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COMBUSTION CHARACTERISTICS IN THE TRANSITION REGION OF LIQUID FUEL SPRAYS

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There have been a number of studies involving the behavior of fuel sprays in the transition region which encompasses droplets in the 10-80 μm size range. In particular, the effect of droplet size on minimum ignition energy of a spray has been examined. Using swirl atomizers to generate fuel sprays, Ballal and Lefebvre (ref. 1) showed that ignition energies increase with increasing Sauter Mean Diameter (SMD). On the other hand, the experimental work of Chan and Polymeropoulos (ref. 2), in an 8-35 μm monodisperse droplet size range, showed an optimum droplet diameter around 15 μm for which the ignition energy was minimum. However, these systems had limitations induced by droplet size distribution or variations in the flow velocities due to the requirements for monosized droplet formation. Thus, in November 1982, an investigation of the droplet ignition requirement was initiated with the following specific objectives:

1) To map the minimum ignition energies for monodisperse fuel sprays in the transition region as a function of droplet size, number density, equivalence ratio, etc.;

2) To isolate the optimum droplet diameter at which the ignition energy requirement is minimum;

3) To study the effects of changing vaporization environment on the minimum ignition energy;

4) To characterize the ignition requirements of polydisperse fuel sprays in terms of the droplet size distribution; and

5) To determine the effects of droplet size and size distribution on flame speed.

The experimental facility developed for this study consists of a Berglund-Liu Vibrating Orifice Monodisperse Aerosol Generator which produces monosized droplets with diameters having a standard deviation of less than 1% of the mean droplet diameter (ref. 3). Based on the vibrating orifice principle, the droplet size can be calculated from the operating conditions of the instrument (fuel feed rate and vibration frequency). After generation, the droplets are subjected to a flow of dispersion air to prevent coagulation. The air/fuel aerosol passes through a flow reducing section where dilution air is added to achieve the desired stoichiometry. The monodisperse fuel spray then flows through the test section, a square pyrex tube, which houses the ignition electrodes. Both electrodes are mounted on micrometer traversing mechanisms to vary the spark gap. In its current configuration (Fig. 1), the experimental facility is operated with downward flow in order to prevent any accumulation of fuel within the combustor.

An ignition system has been developed to supply a capitance spark with independently variable energy, energy density, and duration. The spark energies are determined by integrating (over time) the product of the voltage and current, recorded by a two-channel digital oscilloscope.

Efforts in the first year have concentrated on the development of the experimental facility and performing exploratory measurements. Preliminary measurements have been made in the 10-74 μm monodisperse droplet size range using n-heptane as fuel. Minimum ignition energies are measured as a function of droplet size, equivalence ratio, and flow velocity. Prior to these measurements, the optimum spark gap and duration corresponding to minimum ignition energies are determined for each operating condition. Further measurements using different fuels including alcohols will be made soon.

REFERENCES

1. Ballal, D.R., and A.H. Lefebvre, "Ignition and Flame Quenching of Flowing Heterogeneous Fuel-Air Mixtures," Combustion and Flame 35, 155, 1979.

2. Chan, K.K., and C.E. Polymeropoulos, "An Experimental Investigation of the Minimum Ignition Energy of Monodisperse Sprays," Paper No. ESSCI 81-21, Eastern States Section, The Combustion Institute Meeting, November, 1981.

3. Berglund, R.N., and B.Y.H. Liu, "Generation of Monodisperse Aerosol Standards," Environmental Science and Technology 7, 2, 147, 1973.

OVERALL OBJECTIVES

Study the effects of droplet size and size distribution on

- Minimum Ignition Energies
- Flammability Limits
- Flame Speeds

BACKGROUND

- Spray Burning Widespread
  - 30-50% of Total Energy Consumption
- Modes of Spray Combustion
  - Premixed
  - Diffusive
  - Transition
- Transition Region Effects
  - Increased Flame Speeds
  - Reduced NO_x Emissions
  - Broadened Flammability Limits
  - Lower Ignition Requirements

OBJECTIVES OF IGNITION STUDIES

- Map minimum ignition energies for mono-disperse fuel sprays in transition region
- Determine optimum droplet size corresponding to minimum ignition energy
- Study prevaporization effects on minimum ignition energy
- Examine size distribution effects in poly-disperse sprays on ignition requirements

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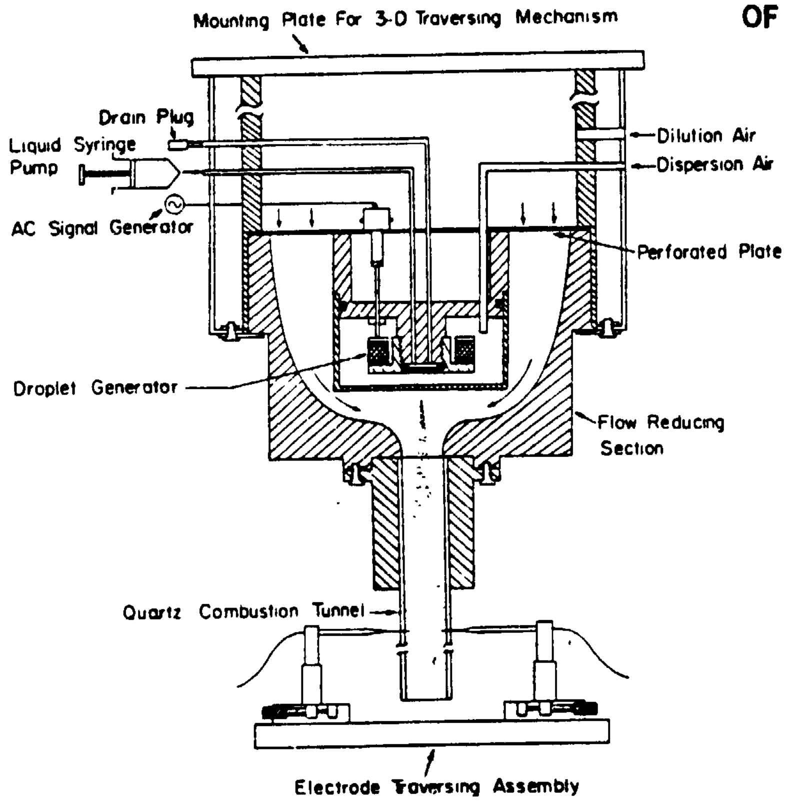

Figure 1 Schematic of the Spray Burner Facility

EXPERIMENTAL VARIABLES

- Droplet Size (10-74 μm)
- Number Density
- Equivalence Ratio
- Extent of Prevaporization
- Flow Velocity
- Fuel Type
- Oxidizer Composition

SUMMARY

- A monodisperse aerosol generator has been modified to study ignition requirements, flammability limits, and flame speeds in the transition region
- An ignition system has been developed and tested
- An optical drop sizing system has been designed and fabrication is nearly complete
- Preliminary measurements of droplet size effects on the minimum ignition energy for n-heptane sprays have been performed.
- Parametric studies of droplet size effects on minimum ignition energies of various fuels including alchohols are in progress