

Environmentally-Neutral Aircraft Propulsion Using Low Temperature Plasma

John Lylegian, Jason Tyll, and Wallace Chinitz

GASL, Inc.

Ronkonkoma, NY 11779

NIAC Annual Meeting - June 6, 2000

Motivation

- NO_x formation is a consequence of the combustion of various fuels.
- Nitric oxide (NO):
- Quickly forms nitrogen dioxide (NO_2), a respiratory irritant.
- Active participant in photochemical smog formation.

Motivation (2)

- Current methods of NO_x reduction involve catalysts used either alone (*e.g.* Rh), or in an atmosphere containing hydrocarbons (*e.g.* Cu or Fe).
- Rhodium is too expensive for widespread use, and extra hydrocarbons in fuel exhaust are undesirable.

Objective

- To reduce NO_x in turbojet emissions by an order of magnitude using a low-temperature plasma.
- “Low-temperature plasma” implies plasma excitation temperatures in the range of 3000 to 5500 K.

Previous Work

- Luo *et al.* (*J. Phys. Chem. A* 102:7954, 1998) decomposed NO in He using a low-temperature plasma at atmospheric pressure.
- The degree of NO destruction is a function of initial NO concentration, residence time, input voltage, and **additives**.

Additive Effects on NO Reduction from Previous Work

- CO_2 and H_2O inhibited the destruction of NO.
- CO , O_2 , C_2H_6 , and other carbon species accelerated the destruction of NO.

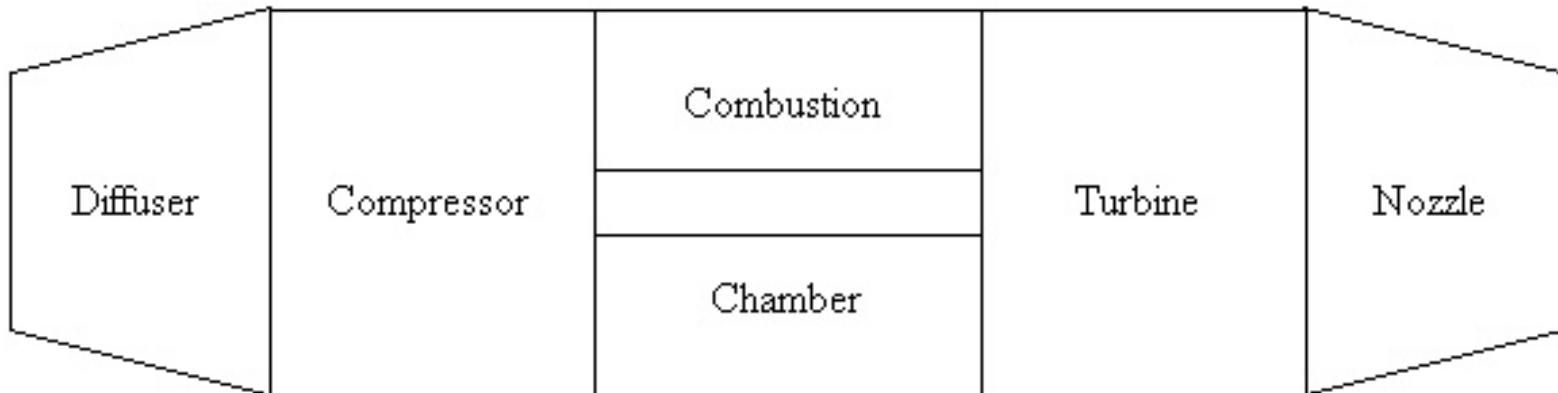
Extending This Concept to the Turbojet Engine

(Could it still work?)

- Higher temperatures (up to 1700 K)
- Higher pressures (up to 40 atm)
- Shorter residence times (~ 0.1 s)
- Presence of different species (O_2 , N_2 , CO_2 , H_2O)

Turbojet Engine

1. Air is compressed and heated in diffuser/compressor
2. Fuel mixed in and burned in combustor
3. Partially expanded in turbine to provide power for compressor
4. Expansion continues through nozzle, generating thrust



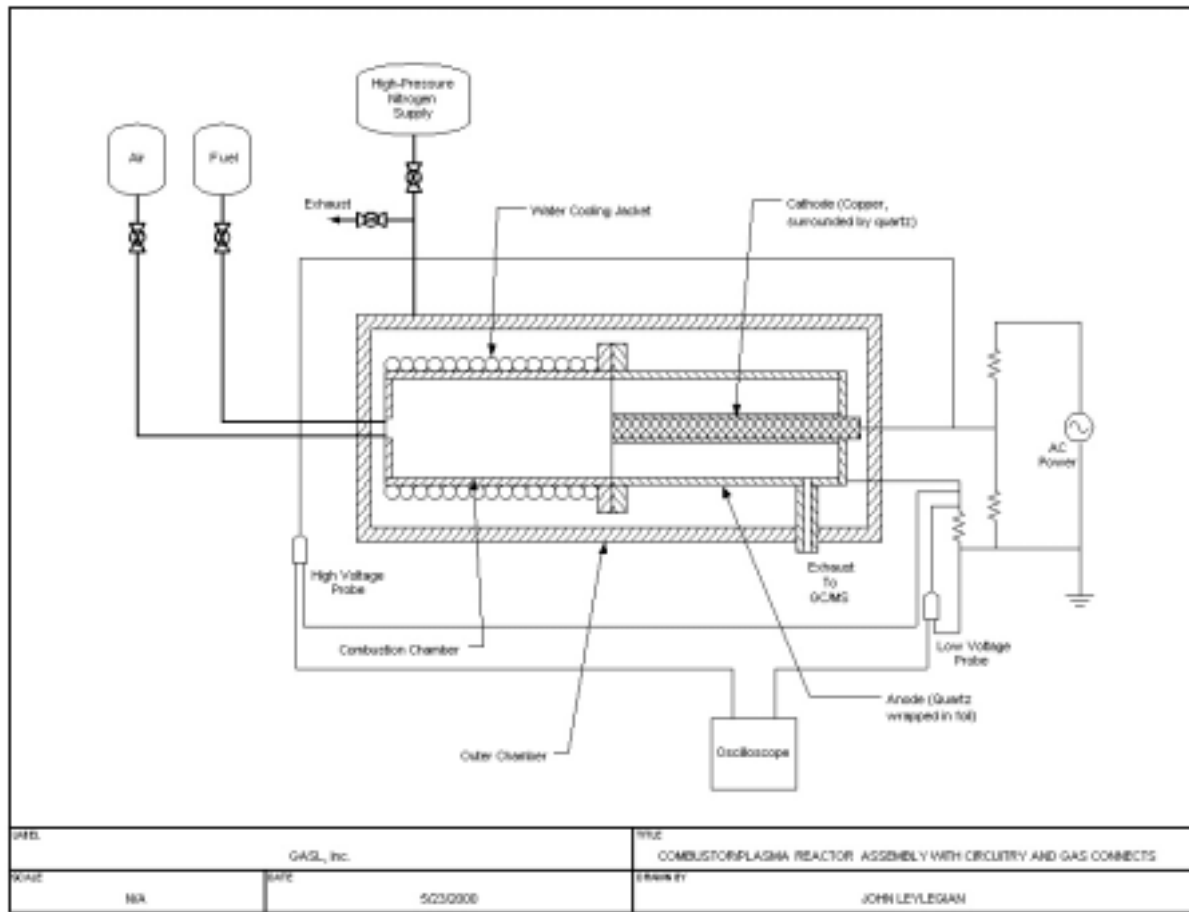
Proposed Work

- Perform experiments similar to those of Luo *et al.*, using the products of hydrocarbon combustion, at conditions similar to those encountered in a turbojet engine.

Program Outline

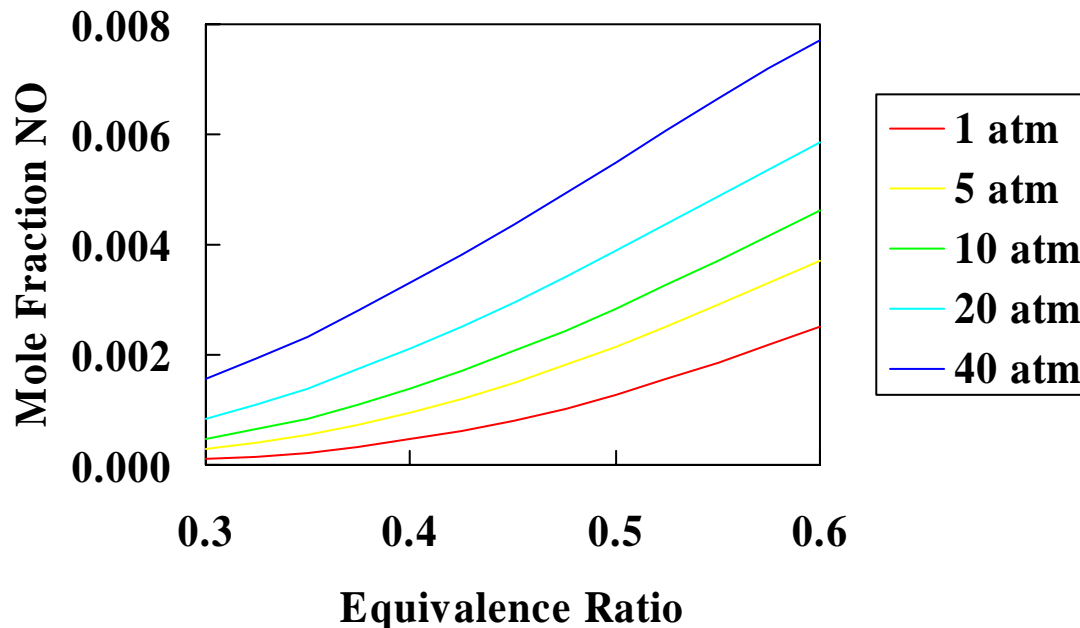
	Task Name	May 2000				Jun 2000				Jul 2000				Aug 2000				Sep 2000				Oct 2000											
		4/30	5/7	5/14	5/21	5/28	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/23	7/30	8/6	8/13	8/20	8/27	9/3	9/10	9/17	9/24	10/1	10/8	10/15	10/22						
1	Equilibrium Calculations	█																															
2	Set up Test Matrix					█																											
3	Design C/PR Configuration					█																											
4	Design Circuit Configuration					█																											
5	Fabricate C/PR													█																			
6	Assemble and Pre-Test Electrical Configuration													█																			
7	Assemble Entire Configuration																	█															
8	Shakedown Test Using Inert Gas Flow																	█															
9	Perform Experiments																	█															
10	Analyze Data; Recommendations for Phase II Experiments																	█															
11	Preliminary Configuration of Reactor for Engine Use																					█											
12	Prepare Phase II Proposal																									█							

Rig Schematic



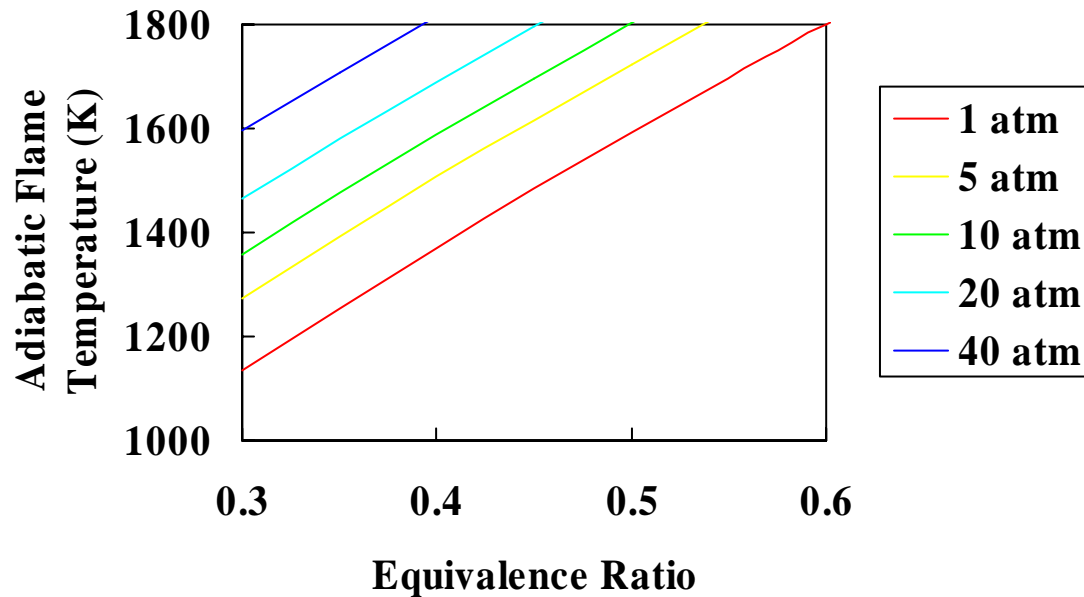
Estimation of NO Levels in Jet Exhaust

- Variation of NO in ethylene/air products with equivalence ratio:



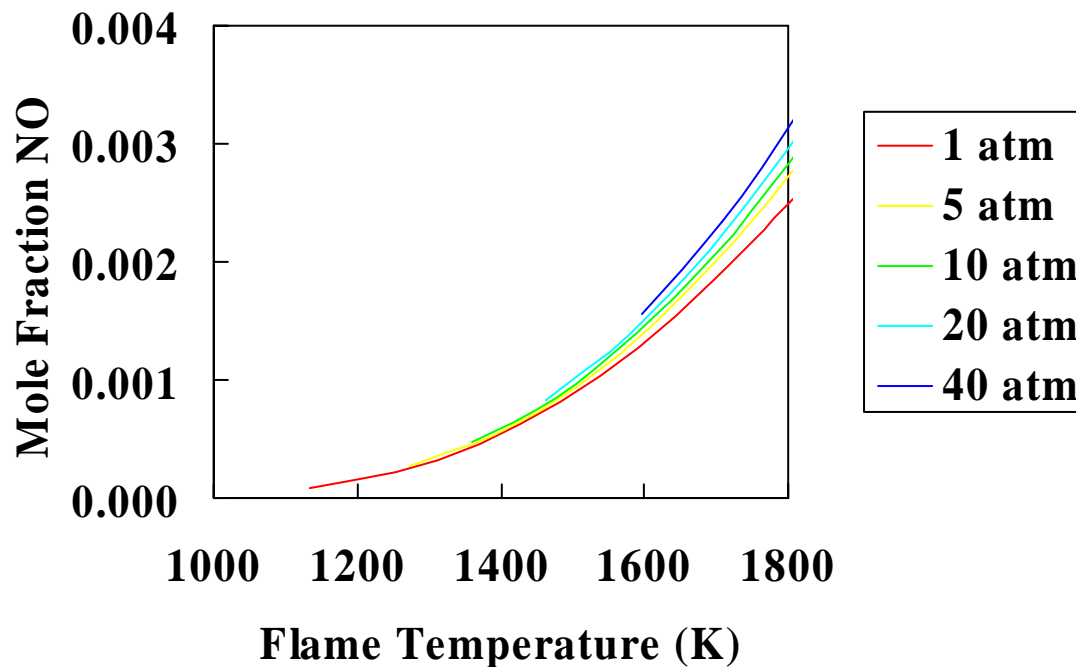
Estimation of NO Levels in Jet Exhaust

- Equilibrium temperatures of ethylene/air mixtures:



Estimation of NO Levels in Jet Exhaust

- Variation of NO in ethylene/air products with temperature:



Determination of Power Requirements (1)

Rate constant for overall reaction:



converted to Arrhenius form: $k = A T^{0.75}$
where A is a function of the input power.

Determination of Power Requirements (2)

Using the power-rate constant data of Luo *et al.* and the LSENS code, the power required for an order-of-magnitude reduction in NO mole fraction can be determined:

$$P \text{ (W)} = 4.868 X_{\text{NO}}^{-1.0196}$$

For $X_{\text{NO}} = 0.002$, $P = 2.75 \text{ kW}$

Power Sources

- Fuel Cells: Automotive PEM fuel cells available up to 20 kW (if DC is required)
- Fuel Cell + Inverter (if AC is required)
- Turbine

Summary

- Oxides of nitrogen, produced by fossil fuel combustion, are environmental and health hazards.
- Use of plasmas to reduce NO levels is a clean and inexpensive method.
- A plasma generator is being designed to test this method on hydrocarbon-air combustion products at high temperature and pressure.