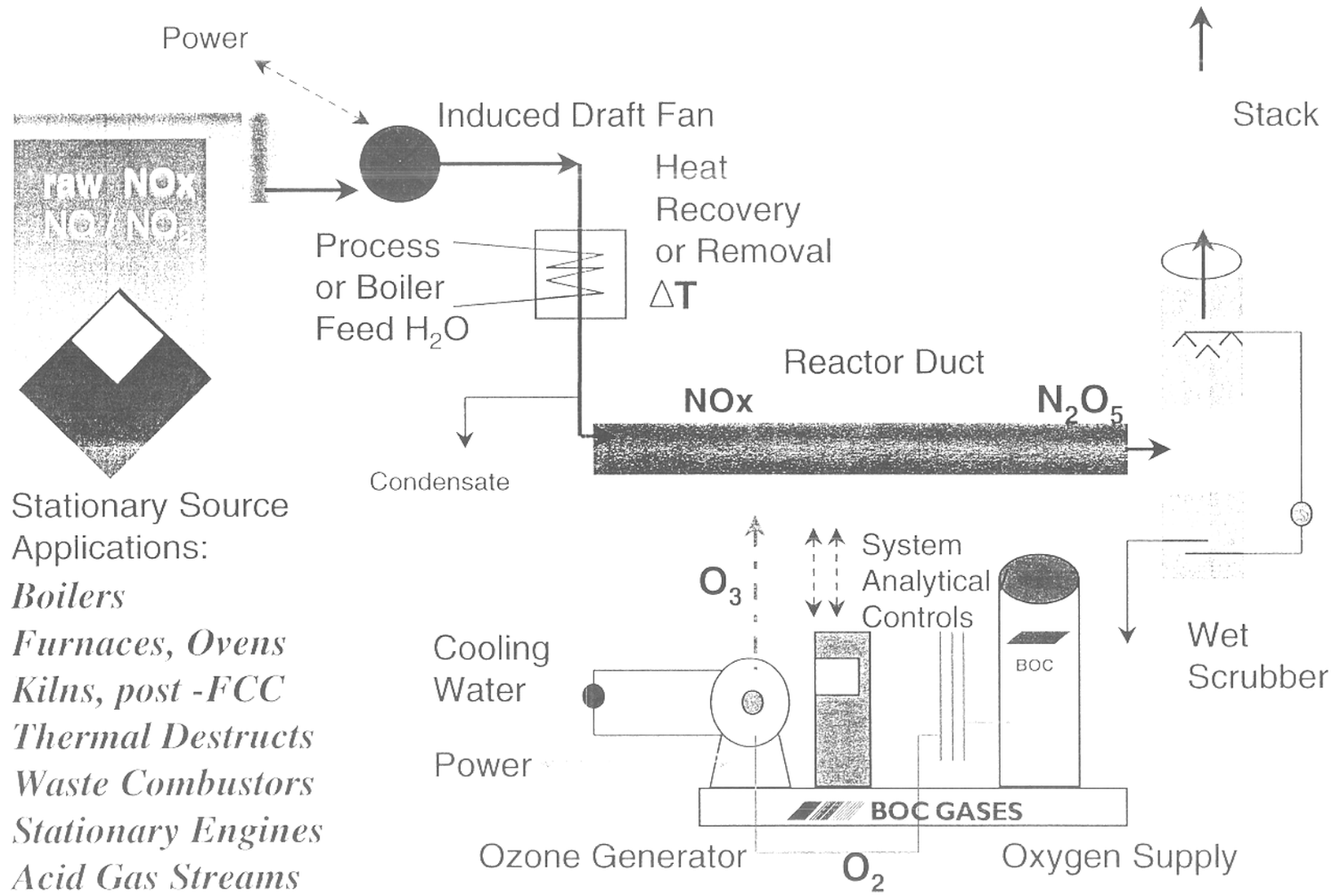
BOC GASES

The BOC Gases LoTOx™ System

Low Temperature Oxidation - Schematic



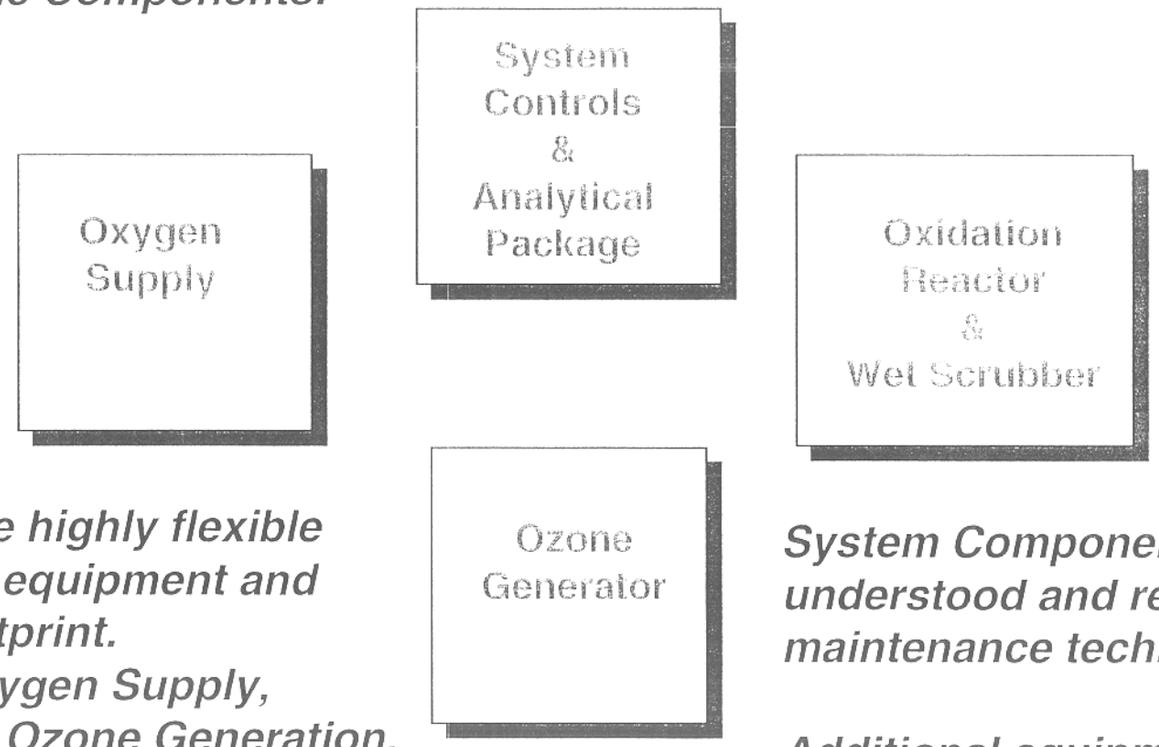
Stationary Source Applications:

Boilers
Furnaces, Ovens
Kilns, post -FCC
Thermal Destructs
Waste Combustors
Stationary Engines
Acid Gas Streams
CO2 Recovery Plants

Stand-Alone Post Combustion system or Hybrid w/SOx Removal, w/SCR, or w/SNCR systems, or combustion modifications

LoTOx Packaged and Modular-packaged Systems

Regardless of the NOx Source Type, the LoTOx System consists of the Same Basic Components:



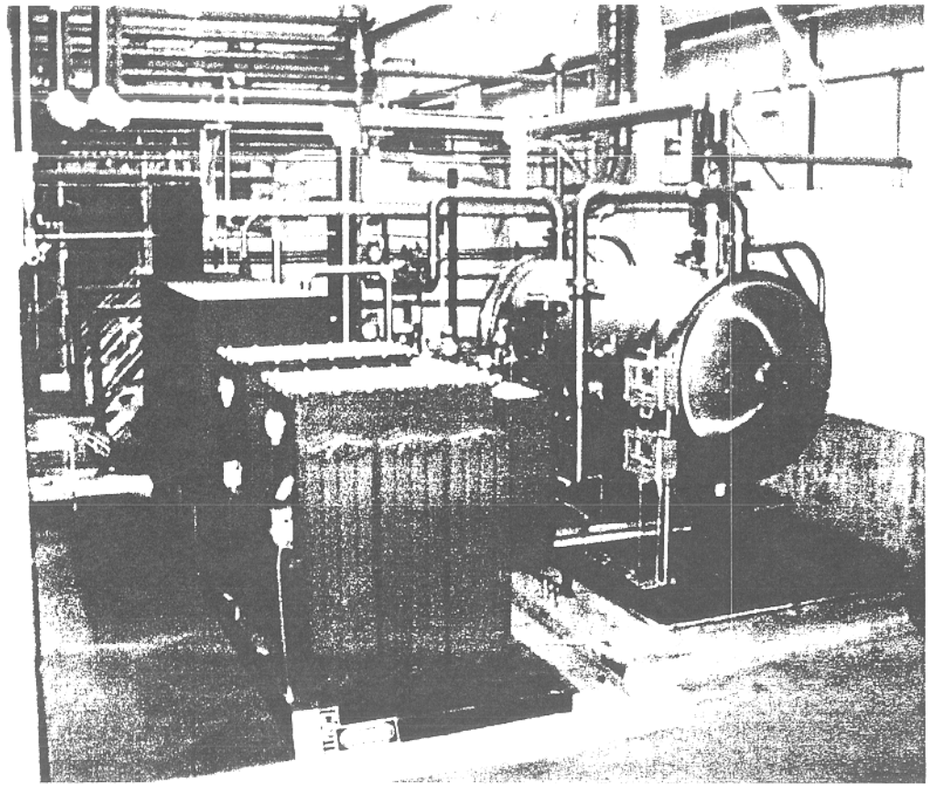
Systems are highly flexible in layout of equipment and over-all footprint.
Mode of Oxygen Supply, Capacity of Ozone Generation, and Sophistication of Control can vary to meet specific customer needs.

System Components are well understood and reliable, low maintenance technologies.

Additional equipment may be needed in some applications.

LoTOx™ System Ozone Generator

BOC LoTOx™ System



A 3400 pound per day ozone generator
LoTOx System for an acid process application

An Ozone Generator (shown here) is used to produce ozone from gaseous oxygen.

Ozone is injected into the waste gas stream to oxidize NOx that is in an insoluble form. Once *oxidized,* NOx is *highly soluble* and can be easily removed by wet scrubbing.

Ozone production is a safe and robust technology, that has replaced chlorine for treatment of drinking water, pools, waste water, and pulp & paper.

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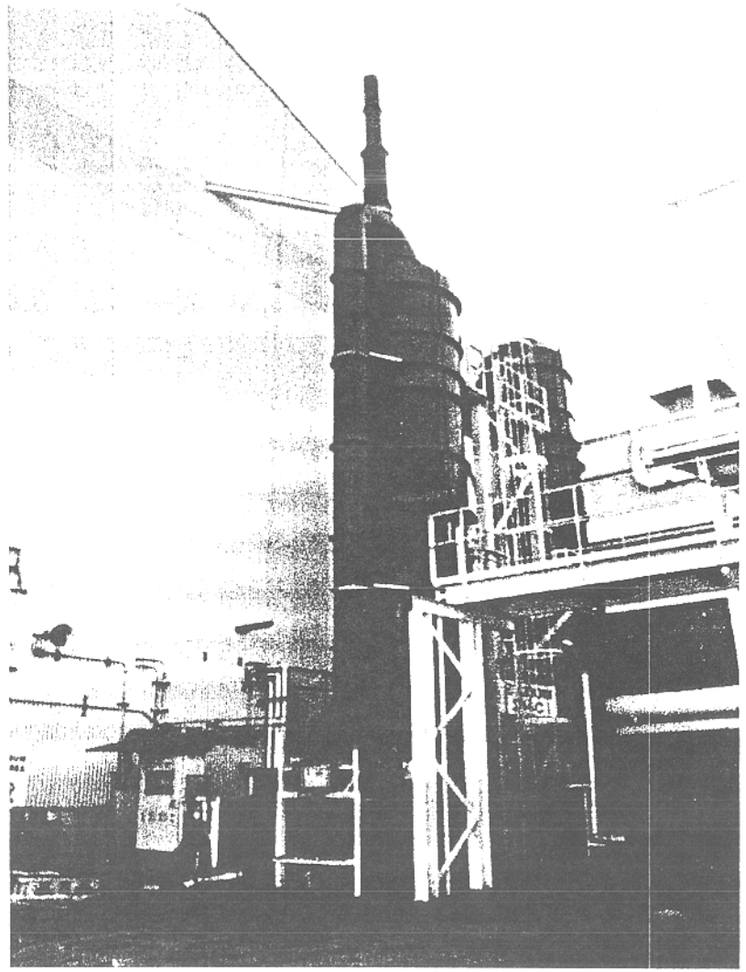
LoTOx System - Scrubber and Reaction Duct



BOC LoTOx™ System

The LoTOx System consists of:

- Oxygen Supply
- Ozone Generator
- Oxidation Reactor Duct (Shown here)
- Aqueous Scrubber (Shown here)
- Analytical and Control Equipment

The low temperature process allows:

- Heat Recovery, Fuel Savings
- Optimal Plant Efficiency
- Maximum NOx Removal
- Multi-Pollutant Control
- Consistent Treatment under highly variable process conditions.
- Flexible System, Space Saving Layout

The LoTOx System makes wet scrubbing highly effective for NOx removal.

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LoTOx™ System Chemistry

Low Temperature Oxidation of NOx by Injection of Ozone = O_3

rate (k) = cm^3/molecule/sec @ 298 K

$NO + O_3 \longrightarrow NO_2 + O_2$ ($k = 1.8 \times 10^{-14}$)

$2\,NO_2 + O_3 \longrightarrow N_2O_5 + O_2$ ($k = 3.5 \times 10^{-17}$)

$CO + O_3 \longrightarrow CO_2 + O_2$ ($k = 1.1 \times 10^{-21}$)

$SO_2 + O_3 \longrightarrow SO_3 + O_2$ ($k = 2.2 \times 10^{-22}$)

Ozone is highly selective for NOx over other species in the gas stream due to the rapid rate of reaction -
NOx is rapidly converted to highly water soluble species ...
These compounds are easily absorbed by aqueous scrubbing:

$N_2O_5 + H_2O \longrightarrow 2\,HNO_3$ (liquid phase)

Moisture in the waste gas stream drives the reaction to completion.
Aqueous acids formed in the scrubber can be used as process water or neutralized by addition of dilute NaOH.

Source: Journal of Physical and Chemical Reference Data

OXIDATION POTENTIAL OF STANDARD OXIDANTS

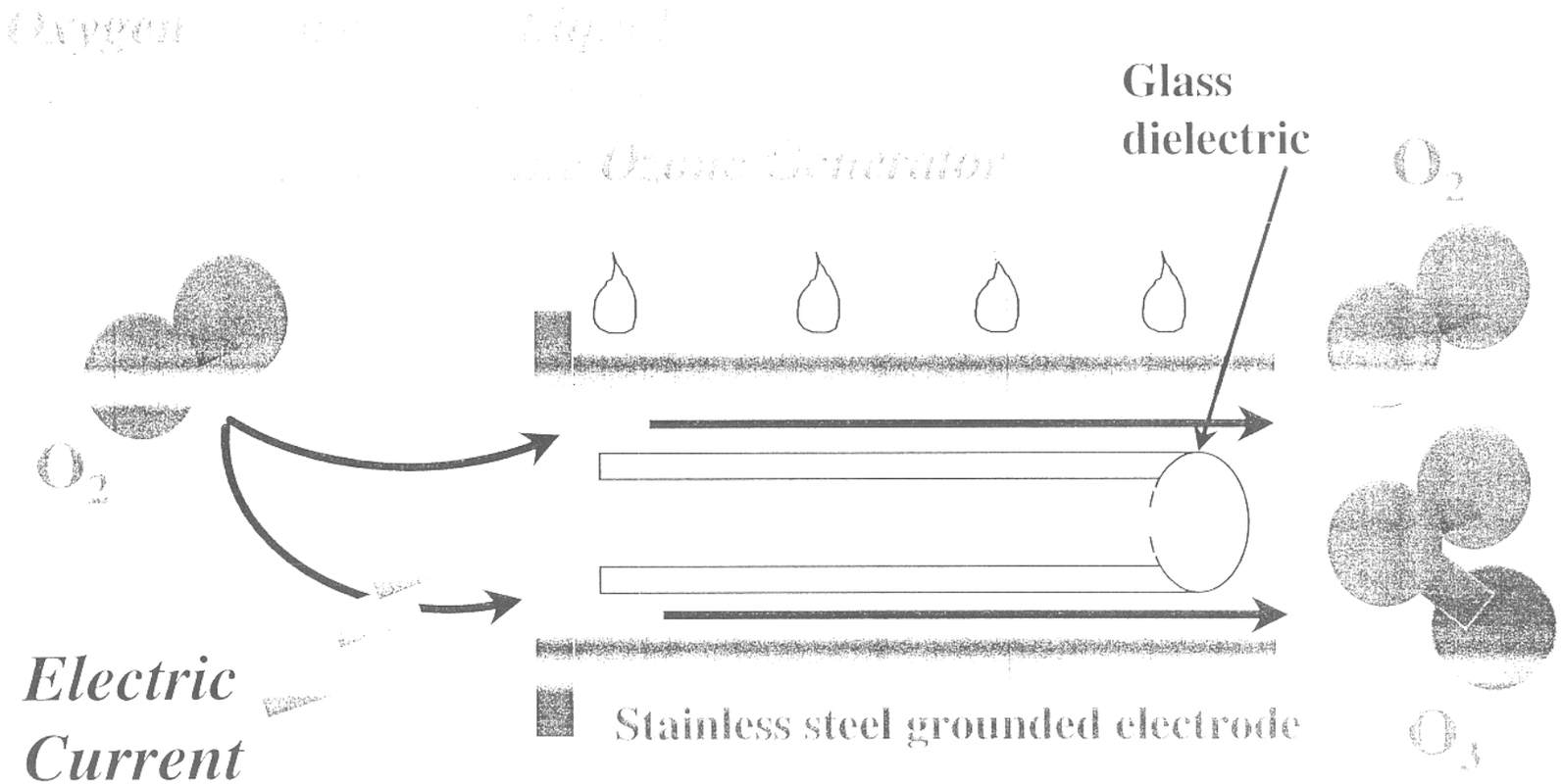
Ozone is a highly efficient treatment chemical for oxidation reactions:

OXIDANT	*OXIDATION POTENTIAL VOLTS*	*OXIDATION POWER (Relative to Chlorine)*
Fluorine	3.06	2.25
*Hydroxyl Radical	2.80	2.05
*Atomic Oxygen	2.42	1.78
Ozone	**2.07**	**1.52**
Hydrogen Peroxide	1.77	1.30
Permanganate	1.67	1.22
Hypochlorous Acid	1.49	1.10
Chlorine	1.36	1.00
Bromine	0.78	0.57

*These species are formed when ozone decomposes in water

Ozone is the optimum treatment chemical for oxidation of NOx

Ozone Production



Cross-Section of a single Ozone Generator Cell

An Ozone Generator is a high tech, tube & shell heat exchanger

Ozone is produced as O2 passes through the corona discharge.

BOC LoTOx™ System - Mobile Demo Trailer

Uses:

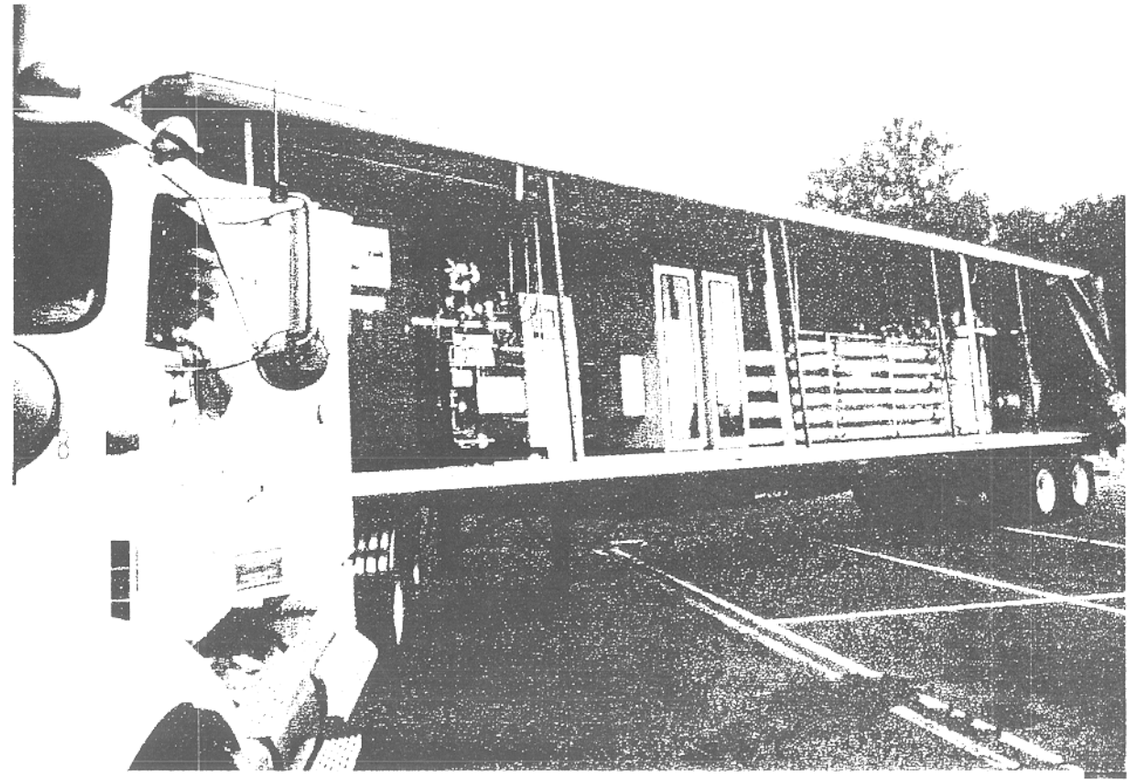
To *evaluate* new types of process gas streams

To *demonstrate* New Applications

To *provide customers wit*l Convincing demo using data from the customer's waste gas stream

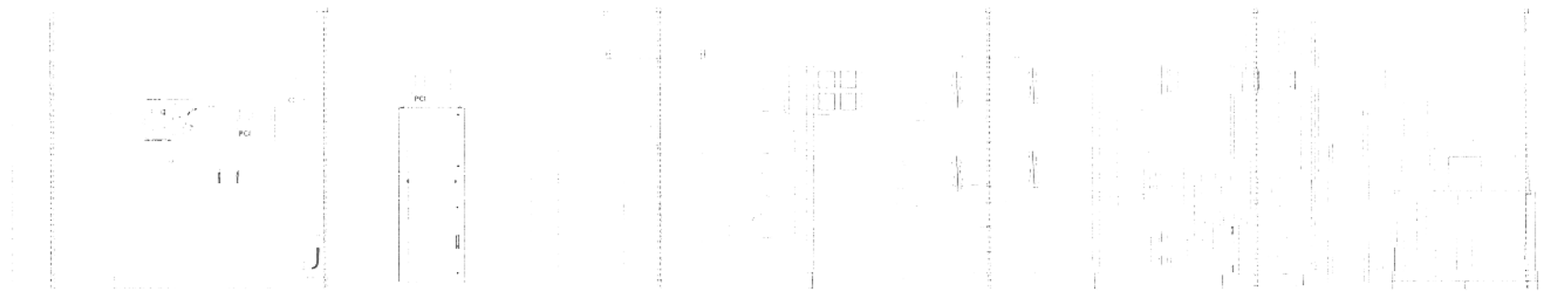
To *provide reliable systen sizing & performance dat*a for system design and process scale up

To *provide* analytical & performance verification capability



The LoTOx Mobile Demo Trailer - Pilot Scale Testing

BOC GASES LoTOx DEMONSTRATION TRAILER



SIDE VIEW

LAYOUT VIEW

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LoTOx™ System Low Temperature Oxidation Demonstration Trailer Schematic

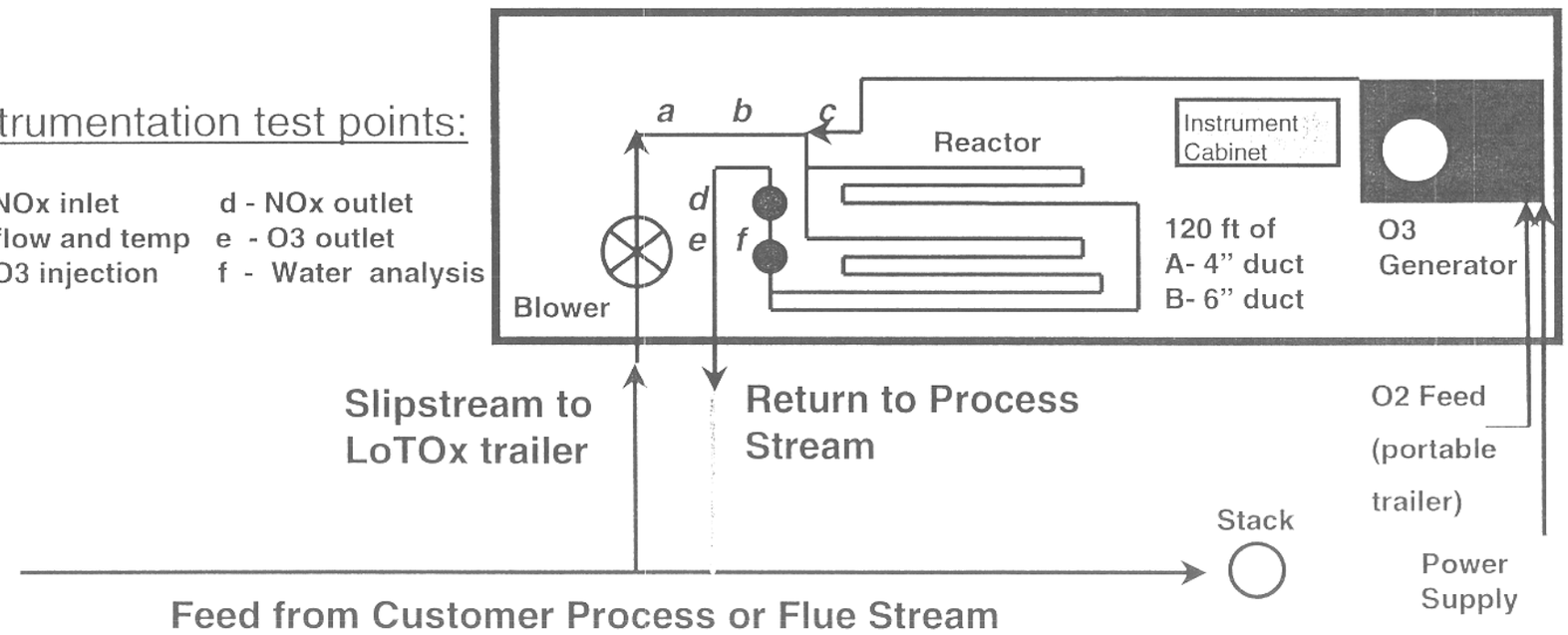
Test Conditions:

Used for Multiple NOx Sources, Characterize variable NO/NO2 ratios
Has handled inlet NOx levels ranging from 200 to over 4500 ppm inlet
Can demonstrate consistent control with highly variable instantaneous levels
Outlet NOx controlled to <10-200 ppm
Used for scale up, process development
Used for Proof of Concept, Technology / Application Verification

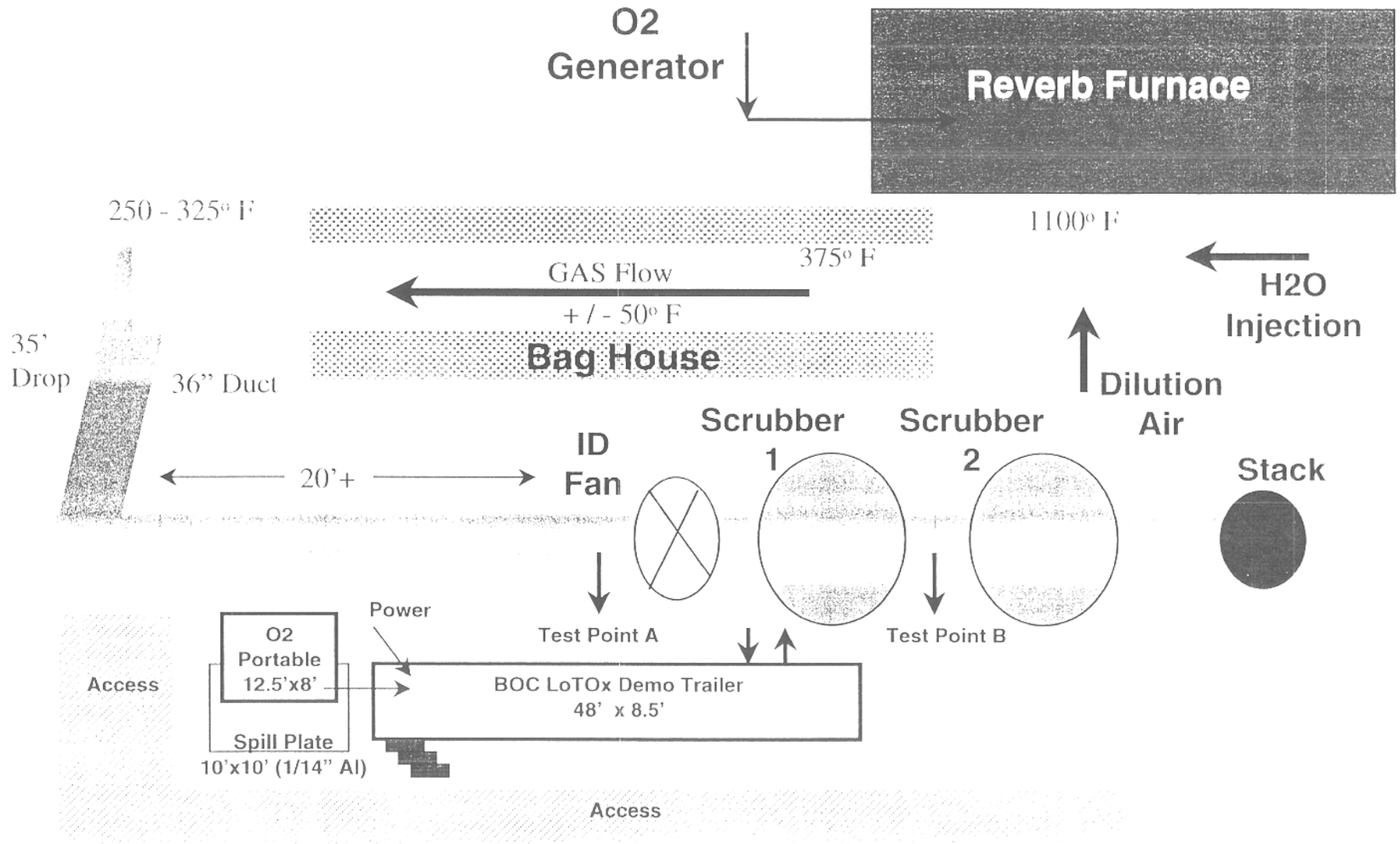
BOC LoTOx Mobile Demonstration Trailer

Instrumentation test points:

a - NOx inlet
b - flow and temp
c - O3 injection
d - NOx outlet
e - O3 outlet
f - Water analysis



RSR Quemetco, City of Industry, CA (Existing EQ)
Demo Trailer Proposed Location



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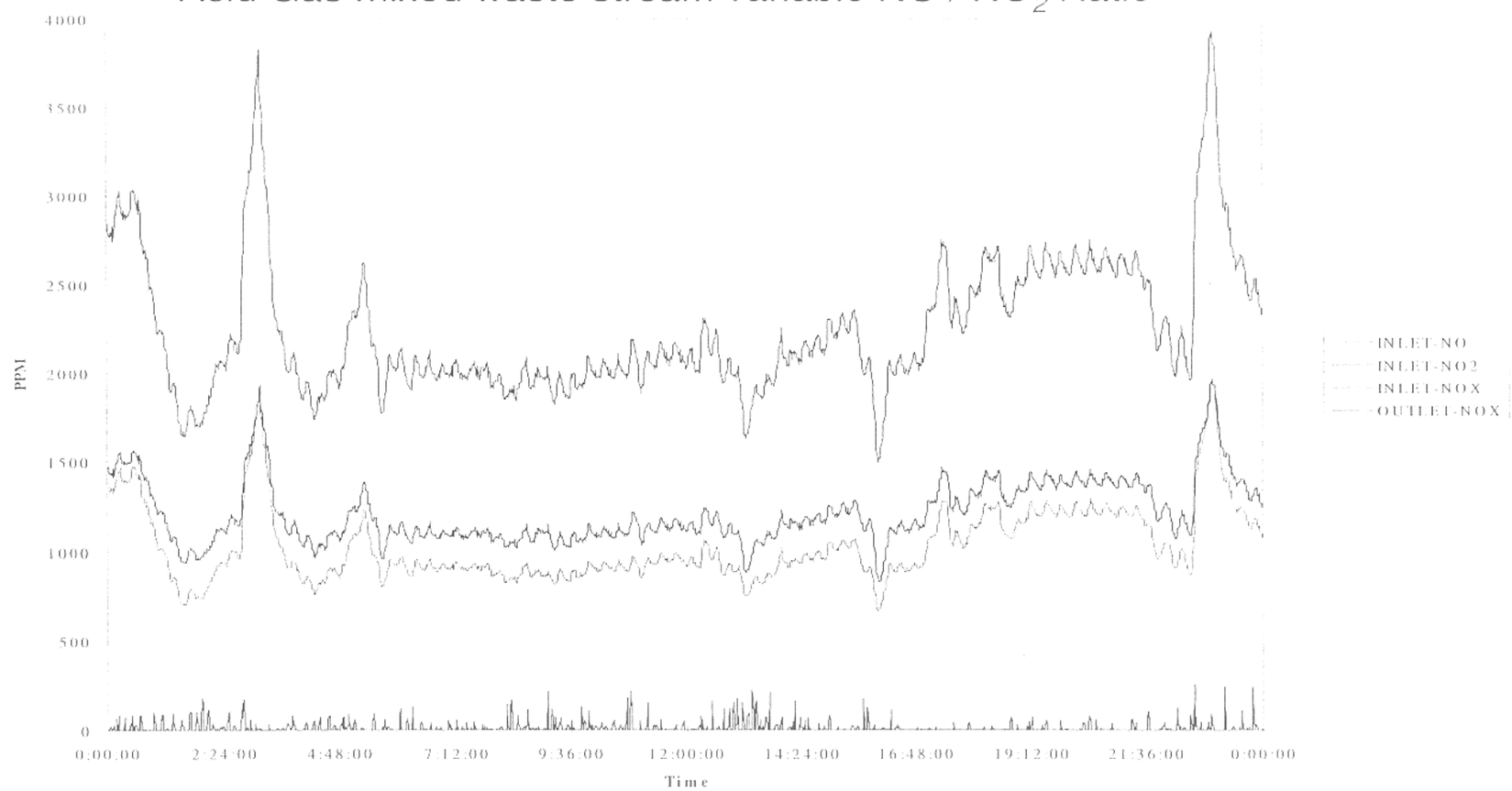
RSR Sample Test Protocol

Run No.	Temp, F	InletNOx, ppm	Residence Time, sec	GasFlow, acfm	% NOx Removal
A1	150	as is	4	133	4 increments 80%-95%
A2	150	as is	2	265	4 increments 80%-95%
A3	225	as is	4	118	4 increments 80%-95%
A4	225	as is	2	236	4 increments 80%-95%
A5	150	280	4	133	4 increments 80%-95%
A6	150	280	2	265	4 increments 80%-95%
A7	225	280	4	118	4 increments 80%-95%
A8	225	280	2	236	4 increments 80%-95%
B1	150	as is	4	133	4 increments 80%-95%
B2	150	as is	2	265	4 increments 80%-95%
B3	225	as is	4	118	4 increments 80%-95%
B4	225	as is	2	236	4 increments 80%-95%
B5	150	280	4	133	4 increments 80%-95%
B6	150	280	2	265	4 increments 80%-95%
B7	225	280	4	118	4 increments 80%-95%
B8	225	280	2	236	4 increments 80%-95%

LoTOx Low Temperature Oxidation System Performance
Industrial Process NOx Control

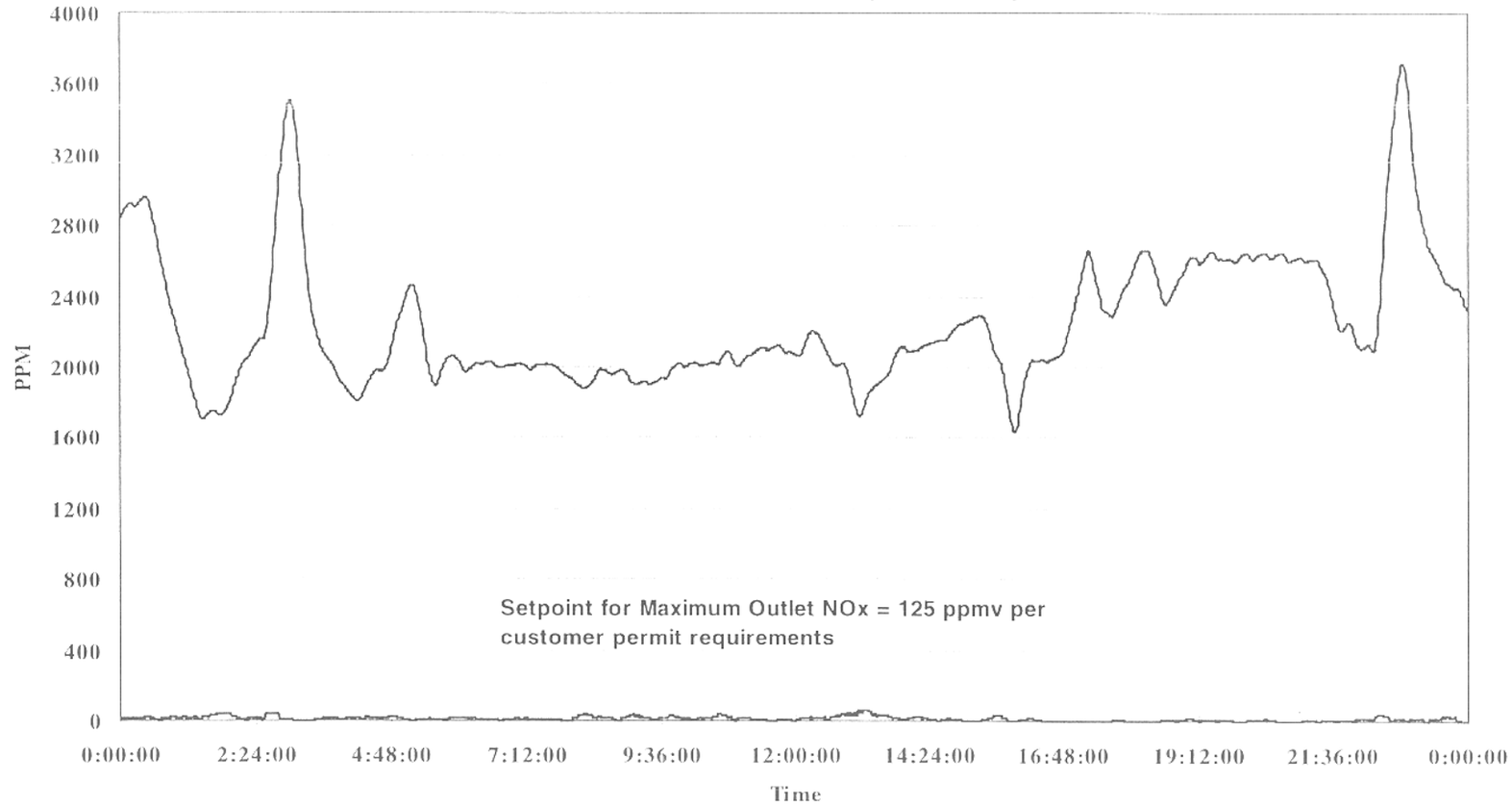
Acid Gas mixed waste stream variable NO / NO_2 Ratio



LoTOx Low Temperature Oxidation System Performance
Industrial Chemical Process NOx Emissions

AVG INLET-NOX
AVG OUTLET-NOX

15-Min Running Average
Inlet & Outlet NOx vs Time (24 hours)



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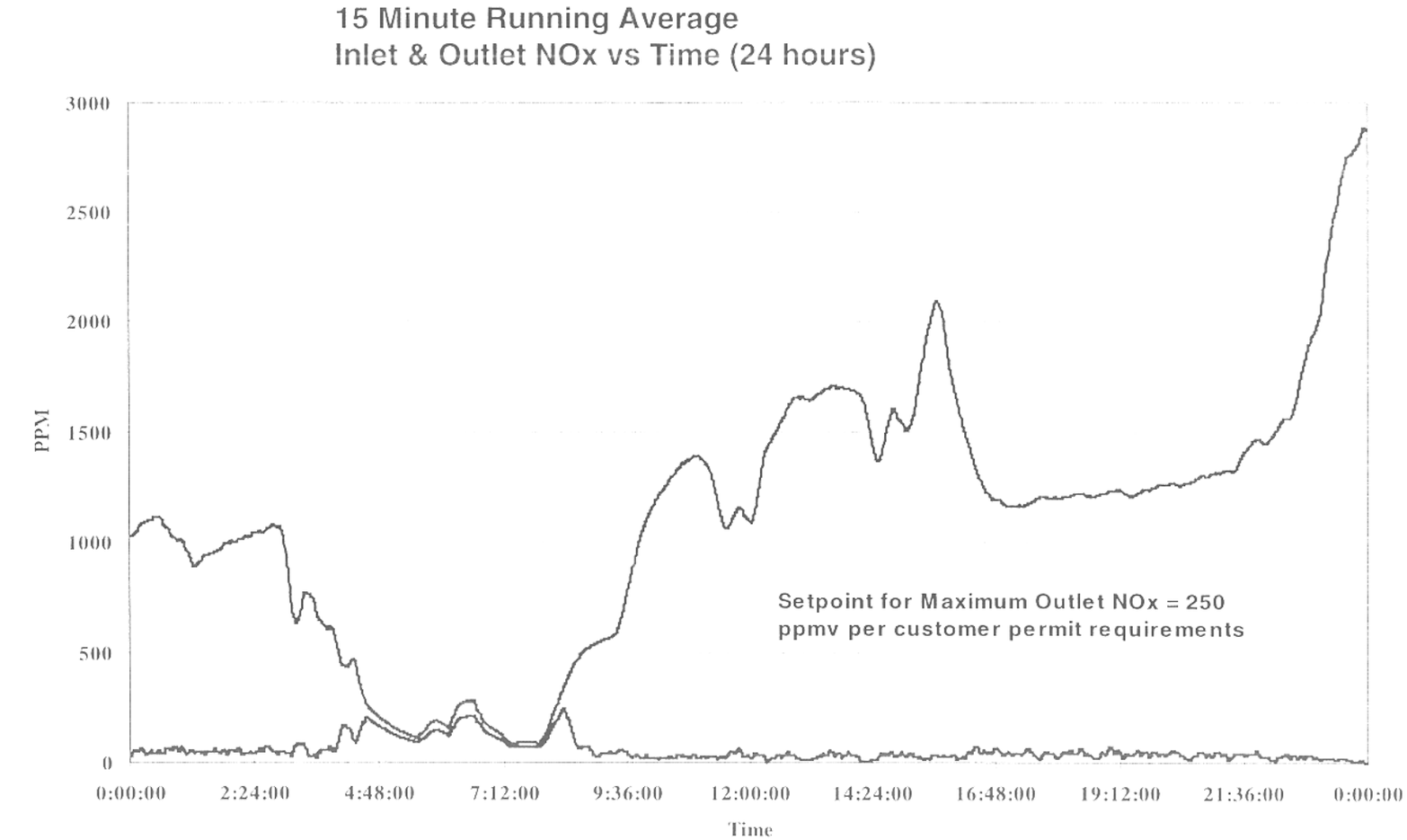
LoTOx Low Temperature Oxidation System Performance
Industrial Chemical Process NOx Emissions



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