AD-A183 952 HIGH-SPEED REACTING FLOWS: RESEARCH TO UNDERSTAND PROCESSES IN SUPERSONIC..(U) ILLINOIS UNIV AT URBANA DEPT OF MECHANICAL AND INDUSTRIAL ENG.. H KRIER ET AL. 31 MAY 87 N00014-86-K-0434

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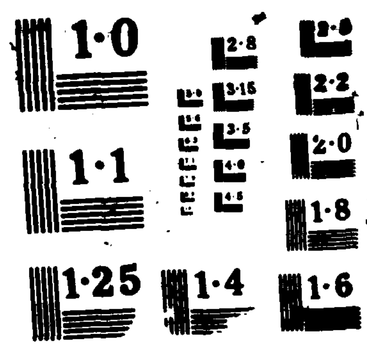
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ANNUAL LETTER REPORT

I. Contract Information

Title: High-Speed Reacting Flows: Research to Understand Processes in Supersonic Combustors

ONR Contract Number: N00014-86-K-0434

Principal Investigators: Dr. H. Krier, Professor
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University of Illinois at Urbana-Champaign

ONR Scientific Officer: Dr. R.S. Miller

Period Covered: 1 June 1986 - 31 May 1987

II. Research Activities

Objective of Research:

The objective of this program is to determine the fundamental fluid dynamic mechanisms occurring in the mixing and entrainment processes in the free shear layer formed between two high-speed (supersonic/sonic) streams. How the fluid mixing and subsequent combustion depends upon compressibility, as well as other parameters of the free shear layer process, is currently being investigated in an experimental study of the two-dimensional, compressible, turbulent reactive free shear layer. Utilization of non-intrusive, laser-based diagnostics including laser Schlieren for flow visualization, Laser Doppler Velocimetry (LDV) for velocity and turbulence measurement, and Planar Laser-Induced Fluorescence (PLIF) for temperature and concentration measurements are being employed. This brief letter report covers the contract activities conducted during the first year of this program.

Turbulent free shear layers are very important to many fluid mechanics systems, particularly in the areas of propulsion, combustion, and aerodynamics. Currently, major emphasis has been placed upon the study of compressible, turbulent reactive free shear layers. This has been due to the renewed interest in hypersonic, air-breathing propulsion in the form of the Trans-Atmospheric Vehicle (TAV), or Orient Express. Under consideration for such an advanced air-breathing propulsion system is the Supersonic Combustion RAMJET, or SCRAMJET, which is conceptually identical to the conventional subsonic ramjet, the difference being that the scramjet is designed to fly at higher Mach numbers and with supersonic flow throughout the combustion chamber [1]. With supersonic velocities inside the engine, though, the fluid mechanics of the fuel/air mixing becomes compressible in nature. Just how the mixing process depends upon compressibility, as well as other parameters of the free shear layer, is currently under investigation in this experimental study of the two-dimensional, compressible, turbulent reactive free shear layer at the University of Illinois [2]. The research is centered on the mixing between a hot, fuel-rich secondary (sonic or slightly supersonic) stream and a cooler primary (supersonic) stream of air for use as an additional oxidizer. The efficiency of the mixing process will greatly affect the overall combustion efficiency of such a propulsive system. The more readily the fuel and oxidizer can be mixed and burned, the shorter the combustor length and the lower the corresponding weight of the engine. Information of this nature will be crucial to engine designers.

Significant Results in the Last Year:

The first year of this research has concentrated on the design of the test facility [2]. It has been necessary to incorporate flexible designs for the test section and new diagnostic equipment so that they mesh with, as well as complement, existing facilities and equipment. Laboratory space with access to an existing air delivery and heating system, consisting of two air compressors, a heat exchanger, and an air storage tank farm, was remodeled. Figure 1 provides a schematic of the experimental air storage, heating and delivery facility that provides the listed input requirements for the twin streams within the test flow facility. Delivery of conditioned air also includes the control valves necessary to properly adjust and maintain input test conditions. The nearly completed test section is comprised of settling chambers with flow control devices, nozzle blocks, a splitter plate, windows for optical diagnostics, and other details [2].

Plans for the Remainder of the Work:

On a near term basis, the focus of the proposed research will be on the non-reactive fluid mechanics of a compressible turbulent free shear layer. The effects on the mixing of two air streams of different temperatures (densities), velocities, free stream Mach numbers (convective Mach numbers and compressibility effects [3,4]), turbulent length scales, and coherent structures will be investigated in the coming year. To simplify the flowfield geometry, initial studies will deal with mixing between essentially parallel streams (small relative flow angles) separated by a thin edge splitter plate. Laser Doppler Velocimetry (LDV) techniques currently being performed in our laboratories [5] will be employed along with flow visualization techniques such as Schlieren photography and laser sheet illuminated scattering. The existing air delivery, storage, and heating facility permits investigation of a wide range of density and velocity ratios, as well as, convective Mach numbers.

Long term goals include the interaction of the fluid mechanics with combustion. The effect of heat release on the shear layer mixing and entrainment processes will be investigated with a relatively new diagnostic technique referred to as Planar Laser Induced Fluorescence (PLIF). With such a technique, the two dimensional temperature and concentration fields within the mixing layer can be non-intrusively probed. To facilitate the acquisiton of such data, an intensified, photo-diode array camera-based Scientific Imaging System (SIS) was acquired from Microtex, Inc., of Cambridge, MA. Figure 2 demonstrates the setup of the proposed PLIF experimental technique. A tunable dye laser, pumped by a excimer laser source, is tuned to a desired wavelength and beam conditioned to form a planar sheet that passes through the shear layer within the test section. Low light level digitized signals can be processed to provide nearly real-time data analysis. Gating the intensified array detector permits collection of fluorescent emission and subsequent temperature and species data as well as scattered light flow visualization data.

References:

1. Waltrup, P.J., "Hypersonic Airbreathing Propulsion: Evolution and Opportunities," AGARD Conference on Aerodynamics of Hypersonic Lifting Vehicles, Paper No. 12, April 1987.

2. Messersmith, N.L., Renie, J.P., Dutton, J.C., and Krier, H., "Design of a Supersonic Turbulent Reactive Free Shear Layer Flow Facility with Access for Laser Diagnostics," Technical Report No. UILU-ENG-87-4003, Department of Mechanical and Industrial Engineering, University of Illinois at Urbana-Champaign, June 1987.

3. Bogdanoff, D.W., "Compressibility Effects in Turbulent Shear Layers," AIAA Journal, Vol. 21, No. 6, pp. 926-927, 1983.

4. Papamoschou, D. and A. Roshko, "Observations of Supersonic Free Shear Layers," AIAA Paper 86-0162, 1986.

5. Samimy, M. and A.L. Addy, "Interaction Between Two Compressible, Turbulent Free Shear Layers," AIAA Journal, Vol. 24, No. 12, pp. 1918-1923, 1986.

EXPERIMENTAL METHODOLOGY

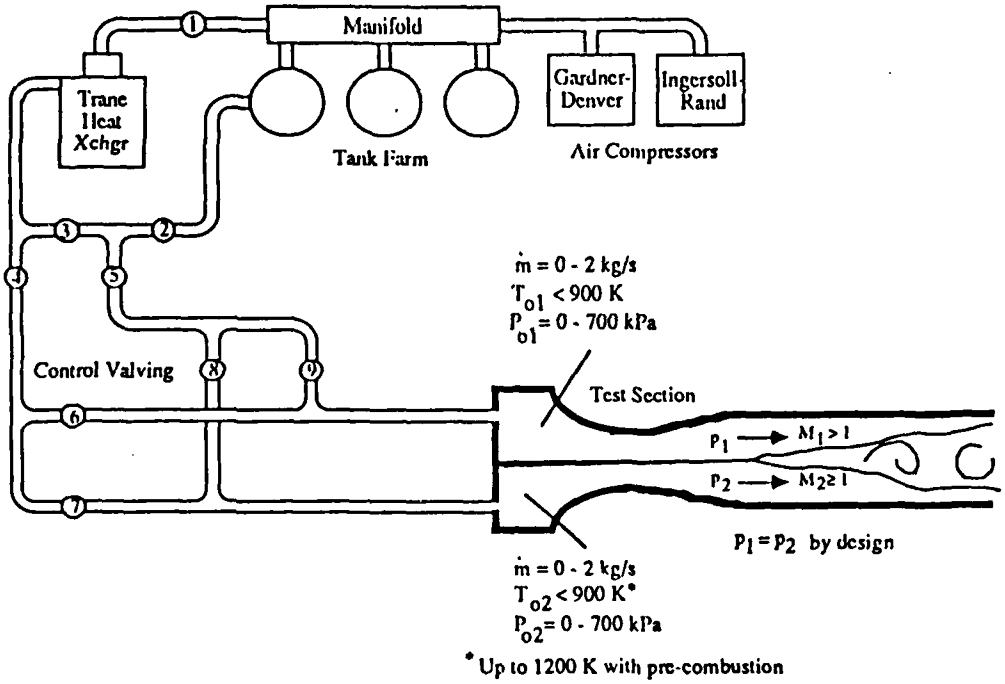

Figure 1. General Schematic of Air Delivery System Components

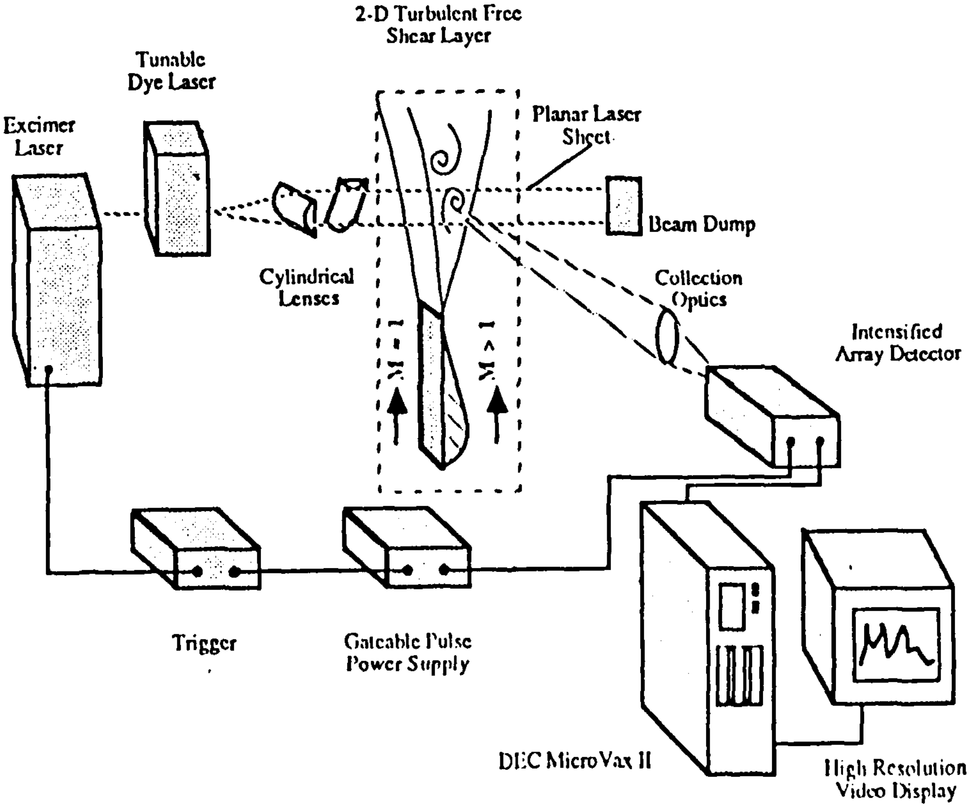

Figure 2. Schematic of Planar Laser-Induced Fluorescence (PLIF) Experiment

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