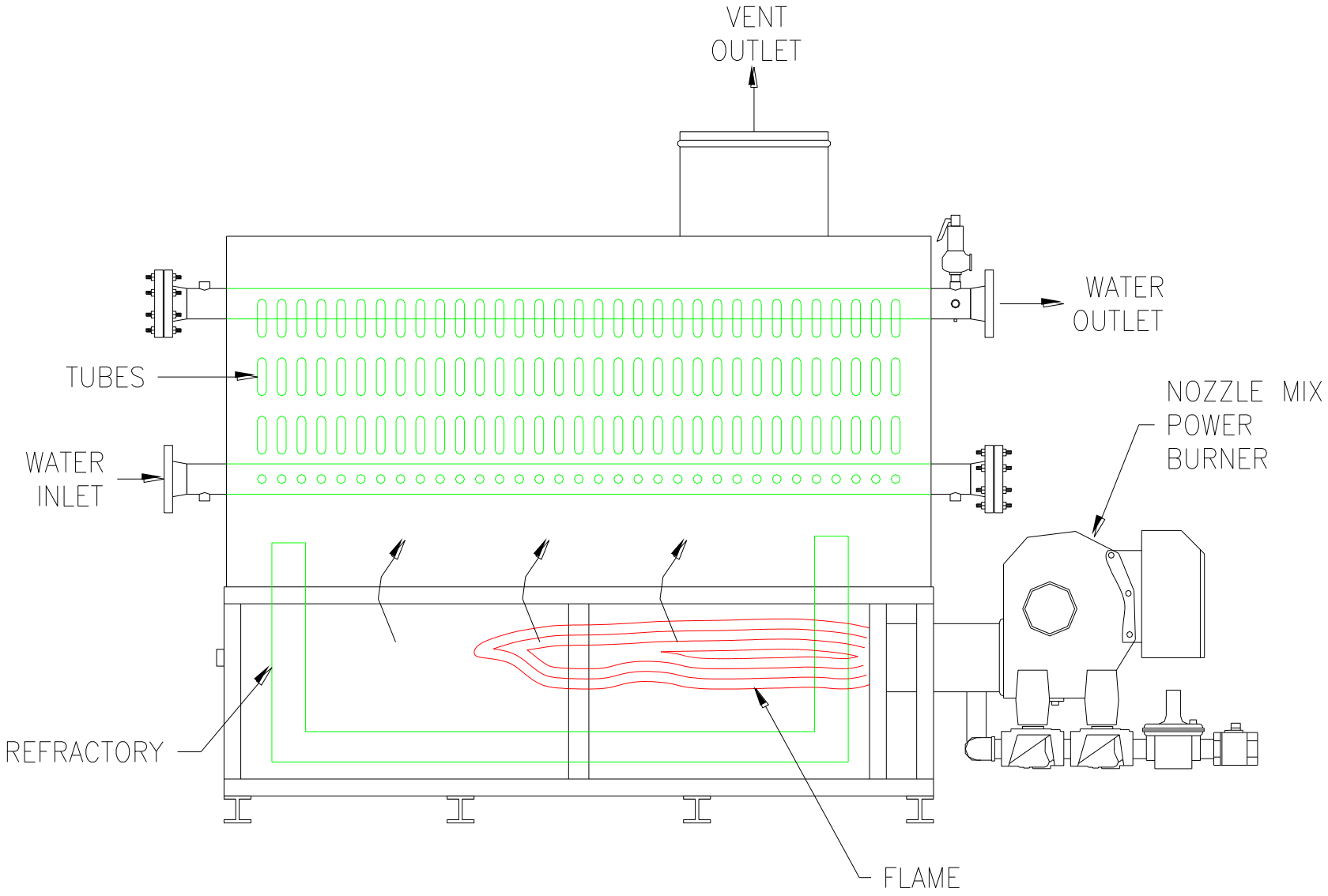


DIAGRAM 1

atm boiler draft hood.dwg



POWER BURNER

NOx CORRECTED TO 3%

O_2 = Oxygen Value in Stack

$\frac{(20.9)-3}{20.9 - O_2}$ = CF (Correction Factor)

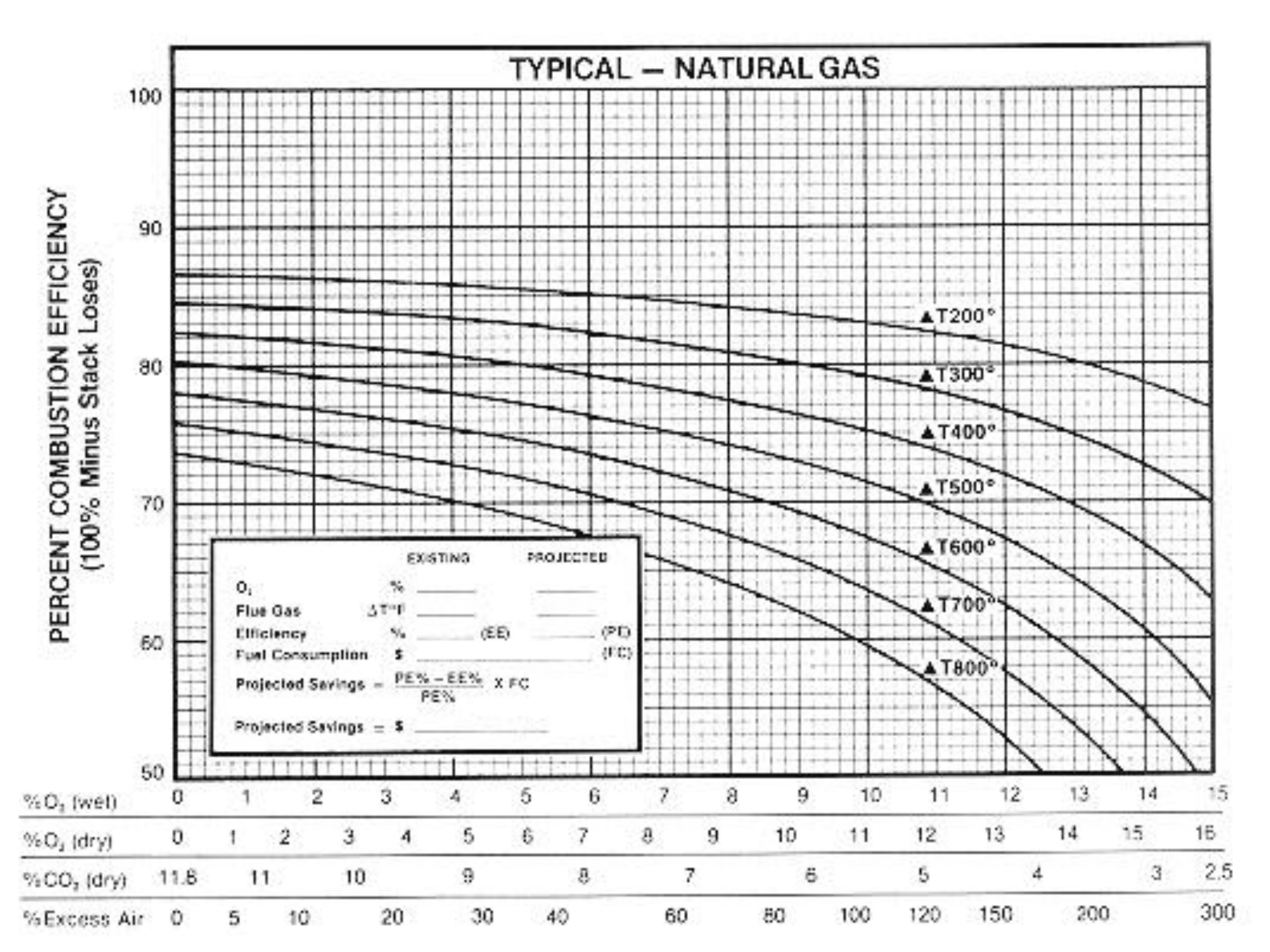
at 7% O_2

$\frac{20.9-3}{20.9-7} = \frac{17.9}{13.9} = 1.28 = CF$

so if NOx reading is 80 ppm

80 ppm @ 7% O_2 is

80 x 1.28 = 102 ppm NOx @ 3% O_2


TYPICAL – NATURAL GAS
PERCENT COMBUSTION EFFICIENCY
(100% Minus Stack Loses)
100
90
80
70
60
50
▲T200°
▲T300°
▲T400°
▲T500°
▲T600°
▲T700°
▲T800°
EXISTING
PROJECTED
O_2 %
Flue Gas ΔT°F
Efficiency % (EE) (PE)
Fuel Consumption $ (FC)
Projected Savings = (PE% – EE%) / PE% X FC
Projected Savings = $
%O_2 (wet) 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
%O_2 (dry) 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
%CO_2 (dry) 11.8 11 10 9 8 7 6 5 4 3 2.5
%Excess Air 0 5 10 20 30 40 60 80 100 120 150 200 300

III. NOx CONTROL TECHNIQUES
BOILER & BURNER NOx CONTROL STRATEGIES
FROM LARGE EQUIPMENT

COMBUSTION MODIFICATIONS

A. Flue gas re-circulation.

B. Staged combustion.

C. Low NOx Burners

D. Reduced Air Preheat

E. Low excess air

F. O_2 Trim

FLUE GAS TREATMENT

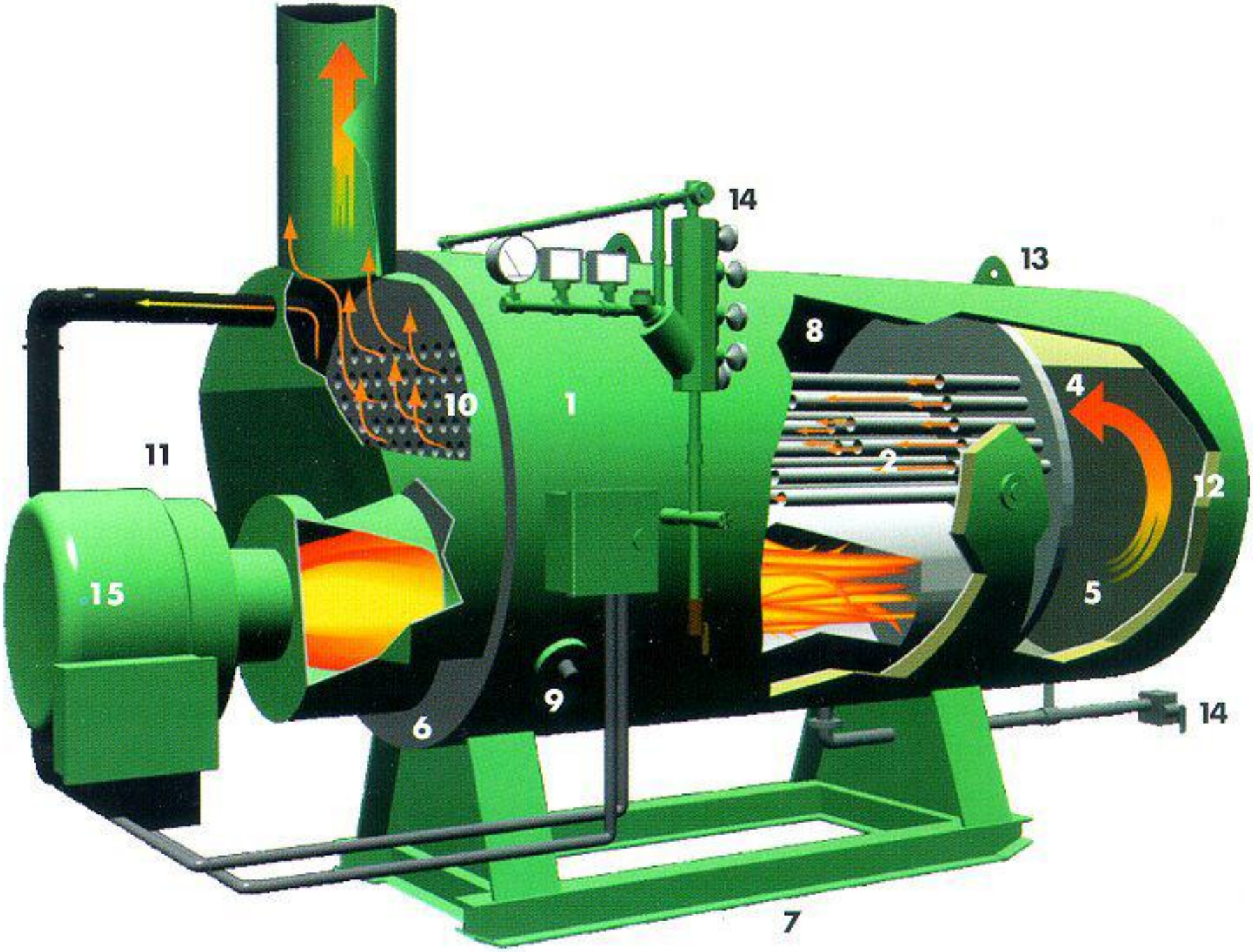
G. Ammonia or Urea injection

H. Selective Catalytic Reduction

I. Non-selective Catalytic Reduction

J. Electron Beam Radiation

K. Chemical Scrubbing


14
13
8
4
10
1
11
2
12
15
5
9
14
6
7

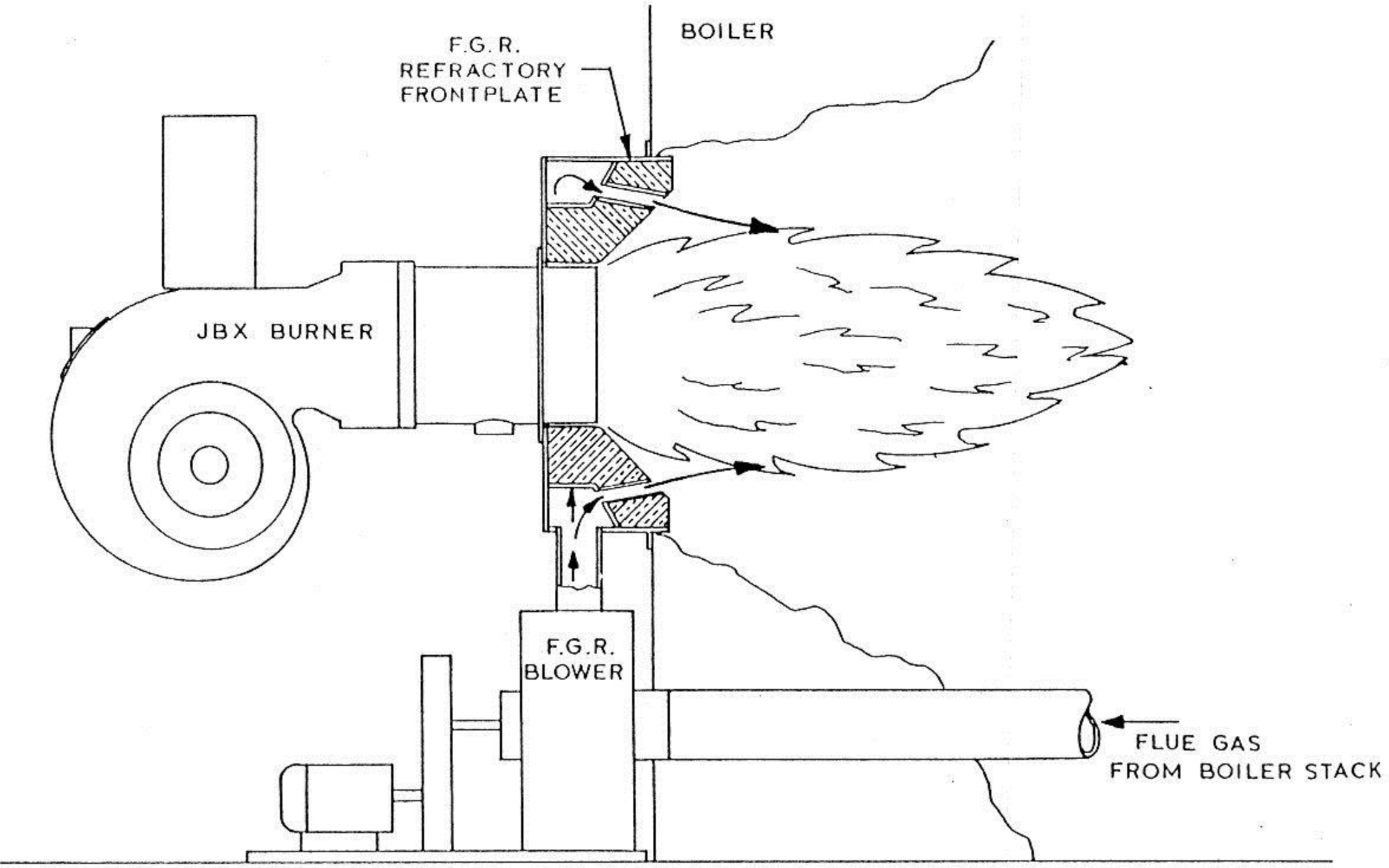
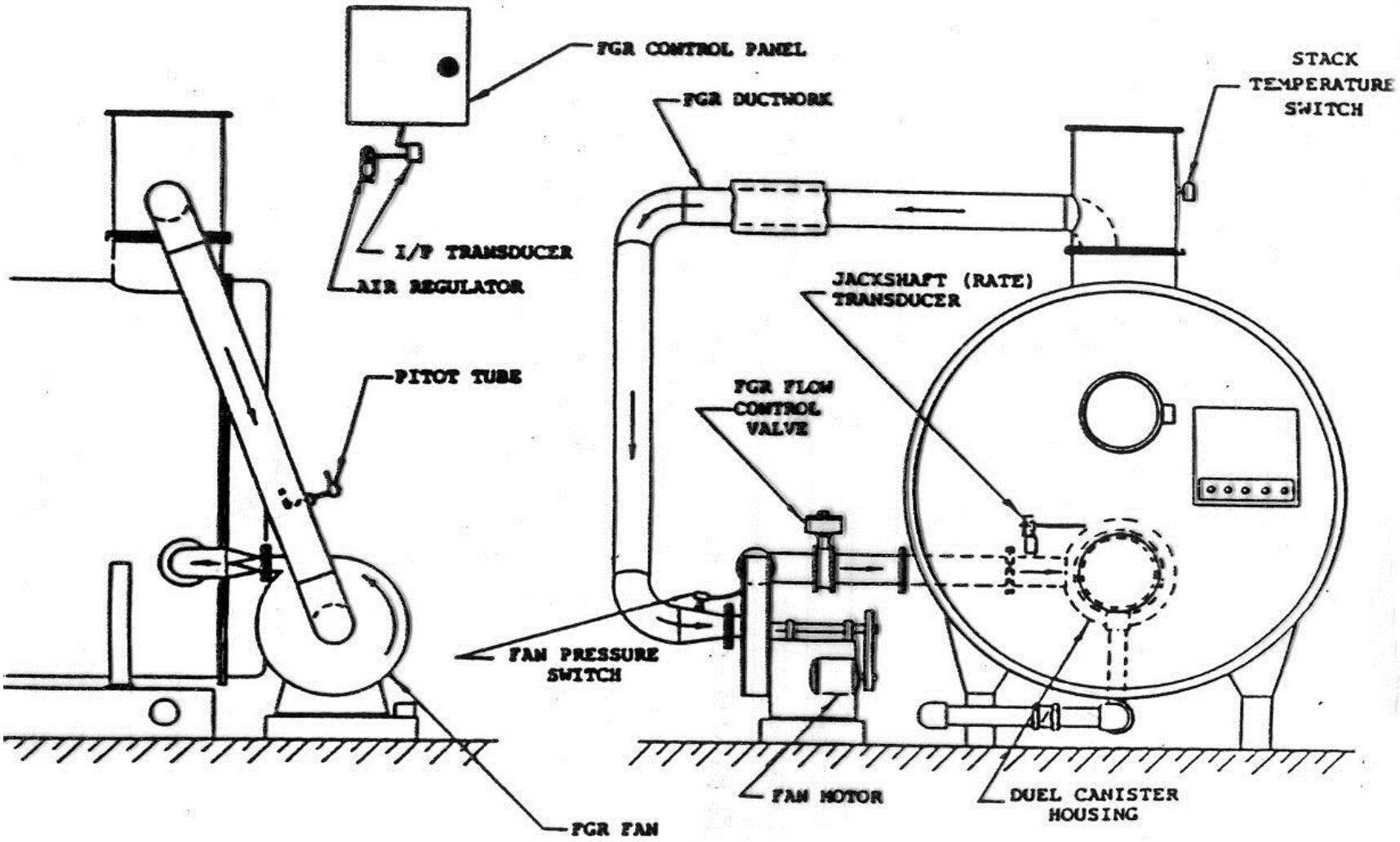
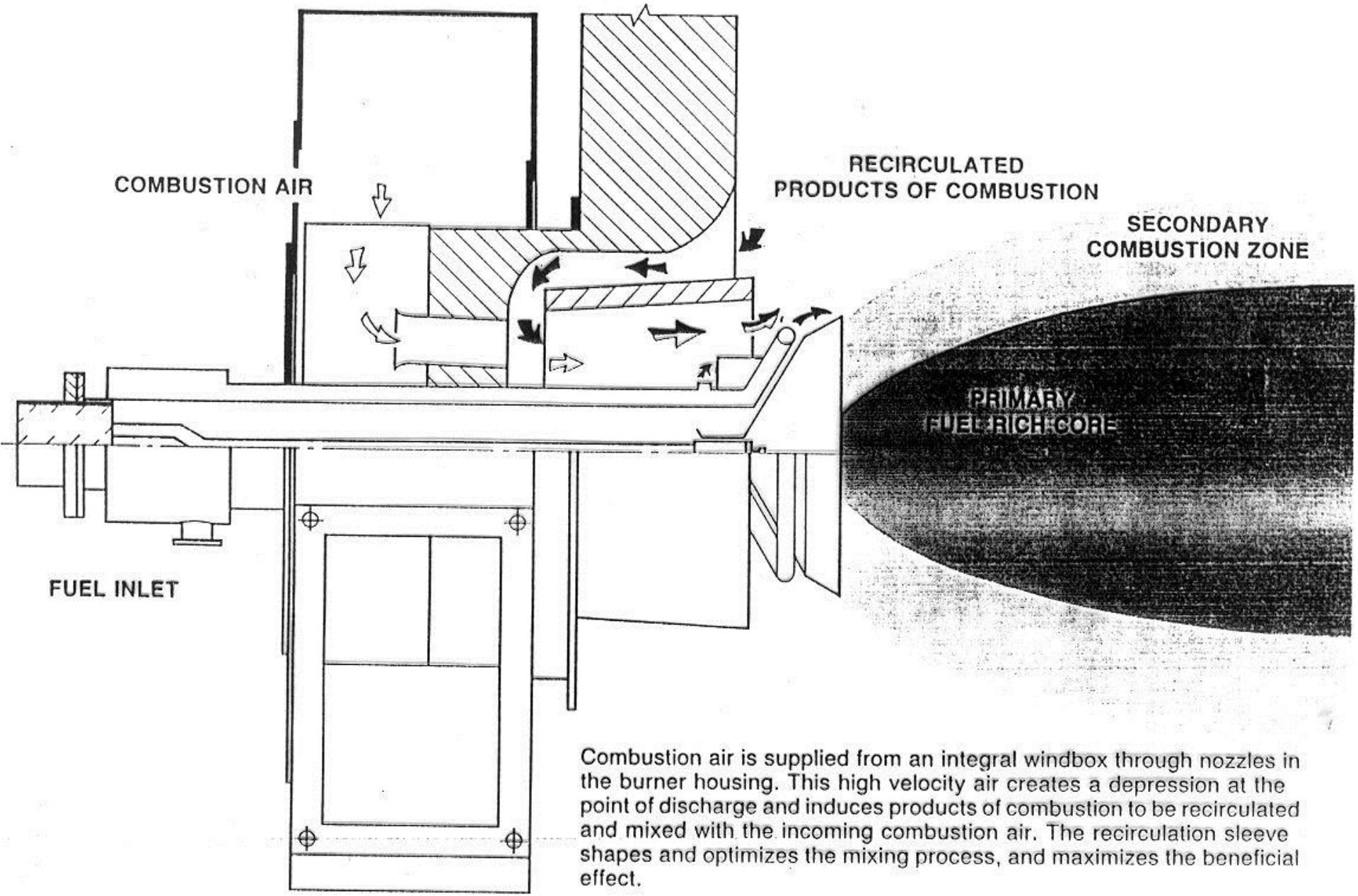
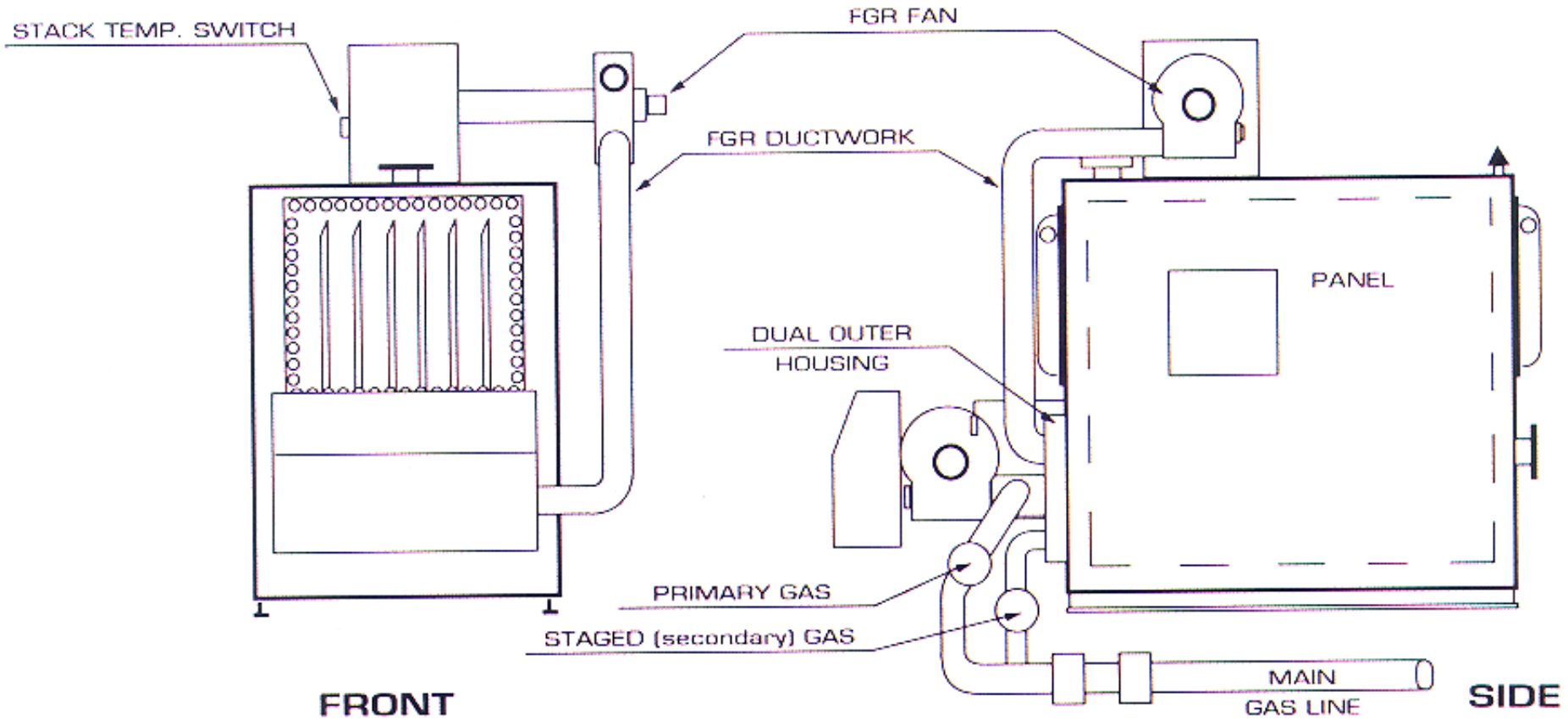

BOILER
F.G.R.
REFRACTORY
FRONTPLATE
JBX BURNER
F.G.R.
BLOWER
FLUE GAS
FROM BOILER STACK

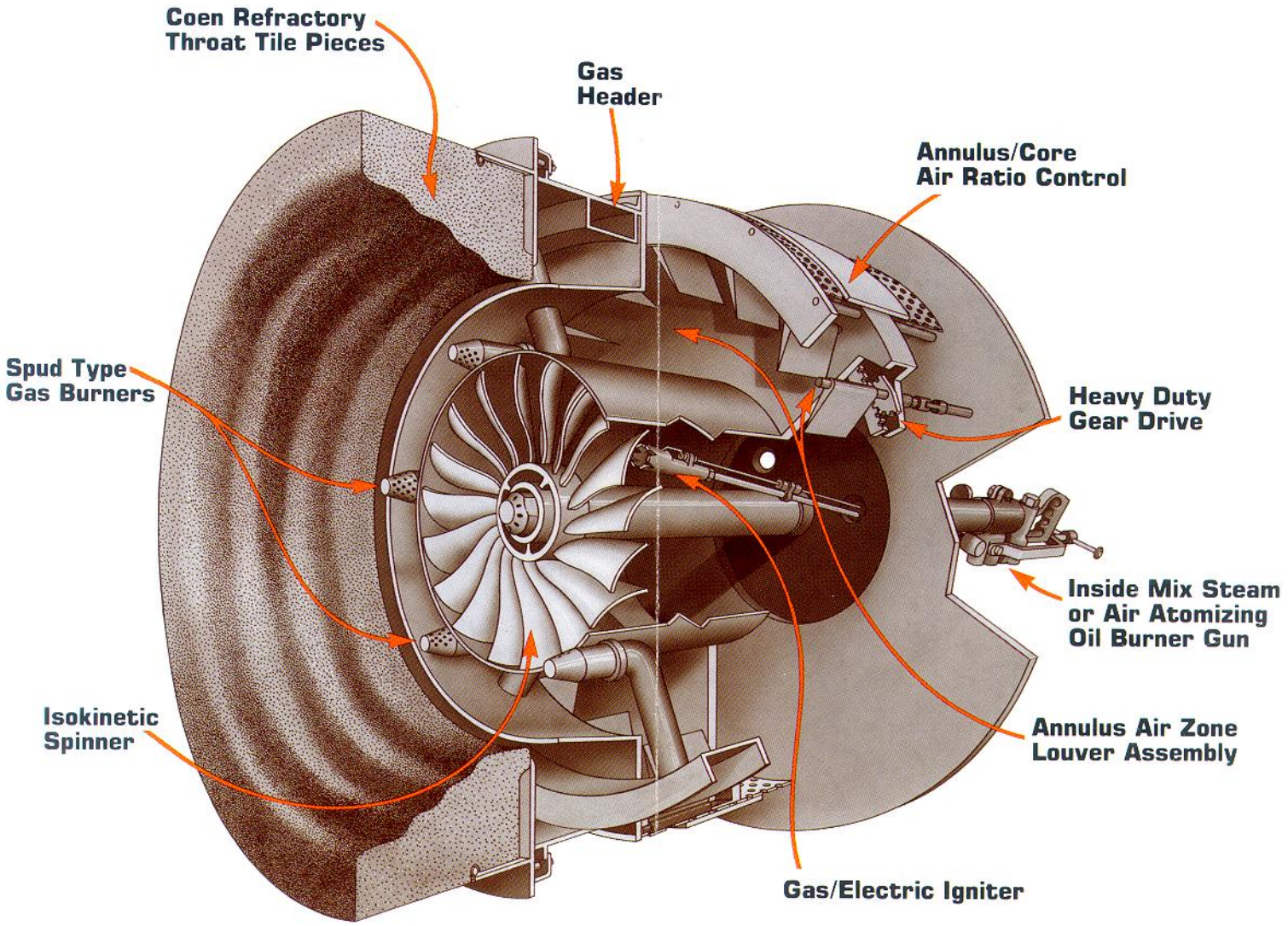
FIGURE 1. Typical flue gas recirculation system





Combustion air is supplied from an integral windbox through nozzles in the burner housing. This high velocity air creates a depression at the point of discharge and induces products of combustion to be recirculated and mixed with the incoming combustion air. The recirculation sleeve shapes and optimizes the mixing process, and maximizes the beneficial effect.


STACK TEMP. SWITCH
FGR FAN
FGR DUCTWORK
PANEL
DUAL OUTER
HOUSING
PRIMARY GAS
STAGED (secondary) GAS
MAIN
GAS LINE
FRONT
SIDE


Coen Refractory
Throat Tile Pieces
Gas
Header
Annulus/Core
Air Ratio Control
Spud Type
Gas Burners
Heavy Duty
Gear Drive
Inside Mix Steam
or Air Atomizing
Oil Burner Gun
Isokinetic
Spinner
Annulus Air Zone
Louver Assembly
Gas/Electric Igniter

Coen Type DAF Operation of Multi-Staged Low NOx Burner

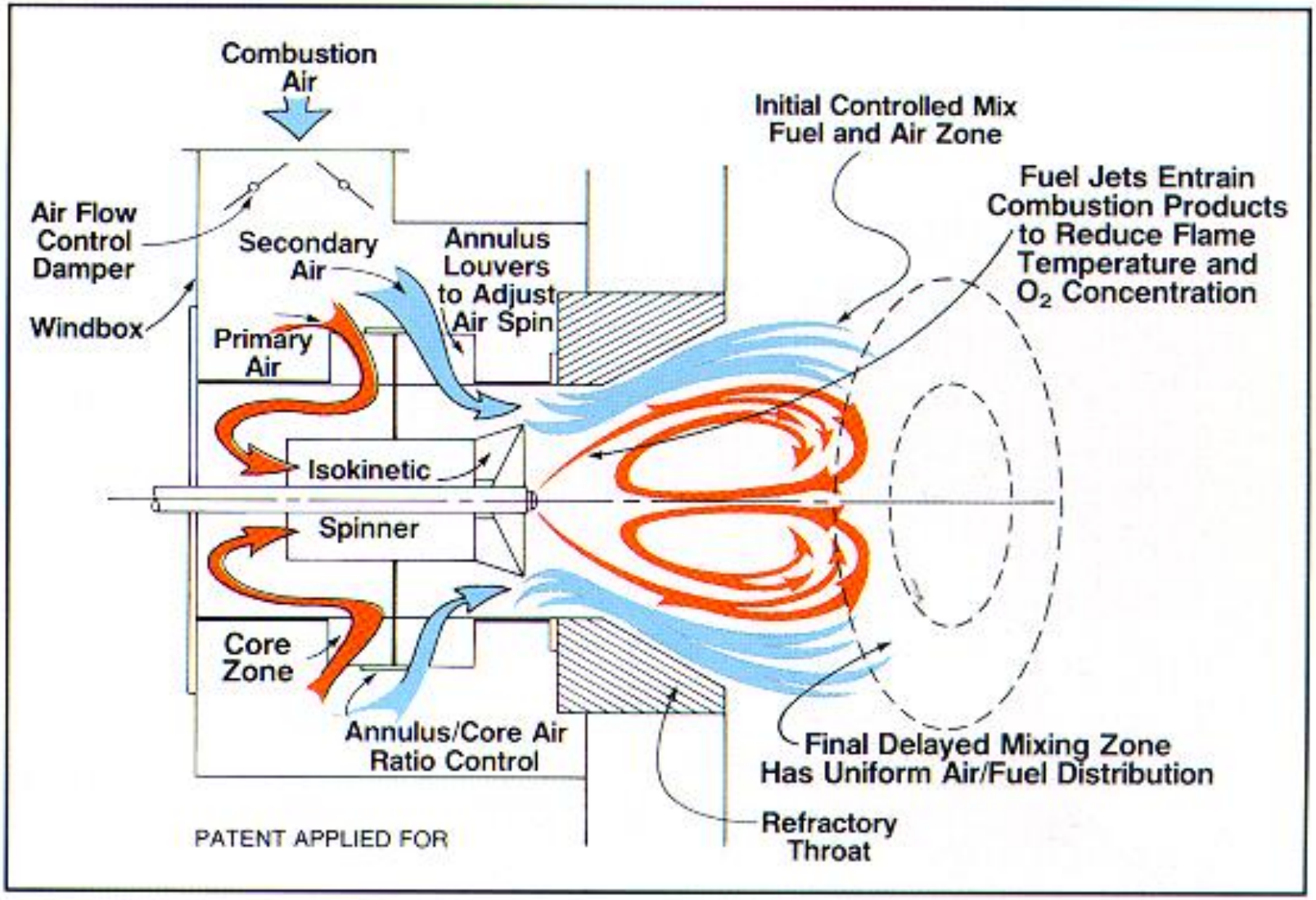
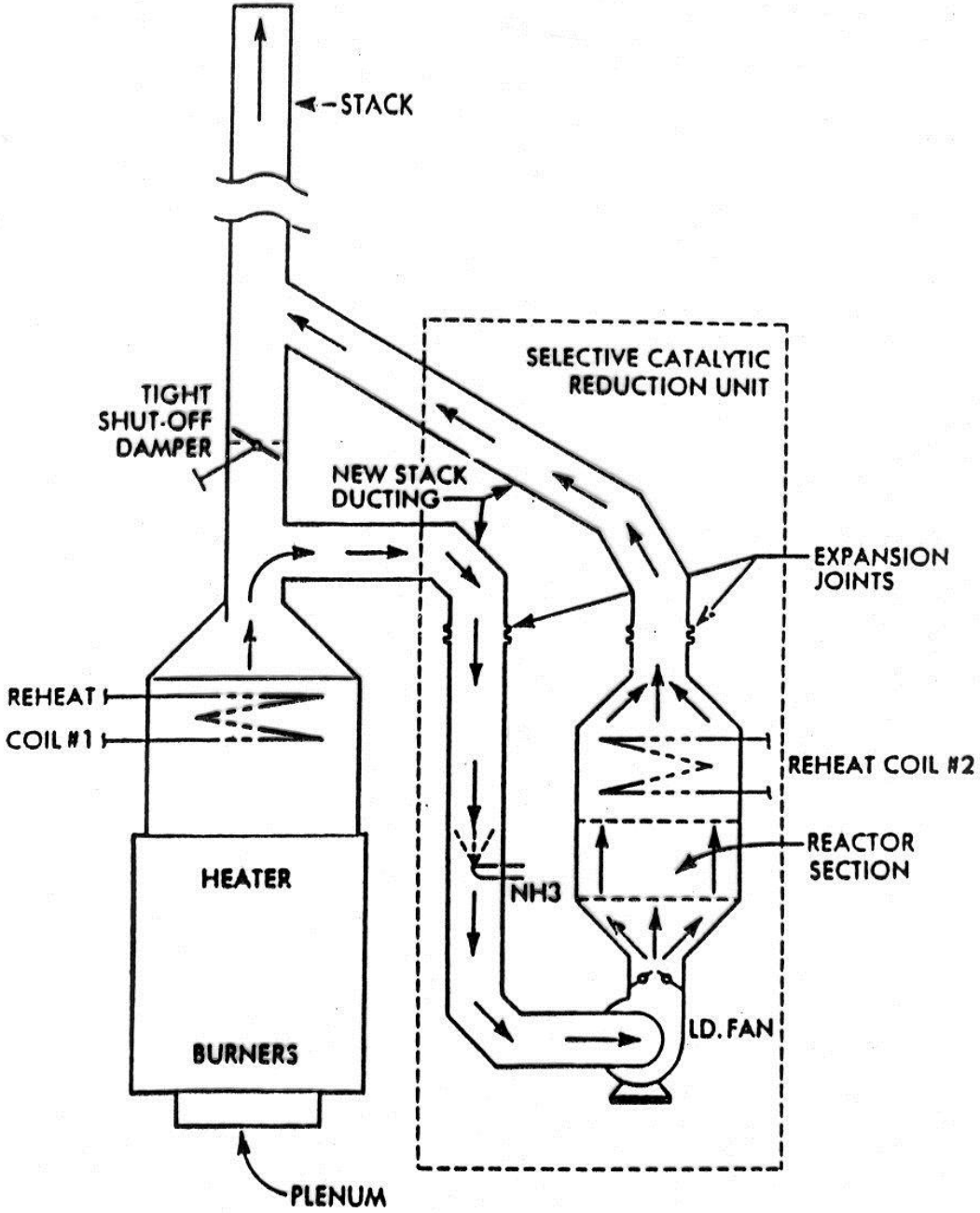
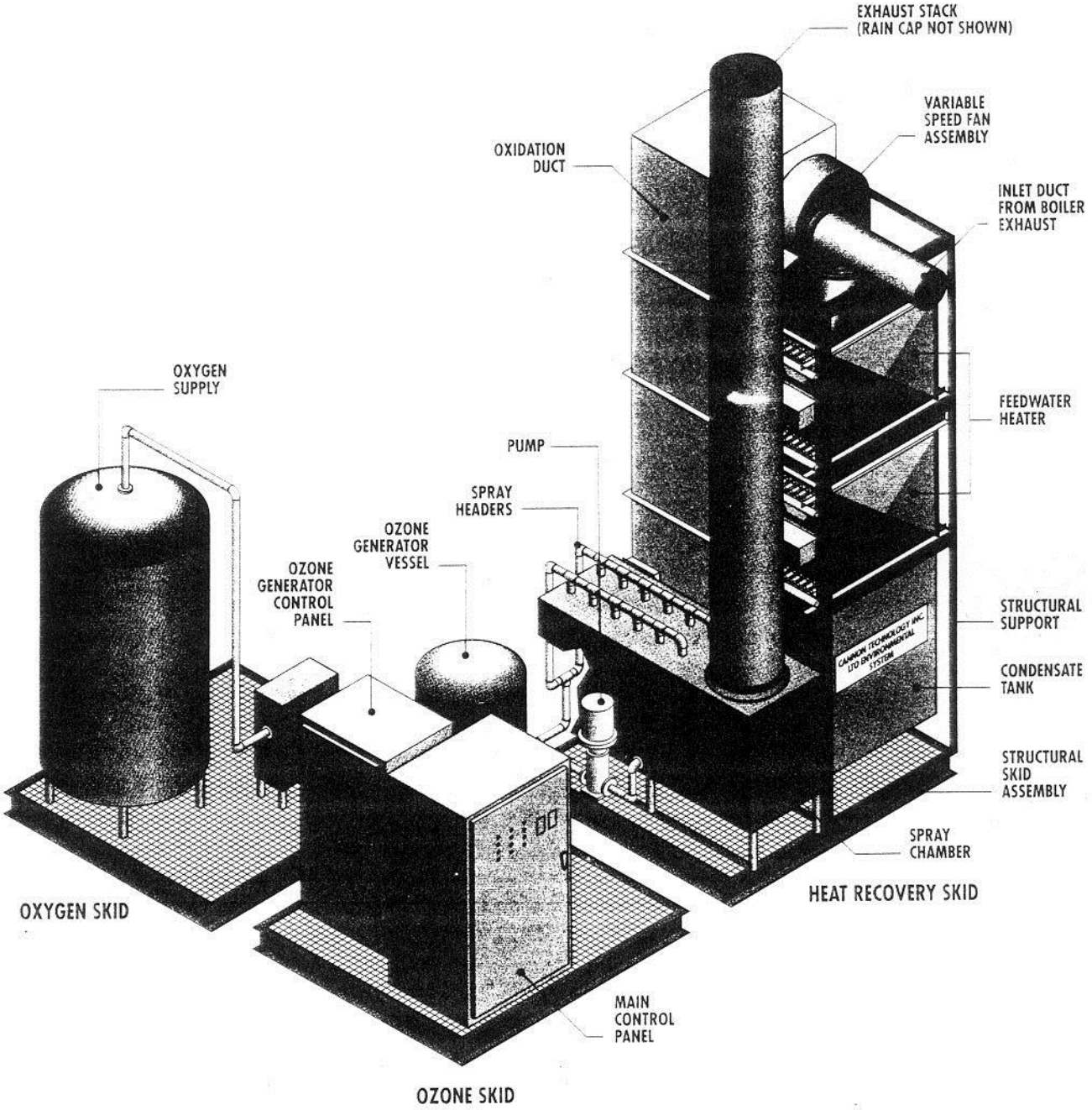


FIGURE 3. Selective catalytic reduction




EXHAUST STACK
(RAIN CAP NOT SHOWN)
VARIABLE
SPEED FAN
ASSEMBLY
OXIDATION
DUCT
INLET DUCT
FROM BOILER
EXHAUST
OXYGEN
SUPPLY
FEEDWATER
HEATER
PUMP
SPRAY
HEADERS
OZONE
GENERATOR
VESSEL
OZONE
GENERATOR
CONTROL
PANEL
STRUCTURAL
SUPPORT
CONDENSATE
TANK
STRUCTURAL
SKID
ASSEMBLY
SPRAY
CHAMBER
OXYGEN SKID
HEAT RECOVERY SKID
MAIN
CONTROL
PANEL
OZONE SKID

LTO

INDUSTRIAL BOILER APPLICATIONS

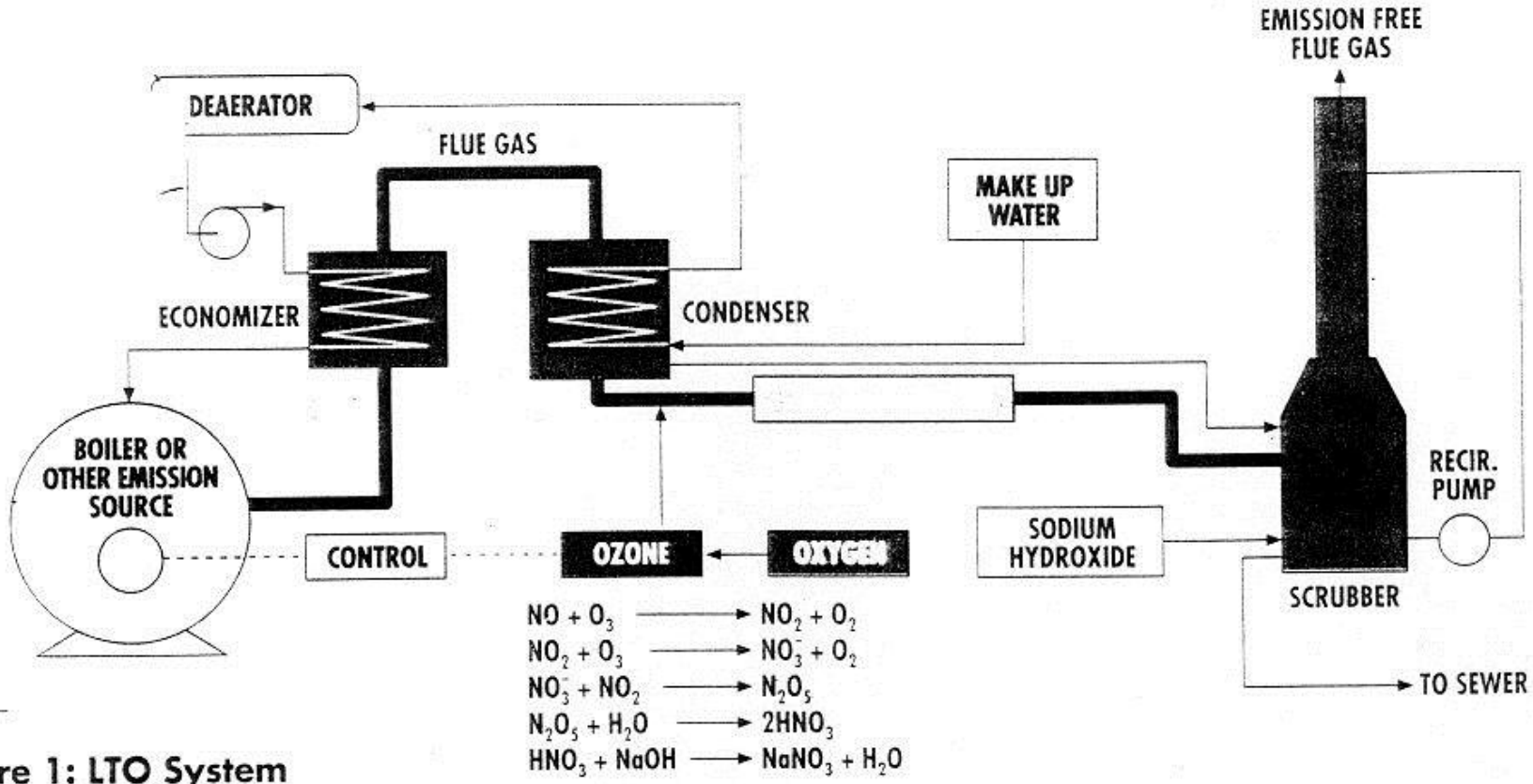


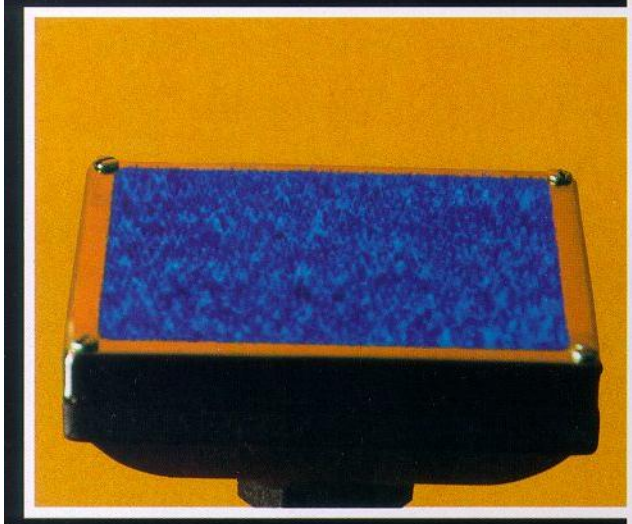
Figure 1: LTO System Process Diagram

III & IV. NOx CONTROL TECHNOLOGIES

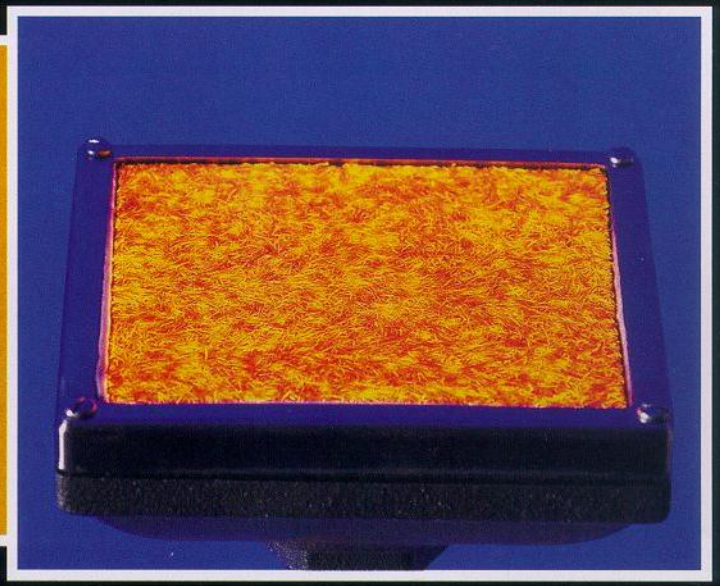
NOx CONTROL TECHNIQUES FROM SMALL EQUIPMENT & EFFICIENCY

A. Premix technology
B. Radiant & Connective Premix Burners
C. Atmospheric Low NOx Burners
D. High Efficiency Boilers

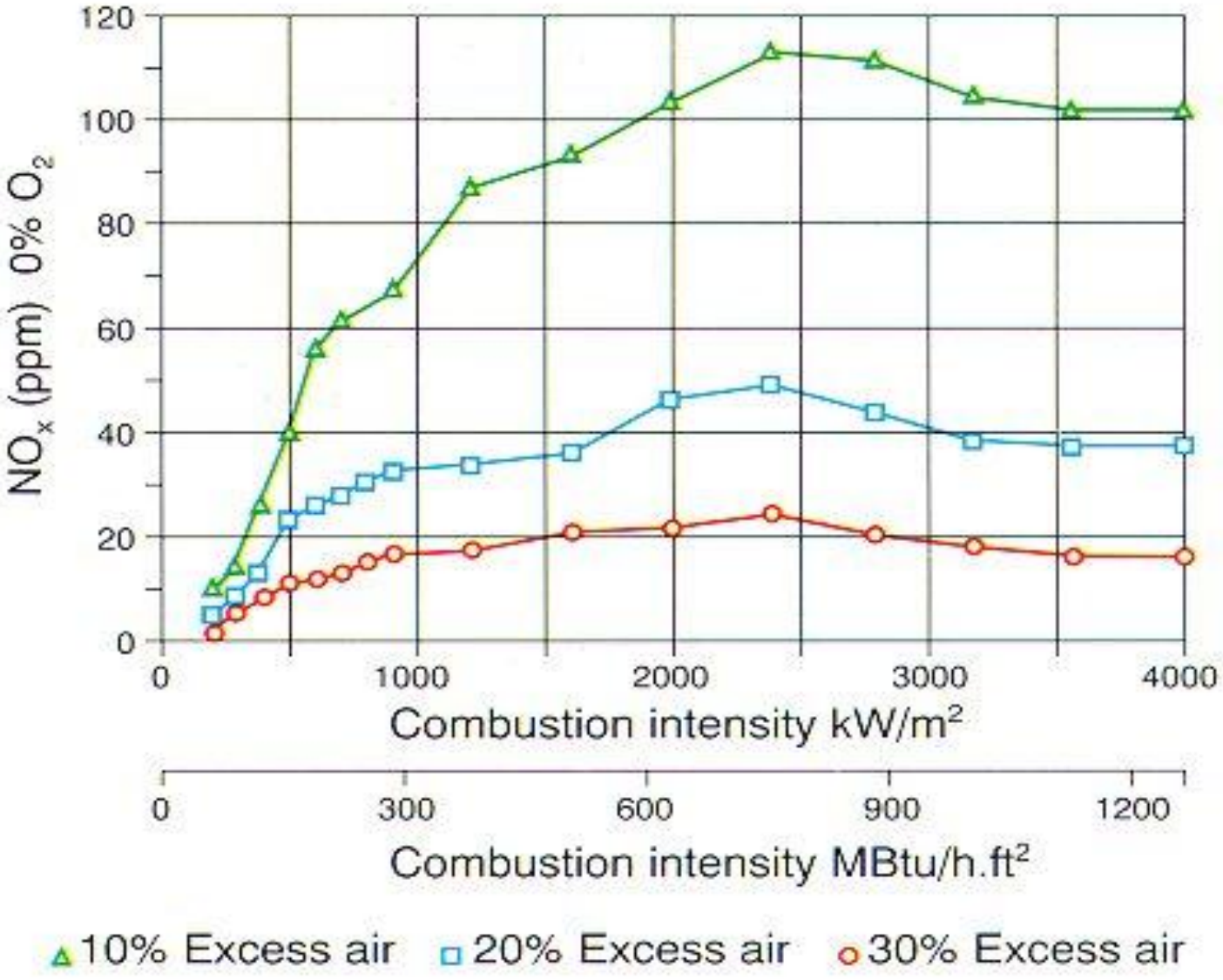
Pre-mix Radiant and Blue Flame Burners

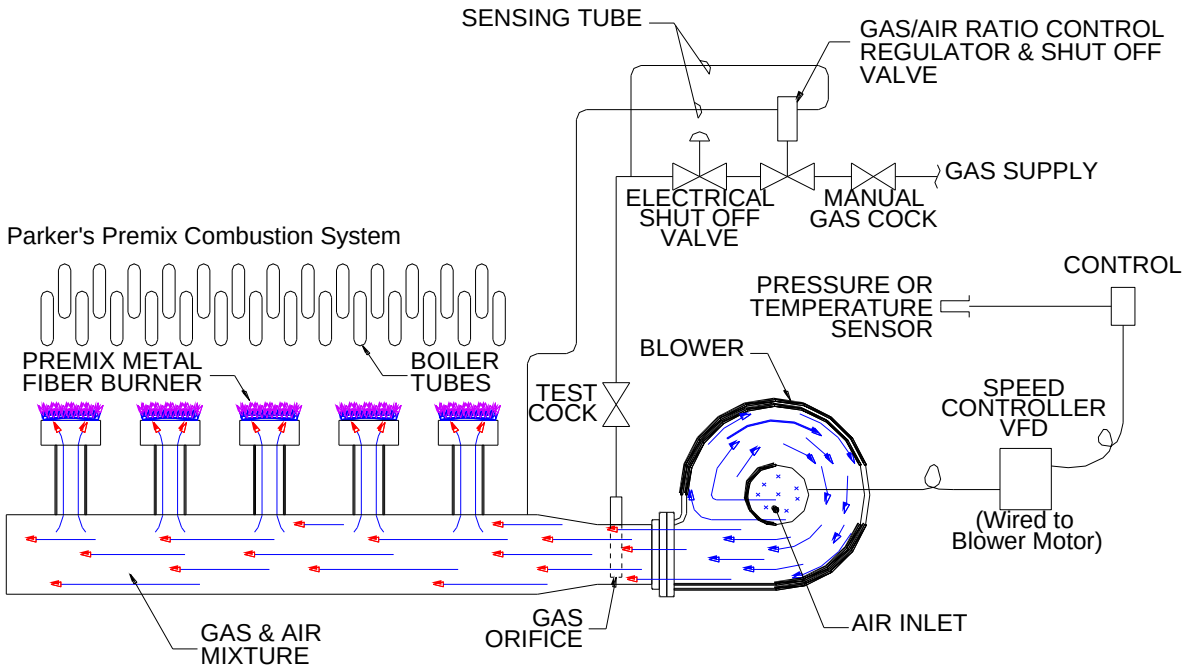


BLUE FLAME MODE



RADIANT MODE


120
100
80
60
40
20
0
NO_x (ppm) 0% O_2
0
1000
2000
3000
4000
Combustion intensity kW/m²
0
300
600
900
1200
Combustion intensity MBtu/h.ft²
10% Excess air
20% Excess air
30% Excess air

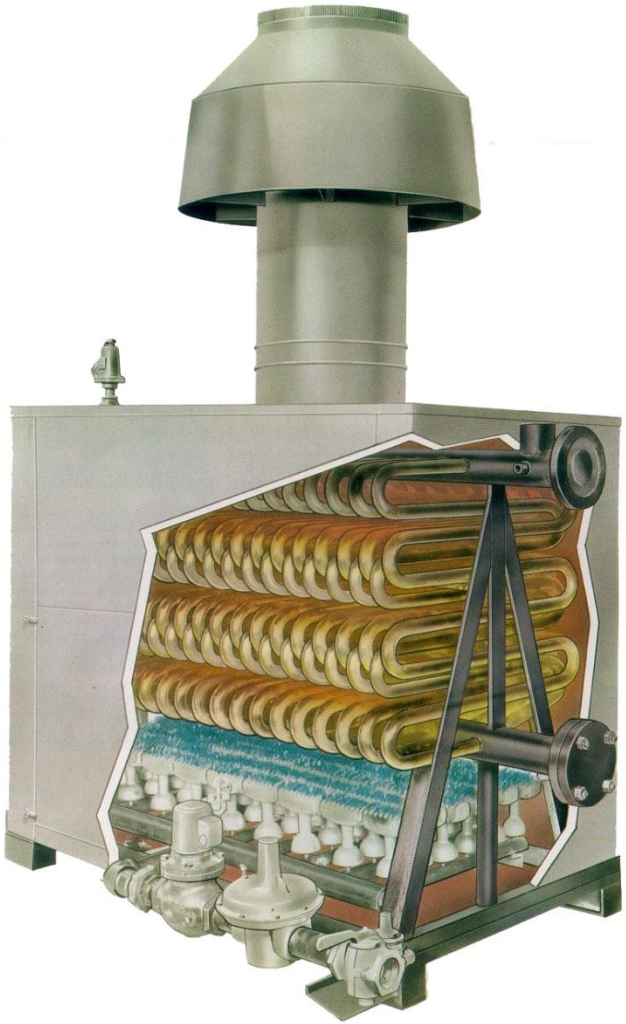


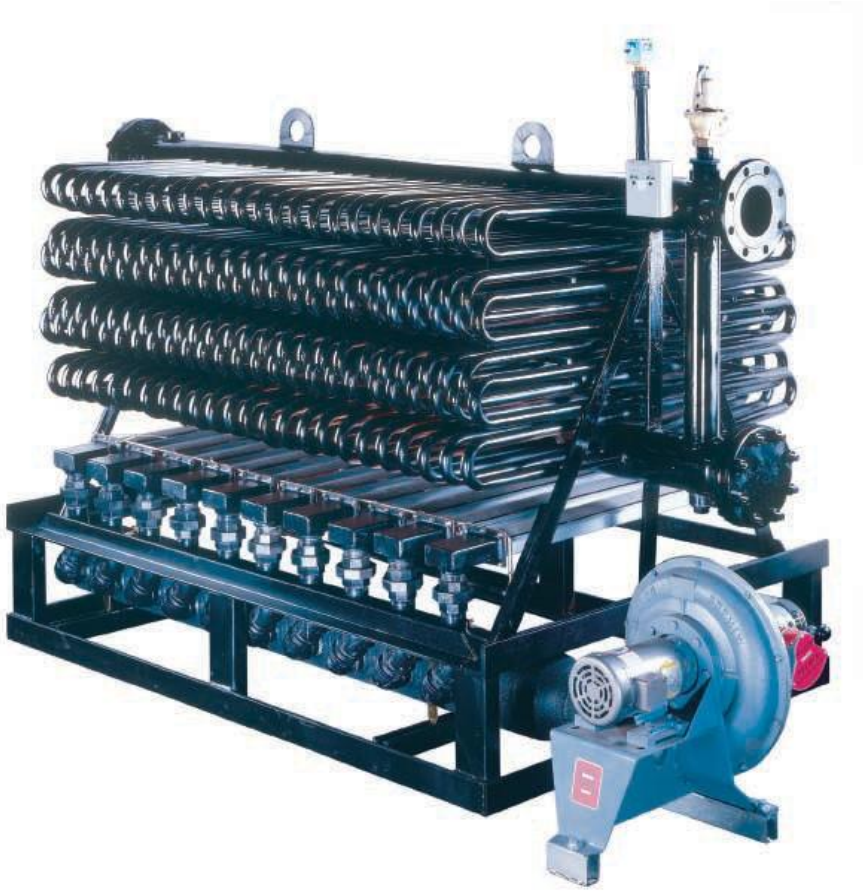
VARIABLE SPEED APPLICATION

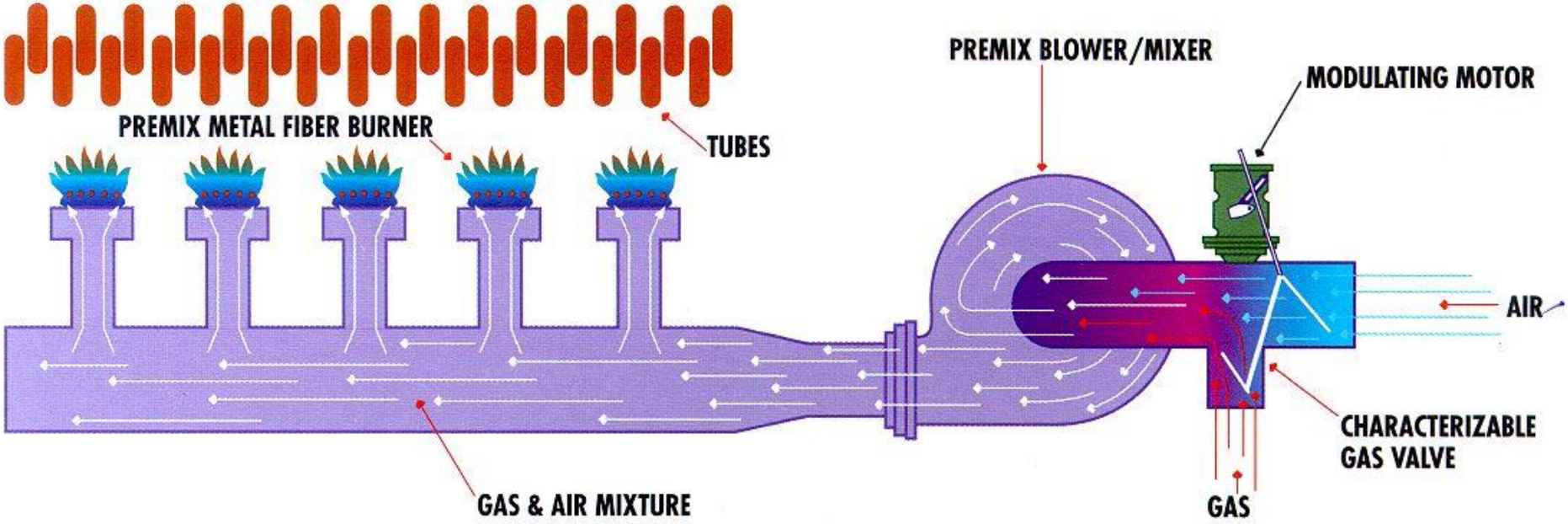
POST MIXING "LVFD" SYSTEM

PREMIX3.DWG

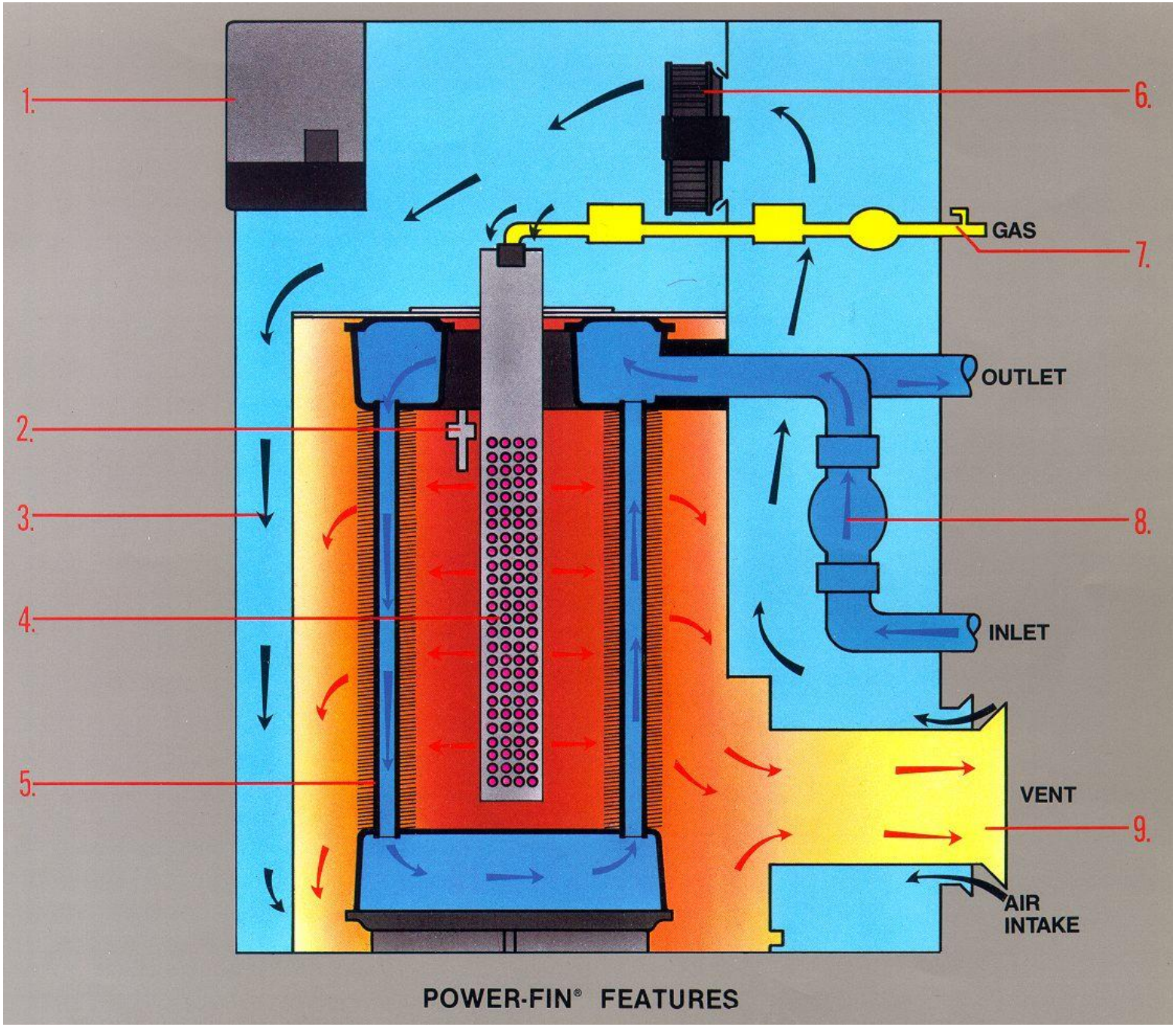
Atmospheric vs. Low NOx Boiler



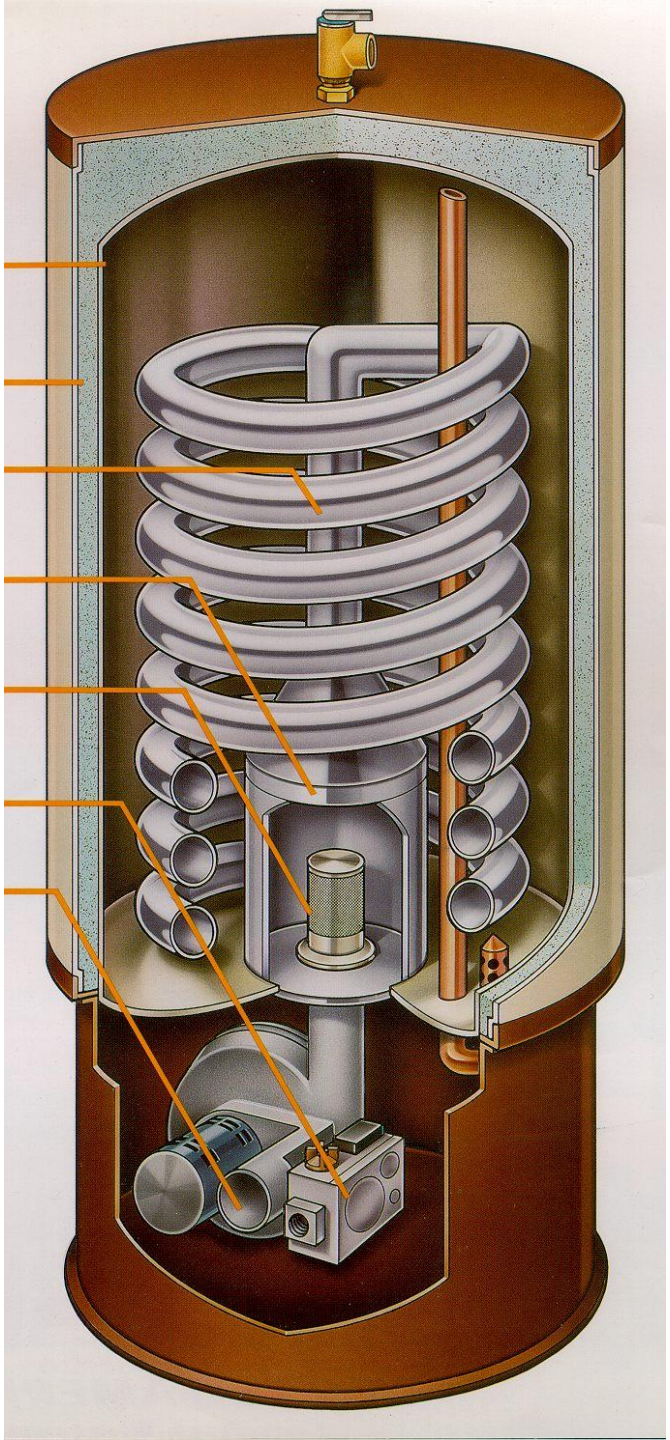



PREMIX METAL FIBER BURNER
TUBES
PREMIX BLOWER/MIXER
MODULATING MOTOR
AIR
CHARACTERIZABLE
GAS VALVE
GAS & AIR MIXTURE
GAS

Metal Fiber Burners

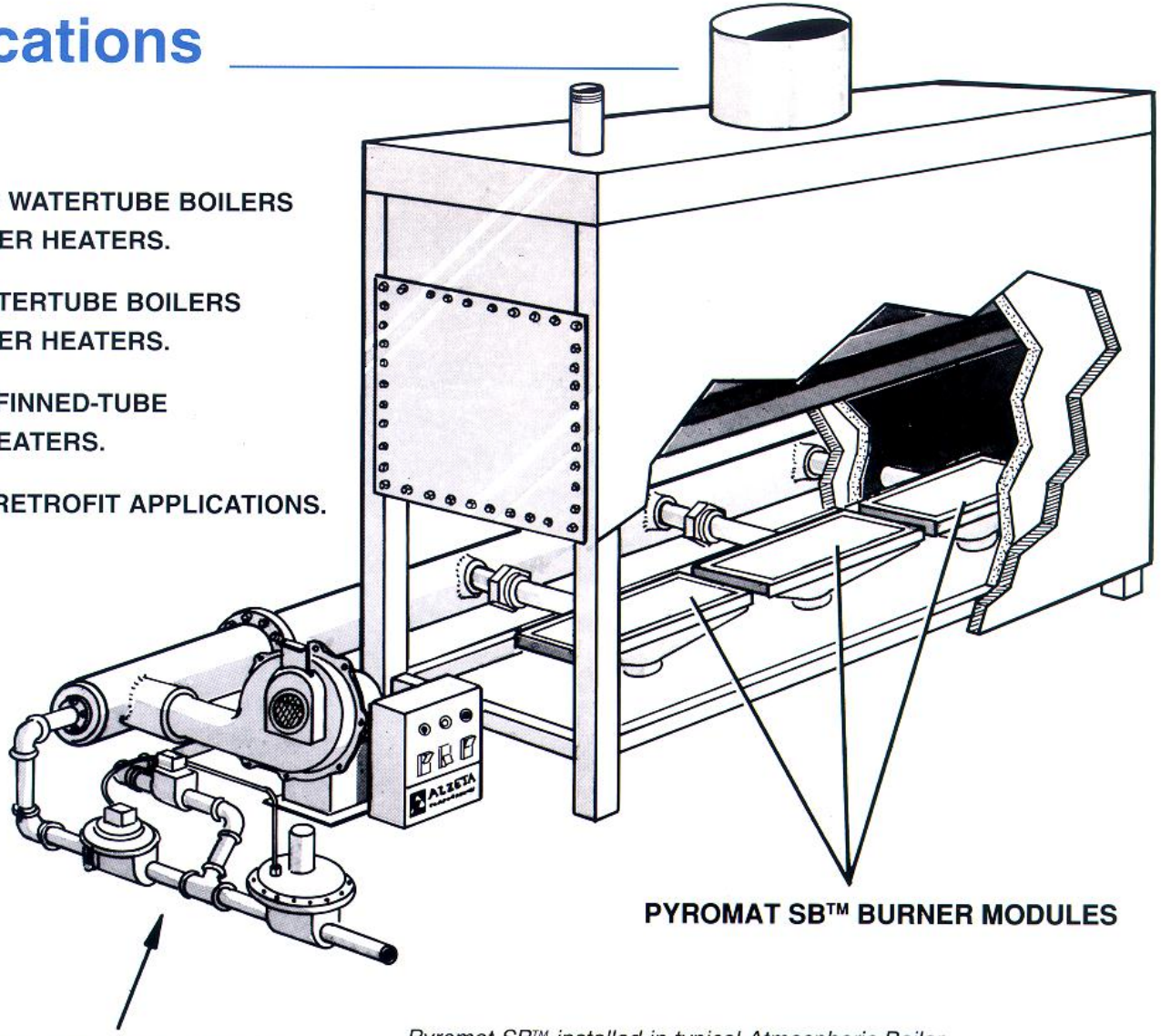


POWER-FIN® FEATURES



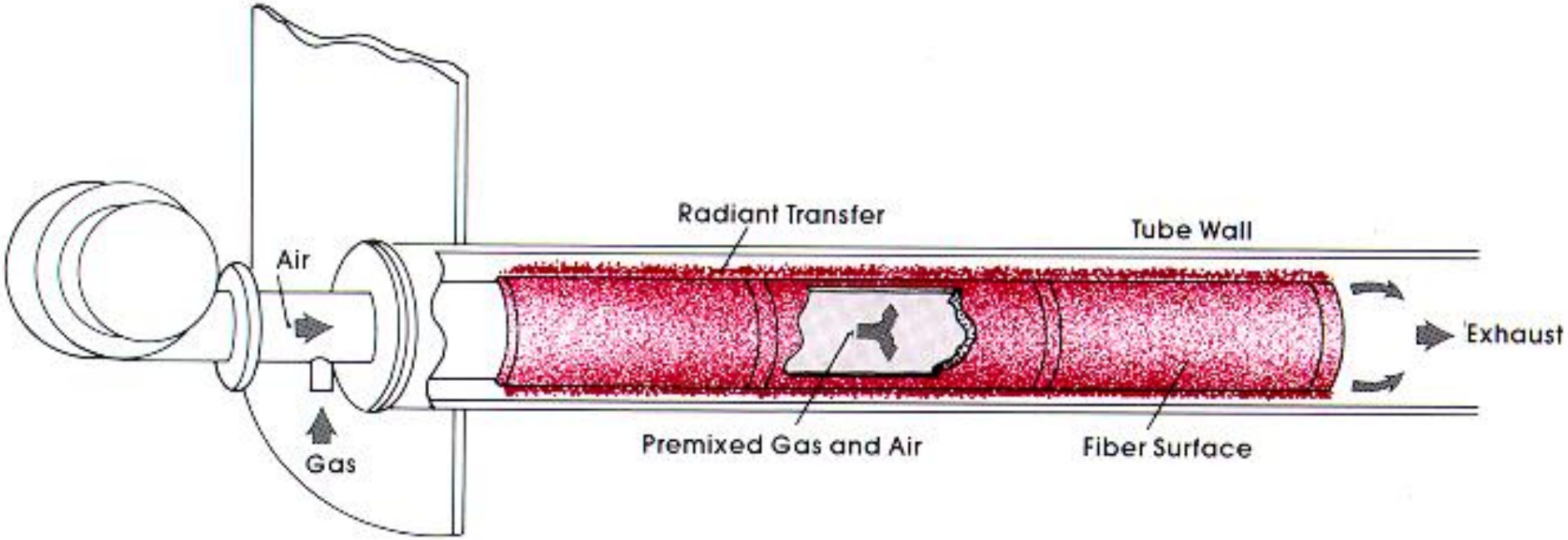
Applications

- INCLINED WATERTUBE BOILERS AND WATER HEATERS.
- BENT WATERTUBE BOILERS AND WATER HEATERS.
- COPPER FINNED-TUBE WATER HEATERS.
- NEW OR RETROFIT APPLICATIONS.

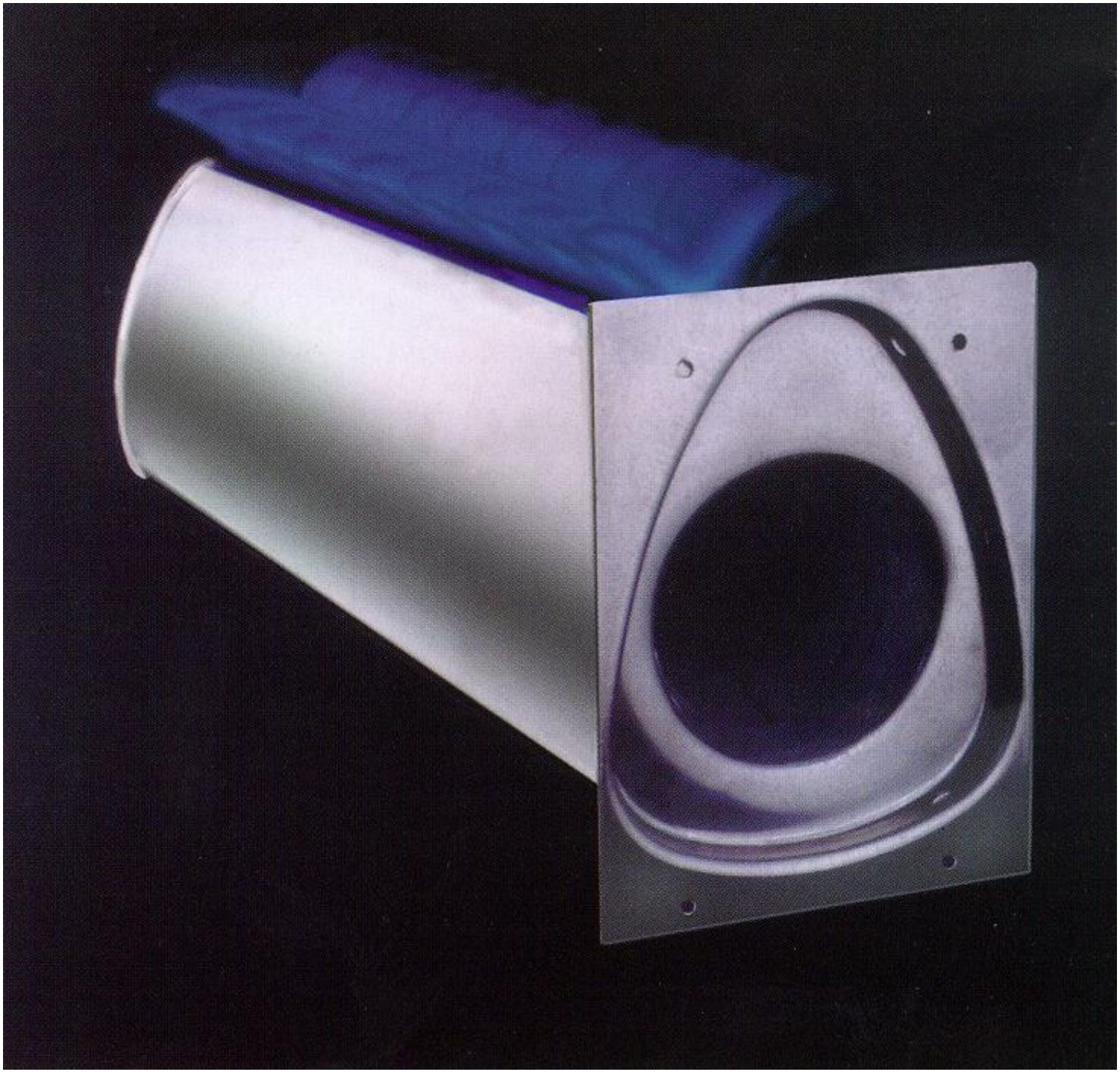


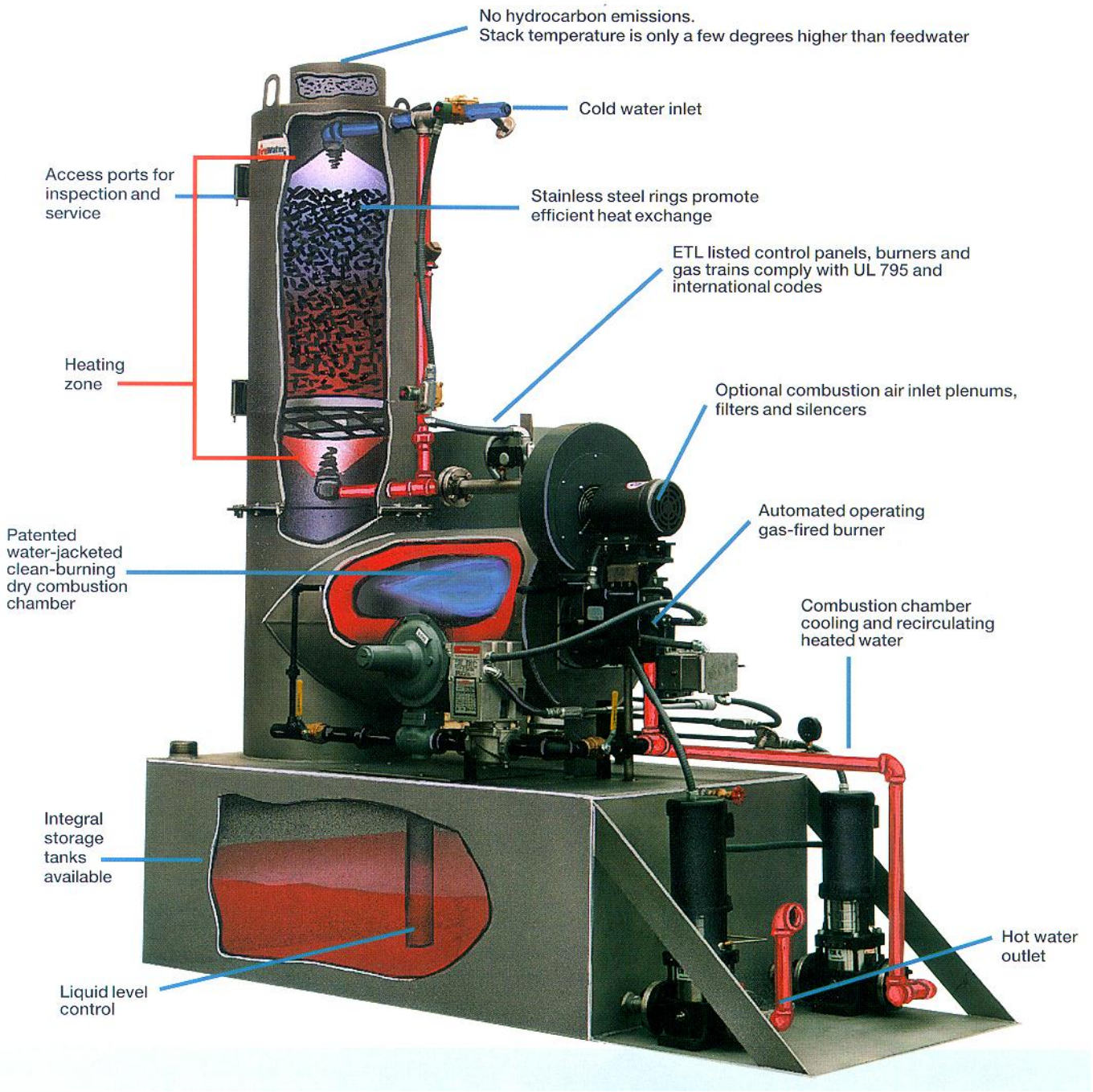
Pyromat SB™ installed in typical Atmospheric Boiler.

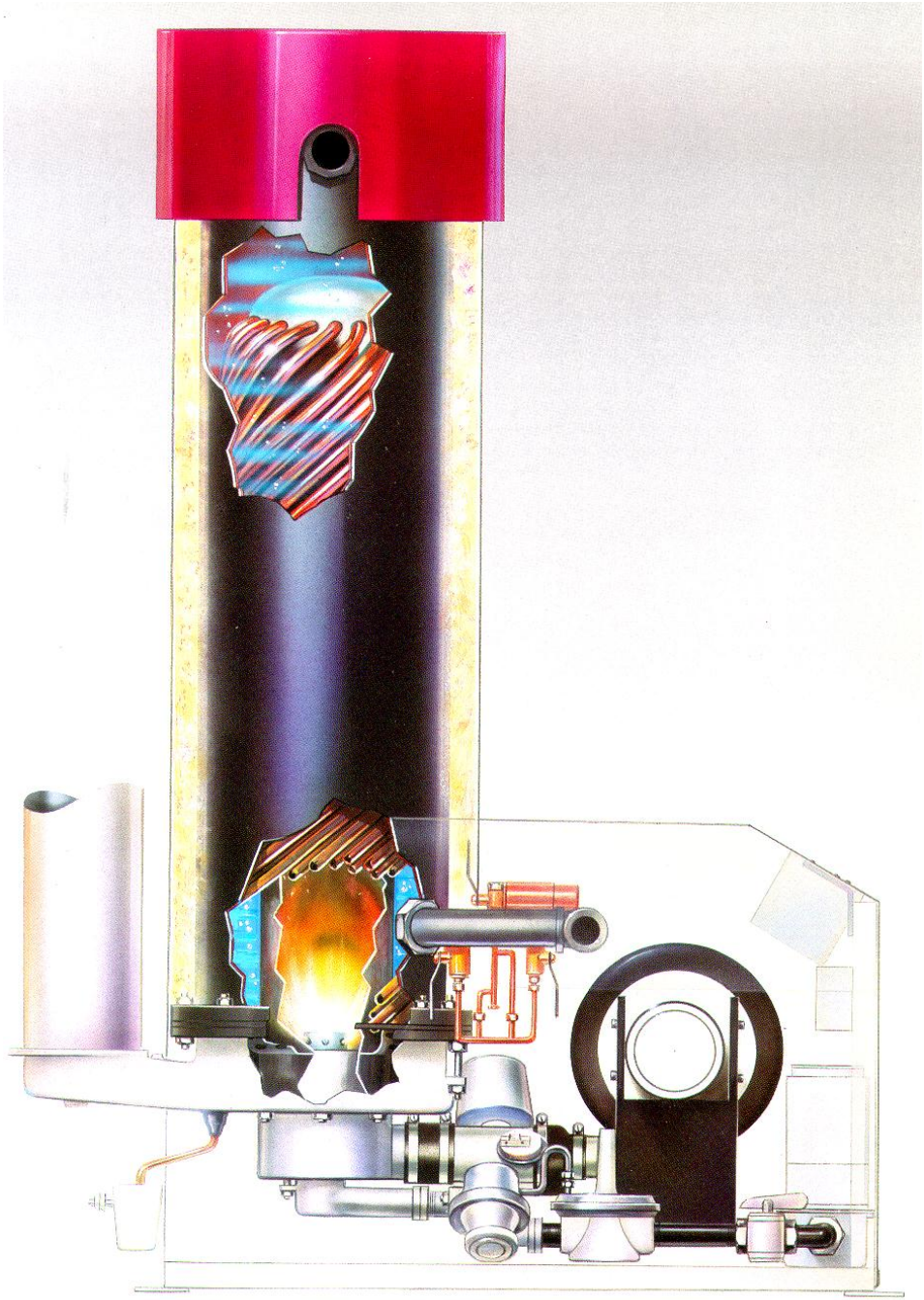
Immersion Tube Burner



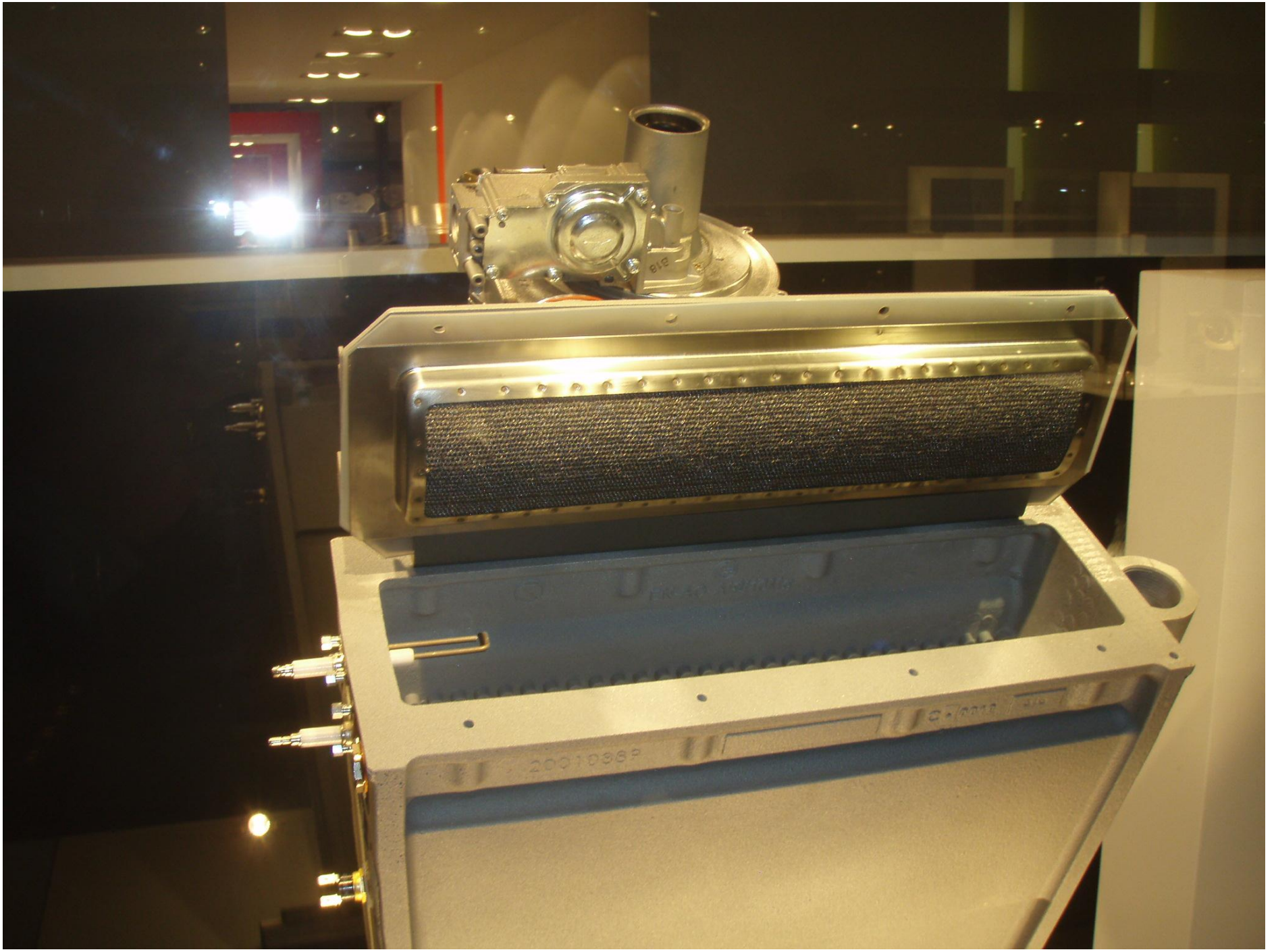

MatriX-Strahlungsbrenner/
MatriX-Katbrenner

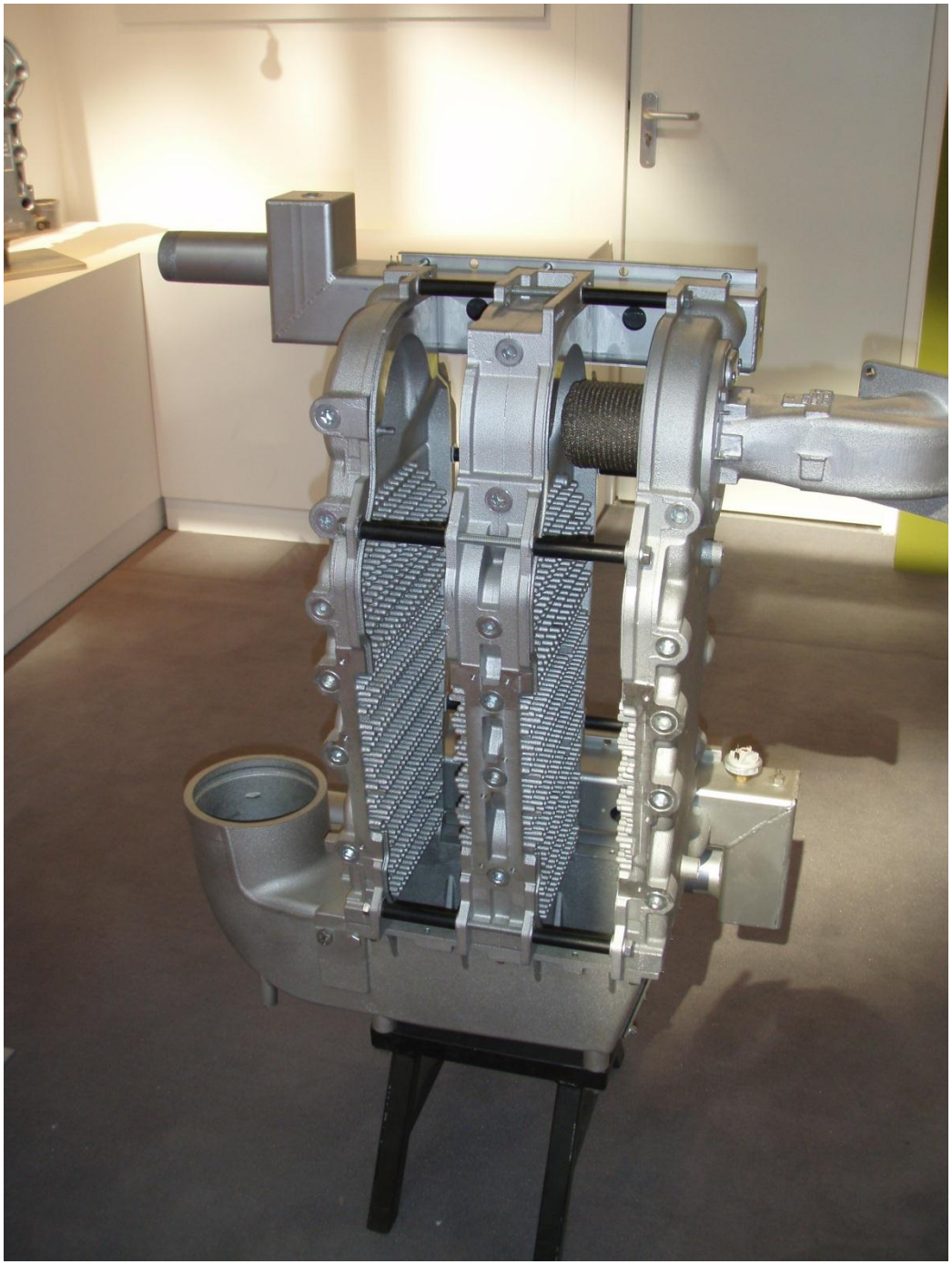


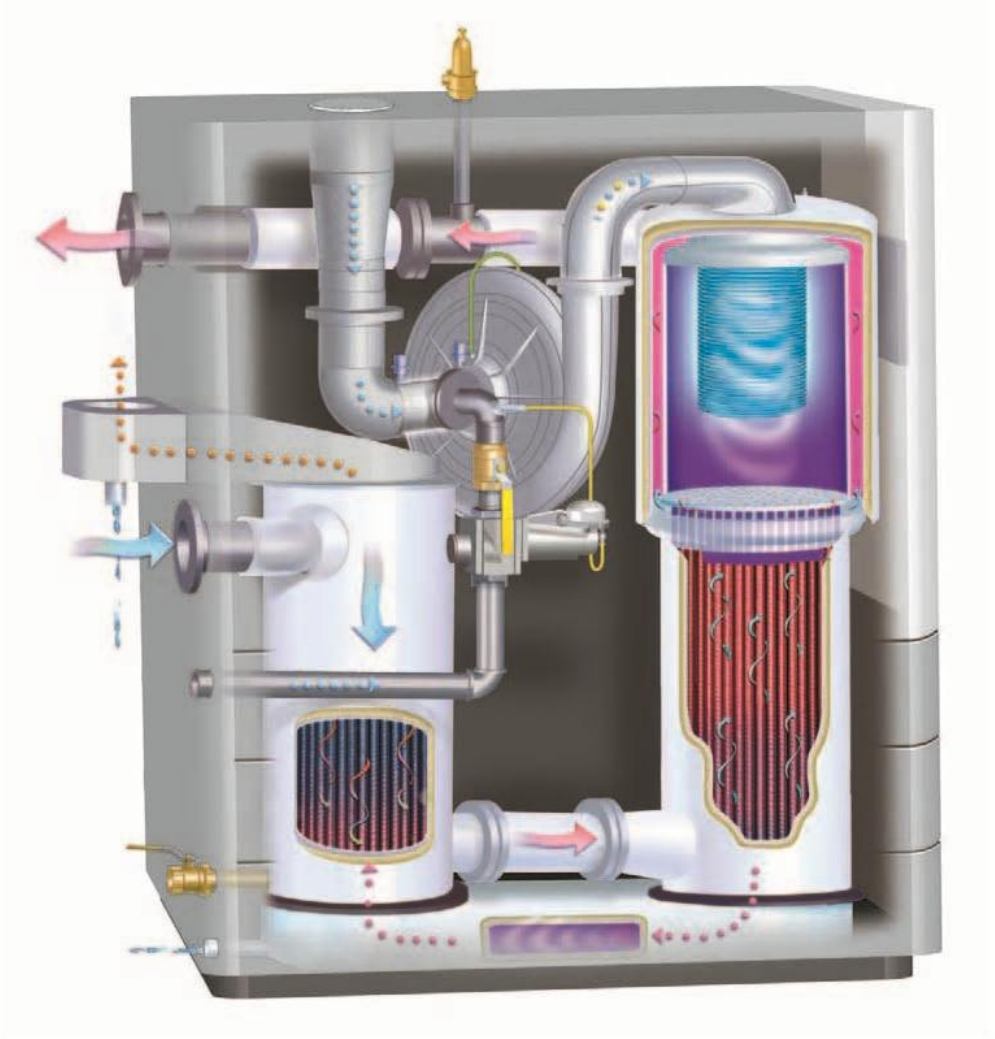

No hydrocarbon emissions.
Stack temperature is only a few degrees higher than feedwater
Cold water inlet
Access ports for inspection and service
Stainless steel rings promote efficient heat exchange
ETL listed control panels, burners and gas trains comply with UL 795 and international codes
Heating zone
Optional combustion air inlet plenums, filters and silencers
Automated operating gas-fired burner
Patented water-jacketed clean-burning dry combustion chamber
Combustion chamber cooling and recirculating heated water
Integral storage tanks available
Hot water outlet
Liquid level control




HEATER
NO. 2







= Cold Water
= Hot Water
= Air
= Natural Gas
= Air/Gas Mix
= Hot Exhaust
= Cool Exhaust
= Condensate

Benchmark 3.0 Low NOx

BTU Input	3,000,000 BTU/hr.
BTU Output	2,610,000–2,883,000 BTU/hr.
Efficiency	99.4% at low fire with 60°F inlet water
Turndown Ratio	15:1
Dimensions	79"H x 28"W x 64"D
Gas Requirements	4" W.C. minimum at full load
Weight, Wet	2,580 lbs.

— Condensing Operation — Advanced Controls — Precise Temperature Control

V. WHAT'S NEXT

Burning Questions:

How to Achieve
Environmental Détente,
Energy Security & Clean Air
in a Combustion Constrained World?

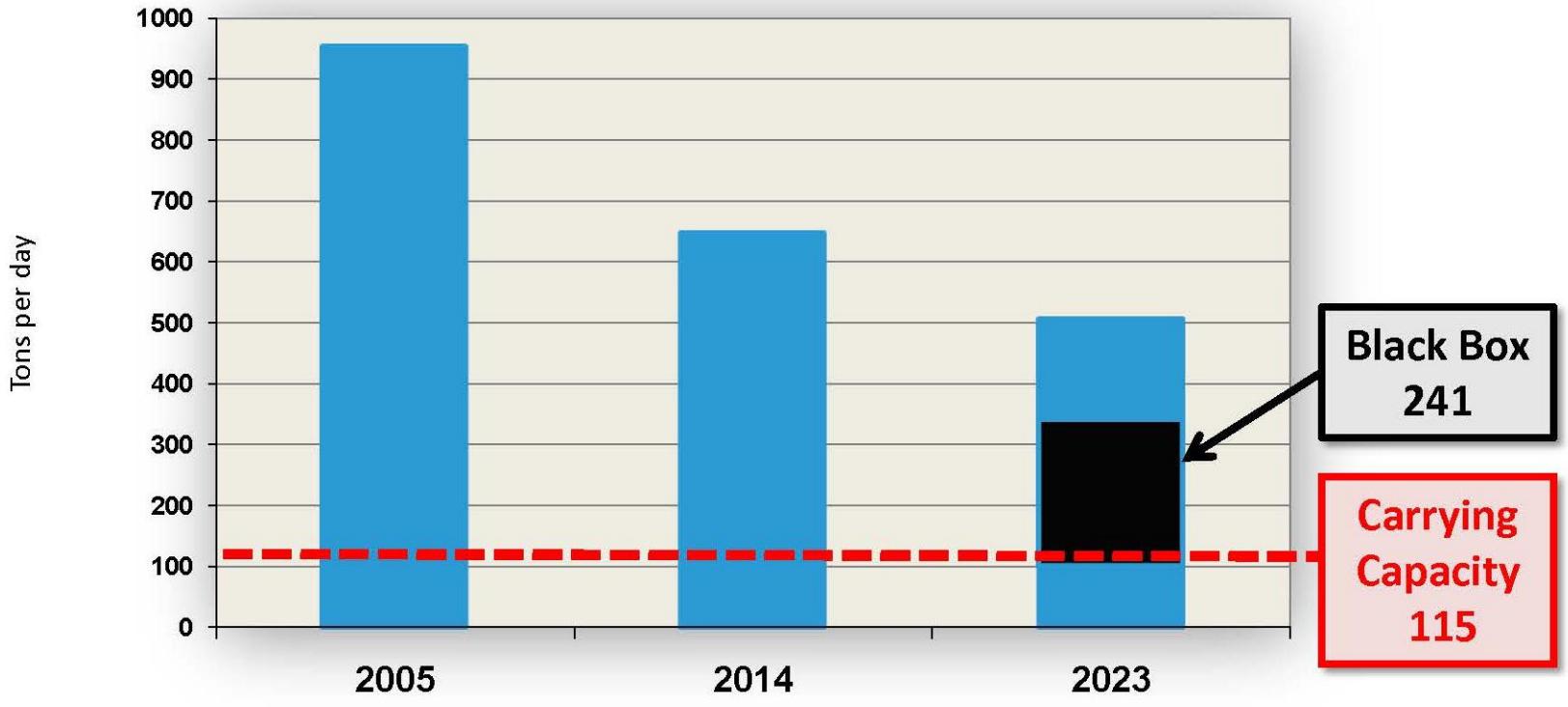




Baseline NOx Emissions and Federal 1997 Ozone Standard Carrying Capacity

Data from 2007 AQMP

Including benefits of rules adopted to 2007



Needed *Additional* NOx Reductions*

by 2023: **75%**

Is such a path
possible in the *real world*

?