Type RX Ultra-low NOx Burner

Innovative Clean Air Technology

S.T. Johnson Company

Celebrating a Century of Innovation

INNOVATIVE CLEAN AIR TECHNOLOGY

DEMONSTRATION OF AN ULTRA LO-NOx BURNER ON A FIRETUBE BOILER

A JOINT EFFORT BY:
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ALTEX TECHNOLOGIES INC, SANTA CLARA CA

WITH SUPPORT FROM:
CALIFORNIA DAIRIES INC, TIPTON CA
MOEHLMAN BOILER TECHNOLOGY, FRESNO CA
RELIABLE EMISSIONS MEASUREMENTS, FRESNO CA

WITH MATCHING GRANT FUNDS FROM:
CALIFORNIA AIR RESOURCES BOARD
INNOVATIVE CLEAN AIR TECHNOLOGY GRANT PROGRAM

The Benefits and Costs of Ultra-low NOx Emissions

Benefits:

- Smog reduction
- Acid rain reduction
- Healthier air

Costs:

- Low efficiency
- High capital cost
- High operating cost
- More maintenance
- Safety

CURRENT & PROPOSED METHODS EMPLOYED TO ACHIEVE SUB 9ppm NOx

CURRENT:

- MASSIVE FGR BURNERS
- PREMIX POROUS MATRIX BURNERS
- POST COMBUSTION TREATMENT

PROPOSED (Series RX Burner):

- MOLECULAR MODIFICATION DURING COMBUSTION PROCESS COUPLED w/ STAGED COMBUSTION & MODERATE FGR

MASSIVE FGR BURNERS

FEATURES

- CAN USE FGR FLOWS AS HIGH AS 40% OF THE TOTAL STACK EFFLUENT
- SOME SYSTEMS OPERATE VERY CLOSE TO THE LIMITS OF FLAMABILITY
- SOME SYSTEMS OPERATE WITH VERY RAPID MIXING, VERY CLOSE TO STOICHIOMETERY.

CON'S

- HIGH ELECTRICAL USAGE *(FGR fan HP doubled compared to RX system)*
- LOW TEMPERATURE, TRANSLUCENT, FLAME REDUCES HEAT TRANSFER & EFFICIENCY.
- COMBUSTION INSTABILITY
- CAN'T CHANGE FIRING RATE FAST ENOUGH TO FOLLOW CHANGING LOAD DEMANDS

PREMIX POROUS MATRIX BURNERS

FEATURES

- REQUIRES DELICATE, EXPENSIVE, POROUS MATRIX MATERIALS
- REQUIRES EXCESS AIR LEVELS AS HIGH AS 65% TO OBTAIN NOx <9ppm
- REQUIRES FILTERED AIR.
  (Matrix materials can easily become fouled)

CON'S

- HIGH ELECTRICAL USAGE DUE TO EXCESS AIR & HIGH PRESSURE DROP THROUGH SYSTEM (Fan HP >50% more than RX System)
- REDUCED EFFICIENCY DUE TO EXCESS AIR. *(73% vs. 82%)*
- DURABILITY OF MATRIX MATERIALS IS LIMITED
- MATRIX FAILURE CAN LEAD TO PROPERTY DAMGE AND PERSONNEL INJURY
- LIMITED TURNDOWN RATIO
  (MAX FUEL INPUT/MIN FUEL INPUT)
  (3:1 vs. 5.5:1 for Series RX)

POST COMBUSTION TREATMENT

FEATURES

- SCR SYSTEMS UTILIZIE EXOTIC CATALYST MATERIAL.
  (TEMPERATURES (500-850F)
  (90+% NOx REMOVAL)
- SNCR SYSTEMS OPERATE @ HIGH TEMPERATURES (1700-2100F)
  (50% NOx REMOVAL)
- CAN USE SODIUM HYDROXIDE, UREA, OR AMMONIA INJECTION.

CON'S

- HIGH UPFRONT & OPERATIONAL COSTS.
- CAN RESULT IN CHEMICAL WASTE STREAMS (e.g. SODIUM NITRATE, AMMONIA)
- REQUIRES ELABORATE SENSORS/CONTROL SYSTEM TO METER THE PROPER INJECTION VOLUMES.

RX Technology Goals: Minimize the Costs and Maximize the Benefits of Ultra-low NOx Technology

- Increase efficiency
- Lower the cost to industry
- Improve reliability
- Improve safety

Increase Efficiency

- The RX burner operates optimally with 3% O_2 in the stack. *Matrix burners typically operate with O_2 >9% resulting in efficiencies at approximately 73%. RX efficiency is approximately 82%.*
- By optimizing the combustion process we minimize FGR requirements. *Producing less NOX requires less NOx suppression.*
- Utilizing multiple stabilized flame zones improves turndown performance, typically 5.5:1 or better. *Some existing designs only operate @ 3:1, or less.*

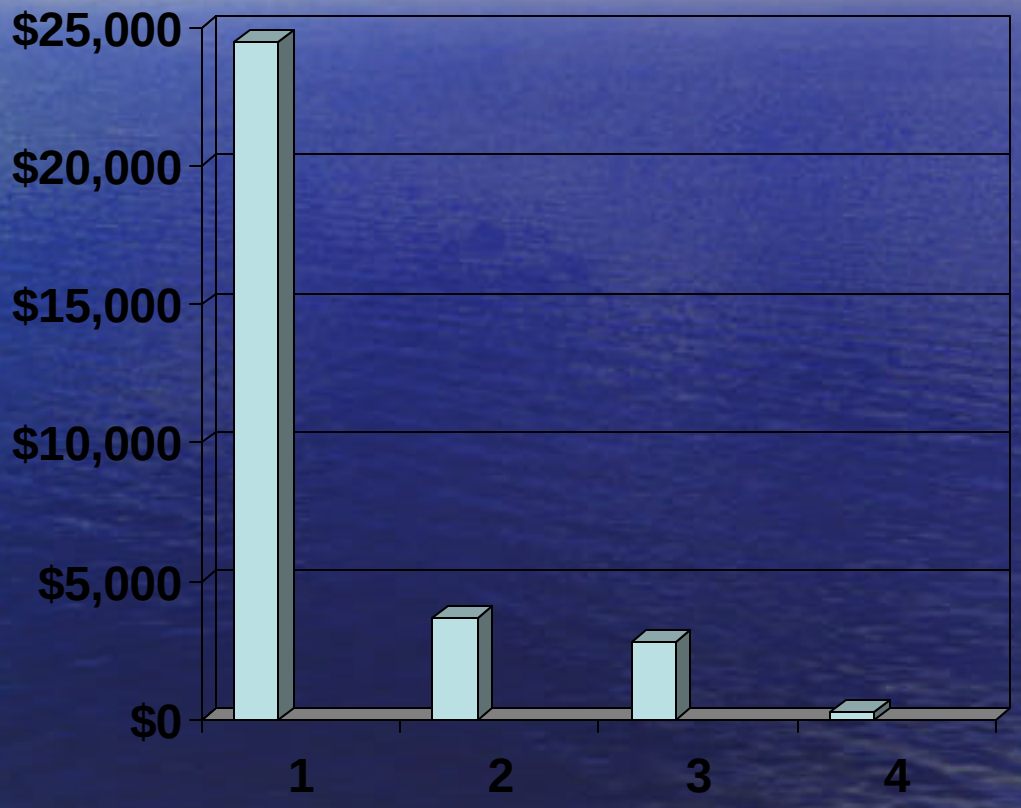
Lower Cost to Industry

- Simple durable refractory and steel construction results in:
  - Lower initial cost
  - Lower maintenance costs
- Lower operating cost
  - Less stack losses due to low excess air and low FGR requirements
  - Lower fan costs
  - Eliminates the need for chemicals & catalysts

COST/ TON NOx REMOVED

NEW BOILER SYSTEMS

- POST COMBUSTION
  $ 24500
- MASSIVE FGR
  $ 3676
- POROUS MATRIX
  $ 2787
- RX TECHNOLOGY
  $258

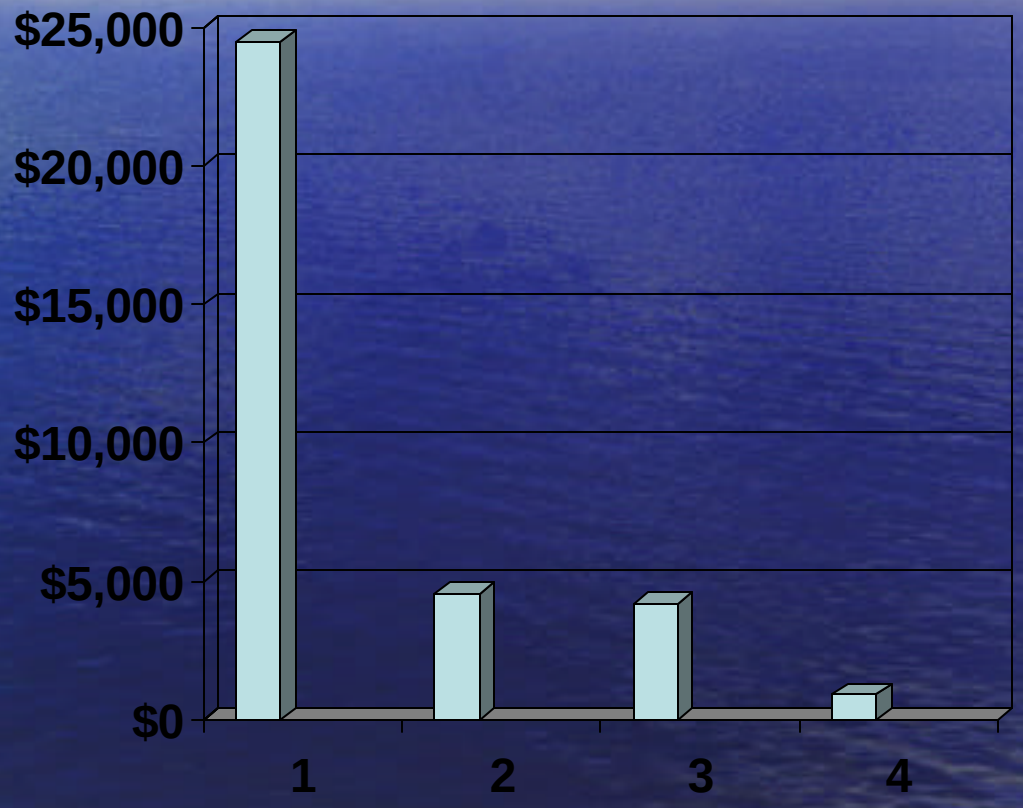


INITIAL & OPEATING COST

COST/ TON NOx REMOVED

BOILER RETROFITS

- POST COMBUSTION
  $ 24500
- MASSIVE FGR
  $ 4568
- POROUS MATRIX
  $ 4177
- RX TECHNOLOGY
  $ 889



INITIAL & OPEATING COST

Improve Reliability

- Proven durable construction over an 11 month field test.
- Good flame radiation for reliable flame detection and a high radiant heat transfer rate.
- No small orifices to get plugged with particulate matter in the combustion air.
- No ceramic fiber or metallic material to degrade.

Improve Safety

- RX provides good stability with a stable anchored flame at all firing rates and during transition. *No flame retention problems.*
- Multiple flame zones promote smooth modulation of load without instabilities, noise and flashback.
- Multiple flames zones also reduce the likelihood of destructive acoustic coupling. (*Combustion harmonics or vibrations can be destructive to equipment)*
- No requirement for an active control system. (*O_2 trim or vibration detectors)*

COMBUSTION MODIFICATION

- OVER 200 REACTIONS INVOLVING 20 DIFFERENT SPECIES OCCUR DURING THE COMBUSTION PROCESS

- THE MOST USEFUL COMPONENTS FOR OUR PROCESS ARE:

  PARTIALLY OXIDIZED FUEL

  (CHi, CO & SOOT)

  AMINES SPECIES

  (NHi)

- THESE COMPONENTS ARE FORMED IN THE COMBUSTION PROCESS IN A REDUCING ATOMOSPHERE. *Stoichiometry <.6*

COMBUSTION MODIFICATION

- **NOx FORMATION**

$N + O \longrightarrow NO$

$N + OH \longrightarrow NO + H$

- **NOx REDUCTION**

$CH + NO \longrightarrow HCN + O_2$ (Reversible)

$CH_2 + NO \longrightarrow HCN + OH$ (Reversible)

$C + NO \longrightarrow CN + O_2$

$NH_i + NO \longrightarrow N_2 + H_2O$

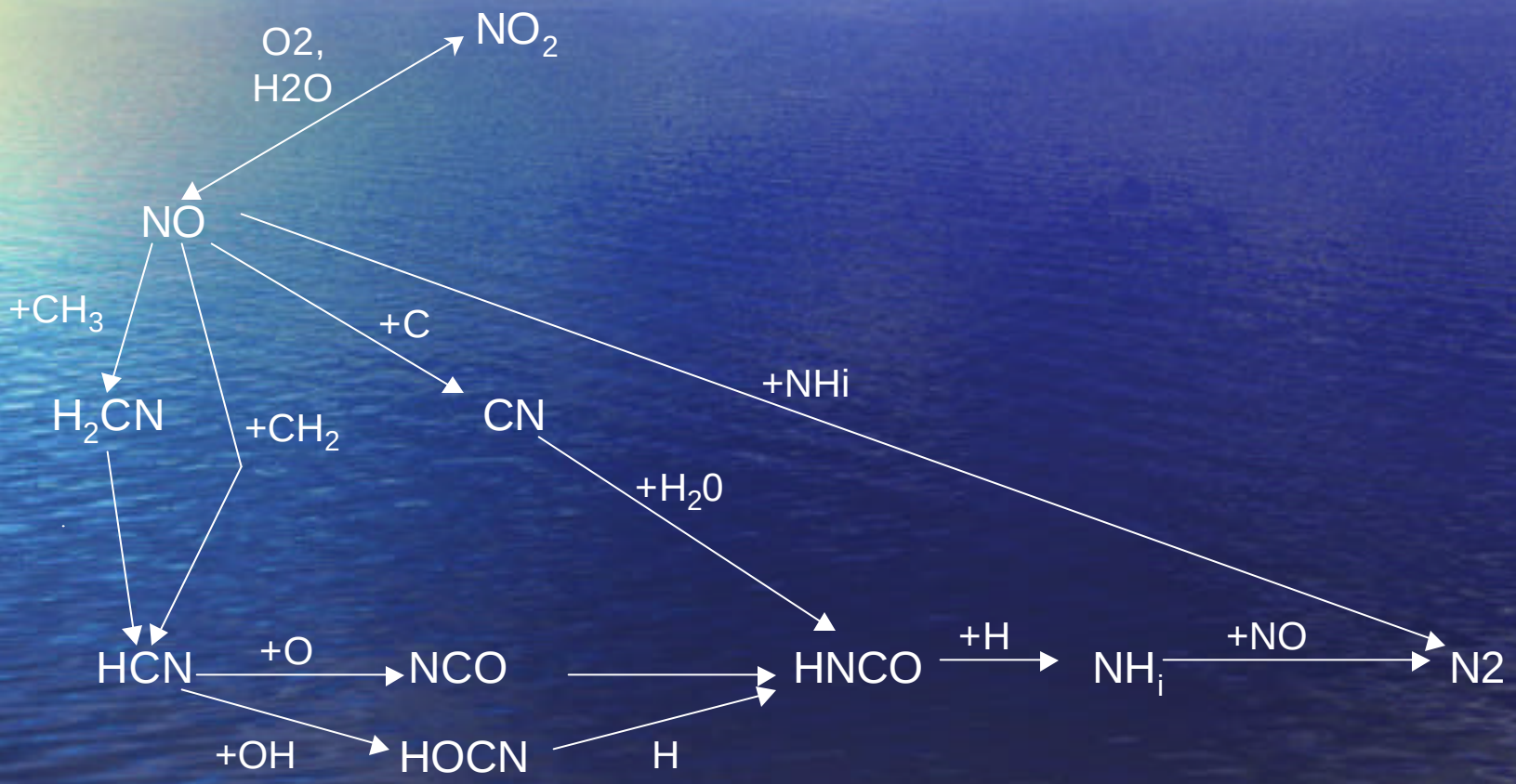
THESE NOx REDUCTANTS ARE FORMED BY PARTIAL COMBUSTION IN A REDUCING ATMOSPHERE

THE INTERMEDIATE SPECIES, HCN & CN, ARE CONVERTED TO N2, CO2 & H2O IN THE FINAL BURNOUT ZONE

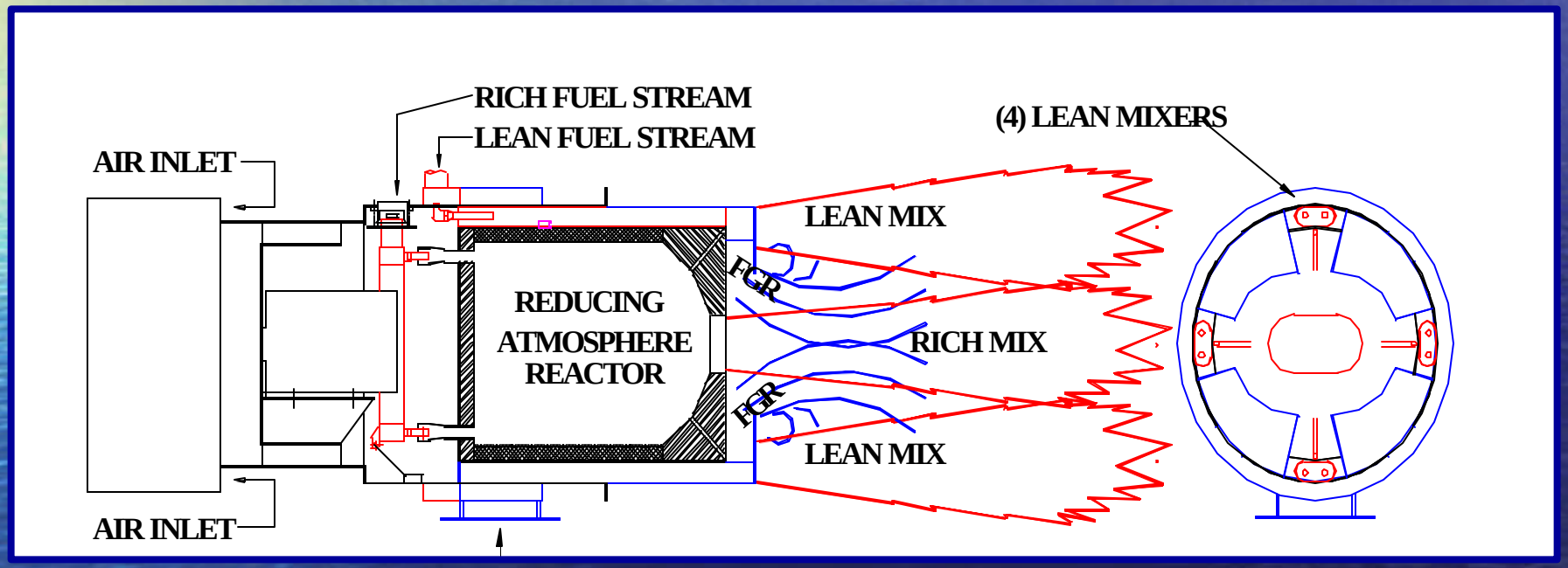
PROMPT NOx

- Rapid Formation <1ms.
- Little affect from temperature.
- Presence of CHi & HCN during initial combustion can contribute to prompt NOx formation in an oxidizing environment, but will inhibit NOx formation in a reducing environment.
- Presence of C & NHi in initial combustion process reduces the formation of prompt NOx.
- Reactor combustion is controlled to a stoichiometry <.6 and a temperature <2400F.

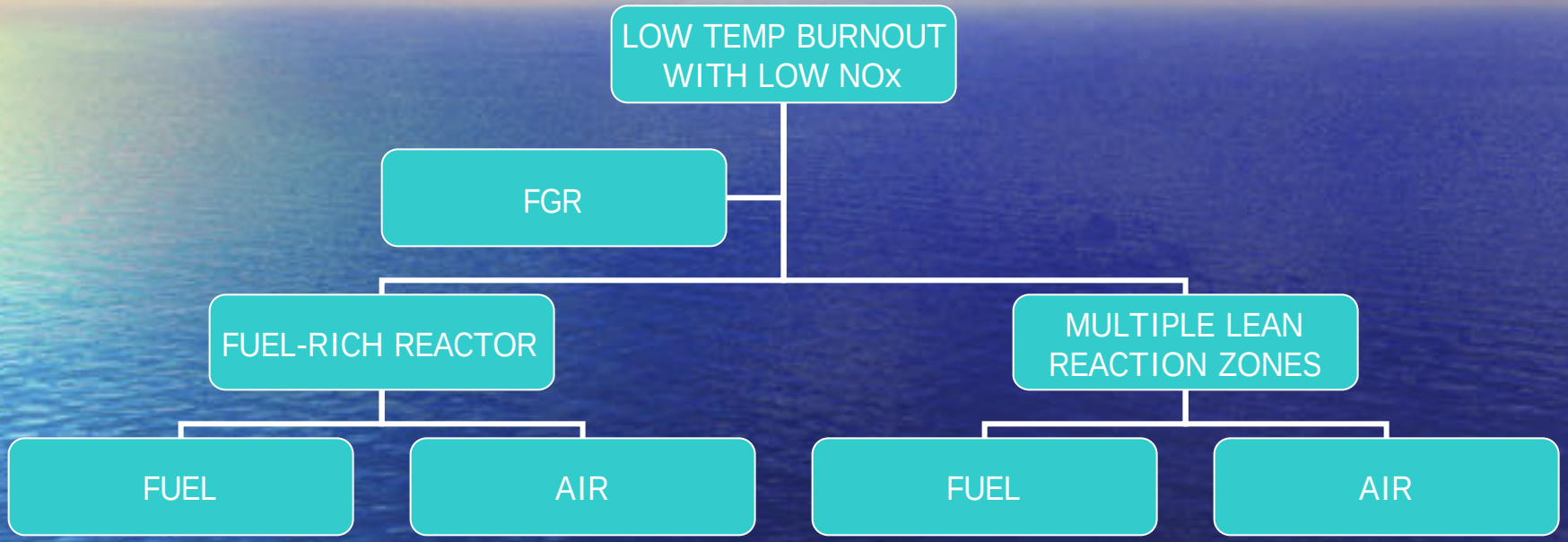
PROMPT NOx


O2,
H2O
NO_2
NO
$+CH_3$
H_2CN
$+CH_2$
+C
CN
+NHi
$+H_20$
HCN
+O
NCO
HNCO
+H
NH_i
+NO
N2
+OH
HOCN
H

Type RX Cross-sectional View



Type RX Ultra Reduced NOx Burner Process



- Rich Reactor produces hydrogen, CO and NOx reducing nitrogenous species.
- Combines with the Lean Combustion products in the lower temperature Burnout Zone.
- Results in stable combustion with low NOx emissions and good CO burnout.

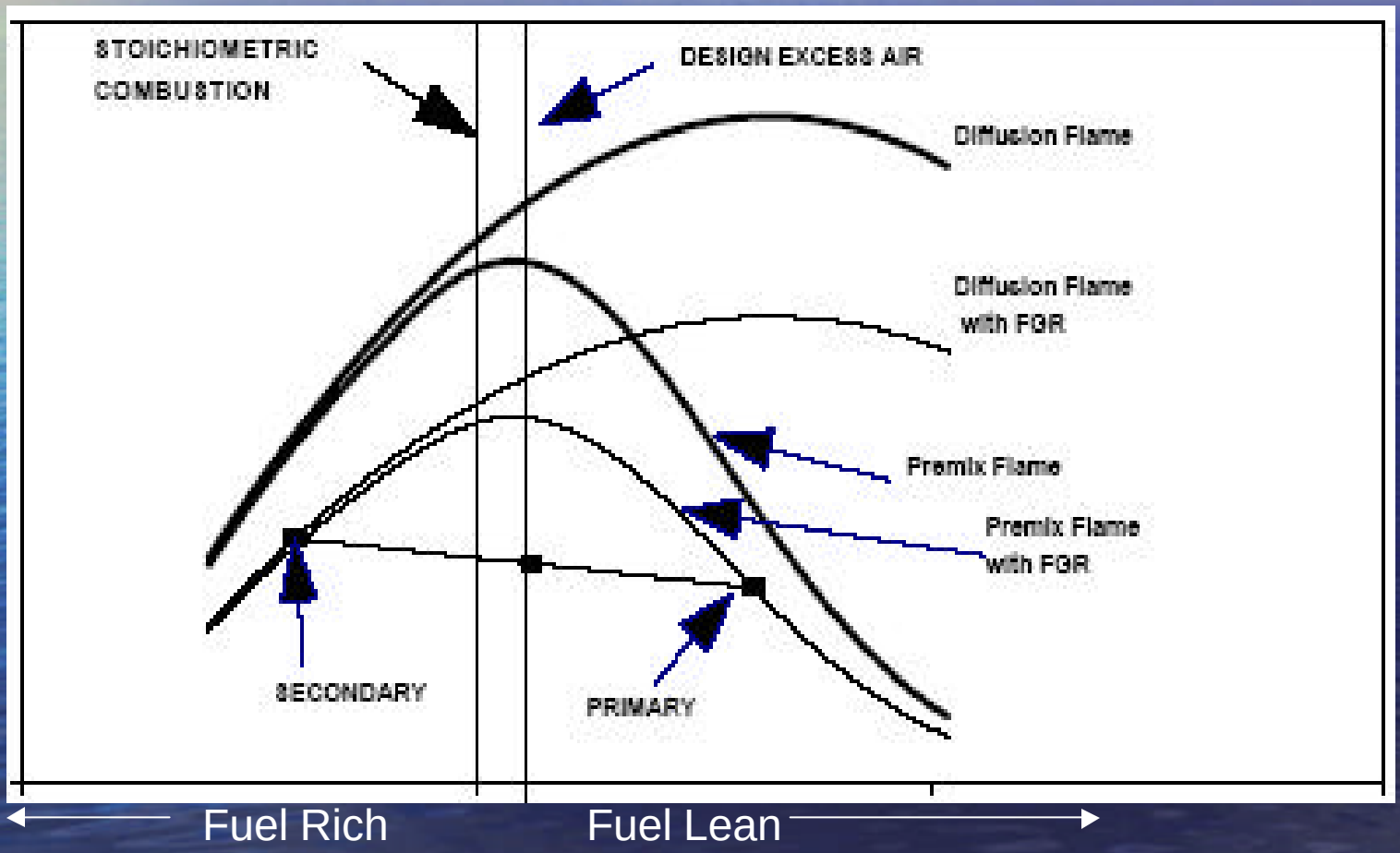
Fuel Modification “Rich Reactor”

- Stabilizes combustion through early recirculation of hot products to the reactants.
- Controls the production of prompt NOx and the reduction of nitrogenous species (e.g. HCN, CN, NHx, NOx) back to molecular nitrogen.
- Converts natural gas to mainly HCi, NHi, CO and soot which all have a reducing affect on NOx molecules.
- Good flame radiation for reliable flame detection using standard flame detection equipment.

The Lean Reaction Zone

- Lean premixed flames minimize NOx:
  - Excess air suppresses thermal NOx production
- Stabilized and continuously ignited by gases directed from the Rich Reactor.
- Excess oxygen promotes final CO burnout.
- Flames quickly transfer heat to the furnace section with no negative quenching effect, because the lean premix flames have little CO or HC content.
- High exit velocity generates gas recirculation zones near the face of the burner.

NOx Formation vs. Stoichiometry



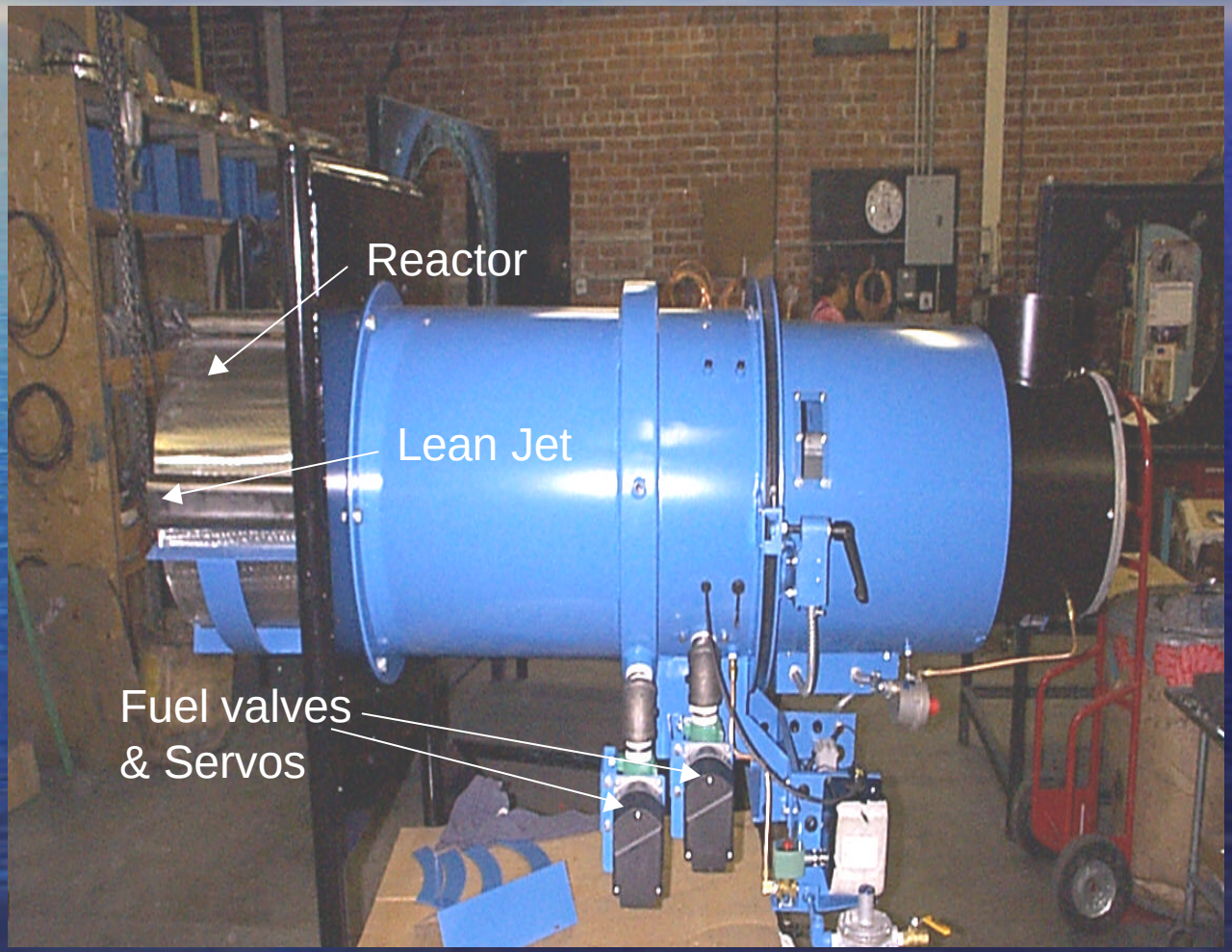
The Final Burnout Reaction Zone

- Products of the Rich and Lean Reactors combine for good CO burnout.
- Amine species, CO and soot exiting the Rich Reactor reduce thermal NOx produced in the burnout reaction zone for very low final levels.
- The relatively low temperature of the burnout zone inhibits thermal NOx production.
- 10-25% FGR is introduced to further reduce Burnout temperature if NOx requirement <20ppm.
- Soot burns to produce a strong radiation for good radiant heat transfer.

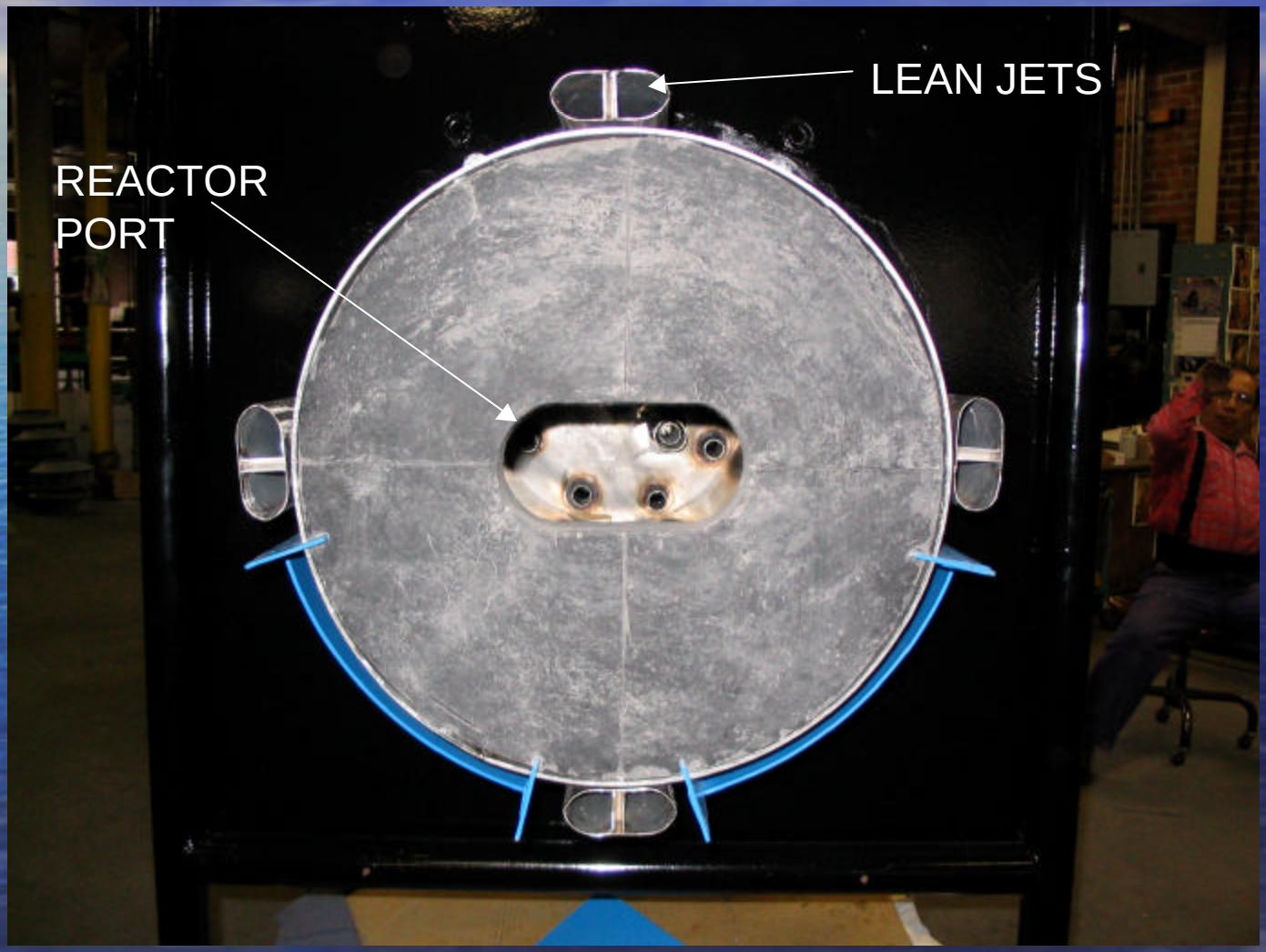
The Result: Single Digit NOx

- Sub-20 ppm NOx without FGR.
- Single digit NOx with 15 to 25% FGR.
- Suitable for all firetube boiler applications.
- Adaptable to watertube boiler applications.

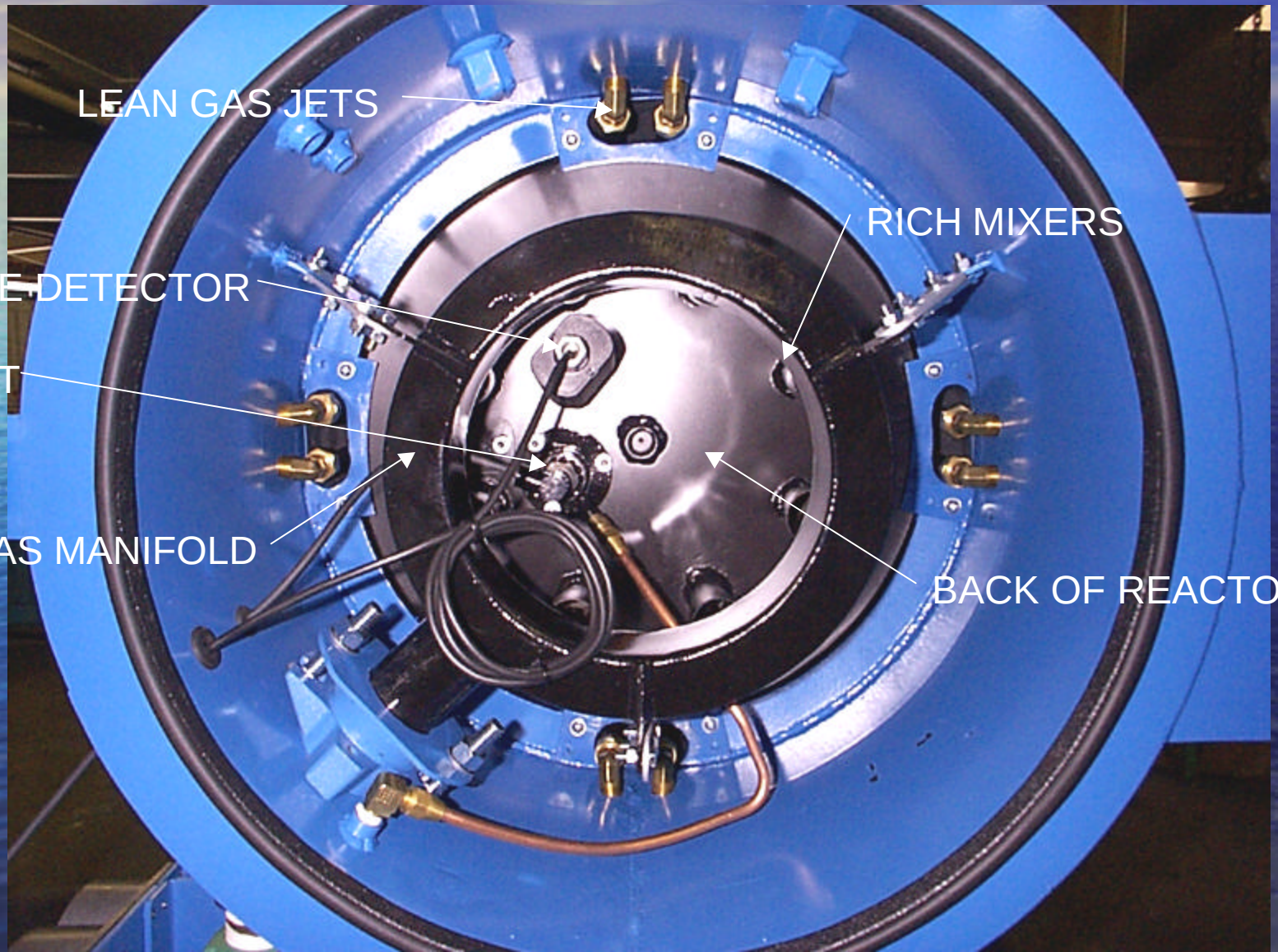
TYPICAL COMPONENTS



TYPICAL COMPONENTS



TYPICAL COMPONENTS



Existing 30ppm LO-NOx System

Existing Emissions & Goals

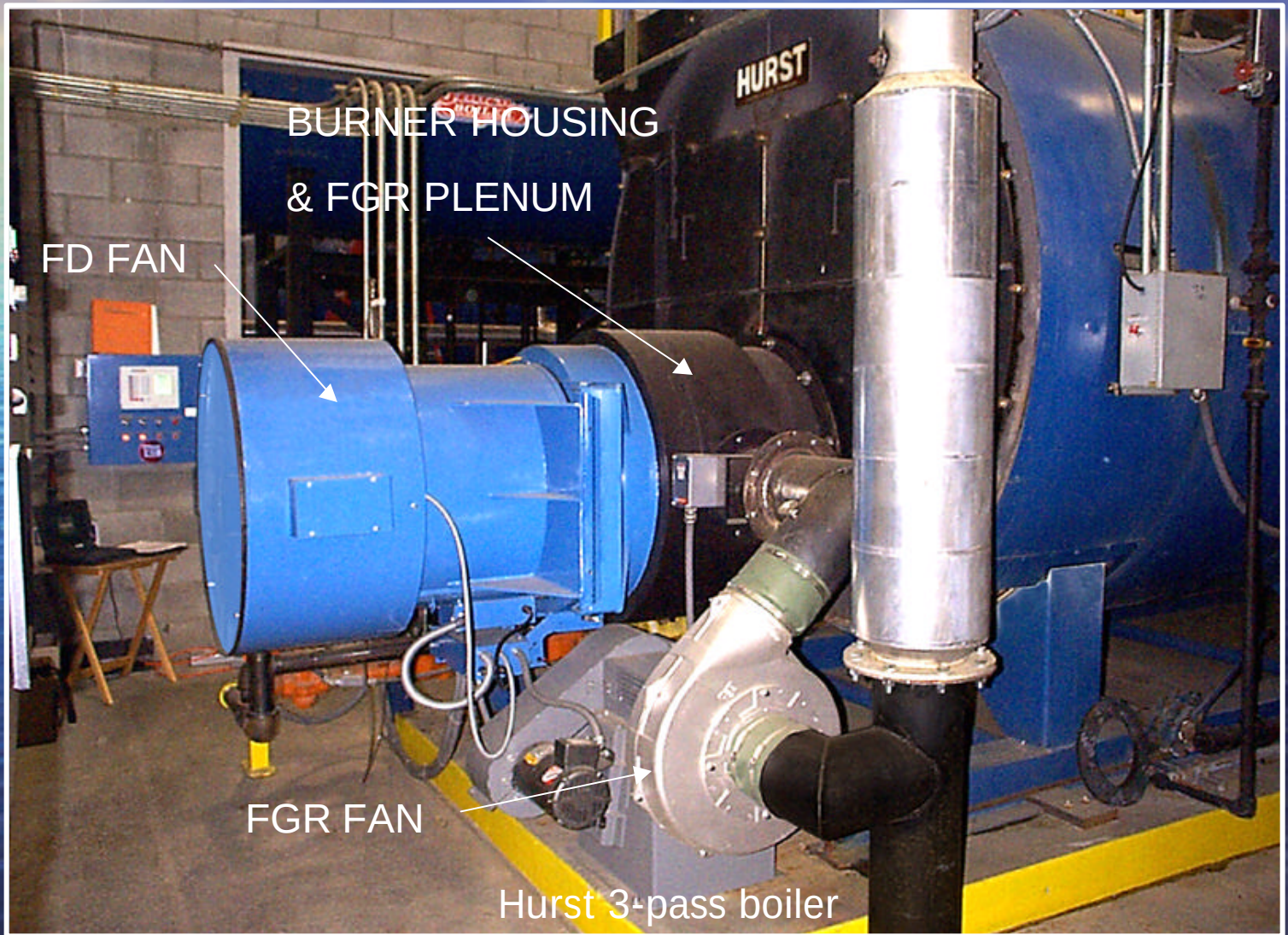
Emission	Existing	Proposed
NOx ppm@3% O2	25.3	5 - 6
CO ppm@ 3% O2	70.2	<50
Stack O2, %	6.2	2.5 – 3.2

Reduce NOx by 75%

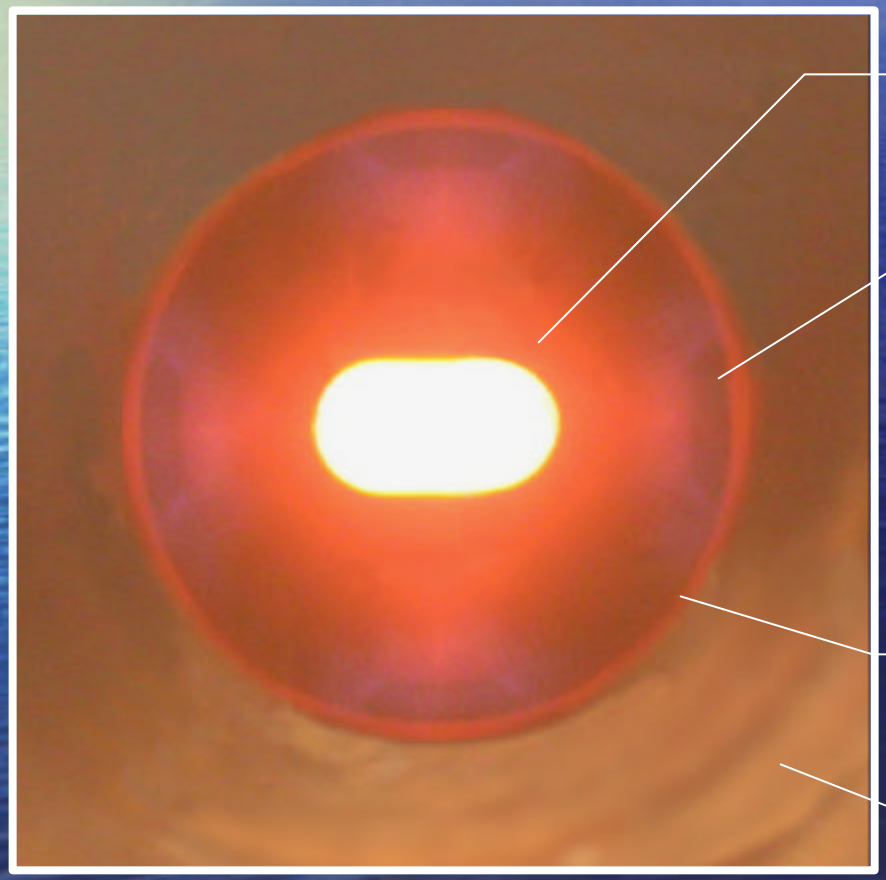
Reduce O2 by 48 - 60%

Reducing O2 from 6% to 3% saves this customer 273 CFH of nat gas

500HP INSTALLATION



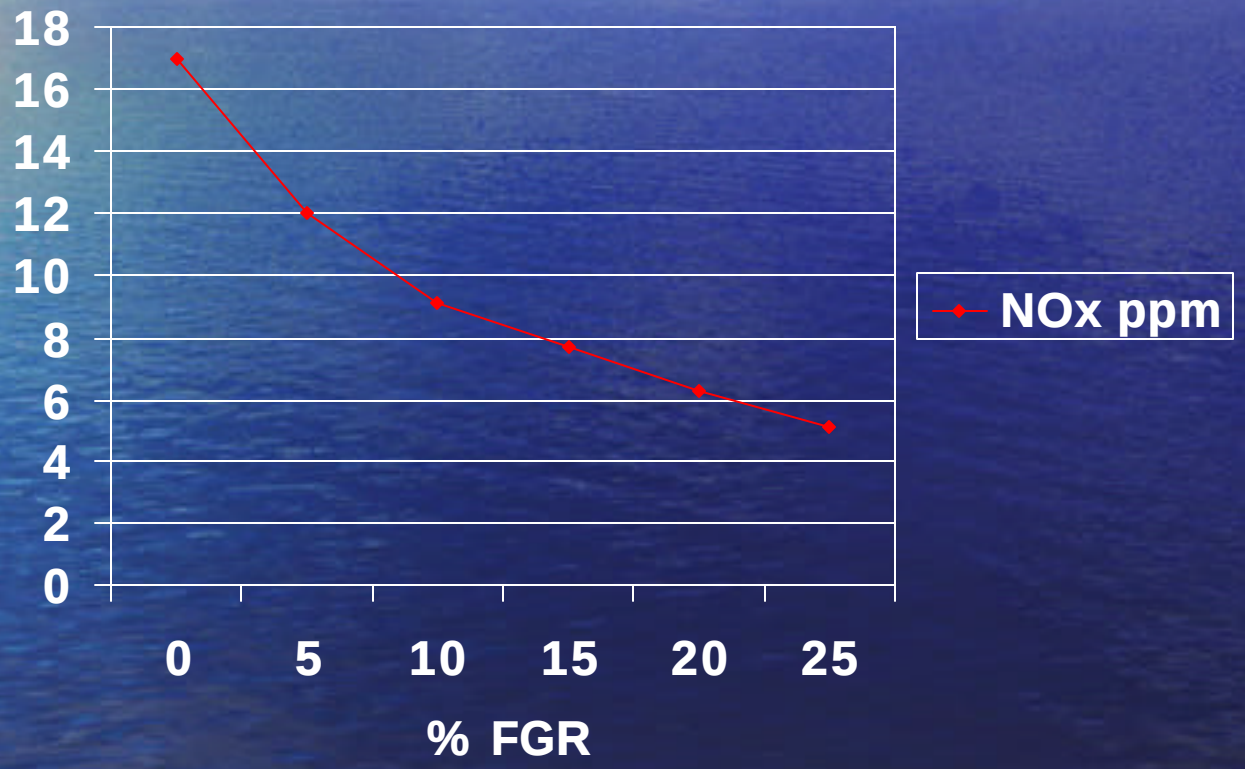
A Look Down the Furnace



THE NUMBERS

	MIN	INT 1	INT 2	MAX
INPUT CFH	3721	5187	10707	20190
O2 %	3.5	3.2	3.2	3.0
CO PPM @ 3% O2	75	45	20	0
NOx @ 3% O2	6.0	5.1	5.0	6.2

Affect of FGR



Summary of the Technology

- The RX burner brings NOx suppression and NOx reduction technology together in a single design.
- Generates several reaction zones in which NOx control is balanced with important combustion characteristics such as low CO and HC emissions, low noise and high stability.
- Features simple yet durable construction for a lower initial cost and a lower cost of ownership.
- Provides conventional burner performance with single-digit NOx emissions.

Any Problems?

- You bet!
- After 10 months of tracking emissions data –
- The initial source test was not passed.
- The reason –
- Faulty feedback drive on the air damper servomotor.

Have the Goals Been Met?

- Several prototypes and nearly $900,000 has validated the technology.
- Laboratory-proven at 25HP, 100HP & 300HP.
- Field-proven at 500 HP, in constant operation since May 2003:
  - Emissions goals met
  - Good stability with low noise levels
  - Optimum performance found between 2 and 3% O_2
  - 5.5:1 turndown ratio with smooth modulation
  - Good structural integrity
- Lower cost relative to other technologies.

THE AFTERMATH

- This project has led to a 20 year licensing agreement to utilize the technology in the production of sub 15ppm & sub 9ppm industrial combustion systems.
- The product received an honorable mention award at the 2004 AHR Expo for most innovative product.
- Several systems have been purchased; the first has been installed in the San Diego area and is scheduled for commissioning in April 2004.
- Development of smaller, sub 20ppm & sub 15ppm, systems is currently being considered.

Thank you
California Air Resources Board

Johnson Burners