Microwave Scrubber for destroying hypergolic fuel vapors

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Microwave Scrubber for Hypergolic Rocket Fuel

Presented at
International Pollution Prevention and Sustainable Development

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Defining The Problem

- The loading of liquid propellants used to power and launch rockets produces a nitrogen or helium stream saturated with toxic propellant vapors.
- Propellants being used today include:
  - Dinitrogen Tetroxide (N_2O_4)
  - Hydrazine
  - Monomethylhydrazine (MMH)
  - Unsymmetrical Dimethylhydrazine (UDMH)

Current Technologies

- Currently, the toxic propellant vapors are disposed of using a wet chemical scrubber.
- This scrubber is capable of removing more than 90% of the propellant vapors in the stream.
- The scrubber system creates a toxic liquid waste stream which must also be treated.

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Microwave-Induced C-NO Reaction

- $N_2O_4 \longrightarrow 2\,NO_2$
- $2\,NO_2 \longrightarrow 2\,NO + O_2$
- $2\,NO + C \longrightarrow N_2 + CO_2$
- Activation energy, Ea = 17 kJ/mole for microwave induced C-NO reaction
- Ea = 63-68 kJ/mole for thermal C-NO reaction

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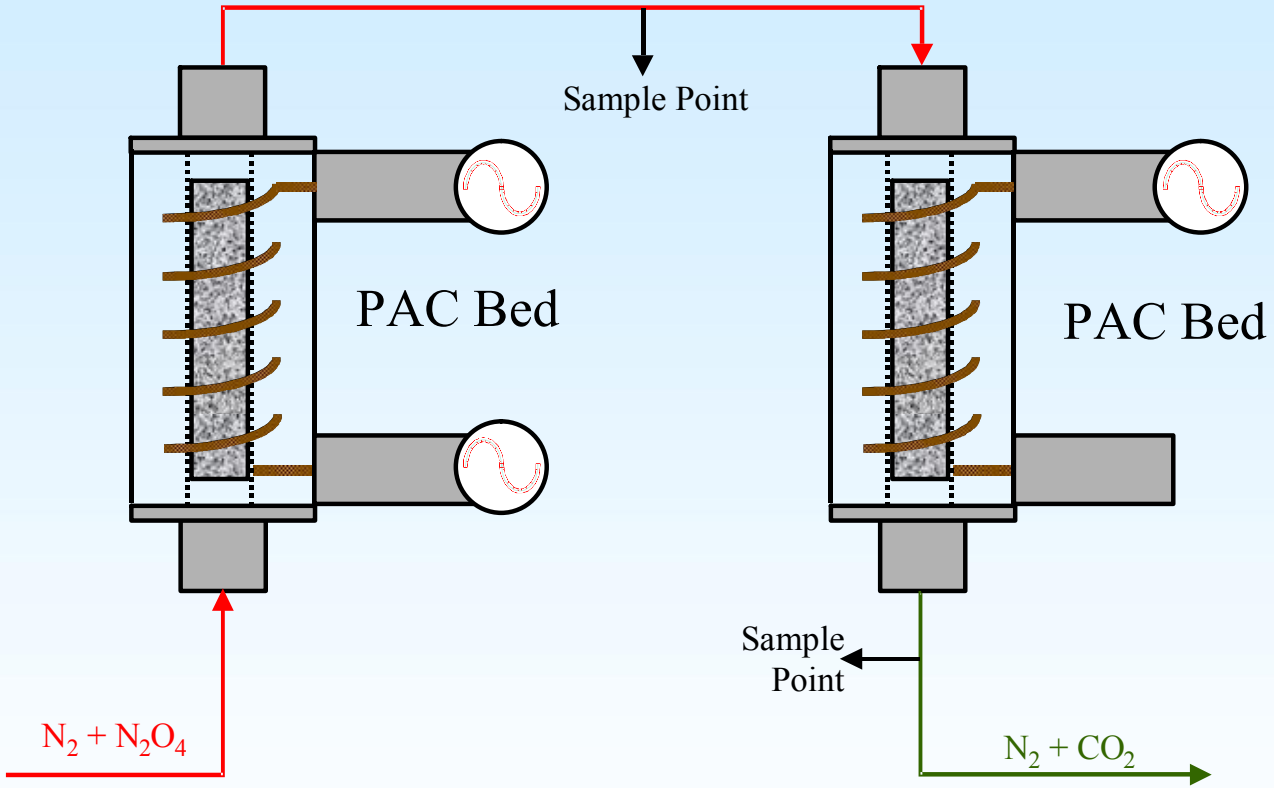
Optimization Test Set-Up



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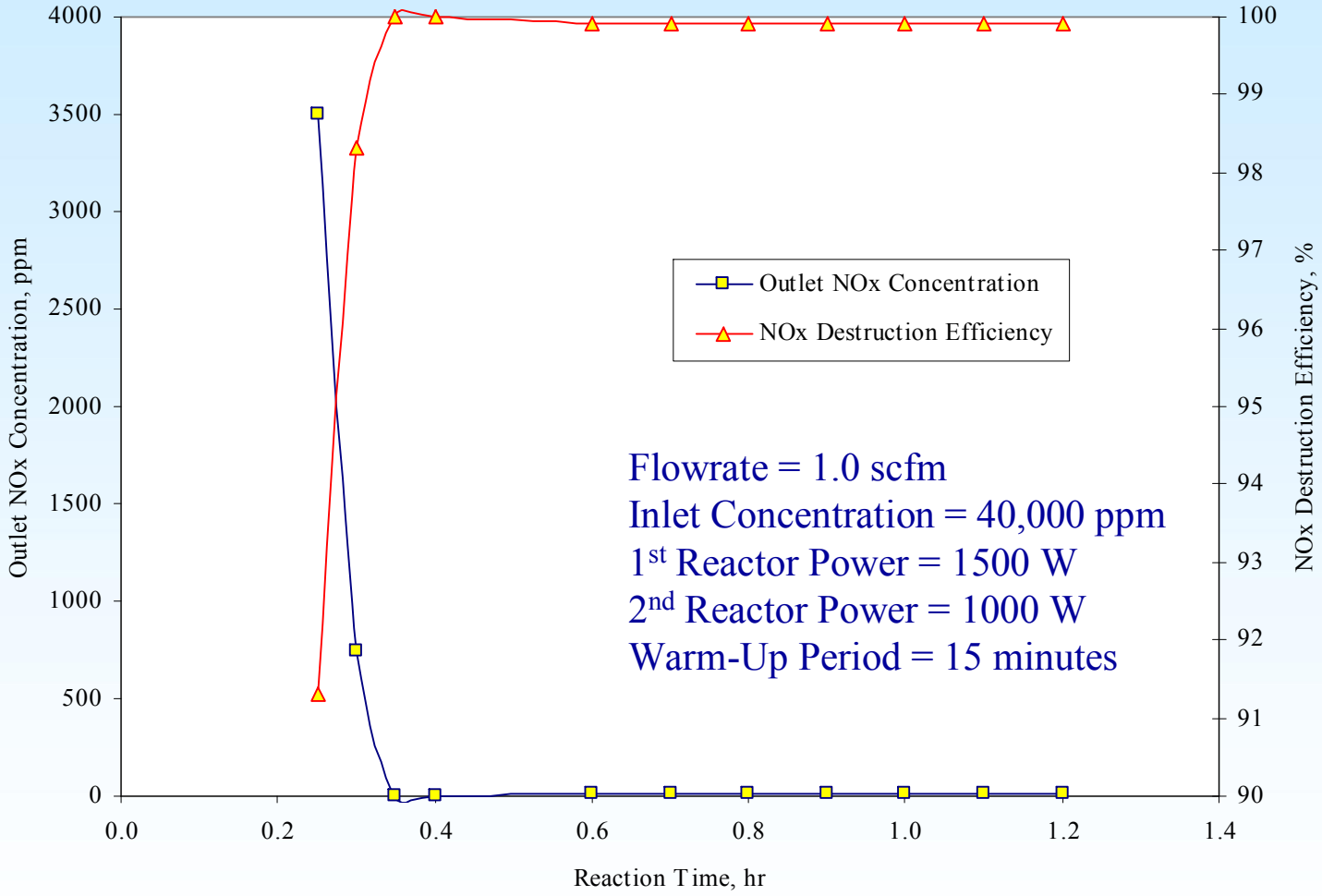
Typical Experimental Result



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Decomposition of Aerozine-50 over a Carbon Bed by Microwaves

$$N_2H_4 \longrightarrow N_2 + 2\,H_2$$

$$2\,N_2H_4 \longrightarrow N_2 + H_2 + 2\,NH_3$$

$$(CH_3)_2H_2N_2 \longrightarrow 2CH_4 + N_2$$

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Microwave-Induced Oxidation in SiC Bed

$$CH_4 + O_2 \longrightarrow CO_2 + 2H_2O$$

$$2H_2 + O_2 \longrightarrow 2H_2O$$

$$2NH_3 + 1.5O_2 \longrightarrow N_2 + 3H_2O$$

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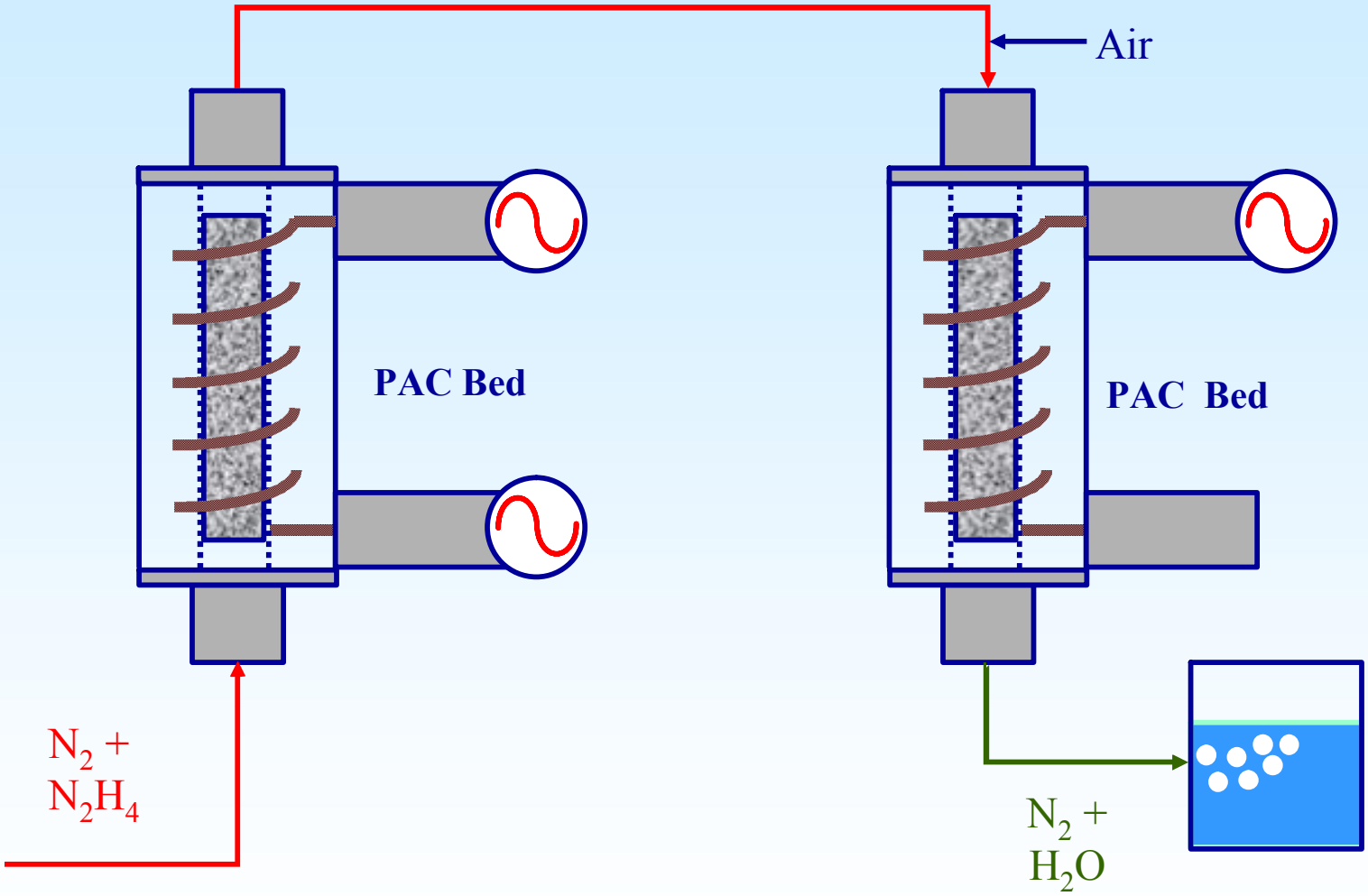
Hydrazine Destruction Apparatus



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Hydrazine Destruction in a Carbon Bed

N_2 Flow Rate, scfm	1st Reactor Power, W	2nd Reactor Power, W	Pressure Drop, psig	Hydrazine Emitted, g	Amount of Hydrazine Forming Ammonia (%)
1.0	1500	1000	0.8	0	0.001
1.5	1500	1000	1.0	0	0.008
2.0	1500	1000	1.7	0	0.079

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Fuel Site Field Demonstration

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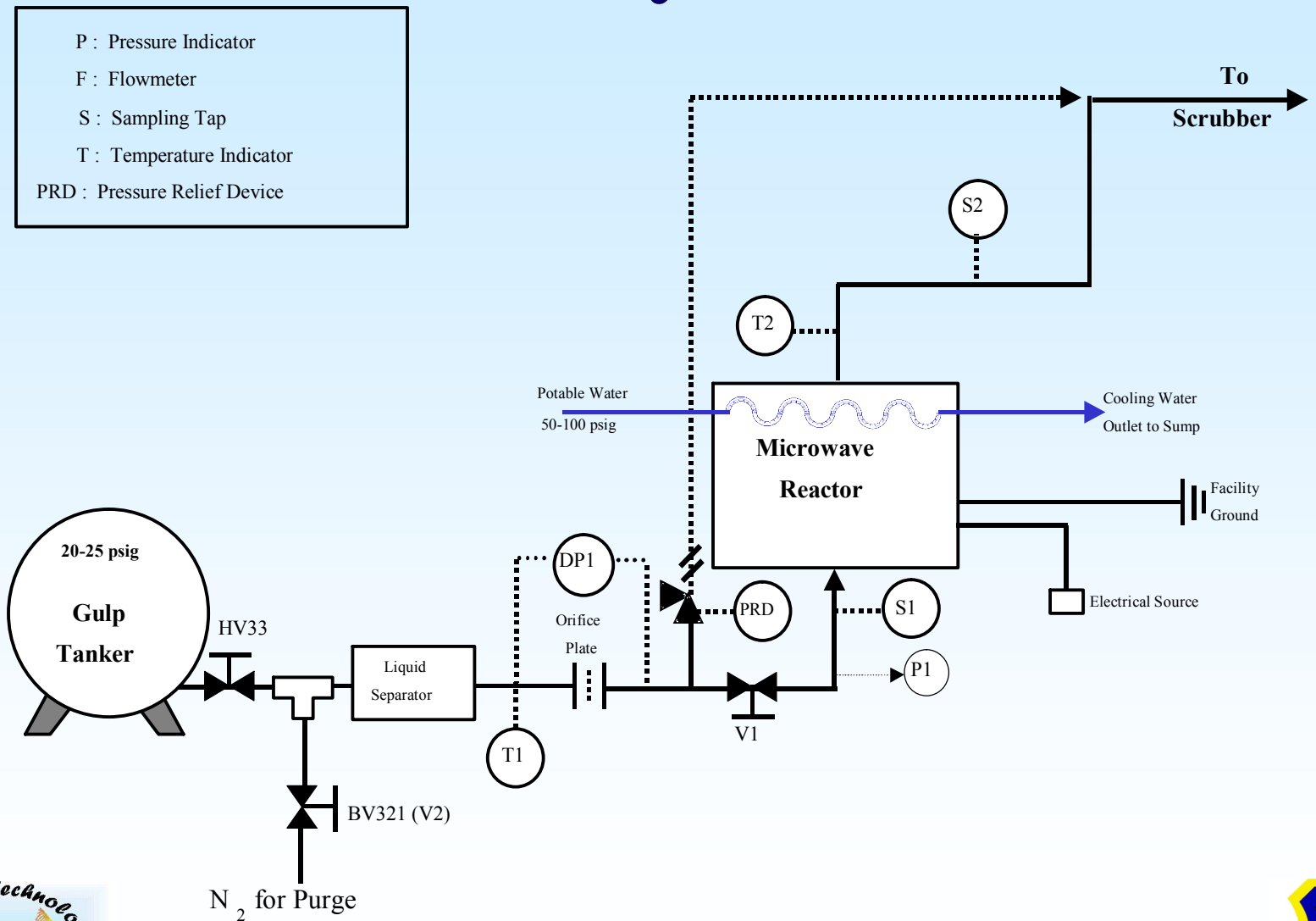
Reactor System PFD



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Reactor In Laboratory

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Fuel Site Scrubber System

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Reactor at Fuel Site

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Summary Fuel Test Results

- The Average Inlet Concentration = 11,000 ppm
- The Average Outlet Concentration = 63 ppm
- Microwave Destruction Efficiency = 99.4 %

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Oxidizer Site Field Demonstration

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Oxidizer Site Tanker

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Oxidizer Test Results

- Average Inlet Concentration = 396,000 ppm
- Average Outlet Concentration = 57 ppm
- Microwave Destruction Efficiency = 99.99%
- Percent of NOx Destroyed in 1st Reactors = 93%

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Construction of Microwave Scrubber for Destroying of Oxidizer Vapor

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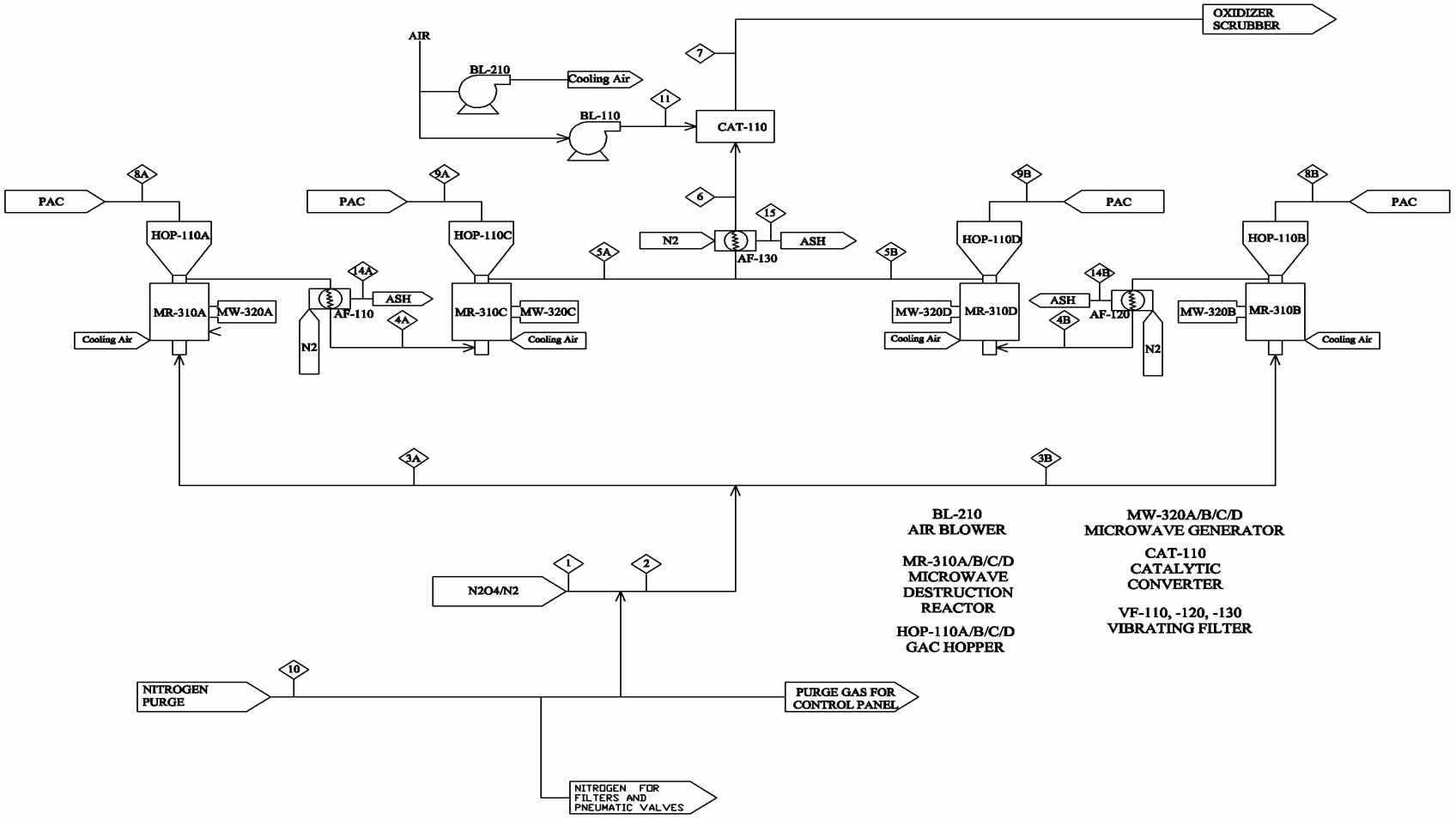
Process Flow Diagram



Reactor Bank

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Back Right Corner of Microwave Scrubber

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Back View of Microwave Scrubber

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Front View of Microwave Scrubber

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Electrical Cabinet

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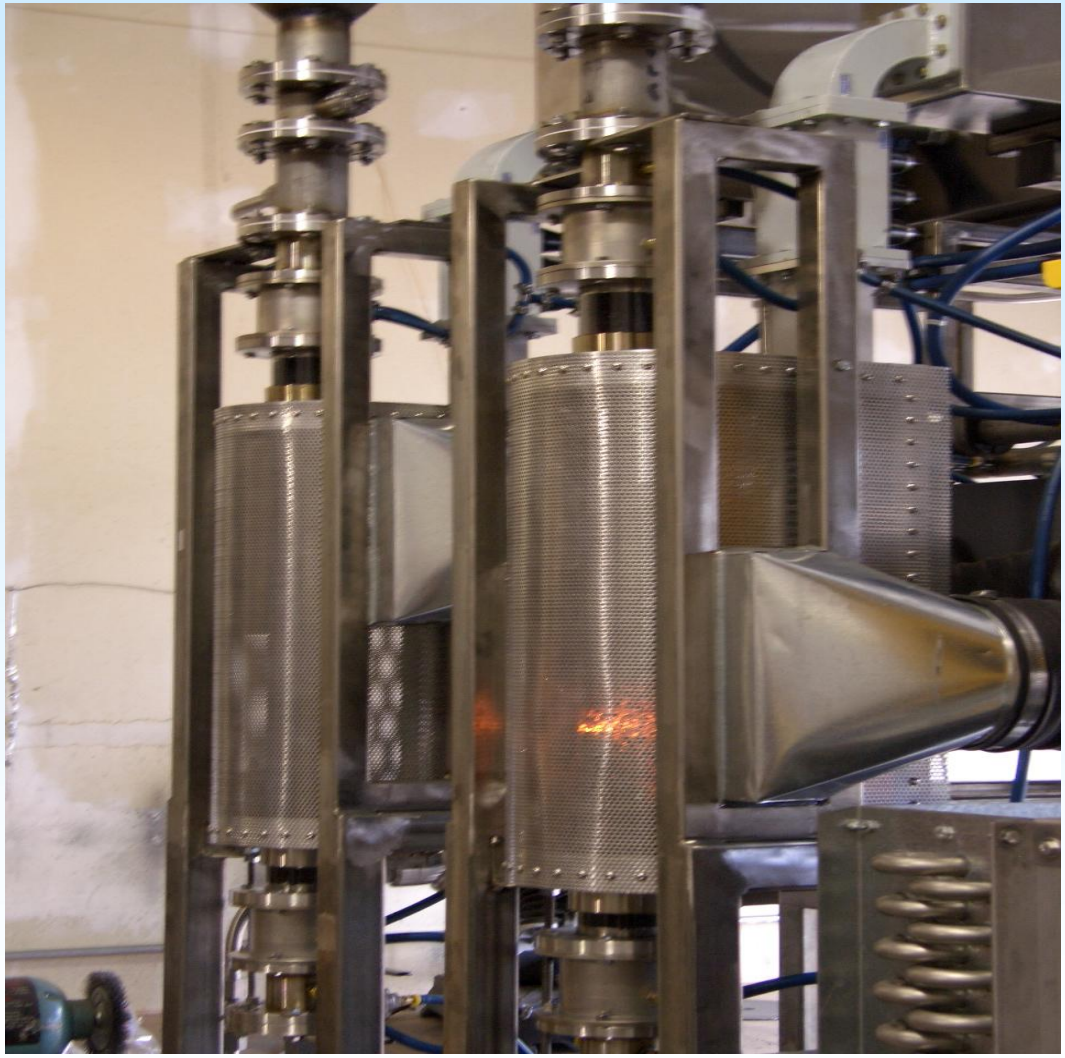
Microwave Reactor



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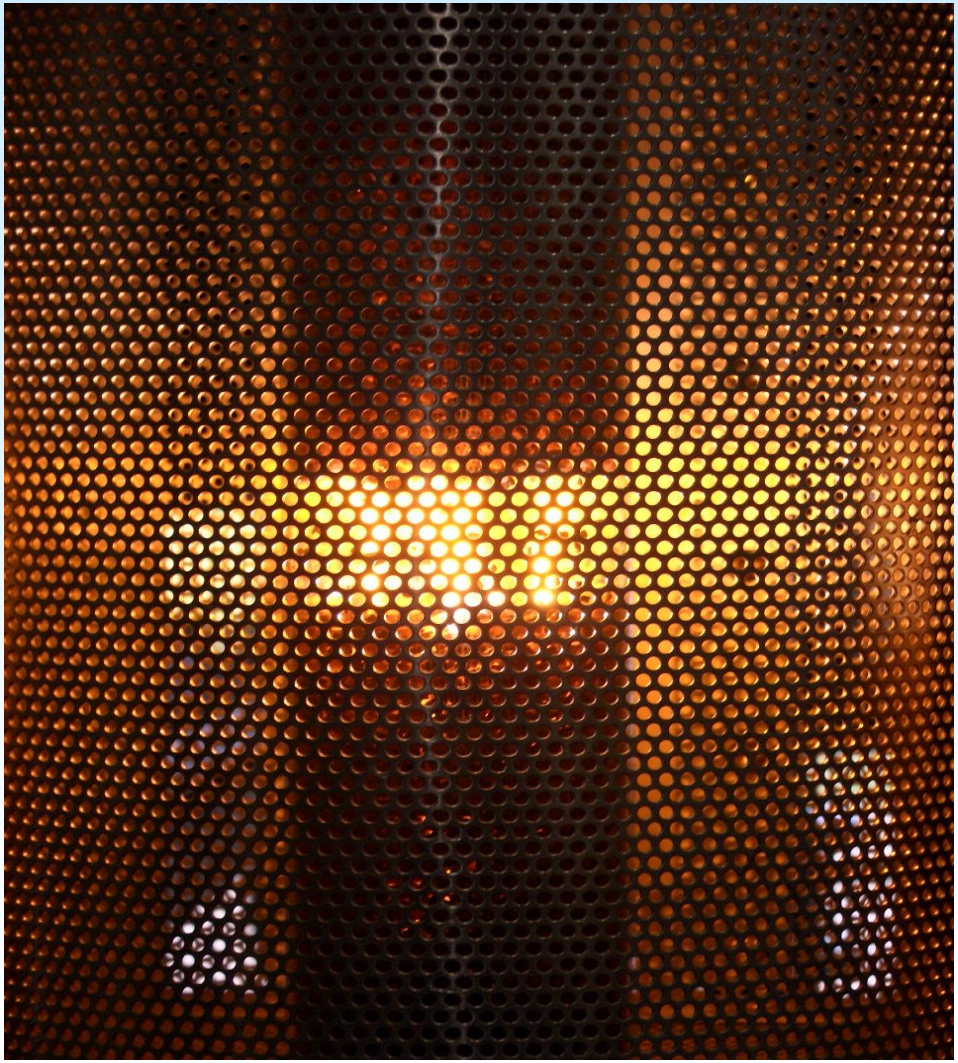
Reactor Tube Inside View



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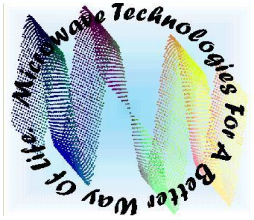
Test Results from Depressurization of 2,000-gallon Tank Containing N_2O_4 Liquid in Nitrogen ($F_{initial}$ = 7.5-scfm)

Time (min)	Process Pressure (psig)	Tank Pressure (psig)	Reactor 1 Temp. (F)	Reactor 2 Temp. (F)	Reactor 3/4 Temp. (F)	Measured Outlet NOx Concentration (ppm)
0	1.8	34	81.4	80.9	85.4	0
10	2.64	31	138	153.7	163	0
20	2.42	28	142.2	151.5	175.5	0
30	2.23	25.5	139.4	140.7	176.9	0
40	2.07	23	125.8	136.2	175.1	0
50	1.87	20.5	124	134	171	0
64	1.67	18	121.3	130.5	164.8	0
70	1.59	16.5	120.6	127.1	161.8	0
80	1.45	15	119.1	126.1	157.8	0
90	1.32	13	118.2	123.8	152.1	0
100	1.21	11	116.6	121.5	146.8	0
110	1.09	9.5	115.7	120	152.2	0
120	0.97	8	114.3	117.9	137.1	0
130	0.89	6.5	113.3	118.4	136.9	0
140	0.78	5	112.1	116.2	135.8	0

140 **Microwave Scrubber shut down normally**



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Microwave Scrubber for Fuel Vapor

- Microwave scrubber for fuel vapors is currently being constructed
- Construction will be complete by the end of December 2006
- Laboratory testing of the microwave scrubber will be conducted in January 2007
- Microwave scrubber will be installed at VAFB in February 2007

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PFD for Microwave Fuel Scrubber