N87-11203

LATERAL JET INJECTION INTO TYPICAL COMBUSTOR FLOWFIELDS

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A three-year research program is underway which deals both experimentally and theoretically with the problem of primary and dilution lateral jet injection into typical combustor flowfields in the absence of combustion. Parameter variations to be systematically investigated include: lateral jet size and velocity, main inlet-to-combustor expansion ratio, combustor inlet swirl strength, downstream contraction nozzle, multijet injection, and jet inlet angle. Helium bubble and smoke flow visualization, five-hole pitot probe time-mean velocity measurements, and one-wire and two-wire hot-wire normal and shear stress turbulence data are to be obtained in the experimental program. A fully three-dimensional computer code simulation is to be used in the theoretical contribution. The basic aim is to characterize the time-mean and turbulence flowfield, recommend appropriate turbulence model advances, and implement and exhibit results of flowfield predictions.

Recently, experimental and theoretical research has been completed on 2-D axisymmetric geometries under low speed, nonreacting, turbulent, swirling flow conditions, in the absence of any lateral jets (ref. 1). The flow enters the test section and proceeds into a larger chamber (the expansion D/d = 2) via a sudden or gradual expansion (side-wall angle α = 90 and 45 degrees). A weak or strong nozzle may be positioned downstream to form a contraction exit to the test section. Inlet swirl vanes are adjustable to a variety of vane angles with values of ϕ = 0, 38, 45, 60 and 70 degrees being emphasized. The objective was to determine the effect of these parameters on isothermal flowfield patterns, time-mean velocities and turbulence quantities, and to establish an improved simulation in the form of a computer prediction code equipped with a suitable turbulence model.

The principal aim of the new research program is to investigate the trajectory, penetration and mixing efficiency of lateral air jet injection into typical combustor flowfields in the absence of combustion, so as to characterize the time-mean and turbulence flowfield for a variety of configurations and input parameters, recommend appropriate turbulence model advances, and implement and exhibit results of flowfield predictions. A combined experimental and theoretical approach is to be followed, in a modified version of the test facility, equipped initially with one and two lateral jets, located one test-section diameter downstream of the inlet. A recent research paper (ref. 2) describes some of the earlier studies. Parameters to be systematically investigated include:

1. lateral jet size and velocity,

2. main inlet-to-combustor expansion ratio,

3. combustor inlet swirl strength,

4. downstream contraction nozzle,

5. multijet injection,

6. jet inlet angle,

and their effects on the subsequent flowfield are to be observed and characterized. The specific objectives of the proposed research are:

1. To **exhibit** the flowfield characteristics utilizing appropriate flow visualization technques, so as to define clearly areas for later detailed study.

2. To **measure** the time-mean flowfield and normal and shear turbulent Reynolds stresses for a variety of flow conditions, so providing a direct comparision with results of nondiluted experiments previously obtained. Main and lateral airflow inlet conditions will be carefully recorded with emphasis on those parameters of interest in associated computational flow studies.

3. To **present** results of interest in combustor design, illustrating the **effects** of many parameters (lateral jet size and velocity, main inlet-to-combustor expansion ratio, combustor inlet swirl strength, downstream contraction nozzle, multijet injection, and jet inlet angle) **on** subsequent flowfield patterns, like streamlines, time-mean velocities, and normal and shear turbulent Reynolds stresses.

4. To **characterize** the turbulence flowfield in a general sense, leading to the **recommendation** of suitable turbulence modeling advances.

5. To **develop** a fully 3-D computational technique and **evaluate** its predictive capability using the determined turbulence model, for a variety of input parameter variations.

References

1. Lilley, D. G., "Investigations of Flowfields Found in Typical Combustor Geometries", NASA CP-2309, 1984, pp. 139-151.

2. Ferrell, G. B., Abujelala, M. T., Busnaina, A. A., and Lilley, D. G., "Lateral Jet Injection into Typical Combustor Flowfields", Paper AIAA-84-0374, Reno, Nevada, January 9-12, 1984.

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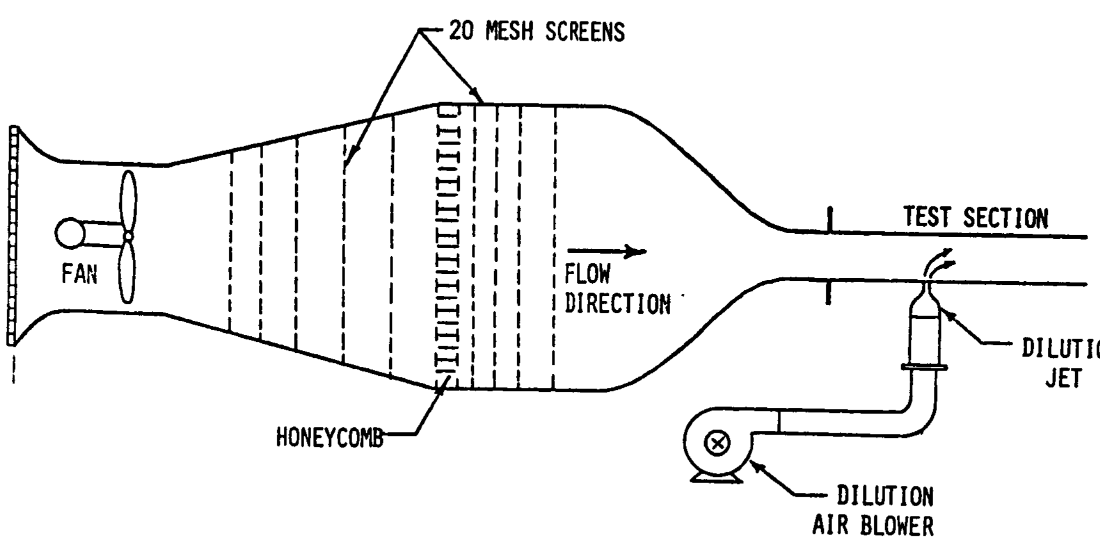
1. Introduction

1.1 The Test Facility



Initial Proposed Test Apparatus

1.2 Objectives

To determine the effect of

1. inlet swirl strength
2. inlet to test section expansion ratio
3. lateral jet size and velocity
4. downstream contraction nozzle size and location
5. number, location and injection angle of lateral jets

on

1. isothermal flowfield patterns
2. time-mean velocities
3. turbulence quantities

1.3 Approach

1. Time-mean flowfield characterization by five-hole pitot probe measurements and by flow visualization.
2. Turbulence measurements by a variety of single- and multi-wire hot-wire probe techniques.
3. Flowfield computations using the computer code developed during the previous year's research program and/or other codes.

2. Facilities and Techniques

2.1 Facilities

1. wind tunnel,
2. one variable-angle vane swirler,
3. three plexiglass text sections of diameters 30, 22.5 and 15 cm,
4. expansion blocks of 90 and 45 deg., for each of the three test sections,
5. weak and strong downstream contraction nozzles, for each of the three test sections.

2.2 Recent Studies with No Lateral Jets

1. Flow visualization using neutrally-buoyant helium-filled soap bubbles.
2. Time-mean velocities with a five-hole pitot probe for a full range of swirl strengths.
3. Turbulence measurements using a six-orientation single-wire hot-wire technique.
4. An advanced computer code has been developed to predict corresponding confined swirling flows to those studied experimentally.
5. Tentative predictions have now been supplemented by predictions made from realistic inlet conditions.

2.3 Lateral Jet Nozzle Details

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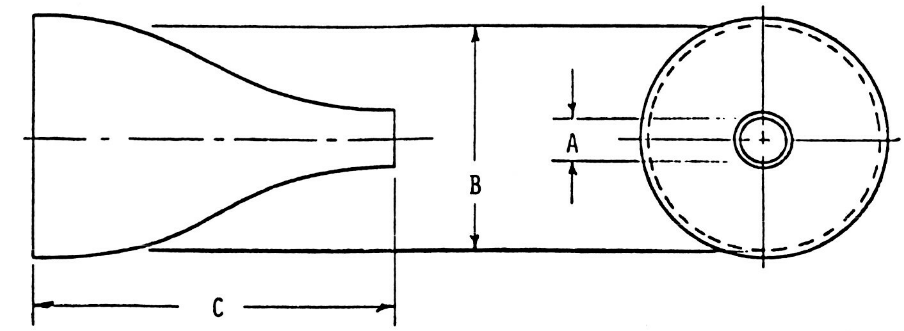


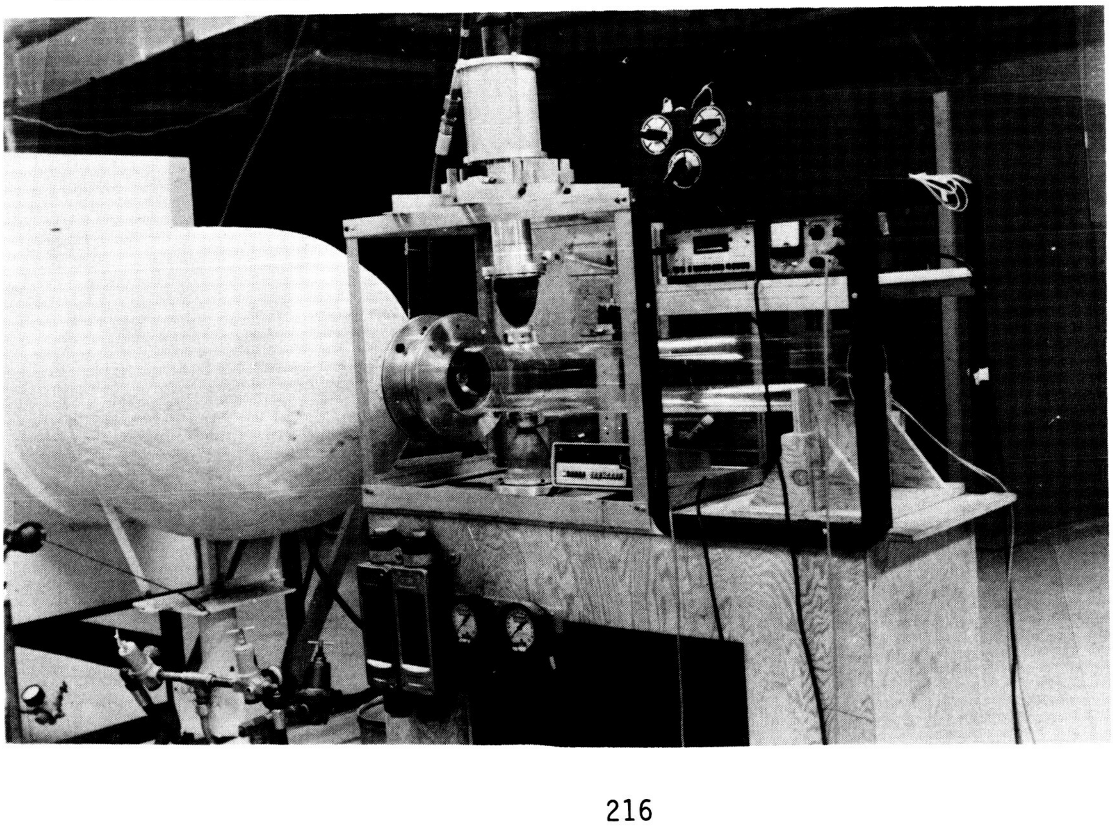
$A_{COMB.}/A_{JET}$	A	B	C
50	2.12	10.00	20.00
100	1.50	10.00	20.00
150	1.22	10.00	20.00

NOTE: ALL DIMENSIONS IN CM

Lateral Jet Nozzle Details

3. Progress

3.1 Test Facility



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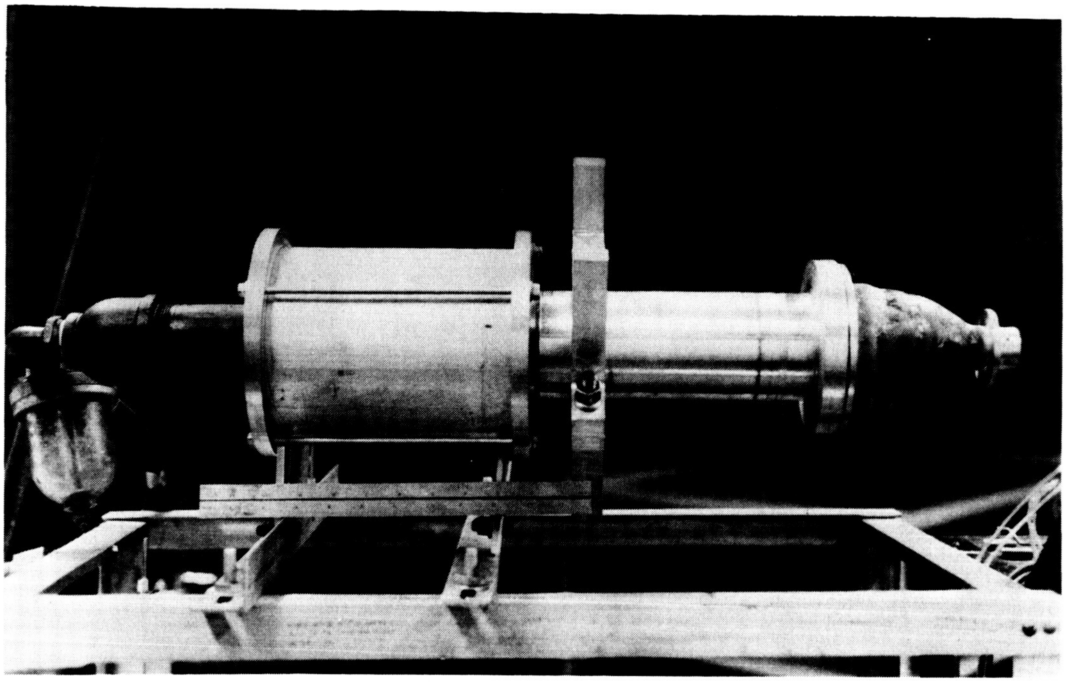
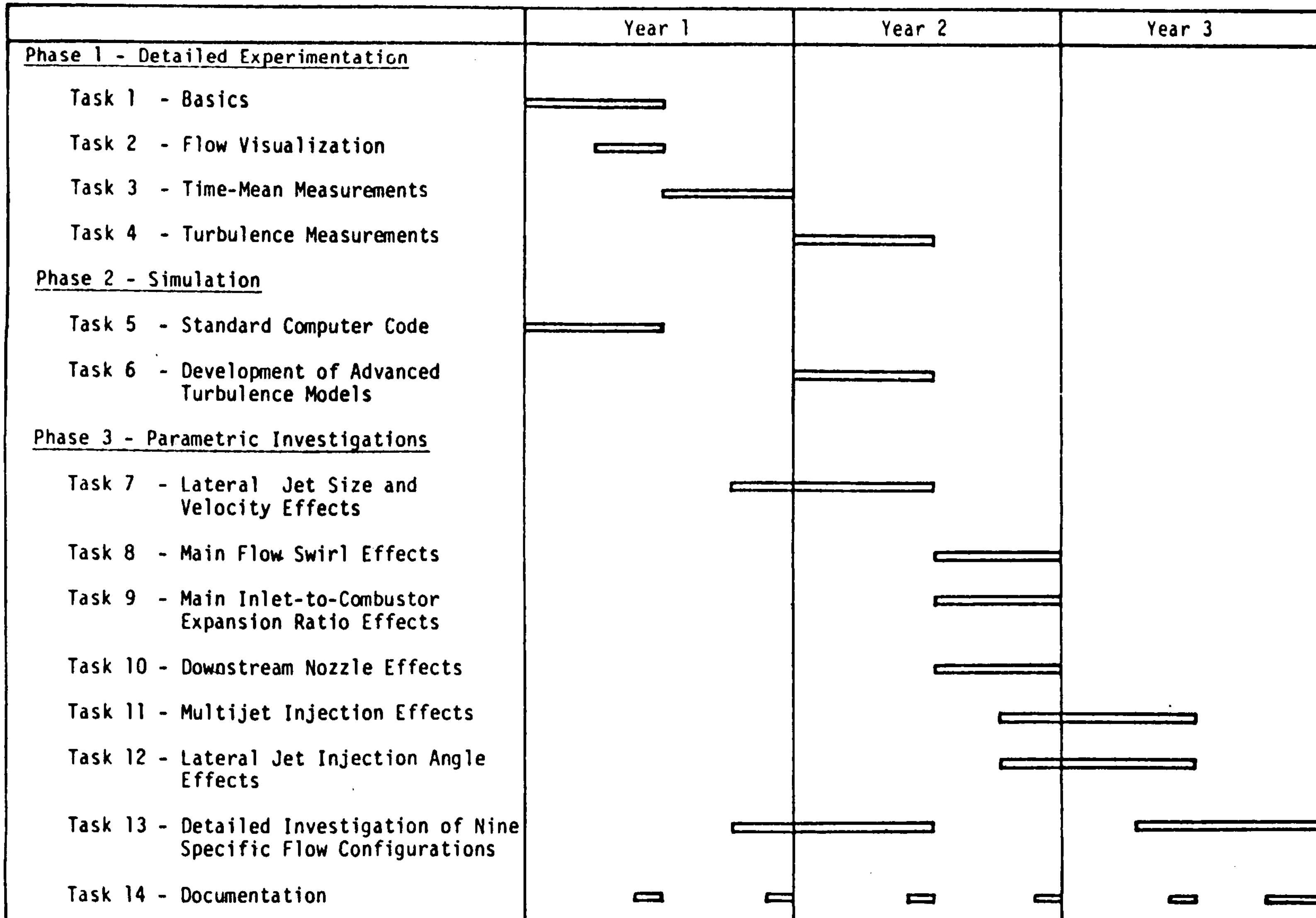
3.2 Lateral Jet Assembly



3.3 Approach

1. Experimental and theoretical program
2. 14-task approach
3. Phase 1 - detailed experimentation
4. Phase 2 - simulation
5. Phase 3 - parametric investigations

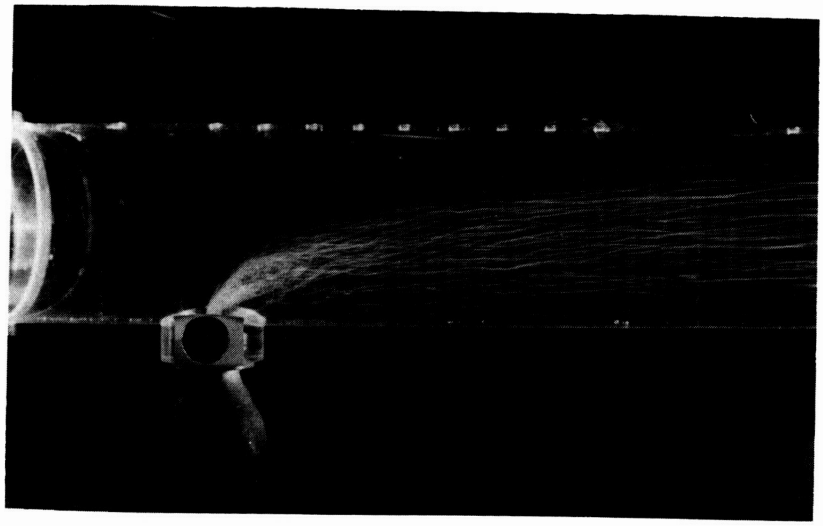
TABLE 1. Program Tasks and Time Schedule



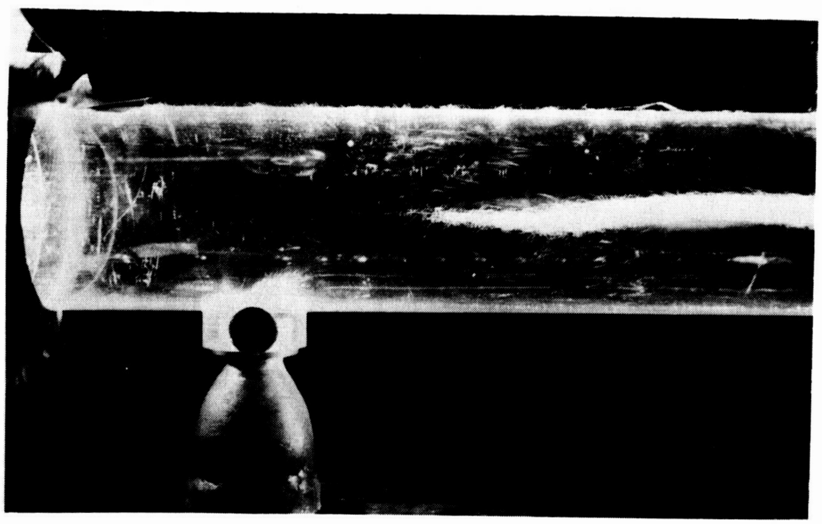
3.4 Flow Visualization

One jet with R = 4

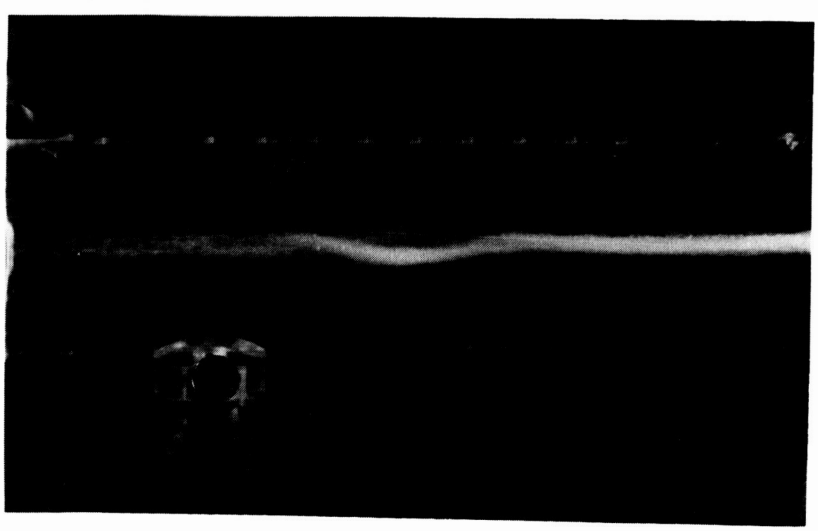
$\phi = 0^o$



$\phi = 45^o$



$\phi = 70^o$



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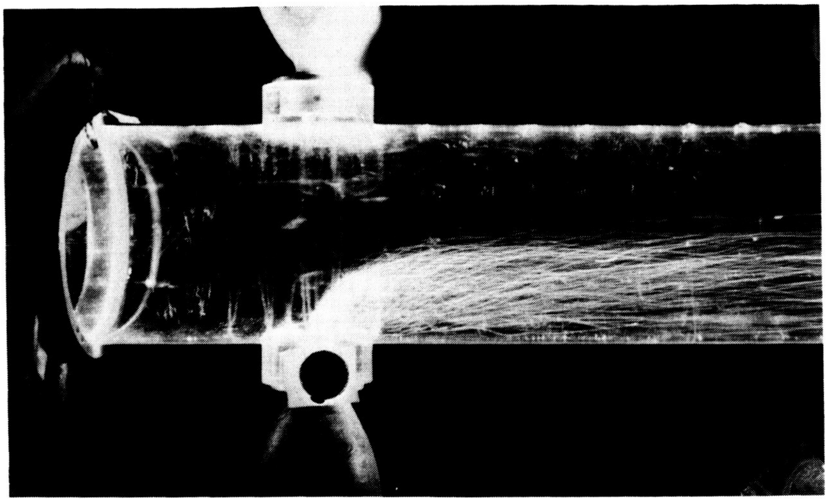
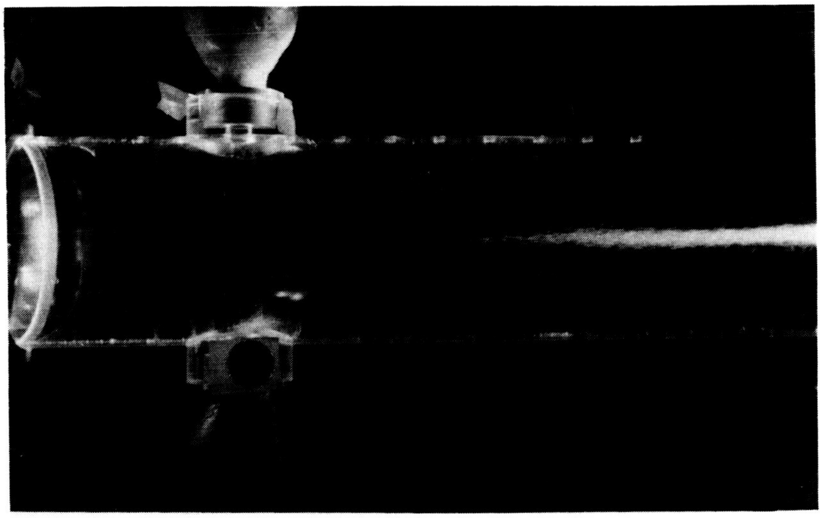
3.5 Flow Visualization

Two jets with R = 4

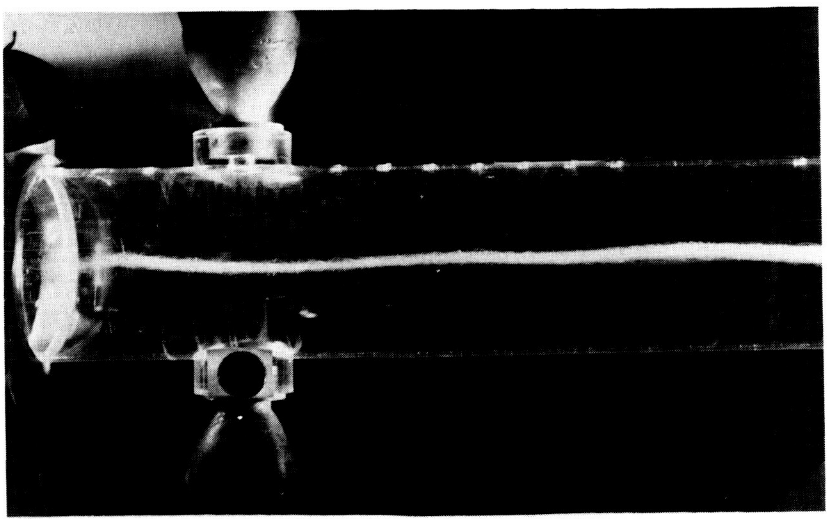
$\phi = 0^o$



$\phi = 45^o$



$\phi = 70^o$



4. Closure

1. Lateral multi-jet injection into typical combustor flowfields - round-sectioned crossflow with swirl.
2. Measurements of effects of many input parameters on flowfield patterns.
3. Computer prediction and turbulence modeling of associated phenomena.