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MEASUREMENT OF SPRAY COMBUSTION PROCESSES*

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The objectives of this planned three-year investigation of spray combustion processes include the following:

(1) Making measurements of noncombusting spray fields to aid in developing adequate computational models of the dynamic interaction between the droplets and the turbulent gas phase.

(2) Making measurements of hydrocarbon-air spray flames to provide benchmark results that can be used in the verification and refinement of numerical models of the entire spray combustion process.

(3) Developing techniques for making laser measurements in typical spray combustion environments, along with techniques for acquiring, processing, displaying, and interpreting the data.

The freejet configuration selected for the experimental study is shown in figure 1. The central droplet-air jet is the exhaust from a plain-jet atomizer of the type investigated by Lorenzetto and Lefebvre (ref. 1). At a nominal air velocity of 100 m/s, the atomizer provides a Sauter mean droplet diameter of 60-80 μm. The diameter of the centerbody is 5.4 cm, the diameter of the atomizer nozzle exit is 1.27 cm, and the diameter of the outer nozzle exit is 45.7 cm. For the combustion experiments, the recirculation zone formed downstream of the centerbody acts as a flameholder.

Conventional pressure, temperature and flowrate instrumentation is used to monitor and control the experimental apparatus. The gas velocity field in the turbulent spray zone is measured with a laser velocimeter (LV) system, which yields two components of the instantaneous velocity vector of a small seed particle in the optical probe volume. A schematic diagram of the UTSI-developed LV system (ref. 2) is shown in figure 2. The relatively large droplets from the atomizer cannot be assumed to be in dynamic equilibrium with the gas phase; consequently, amplitude discrimination is used to eliminate those light-scattering events that result from large particles in the probe volume. (The diameter of the seed particles is only about 2 μm.) Using this LV technique to measure many light-scattering events for a given position of the probe volume, one can determine two components of the mean gas velocity vector as well as the variances and the covariance.

The large-droplet size and number density, along with one component of the velocity, are measured with the Particle Sizing Interferometer (PSI) technique initially proposed by W. M. Farmer (ref. 3). A schematic diagram of the PSI system developed at UTSI is shown in figure 3.

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In the hydrocarbon spray combustion experiments, space and time-resolved measurements of temperature and species number density will be made with either laser-Raman or laser-fluorescence techniques. The equipment required for these measurements is already available at UTSI. These measurements will be made with the collaboration of Prof. J. W. L. Lewis.

The first year of this research program was devoted to preparing the experimental equipment. A pictorial view of the new spray combustion facility is shown in figure 4. This facility was designed, the required components were procured and/or fabricated, and the facility was installed in one of the UTSI laboratories. The outer air flow is drawn from the atmosphere by a fan located in the downleg of the facility; a variable-speed DC fan-drive motor provides well controlled bellmouth exit speeds up to approximately 11 m/s. As shown in figure 4, turning vanes and screens are used to provide a nearly uniform flow at the bellmouth entrance. The atomizer air is supplied by the UTSI low-pressure compressor system, which provides up to 0.2 kg/s of air flow at pressures up to 10 atm. After passing through a pressure regulator, the atomizer air passes through a choked venturi, which is used to provide an accurate measurement of the flow rate. The atomizer liquid (either water or hydrocarbon fuel) is supplied from a nitrogen-pressurized tank located in a heated enclosure outside the laboratory. The pressure drop across a parallel array of capillary tubes is used to determine the liquid flow rate.

Not shown in figure 4 is the optical table on which the various laser measurement systems are mounted. This table, which is located beneath the freejet test section, provides translation in three directions; a total axial travel of approximately 75 cm is available.

At present (February 1984), all subsystems of the spray combustion facility are operational. All the conventional instrumentation systems have been calibrated and the microcomputer software for processing the signals has been developed. The LV system has been installed and aligned, and all other preparations have been made for commencing the water-droplet experiments. We plan to complete the LV and PSI measurements on the water-droplet system in mid-1984. At that time, the hydrocarbon combustion experiments will be initiated.

REFERENCES

1. Lorenzetto, G. E. and Lefebvre, A. H.: Measurements of Drop Size on a Plain-Jet Airblast Atomizer. AIAA Journal, Vol. 15, No. 7, July 1977, pp. 1006-1010.

2. Farmer, W. M. and Hornkohl, J. O.: Two-Component, Self-Aligning Laser Vector Velocimeter. Applied Optics, Vol. 12, No. 11, Nov. 1973, pp. 2636-2640.

3. Farmer, W. M.: Measurement of Particle Size, Number Density and Velocity Using a Laser Interferometer. Applied Optics, Vol. 11, 1972, p. 2603.

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SCHEMATIC OF COAXIAL FREE-JET FLOWFIELD

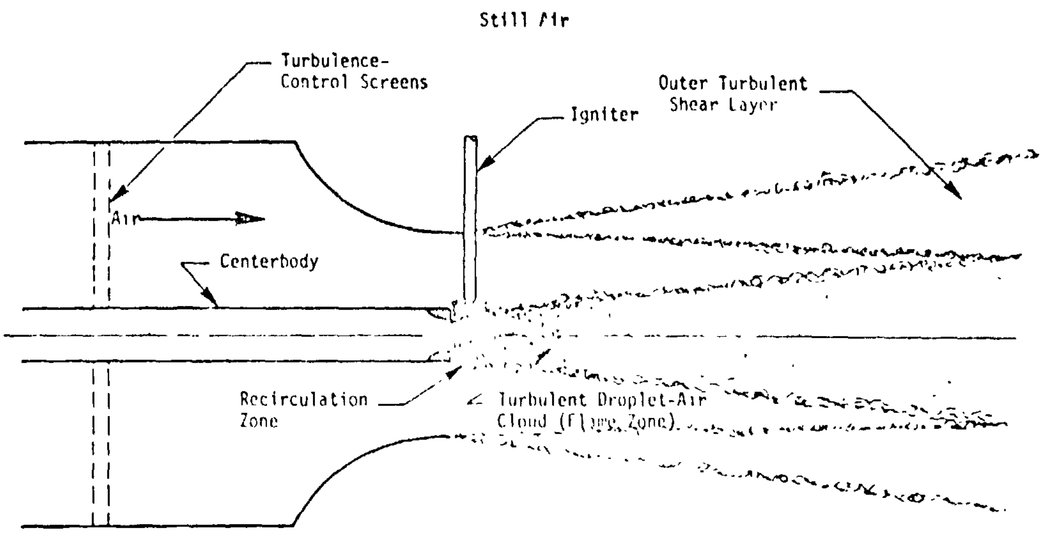

Figure 1.

SCHEMATIC DIAGRAM OF BRAGG-CELL,
FRINGE-TYPE LASER VELOCIMETER OPTICAL SYSTEM

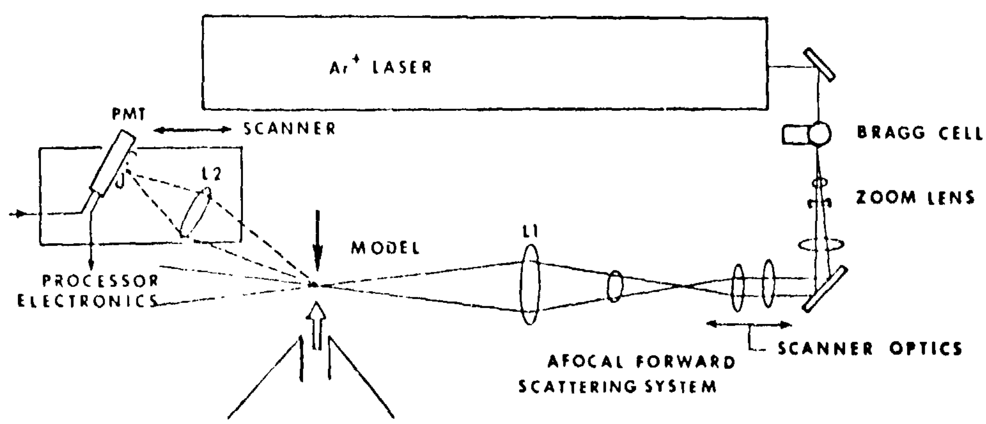

Figure 2.

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SCHEMATIC DIAGRAM OF PSI OPTICAL SYSTEM

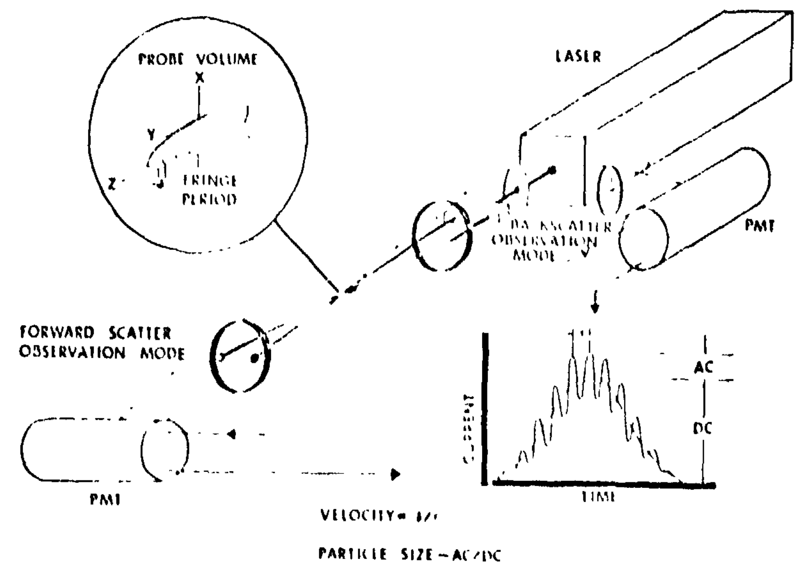
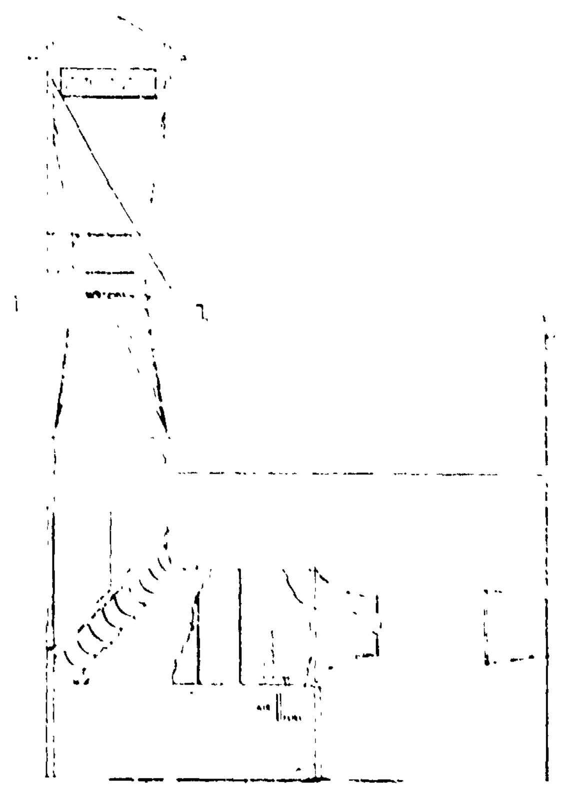


Figure 3.

PICTORIAL VIEW OF THE SPRAY COMBUSTION FACILITY



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