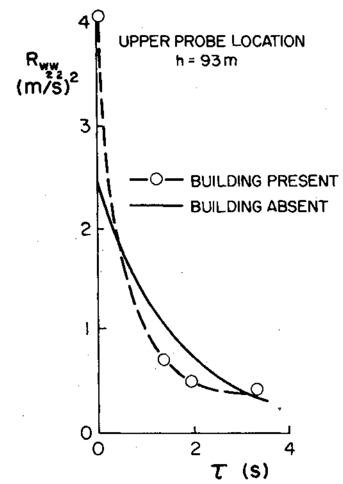

Fig. 2 Turbulence correlation $R_{W_2W_2}$.

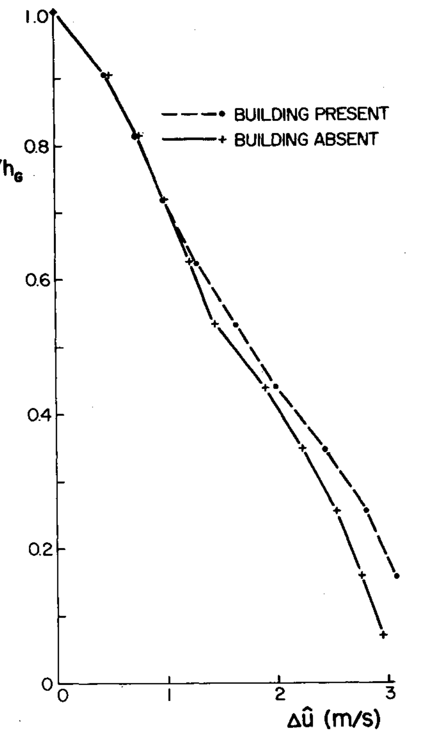

Fig. 3 Root-mean-square response to turbulence $\Delta\hat{u}$.

Computation of a STOL Aircraft's Response to Turbulence During the Landing Approach

The aircraft employed in this analysis was a twin-engine, turboprop light STOL transport (4994 kg) whose properties are described in Ref. 5. The reference equilibrium flight condition was a constant airspeed landing approach in the presence of a constant headwind. A fixed-controls case was employed in order to demonstrate the turbulence effects through aircraft state vector dispersions. (If an autopilot or human pilot model were used to close the control loop, then the effects of turbulence would best be studied by observing the control activity.)

The dispersions in the longitudinal state vector $\Delta x(t)$ at various locations along the glideslope were computed by implementing Eq. (3) on a digital computer. Typical results are plotted in Fig. 3, which presents the airspeed dispersion. The presence of the building resulted in a general increase in the predicted dispersions of the state vector with the extent of the increase becoming greater towards the bottom of the glideslope as the aircraft gets closer to the building. Thus, of the two effects that the building had on the shape of $R_{W_1W_1}(\tau)$ and $R_{W_2W_2}(\tau)$, it is seen that the increased values at $\tau=0$ dominate over the more rapid falloff with $|\tau|$. Based on the observed results, it appears that the presence of the upwind building has had only a minor impact on the turbulence-induced disturbance to the landing approach of the STOL transport.

Acknowledgments

This research has been supported by Environment Canada and the Natural Sciences and Engineering Research Council of Canada. The author would also like to acknowledge the assistance provided by P.S. Spedaler and W.O. Graf in gathering and processing the experimental data.

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AIAA 81-1712R

Turbulence Measurements in an Ejector Wing Flowfield

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Introduction

CONSIDER the principle of an ejector.[1] In the simplest case, coaxial jets are confined to a duct rather than to a

Presented as Paper 81-1712 at AIAA Aircraft Systems and Technology Conference, Dayton, Ohio, Aug. 11-13, 1981; submitted Dec. 14, 1981; revision received March 1, 1982.

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constant pressure atmosphere. For this flowfield, the mass flow rate averaged mean axial momentum is not conserved and the static pressure may vary with downstream location. There will be an increase of pressure with increasing downstream position as the jet cores are being consumed by rapid shear layer mixing. In fact, the pressure may also continue to rise in the developing flow zone downstream of the disappearance of the cores. This pressure rise can be considered the source of the pumping effect of the ejector.

Significant and fundamental developments in thrust augmenting ejectors have been accomplished in the last several years. Hypermixing nozzles have been developed with a resultant increase in ejector compactness realized.[2] Mixing and diffusion of flows have been achieved simultaneously with performance advantage. Thrust augmentation ratios on the order of 2 in an ejector of inlet area ratio 23 have been achieved experimentally.[3] A theoretical methodology which can evaluate the performance of the ejectors subject to a wide range of variation in the thermodynamic parameters of the injected and the entrained fluids has been developed for incompressible and compressible flows for a constant area duct.[4] High lift characteristics of an ejector-flapped wing have been evaluated.[5] A numerical prediction of three-dimensional ejector flows has been proposed.[6]

Although the literature on ejectors in general and, particularly, on thrust augmenting ejectors, is quite extensive, the turbulence field has been essentially ignored. The information that is available is predominantly concerned with flows in constant area pipes, with Razinsky and Brighton[7] presenting an extensive set of one point statistical measurements for varying mean velocity ratios and jet/pipe diameter ratios.

The purpose of this investigation is to conduct an extensive survey of the resultant velocity flowfield of a given ejector wing design. The effectiveness of the ejector will be assessed by comparing the flowfield with the ejector powered and with the ejector unpowered. The data in this experiment are obtained by use of a laser velocimeter in conjunction with a photon correlation processing technique.

Experimental Equipment and Technique

The facility used for this investigation is a two-dimensional smoke tunnel which employs an open return system of flow, capable of subsonic incompressible velocities up to 23 m/s. All measurements are taken at a nominal freestream velocity of 8 m/s with a freestream turbulence intensity equal to 0.05 ±0.02.

The specific flowfield investigated is an ejector wing design conceived by Vought under contract with the Flight Dynamics Laboratory at Wright Patterson AFB (Fig. 1).[8] A two-dimensional model is constructed and placed in the test section of the wind tunnel. The ejector plenum is supplied from the laboratory compressed air reservoir. Considerable effort was expended in attempting to achieve a uniform exit velocity profile with relatively low values of the turbulent intensities. The aspect ratio of the rectangular nozzle is 4.1:1 and the solidity ratio is 0.327:1. The mean velocity at the nozzle exit plane, U_0, is kept at a constant 16 m/s.

The velocity measurements are obtained from a photon correlation based laser velocimeter. The photon correlator possesses a resolution time of from 50 ns to 1 s. Measurements were taken in the single clipped autocorrelation mode and at an infinite sample rate.

Special note should be made of the turbulent intensities measurement technique. Care is taken to minimize the problems of background flare light and photon pileup. The effects of these two phenomena can result in a skewness or a distortion of the photon correlation function from which the mean velocity and local turbulent intensity are calculated. Therefore a numerical technique[9] is employed which results in the alleviation of the skewness problem.

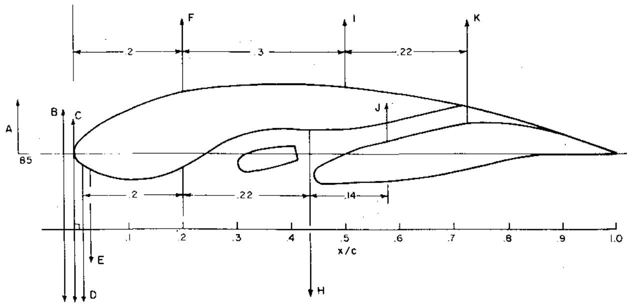

Fig. 1 Two-dimensional ejector wing model with measurement locations.

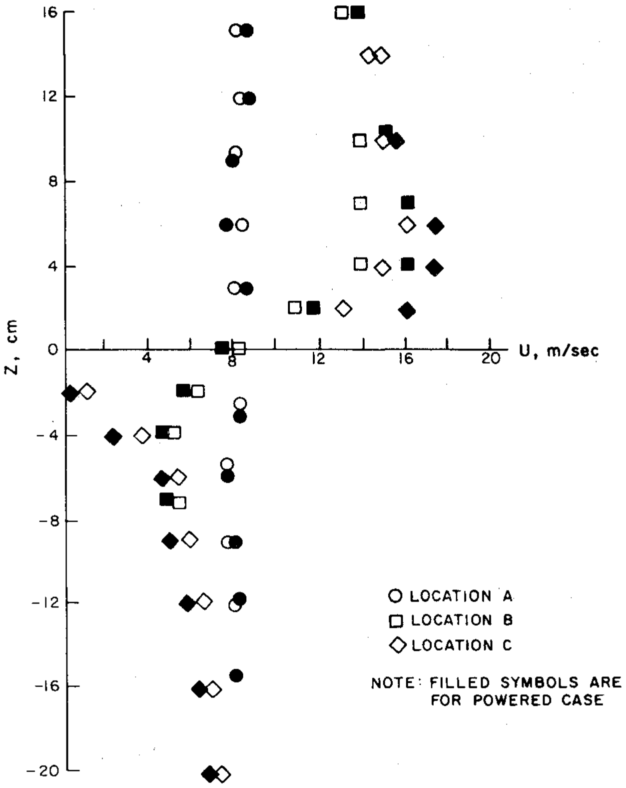

Fig. 2 Mean velocity profiles near the leading edge.

Experimental Results and Discussion

In Fig. 1, the location of the mean velocity and turbulent intensity data obtained are shown. Note that in all cases, x is measured longitudinally from the leading edge and z is measured vertically from the airfoil surfaces.

Turbulent intensity is defined here as the ratio between the root mean square of the velocity fluctuations, u_{rms}, nondimensionalized by the local mean velocity, U.

Figure 2 shows mean velocity profiles upstream of the ejector wing. The effect of the ejector in the mean velocity profiles is to accelerate the mean flow above the upper surface and to decelerate the mean flow beneath the ejector wing. This effect is quite pronounced immediately upstream of the leading edge.

Mean velocity and turbulent intensity profiles are shown in Fig. 3 for the downstream location $x/c = 0.2$. The mean flow is consistently faster in the ejector powered case. The value of the turbulent intensities reduce to the freestream value closer to the wing surface with the ejector working. This would indicate a shift of the potential flow down toward the upper surface.

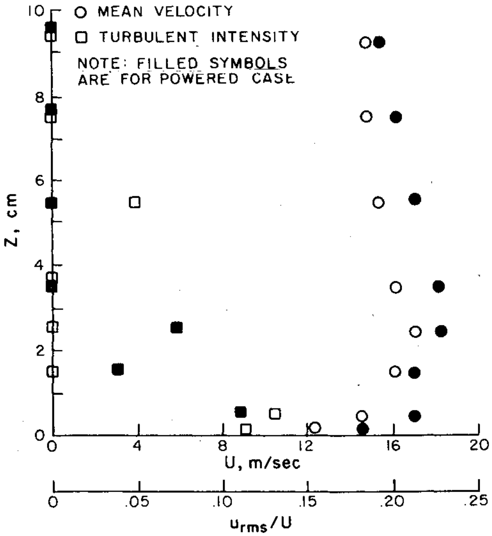

Fig. 3 Mean velocity and turbulent intensity profiles above upper airfoil section at $x/c=0.2$.

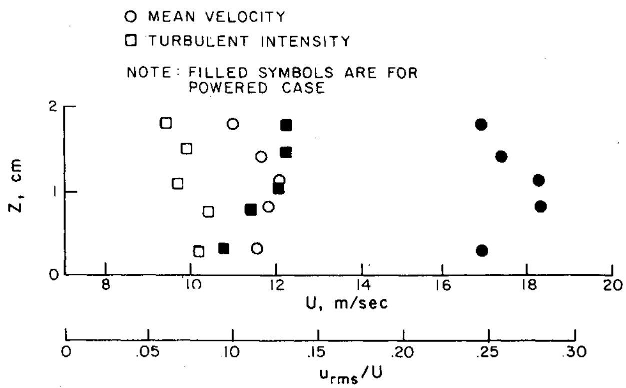

Fig. 4 Mean velocity and turbulent intensity profiles at $x/c=0.58$.

The mean and turbulent velocity fields downstream of the ejector nozzle are examined in Fig. 4 for $x/c=0.58$. A comparison of Figs. 3 and 4 results in the observation that for the ejector powered case, the flow accelerates after it enters the constant area mixing duct and the turbulent intensities are increased. The measured value of u_{rms}/u equal to 0.30 is characteristic for jet mixing rather than duct-type flow.

Summary

An experimental investigation of the resultant turbulent flowfield about an ejector wing design incorporating a constant area mixing duct is made. Mean velocities and turbulent intensities are calculated from the photon correlation functions. Comparison between the ejector powered and nonpowered cases are made. The following results are obtained.

1) The ejector consistently accelerated the flowfield above the wings' upper surface. The influence is felt upstream of the model's leading edge.

2) The stagnation point moved further downstream along the lower surface for the ejector powered case, indicating an apparent increase in the effective angle of attack.

3) The turbulent intensities in the confining duct are of free or coaxial jet magnitude.

4) The streamlines above the wing's upper surface are compressed downwards toward the airfoil, indicating a reduction of the wake region.

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