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Date: August 2, 1989

Investigation of Advanced Mixer-Ejector Exhaust System
Progress Report No. 3
Technical Narrative

AD-A211 943

15 April 1989 through 15 July 1989
Contract N00014-88-C-0654

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I. Introduction

A combined experimental and analytical investigation is being conducted to study advanced mixer-ejector exhaust systems. The program is designed to provide benchmark experimental data relative to several advanced mixer-ejector exhaust system configurations; in addition, analytical flowfield development and plume assessment calculations will be performed. Exhaust mixing, ejector pumping, and the mixer-ejector exit plane three-dimensional velocity field will be investigated. A slot nozzle ejector configuration will be investigated under the contractor's internal research program in gas dynamics, in order to provide a baseline with which to compare mixer-ejector results. The **UTRC JETPATH** code shall be used to calculate flowfield development downstream of the mixer-ejector for the purpose of generating aerodynamic input for plume assessment calculations. Plume assessment calculations will be performed using the **UTRC IPAT** code. In addition, an experimental compressibility assessment of convoluted exhaust nozzle mixing effectiveness will be performed. This involves low speed testing of an advanced mixer nozzle which was tested previously at a supersonic operating condition under Navy Contract N00014-85-C-0506. The compressibility assessment will assist a parallel contract effort at the Massachusetts Institute of Technology to develop improved prediction procedures for vortical flowfield development downstream of convoluted trailing edge configurations.

Exhaust mixing will be characterized for the various studies by mapping of total temperature, total pressure, and static pressure distributions at the mixer-ejector exit plane, and at several planes downstream. Plume centerline total temperature, total pressure, and static pressure measurements will also be obtained. Ejector pumping will be documented by measuring the nozzle flow and calculating the secondary flow based on measured static pressure distributions in the secondary duct. Upstream nozzle weight flow will be measured using a standard venturi meter. The ejector exit plane three-dimensional velocity field will be measured using Laser Doppler Velocimetry (LDV) techniques which were developed in Navy Contract N00014-85-C-0506. The program consists of the following tasks: (I) Mixer-Ejector Parametric Experiments, (II) Benchmark Data Set, (III) Ejector Exhaust Code Calculations, (IV) Plume Assessment Calculations, and (V) Compressibility Assessment.

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II. Technical Progress Summary

During the current reporting period the Task I (mixer ejector parametrics) and Task V (compressibility assessment) experiments were completed. In addition, the total temperature/total pressure data portion of the Task II experiment was completed as well. The Laser Velocimetry (LV) measurements required in Task II represent the only experimental task remaining.

In addition to performing the above described items in the contract statement of work, a UTRC funded experiment was carried out to study conventional supersonic nozzle ejector pumping and mixing characteristics. A converging-diverging supersonic slot nozzle (aspect ratio=3.7) was tested in the present ejector shroud at several forward flight Mach numbers, ejector area ratios, and nozzle pressure ratios. Detailed total temperature, total pressure, and static pressure surveys were performed at the shroud exit as well as at several downstream crossplanes to quantify the mixing process. Plume centerline axial decay total temperature/total pressure/static pressure data was also obtained.

The conventional nozzle ejector data forms a baseline with which to compare mixer ejector results. The unshrouded mixing characteristics of the advanced mixer and slot nozzles were documented previously under contract N00014-85-C-0506, and showed the advanced mixer nozzle to provide significantly enhanced mixing relative to the slot nozzle. As expected, preliminary evaluation of the ejector exit flowfields also shows significant mixing improvements for the mixer ejector relative to the conventional ejector.

Figures 1 and 2 show detailed exit plane total temperature distributions for the two ejectors at $A_e/A_n=4.0$, $X/L=0.17$ (see previous progress report R89-957928-2, Fig. 1, for geometry definition). The operating condition is defined by $M_0=0.5$, $NPR=3.4$, and $T_{TP}=1000^\circ\text{F}$. Figure 1 shows total temperature data for the conventional ejector which has been obtained in a detailed survey over a single quadrant of the ejector exit plane then projected symmetrically to fill the other quadrants and build the complete picture. As seen in this figure, a large high temperature region exists in the center of the shroud. Two-dimensional shear layer spreading provides a mixing region, and there is a large area of cold secondary flow that has not been mixed. The center hot region possesses maximum temperatures near 1000°F , with a spatially large region where the temperature is between 900°F and 1000°F .

Figure 2 shows a significantly different mixing result for the mixer ejector. Again, total temperature was measured in a detailed survey over one quadrant and then symmetrically projected onto the other quadrants. Here, the bulk of the exit plane flowfield is well-mixed, with total temperatures below 500°F over a large region. The maximum total temperature is approximately 750°F , and is present over only a small portion of the flowfield. The mixer ejector is clearly superior to the slot nozzle ejector in mixing the primary and secondary streams.



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III. Work Planned

During the next reporting period, data reduction will continue for the Task I, II, and V experiments. Set-up of the Task II LV experiment will be initiated toward the end of the reporting period, coincident with an opening in the Acoustic Tunnel schedule which has been set aside for performing these measurements.

IV. Financial Summary

Total expenditures for the study reached 44 percent of the contract value during this report period.

Very truly yours,



T. G. Tillman

Nomenclature

- A_s = Ejector secondary area, in².
 A_p = Ejector primary area (nozzle exit area), in².
 L = Length of ejector shroud, in.
 M_o = Wind tunnel freestream Mach number
 NPR = Nozzle pressure ratio (P_{TP}/P_{So})
 P_T = Flowfield total pressure, psia
 P_S = Flowfield static pressure, psia
 P_{TP} = Nozzle supply pressure, psia
 T_T = Flowfield total temperature, Deg. F
 T_{TP} = Nozzle supply total temperature, Deg. F
 W_s = Ejector secondary weightflow
 W_p = Ejector primary weightflow
 X_p = Axial penetration of nozzle exit plane into ejector shroud, in.

CONVENTIONAL SLOT NOZZLE EJECTOR SHROUD EXIT PLANE TOTAL TEMPERATURE DISTRIBUTION

$$A_s/A_p = 4.0$$

$$X_p/L = 0.18$$

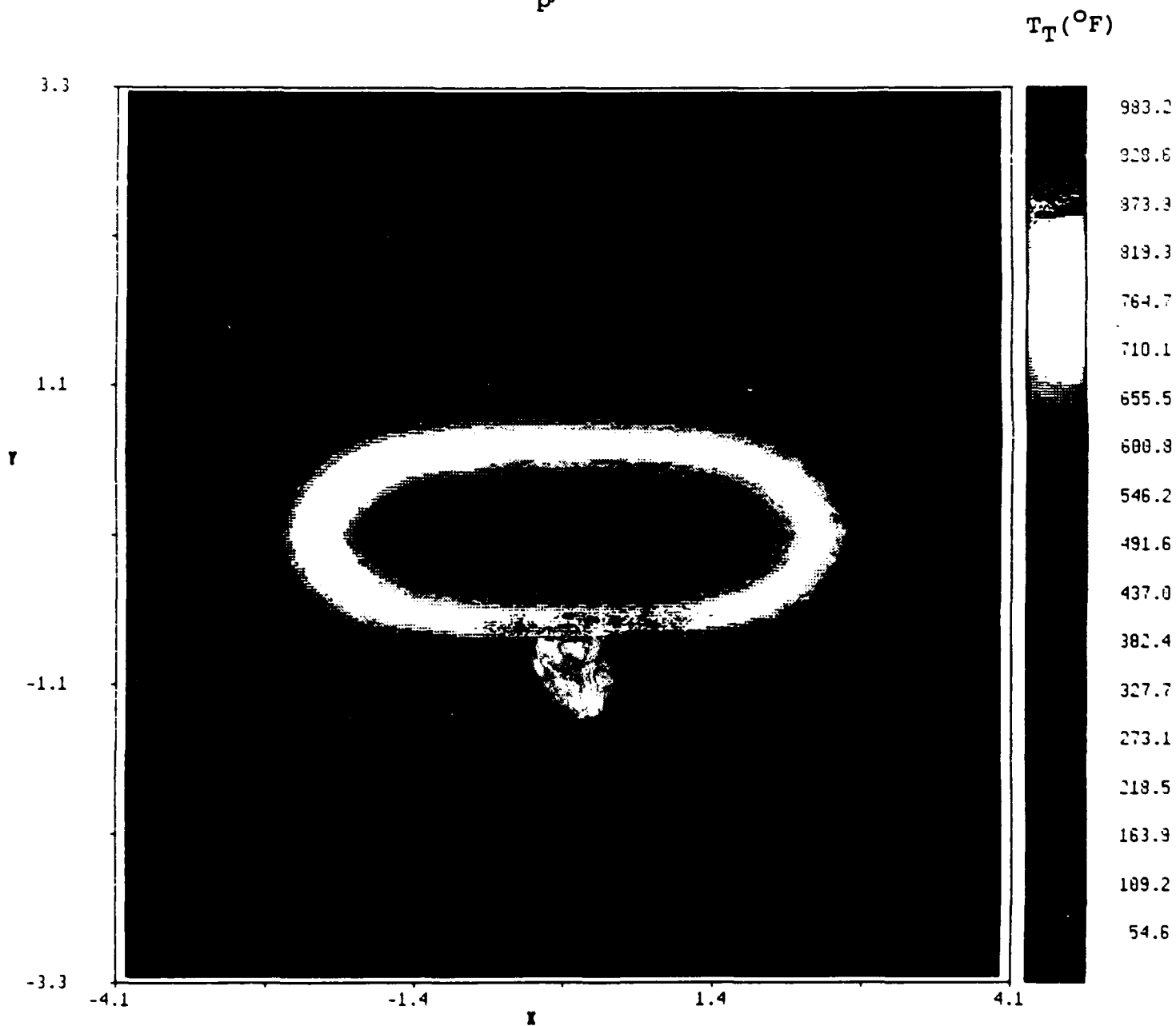


Figure 1

MIXER EJECTOR SHROUD EXIT PLANE TOTAL TEMPERATURE DISTRIBUTION

$$A_s/A_p = 4.0$$

$$x_p/L = 0.17$$

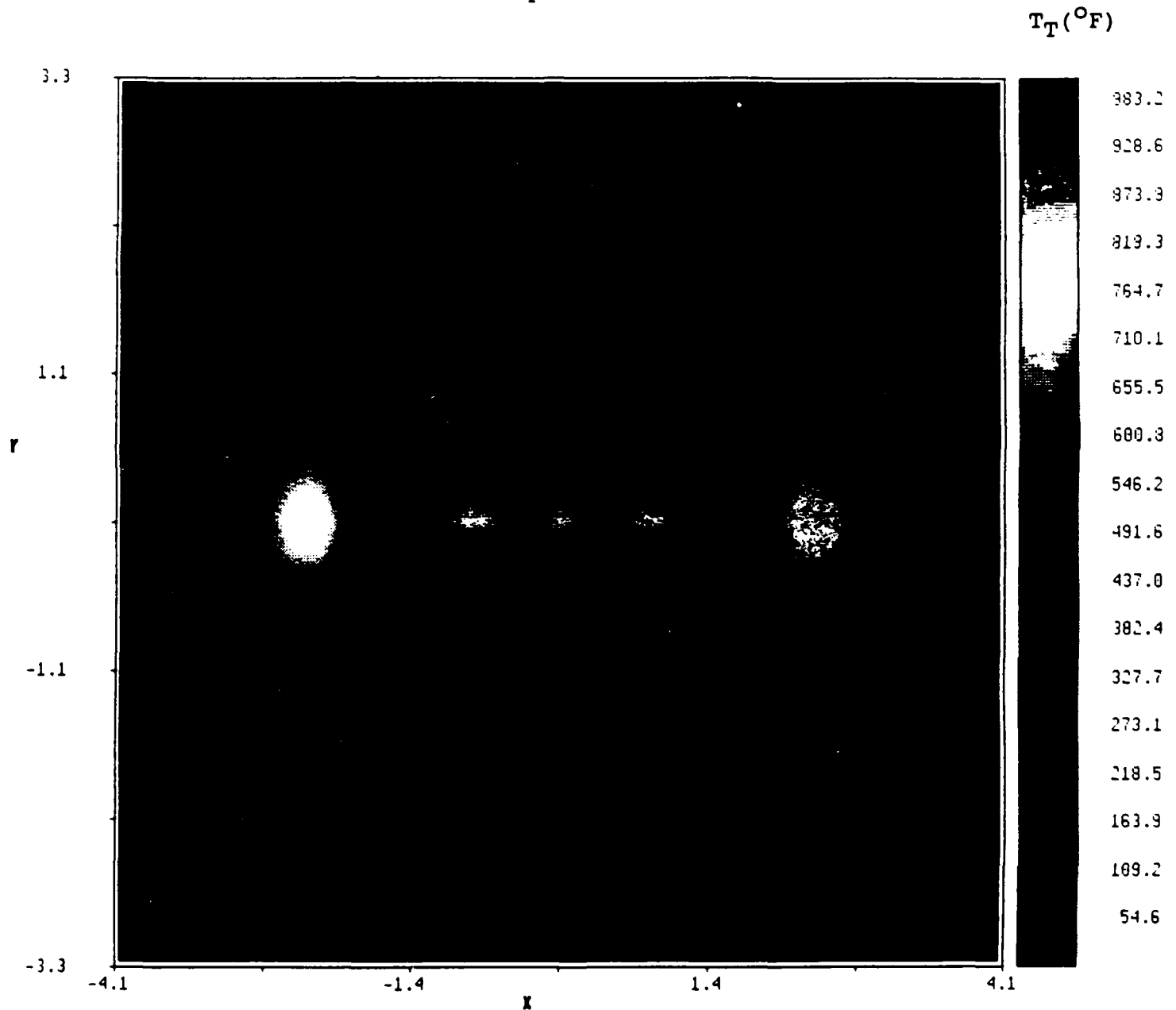


Figure 2

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