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OMICS Group International is a pioneer and leading science event organizer, which publishes around 400 open access journals and conducts over 300 Medical, Clinical, Engineering, Life Sciences, Pharma scientific conferences all over the globe annually with the support of more than 1000 scientific associations and 30,000 editorial board members and 3.5 million followers to its credit.

OMICS Group has organized 500 conferences, workshops and national symposiums across the major cities including San Francisco, Las Vegas, San Antonio, Omaha, Orlando, Raleigh, Santa Clara, Chicago, Philadelphia, Baltimore, United Kingdom, Valencia, Dubai, Beijing, Hyderabad, Bengaluru and Mumbai.

Bio-Fuels Combustion Research

An Integrative Approach

with a Focus on
The Research Program at the
School of Aerospace and Mechanical Engineering
The University of Oklahoma

Presented by

S. R. Gollahalli
Professor and Lesch Centennial Chair

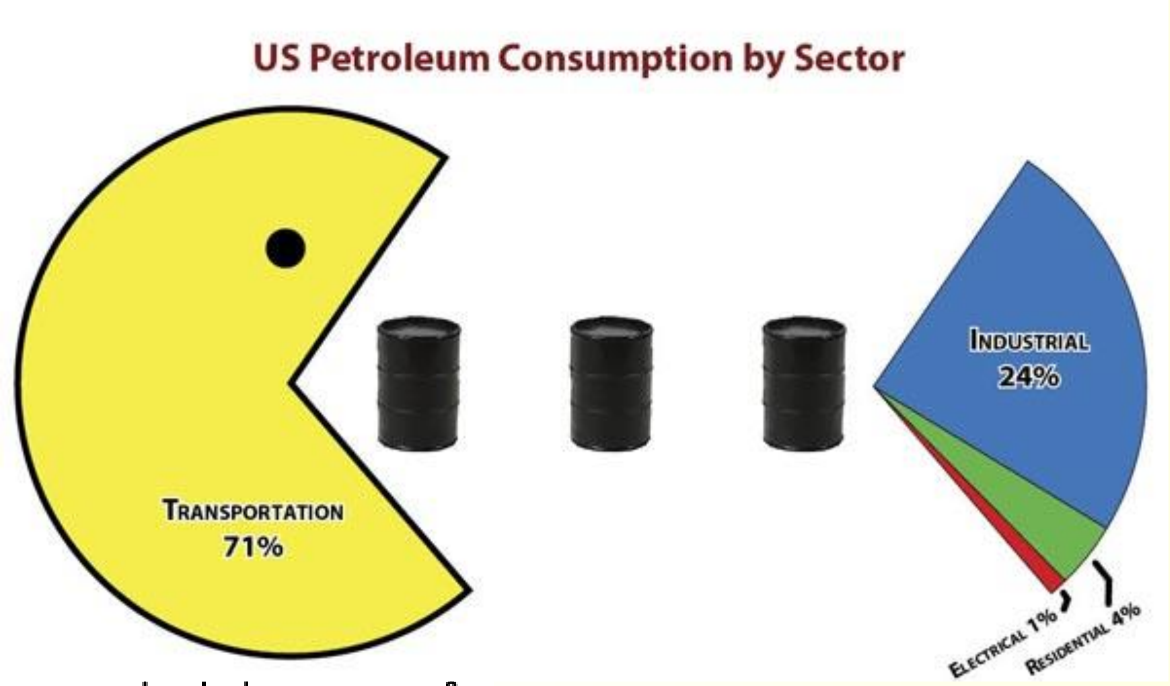
Why Alternative Fuels?

- Global Climate Change
- Energy Independence
- Oil is a Limited Resource

college of engineering

Where We Need Alternatives?

- Transportation Sector
  - Largest Consumer of Petroleum
  - Fastest Growth in Consumption of Petroleum



school of aerospace & mechanical engineering
college of engineering

Biofuels: Best Option Currently

- Little Modification
  - Vehicle
  - Current Storage
  - Infrastructure
- Renewable
- Carbon Neutral
- Low Cost

Biofuels

- Fuels obtained from non-fossil sources.
- Fastest growing alternative energy source in the US* and Europe**
  - First generation – Sugars and vegetable oils
  - Second generation – Non-food (biomass)
  - Third-generation – Algae

*The National Biodiesel Board

**European Biodiesel Board

Current techniques
Black Box approach

Input:
- Liquid or Gas Fuel

Engine/
Combustor
Test

Output:
- Pollutant Emissions
- Particulate Matter
- Cetane Number
- Octane Number,
- BHP, etc.

  - require large amounts of fuel and time
  - require various testing methods to measure outputs

Laboratories

Combustion and Flame Dynamics Lab
Internal Combustion Engines Lab
Aero-Propulsion Lab
Fire Research Lab

Focus

To Understand Fundamental Thermochemical Processes in Bio-fuel Combustion relative to Petroleum fuel-Combustion in Different Combustors

An Integrative Technical Approach

Level A: Laminar flame studies-Chemistry Effects only

Level B: Spray and Turbulent Flames-Controlled understanding of Fluid Mechanics as well Atomization and Phase change effects in addition to Chemistry Effects

Level C: Engine Studies-Practical (Design-Operating Conditions-separately and combined)-Diesel Engines and Gas Turbines

Technical Approach (Cont'

- **Level D: Novel Burner Development (Porous Media Burners)**
- **Level E: Fire-Safety and Handling (Pool Fires)**

A. Laminar Flame Studies

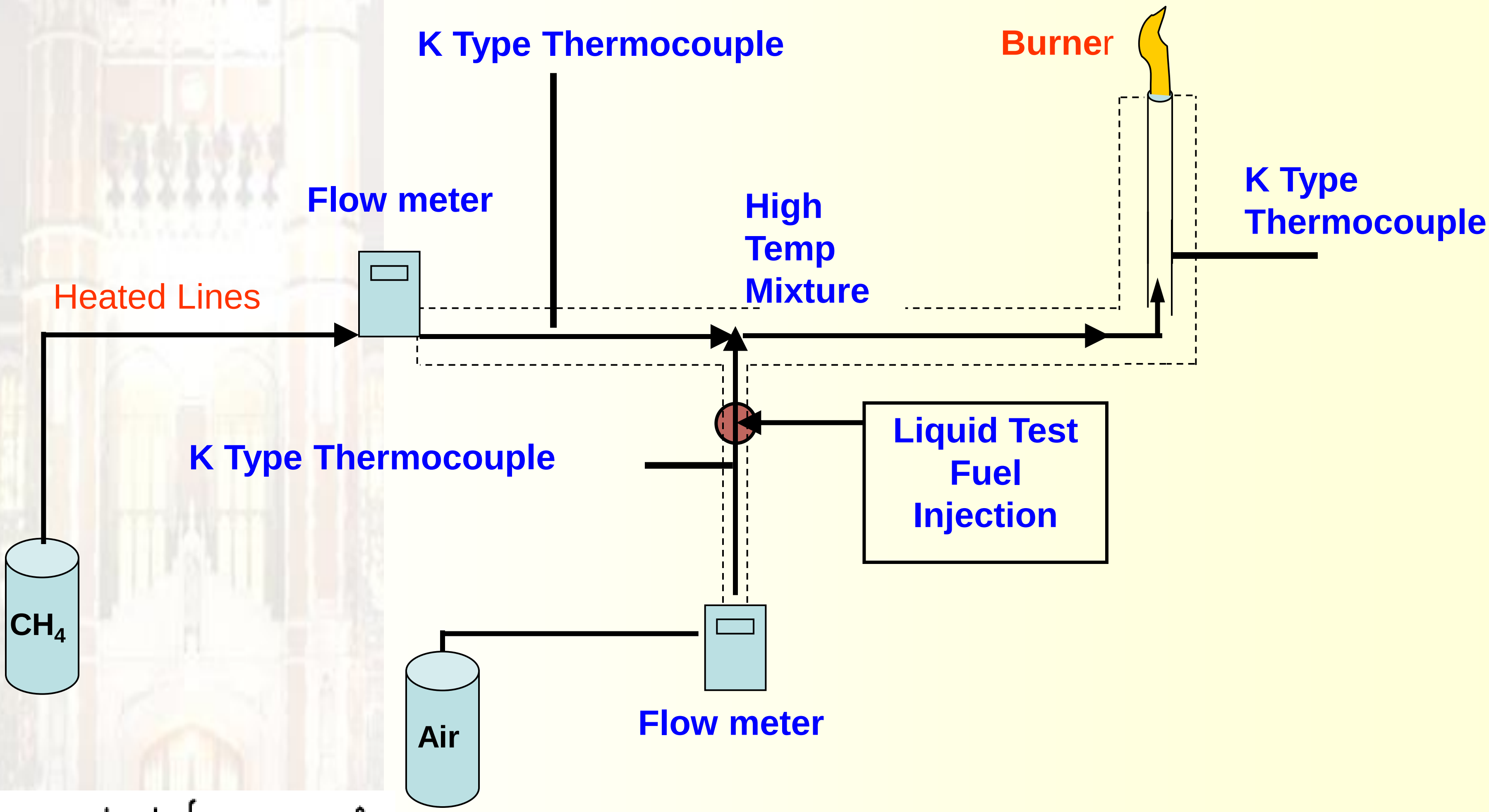
Method for the Rapid Characterization of Combustion Properties of Liquid Fuels Using a Tubular Burner

Why do we need to develop the technique?

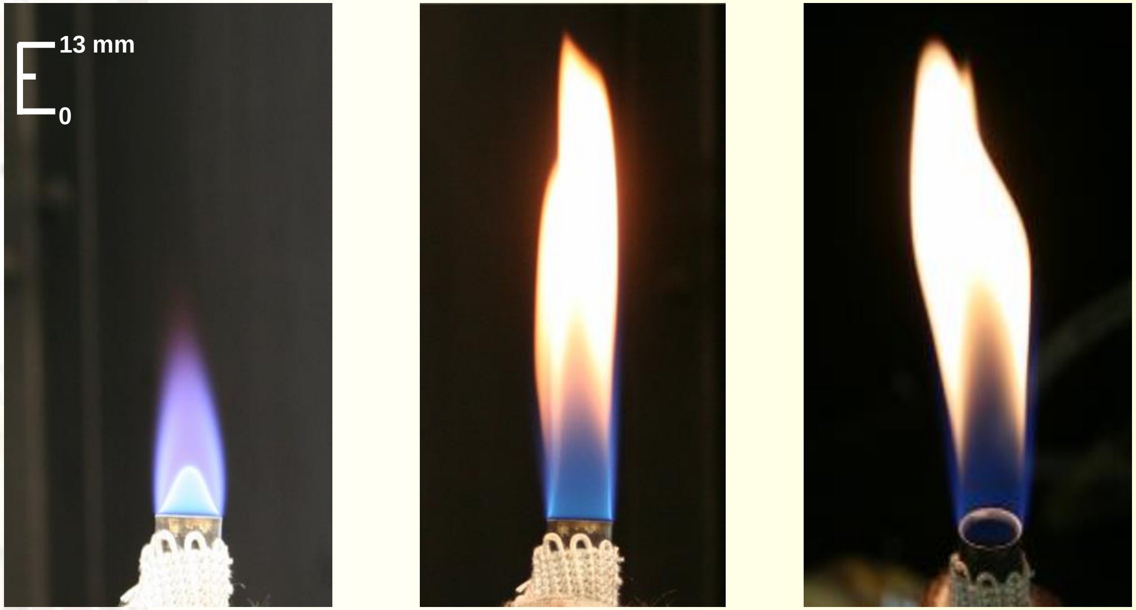
New fuels created in a lab are supplied in small amounts and cannot be run in an engine

Several variables are involved in the internal combustion engine. We want to study the properties attributable to fuel chemical structure.

Experimental Set-up



Flame Images



Methane Pentane* CME*

0.82 cm^3/min liquid fuel flowrate

Radiation

- Radiative Heat Fraction

$$F = \frac{q''_{rad}\left(4\pi L^2\right)}{LHV_{fuel}\left(m_{fuel}\right)}$$

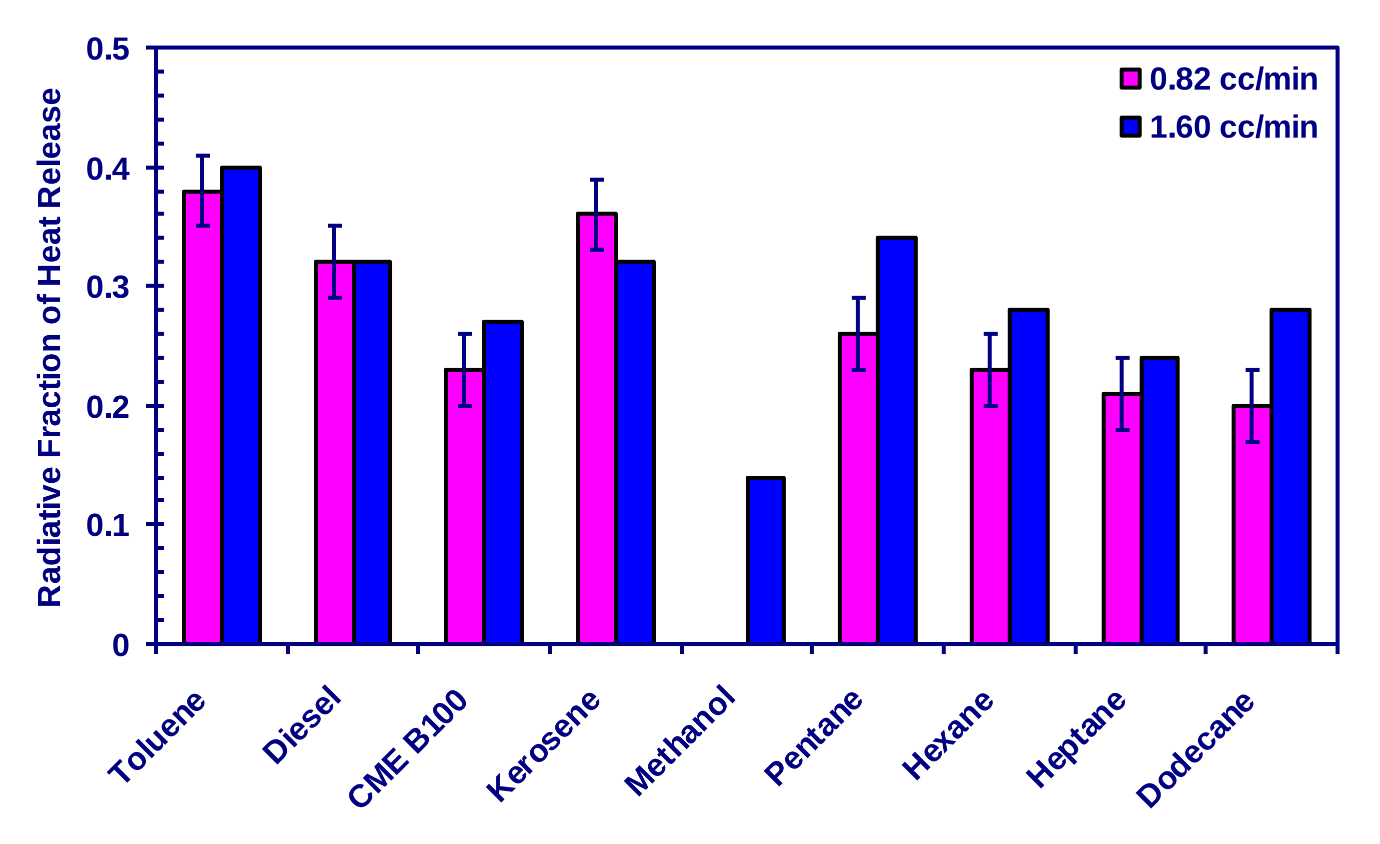
q''_{rad} = Radiative heat flux incident on radiometer

L = Radiometer distance from flame

LHV_{fuel} = Lower Heating Value of fuel

m_{fuel} = Mass of fuel injected

Radiation Results



Emissions

$$EI_i = \frac{x_i}{\left(x_{CO_2} + x_{CO}\right)} \cdot \left(\frac{X \cdot MW_i}{MW_f} \right)$$

x_i = molar concentration of species

x_{CO2} = molar concentration of carbon dioxide

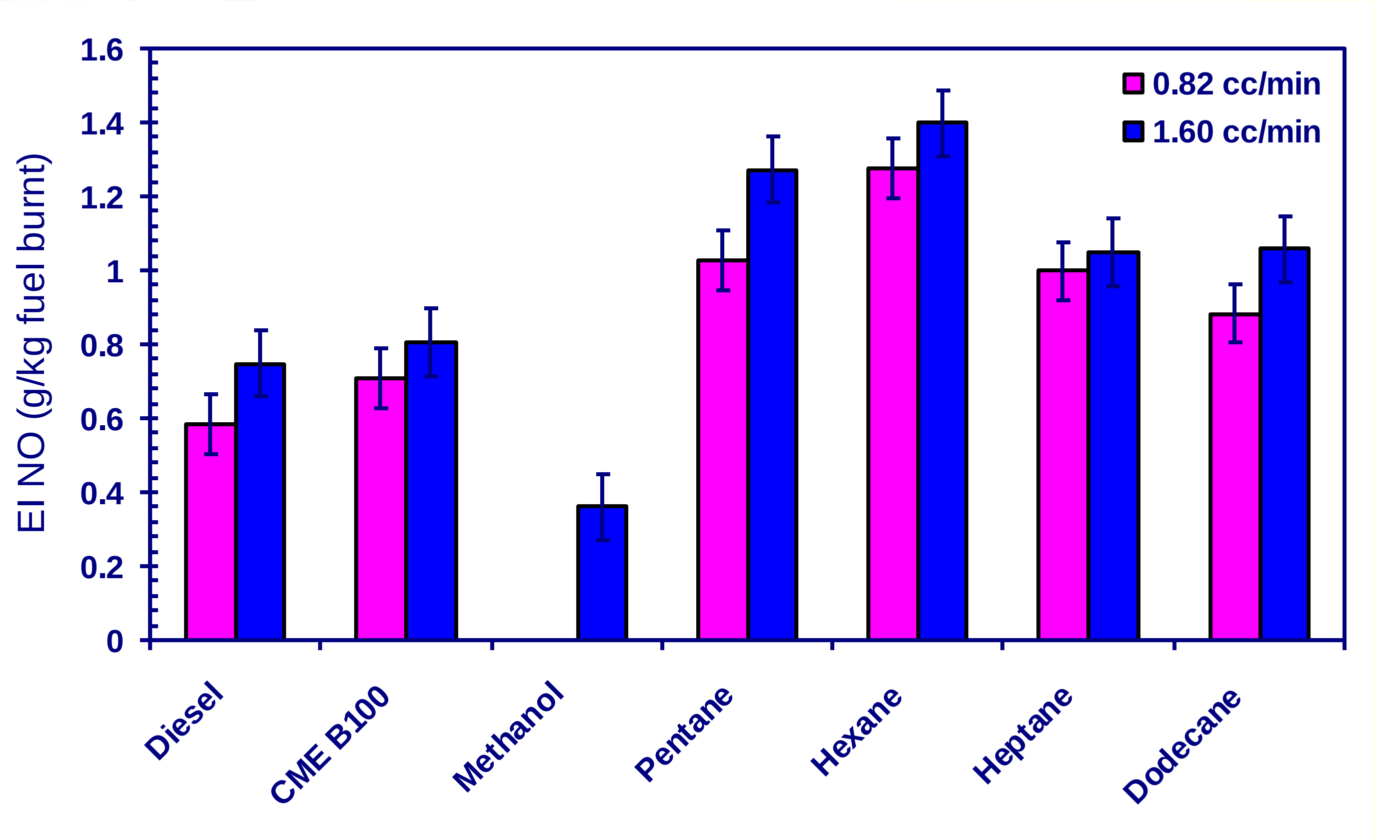
x_{CO} = molar concentration of carbon monoxide

X = number of carbon atoms

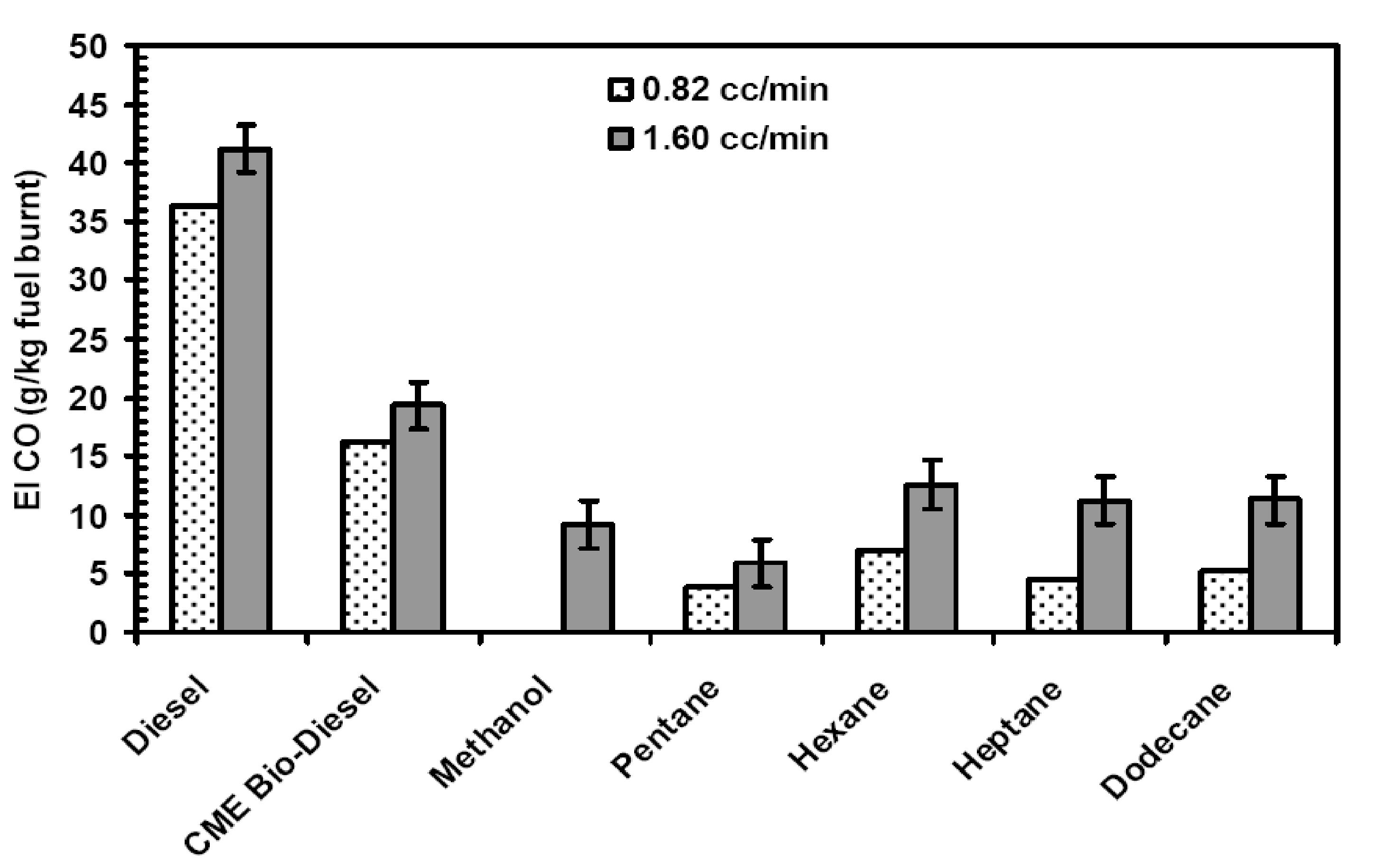
MW_i = molecular weight of species

MW_f = molecular weight of liquid fuel

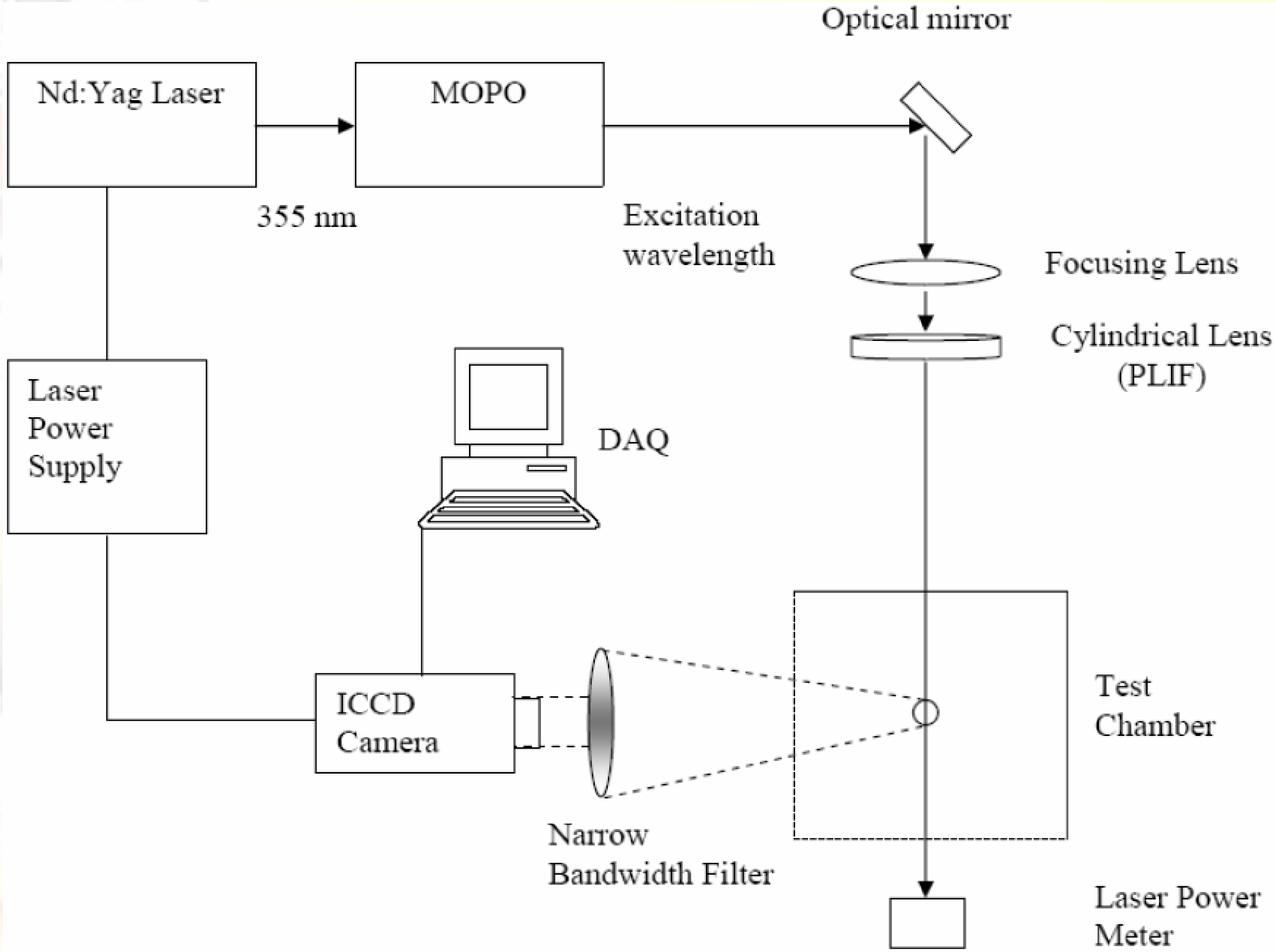
NO Emissions Results



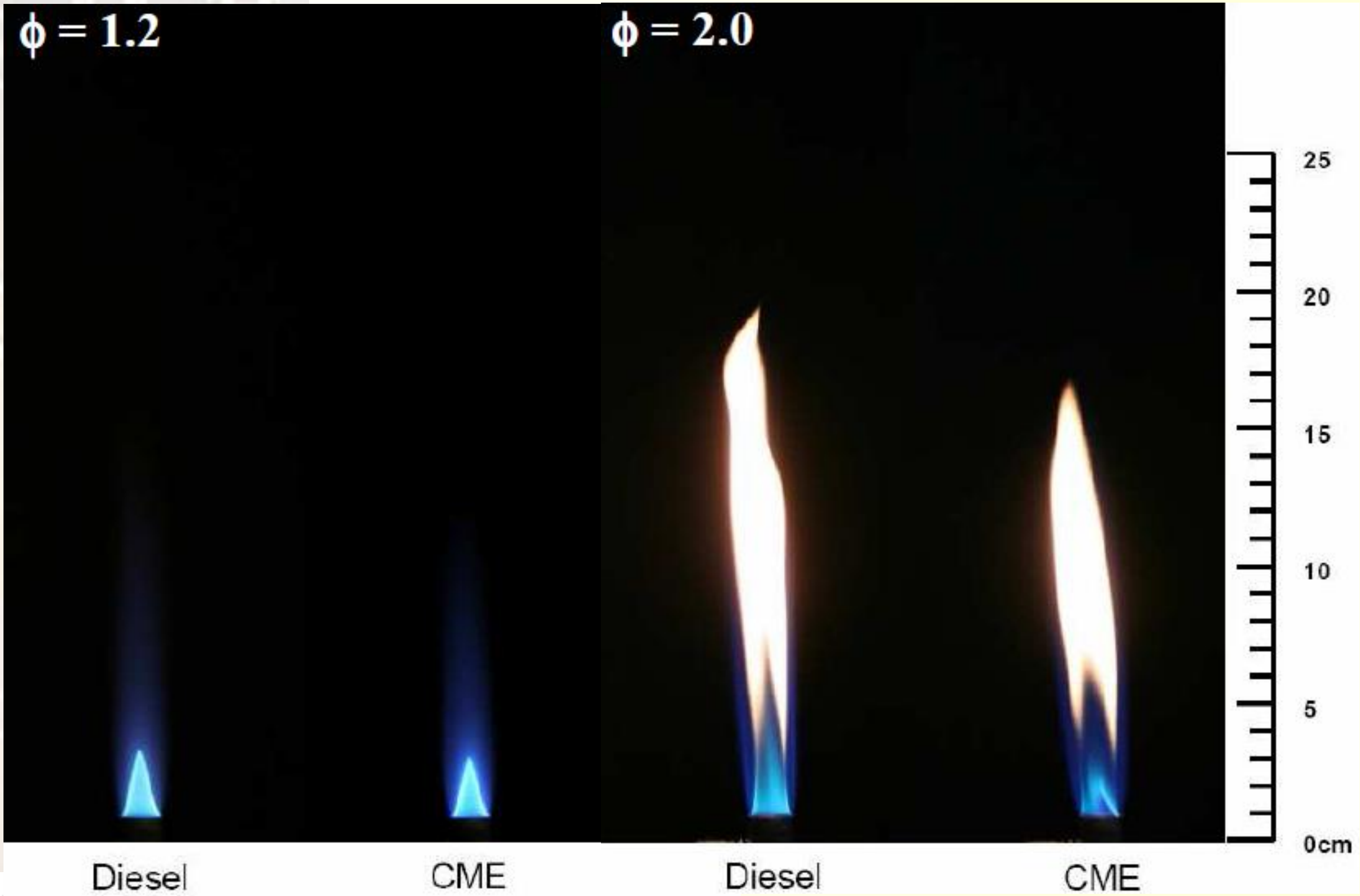
CO Emissions



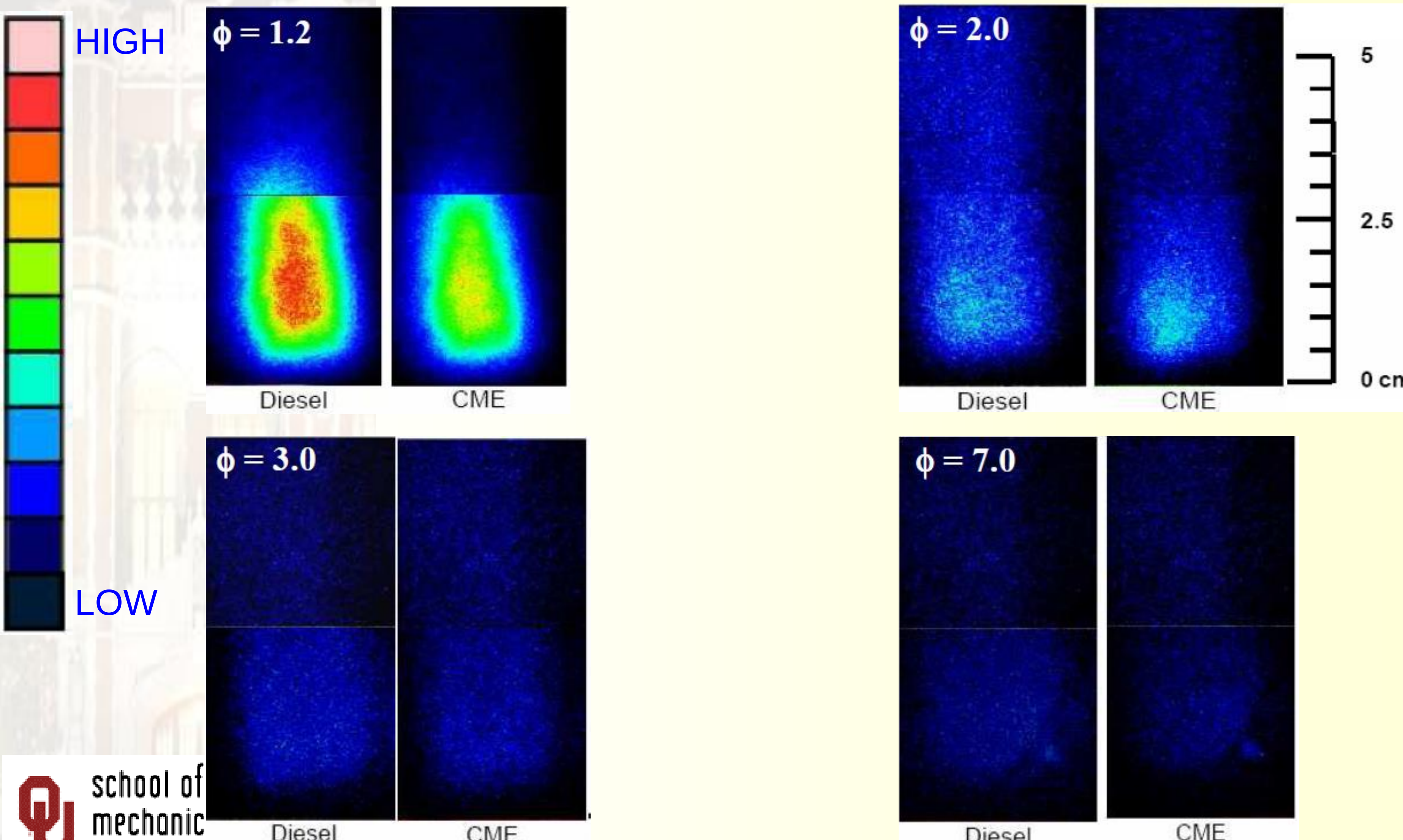
Laser Diagnostics Setup (OH)



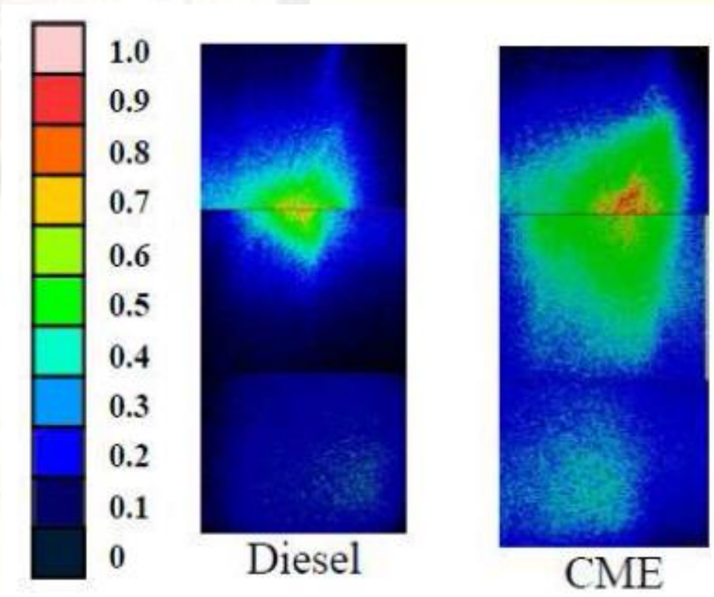
Results – Visible Flame

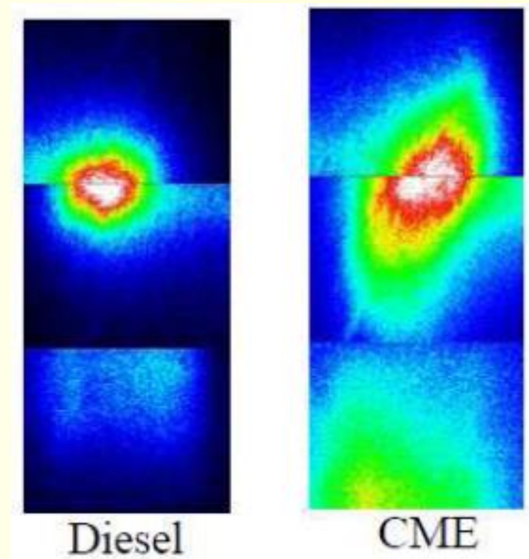


OH Concentration



CH Radicals





$\Phi = 3$ $\Phi = 7$

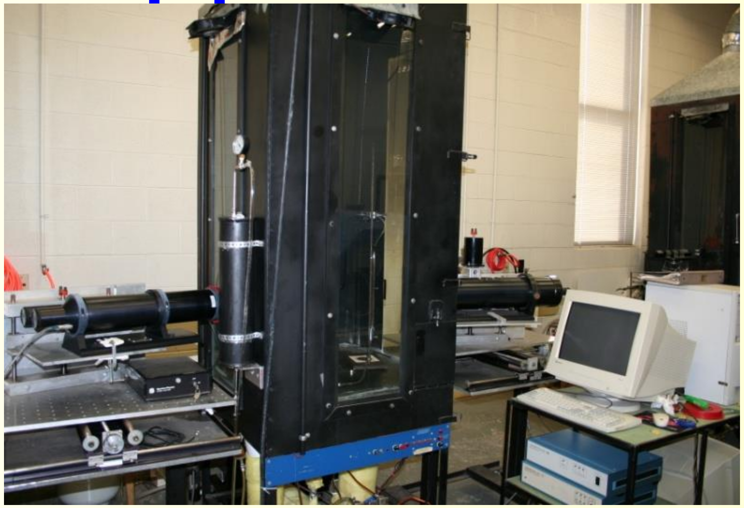
The maximum intensity detected was used to normalize all other detected values.

B. Spray Studies

- Atomization
- Combustion

Experimental Apparatus

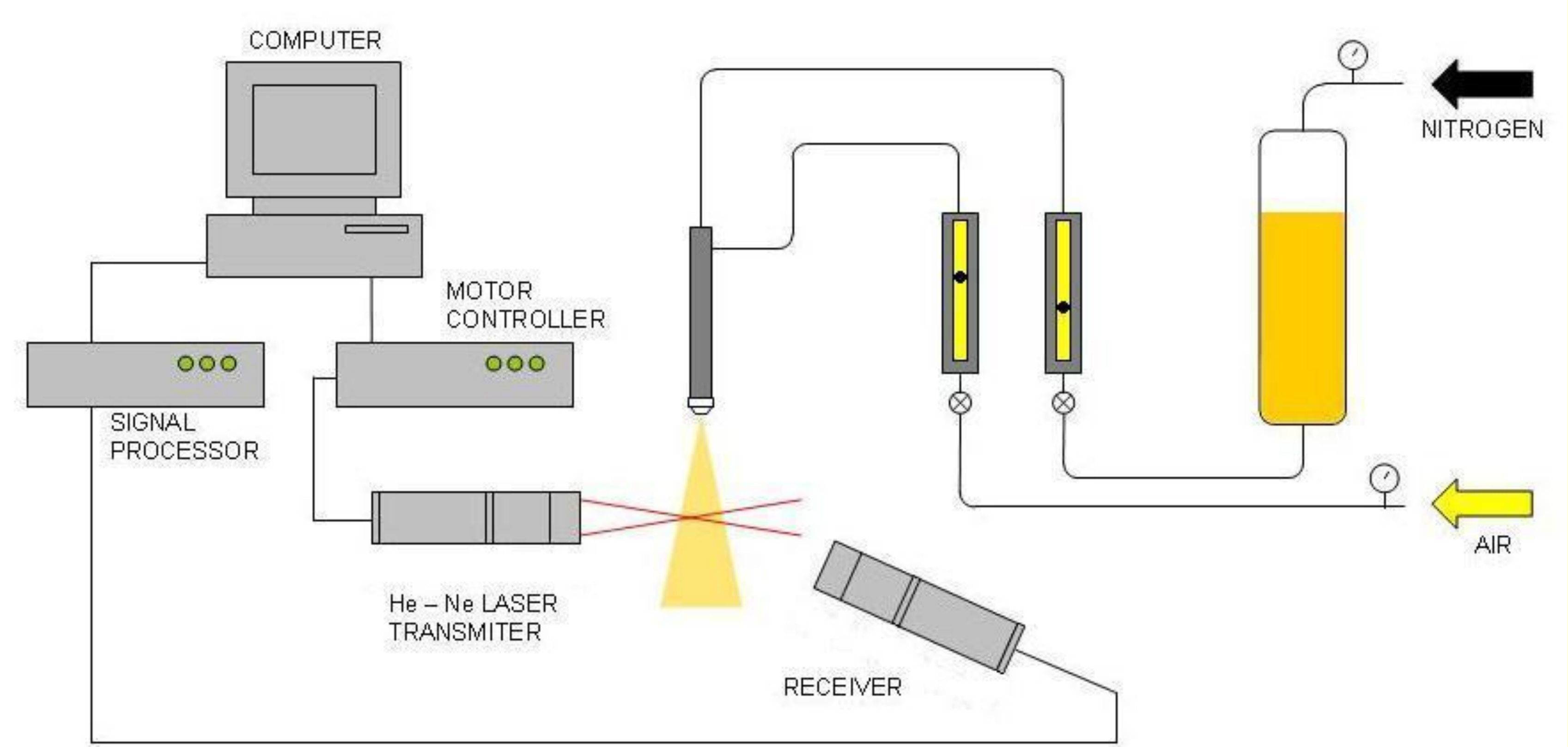
- **Steel combustion chamber with windows**
  - **0.76 x 0.76 x 1.2 (m)**



- **High temperature air heater supplies co-flow of air**
  - **Simulates temperature at the end of compression stroke in a diesel engine**

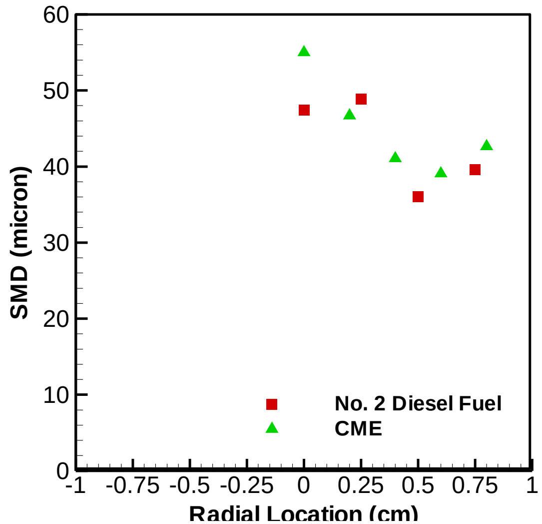
Instrumentation

- Aerometrics Phase Doppler Particle Analyzer
- Measurements of axial velocity and droplet diameter

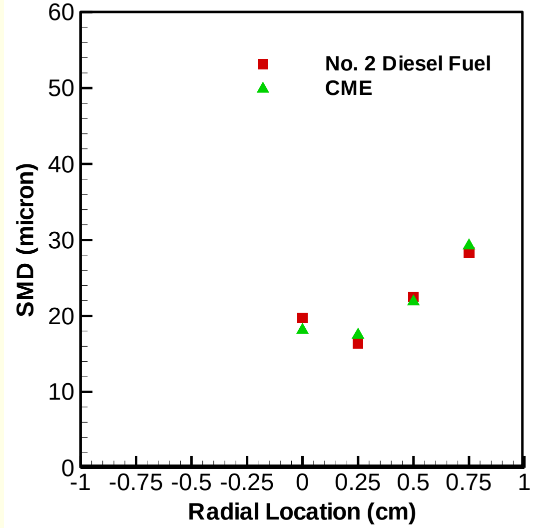


Spray Flames - SMD Radial Profiles

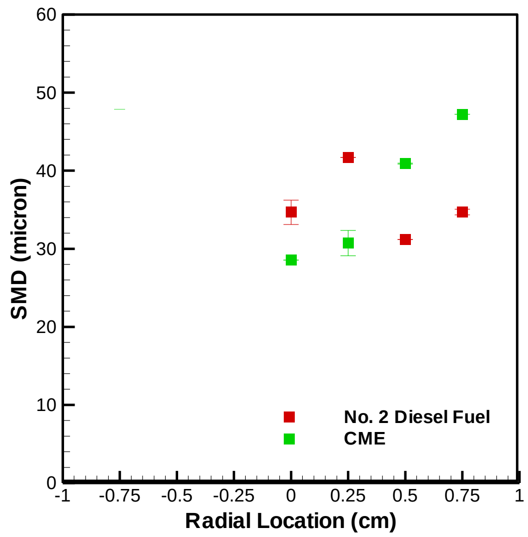
0.5 cm



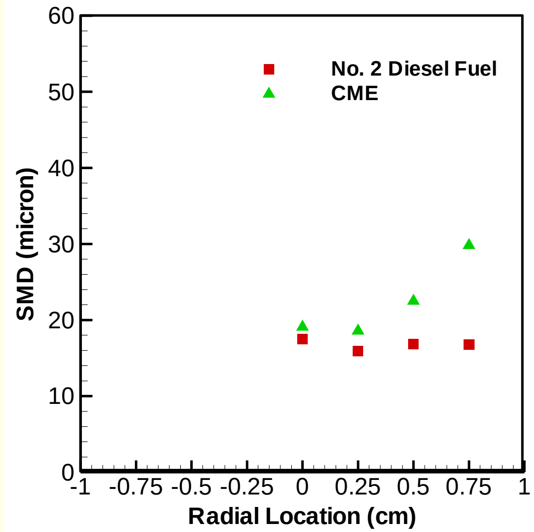
2 cm



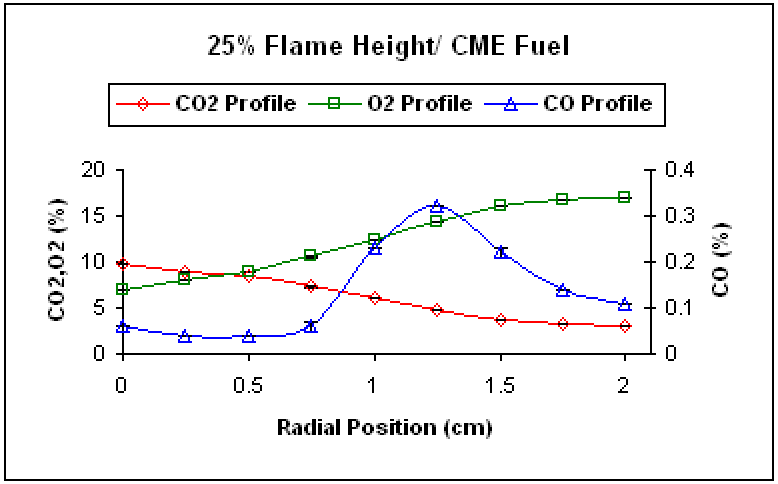
1 cm

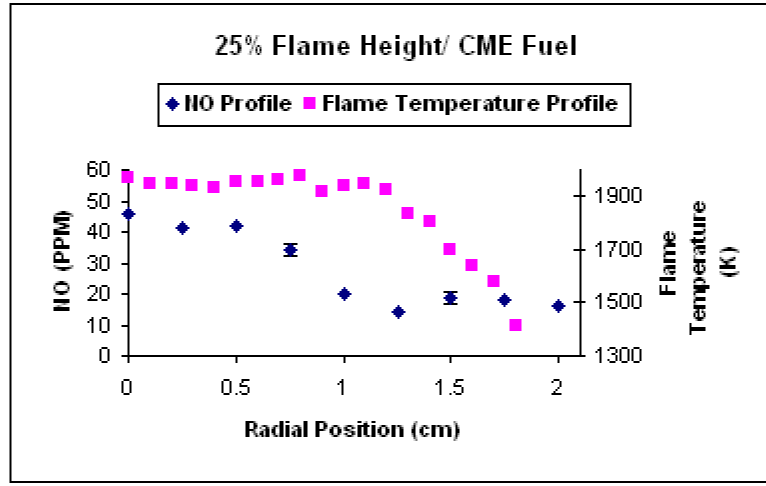


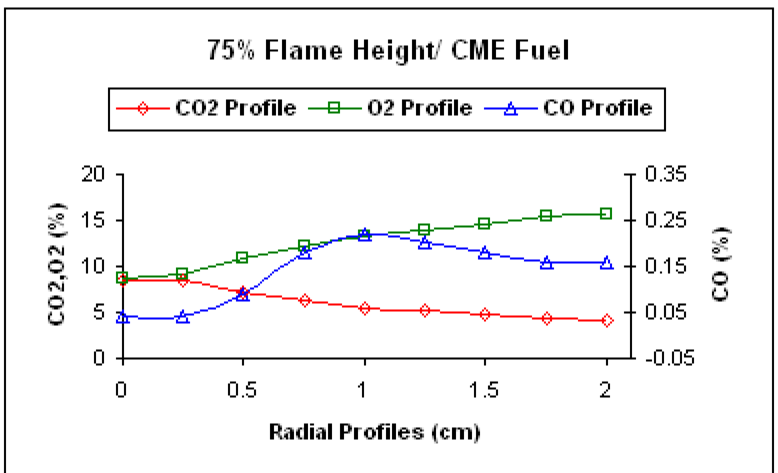
3 cm

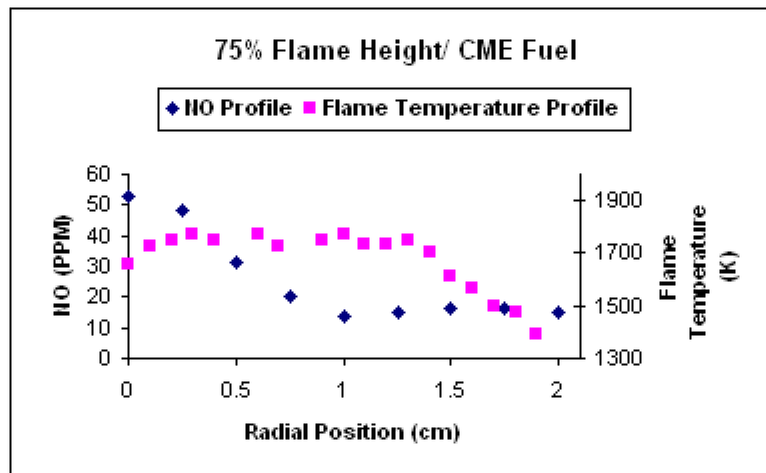


In-Flame Species Concentration









CME Spray Flame

C1. Diesel Engine Studies

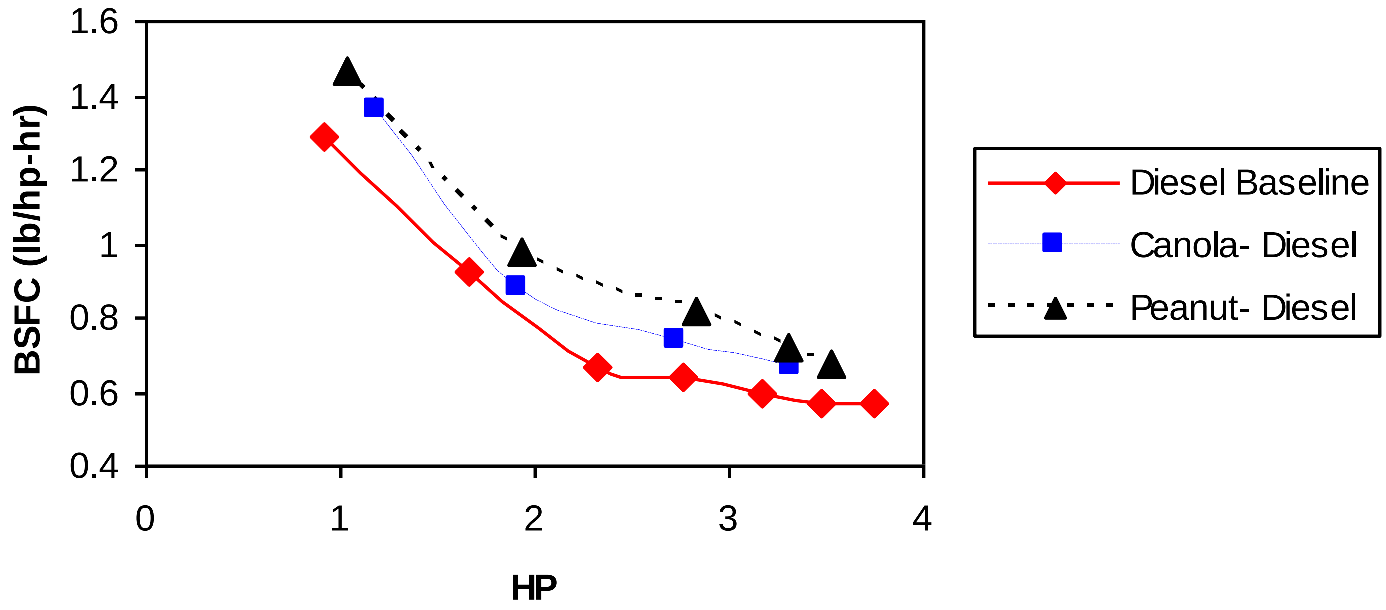
- Performance
- Emissions

Apparatus

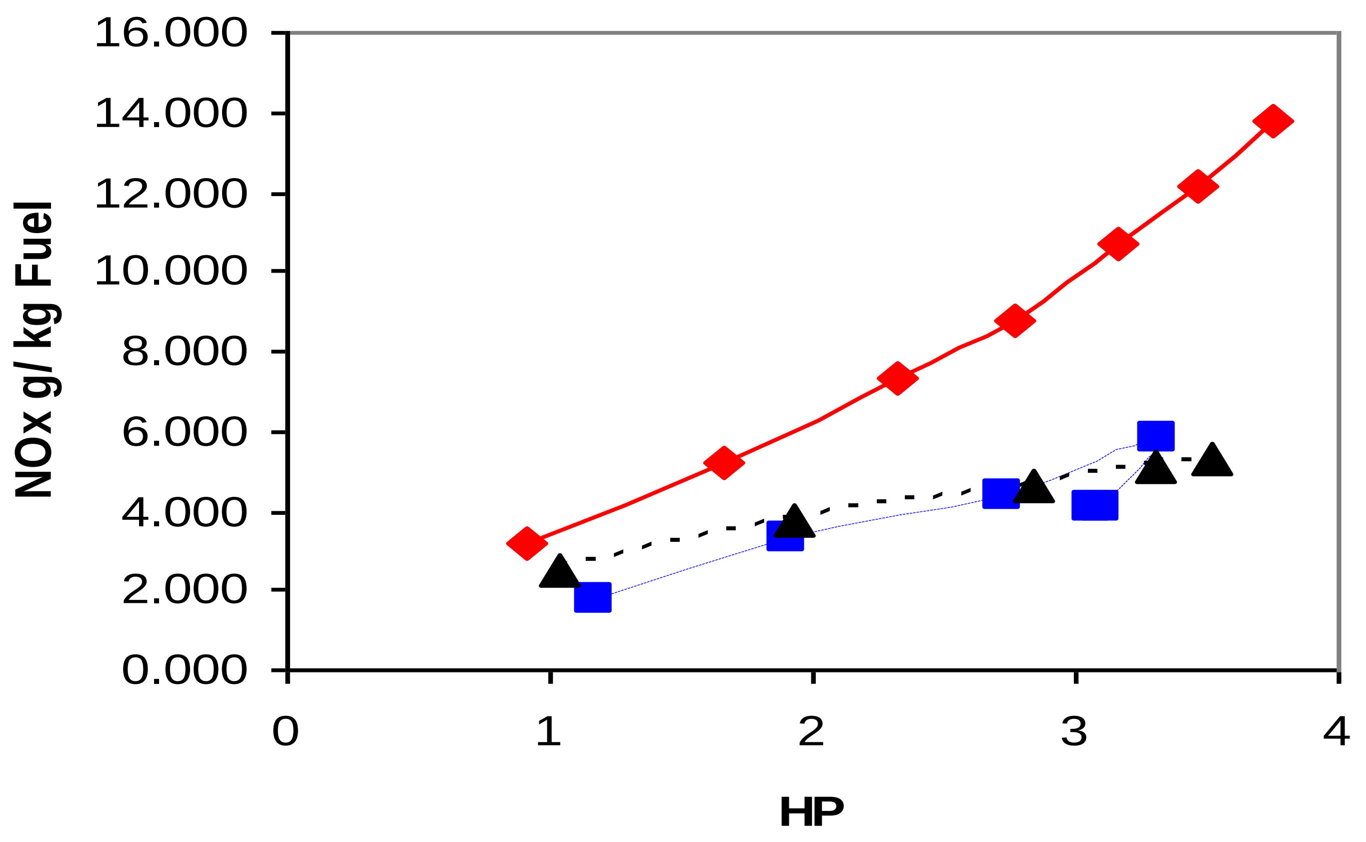
Single Cylinder Diesel Engine

- 17 in^3 displacement
- 3000 rpm, 5 hp, air-cooled, direct injection

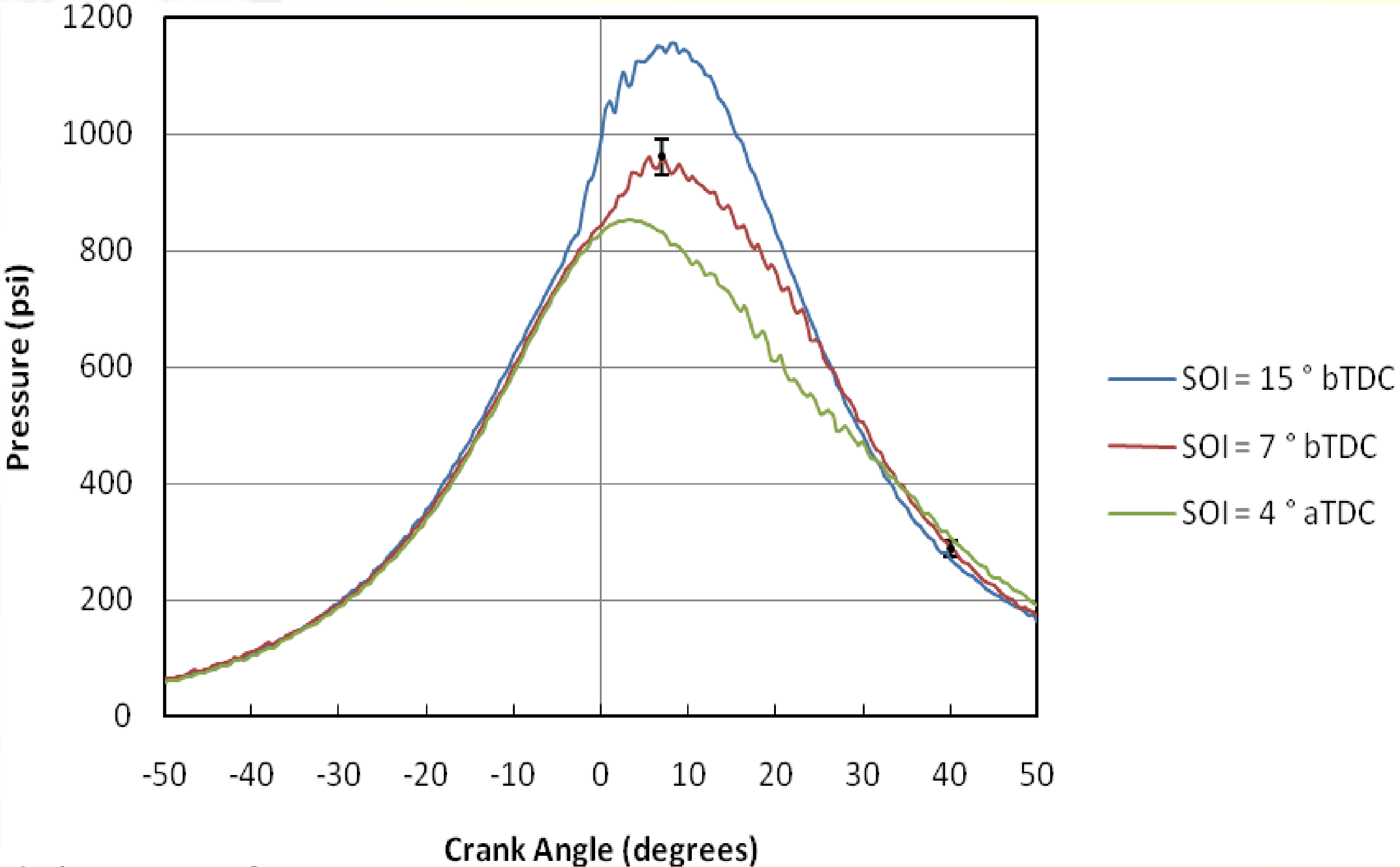
Raw Vegetable Oils



Raw Vegetable Oils



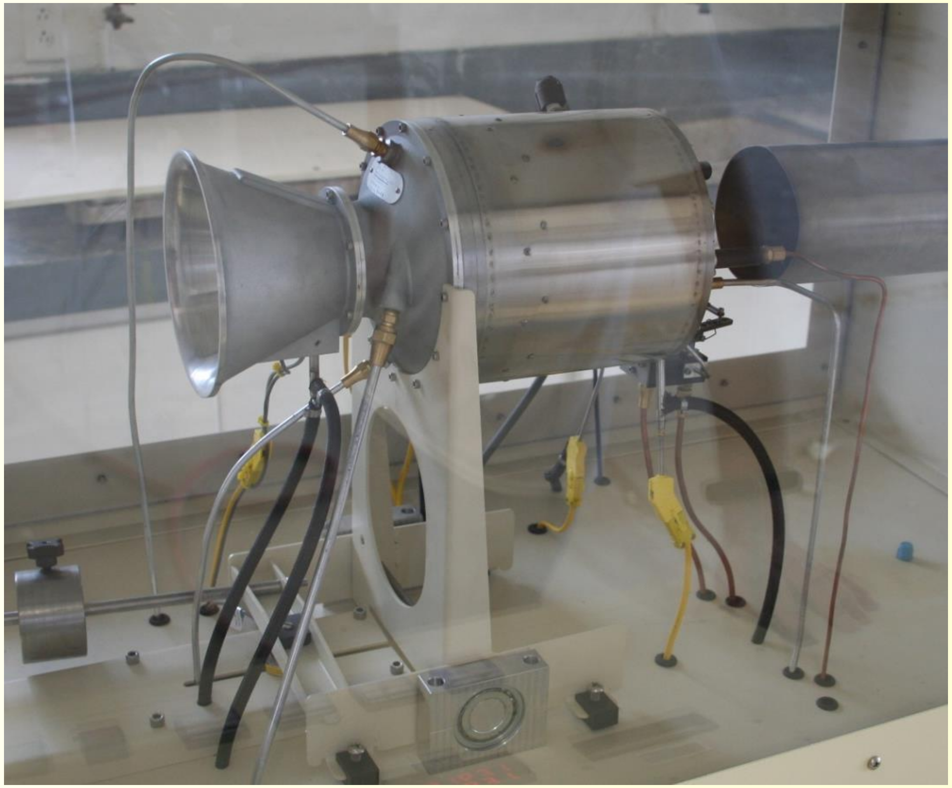
Effect of Injection Timing on Pressure-Crank Angle Diagram (CME B100)



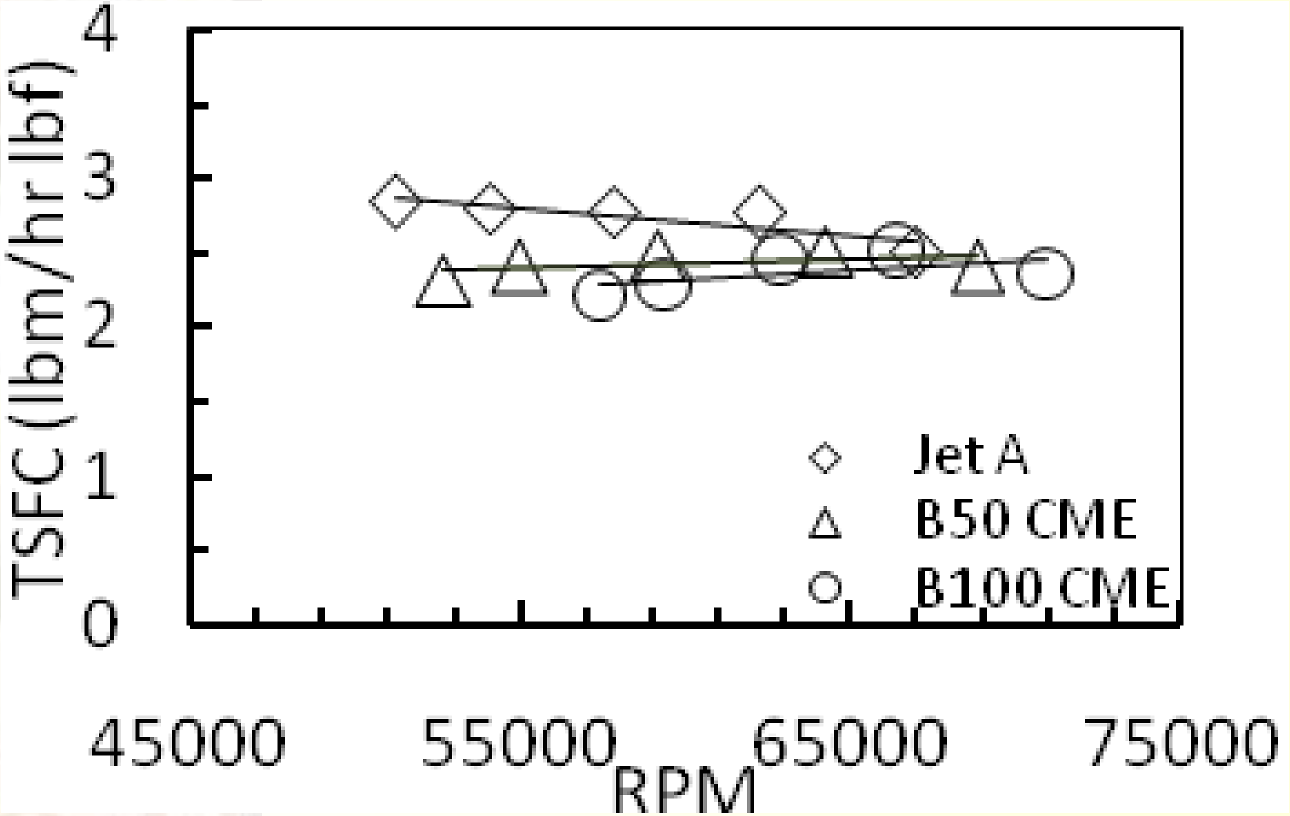
C2. Gas Turbine Engine

Aero-Propulsion Lab

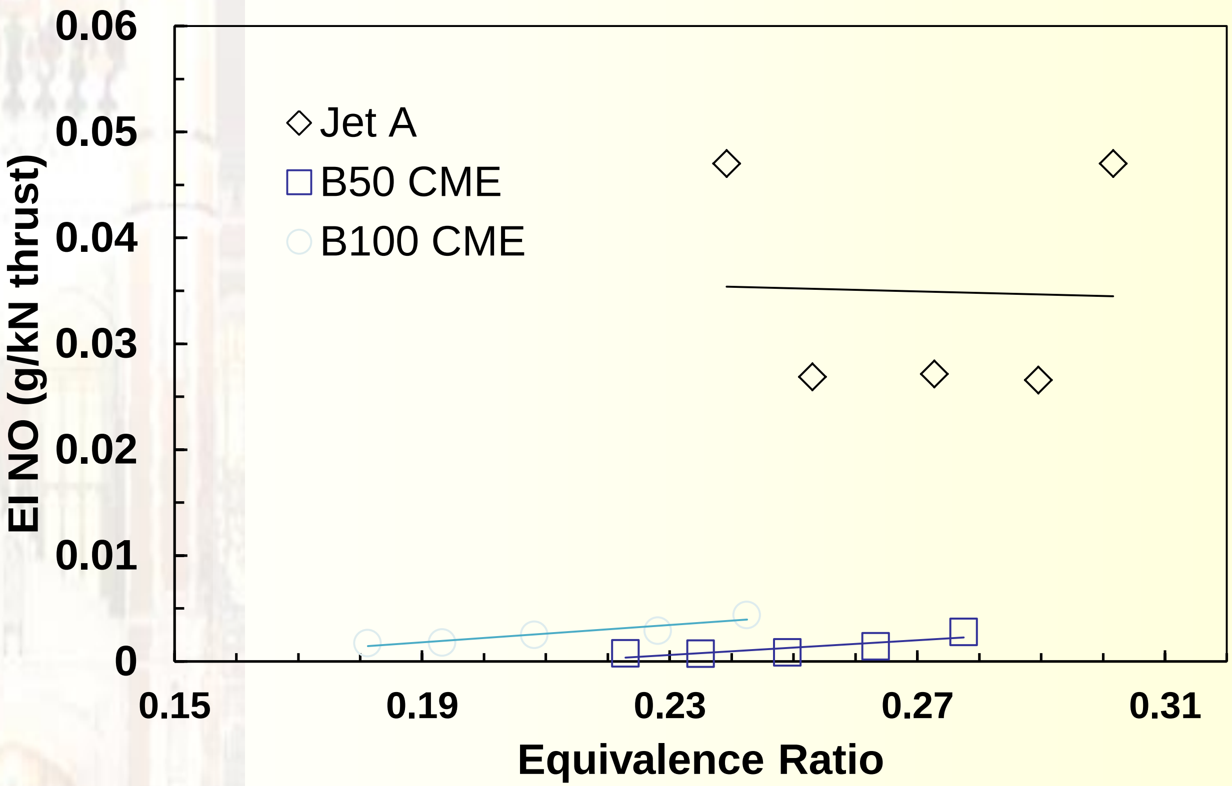
- Turbine Technologies -SR-30 Gas Turbine
- 30 kW
- Single-stage centrifugal turbine compressor (pressure ratio 2.5), single-stage axial flow turbine, annular combustor
- Heavy fuels (jet fuels, kerosene, diesel, biodiesel)
- 6.8 inch diameter, 10.8 inches long
- Air mass flow rate: 1.1 lbm/s
- Maximum thrust: 40 lbf
- Mid-thrust TSFC: 1.2 lbm/hr lbf (mid-thrust)
- Maximum 87,000 RPM
- Maximum turbine inlet temperature of 870°C
- Maximum exhaust gas temperature of 720°C
- Operate at an ambient air temperature between 0°C and 41°C (32°F-106°F).
- Pressures and temperatures at different engine locations, fuel flow rate, thrust, RPM, and oil, fuel, and air supply pressures recorded



Experimental Results



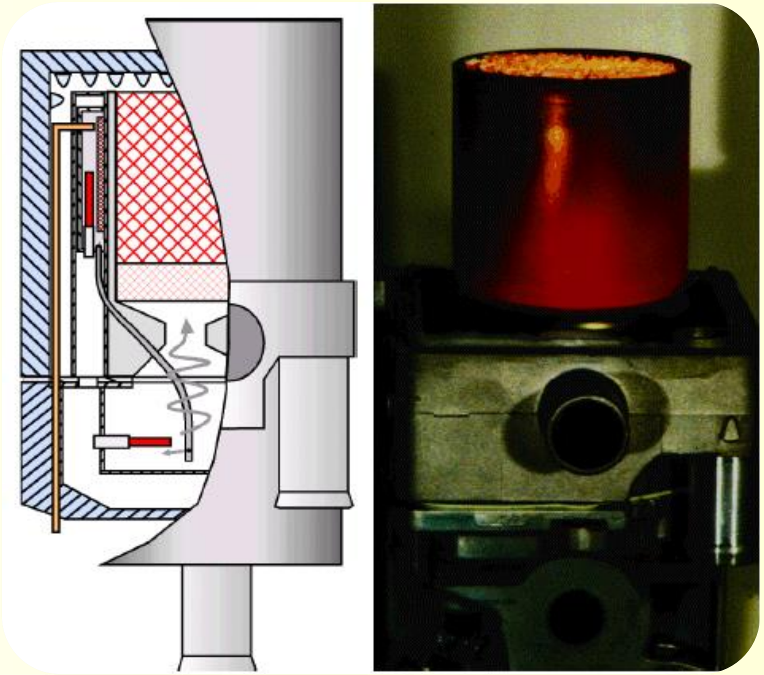
Experimental Results



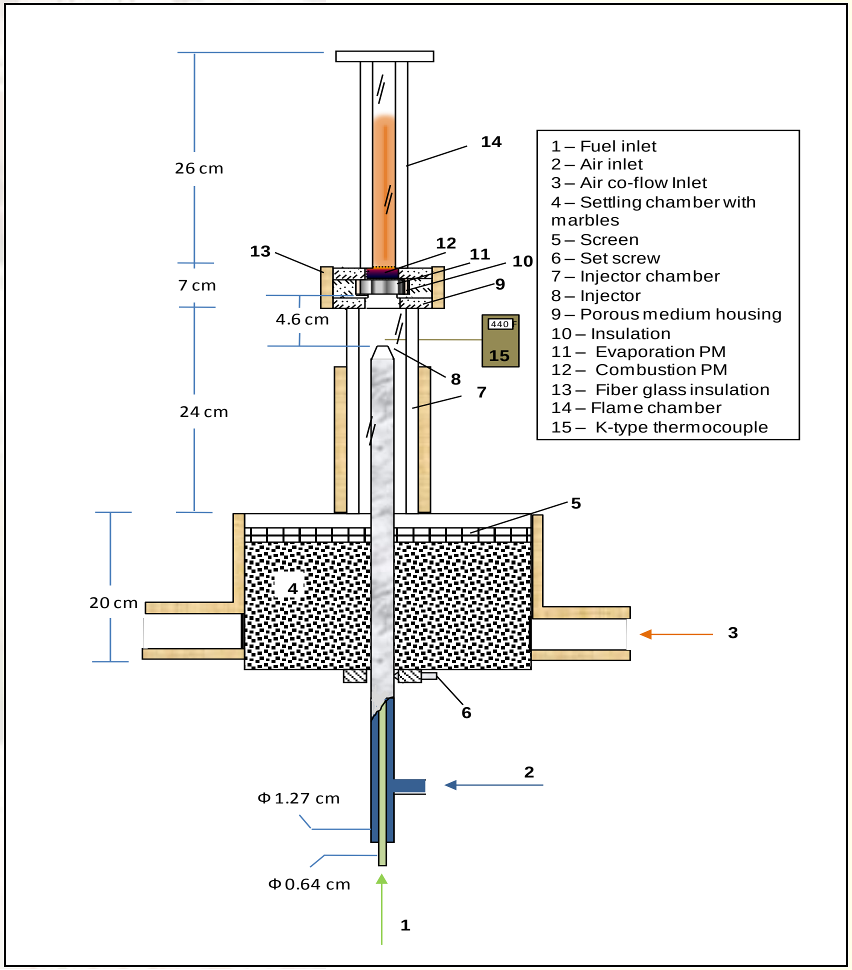
D. Novel Burners

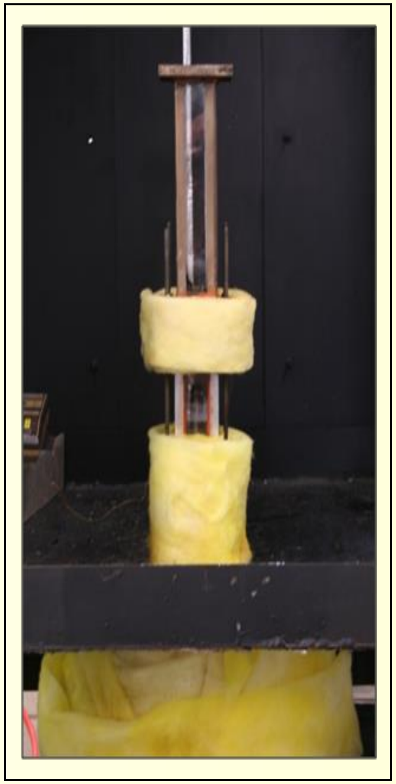
Porous Media Media Burners

- √ APPLICATIONS HAVE BEEN REALIZED AND ARE BEEN DEVELOPED
- √ HOUSEHOLD AND AIR HEATING SYSTEMS
- √ GAS TURBINE COMBUSTION CHAMBERS
- √ STEAM GENERATORS



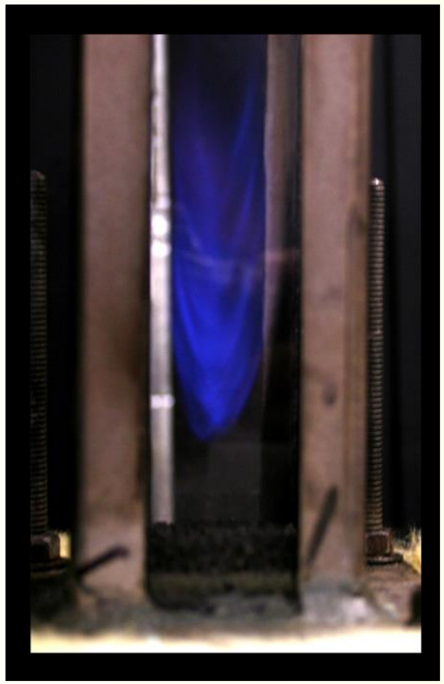
Test Section



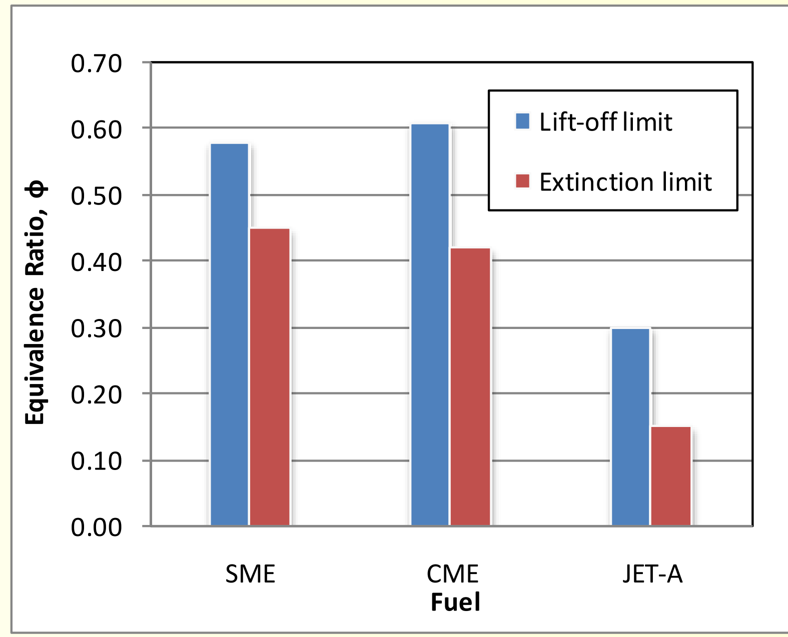


Flame Lift-off and Extinction Limits

Lift-off



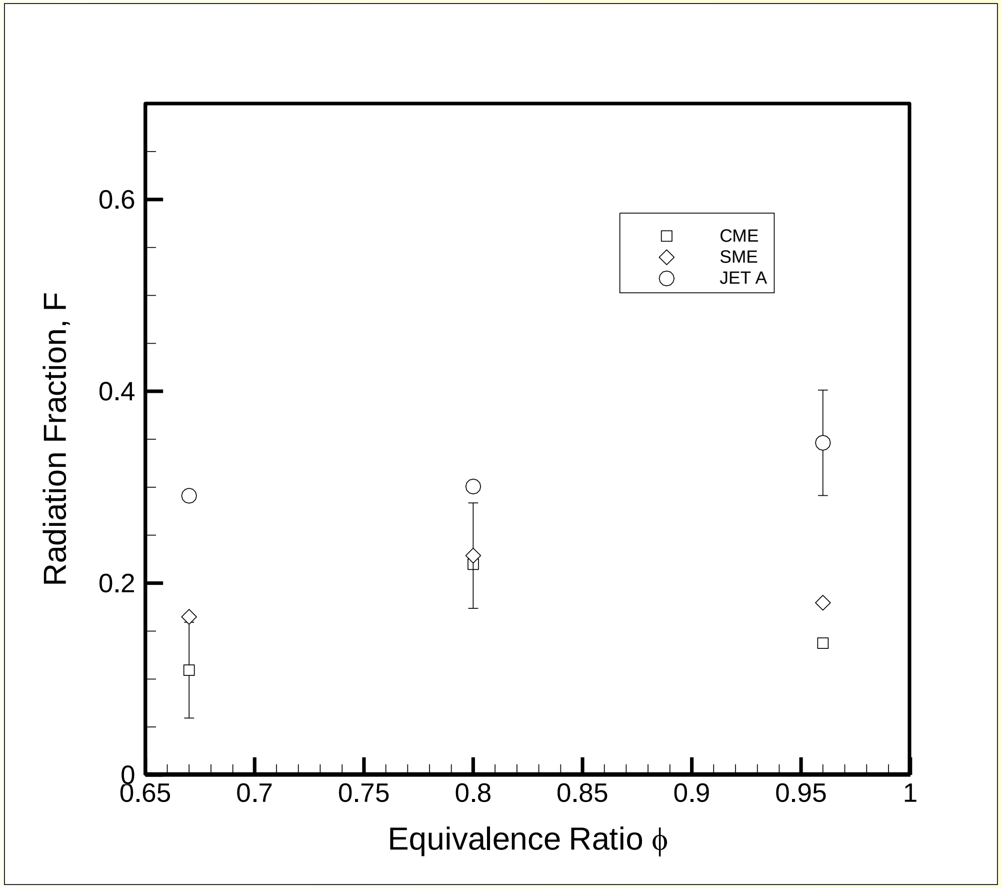
Extinction



- √ Incomplete fuel vaporization
- √ Higher heat feedback for biodiesel
- √ Periasamy and Gollahalli (2007)

RADIATION FRACTION

$$F = \frac{4\pi l^2 R}{\dot{m}\,LHV_{fuel}}$$



$\dot{m}$ (kg/s)

LHV (J/kg)

l **(m)**

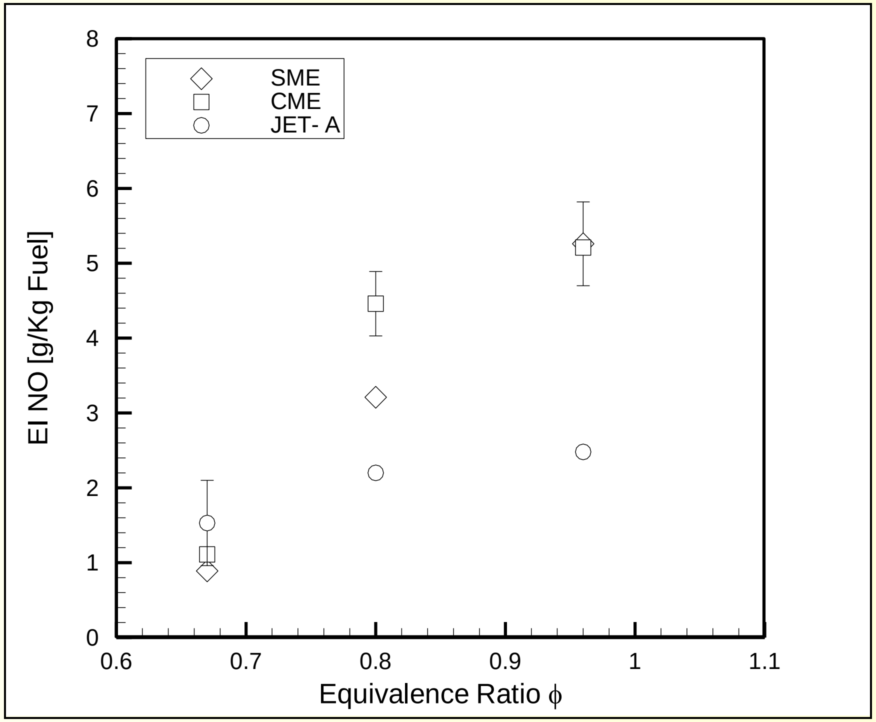
R **(W/m²)**

√ BRZUSTOWSKI (1975)

√ LOVE ET AL. (2009)

Emission Index of NO

$$EI_{NO} = \left(\frac{X_{NO}}{X_{CO} + X_{CO_2}} \right) \cdot \left(\frac{x \cdot MW_{NO}}{MW_F} \right)$$



X= mol fraction of pollutant

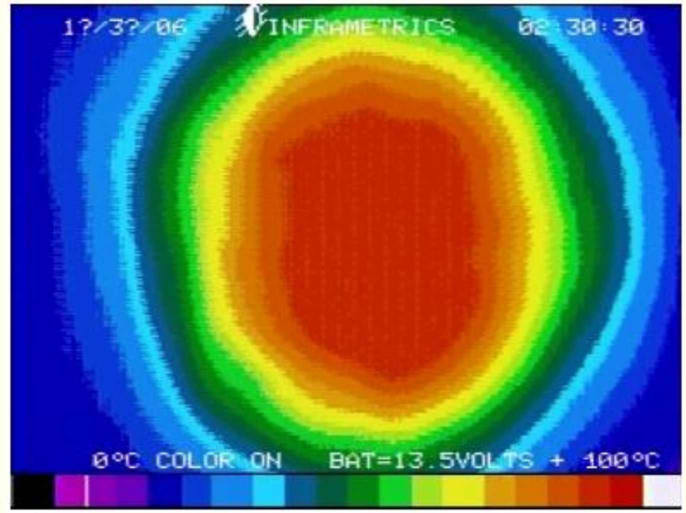
x= # of carbon atoms

MW= molecular weight

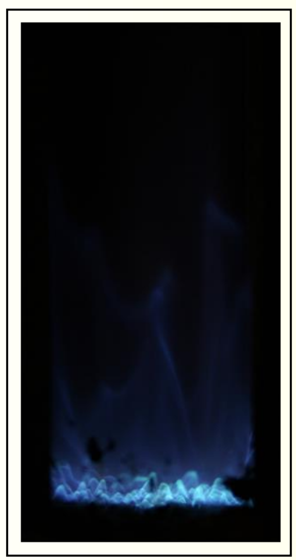
- √Turns, 2000
- √Love et al (2009)
- √ Jugjai and Pjothiya (2006)
- √ N_2O intermediate mechanism

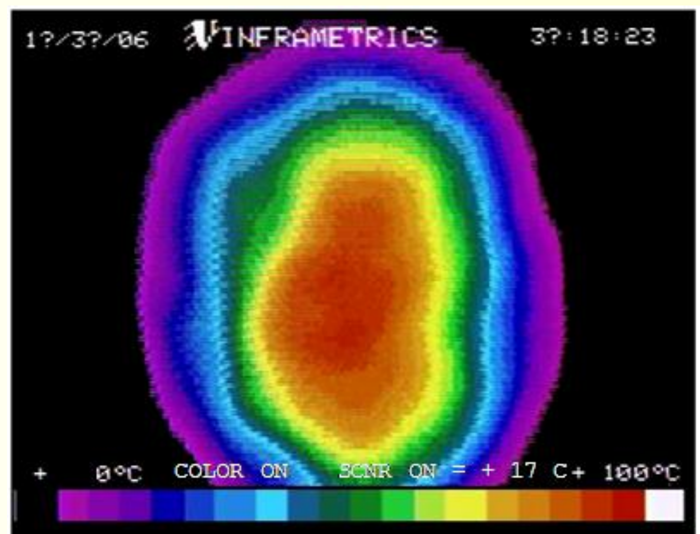
Infrared Images

√ SME



√ JET-A



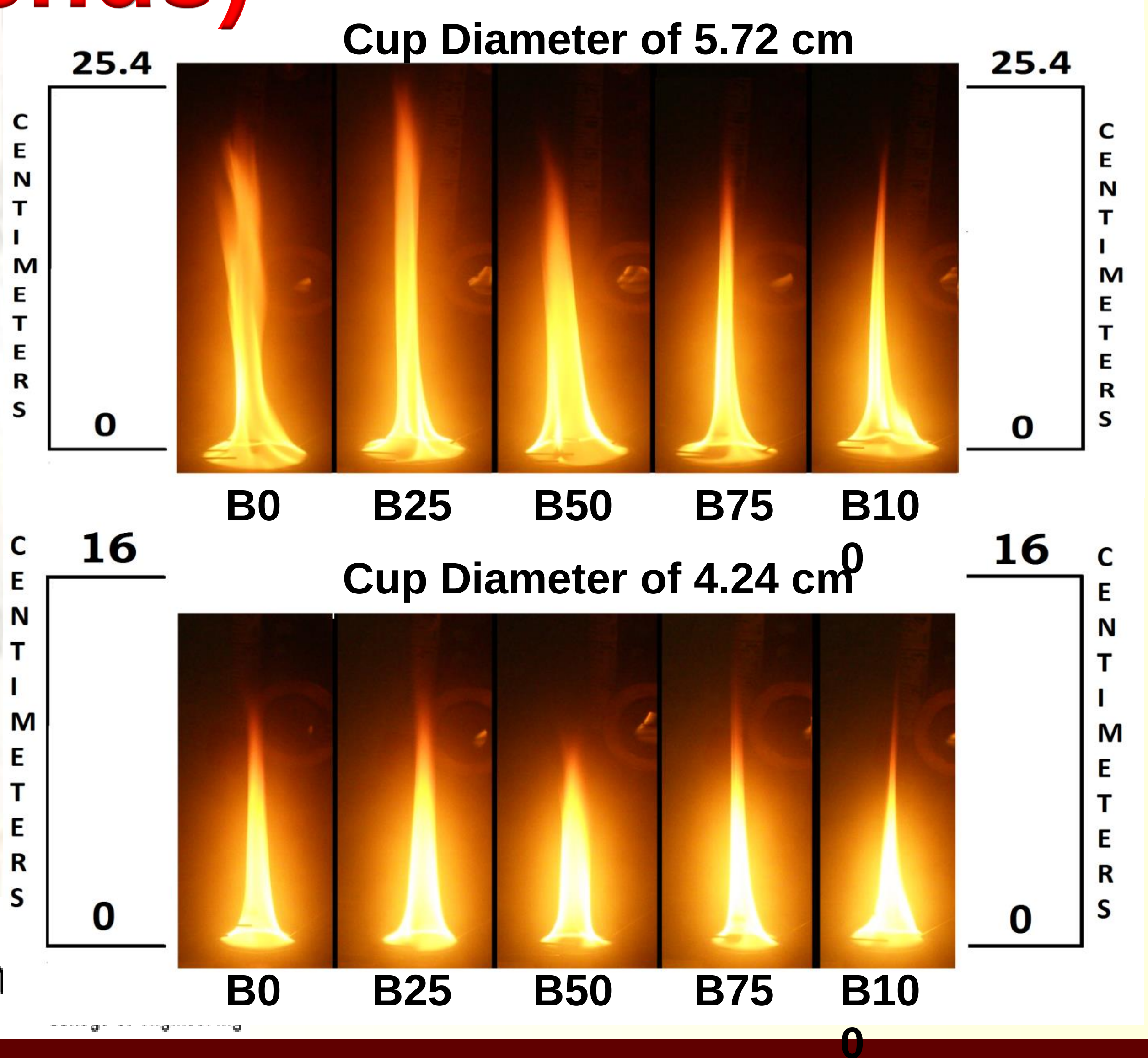


E. Biofuel Fire Research

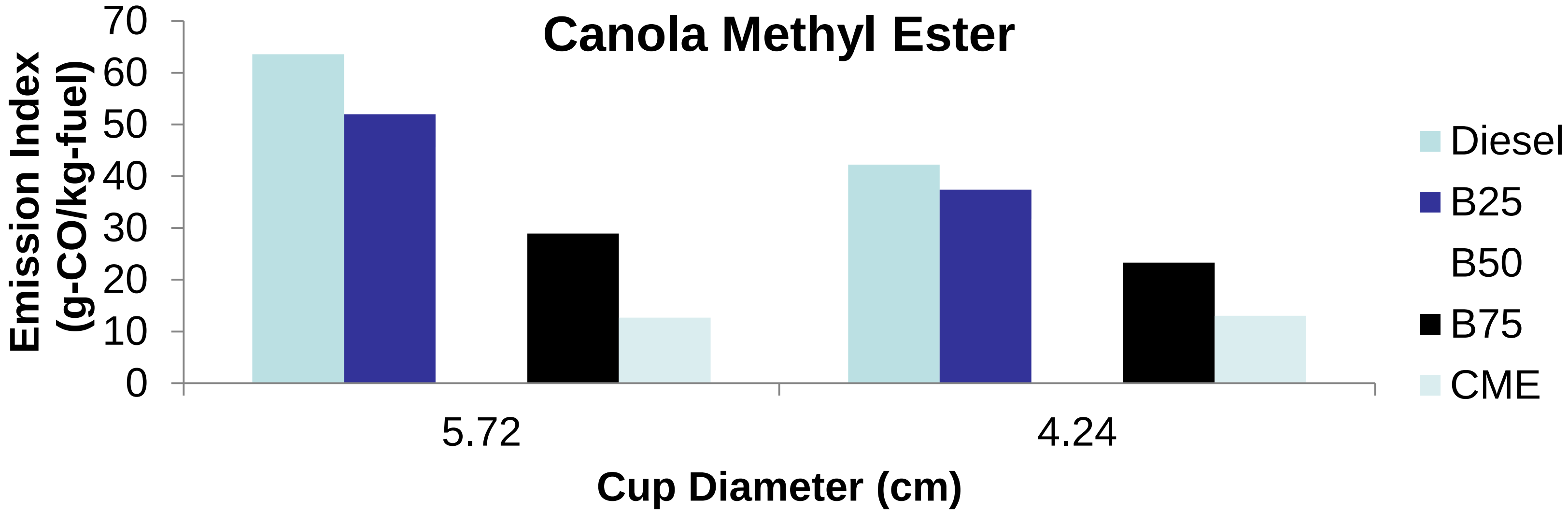
- Handling, Transportation, and Safety of Biofuels not Understood
- Existing Literature limited to Petroleum Pool Fires.
- Flash and Fire Points data are scanty.
- Flammability, Ignition, and Extinction are Characteristics not known.

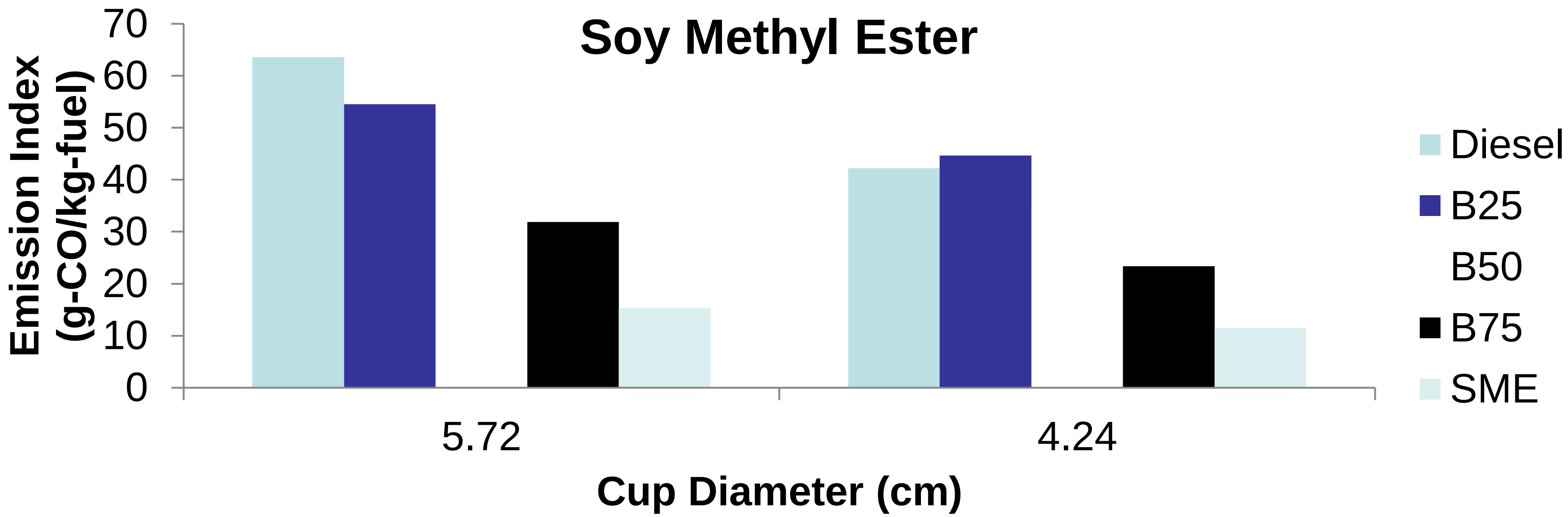
Setup

Flame Appearance (CME Blends)

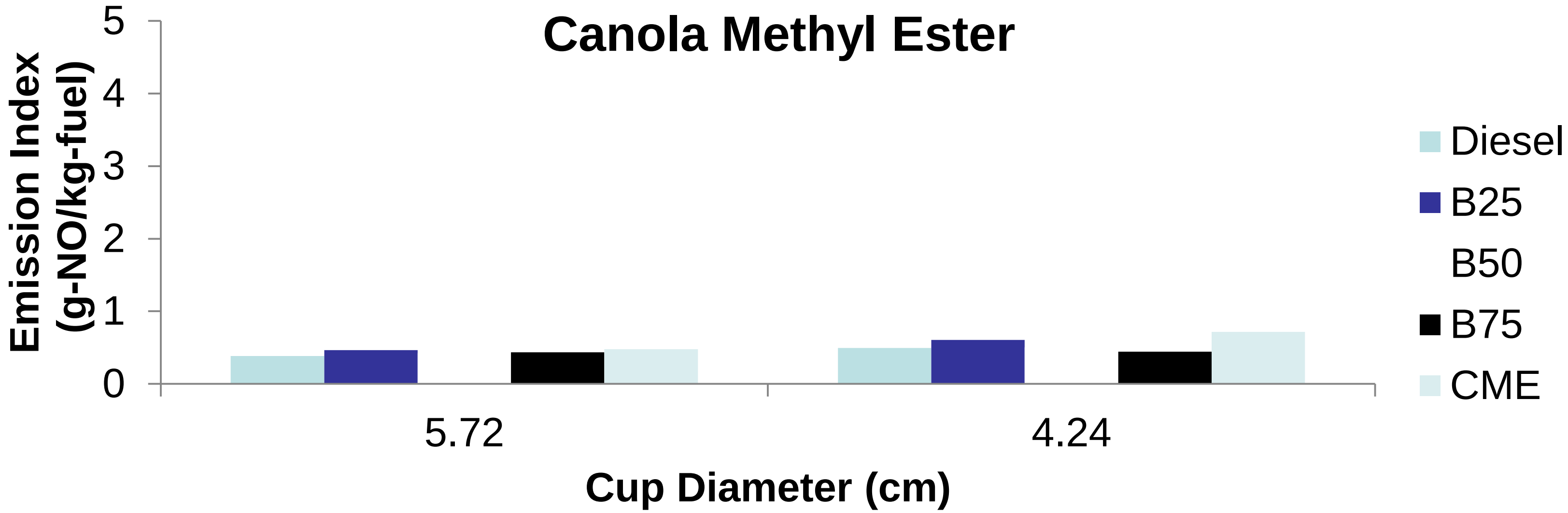


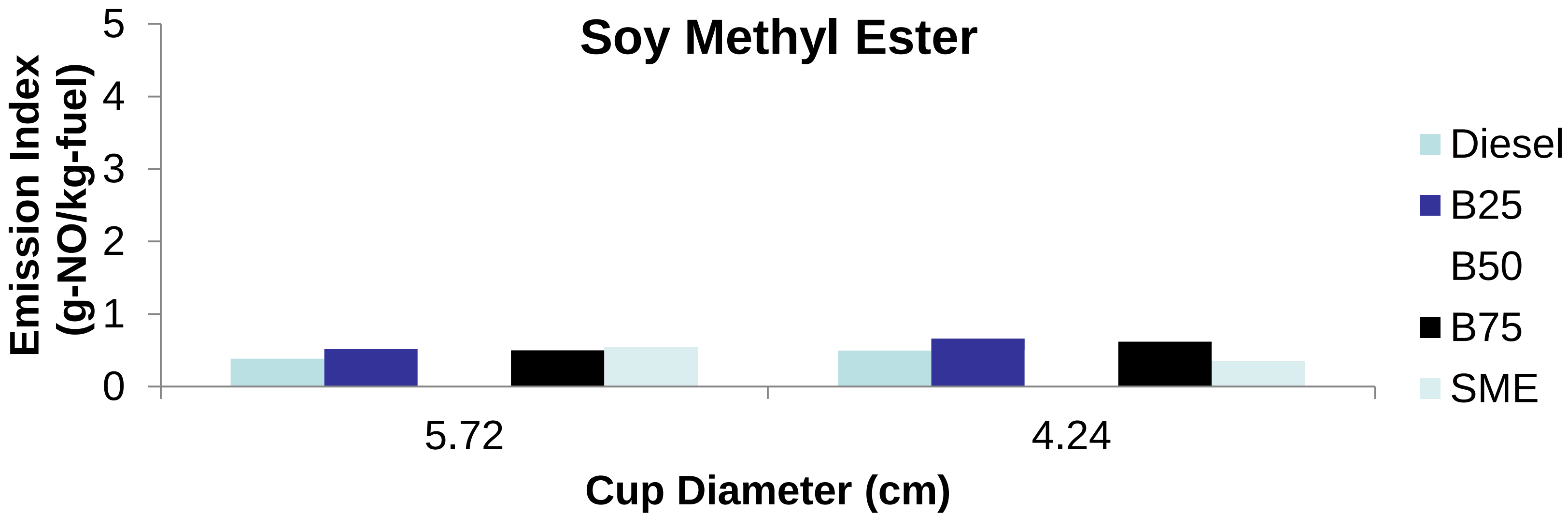
CO Emission Index





NO Emission Index





THANK YOU

☺