NASA Technical Memorandum 102387
AIAA-90-0048

Some Observations on Transitory Stall in Conical Diffusers

K.B.M.Q. Zaman and M.D. Dahl
Lewis Research Center
Cleveland, Ohio

Prepared for the
28th Aerospace Sciences Meeting
sponsored by the American Institute of Aeronautics and Astronautics
Reno, Nevada, January 8-11, 1990

NASA

(NASA-TM-102387) SOME OBSERVATIONS ON TRANSITORY STALL IN CONICAL DIFFUSERS (NASA) 13 p CSCL 01A

N90-12561

Unclas
G3/02 0243263

SOME OBSERVATIONS ON TRANSITORY STALL IN CONICAL DIFFUSERS

K.B.M.Q. Zaman and M.D. Dahl
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, OH 44135

Abstract

Results from an experimental investigation on the flow through conical diffusers are presented. The mean and fluctuating velocity fields are compared for three diffusers with total diffusion angles of 16°, 20° and 24°, in the throat Mach number (M_t) range of 0.05 to 0.95. Each of the diffusers were 14 cm long and had a 5.08 cm inlet diameter, and the flow exited into the ambient. The boundary layer at the throat was thin with the throat diameter (D_t) to momentum thickness (Θ) ratio being as high as 800 at $M_t = 0.4$. While the 16° diffuser flow exited with a top-hat mean velocity profile, increasing losses due to increasing separation resulted in fuller profiles for the 20° and 24° cases. A detailed flowfield study was conducted for the 16° diffuser. The u'-spectrum, measured at the exit plane, exhibited a peak apparently due to the ensuing jet column instability throughout the M_t range covered. In addition, a much lower frequency spectral peak also occurred in the M_t range of 0.3 to 0.7. Both of the spectral peaks were due to axisymmetric flow fluctuations. A self-sustaining flow oscillation occurred in the M_t range of 0.6 to 0.85, emitting a loud tone, when the jet column instability frequency matched the resonance frequency of the diffuser. Limited data showed that artificial acoustic excitation was effective in reducing the flow fluctuations, with a resultant increase in the pressure recovery, at low M_t.

1. Introduction

A diffuser is an important element in internal fluid machinery. There can be numerous situations where the designer may have to demand optimum pressure recovery within shortest possible lengths. This means operating near the brink of stall yet avoiding actual stall. This can be difficult and risky as the flow involving incipient stall is not easily predictable. Such a flow is sensitive to operating conditions, e.g., to the mean velocity distribution, the turbulence intensity and spectrum, and the boundary layer state at the throat.[1-3] Moreover, such operating conditions may induce transitory stall which involves large unsteady fluctuations resulting in excessive loss and noise as well as large unsteady forces.

Transitory stall has been investigated primarily in two-dimensional diffusers,[4,5] and it is fair to say that the mechanisms of this class of flow in any flow geometry remain very little understood. For lack of a clearer definition, we will consider any intermediate state between fully attached and fully stalled states to involve transitory stall. The present experimental program was initiated to study transitory stall in conical diffusers as well as its response to artificial acoustic excitation. The program is part of an overall effort in flow control by artificial excitation at the NASA Lewis Research Center,[6] and was easily implemented in view of the availability of a sophisticated jet flow facility with provision for acoustic excitation. Several diffuser sections were built to fit a specially built nozzle piece. These provided flows with varying degrees of transitory stall. Limited experiments have been conducted so far, and this paper should be considered as a progress report of this program.

2. Experimental Facility

Figure 1(a) is a photograph of the experimental facility which has been described in detail in Ref. 7. The flow, after passing through a large plenum, exited through a contoured nozzle. Each of the straight conical diffusers was attached to a flange at the end of the nozzle. A schematic of the essential parts of the flow facility is shown in Fig. 1(b). Three diffusers with total diffusion angles (ψ) of 16°, 20° and 24° were used in the experiment. The nozzle end and the entrance to the diffusers were machined to provide a smooth junction. A cylindrical section, extending approximately 1.27 cm on either side of the junction, will be referred to as the "throat". The cylindrical section was smoothly faired into the beginning of the diffuser section. The diffuser section was 14 cm long; the exit diameters were 9.02, 10 and 11.02 cm for the 16°, 20° and 24° cases, respectively. Also shown in Fig. 1(b) are the acoustic drivers used for excitation purposes. A tap at the throat was used to measure the corresponding static pressure (P_{st}). Standard hot-wire and pitot-static measurements were made. Probe traverses and data acquisition were done by automated computer control.

3. Results and Discussion

3.1 Comparison of the Three Diffusers

Figure 2 shows the variations of the total gauge pressure (P_{tt}) and the static gauge pressure (P_{st}), measured at the throat, as a function of M_t. Note that P_{st} would be zero in the limiting case of a nozzle discharging as a jet and P_{tt} would be zero in the ideal case of a diffuser with infinite expansion and full pressure recovery. For the case of finite expansion but full pressure recovery, P_{tt} should equal the dynamic pressure at the exit of the diffuser. The observed trends of P_{st} and P_{tt} (Fig. 2) with increasing diffusion angle are due primarily to increasing losses within the diffusers owing to increasingly separated flows. The variations of the corresponding pressure recovery coefficient C_p, approximated as $C_p = -P_{st}/(P_{tt} - P_{st})$,[2] are shown at the bottom of Fig. 2. The values of C_p agree reasonably with data reported in the literature for corresponding diffuser geometries with thin inlet boundary layers.[1]

The mean velocity (U) profiles measured 3.5 mm downstream of the exit plane of the diffusers are shown in the upper part of Fig. 3. The mass fluxes computed from these profiles, normalized by the mass flux at the throat, are 1.03, 1.14 and 1.56 for the 16°, 20° and 24° diffusers, respectively. The increasing fluxes are qualitatively reconciled by the fact that ambient air is ingested around the periphery by the transitory stall in the larger diffusers. However, the corresponding reverse flows introduced some errors in the hot-wire measurements, and thus, the measured fluxes should not be accurate for the larger diffusers. For the 16° diffuser, however, the mass flux is nearly conserved, indicating insignificant amount of such error in that case. The lower part of Fig. 3 shows the corresponding root mean square velocity fluctuation (u') profiles. Note that the data are normalized by the throat velocity (U_t) and thus the intensities normalized by the local velocities are much larger, e.g., about 0.32 in the core flow of the 24° diffuser.

The streamwise variations of U and u' along the axis are shown in Fig. 4. ($x/D_t = 3$ represents the exit plane). Consider the U-profile for the 16° case which apparently involves negligible flow separation. If the flow expanded ideally, with a top-hat profile having a thin boundary layer, U/U_t would be expected to be about 0.32 at $x/D_t = 3$. However, the measured value there is about 0.5. The difference is due to a large boundary layer growth about which an idea can be obtained from Fig. 3 (further data are discussed later). The 24° case involves the largest fluctuations occurring at the farthest upstream location; the initial rate of decrease of the ceterline mean velocity is the least for this case. Presumably, the flow in this diffuser separates shortly downstream of the throat and thus higher velocity is maintained around the axis. But farther downstream, the large fluctuations result in a faster decay of U. The u'-profiles in Fig. 4 bear some resemblance to corresponding profiles in a free jet,[7] however, the flow evolution in the present cases is governed by the diffuser geometries which determine the imposed pressure gradient and the location of separation.

The spectra of the velocity fluctuations measured at the exit plane for the three diffusers at $M_t = 0.3$ are shown in Fig. 5. The ordinate scale is arbitrary (linear) and the amplitudes for the 16° case are much lower than those in the other two cases (see figure caption). These spectra traces identify the frequency content in the fluctuations. For the 16° case there are two identifiable spectral peaks--one at very low frequency and the other at a higher frequency. These are discussed further in section 3.4. For the 20° case, a large concentration of energy occurs at low frequencies although no clear peak could be identified. Such low frequency energy gets engulfed in fluctuations over a wider band of frequencies in the 24° case. At $M_t = 0.3$, the 20° diffuser flow appeared audibly louder; this loudness arising from the low frequency fluctuations was much lower in the 16° case and appeared "dulled" in the 24° case. The differences in these unsteady fluctuations are currently under further study and will be reported later.

3.2 Boundary Layer at the Throat

The boundary layer momentum thickness at the throat is shown in Fig. 6 as a function of M_t. Note that the thickness remains the same with or without the diffuser. Measurement at $M_t = 0.2$ also show that θ is the same at positive or negative y, indicating good symmetry in the flow. The solid line in Fig. 6 represents the equation $\theta/D_t = 0.8/(Re_D)^{1/2}$, fitted through an average value of the data at $M_t = 0.2$; Re_D is Reynolds number based on D_t. The shape factor H_{12} was between 2.2 and 2.3 for all the data. The maximum turbulence was between 3 and 5 percent of U_t; the turbulence was somewhat higher on the positive y side because of small probe vibrations due to impingement of the flow on the probe stem in that probe configuration. The boundary layer can thus be considered as "nominally laminar" throughout the M_t range covered in Fig. 6. At even higher M_t the boundary layer could be turbulent as the Reynolds number based on θ at $M_t = 0.4$ is already quite high, about 660. Measurements at higher M_t were not attempted because of obvious complications in the hot-wire measurements due to compressibility.

3.3 Flow Field at $M_t = 0.3$ for the 16° Diffuser

Details of the flowfield were measured for the 16° diffuser at $M_t = 0.3$. The variation of the static pressure along the centerline is documented in Fig. 7. The continuous increase of P_s from the throat downstream indicates the lack of significantly separated flows within the diffuser (see also the discussion of Fig. 3). P_s is found to increase rapidly immediately downstream of the throat and then increase gradually farther downstream. This is reconciled by the observed rate of decrease in the core velocity which becomes slower as the exit is approached, as can be seen in Fig. 4. The velocity profiles within the diffuser are shown in Fig. 8(a). Note that the profiles in this and some of the following figures have been staggered for easy comparison; in all cases, the ordinate shown pertains to the curve at the bottom. The profiles are top-hat in shape but the boundary layer thickens rapidly with increasing downstream distance. The momentum thickness (mm) was 0.07, 0.66, 1.37 and 2.37 at $x/D_t = 0$, 0.75, 1.5 and 2.25, respectively; the corresponding shape factor (H_{12}) was 2.25, 1.82, 2.13 and 2.55, respectively.

The evolution of the full velocity profiles downstream of the diffuser exit are shown in Fig. 8(b). The axial variation of the centerline mean velocity and the half-velocity-diameter based on the data of Fig. 8(a) and (b) are shown in Fig. 9. One finds that the jet flow downstream of the diffuser exit is still evolving, as the slopes of these curves are changing, and has not reached a self similar state within the x-range covered.[8] The longitudinal root mean square fluctuation intensity profiles, corresponding to the data of Fig. 8(a) and (b), are shown in Figs. 10(a) and (b).

3.4 Unsteady Flow Characteristics for the 16° Diffuser

While the data in section 3.3 pertain to $M_t = 0.3$, the flow characteristics changed considerably with varying Mach number. An indication of this can be obtained from the data in Fig. 11. The u' intensity was measured at a fixed location at the exit plane while M_t was varied. The probe location was chosen to be off-axis ($y/D_t = -0.25$) so that fluctuations due to possible helical mode oscillations could be captured, but close enough to the axis to be within the top-hat core flow. At low M_t the fluctuation intensity is found to be very large, but diminishes rapidly with increasing M_t to a plateau. The intensity essentially remained constant within the M_t range of 0.2 to 0.6. For $M_t > 0.6$ a large increase in the fluctuation intensity occurred which was accompanied by the generation of a loud, audible tone.

The spectral contents of the u-fluctuations are shown in Fig. 12. At the intermediate M_t range of 0.3 to 0.6, the spectra are characterized by two peaks. The one at the higher frequency seems to be associated with the jet column instability of the ensuing flow. The corresponding Strouhal number based on the throat conditions ($St = fD_t/U_t$) turns out to be about 0.125 throughout the above M_t range. However, when the exit conditions from Fig. 3 are used, i.e., velocity $\approx 0.5\ U_t$ and jet diameter $\approx 1.4\ D_t$, the corresponding Strouhal number turns out to be 0.35, reasonably agreeing with data in the literature on the "preferred" frequency of jet column instability. In comparison, the St corresponding to the lower frequency peak is found to be only about 0.008 throughout the M_t range of 0.3 to 0.6. The occurrence of the lower frequency peak is confirmed by spectral analysis within a shorter 0 to 200 Hz range (data not shown). The origin of these lower frequency fluctuations remains unclear. However, these could be morphologically similar to the phenomenon of low frequency oscillation at incipient separation in the flow over an airfoil studied in Ref. 9.

The u'-spectra at higher values of M_t are shown in the lower part of Fig. 12. The flow in this range is dominated by a tone. The occurrence of the tone was found to be sensitive to ambient and other conditions. For example, placement of the pitot tube stem across the flow near the diffuser exit disrupted the tone and made it much weaker. The amplitude also varied from day to day; in general it was found to occur persistently over the M_t range of 0.6 to 0.85. The value of St corresponding to the dominant peaks in the spectra traces of Fig. 12 are plotted in Fig. 13 as a function of M_t. The low frequency component is shown by the square data points. The higher frequency component, due to the jet column instability, is shown by the circular data points with the solid circles representing the tonal oscillation conditions. It is apparent that the tone is a continuation of the jet column instability.

The fundamental (plane wave) resonant frequency could be estimated for a driven conical horn representing the 16° diffuser. Based on the assumption that the resonant frequencies are those with the largest input impedance, a fundamental frequency of 652 Hz is obtained for no flow condition.[10] This is somewhat higher but close to the frequencies of the tone observed in Fig. 12. Thus, the tone apparently is set up when the "preferred" frequency of the issuing jet falls close to the acoustic resonance frequency of the conical diffuser.

The nature of the flow fluctuations associated with the spectral peaks of Fig. 12 were investigated. Two hot-wires were located at the exit plane, 1.27 cm away from the axis on either side. The cross-spectrum and phase between these two signals were measured at various M_t. Figure 14(a) to (c) show such data for $M_t = 0.11$, 0.47 and 0.7, respectively. The cross-spectrum amplitude (and thus the coherence) is found to be relatively high at the dominant frequencies in all cases. Note that this is true for both the low and high frequencies in Fig. 14(b). Furthermore, the associated phase values are essentially zero at the frequencies corresponding to these peaks. This indicates axisymmetric flow oscillations at all these frequencies. (However, a similar measurement for the 20° diffuser indicated a predominantly non-axisymmetric, flapping motion which is being further investigated.)

The tone at $M_t = 0.7$ (Fig. 14(c)) also involves an axisymmetric flow oscillation. The corresponding variation of the phase along the axis is shown in Fig. 15. The slope of this curve in the x/D_t range of 3.5 to 5.5 yields a wavelength of 2.6 D_t. The corresponding phase velocity turns out to be about 0.32 U_t. Thus, the fluctuations are hydrodynamic and not due to, say, an acoustic standing wave. The "mode shape" associated with this (575 Hz) oscillation, at the exit plane, is documented in Fig. 16. The radial variation of the phase and the fundamental root mean square amplitude (u_f') are shown by the two curves at the top; the corresponding variation of the mean velocity is shown by the curve at the bottom.

3.5 Effect of Acoustic Excitation

Preliminary experiments were done on the effect of acoustic excitation on the unsteady diffuser flow. Excitation at certain high frequencies was found to suppress the fluctuations dramatically, especially at low M_t. The effect of excitation frequency (f_p) on the fluctuations at the exit plane is shown in Fig. 17 for the 16° diffuser. Clearly, the fluctuations are damped in a range of f_p and the band of effective f_p shifts progressively with increasing M_t. At M_t higher than 0.2, very little effect of the excitation could be observed. Referring back to Fig. 11, one finds that the excitation is effective when the unsteady fluctuations are already high. At the low M_t, however, the fluctuations are suppressed significantly. This is also associated with an increase in the pressure recovery coefficient (C_p), by as much as 12 percent. A more pronounced effect of the excitation was observed for the 20° diffuser which persisted up to about $M_t = 0.4$.

4. Concluding Remarks

The flow through conical diffusers involving transitory stall was investigated experimentally. The steady and unsteady flowfields were compared for three diffusers with total diffusion angles of 16°, 20° and 24°. This was followed by a detailed investigation of the flowfield for the 16° diffuser. For this case, the u'-spectrum near the exit was characterized by a peak apparently due to the ensuing jet column instability, at all mach numbers. In the M_t range of 0.6 to 0.85, when the jet column instability matched the fundamental acoustic resonance of the diffuser geometry, a self-sustaining flow oscillation took place, emitting a loud tone. In the range 0.3 to 0.6, a much lower frequency flow fluctuation could also be detected. The unsteady fluctuations at all these frequencies were found to be primarily axisymmetric in nature for the 16° diffuser. For M_t < 0.2, the flow fluctuations near the exit were unusually large in amplitude. In this range of M_t, acoustic excitation was found effective in reducing the fluctuations. This was accompanied by an increase in the pressure recovery coefficient. Reflecting on the overall results various aspects of the unsteady flow appear intriguing and deserve further comment. First, the dramatic increase in the flow fluctuation levels as M_t is decreased below about 0.2 is rather puzzling. It appears that the change in boundary layer characteristics at the throat may be causing the flow to behave differently. However, such a change is not clearly discernible. With decreasing M_t only the boundary layer thickness has increased, although it is still quite thin, e.g., $D_t/\Theta \approx 400$ at M_t = 0.1. The shape factor and turbulence intensity, on the other hand, have not changed significantly. Second, the occurrence of the low frequency spectral peak in the intermediate M_t range for the 16° diffuser needs further study. As mentioned in the text this could be similar in origin to the low frequency fluctuation in the flow over airfoils.[9] Third, the preliminary data illustrate a drastic change in the nature of the low frequency fluctuations between the 16° and the 20° diffusers. The fluctuations are axisymmetric in the 16° case and the spectrum exhibited a clear peak. In the 20° diffuser, the fluctuations became flapping type and the spectrum did not have identifiable low frequency peak(s). These aspects together with the effect of the acoustic excitation for all three diffusers are currently under further investigation.

References

1. Bradley, C.I., and Cookrell, D.J. "The Response of Diffusers to Flow Conditions at Their Inlet," Symposium on Internal Flows, University of Salford, Lancaster, England, 1971 pp. A32-A41.

2. Thompson, R.G., "Performance Correlations for Flat and Conical Diffusers," ASME Paper 79-GT-52, Mar. 1979.

3. Markland, E., and North, P., "Performance of Conical Diffusers up to the Choking Condition," 6th Conference on Fluid Machinery, Vol. 2, L. Kisbocskoi and A. Szabo, eds., Akademiai Kiado, Budapest, Hungary, 1979, pp. 703-714.

4. Ashjaee, J., and Johnston, J.P., "Straight-Walled, Two-Dimensional Diffusers -- Transitory Stall and Peak Pressure Recovery," Journal of Fluids Engineering, Vol. 102, No. 3, Sept. 1980, pp. 275-282.

5. Wysocki, W., and Kazimierski, Z., "Analysis of Subsonic Transitory Stalled Flows in Straight-Walled Diffusers," Journal of Fluids Engineering, Vol. 108, No. 2, June 1986, pp. 222-226.

6. Rice, E.J., and Zaman, K.B.M.Q., "Control of Shear Flows by Artificial Excitation," AIAA Paper 87-2722, Oct. 1987. (NASA TM-100201).

7. Raman, G., Zaman, K.B.M.Q., and Rice, E.J., "Initial Turbulence Effect on Jet Evolution With and Without Tonal Excitation," Physics of Fluids A, Vol. 1, No. 7, July 1989, pp. 1240-1248.

8. Zaman, K.B.M.Q., "Flow Field and Near and Far Sound Field of a Subsonic Jet," Journal of Sound and Vibration, Vol. 106, No. 1, Apr. 8, 1986, pp. 1-16.

9. Zaman, K.B.M.Q., McKinzie, D.J., and Rumsey, C.L., "A Natural Low-Frequency Oscillation of the Flow Over an Airfoil Near Stalling Conditions," Journal of Fluid Mechanics, Vol. 202, May 1989, pp. 403-442.

10. Kinsler, L.E., and Frey, A.R., "Fundamentals of Acoustics," Second Edition, John Wiley & Sons Inc., New York, 1962.

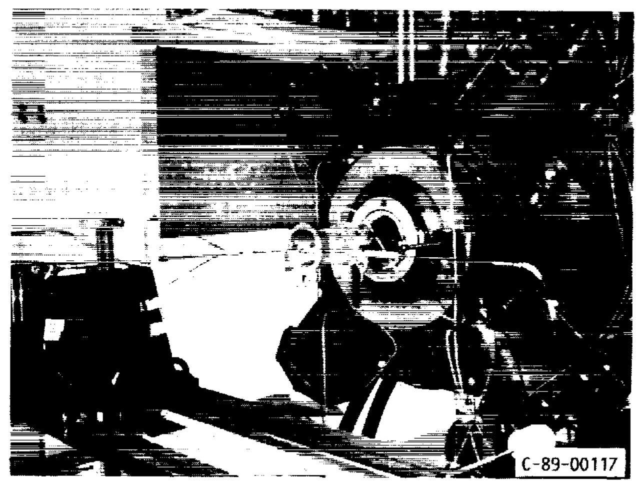

FIGURE 1A. - PHOTOGRAPH OF FLOW FACILITY.

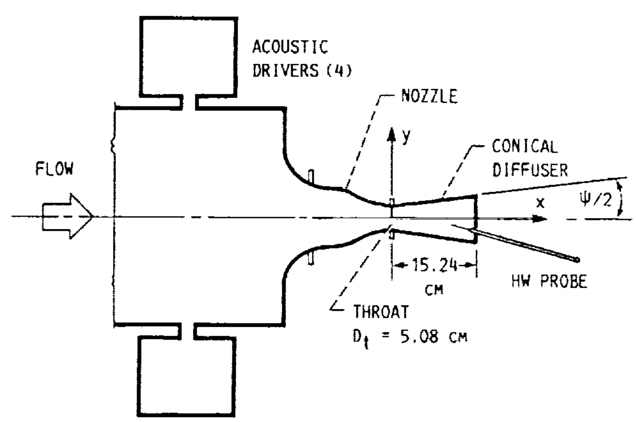

FIGURE 1B. - SCHEMATIC OF FLOW FACILITY.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

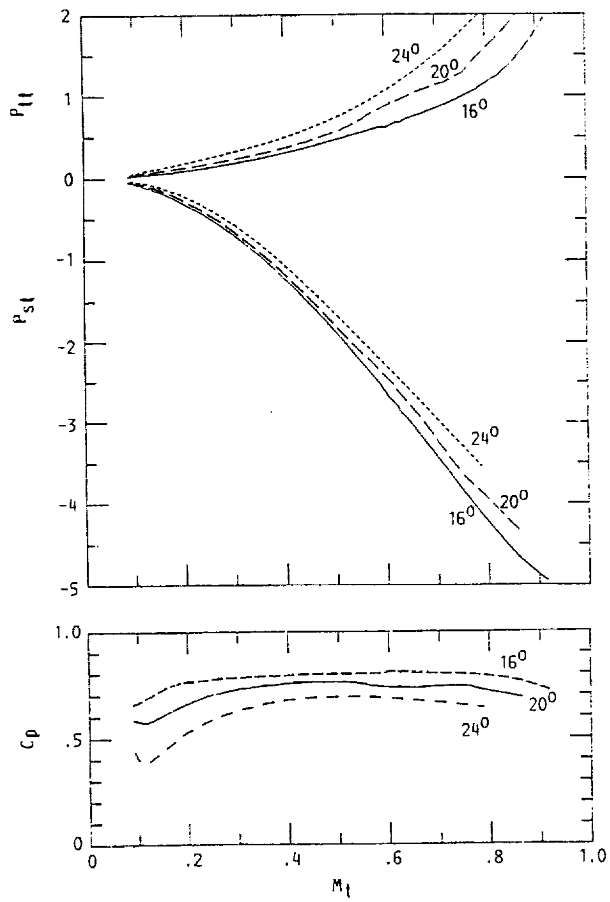

FIGURE 2. - VARIATIONS OF TOTAL (P_{tt}) AND STATIC (P_{st}) PRESSURES (PSIG) AT THROAT, AND THE PRESSURE RECOVERY COEFFICIENT (C_p) WITH THROAT MACH NUMBER (M_t) FOR THE THREE DIFFUSERS.

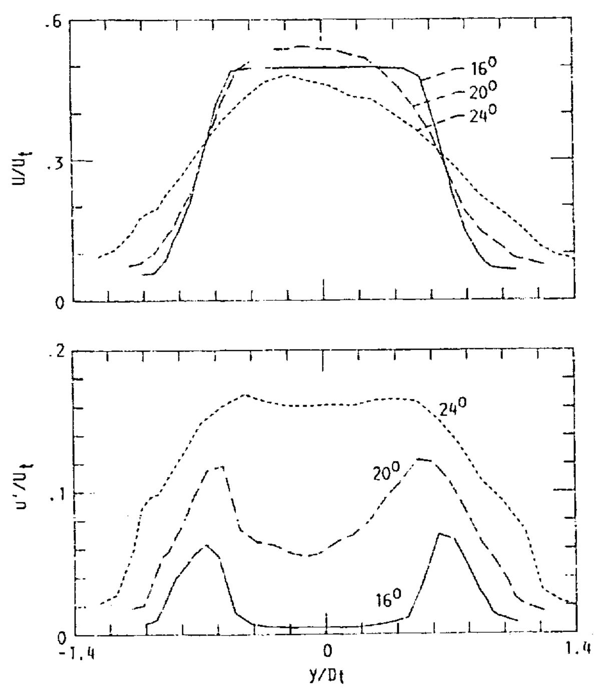

FIGURE 3. - DIAMETRAL PROFILES OF LONGITUDINAL MEAN VELOCITY (U) AND R.M.S. FLUCTUATION (u') INTENSITY AT THE EXIT OF THE DIFFUSERS AT M_t = 0.3.

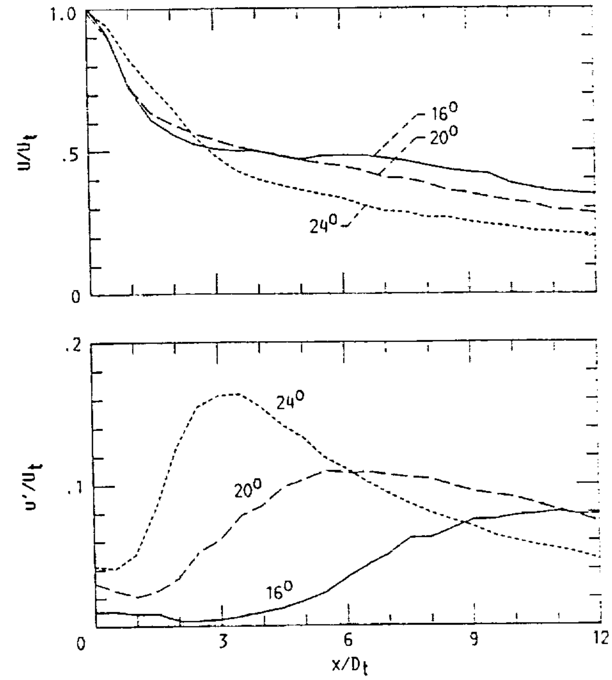

FIGURE 4. - VARIATIONS OF U AND u' ALONG THE AXIS OF THE DIFFUSERS, AT M_t = 0.3.

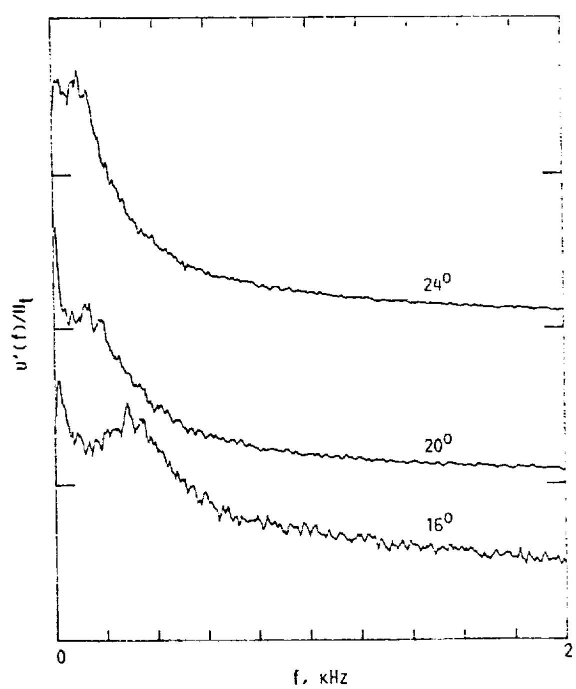

FIGURE 5. - u' SPECTRA MEASURED AT THE EXIT PLANE, 1.27 CM OFF AXIS. ARBITRARY VERTICAL SCALES. PEAK LEVELS OF $u'(f)/U_t$ ARE 0.0007, 0.013 AND 0.031 FOR THE 16°, 20° AND 24° DIFFUSERS, RESPECTIVELY. M_t = 0.3 FOR 24° AND 20° CASES, M_t = 0.36 FOR THE 16° CASE.

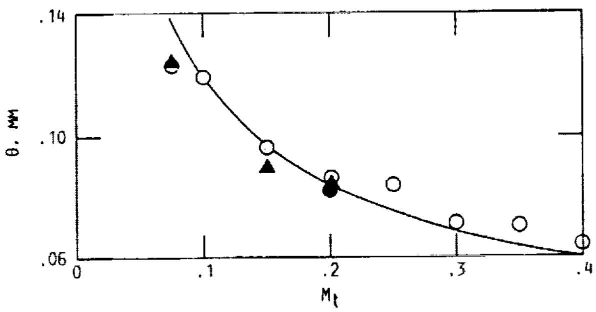

FIGURE 6. - BOUNDRY LAYER MOMENTUM THICKNESS (θ) AT THE THROAT vs. M_t. o, MEASUREMENT AT EXIT OF NOZZLE WITHOUT A DIFFUSER; Δ, AT THE THROAT WITH THE 16^0 DIFFUSER ON. SOLID SYMBOLS FOR MEASUREMENT AT POSITIVE y, OPEN SYMBOLS FOR NEGATIVE y.

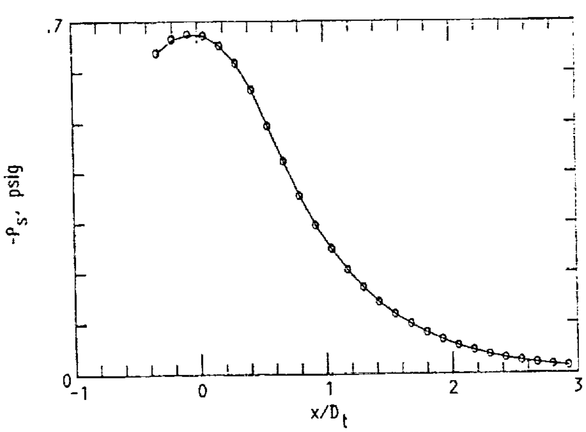

FIGURE 7. - STREAMWISE VARIATION OF STATIC PRESSURE WITHIN THE 16^0 DIFFUSER, MEASURED ALONG THE AXIS, AT M_t = 0.3.

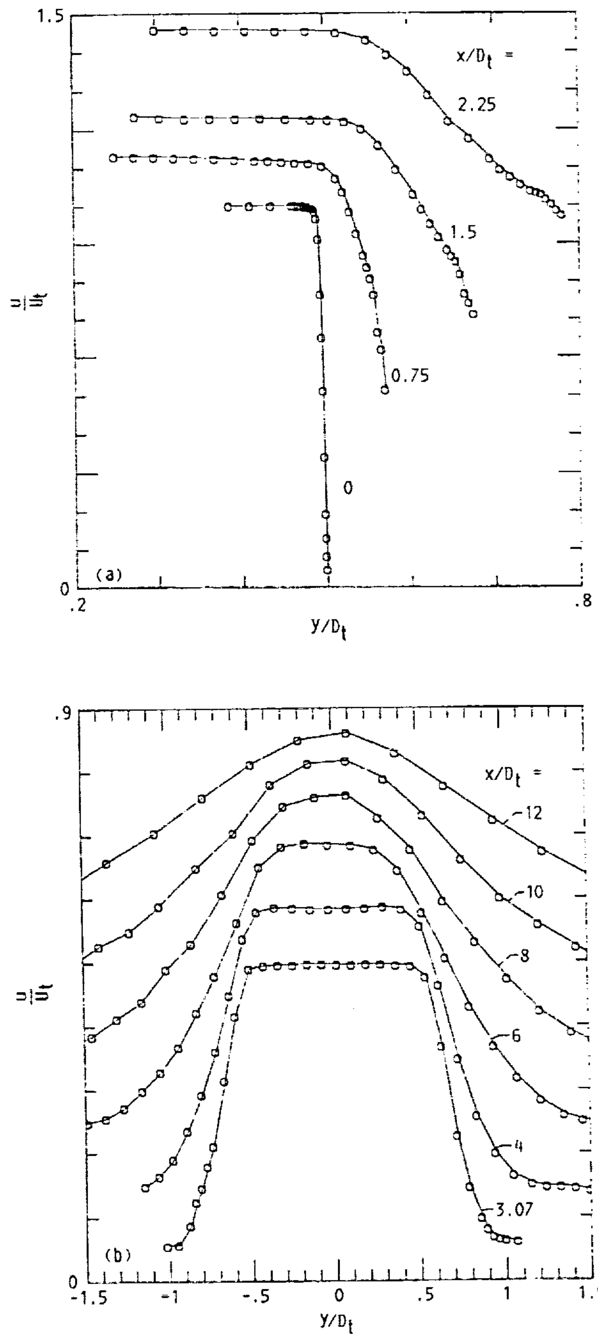

FIGURE 8. - U (Y) PROFILES at M_t = 0.3; 16^0 DIFFUSER. CURVES ARE STAGGERED BY ONE MAJOR ORDINATE DIVISION. (a) PROFILES WITHIN THE DIFFUSER. (b) PROFILES DOWNSTREAM OF THE EXIT.

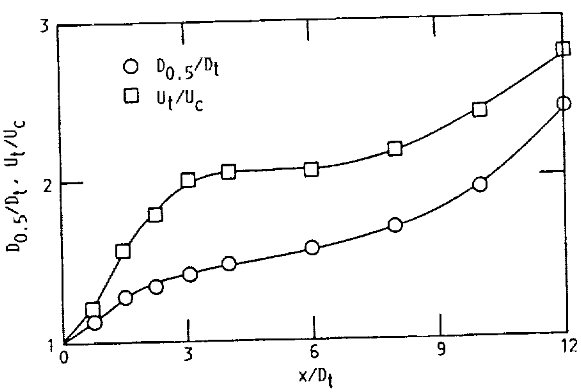

FIGURE 9. - STREAMWISE VARIATION OF: ○, HALF VELOCITY DIAMETER, $D_{0.5}$, AND □, CENTERLINE MEAN VELOCITY (INVERSE), U_c.

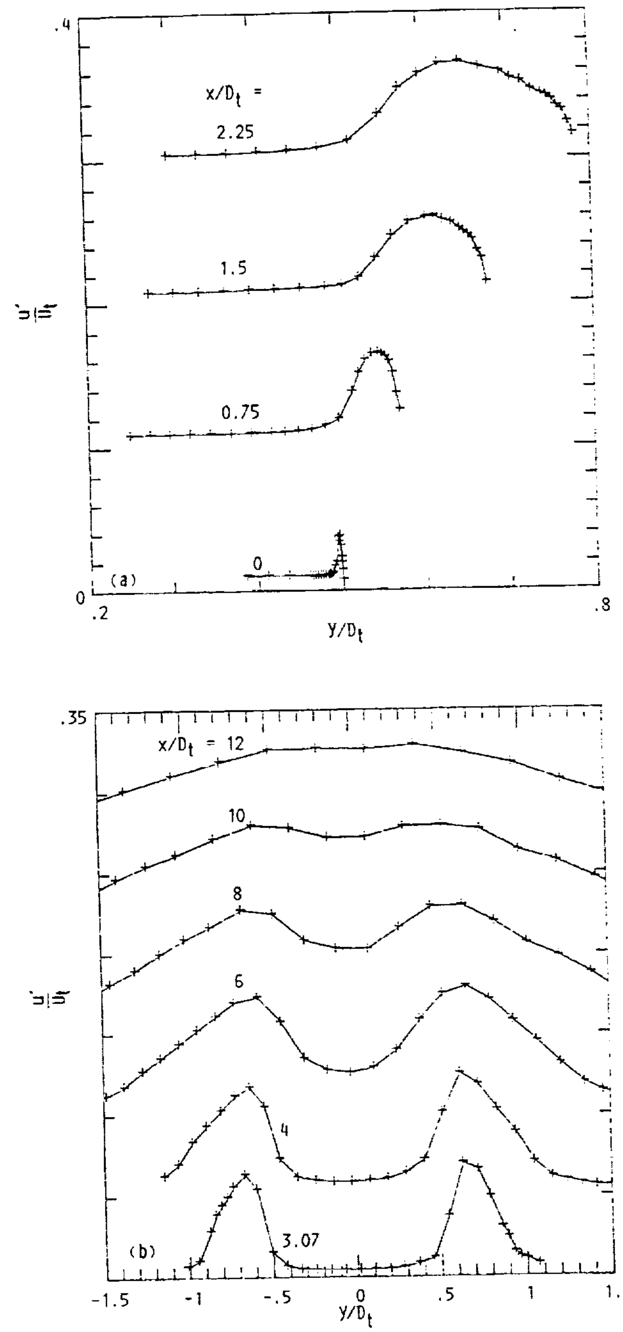

FIGURE 10. - u' (y) PROFILES CORRESPONDING TO THE DATA OF FIGS. 8 (a), (b).

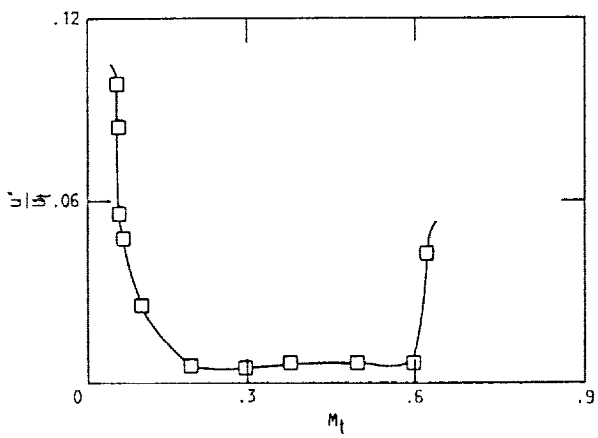

FIGURE 11. u' MEASURED AT THE EXIT PLANE 1.27 CM OFF AXIS, AS A FUNCTION OF M_t; 16° DIFFUSER.

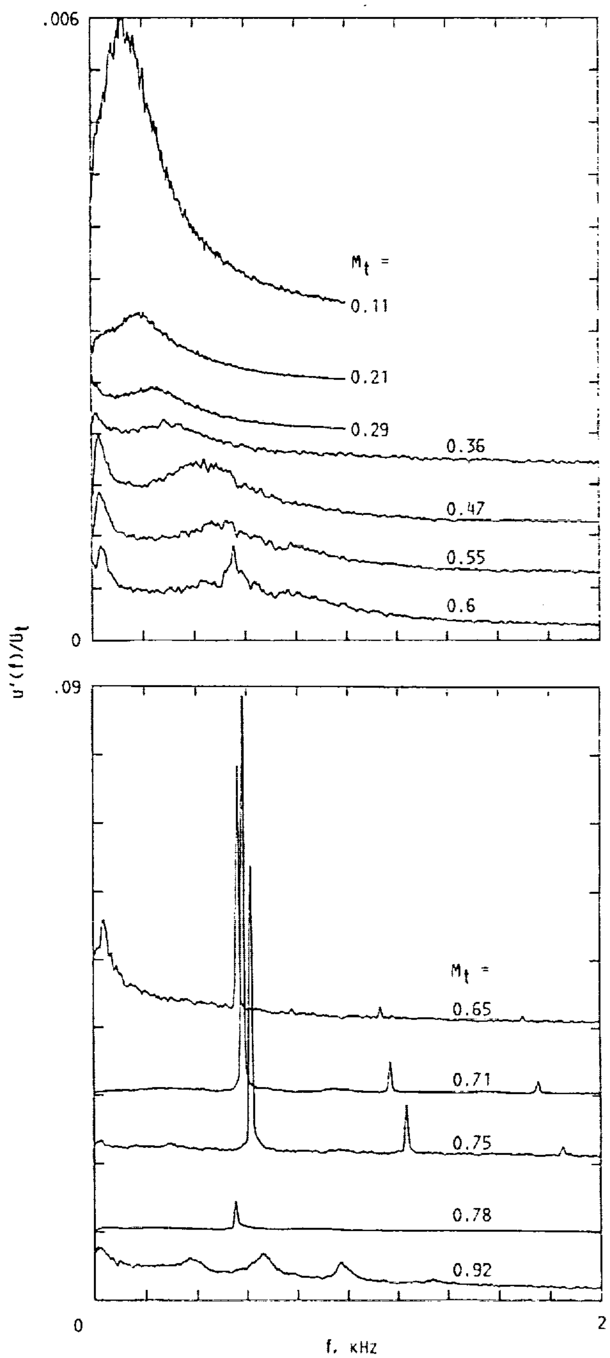

FIGURE 12. - u'-SPECTRA MEASURED AT THE EXIT PLANE 1.27 CM OFF AXIS, AT DIFFERENT M_t; 16° DIFFUSER. TRACES ARE STAGGERED BY ONE ORDINATE DIVISION.

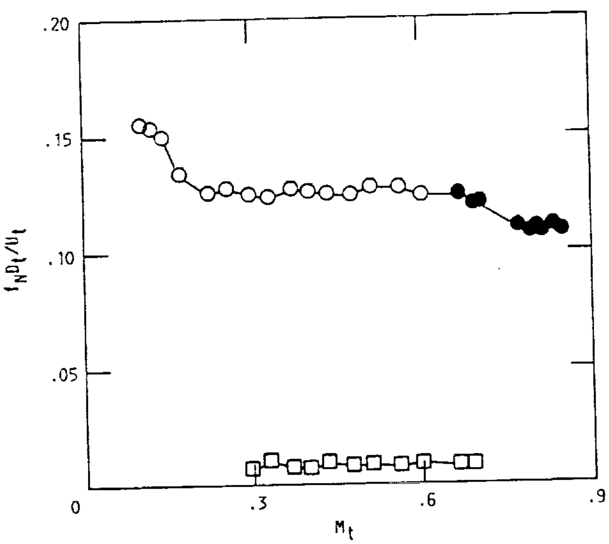

FIGURE 13. - STROUHAL NUMBER CORRESPONDING TO THE SPECTRAL PEAKS (AS IN FIG. 12) VERSUS M_t. SOLID DATA FOR SELF SUSTAINING TONES; SQUARES FOR THE LOWER FREQUENCY SPECTRAL PEAKS.

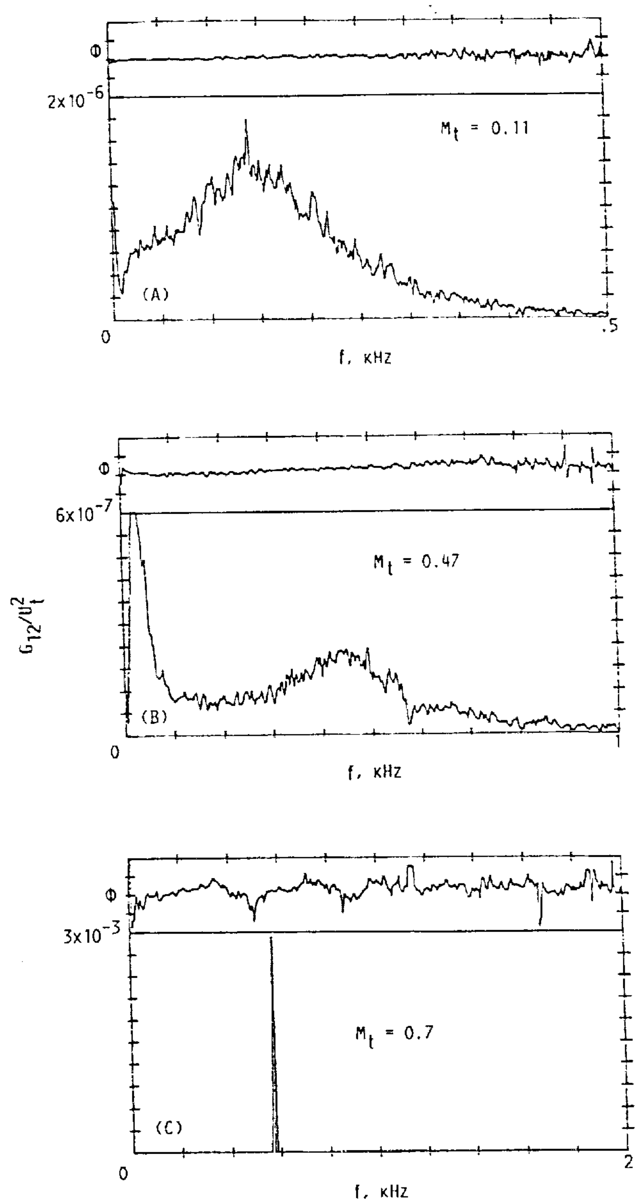

FIGURE 14. - CROSS-SPECTRA (G_{12}) AND PHASE (Φ) BETWEEN TWO U-SIGNALS OBTAINED FROM HOT-WIRES LOCATED, AT THE EXIT PLANE, 1.27 CM ON EITHER SIDE OF AXIS. ORDINATE SCALE FOR Φ RANGES -180° TO 180°.

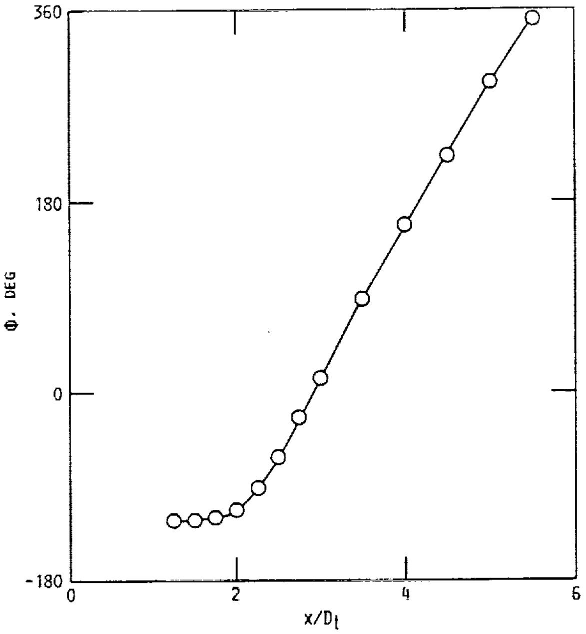

FIGURE 15. - STREAMWISE VARIATION OF PHASE OF THE 575 Hz TONE AT M_t = 0.7. DATA BASED ON U-SIGNAL ON AXIS; 16° DIFFUSER.

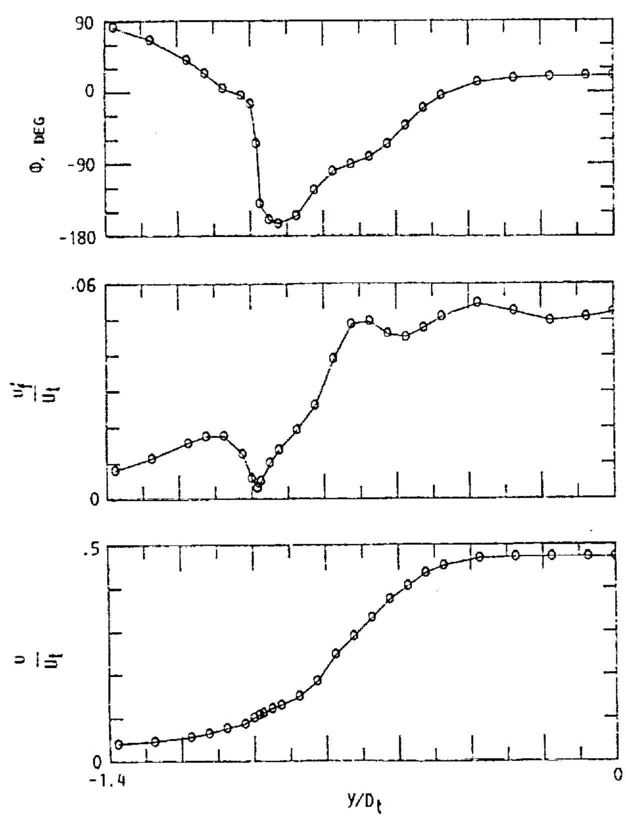

FIGURE 16. - RADIAL PROFILES OF U, u'_f AND Φ FOR THE 575 Hz TONE AT M_t = 0.7. MEASUREMENT AT EXIT, x/D_t = 3.07; 16° DIFFUSER.

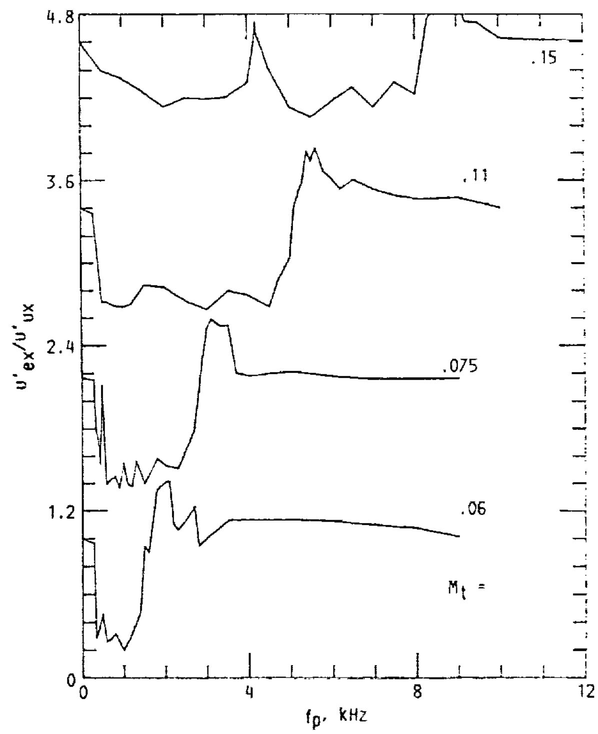

FIGURE 17. - RATIOS OF TURBULENCE INTENSITIES WITH AND WITHOUT EXCITATION, MEASURED AT THE EXIT PLAN 1.27 CM OFF AXIS, FOR VARYING EXCITATION FREQUENCY f_p . CURVES ARE STAGGERED BY ONE MAJOR ORDINATE DIVISION; 16° DIFFUSER.

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No. NASA TM-102387 AIAA-90-0048	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Some Observations on Transitory Stall in Conical Diffusers		5. Report Date
		6. Performing Organization Code
7. Author(s) K.B.M.Q. Zaman and M.D. Dahl		8. Performing Organization Report No. E-5128
		10. Work Unit No. 505-62-21
9. Performing Organization Name and Address National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135-3191		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546-0001		14. Sponsoring Agency Code

15. Supplementary Notes

Prepared for the 28th Aerospace Sciences Meeting sponsored by the American Institute of Aeronautics and Astronautics, Reno, Nevada, January 8-11, 1990.

16. Abstract

Results from an experimental investigation on the flow through conical diffusers are presented. The mean and fluctuating velocity fields are compared for three diffusers with total diffusion angles of 16°, 20° and 24°, in the throat Mach number (M_t) range of 0.05 to 0.95. Each of the diffusers were 14 cm long and had a 5.08 cm inlet diameter, and the flow exited into the ambient. The boundary layer at the throat was thin with the throat diameter (D_t) to momentum thickness (Θ) ratio being as high as 800 at $M_t = 0.4$. While the 16° diffuser flow exited with a top-hat mean velocity profile, increasing losses due to increasing separation resulted in fuller profiles for the 20° and 24° cases. A detailed flow field study was conducted for the 16° diffuser. The u′-spectrum, measured at the exit plane, exhibited a peak apparently due to the ensuing jet column instability throughout the M_t range covered. In addition, a much lower frequency spectral peak also occurred in the M_t range of 0.3 to 0.7. Both of the spectral peaks were due to axisymmetric flow fluctuations. A self-sustaining flow oscillation occurred in the M_t range of 0.6 to 0.85, emitting a loud tone, when the jet column instability frequency matched the resonance frequency of the diffuser. Limited data showed that artificial acoustic excitation was effective in reducing the flow fluctuations, with a resultant increase in the pressure recovery, at low M_t.

17. Key Words (Suggested by Author(s)) Diffuser Transitory stall Unsteady flow	18. Distribution Statement Unclassified – Unlimited Subject Category 02

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of pages	22. Price*
Unclassified	Unclassified	12	A03

NASA FORM 1626 OCT 86

*For sale by the National Technical Information Service, Springfield, Virginia 22161