CATALYTIC OXIDATION TECHNOLOGY TRANSFER PROGRAM

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US Army, Research Development and Engineering Command

Report Documentation Page

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

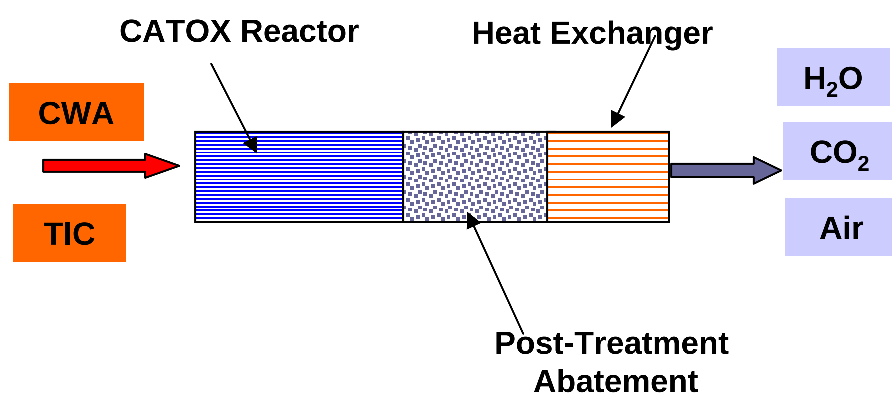
Overall Objective

- Design, construct and evaluate a catalytic air purification system for collective protection applications
  - Demonstrate Broader Protection of Catalytic versus Single Pass Filtration Technology
  - Optimize Power, Weight and Size of Catalytic Process

Approach

-Incorporate commercial/newly developed catalysts for chemical, biological and TICs destruction (leverage w/ Advanced Adsorbents Program)

-Establish design relationships for predicting system size and energy requirements for potential applications



Program Leverage

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DARPA Investment

TECHNOLOGY READINESS LEVELS

- identification and evaluation of acid gas abatement strategies

ECBC/INDUSTRY

COLLABORATION

LAB-SCALE TESTING (COMPONENT)

- evaluation of commercial catalysts

SYSTEM-SCALE TESTING

- evaluation and optimization of catalyst system components
- integration of system components
- determine size and energy requirements of scalable AP system

DARPA Investment

– Objectives

- Technology maturity level/Technology readiness level
- Applicability/relevance to DoD CB Defense Acquisition Program
- Potential to mature for evaluation in field environment
- Availability of other funding to leverage Technology Transition investment
- Availability to government of data bases, methodology details, and design concepts

Chemical delivery sensitivities

- Single pass filters have their capacity defined in terms of CT (conc x time).
- This is a misleading indicator for CATOX.
- CATOX challenges must be as close to the application's threat to account for performance sensitivities to:
  - # of attacks
  - Dosage per attack
  - Peak concentration
  - Frequency of attacks
- CATOX systems can succeed or fail for a given CT if any of these variables are changed.

Benefits

Current filter technology

- limited capacity for agents that are removed by chemical reaction and/or weakly adsorbed
- minimal protection versus several of the toxic industrial chemicals (TICs)
- prolonged environmental exposure has been shown to reduce the capacity of these filters for agents that are removed by chemical reaction

Catalytic oxidation

An alternative air purification technology

(1) broad and universal protection against the chem-bio threat,
(2) reduced logistics due to long operational life,
(3) greatly increased capacity for CB agents and TICs compared to current NBC collective protection technologies and
(4) lower energy costs relative to other regenerative filtration technologies.
(5) Catalytic oxidation is a destructive technology, converting CB agents and TICs to CO_2 (catalysts exist that are capable of decomposing nitrogen-containing compounds with minimum NOx formation), H_2O and haloacids (should halogens be associated with the parent compound).

Challenges

- Issues
  - Toxic By-products
  - Catalyst Stability
  - Energy
  - Post treatment
- State of the Art
  - High activity
  - Stable catalysts
  - NO_x, acid retention
  - Improved acid abatement technologies

- **Mitigation of reaction product emissions**
- **Maximize heat recovery to minimize energy utilization**

Material Development

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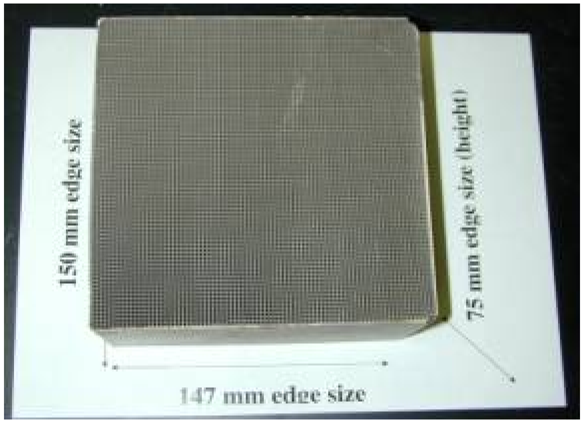
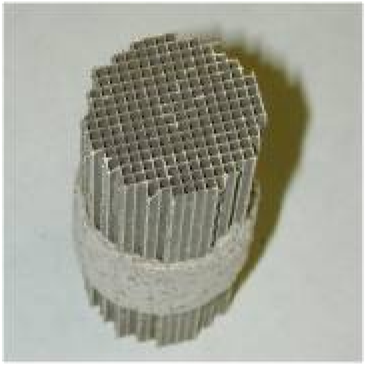
-Incorporate commercial/newly developed catalysts for chemical, biological and TICs destruction





Downselect (light-off curves and selectivity)

Monolithic Bed Catalyst Suppliers

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Manufacturer	Catalyst Designation	Cell Density
Engelhard Corporation	Engelhard Catalyst	200 Cells/in^2
United Emissions Catalyst	NB001-73-01	200 Cells/in^2
United Emissions Catalyst	NB001-73-02	200 Cells/in^2
Sud Chemie Prototech	LS02-03145	400 Cells/in^2
Sud Chemie Prototech	Misc-03144	400 Cells/in^2
Guild Associates	No-NO_x	400 Cells/in^2
Guild Associates	3X	400 Cells/in^2
Johnson Matthey	CatalyK6 Sample	400 Cells/in^2

Lab-scale results

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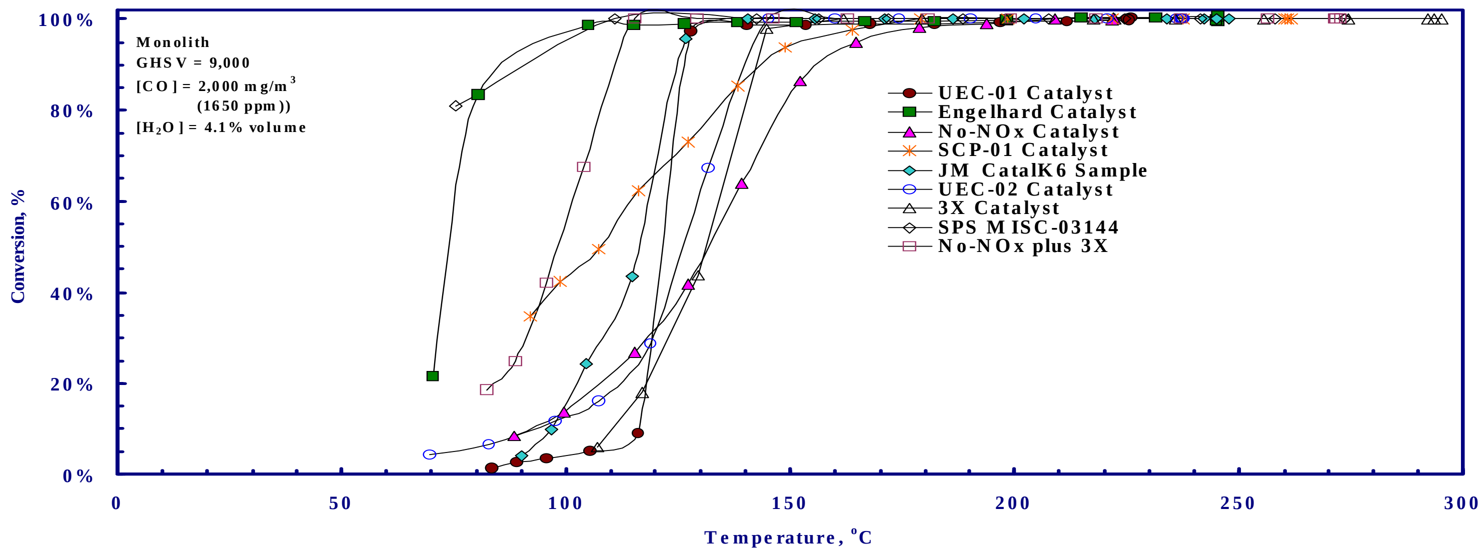
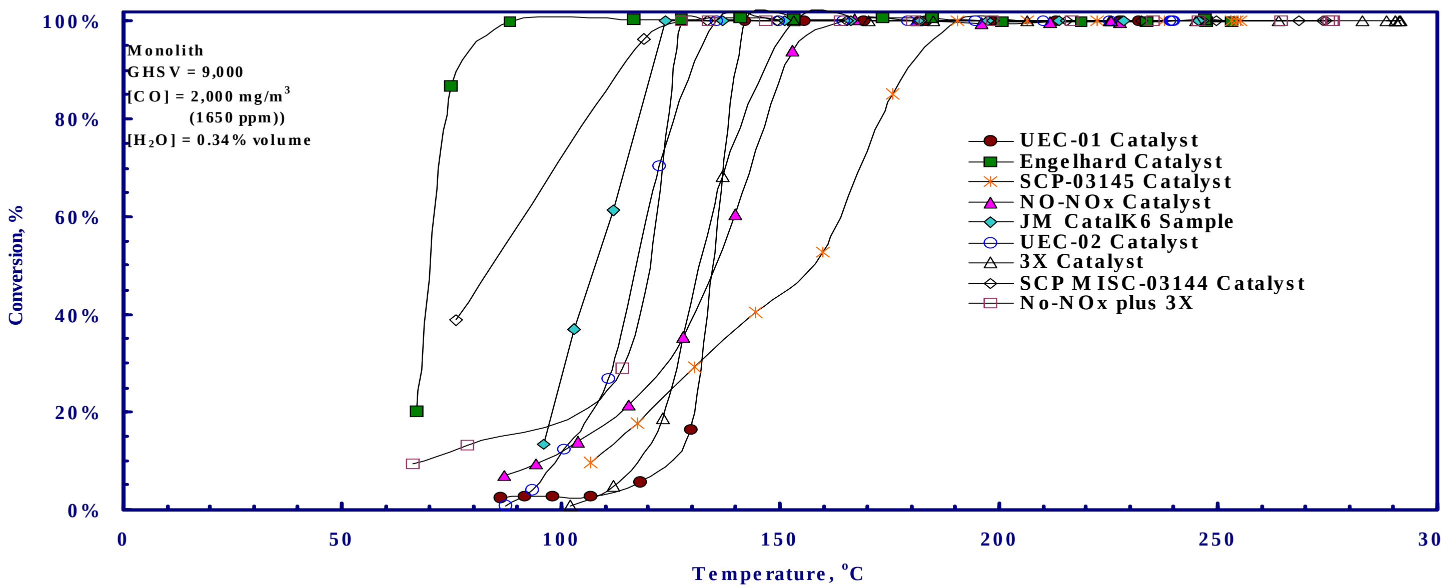
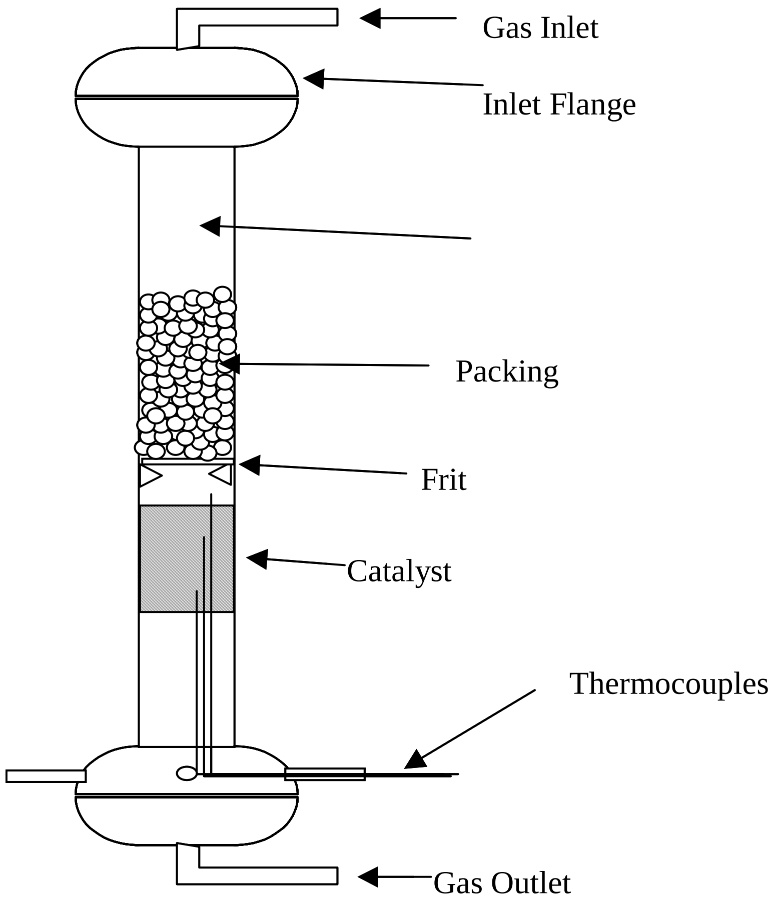
Catalyst oxidation of CO by catalytic materials under low and high humidity conditions (materials improvement)

- **good indicator of catalyst activity (very clean parent and byproduct)**
- **poor effective filtration by current NBC systems**

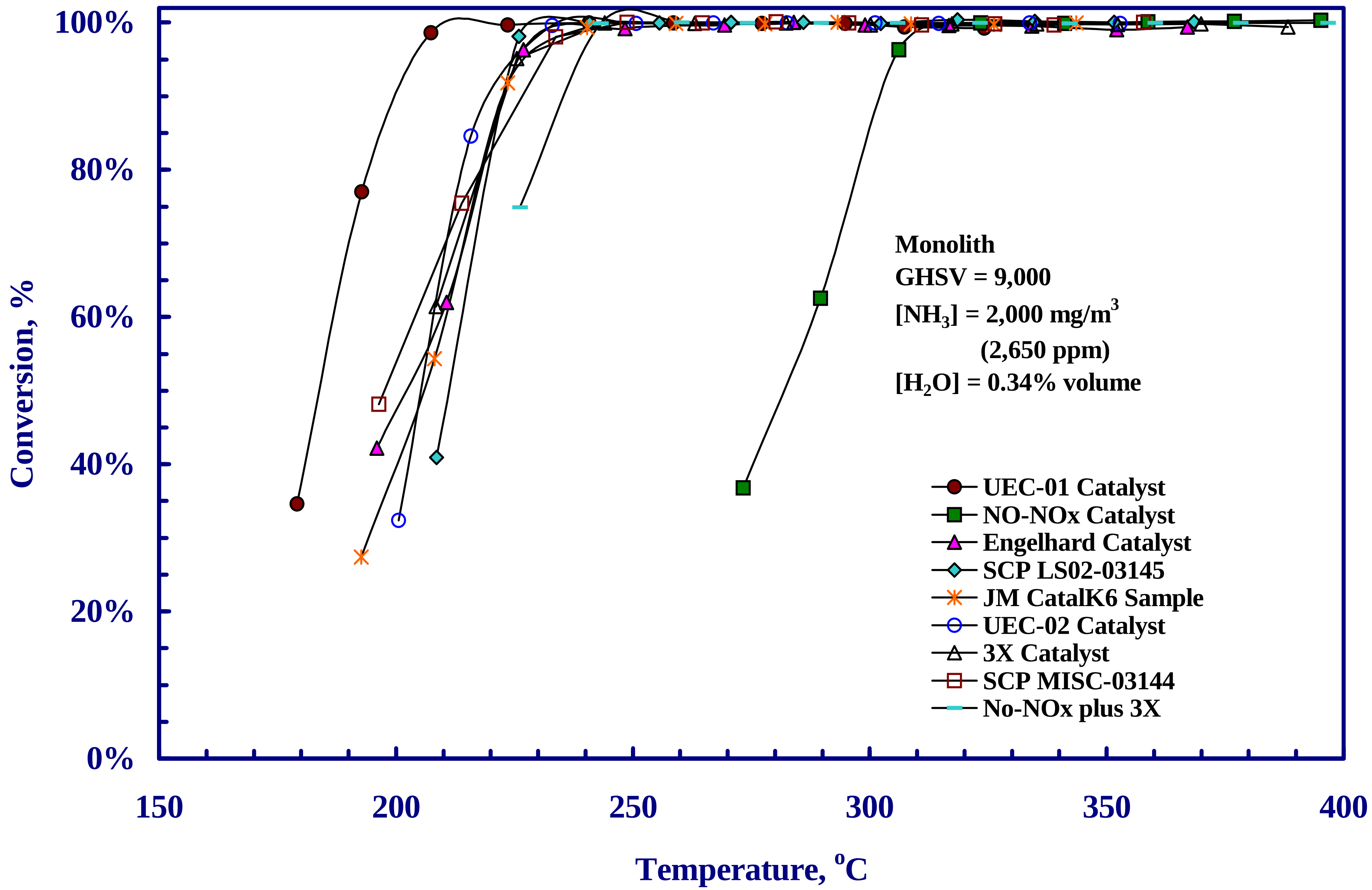




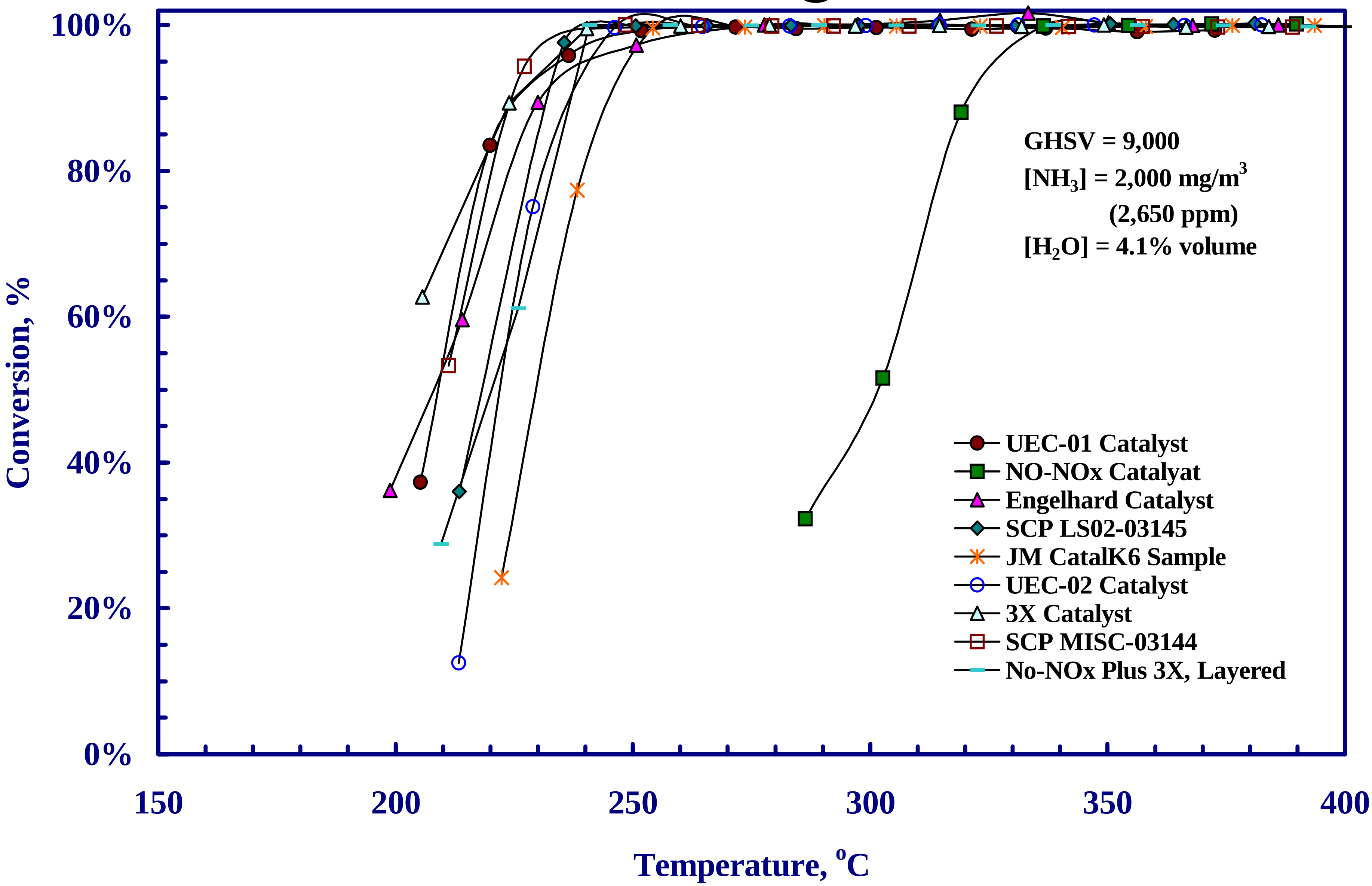
Schematic representation of catalytic reactor



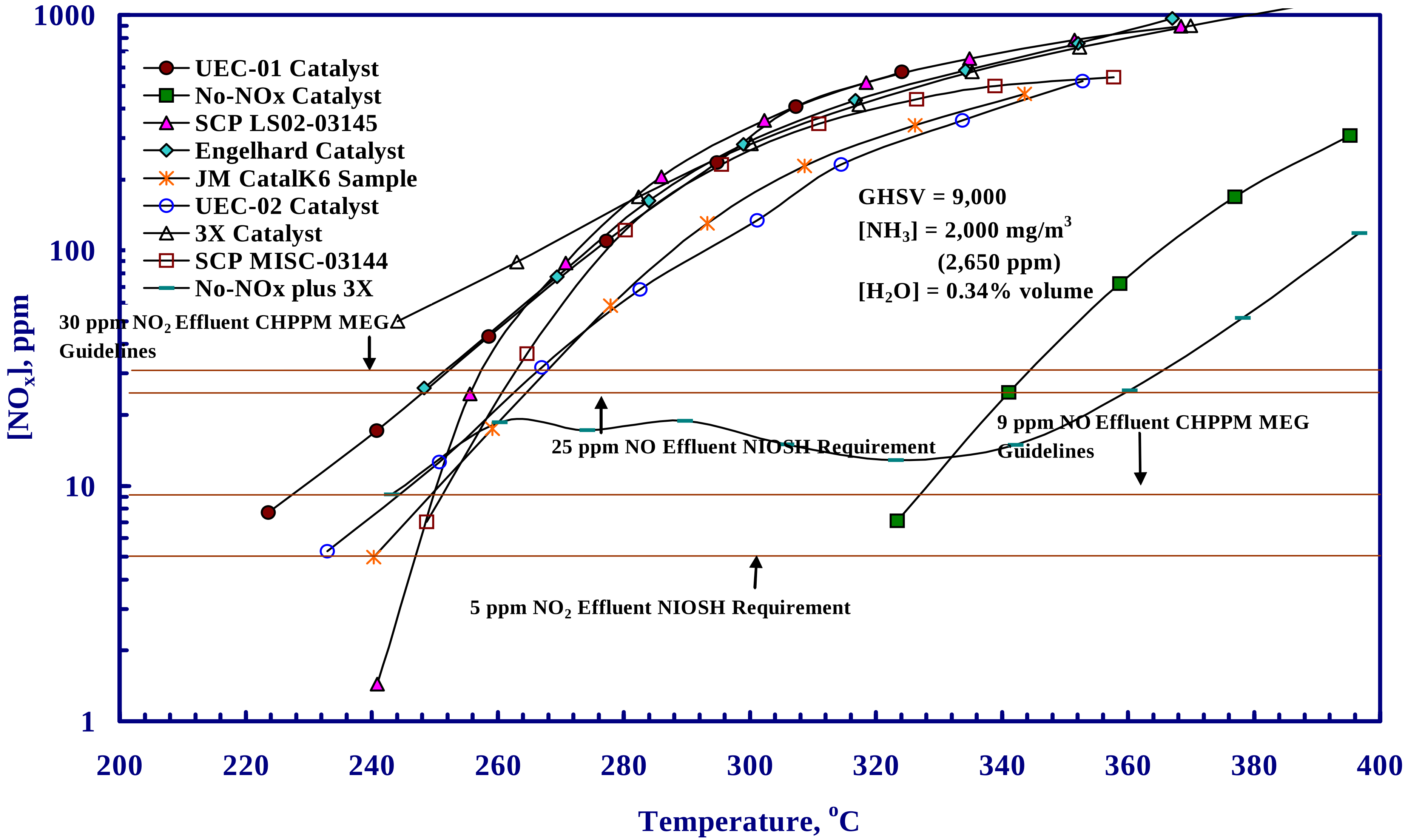
Dry NH_3 tests



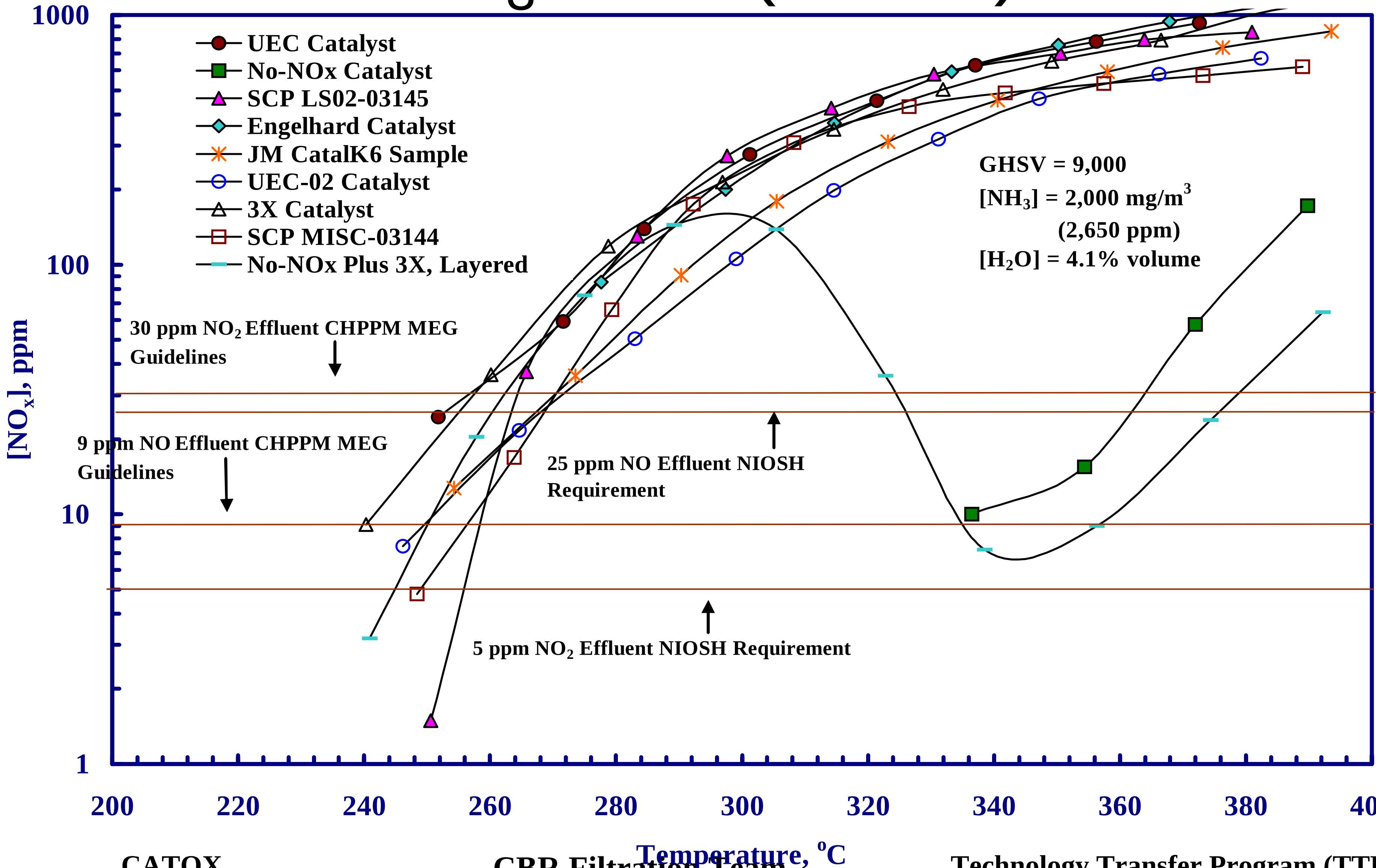
Humid NH_3 tests



Selectivity (NO_x): NH_3 tests (dry)



Selectivity (NO_x): NH_3 tests (humid)



Selectivity (N_2O): NH_3 tests (dry)

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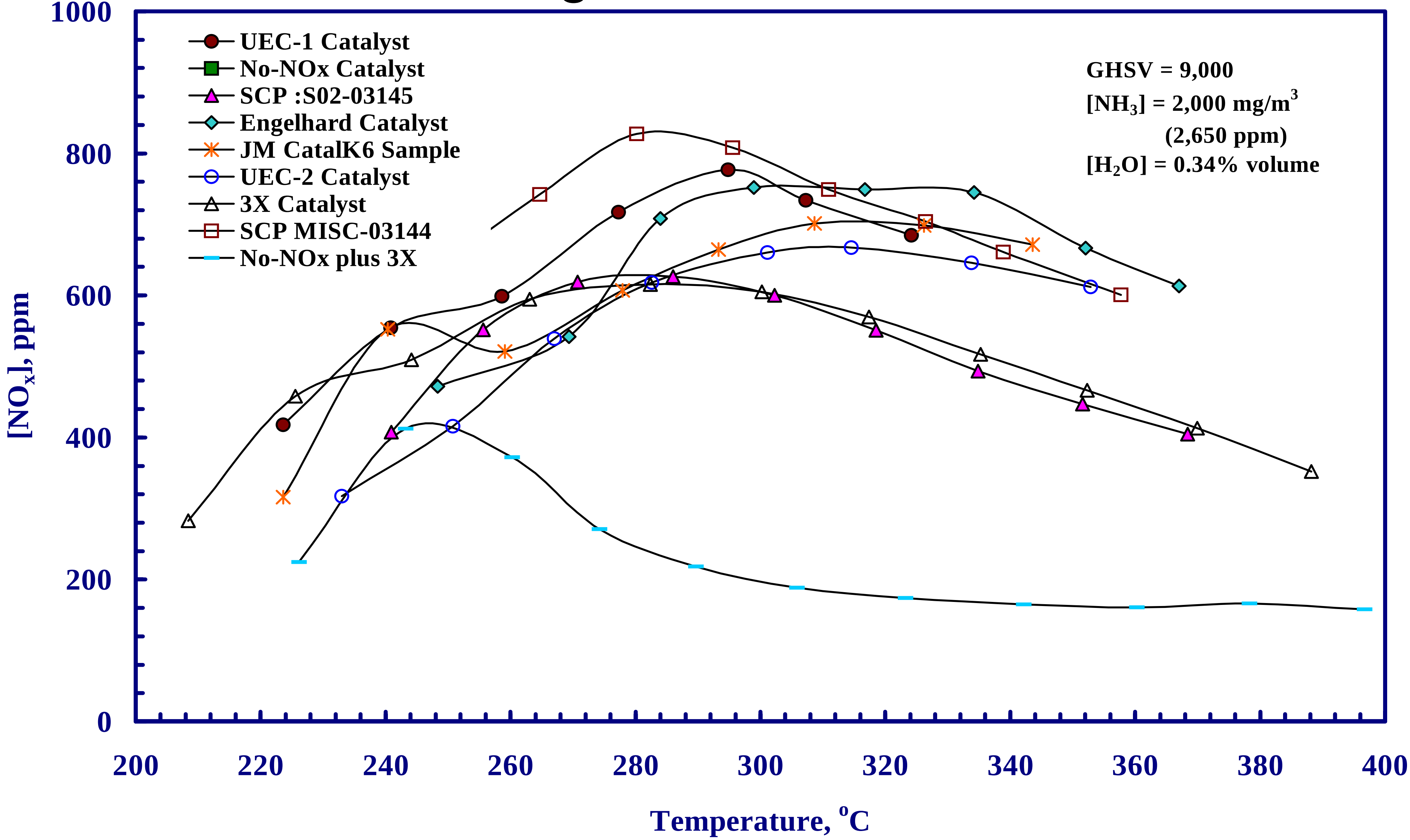
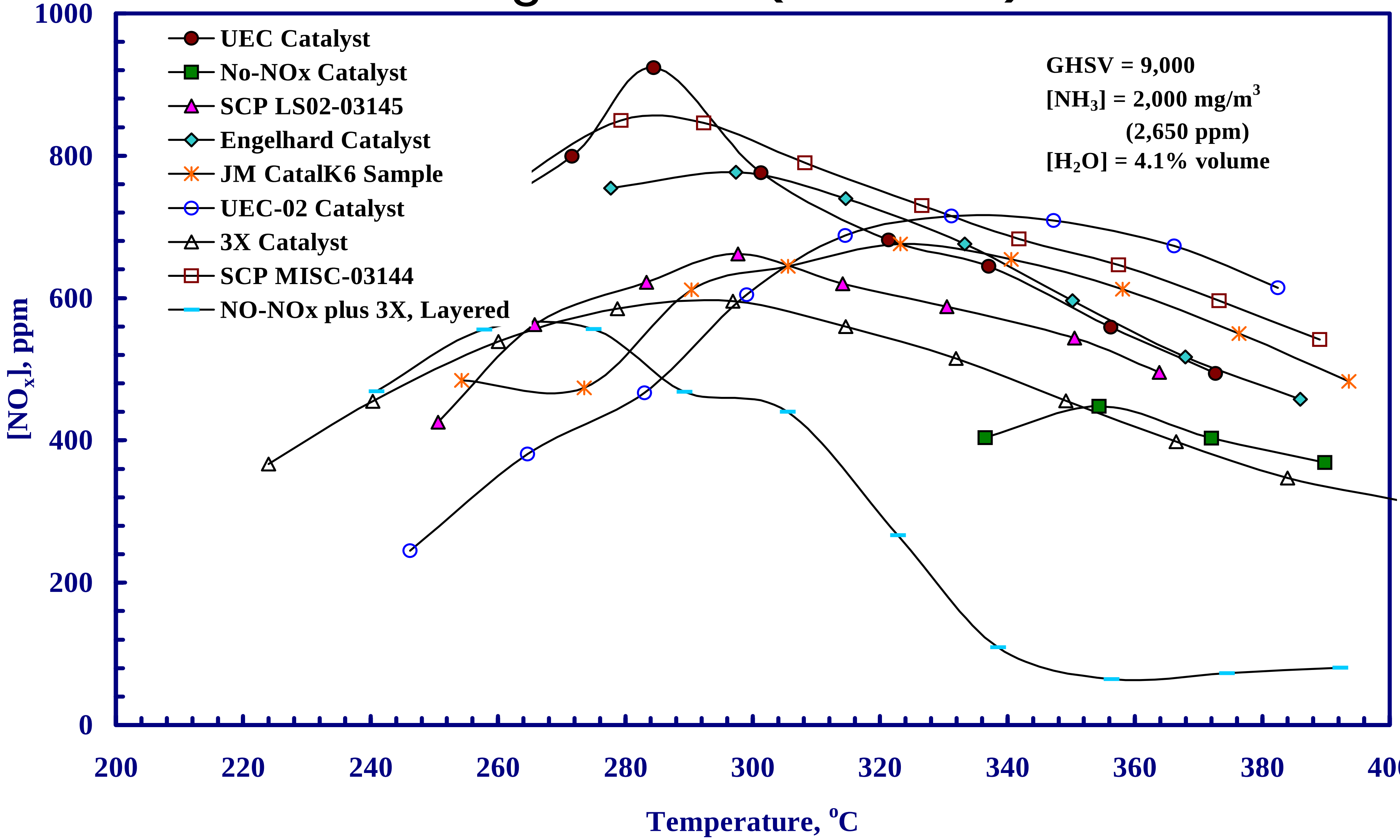
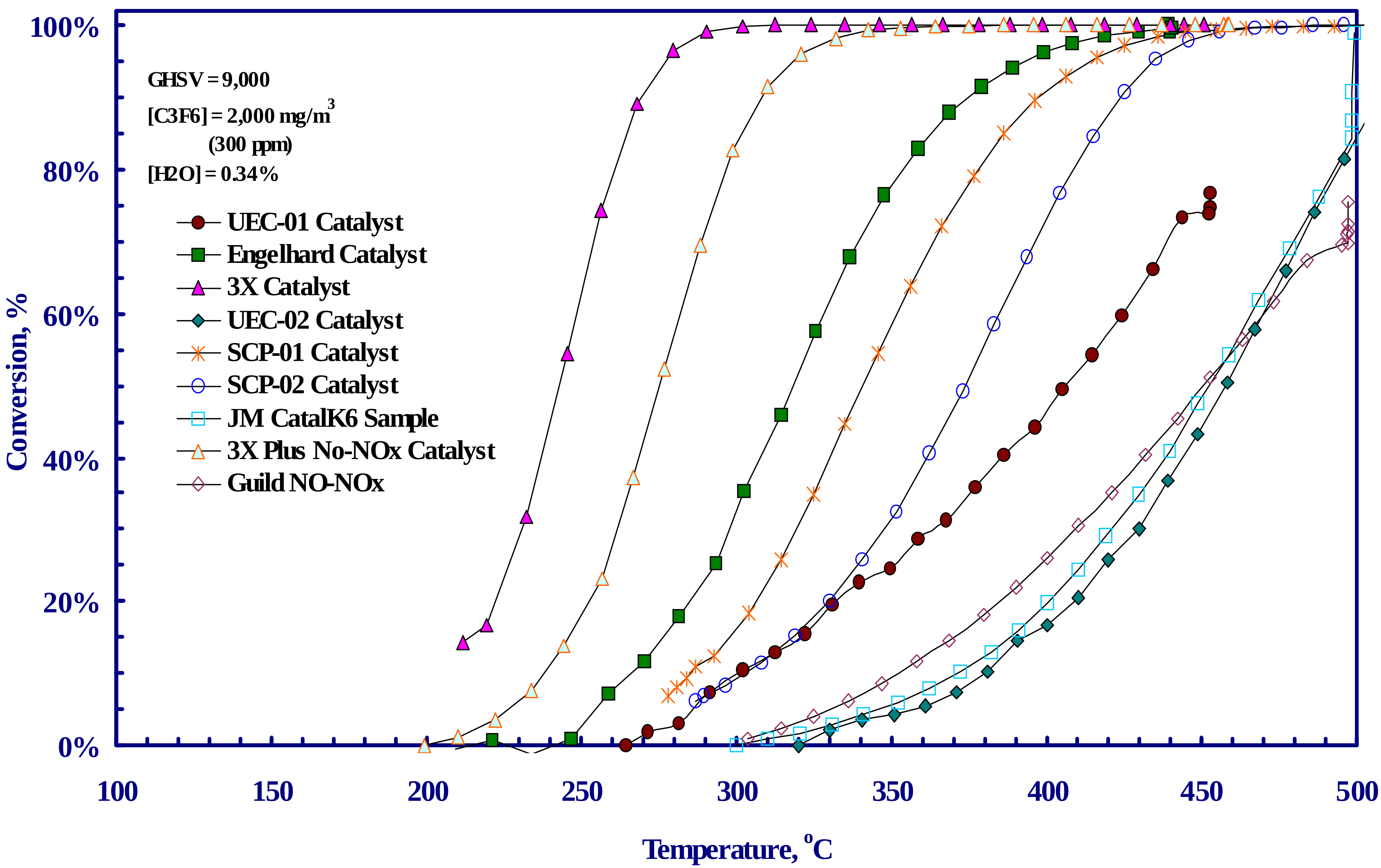


Selectivity (N_2O): NH_3 tests (humid)

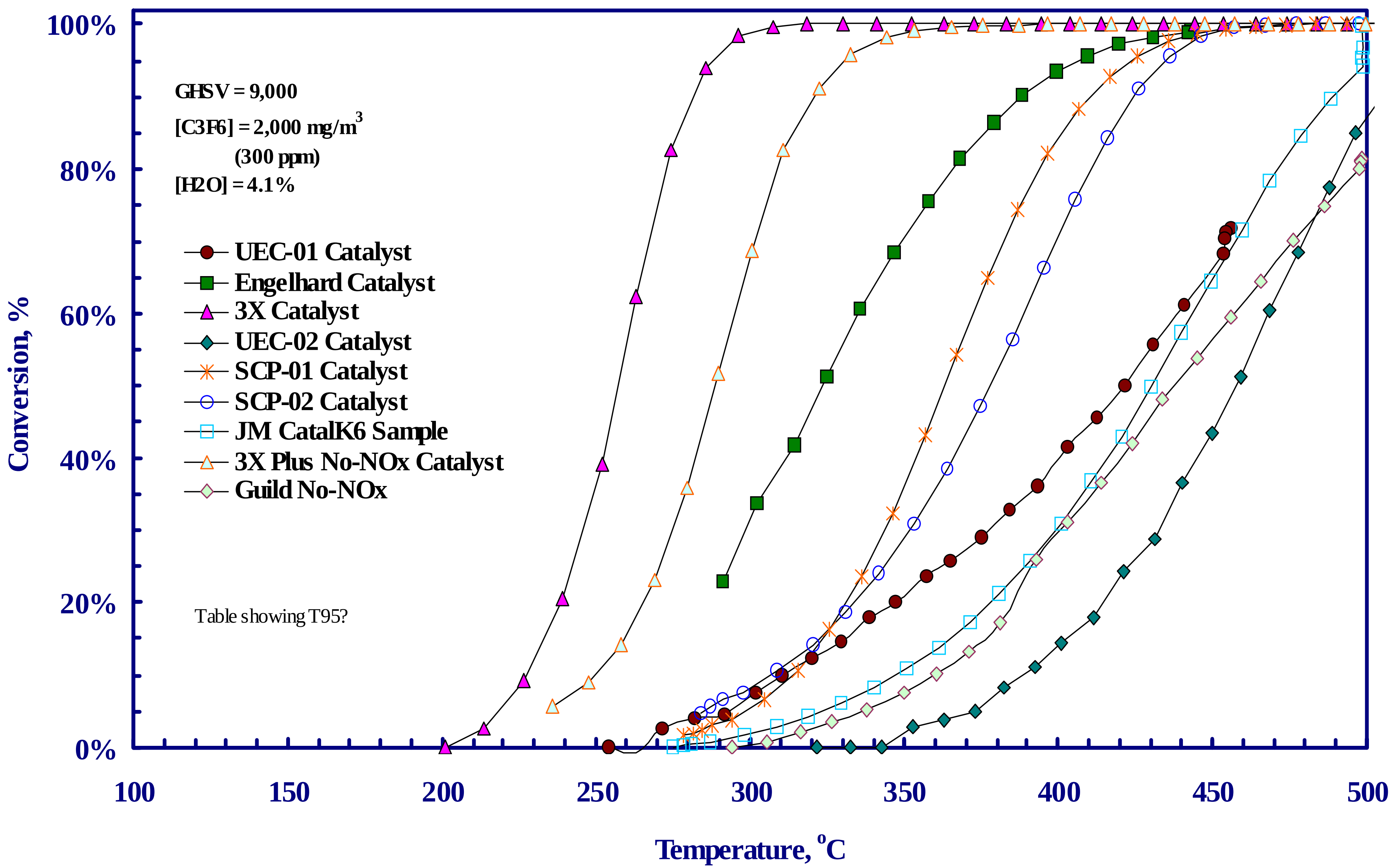
Guild Associates, Inc.



Dry C_3F_6 tests



Humid C_3F_6 tests



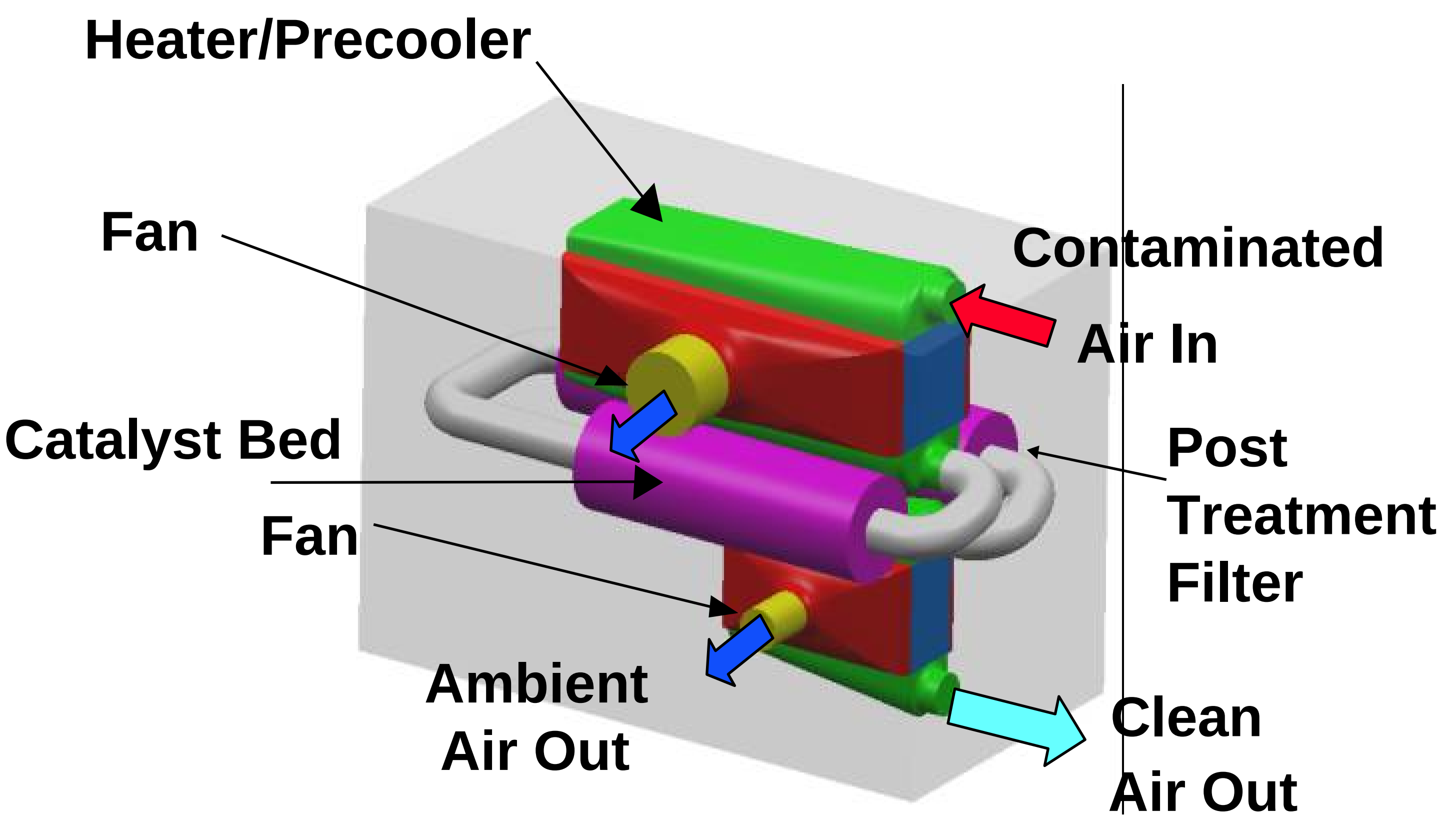
Catalyst Performance

Catalyst performance summary information

Catalyst	Design Lim. Chemical[1]	Temperature[2]	Ammonia $[NO_x]$[3]	Ammonia $[N_2O]$[3]
Guild No-NO_x	C_3F_6	T > 500°C	> 500 ppm	> 300 ppm
Guild No-NO_x Plus 3X	C_3F_6	350°C	15 ppm	160 ppm
Guild 3X	C_3F_6	310°C	400 ppm	550 ppm
Engelhard #164217005	C_3F_6	440°C	> 1,000 ppm	~ 300 ppm
UEC NB001-73-001	C_3F_6	T > 500°C	> 1,000 ppm	~ 300 ppm
UEC NB001-73-002	C_3F_6	T > 500°C	> 1,000 ppm	~ 300 ppm
SCP LS02-03145	C_3F_6	450°C	> 1,000 ppm	~ 300 ppm
SCP MISC-03144	C_3F_6	450°C	> 1,000 ppm	~ 300 ppm
JM CatalyK6 Sample	C_3F_6	T > 500°C	> 1,000 ppm	~ 300 ppm

[1]Chemical requiring greatest temperature to achieve 99% destruction
[2]Temperature required to achieve 99% destruction of design limiting chemical
[3]NO_x or N_2O concentration formed during destruction of NH_3 at temperature

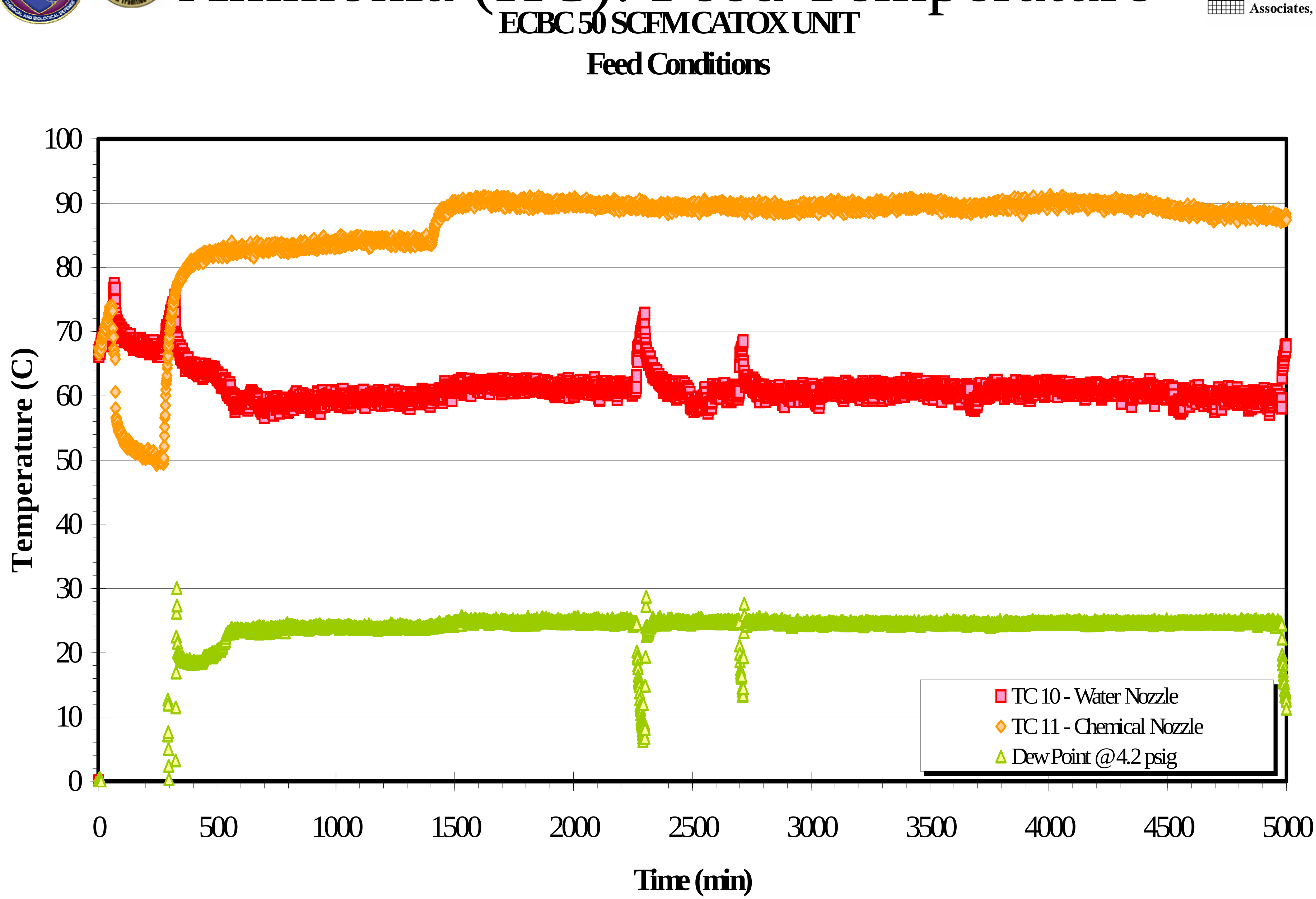
NBC Subsystem Summary



Targeted for:

- FCS Application
- Scalable for building protection
- Transportable shelters (JECP)

Ammonia (HC): Feed Temperature

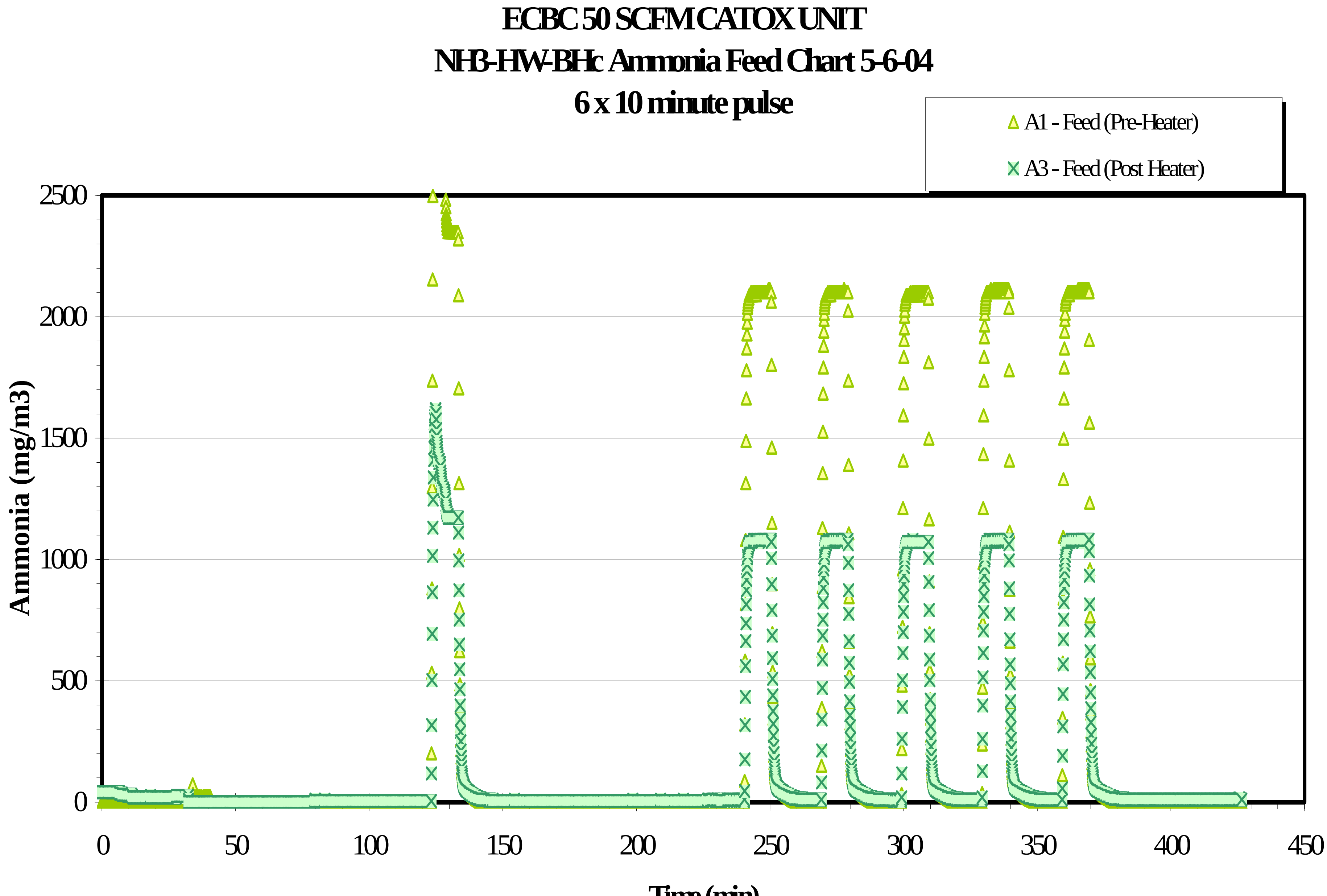


ATD Experimental Design

- 6 x 2000 mg/m^3 x 10 minutes
  (C_T = 120,000 mg-min/m^3)
- 6 x 200 mg/m^3 x 100 minutes
  (C_T = 120,000 mg-min/m^3)

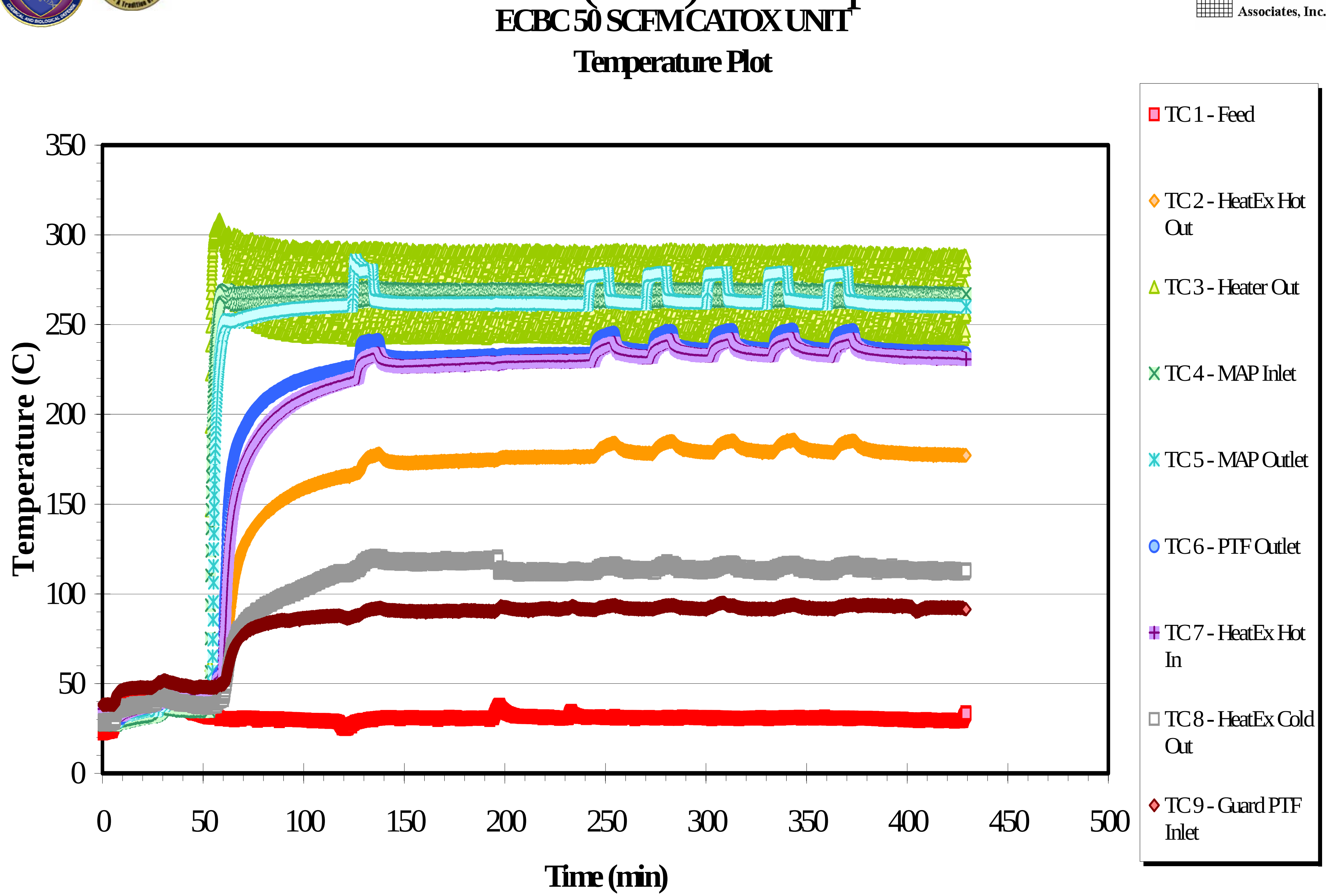
C_T = 240,000 mg-min/m^3
(under 2.5% water (volume) and 50 cfm)

Ammonia (HC): Feed Concentrations



CATOX CBR Filtration Team Technology Transfer Program (TTP)

Ammonia (HC): Temperature



Ammonia (HC); Parent compound

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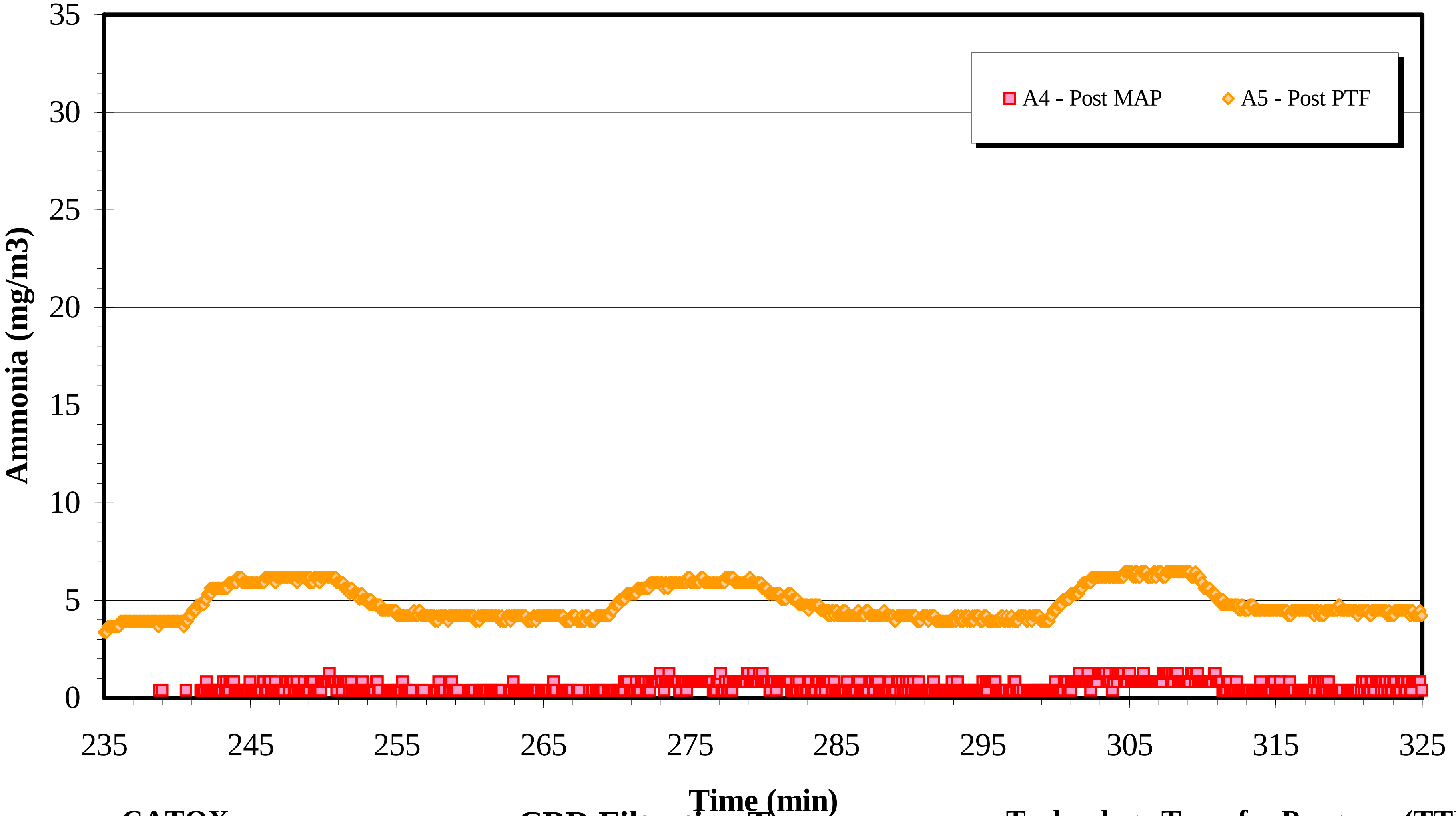
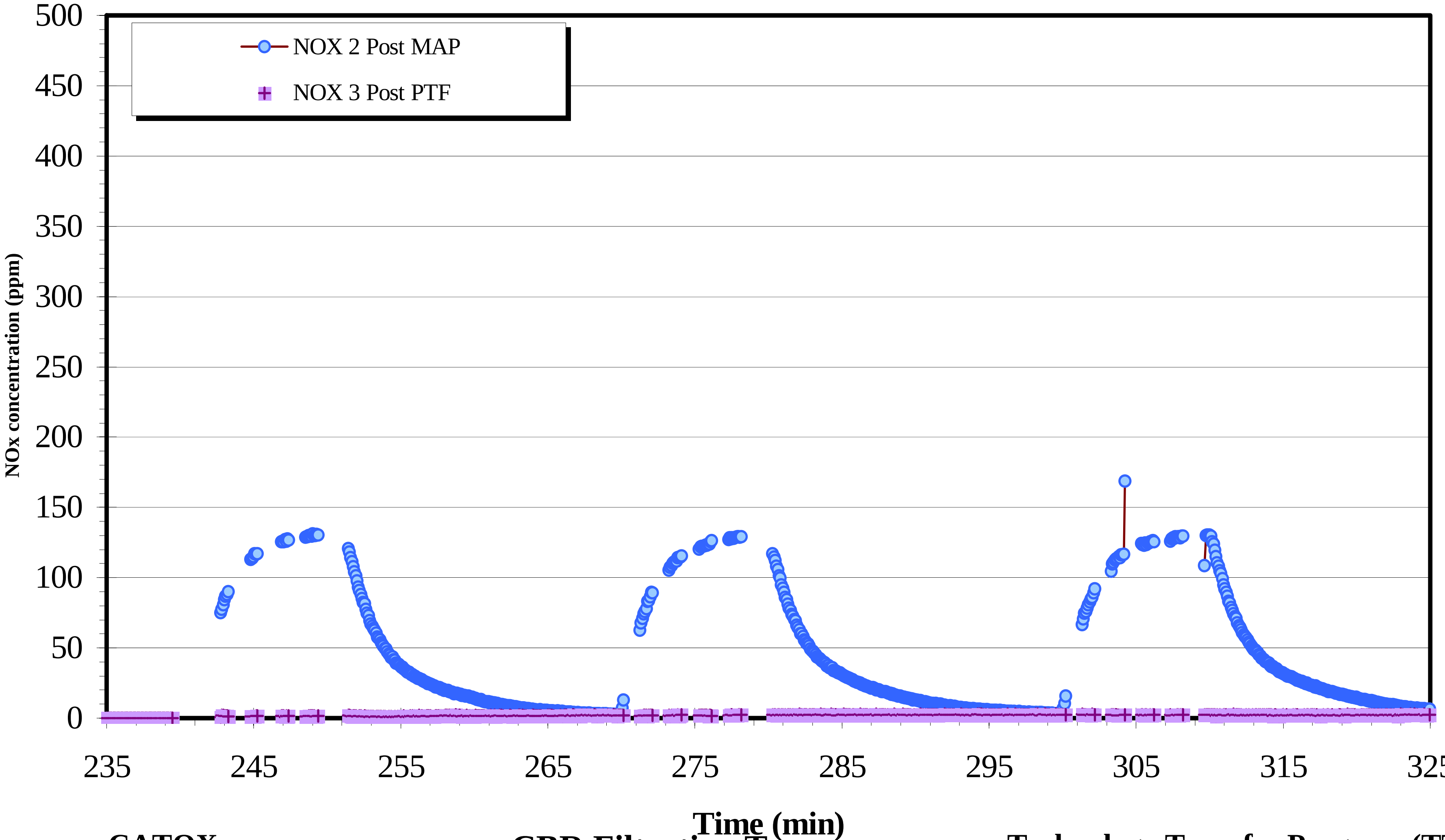
ECBC 50 SCFM CATOX UNIT
Analog Signal Chart



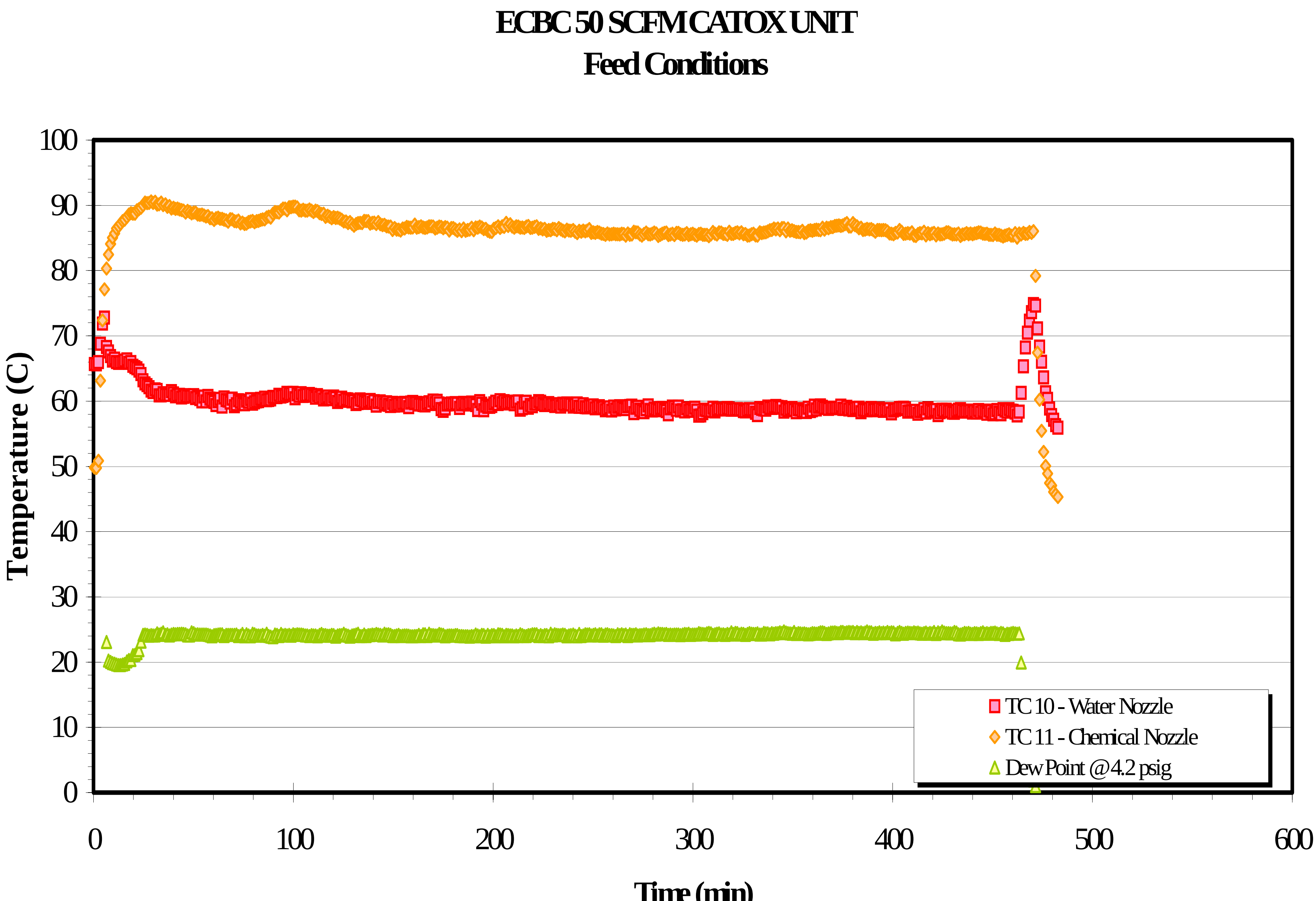
Ammonia (HC): By-products

ECBC 50 SCFM CATOX UNIT

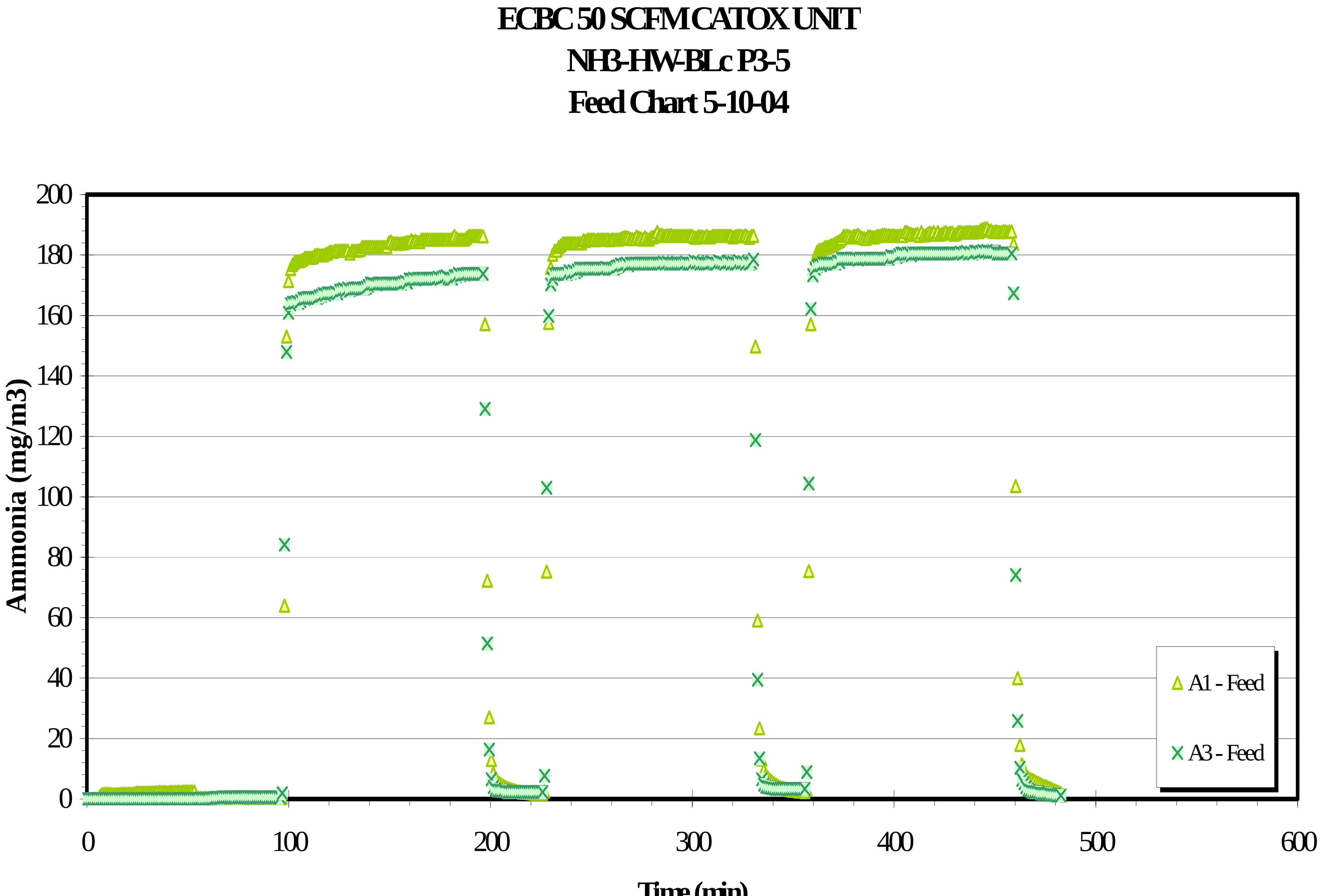
Analog Signal Chart



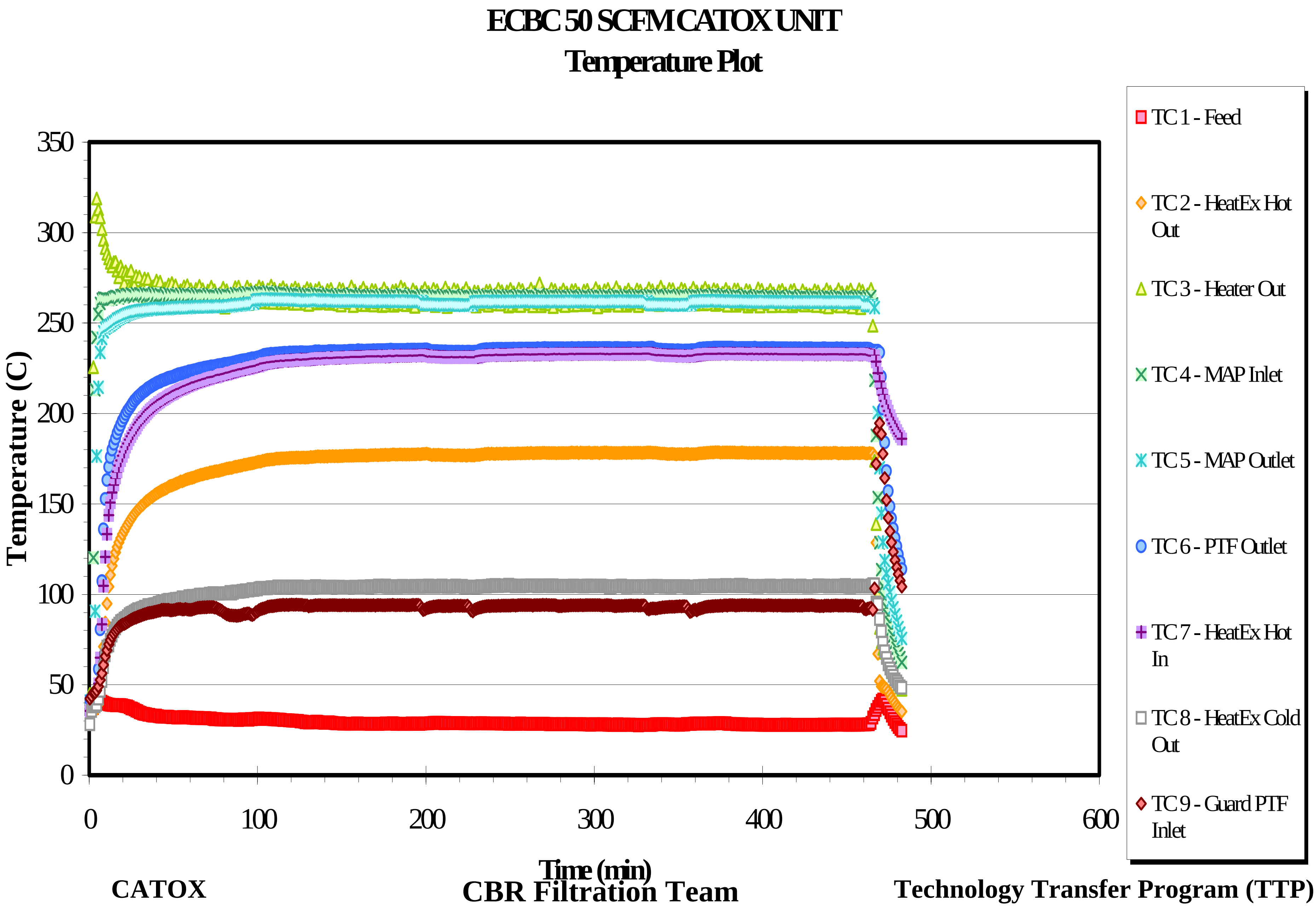
Ammonia (LC): Feed Temperature



Ammonia (LC): Feed Concentrations

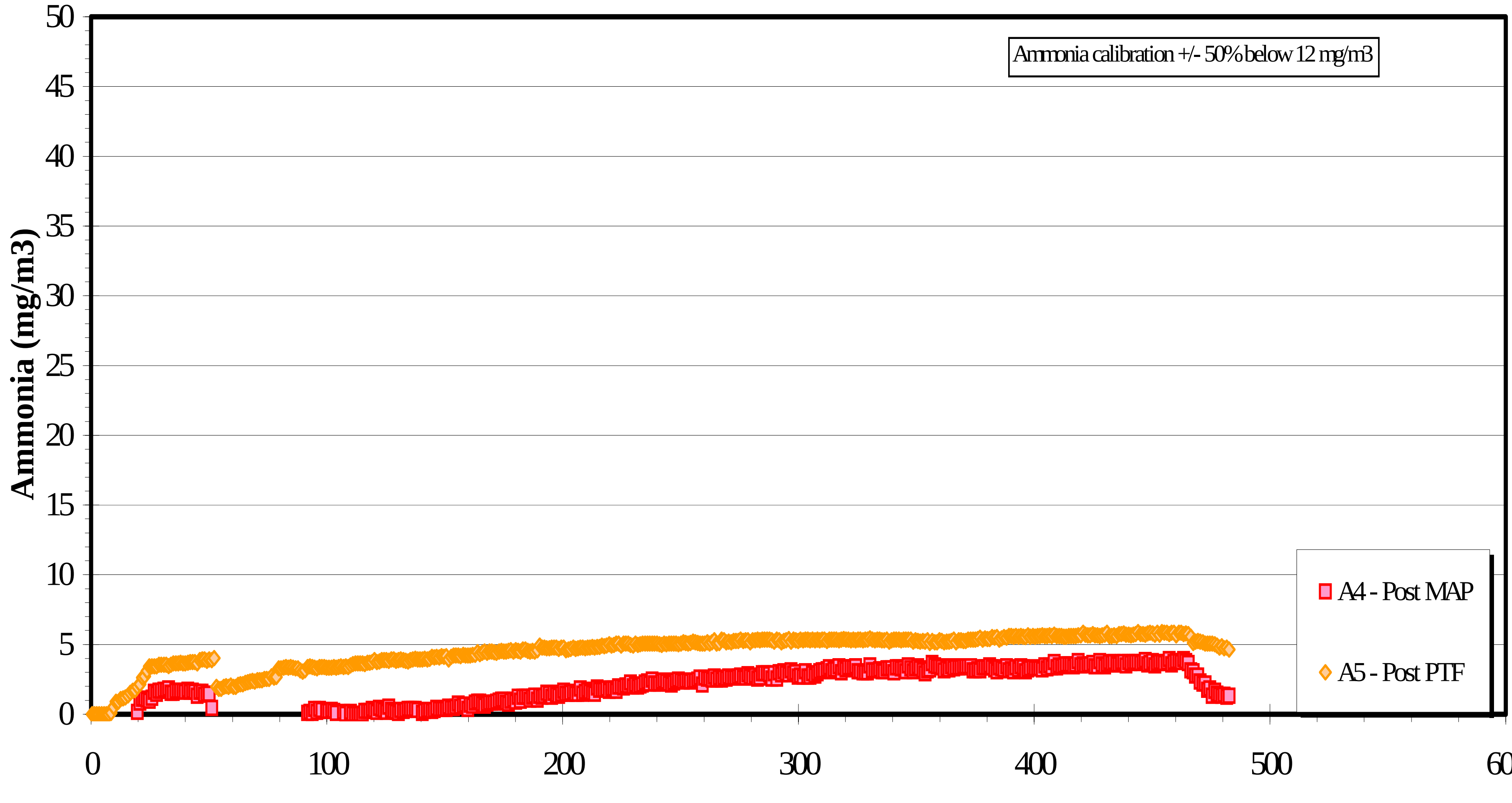


Ammonia (LC): Temperature



Ammonia (LC): Parent

ECBC 50 SCFM CATOX UNIT
NH3-HW-BLc P3-5
Effluent Chart (NH3) 5-10-04



Ethylene Oxide (HC): Temperature

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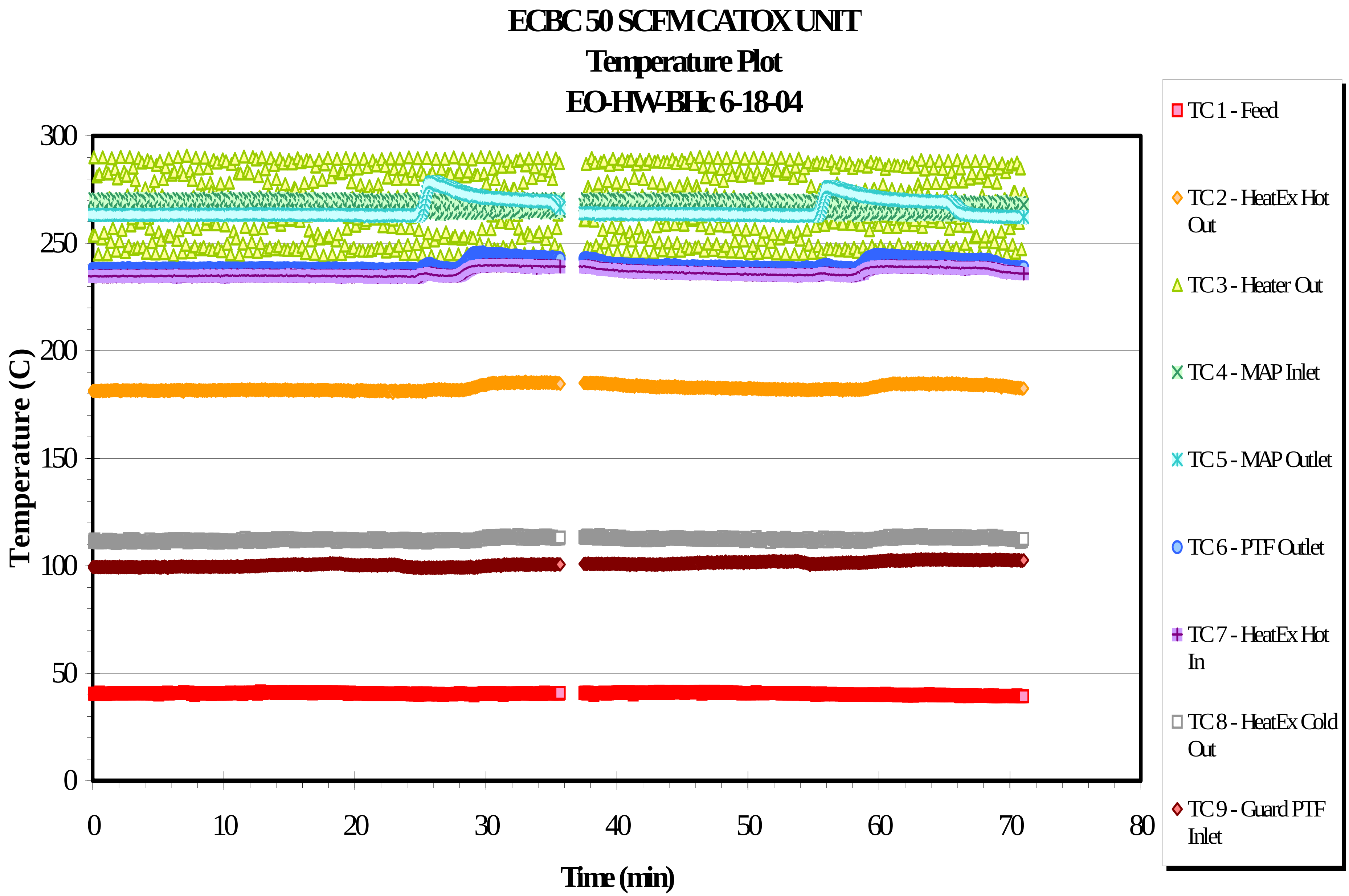

Ethylene Oxide (HC): Feed Concentrations

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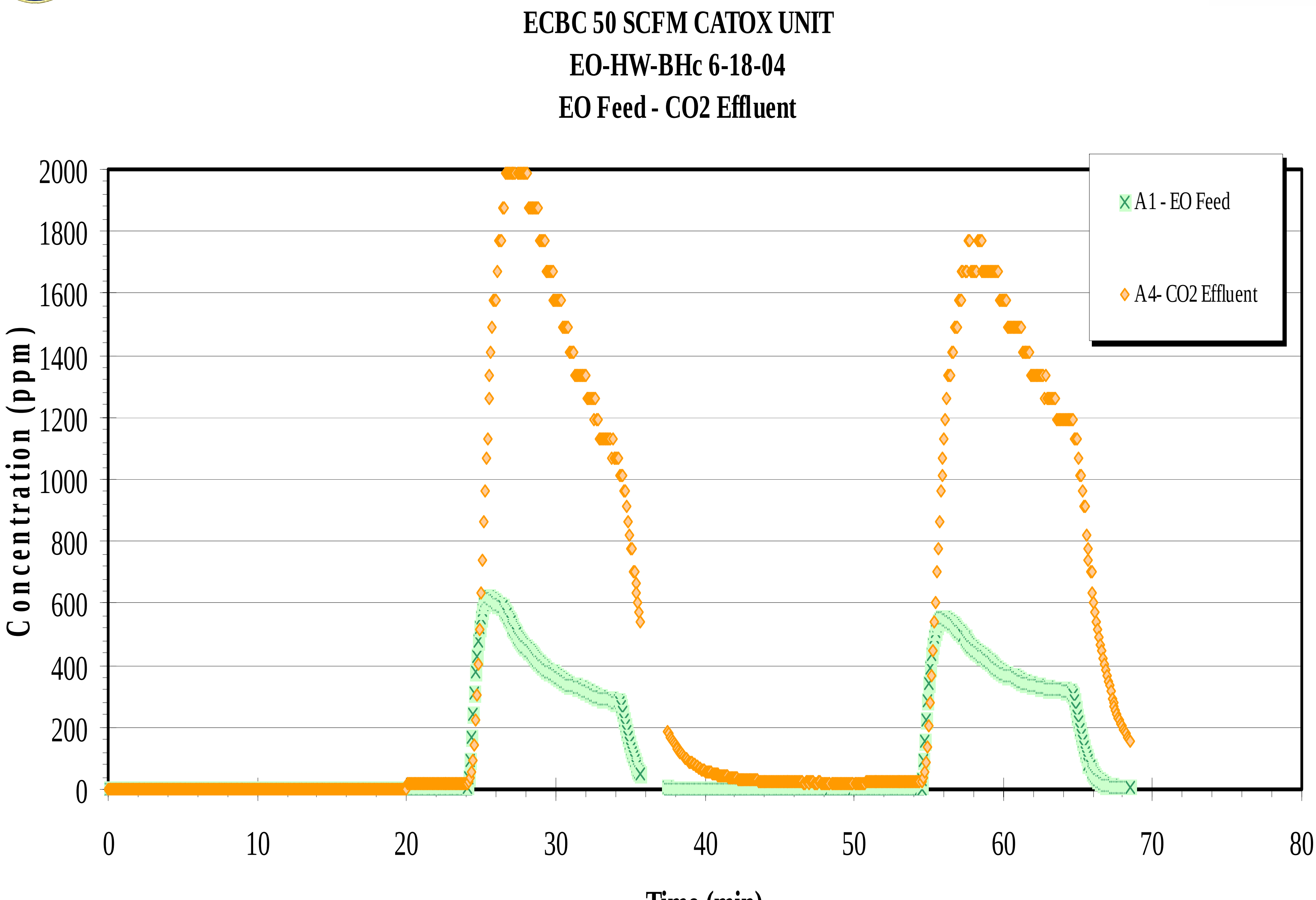

Ethylene Oxide (HC): By-products

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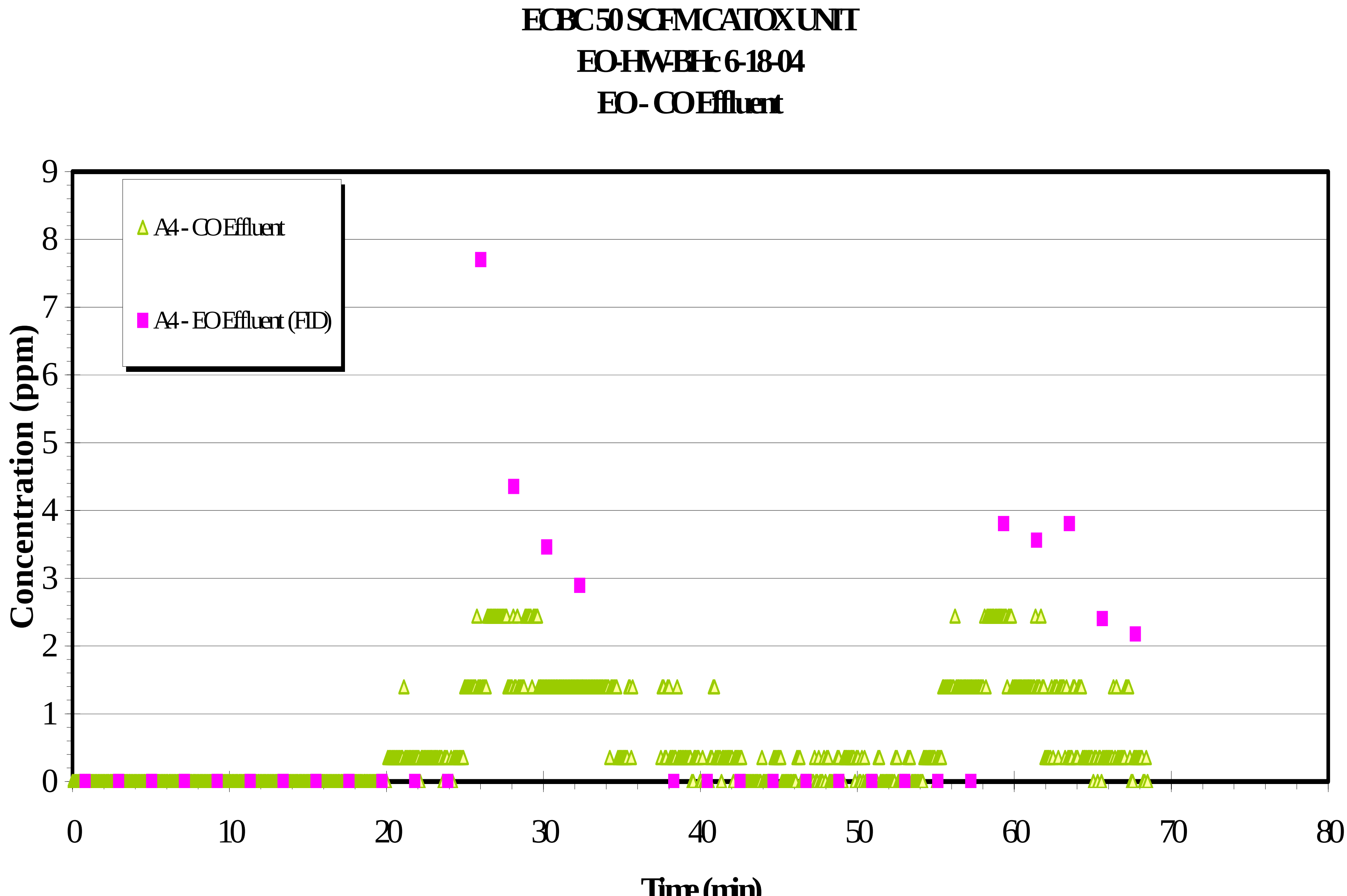
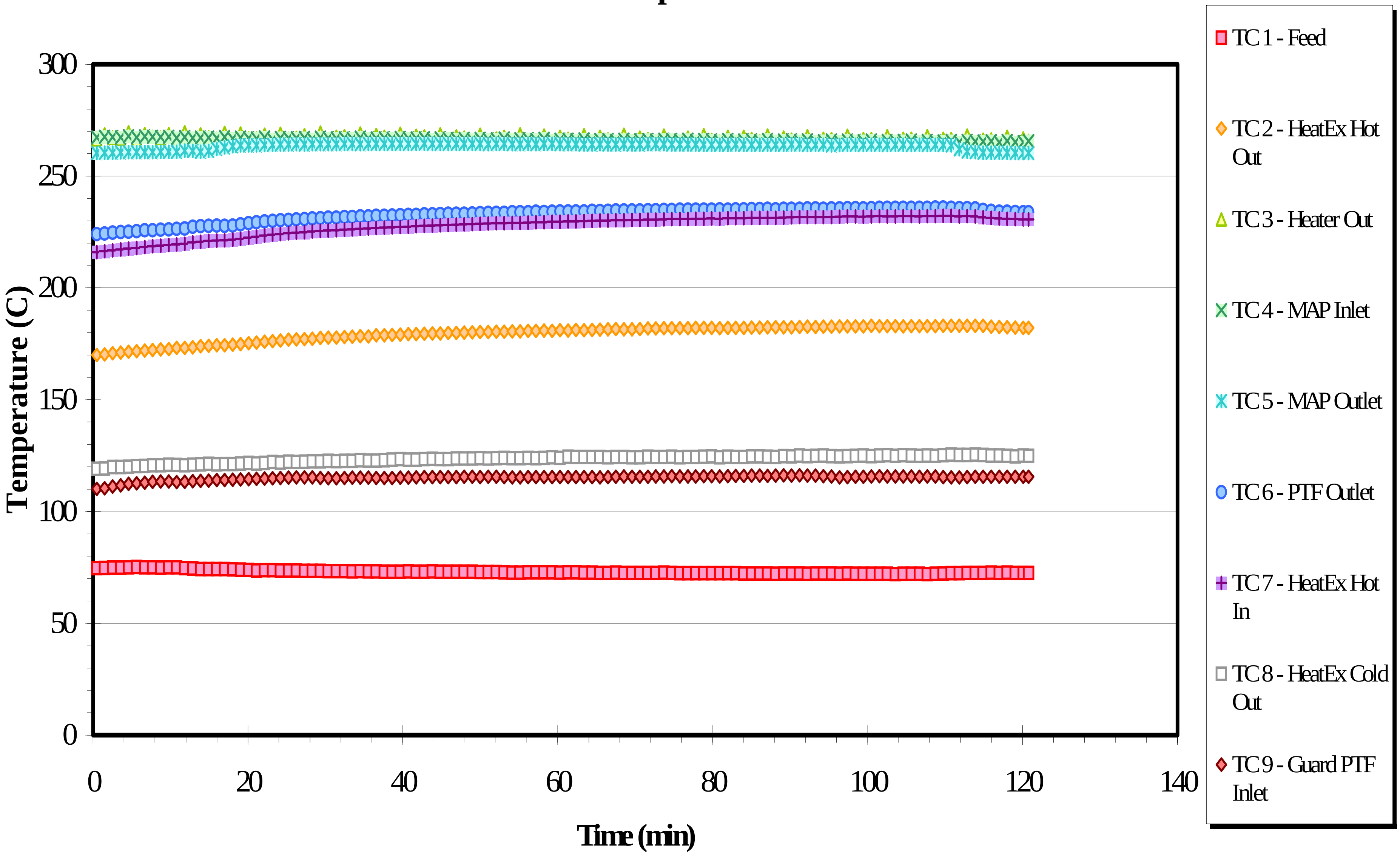


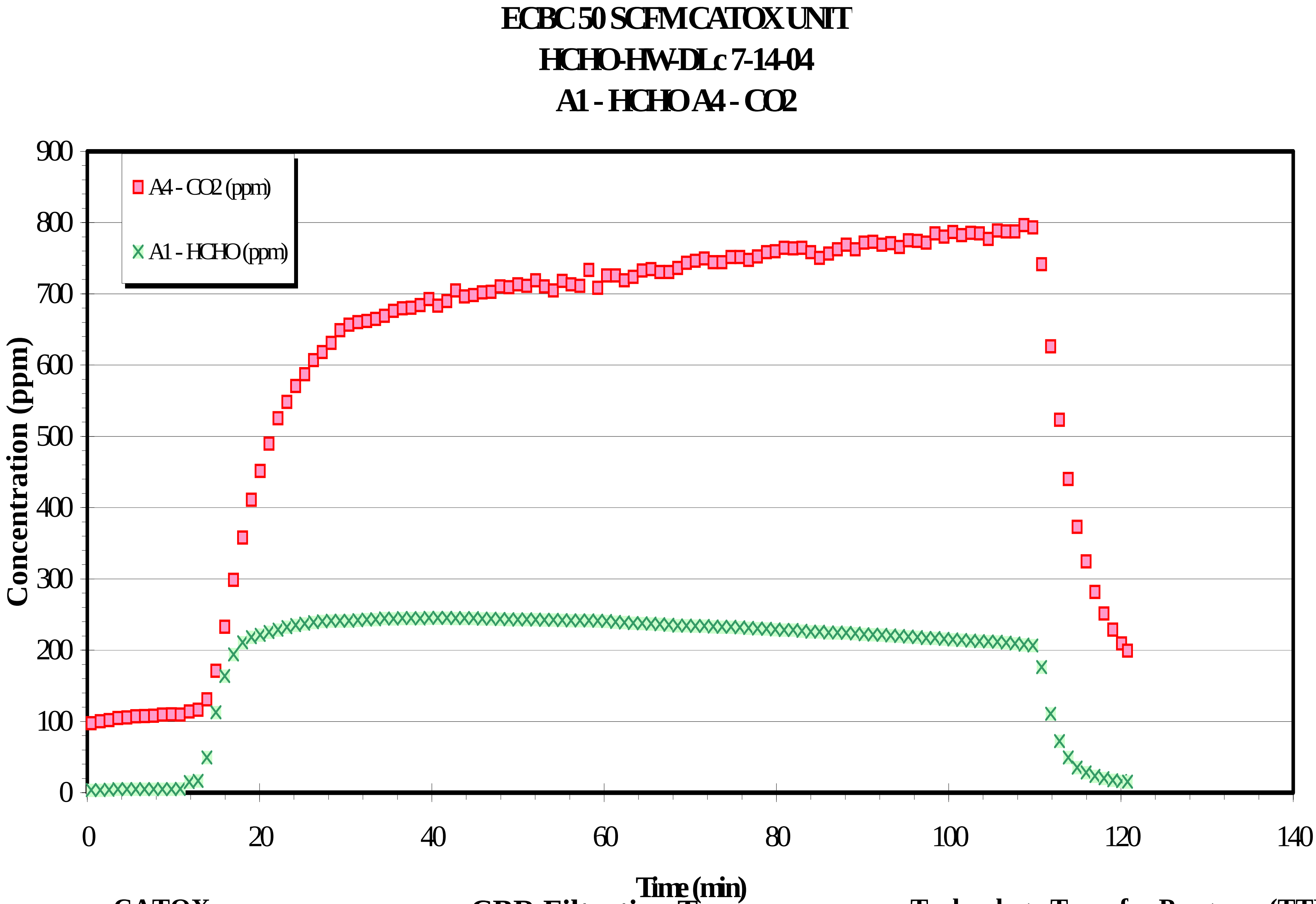
Formalin (LC)

ECBC 50 SCFM CATOX UNIT

Temperature Plot



Formalin (LC)



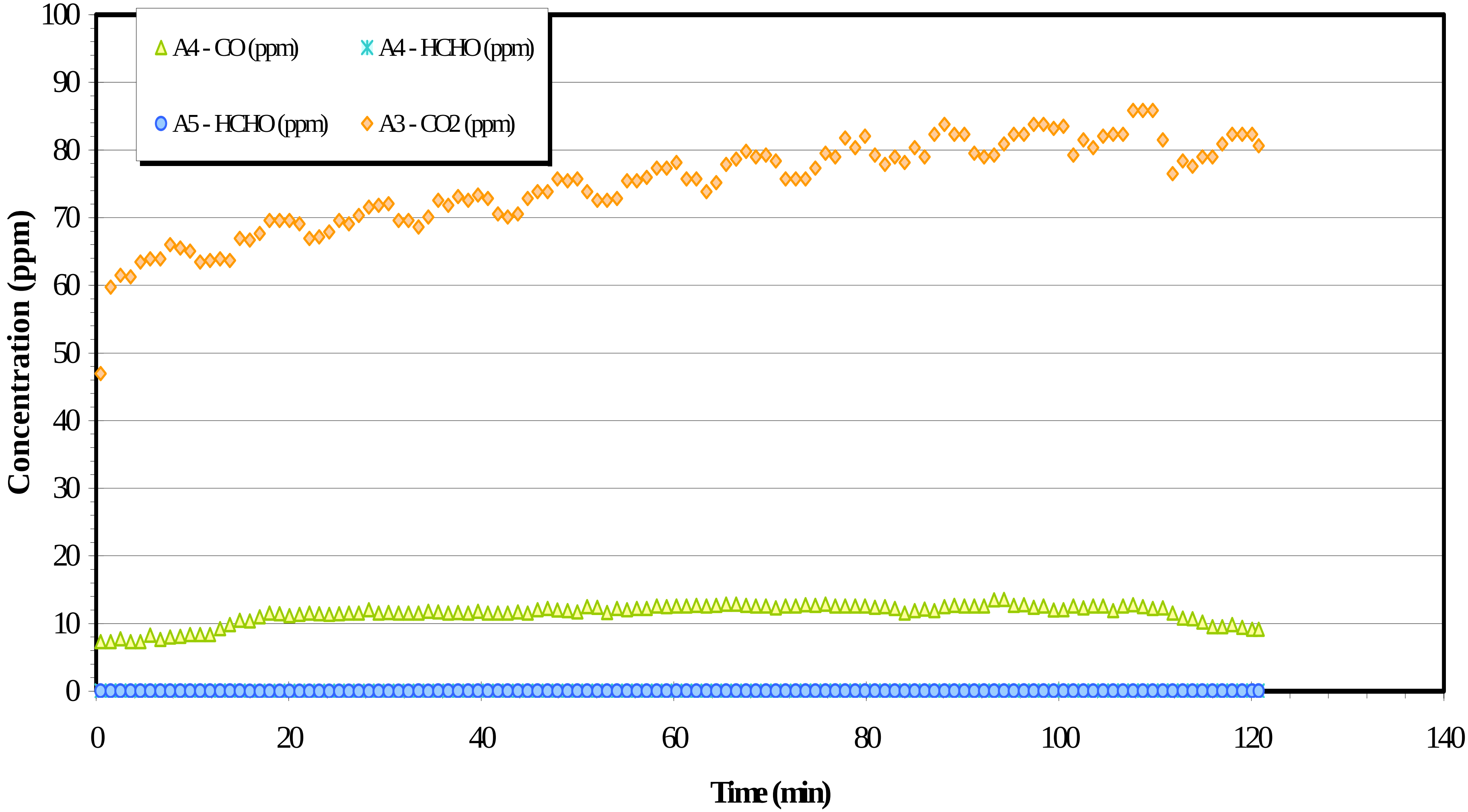
ECBC 50 SCFM CATOX UNIT
HCHO-HW-DLc 7-14-04
A1 - HCHO A4 - CO2
A4 - CO2 (ppm)
A1 - HCHO (ppm)
Concentration (ppm)
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140
Time (min)

Formalin (LC)

ECBC 50 SCFM CATOX UNIT

HCHO-HW-DLc 7-14-04

A3 - CO2 A4 - CO A4 - HCHO A5 - HCHO



CATOX **CBR Filtration Team** **Technology Transfer Program (TTP)**

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Chemicals tested:

Carbon Monoxide

Ammonia

Ethylene Oxide

Formalin

Chemical underway:

Acetonitrile

Chemicals left:

Chloroform

CK

CS_2

Nitric Acid

CEES

HF

HFP

DMMP

Field conditions impacting CATOX

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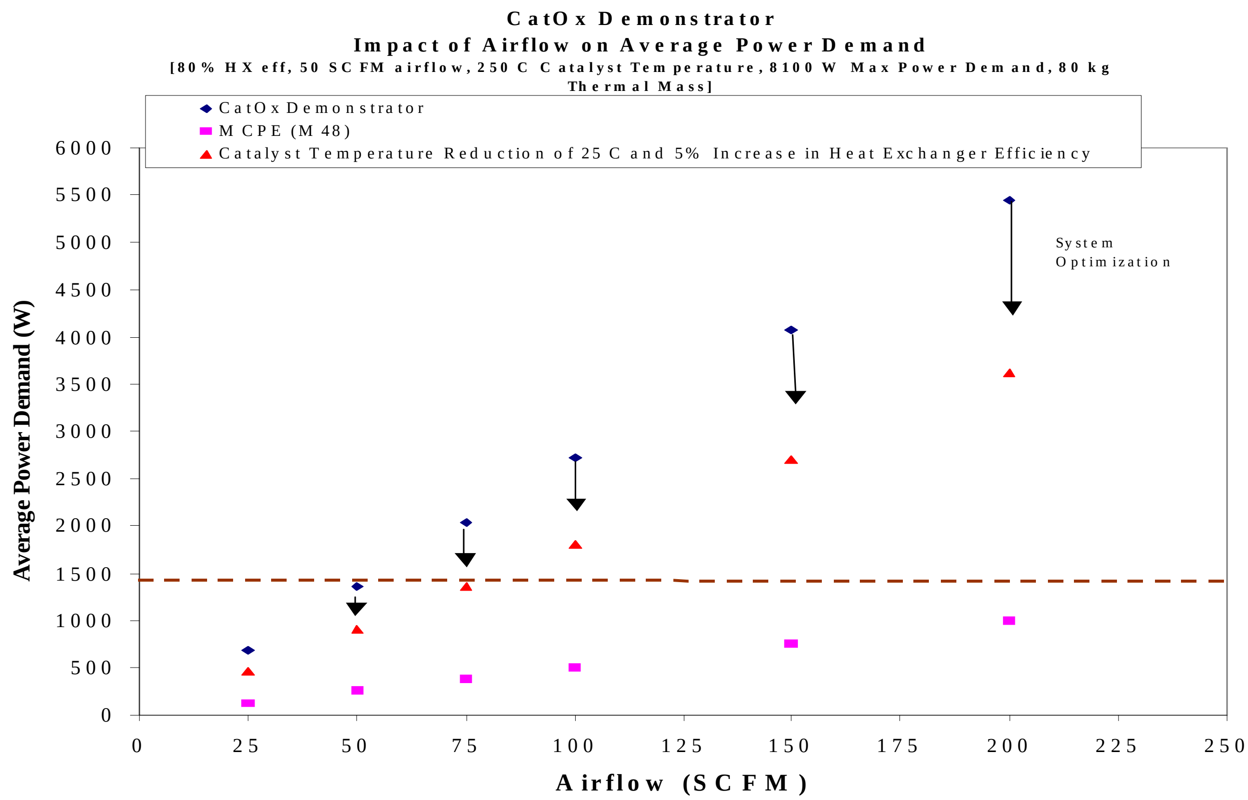
In a fielded system, one catalyst bed operating at one flow rate and one operating temperature will be employed.

Power and weight optimization



CATOX | **CBR Filtration Team** | **Technology Transfer Program (TTP)**

Improvement of Subcomponents

- Next Generation PTS
- Catalyst Improvements
- Heat Exchanger (greater 90% heat recovery efficiency
- Modular System
- Lighter, Smaller Overall Footprint

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