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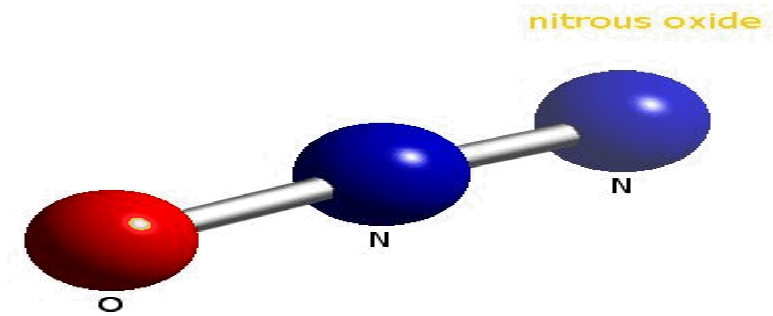



# Nitrous Oxide an Overview

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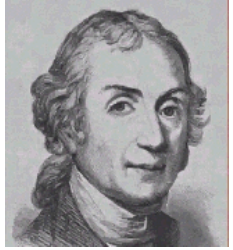
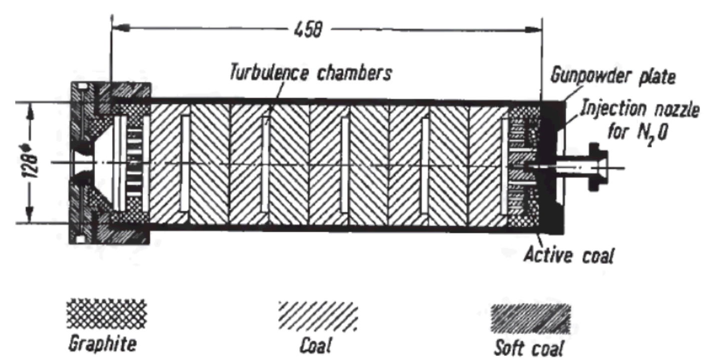
# History



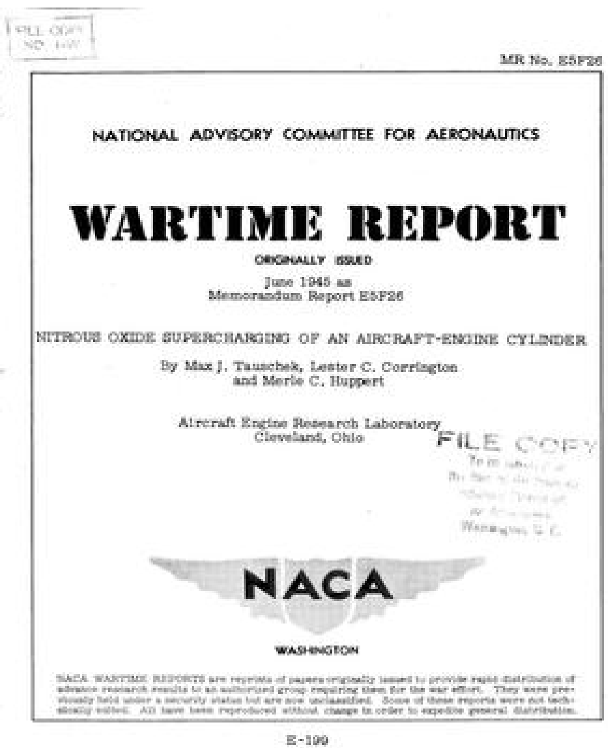
- First discovered
  - 1772 Joseph Priestly
- Recreational use or scientific investigation?

  - 1799, Sir Humphyr Davey (1778-1829)
    - “The experiments quickly increased in frequency and also intensity”
- Anesthesia
  - 1840’s Horace Wells, modern dental/medical Anesthesia
  - George Poe, Trenton NJ USA, liquefied $N_2O$, 1883 large dental supplier
- Propulsion
  - 1935 Mono prop > nitrous oxide & anhydrous ammonia (green propulsion)
    - Working with I.G. Farben, Otto Lutz
  - 1937 Hybrid > nitrous oxide & coal (green propulsion)
    - Burning tests at I.G. Farben by L. Andrussow, O. Lutz and W. Noeggerath.
    - Thrust 10,000 nt, propellants: Coal and gaseous nitrous oxide.



# History

- Aircraft super performance (thru-WW2)
  - 100% power increase documented
    - Refrigerated liquid use (-90 C)
    - Anti-detonation fluid ( cooled intake charge)
    - GM1
    - Etcetera
- Successful operationally


MR No. E5F26

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

June 1945 as
Memorandum Report E5F26

NITROUS OXIDE SUPERCHARGING OF AN AIRCRAFT-ENGINE CYLINDER

By Max J. Tauschek, Lester C. Corrington
and Merle C. Huppert

Aircraft Engine Research Laboratory
Cleveland, Ohio

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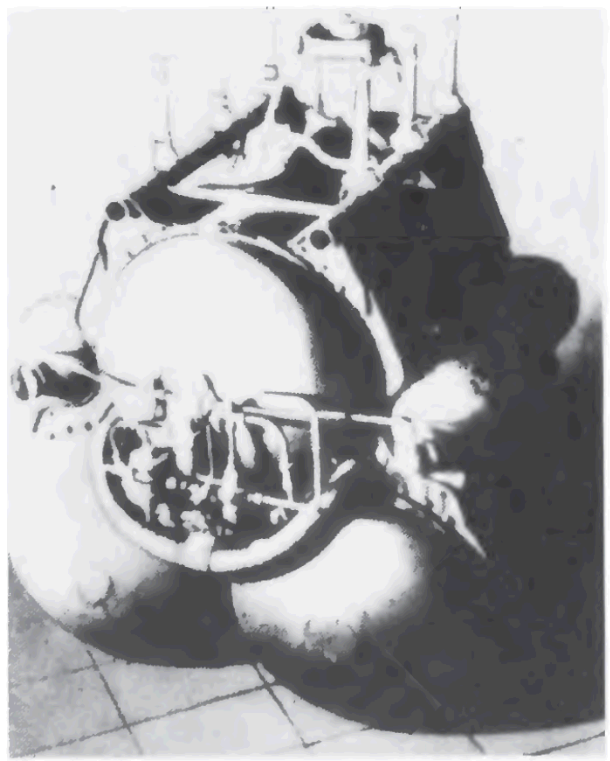
E-199



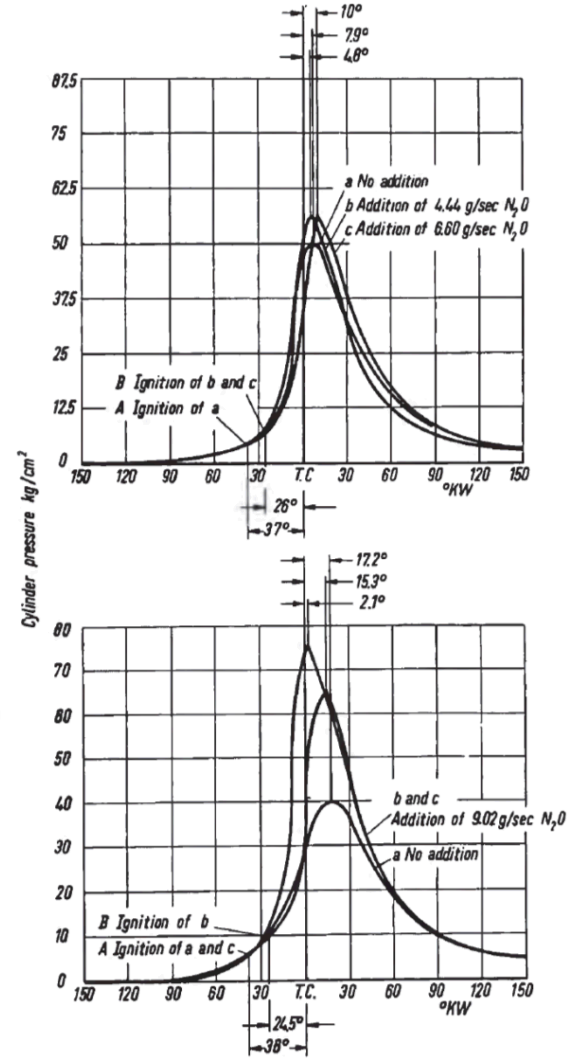
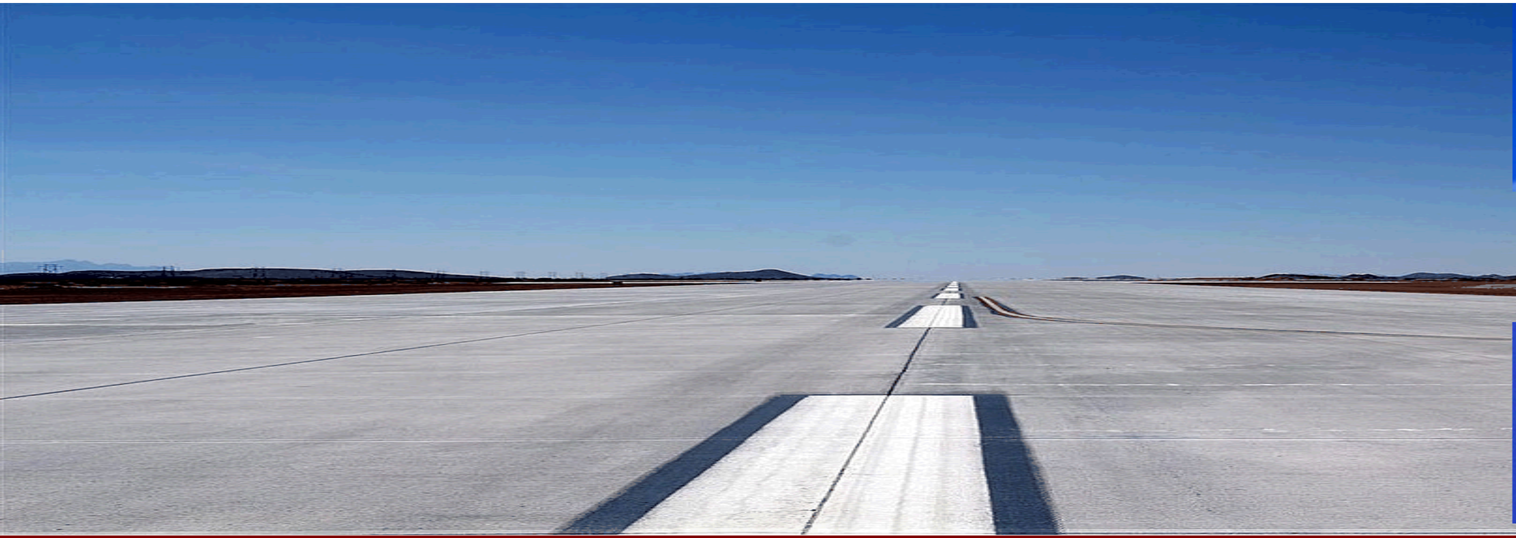
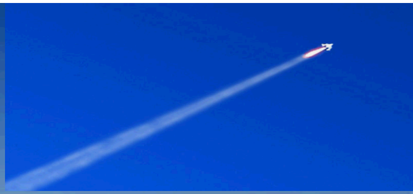



FIGURE 7.—Pressure-time diagrams (T. C. = top center, °KW = crankshaft angle).


# History

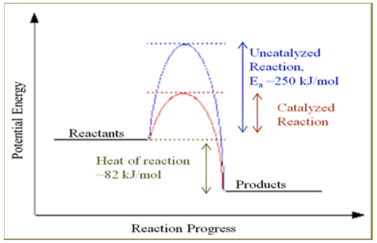
- Automotive applications
  - Consumer and racing use (1000 HP gains)
- Amateur rocketry, late 1980's +
  - Basis for almost all hobbyist hybrid rocketry
    - Eliminated shipping and storage problems for non-professional rocketry
- Modern aerospace applications
  - 1940's-50's freezing point depressant
  - 1961 Texaco $N_2$0-carbon patent (?)
  - 1988/89 JHUAPL demonstrates $N_2$0- HTPB- Al hybrid
    - Bulk mode instabilities and screech
      - **Proving that hybrids engines can embody the worst of both solids and liquids!**
  - 1990-today Amroc, Space Development, Surrey Satellite, Sierra Nevada, Scaled Composites, Environmental Aero Sciences, Orbitec, Virgin Galactic.
    - **Robust commercial suborbital flight hybrids engines**

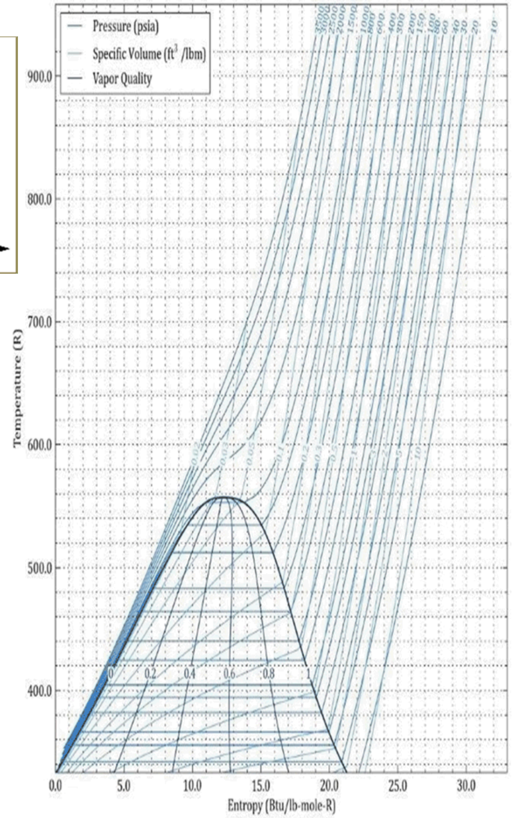




# The Good and the Bad

- Stable liquefied gas under pressure
  - +Storage properties
  - -Solvent (de-caffeinater explosion)
  - +Self pressurizing but, not recommended
  - -/+Large pressure-density change with temperature
  - -/+Regenerative cooling, possible but risky…

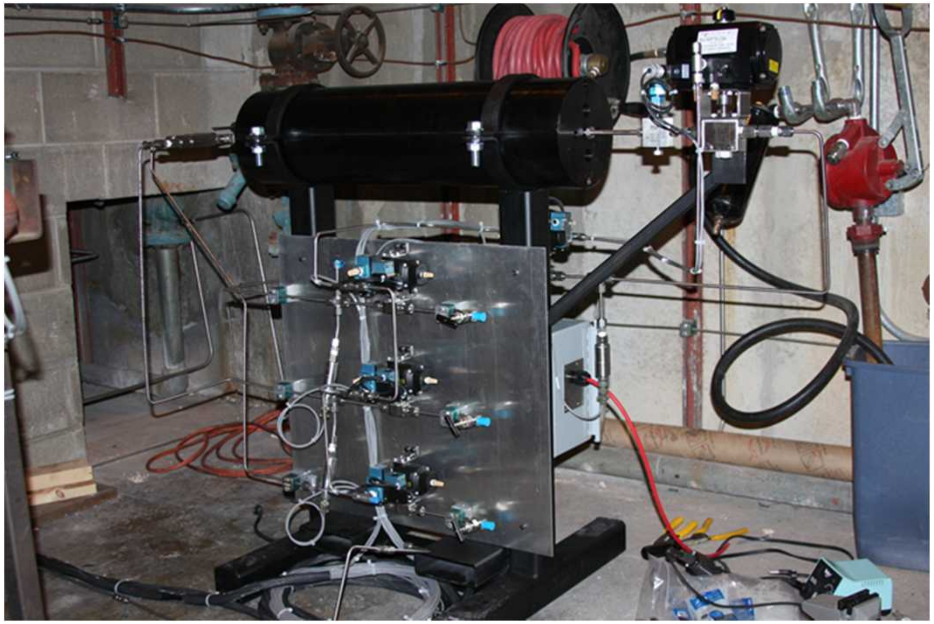



- Monopropellant
  - - Catalytic decomposition, gas phase, liquid, low mass flux
- Bipropellant
  - +Wide flat MR (O/F), exothermic decomposition
    - Chemical steam generator with ammonia!
  - +/-$I_{sp}$ relatively independent of fuel; ~250-275 >325s
    - Mono-props can increase density impulse (NM, etc.)
  - -Non-hypergolic
    - Chemical ignition possible with TEA/TEB, Li, $SiH_4$
      - Pre-mixed or pilot ignition
- Hybrid
  - +++flight proven!

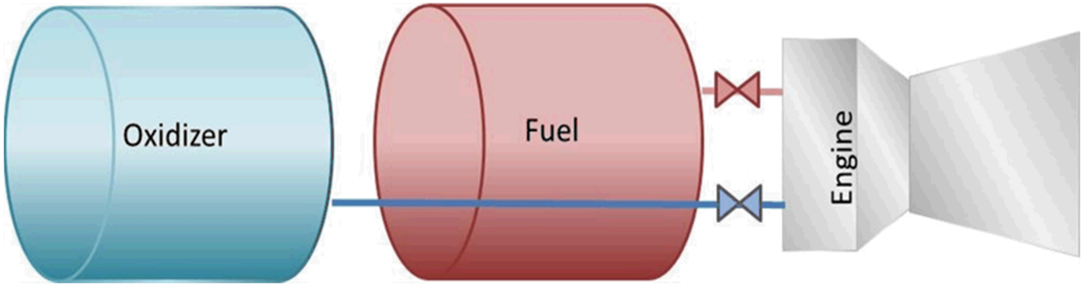
# Nitrous oxide & Ethylene testing

- High pressure bi-prop hard start testing (Zucrow Laboratories at Purdue University)
  - DDT event with hot wire ignition; overdriven detonations observed
  - Tremendous pressure spikes (250psi >>30,000 psi!)



# The path forward

- Excellent academic propellant
  - Possible cold flow with $CO_2$ as a surrogate
  - Readily available
  - Simple pressure vessel tankage
  - Handle like GOX/LOX, cleanliness important
  - Supplemental pressure feed, not self pressurizing
- Bi-prop design
  - Ground up facility
  - Fuel, ethanol (no "hard start", "hard stop" or DDT)



# Develop rocket engine ground-test capabilities at New Mexico Tech

- Design and construct a liquid-fueled rocket engine test facility:
  - $N_2O$-ethanol fuel mixtures
  - Thrust of less than 500 lbs
  - Pressure fed fuel and oxidizer delivery system
- Research efforts:
  - Evaluate  fuel-oxidizer performance
  - Develop “green” systems
  - Optical diagnostics for rocket nozzle exhaust measurements

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# Rocket test stand design and construction

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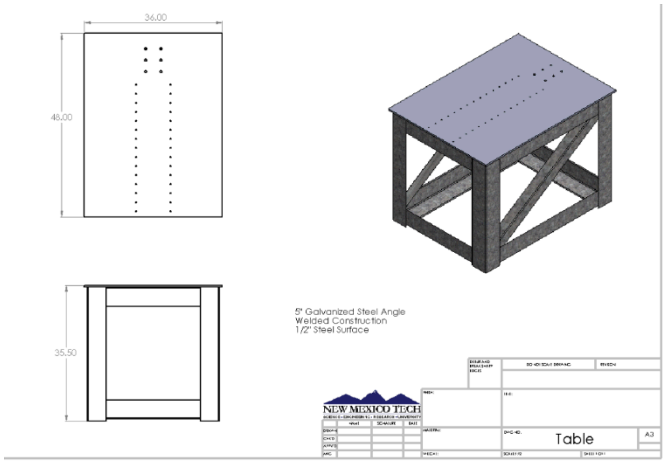
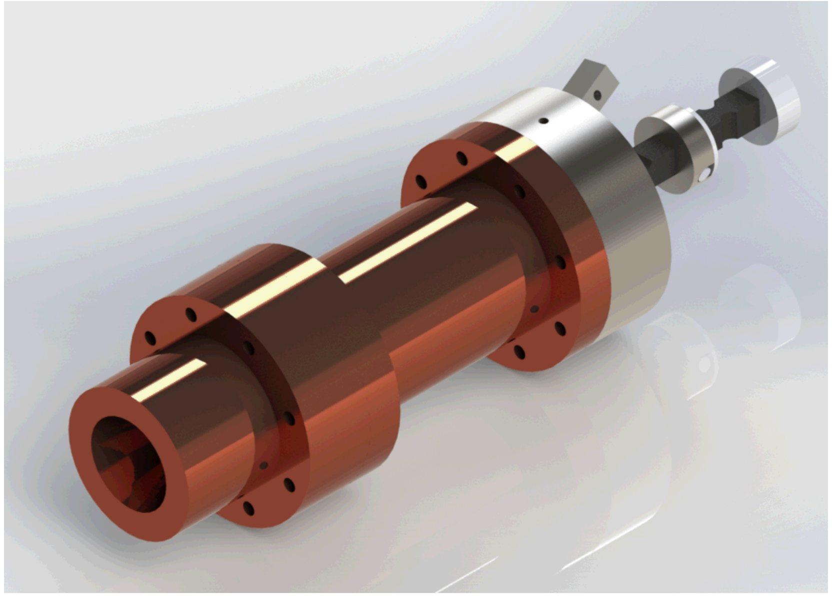
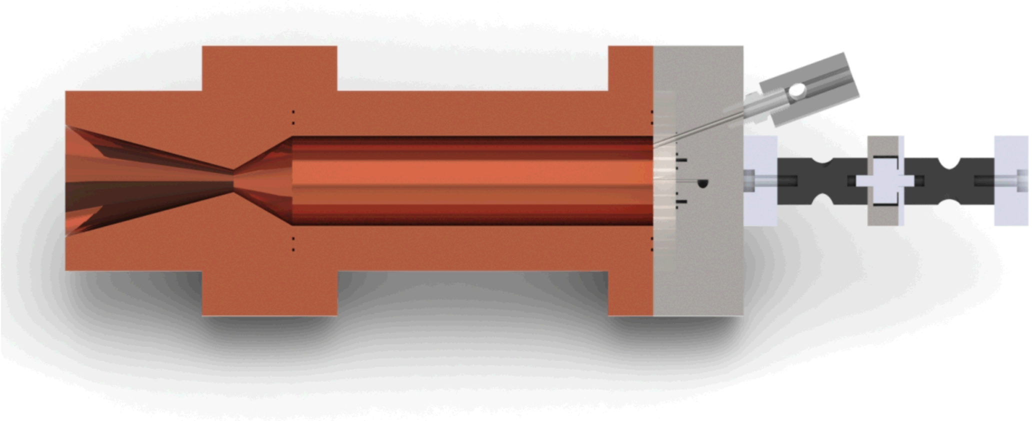
- Designed by undergraduate students design class
- Variable mounting points to allow different engines and future research efforts
- To be installed at a site on the Energetic Materials Research and Testing Center (EMRTC) adjacent to New Mexico Tech campus




# Rocket engine design

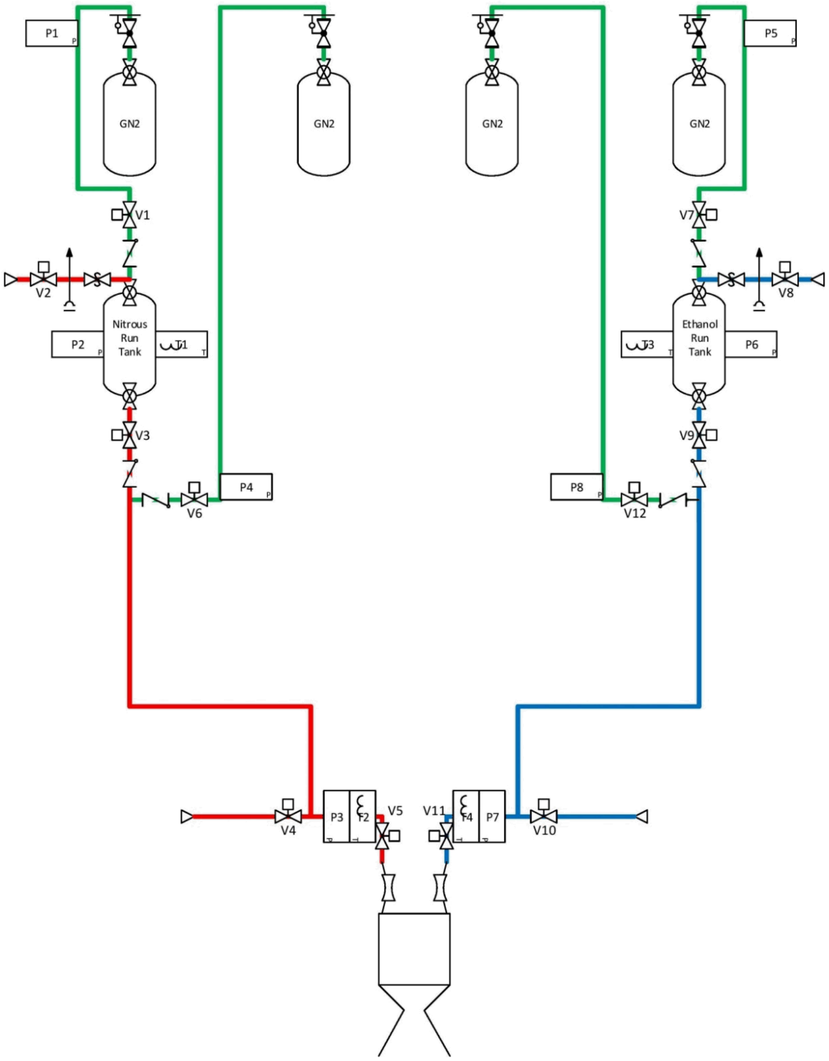
- Current MS thesis project
- Modular design
  - Impinging jet injector plate
  - 2” diameter, 8” long combustor section
  - ~250 lbs. thrust nominal
- Propane/oxygen torch ignition system



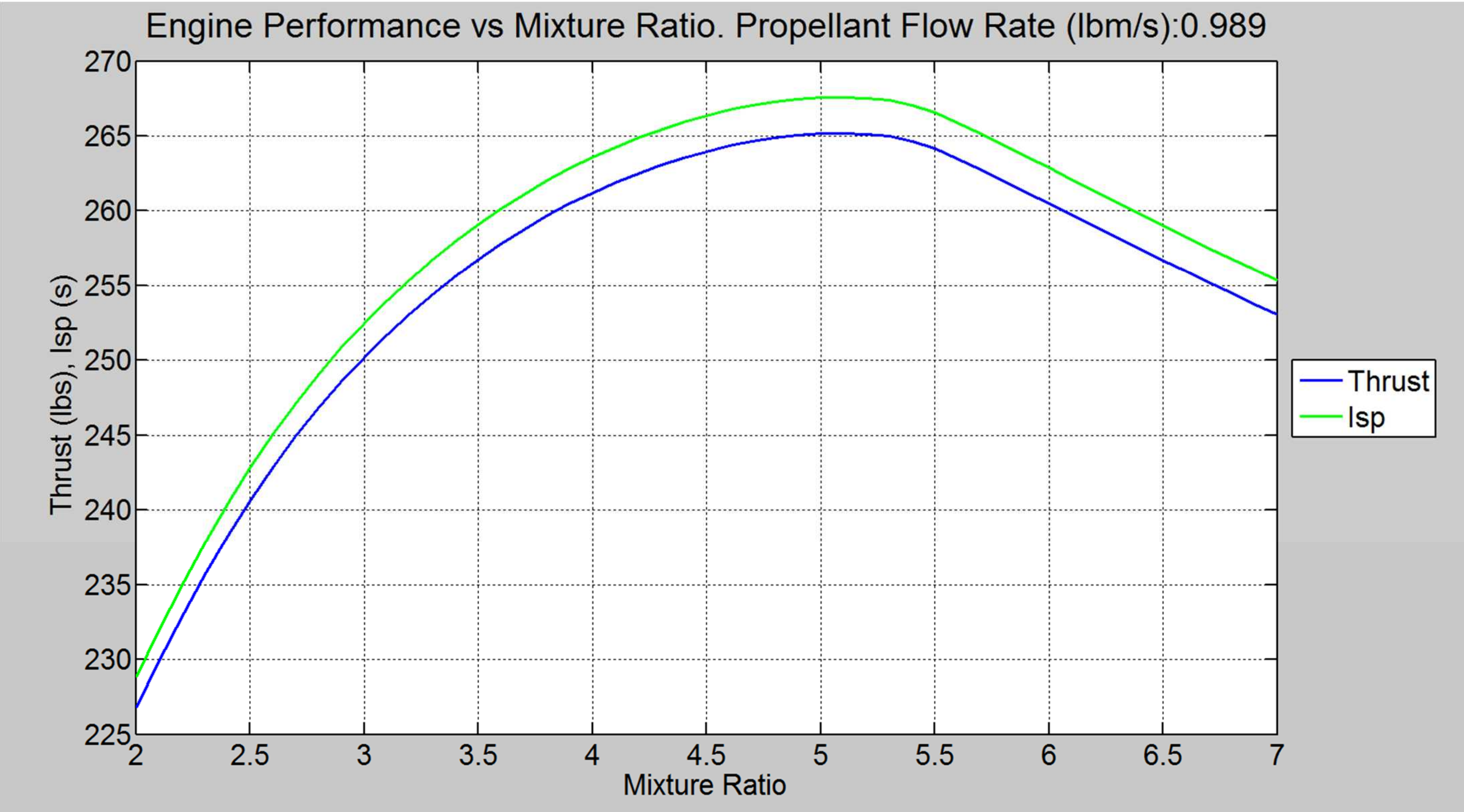


# Engine test system

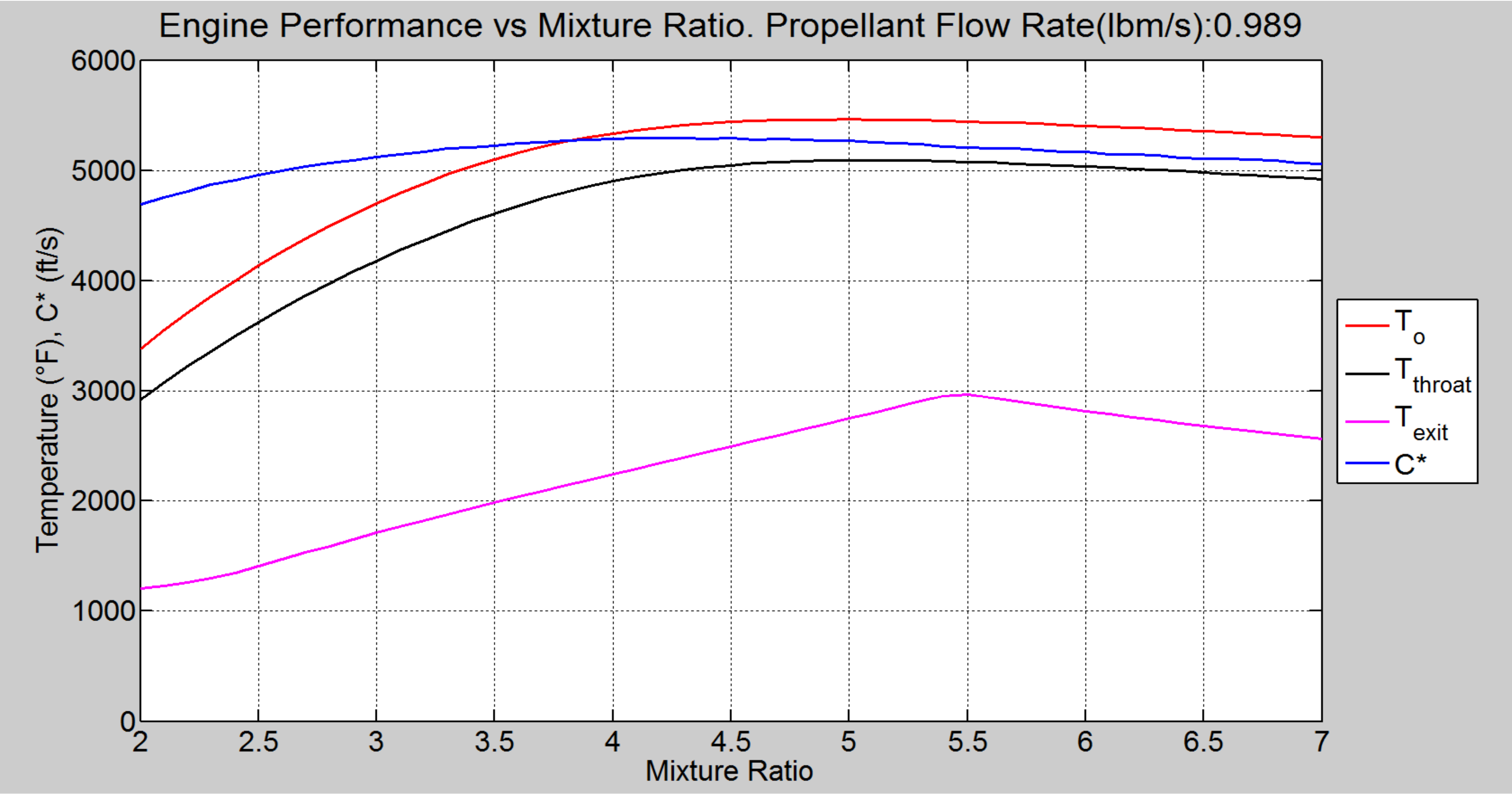
- Blow-down delivery of $N_2O$ and ethanol
- Maximum system working pressure 1800 psi
- Propellant flow rates controlled via cavitating venturis



# Calculated Performance $N_2O$ Ethanol



# Engine performance as a function of mixture ratio for 1000 psi chamber pressure at MR 4.5



# Safety- Thermal / Contamination / Adiabatic compression

**"Nitrous Oxide Trailer Rupture", July 2, 2001, The Netherlands, Eindhoven; CGA Seminar, "Safety and Reliability of Industrial Gases, Equipment and facilities", Konrad Munke, St. Louis, Missouri, October 15-17, 2001.**

**Mojave, CA, Aug 2007, 3 killed by "safe" system associated with space access vehicle. Guy Norris, Aviation Week & Space Technology, August 6, 2007**

# Recommendations

- Resource

IHS ESDU

**91022**

Issued September 1991

**Thermophysical properties of nitrous oxide**

# Questions

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- Always remember:
  - **"Nitrous oxide is one of the safest rocket engine propellants; it can just barely kill you". mcg**