

**DEER 2002**

**PLASMA ASSISTED CATALYSIS SYSTEM  
FOR NO<sub>x</sub> REDUCTION**

**BY NOXTECH**

**With the Support & Cooperation of DOE**

# Noxtech, Inc.

- **Delaware Corporation registered to do business in California**
- **MBO from Cummins Engine CO 1996: Total \$28 million invested (Cummins & Noxtech) emissions control technology**
- **DOE, CEC & AQMD supplied significant funding for all technology developed.**
- **Stationary Markets Autocatalytic Process that is patent (three) protected (boilers & IC engine powered generators):**
  - **ICE Generators: Currently being produced and sold**
  - **Boilers: Successfully demonstrated under license 200 MW boiler**
- **Transportation Market patent (one basic) protected Plasma process: 80 hp Plasma System prototype demonstrated 94% NOx reduction next generation system being fabricated**

# Autocatalytic Noxtech System Capabilities

- **Controls NO<sub>x</sub> to 30 ppm for diesel, NG, coal fired combustion**
- **Concurrent Depletion of UBHC, CO, Soot, & NH<sub>3</sub> slip**
- **Can use polishing catalysts to achieve very low levels of NO<sub>x</sub> (10 ppm) & particulates**
- **Low operating costs: no catalyst replacement, uses low grade urea**
- **Low operating back pressure minimizes fuel consumption**

# **Commercial Status Advanced Noxtech Technology Auto-Catalytic NO<sub>x</sub> Reduction system**

## **IC Engine/generators**

- **Commercial sales of systems to treat the exhaust of diesel and natural gas powered generators in 2002.**
- **Projected market of over \$500 million (retrofits of 7500 MW's) in California and \$5 billion US: Stand-by diesel powered and bio-diesel powered generators**

## **Boilers**

- ❖ **License granted to Mitsui-Babcock Corporation**
- ❖ **Noxtech process has been successfully demonstrated on a TVA 200 MW coal fired boiler located in Kingston TN by Mitsui-Babcock anticipate 4 additional coal fired boiler installations fourth quarter 2002.**

# NOXTECH

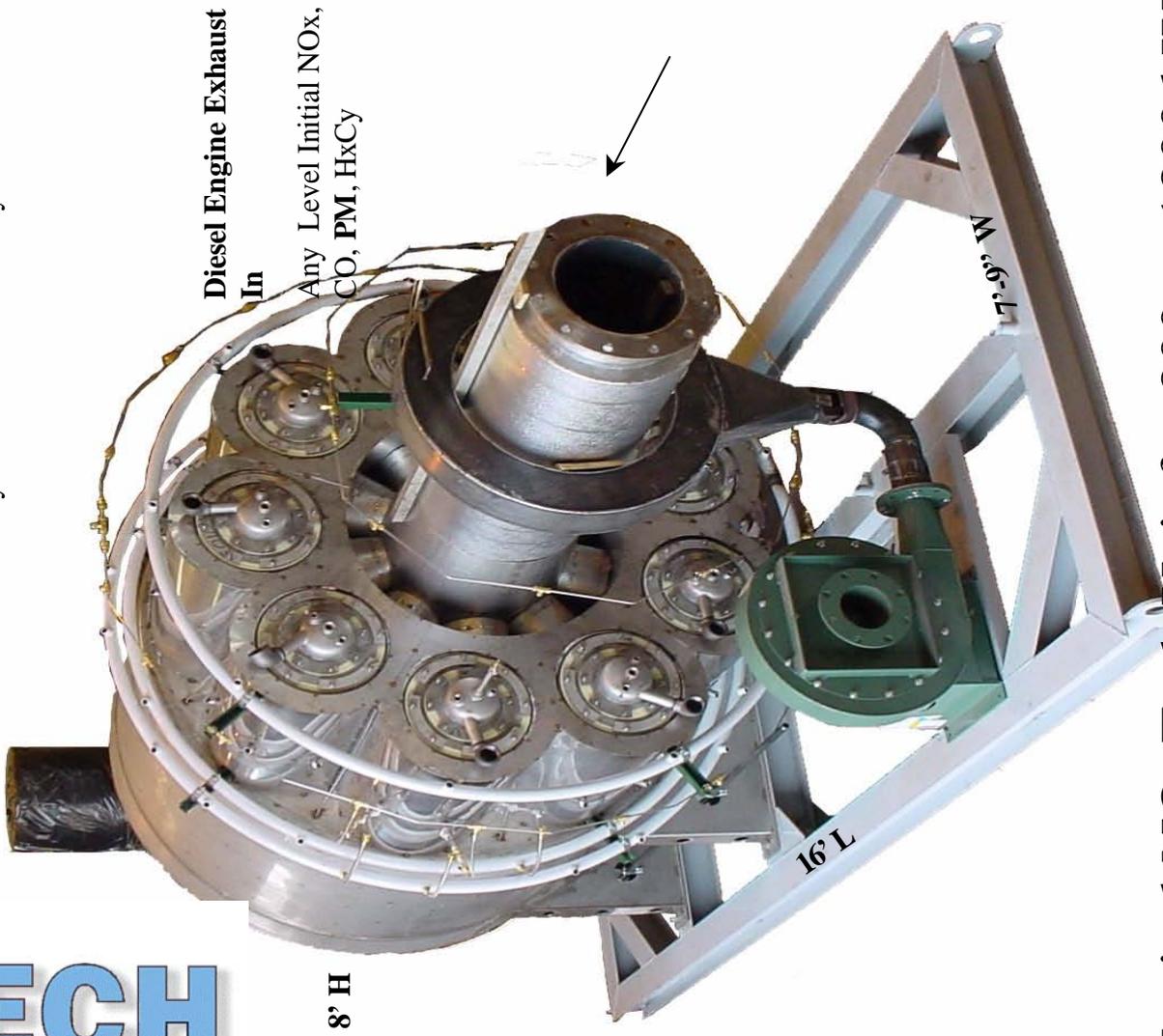
## Treated Exhaust Out

< 0.4 g/bhp-hr NOx

< 50 ppm CO

PM reduced by > 95%

Unburned Hydrocarbons Reduced by > 95%



Diesel Engine Exhaust  
In

Any Level Initial NOx,  
CO, PM, HxCy

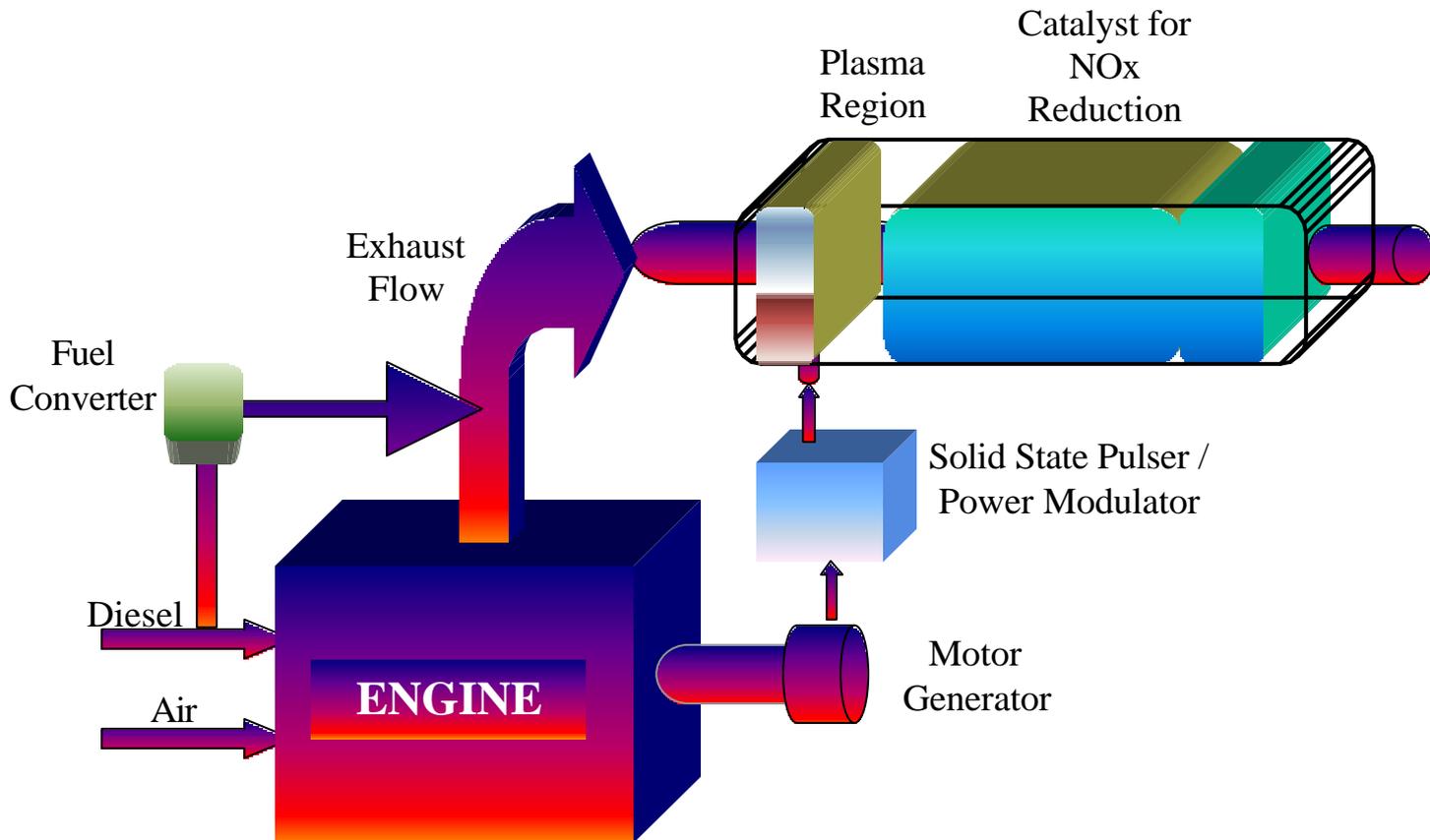
8' H

16' L

17'-9" W

Typical NOxTech Unit for 800 to 1800 kW  
Standby Diesel Engine Generator,  
(Without Integral Heat Exchanger) Total Weight: 8000 lbs

# PAC SYSTEM SCHEMATIC



# Program Objectives 2002

❖ Fully characterize (parametric studies), redesign and refine 80 Hp system with advanced (practical, semi-commercial) components:

- Thyatron pulser ----> solid state pulser

- diesel fuel conversion system: improved performance/design

- Develop & improve catalysts: spheres --> monolith, enhanced performance: space velocity, available surface, selectivity

- plasma reactor -----> smaller more efficient

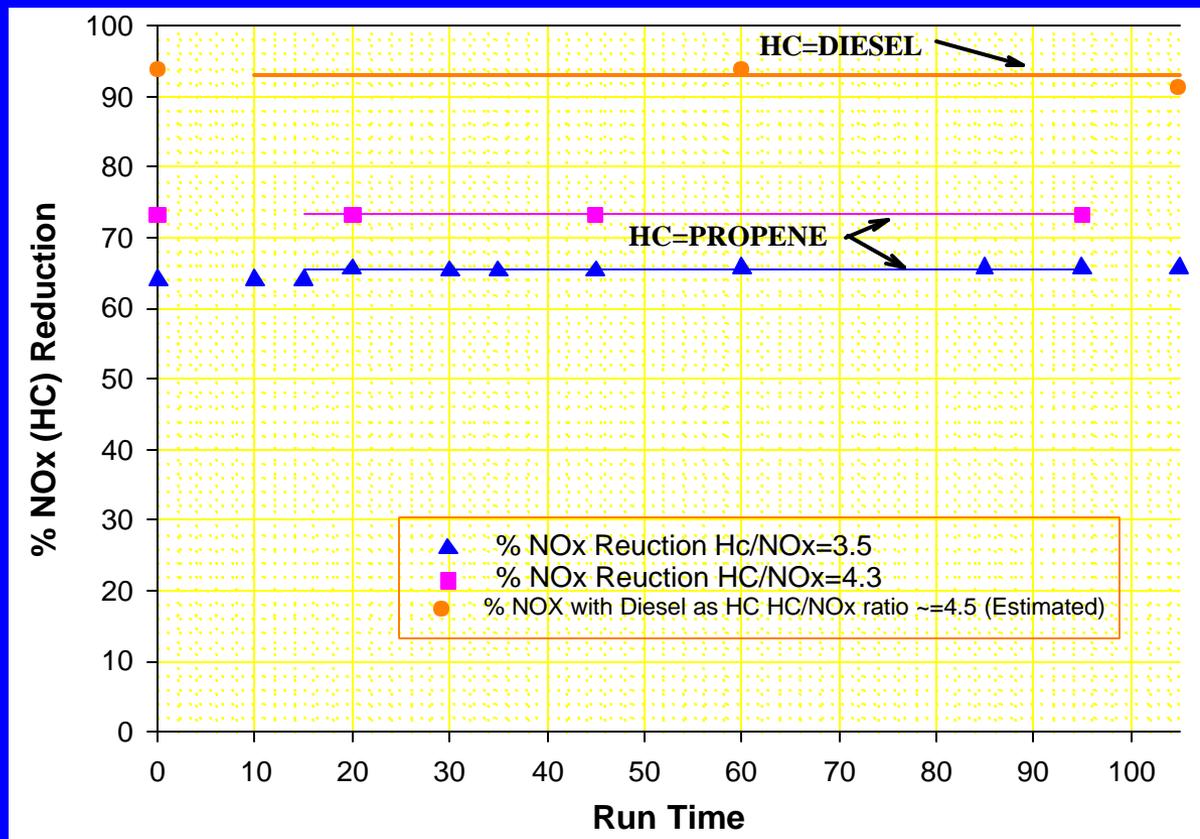
❖ Scale, design 250 Hp system.

❖ Supply 80 hp prototypes for third party evaluation

# Plasma Program Accomplishments

- **Demonstrated 94% NO<sub>x</sub> reduction @30,000 on original design 80 hp system**
- **Performed parameter studies to obtain design data for advanced unit**
- **Resigned, built and currently evaluating an advanced version of the original 80 hp capable prototype.**
- **Demonstrated technical viability & improved design/performance of all system components:**
  - **Diesel fuel converter: demonstrated ability to use No. 2 (500 ppm off-highway) diesel fuel as a reductant**
  - **Pulser: converted to solid state major reduction in size and components**
  - **Plasma reactor: reduced size, improved efficiency, simplified construction/fabrication**
  - **Demonstrated a sulfur tolerant ceramic catalyst, with broad temperature activation range**

# Noxtech's 80 Hp Plasma Assisted catalyst system Performance at Steady state with 1988 Cummins 80 Hp Engine



Some data on steady state run with Series B Engine and Diesel and Propene as HC reductant source.

Sp. Plasma energy = 17.5 J/lit :

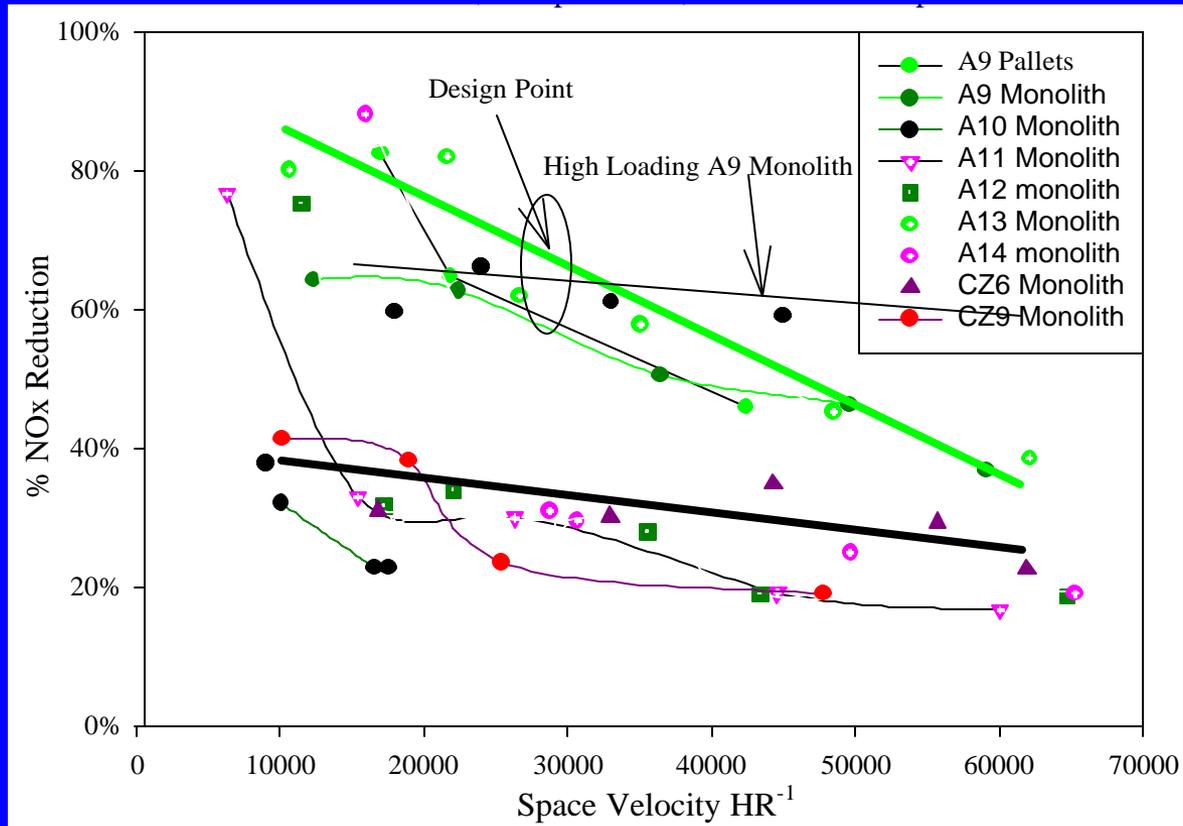
Engine load = 48

Hp : Diesel Exhaust

## Conclusion

Initial testing shows good NOx reduction can be achieved with PAC system operating with diesel as a reductant source.

# NO<sub>x</sub> reduction Vs. Space velocity for catalysts tested in phase 2(2002)



**HC/NO<sub>x</sub> Ratio = 5**

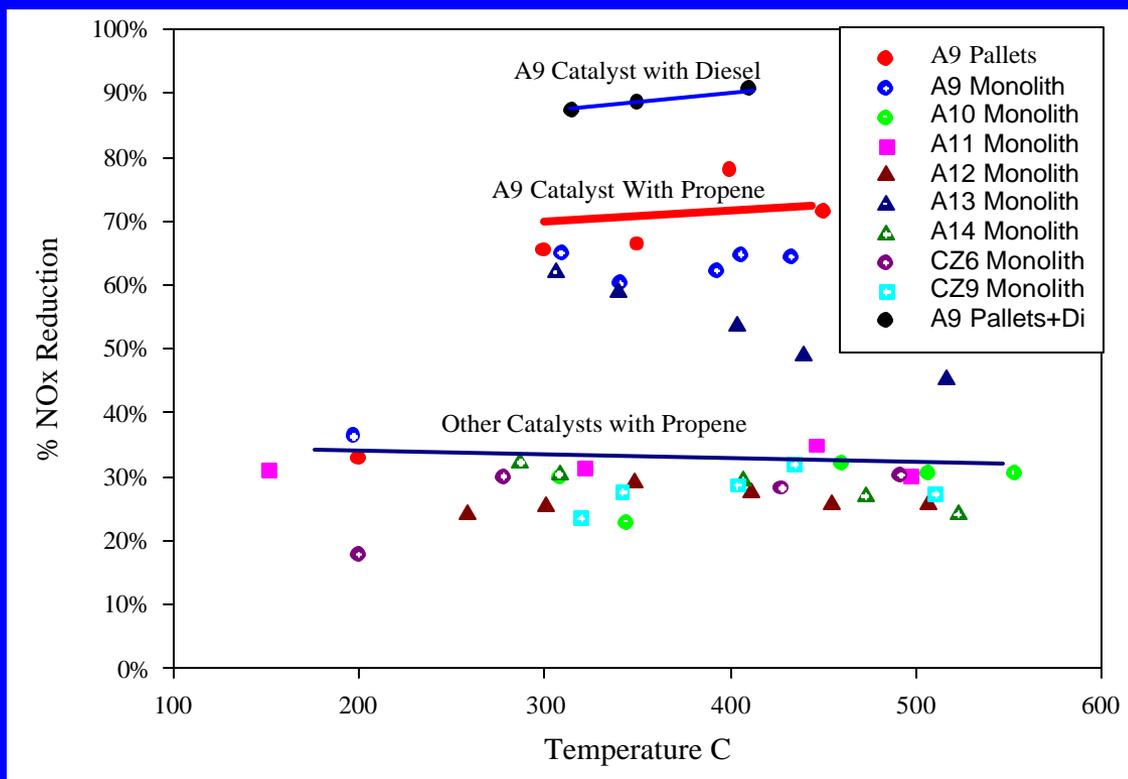
**Temp = 350°C**

**HC source=  
Propene**

**Simulated gases**

**300 PPM NO<sub>x</sub> Feed**

# Temperature vs. NO<sub>x</sub> Reduction for catalysts tested in phase 2(2002) on a bench reactor



**HC source= Propene**

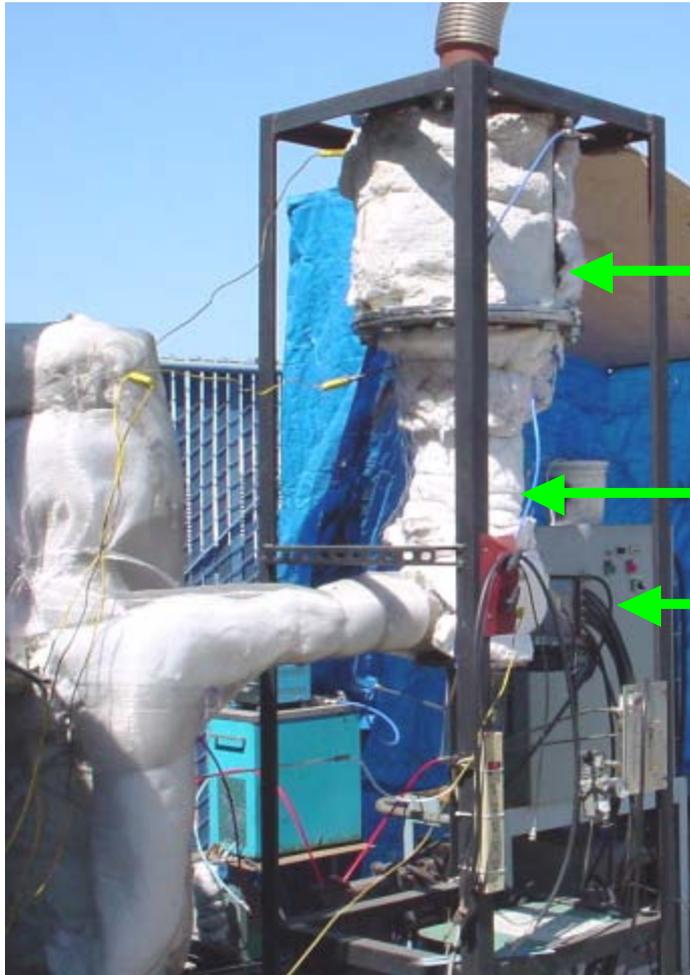
**HC/NO<sub>x</sub> = 5:**

**NO<sub>x</sub> feed = 300 PPM**

**Simulated gases**

**Sp. Velocity 30K HR<sup>-1</sup>**

# Initial 80 Hp Plasma Assisted catalyst system

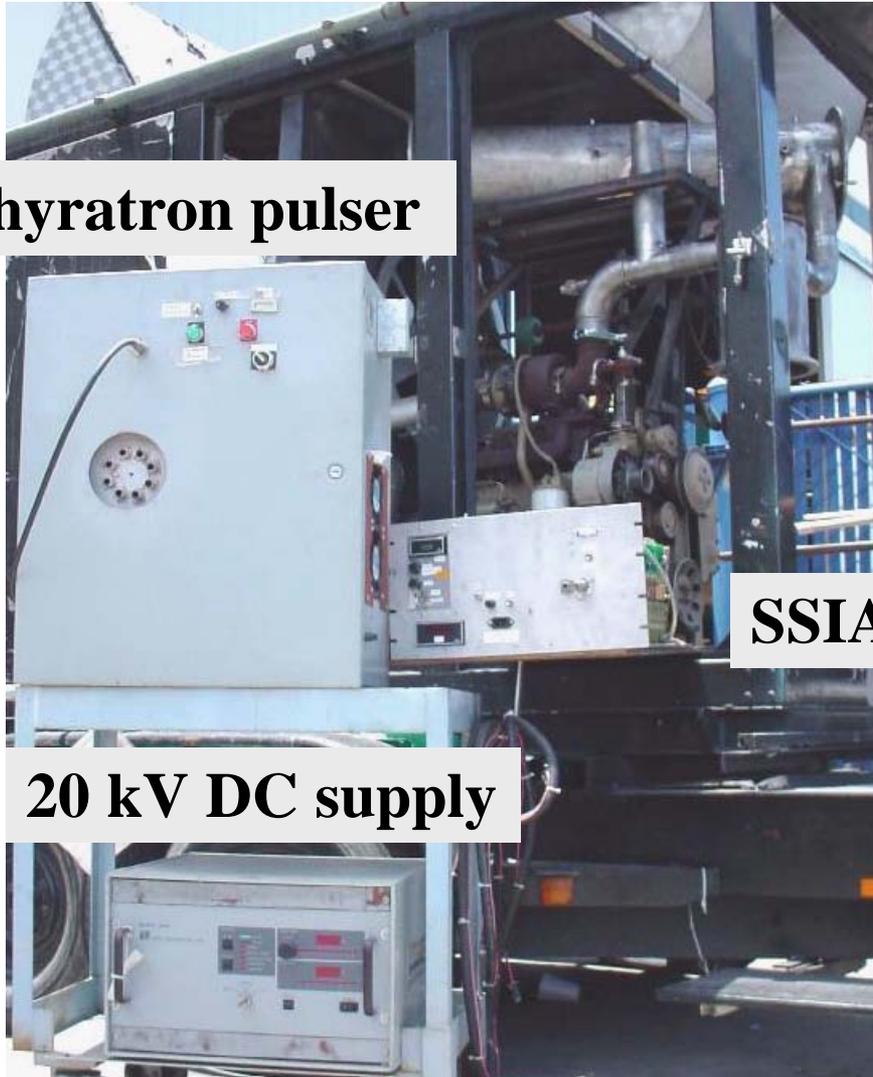


← **Catalytic Reactor**

← **Co-axial Plasma reactor**

← **Thyatron based power supply**

# Initial Power Supply & Pulsar 80 hp Unit



**Thyratron pulser**

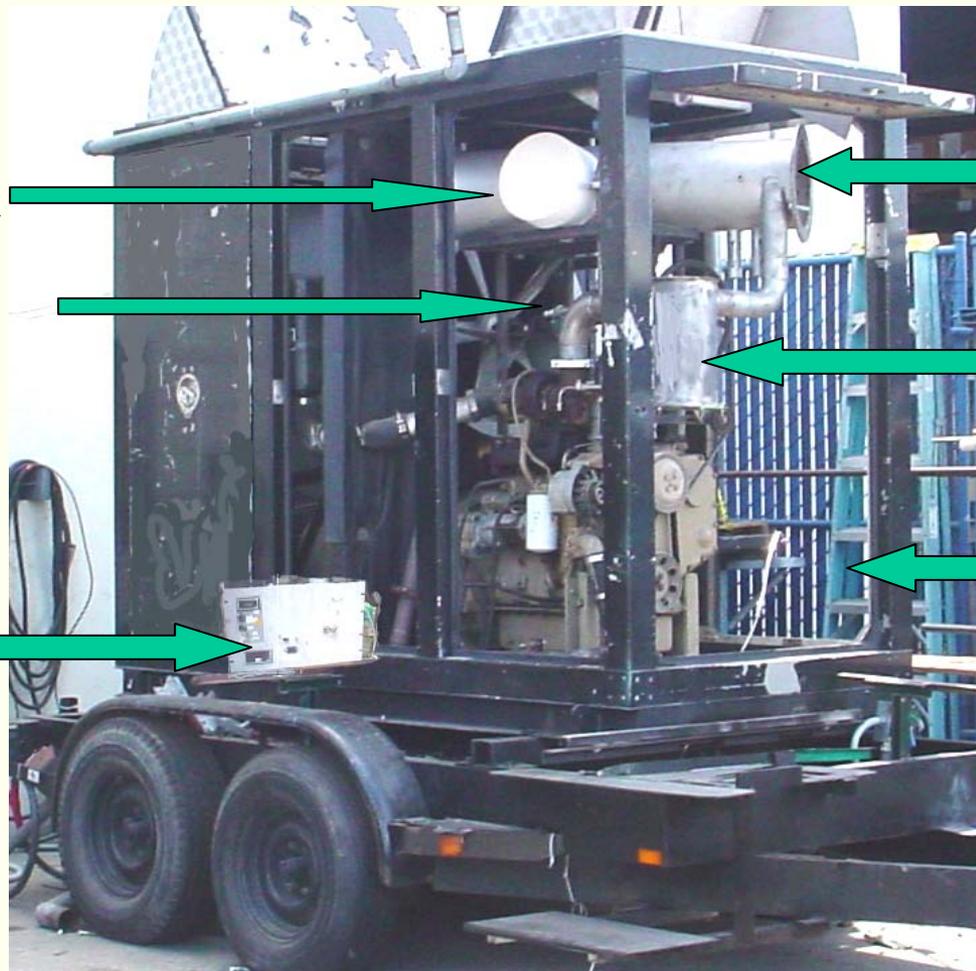
**Plasma-catalytic reactor**

**60 kW diesel generator**

**SSIA pulser**

**20 kV DC supply**

# Noxtech Advanced 80 hp Plasma System



Monolith Catalyst

Fuel converter

Solid State  
Power Supply

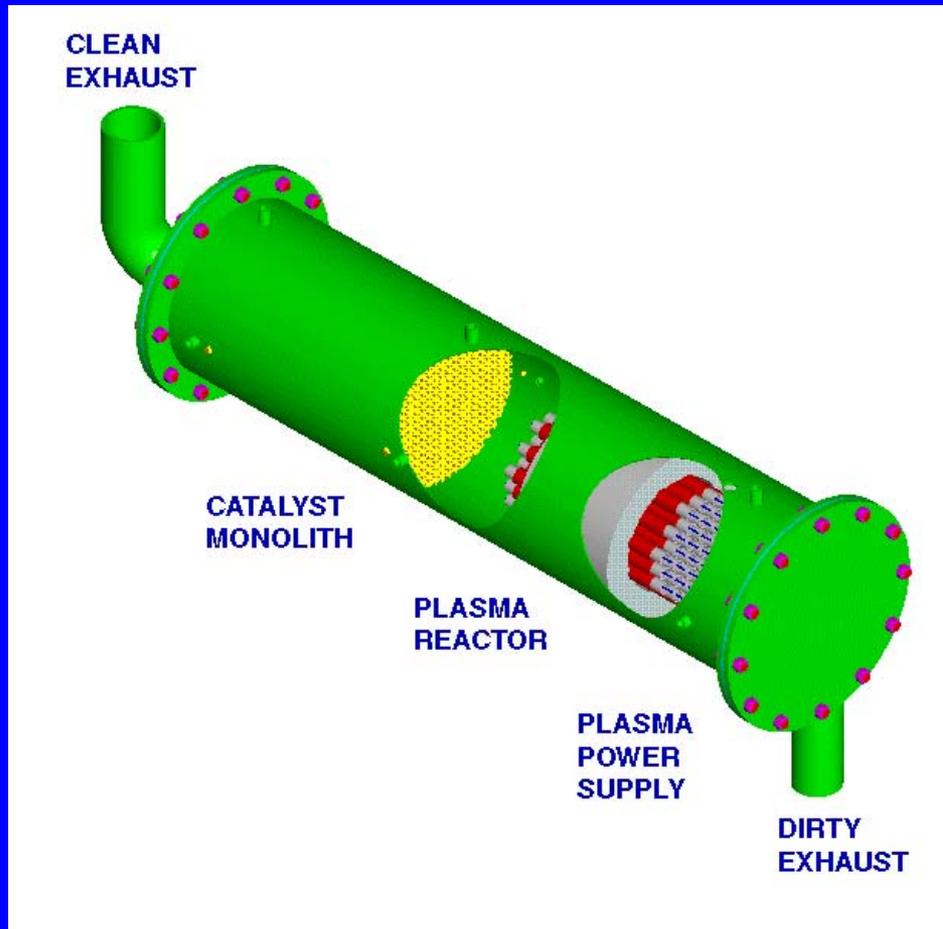
Plasma/catalytic  
reactor

Particulate Filter

Cummins series B  
80 HP diesel Genset

**NOXTECH**

# NOXTECH'S INTEGRATED 80 HP PAC SYSTEM



**Overall**

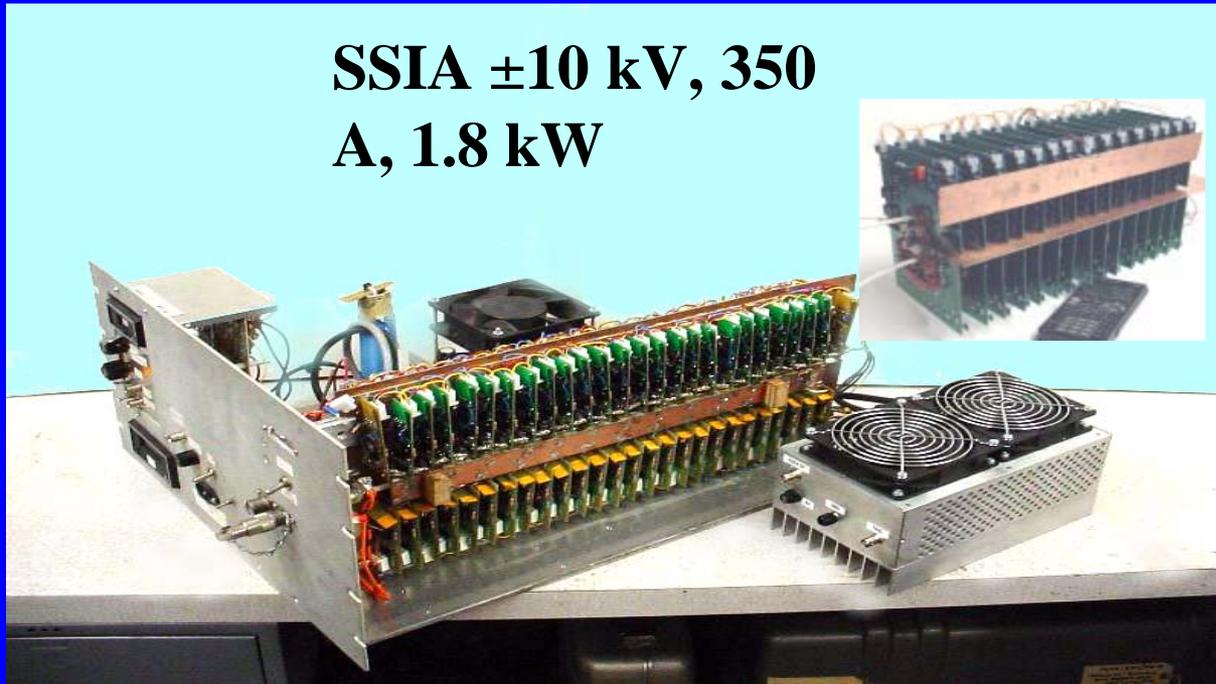
**10" OD X 45" Long.**

**Integrated in current  
80 Hp Genset.**

**Passive system**

# Noxtech's Solid-State Pulsers

**SSIA  $\pm 10$  kV, 350  
A, 1.8 kW**



**SSIA: 8 kV, 160 A, 0.5 kW**

**SSOS: 8 kV, 200 A, 250 W**

# PLASMA REACTOR FOR 80 HP SYSTEM



**Total reactor 7" OD X 12" Length**

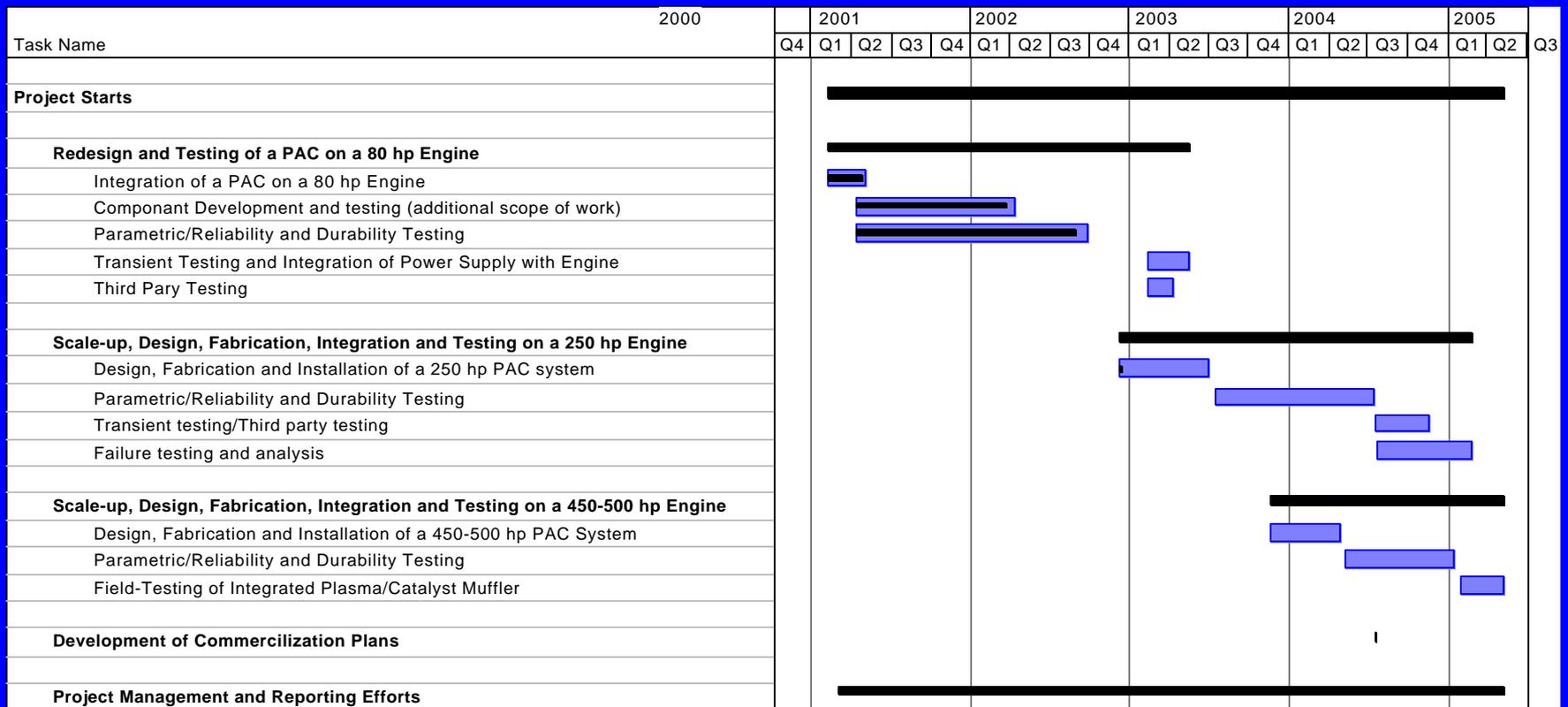
**Very High space velocity  
throughput.**

**Lightweight.**

# Project Goals & Objectives for 2003

- Evaluation of advanced 80 hp PAC prototype under transient operation
- Fabrication and demonstration of 250 hp prototype
- Third party evaluation of 250 hp prototype
- Evaluation of 250 hp prototype system under transient operation
- Continue to refine and improve system components: size, performance, efficiency, durability and producibility
- Design 450-500 hp PAC prototype

# OVERALL PROJECT TIMELINE



# PARTNERS



## John Deere

- One of the major Diesel engine producer in the world.
- Presence in 160 countries with 37,000 work force.
- \$960 Million dollar profit in 1997 on \$12.79 Billion sales.
- Factories located worldwide.



## Mack Trucks Inc.

- Founded in 1900
- One of largest producers of heavy-duty trucks and engines.
- \$105 Million dollar profit in 1998 on \$2.77 Billion sales.
- Factories located worldwide.

## Sud-Chemie Prototech



- Part of Süd-Chemie AG of Munich, Germany.
- One of largest producers Catalyst, Specialty Chemicals and industrial minerals.
- Operates 25 Plants in 18 Countries.

## ArvinMeritor

- ArvinMeritor is joining of two companied namely Arvin industries Inc and Meritor Automotive Inc.
- One of the largest producers of OEM and aftermarket automotive parts
- 1999 combined revenue of \$7.6 Billion dollars.

**ArvinMeritor™**

**NOXTECH**

# Acknowledgements & Thanks

- **DOE: John Fairbanks, Program Manager**
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