FUEL SPRAY DIAGNOSTICS

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BACKGROUND:

The two most significant parameters which characterize fuel spray combustion are the droplet size and the size distribution. Since the basic interactions between fluid mechanics and the combustion process are not well understood, a great deal of research, both experimental and theoretical, has addressed itself to the problem of spray combustion. Turbulent fuel and air motions influence the chemical reactions by increasing the oxygen supply to the fuel. The relative velocities between the fuel's gas phase and liquid droplets affect the evaporation, burning rate and the pollutant formation. Thus, it is necessary to measure the size and velocity distributions of the spray droplets and the evolution of these distributions with the flow. Such measurements will enable researchers to get a better picture of spray combustion and in turn help in both fuel nozzle research and developing theoretical models of spray combustion.

The Droplet Sizing Interferometer has promised to be very successful in producing droplet size and velocity and size-velocity correlations measurements under a variety of spray conditions. By using off-axis large angle light scatter detection, the measurement region has been substantially reduced and spatial resolution was significantly improved. Using the light scattered by reflection and refraction made the measurement of droplet size and velocity possible in dense sprays. Such measurements are important to enable comparisons of different fuel injectors and to characterize the combustion processes in gas turbine engines.

B. RESEARCH OBJECTIVES:

Using water as a fuel substitute, several fuel nozzles will be selected for measurement of droplet size and velocity at representative test conditions. In addition, the turbulent interactions between flowing air streams and simulated fuel sprays will be studied. Later experiments will investigate simple flow fields using small particles for air flow seeding to track the flow characteristics.

C. TECHNICAL SIGNIFICANCE:

These experiments will provide the fundamental experimental data base for turbulent flow mixing models and lead to better prediction of more complex turbulent chemical reacting flows. The experiments will also be useful for analytical application to combustor design and provide a better fundamental understanding of the combustion process.

D. APPROACH:

Several experimental configurations are currently being considered for laser diagnostic investigation. The initial experimental configuration will consist of a simple mounting device for fuel nozzle characterization tests. The device will have manual traversing capability to get several probe volume positions for mapping the fuel nozzle flow distribution and variations with test conditions. Another experimental configuration would utilize a fuel nozzle/swirler combination to study simulated fuel/air mixing characteristics. A possible simple turbulent mixing study would utilize a flexible arrangement of clear tubular lucite sections in a configuration to permit flow seeding and adjustable positioning features to permit manually scanning of the turbulent flow field. Details of these various configurations will be developed, progressing with additional experience and developing expertise with the laser diagnostic equipment.

With each experimental configuration, the Droplet Sizing Interferometer apparatus will be used to obtain a series of measurements to fully map droplet size and velocity distributions. Two receiver units will be positioned off-axis at a collection angle selected to cover the expected size range with acceptable signal/noise ratio. Each receiver unit contains the collection optics, photomultiplier tube assembly, and high voltage power supply. A visibility and Doppler signal processor accepts signals from the PMT and simultaneously processes each signal for visibility and Doppler period which correspond to size and velocity. Data from the visibility processor are accepted and displayed by the Data Management System (DMS).

E. DATA SYSTEM DESCRIPTION:

The Droplet Sizing Interferometer (DSI) consists of 13 major components which include a transmitter unit, two receiver units, two signal processors, two data management systems, two Bragg cell systems, two printer/plotters, a laser, power supply, and a color monitor. The transmitter unit includes a 0.5 watt Argon-Ion Laser, beam steering devices, frequency shifting capability, beam splitting and focusing components. The system is a two-color, two component system. Two independent, orthogonal measurements of size and velocity components can be made simultaneously.

The Data Management System (DMS) includes a 6502-based micro-computer, dual disk drives, video display, and I/O hardware to interface the visibility processor. A printer/-plotter is included to provide hard copy records. The DMS is designed to accept data from the visibility processor and display the data in real-time in histogram form on the video monitor. The data can be stored and retrieved from mini-floppy disks. The DMS also handles data reduction. The software package provides a variety of mean diameter calculations, velocity calculations, and data plots.

F. STATUS:

Initial training and practice sessions have been conducted during the past year with simple laboratory spray experiments.

The test cell for formal spray diagnostic experiments is now operational; experimental spray configurations are in the process of being set-up. The test facility is presently equipped with 2 fixed optical tables, experiment breadboards, and other optical accessories. A traversing optical table system is on order with delivery expected in 4-6 months.

Two contracts have been awarded for further development and improvements to the system. These contracts promise to extend the size range capability, reduce beam alignment difficulties, and reduce the system sensitivity to laser beam quality and differences in the relative intensity of the beams.

Data obtained to date have been limited to verification experiments with a monodisperse droplet generator and system familiarity experiments.

G. REFERENCES:

Bachalo, William D. : Method for Measuring the Size and Velocity of Spheres by Dual-Beam Light-Scatter Interferometry; Applied Optics, Vol. 19, P. 363, Feb. 1980.

LASER DIAGNOSTIC PROGRAM

OBJECTIVE:

- MEASURE SPRAY DROPLET SIZES AND VELOCITIES SIMULTANEOUSLY
- MEASURE TWO COMPONENT TURBULENT FLOW PARAMETERS
- CHARACTERIZE FLOW MIXING PROCESSES

SIGNIFICANCE:

- EVALUATE FUEL INJECTOR FLOW DISTRIBUTION PATTERNS
- FUNDAMENTAL DATA BASE FOR TURBULENCE MODEL DEVELOPMENT
- EVALUATE TURBULENCE INTENSITY AND REACTION CONDITIONS IN COMBUSTION ZONES

LASER DIAGNOSTIC FACILITY

PURPOSE

- CONDUCT FUNDAMENTAL COMBUSTION PROCESS RESEARCH USING DIAGNOSTIC MEASUREMENTS FROM A UNIQUE LASER INTERFEROMETER APPARATUS.

METHOD

- NON-INTRUSIVE MEASUREMENT PROBE FORMED BY COHERENT LASER BEAMS THAT PRODUCE INTERFERENCE FRINGE BANDS.
- DROPLETS/PARTICLES GENERATE LIGHT SCATTER PATTERNS WHICH ARE DETECTED WITH PMT.

YIELD

- FAST REAL TIME DATA ANALYSIS OF FLOW CHARACTERISTICS.

INTERFEROMETER APPARATUS

DESCRIPTION

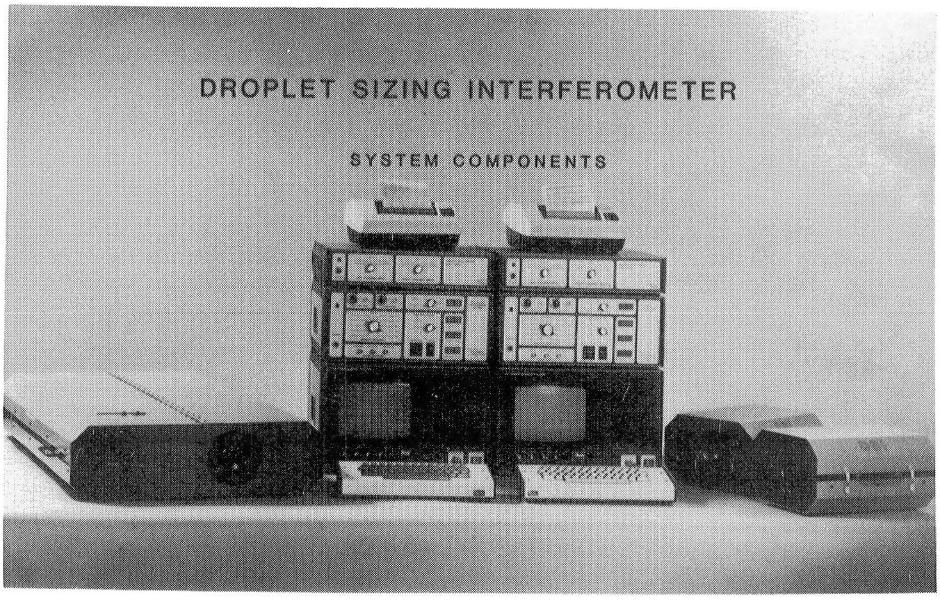
- ARGON-ION LASER
  LEXEL MODEL 85-.5
  0.5 WATT POWER

- TRANSMITTER TWO RECEIVER SYSTEM
  SPECTRON LABS MODEL 4000
  TWO-COLOR, TWO-COMPONENTS WITH ORTHOGONAL PAIRS OF BEAMS

CAPABILITIES

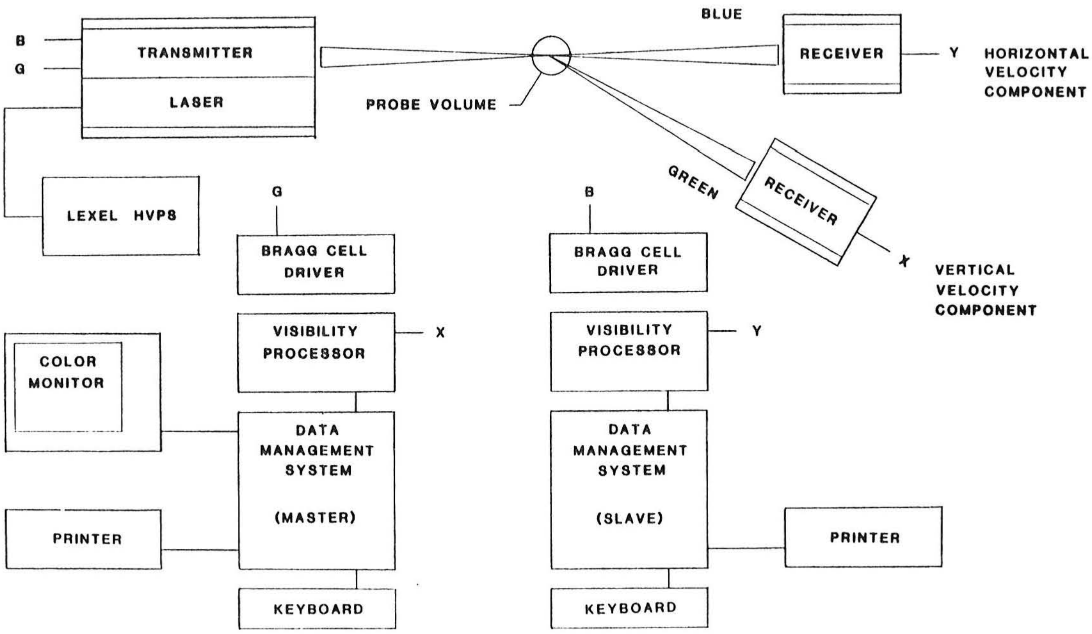
- DROPLET SIZING
  OFF-AXIS DETECTION
  3 TO 3000 MICROMETERS
  THREE DECADE RANGES

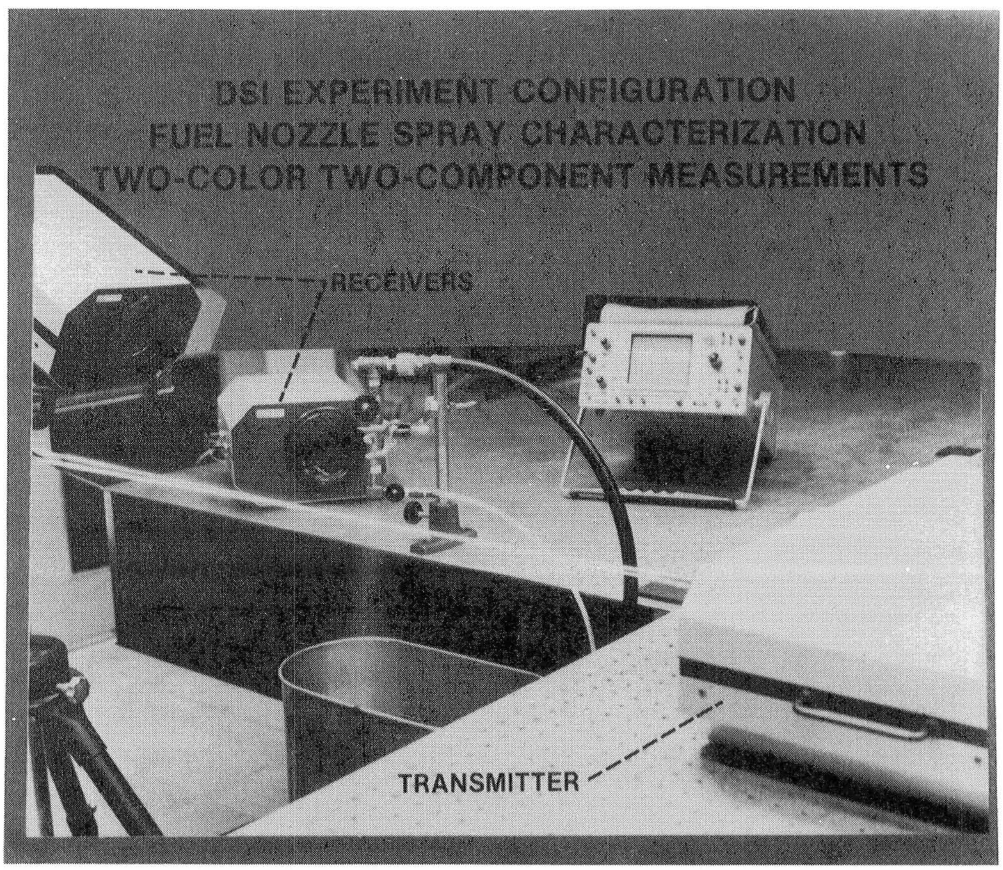
- TWO VELOCITY COMPONENTS
  UP TO 100 M/SEC
  ELEVEN RANGES

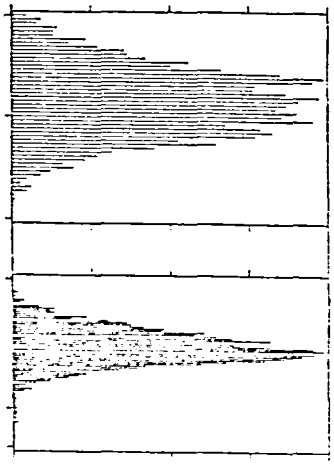


LASER DIAGNOSTICS FACILITY

SYSTEM LINE DIAGRAM

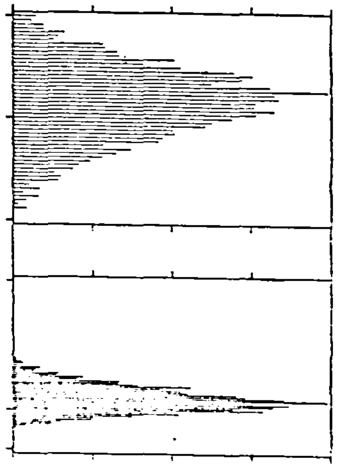






TYPICAL
DSI
DATA

2-COLOR
2-AXIS



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PLOT LABELS
 DIA AT 100% VISIBILITY: 11 MICRONS
 DIA AT 50% VISIBILITY : 64 MICRONS
 DIA AT 15% VISIBILITY : 117 MICRONS
 LOW VELOCITY : 3.64 M/S
 MID VELOCITY : 17.79 M/S
 HIGH VELOCITY: 25.89 M/S

DATE: 12/9/81
SERIES: SPRAY2
RUN: 04
COMMENTS: TEST SPRAY 2-COLOR

TIME PERIOD: 14.45 SECONDS
VALID VELOCITY SAMPLES: 2375
VALID SIZE SAMPLES: 937
ACQUISITION
LASER WAVE LENGTH: .5145 MICRONS
COLLECTION FACTOR: 8
FRINGE SPACE: 17.3 MICRONS
BEAM SPACE: 2.52 MM
XMIT LENS FOCAL LENGTH: 88.5 MM

VP-1001 STATUS
 DATA RATE:     2689
 RANGE:         3
 FRINGE COUNT: 13
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PLOT LABELS
 DIA AT 100% VISIBILITY: 10 MICRONS
 DIA AT 50% VISIBILITY : 56 MICRONS
 DIA AT 15% VISIBILITY : 101 MICRONS
 LOW VELOCITY : 3.84 M/S
 MID VELOCITY : 7.91 M/S
 HIGH VELOCITY: 12 M/S

DATE: 12/9/81
SERIES: SPRAY2
RUN: 04
COMMENTS: TEST SPRAY 2-COLOR

TIME PERIOD: 14.45 SECONDS
VALID VELOCITY SAMPLES: 2375
VALID SIZE SAMPLES: 956
ACQUISITION
LASER WAVE LENGTH: .488 MICRONS
COLLECTION FACTOR: 8
FRINGE SPACE: 15 MICRONS
BEAM SPACE: 2.87 MM
XMIT LENS FOCAL LENGTH: 88.5 MM

VP-1001 STATUS
 DATA RATE:     386
 RANGE:         4
 FRINGE COUNT: 13
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LASER DIAGNOSTICS PROGRAM SCHEDULE

EXPERIMENT DESCRIPTION	1982			1983				1984			
	2	3	4	1	2	3	4	1	2	3	4
• SPRAY CHARACTERIZATION-H2O -VARIOUS NOZZLE TYPES -PRESSURE EFFECTS---DISTRIBUTION -MAP SEVERAL PLANES		●			●			●			
• TURBULENCE STUDIES-SEEDED -VARIOUS SWIRLER CONFIGURATIONS -VANE ANGLE EFFECTS -AIRFLOW SPLITS			●			●			●		
• FUEL-AIR REACTION STUDIES -VARIOUS EQUIVALENCE RATIOS -FUEL EFFECTS -MEASURE TURBULENCE INTENSITY				●			●			●	

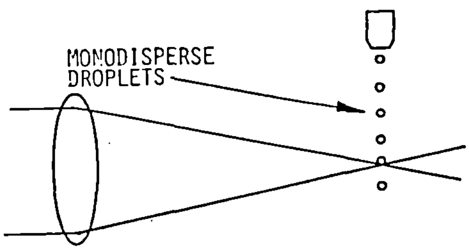
Development of two measurement techniques :

- -The Visibility/Intensity Technique (V/I)
- -The Dual Beam Maximum Intensity Thechnique (IMAX)

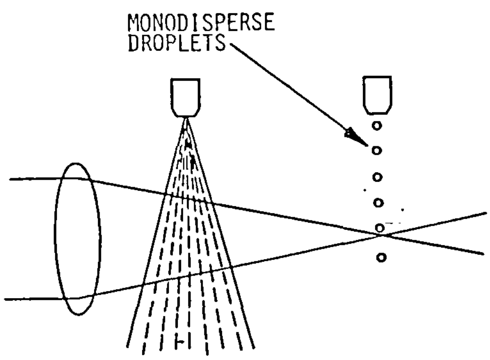
Limitations of the Droplet Sizing Interferometer (DSI) in practical enviroments :

- -Particles prior to crossover alter fringe pattern
- -Multiple particles in probe volume.
- -Visibility is a function of where the particle goes through the probe volume.

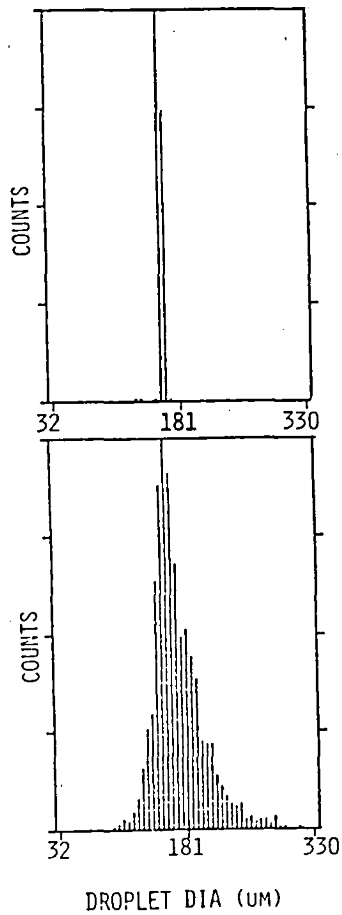
PARTICLE SIZING INTERFEROMETRY



Size Histogram of a Monodispersed Spray in an Undisturbed Probe Volume (Visibility Technique)



Size Histogram of a Monodispersed Spray (Visibility Technique). Laser Blocked by Spray.

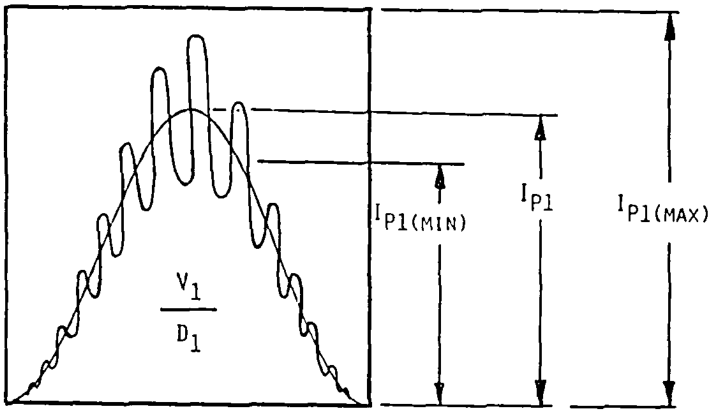


THE VISIBILITY/INTENSITY TECHNIQUE (V/I)

-Makes use of the absolute intensity of the scattered light to provide a criterion for signal validation.

-Method to establish limits for every measured visibility:

droplets that produce certain visibility ➞ must have a given size ➞ must scatter light with a given intensity



Visibility and intensity of a droplet traveling thru the middle of a probe volume.

THE DUAL BEAM MAXIMUM INTENSITY TECHNIQUE (IMAX)

-Eliminates the ambiguity of the Gaussian beam intensity distribution and provides a direct relationship between scattered light intensity and droplet size.

-Method:

A small beam crosses through the middle of a big beam to produce fringes in a region of uniform intensity in the big beam.

OPTICAL CONFIGURATION: