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AEROTHERMAL MODELING PROGRAM--PHASE II*

ELEMENT C: FUEL INJECTOR-AIR SWIRL CHARACTERIZATION

A.A. Mostafa, H.C. Mongia, V.G. McDonnell†, and G.S. Samuelsen†
Allison Gas Turbine Division
General Motors Corp.

The main objectives of the NASA-sponsored Aerothermal Modeling Program, Phase II Element C, are experimental evaluation of the air swirler interaction with a fuel injector in a simulated combustor chamber (Figure 1), assessment of the current two-phase models, and verification of the improved spray evaporation/dispersion models.

This experimental and numerical program consists of five major tasks. Tasks 1 and 2 have been completed. Brief descriptions of the five tasks are given in the following paragraphs.

TASK 1--EXPERIMENTAL CONFIGURATION

This task involved preliminary design of the test section, its details for fabrication, and the experimental plan for data acquisition.

The aim of the experiment is to collect benchmark quality data to study the interaction of the fuel spray with a swirler typical of current use in aircraft turbine engines.

The fuel nozzle and swirler combination is operated at both unconfined and confined conditions (152 mm duct). The experimental plan covers a wide range of tests of varying complexity, with the constituent flows measured separately and then in combination. The duct is designed in such a way to enable the required measurements to be taken at the inlet plane and at seven axial locations downstream of the swirler-fuel injector combination. The measurements include the following quantities: the three components of mean and root mean square (rms) gas velocity as well as Reynolds stresses, the three components of mean and rms droplet velocity, Sauter mean diameter, droplet size distribution, spatial distribution of droplets, cone angle, fraction of liquid evaporated in the duct (vapor concentration), the static pressure along the wall of the duct, and the inlet air temperature.

All the test configurations (Figure 2) are first operated free of injected particles (except for the laser anemometer seed), second with injected monodisperse solid particles (50-micron glass beads) through a diameter jet tube, 24 mm, then with injected solid particles of two sizes (50 and 100 μm glass beads), and finally with a fuel spray (methanol) through an aircraft-type airblast atomizer.

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†University of California at Irvine.

TASK 2--MODELING SENSITIVITY ANALYSIS

Allison had run its 2-D codes (parabolic and elliptic) to predict the distribution of the flow field variables for all proposed flow and geometry test conditions of the experimental test matrix. The main purpose of this task was to determine if the planned experiment is sensitive to the significant variables and which variable and boundary conditions had to be measured.

This effort resulted in two main modifications in the original test plan. First, the 457.2 mm duct that is concentrically located around the nozzle/swirler assembly to simulate the unconfined conditions was replaced by one made of screen mesh. The reasoning was that the permeable wall would permit the entrainment of air that would otherwise necessitate recirculation. Second, the flow rates through the fuel nozzle and the swirler and the low velocity stream of confinement were optimized to avoid spray impingements on the tube wall within the measurements region.

TASK 3--MEASUREMENTS

The efforts of this task have been directed to (1) the testing of the facility, (2) the verification of the two-component laser interferometer diagnostics (see Figure 3), and (3) the acquisition of test data in the spray chamber.

The utility, applicability, and accuracy of phase Doppler (PD) has been tested in a series of experiments in which the technique has been compared to visibility/intensity validation and laser diffraction using a Malvern (see ref. 1 and 2). The PD compared well to the visibility technique with intensity validation (VIS/IV), and exhibits major advantages in the dynamic range of both droplet size and droplet velocity. In trials with laser diffraction using a commercial Malvern analyzer, the composite line-of-sight measurement of spatial-SMD deduced from the PD measurements compares favorably to the single line-of-sight Malvern measurement of spatial-SMD. It is noteworthy that the two measurements are best aligned for the Model-Independent algorithm of the Malvern rather than the Rosin Rammler.

Example data for both the injection of 50 μm beads and the methanol spray are presented in Figures 4 and 5. Although data are taken at seven axial locations, only four are shown for clarity. The glass bead data (Figure 5a) display the axial mean velocity of both the bead and gaseous phase velocity, as well as the bead number density. The centerline hump in the bead number density is clearly discernable in the photograph (Figure 4a). The methanol spray data (Figure 5b) reflect the strong influence of the swirl in both the radial spread of the spray and the radial profiles of both SMD and mean axial velocity.

TASK 4--RESULTS AND ANALYSIS

Experimental data of Task 3 will be reduced and presented in a format suitable to make direct comparison with model predictions and to quantify the effects of the flow and geometric variables in various transport processes.

TASK 5--MODEL IMPROVEMENT

A mathematical model for turbulent evaporating sprays based on the recent work in that area (ref. 3-5) will be validated in this effort. This model will include improved submodels for spray injection, turbulence/droplet interaction, and droplet evaporation.

REFERENCES

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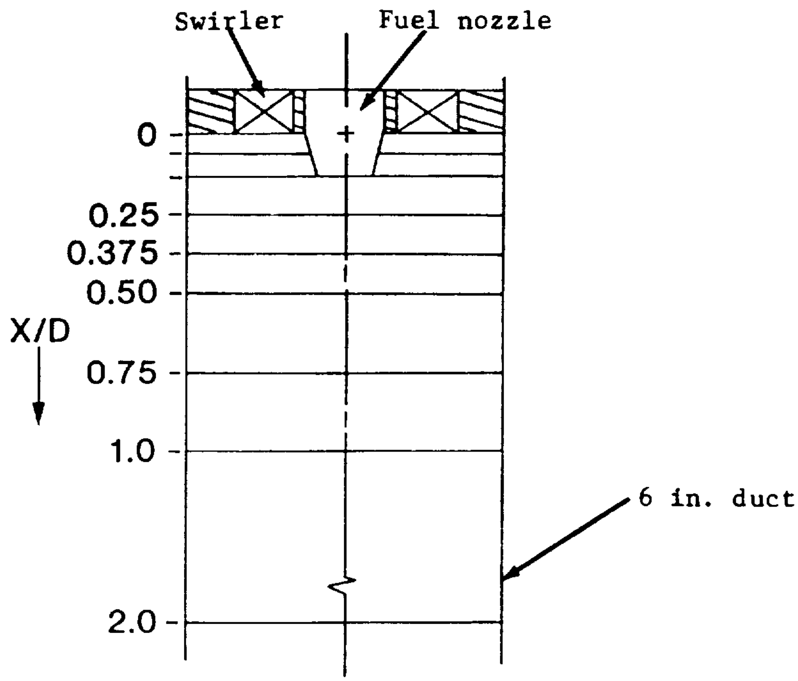


Figure 1. Experimental configuration for confined flow with liquid fuel injection and swirl.

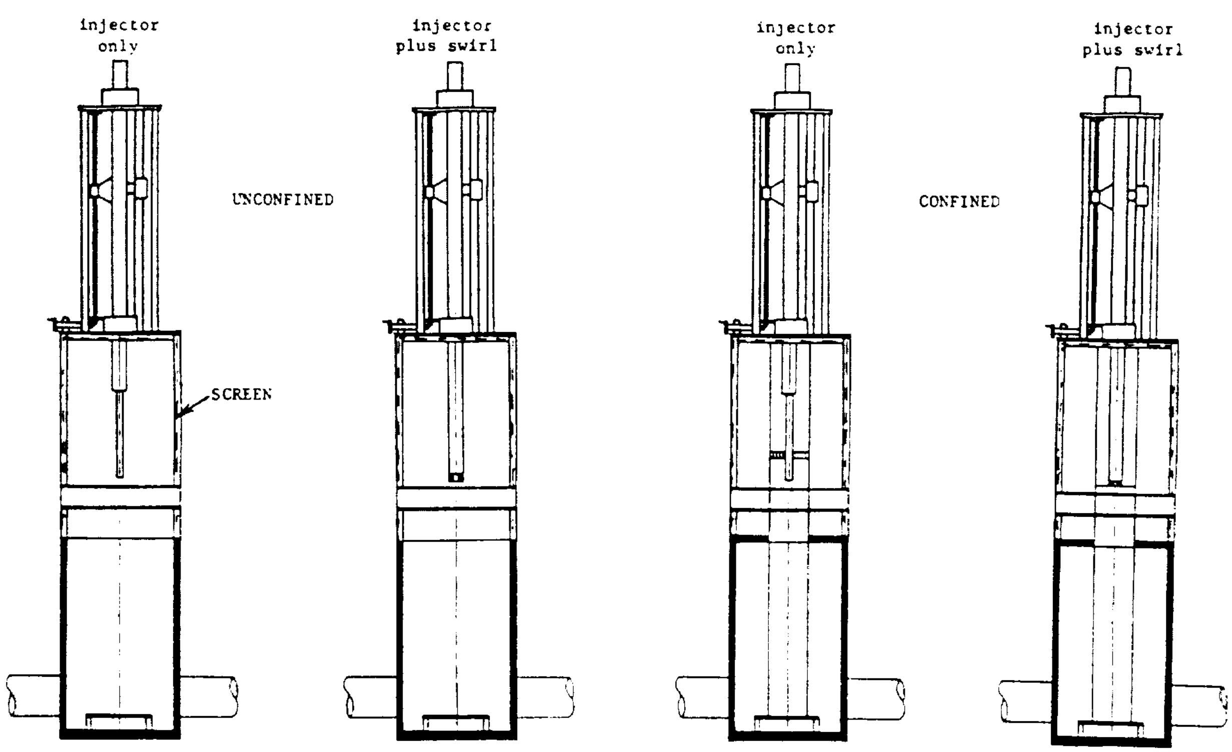


Figure 2. Experimental configurations.

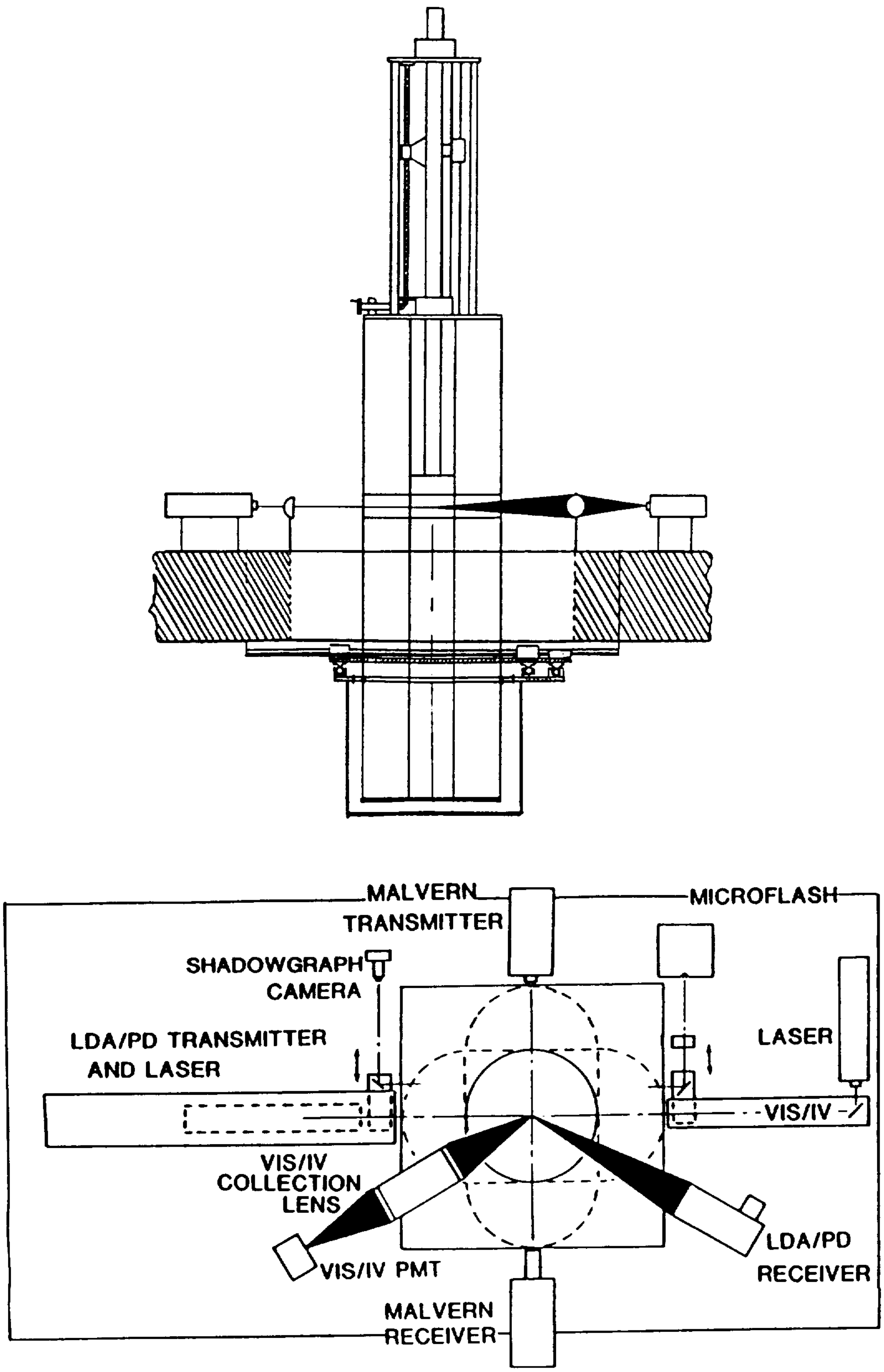
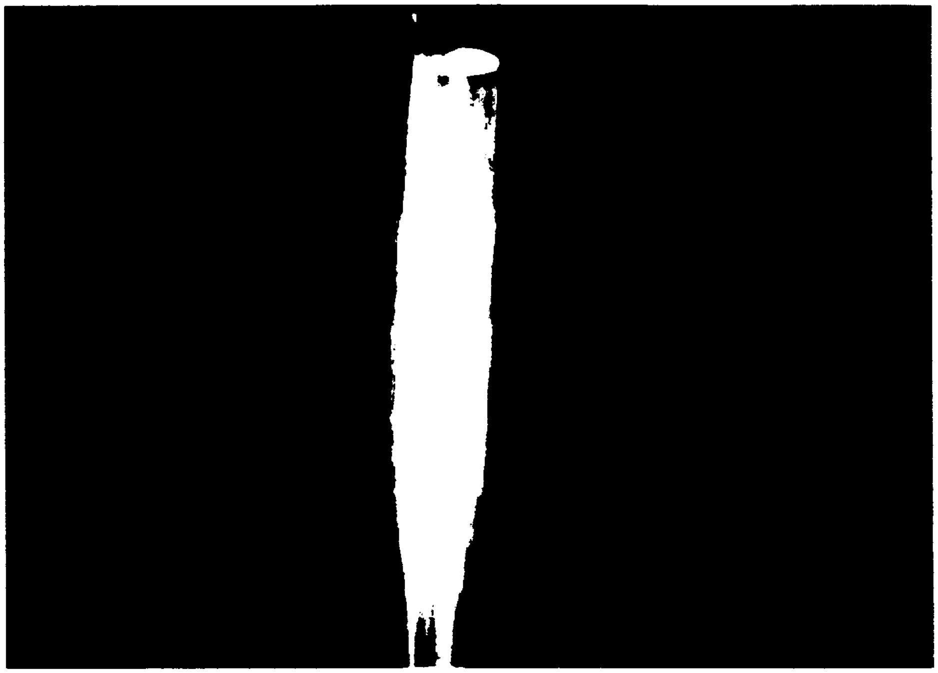


Figure 3. Flow facility and optical arrangement.

a) 50 μm beads (unconfined; without swirl)



b) Methanol spray (unconfined; without swirl)

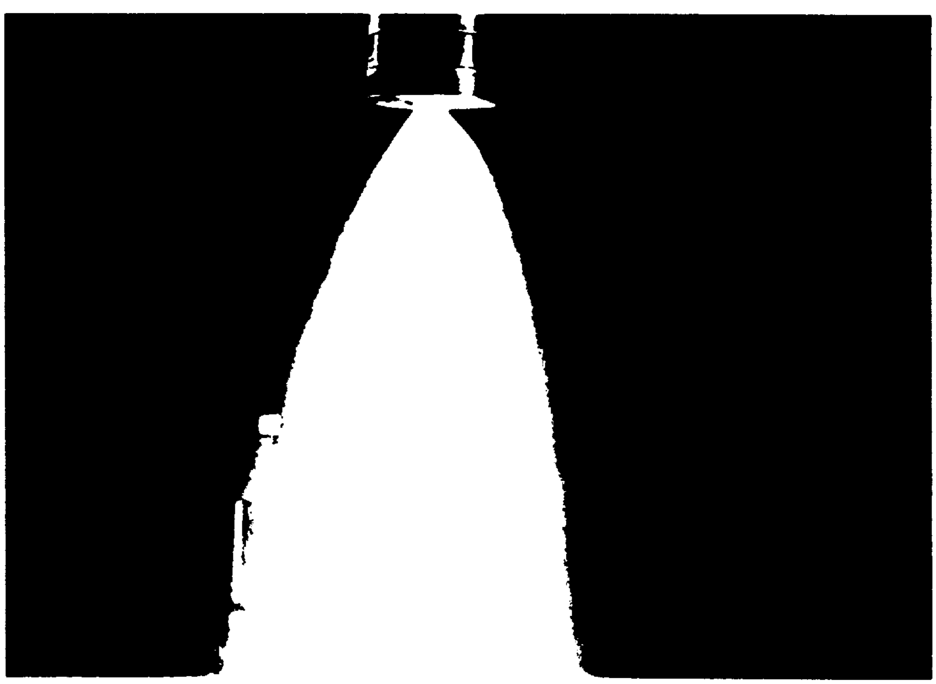


Figure 4. Representative data: photographs.

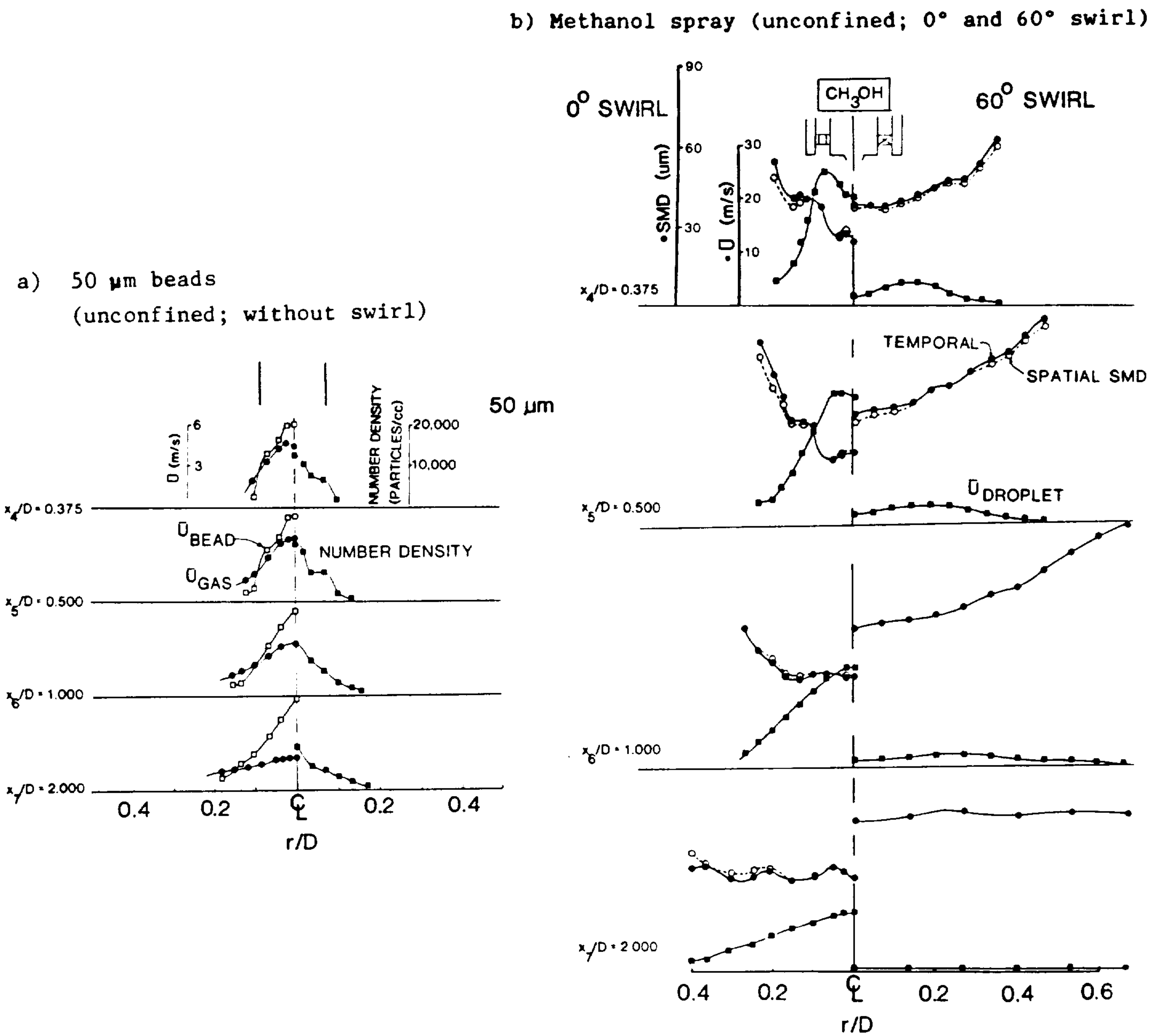


Figure 5. Representative data: radial profiles.