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Effect of inlet swirl on annular diffuser performance.

Uwe H. Schneider

University of Windsor

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Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
EFFECT OF INLET SWIRL ON ANNULAR DIFFUSER PERFORMANCE

A THESIS

Submitted to the Faculty of Graduate Studies through the Department of Mechanical Engineering in partial fulfilment of the requirements for the Degree of Master of Applied Science at the University of Windsor

by

Uwe H. Schneider
B.A.Sc., University of Windsor
Windsor, Ontario
1971
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Four Equiangular Annular Diffusers were investigated with an inlet flow having swirl. The total expansion angles of the inner and outer cones of the diffusers were 40° and the area ratios were 1.25, 1.50, 2.00, 3.00 respectively. The performance of each of these diffusers was studied at various amounts of inlet swirl. The mean swirl angle at the inlet was varied from approximately zero (axial flow) to a value of about 25°. The performance of the diffuser was studied at five different inlet swirl angles with the aim of finding the effect of inlet swirl on the performance. It was found that the Equiangular Annular Diffuser performance was good at axial flow, decreased at low swirl and increased at higher swirl.

The performance of the present diffuser geometry was compared to a set of annular diffusers whose inner cone converged and outer cone diverged. The Equiangular Divergent Annular Diffuser performed better than the Equiangular Divergent-Convergent Annular Diffuser.
The author is grateful to Rev. A. R. Howell and Prof. W. G. Colborne of the Department of Mechanical Engineering for providing the opportunity and for their support for this project.

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NOTATION

A Flow Area
A_t Throat Area
AR Area Ratio
B Inlet Opening of Swirl Vane Unit
C_{PR} Pressure Recovery Factor Based on Mass-Weighted Average Value of Dynamic Head
C_{PR_{I}} Ideal Pressure Recovery Factor Based on Free Vortex Flow
D Diffusion Factor
h Height of the Annular Passage
L Length of the Diffuser Measured Along the Wall
M Mass Flow Rate
P S Static Pressure
P T Total Pressure
r Radius
r_{h} Hub Radius
r_{o} Tip Radius
V Absolute Velocity
V_a Axial Velocity
V_r Radial Velocity
V_t Tangential Velocity
y Distance from Inner Surface of Outer Wall
\eta Diffuser Effectiveness
\psi' Swirl Angle
\gamma Density
Diffuser Divergence Angle or Diffuser Expansion Angle

Sweep Angle of Flow Contour for Design of Swirl Vane Unit

Subscripts

i Inner Wall
0 Outer Wall
I Ideal
1 Diffuser Inlet
2 Diffuser Outlet

Bar over the symbol means mass-weighted average quantity except where it is otherwise stated.
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CHAPTER I

INTRODUCTION

Plane-walled and conical diffusers have been extensively investigated at least, in the absence of swirl; annular diffusers, however, have not yet been thoroughly investigated. Since the flow in turbomachinery is largely through annuli this type of duct is of great interest.

In investigating the performance of a diffuser it is important to measure certain performance parameters, such as pressure recovery and diffuser efficiency, and also to determine the effect if any, of the various geometric and flow variables on the performance parameters.

A comparatively simple type of annular diffuser of practical interest is that in which the mean flow surface is a cone of increasing radius. For such a configuration there are four basic geometrical variables, the inlet hub/tip ratio, the over-all area ratio, the angle of the inner wall, and the angle of the outer wall.

It is also essential that several aerodynamic parameters be carefully measured if a meaningful analysis of diffuser performance is sought. For the inlet, these parameters are the inlet profile shape, turbulence and inlet swirl.

Defects in mass flux and momentum flux at the inlet may be of several kinds, associated with the boundary layer or with the radial or circumferential variations in
flow velocity and pressure. In order to reduce the number of experimental configurations, it was desired to establish a flow that is axisymmetric and to employ a fully developed flow, which would establish a "thick" boundary layer. Repeatability is best achieved if the boundary layer builds up in a long constant area duct.

In practical applications of annular diffusers the flow enters the diffuser with a swirl. The effect of inlet swirl is of major importance, and no performance data on this type of diffuser can be considered complete unless it includes the effect of inlet swirl.

The aim of this research is to investigate the effects of inlet swirl on the performance of a number of annular diffusers of equal divergent angles, but different area ratios.
CHAPTER 2

LITERATURE SURVEY

The material covered in this chapter summarizes briefly the existing literature and also, introduces some of the terminology used in diffuser research.

2.1.0 General Remarks on Diffusers

The diffuser is a device which converts the kinetic energy of a moving stream of fluid into static pressure. Continuity is satisfied by the corresponding reduction in mean velocity. The mean velocity reduction is accompanied by a pressure rise; however, this relationship, between decreasing velocity and increasing pressure is complex. The axial momentum is reduced not only because of the increased pressure, but also because of mixing processes occurring and the shear forces developed on the diffuser walls. With a diffuser a wide variation in axial velocity occurs across the outlet section, the flow separating from the walls if the diffuser expansion angle is sufficiently large.

The simplest flow passing through a diffuser may be considered as one-dimensional. As the flow enters, the streamlines diverge and the fluid experiences a deceleration, velocity decreasing as the flow continues through the diffuser, but static pressure increasing. Most of the analysis on diffuser performance in the past has been done using one dimensional flow through
the diffuser.

Diffusers are classified into three general groups—plane-walled, conical and annular. The various types of diffusers are in Figure (1).

2.2.0 Diffuser Performance

The performance parameters most commonly used in the analysis of diffuser performance are the pressure recovery factor, $C_{PR}$, and the diffuser effectiveness, $\eta$.

The pressure-recovery factor relates the actual pressure rise of a diffuser to the dynamic pressure at the diffuser inlet, i.e.,

$$C_{PR} = \frac{\Delta P}{\bar{Q}_1},$$

(2-1)

$$= \frac{P_{s2} - P_{s1}}{\bar{Q}_1}.$$

The overall diffuser effectiveness is the ratio of actual pressure rise to that achievable from the same diffuser with one-dimensional ideal fluid flow at the same flow rate, i.e.,

$$\eta = \frac{C_{PR}}{C_{PR_i}},$$

(2-2)

where the ideal pressure recovery factor can be readily shown to be a function of only the area ratio of the
diffuser, i.e.,

\[ C_{PE_i} = 1 - \frac{J}{AR^2} \]  \hspace{1cm} (2-3)

Often in the diffuser literature, the term diffuser efficiency is used, rather than effectiveness. Efficiency implies losses, whereas, \( \zeta \), as defined here, is more representative of the effectiveness with which the area change of a diffuser is used for diffusion purposes than it is of the loss which occurs within the device.

When swirl is introduced into the flow, the maximum pressure rise may be obtained at an optimum swirl angle and the effectiveness could be greater than unity. An expression for the pressure recovery factor for ideal fluid flow through an annular diffuser with a free vortex swirl is derived and presented in Appendix B.

2.3.0. Previous Investigations of Diffusers

2.3.1. Conical and Plane Walled Diffusers

Although diffuser research dates back to the eighteenth century, it was not until the early twentieth century that serious, extensive investigations were carried out by Gibson and Eiffel (ref. 3). Both men investigated conical diffusers, the former using air the latter water. McDonald and Fox (ref. 9) did further investigations on conical diffusers, obtaining performance and flow regimes information for
a wide range of diffuser geometries. Later Patterson and Peters (ref. 10 and 11) correlated diffuser losses with the angle of expansion of the diffuser, the shape of the diffuser and the area ratio of the diffuser.

Professor Kline (ref. 7) and his associates investigated extensively the performance and design of straight two-dimensional diffusers (Plane wall ed). Kline found four primary flow regimes, regions of unstalled flow, large transitory stall flow, two-dimensional stall flow, and jet flow and presented these as functions of overall diffuser geometry. The performance of both stalled and unstalled diffuser was mapped for a wide range of geometries and inlet boundary layer thicknesses. In analyzing the diffuser performance, two performance parameters were found- the pressure recovery factor, $C_{PR}$, and the diffuser effectiveness, $\eta$. Using these values, performance plots were obtained. It was found that in the region of unstalled flow, $C_{PR}$ is determined by the area ratio, the diffuser effectiveness is determined by the diffuser expansion angle. In the region of large transitory stall, $C_{PR}$ is determined by the expansion angle. In the two-dimensional stall flow and in the jet flow $C_{PR}$ remains fairly constant.

2.3.2. Annular Diffusers

Johnston (ref. 6) investigated the effect of inlet conditions on the flow, in annular diffusers.

The expansion angles of his annular diffuser varied
from 6.5° to 15°. For a variety of inlet velocity distributions the performance of each diffuser was measured. He found that diffuser efficiency deteriorated as inlet conditions become more non-uniform, this tendency increasing with diffuser angle.

Hensler and Howard (ref. 5) investigated equiangular annular diffusers (converging inner cone, diverging outer cone) with angles ranging between 7° and 20°. They were able to establish the flow regimes and performance as functions of the geometrical parameters of the diffusers. The flow was fully developed at the inlet, without swirl, and it was noticed that the behaviour of the equiangular diffuser was similar to that of two dimensional diffusers.

Thornton-Trump (ref. 15) investigating annular diffusers with a straight inner concentric core and a diverging outer cone found that the performance of the diffuser laid between two-dimensional diffusers and conical diffusers.

Sovran and Klomp (ref. 13) studied the performance of a wide variety of annular diffusers, for flow without swirl, using thin boundary layers and different inner and outer wall angles to obtain a performance chart. They concluded that wall angles and the inlet radius ratio did not affect the performance appreciably; however, the area ratio and the non-dimensional diffuser length were important controlling factors.

2.4.0. Specification of Inlet Swirl

In most practical applications of annular diffuser...
the fluid motion is not one-dimensional, but possesses also a swirl motion. Such a motion in a flow may be set up by means of a swirl vane, turbine blades or compressor blades. Due to the swirl motion, the flow entering the diffuser now has an axial velocity component and also a tangential velocity component. A swirl angle, \( \psi \), the angle of the flow measured relative to a plane through the center line of the duct, is defined. If the swirl angle distribution has a profile of its own, it becomes necessary to find an overall average value of the swirl angle. Schwartz defined a mass weighted average value of the swirl angle denoted by \( \overline{\psi} \).

2.4.1. Previous Investigations of Diffusers—With Inlet Swirl

In 1953, Schwartz (ref. 12) investigated the effects of swirl on the annular diffusers with constant outer diameters and effective angles of 8° and 16°. He found that regions of maximum efficiency occurred when the angle of inflow (swirl angle) equaled the conical angle of expansion and also when the flow was axial. There are sharp reductions in efficiency at high angles of swirl.

The effect of swirl on the Flow Regimes and Performance of Equiangular, Divergent-Convergent Annular Diffuser was investigated by Srinath (ref. 14). It was found that the diffuser performed most efficiently when the mean inlet swirl angle was close to the total expansion angle of the diffuser. Swirl removed stall completely from the outer
wall and transitory stall set in almost immediately on the inner wall. At higher swirl angles, there was great reduction in the efficiency of the diffuser.

2.5.0. Aims of Present Investigation

In view of the need for a better understanding of the effect of swirl on annular diffuser performance and of its importance in numerous practical applications, the present work aims to investigate the effects of inlet swirl on the performance of a number of annular diffusers, of equal inner and outer divergent angles.
CHAPTER 3

TEST FACILITIES AND EXPERIMENTAL PROCEDURE

3.1.0. Test Facilities

A schematic diagram is given in Figure (2) showing the letter code used in the following description of the test facilities. Figure (3) to (8) show a series of photos of the test facilities.

3.1.1. Air Supply and Flow-Calibration Pipe

Air was supplied by a type E, size 7 Canadian Buffalo blower, B, with a rating of 2000 C.F.M., 56.1 inches of water S.P., 3500 R.P.M. and 31.9 B.H.P. This blower was driven by a 40 H.P., 550 volts and 3500 R.P.M. General Electric induction motor. The air flow could be varied by a 10 inch blast plate and a damper, A, fitted at the intake of the blower.

The flow entered a short converging section and then passed into a 30 inch long cold rolled seamless steel pipe, C, with 5 inch O.D. This pipe served as a flow measuring section. A standard pitot-static probe mounted on a traversing mechanism was able to traverse across the pipe and the air flow thus could be determined by knowing the velocity profiles inside the pipe.

3.1.2. Expansion Cone and Plenum Chamber

The expansion cone, D, approximately eight feet long, was constructed out of 1/8 inch plywood sheets. The inner surface was sanded and varnished to ensure a smooth surface.
The plenum chamber, E, consists of four cylindrical sections, 38 inches diameter, built out of 1/16 inch plexiglass, supported by 3/4 inch plywood frames. These sections were joined to form a six foot long settling chamber which contained also a one foot honeycomb section, G, and three screens, H, (30x30 mesh). A fibre glass filter, F, was mounted at the front of the chamber. The plexiglass wall provides a smooth inner surface and also allows for flow visualization at the inlet of the swirl vane unit.

By means of a velometer the velocity profile at the exit of the plenum chamber was measured. The profile showed that a uniform flow had been achieved.

3.1.3. Swirl Vane Unit

A swirl vane unit (or swirl generator), I, was mounted in the last section of the plenum chamber. The unit consisted of two machined pieces of wood (axisymmetric), the outer piece mounted on the outer tube of the annulus, the inner piece mounted on the inner tube and suspended in the chamber by a spider. The inner and outer flow contours were obtained after a detailed analysis to achieve the best flow conditions. This analysis was carried out with the help of United Aircraft of Canada Limited (ref. 16).

According to the analysis, presented briefly in Appendix C, the flow in the swirl unit is continuously accelerated with minimum losses and enters the annular passage at the end. If inlet flow conditions are as
specified in the analysis, no flow separation should occur at the walls.

Between the outer and inner parts of the swirl unit a 1.6 inch gap allows the mounting of twenty-four NACA 0012 airfoils (3 inch chord). By means of a ring mechanism, all twenty-four vanes can be turned through the same angle and different degrees of swirl introduced into the flow.

3.1.4. Annular Pipes

From the swirl vane unit, the air passed through the annular space between two twelve-foot aluminum pipes, J, the inner pipe being 5 inch O.D., the outer pipe 8 inch I.D.. Spacers were not used to separate the annular pipes in order to reduce distortion of the swirl as it passed down the annular passage. To ensure concentricity of the pipes and keep vibrations to a minimum, considerable work was done to suspend the inner pipe firmly at one end by a spider located in the plenum chamber, at the other end by a solid-angle stand. The outer pipe was cradled firmly by two solid stands, which also allowed levelling of the outer pipe to ensure concentricity of the inner and outer pipes. The last foot of the outer pipe was replaced by a plexiglass section, K, of the same diameter. The section was threaded and flanged on, so that the probe attached to it could be rotated about the inner pipe.
3.1.5. The Test Section: The Diffuser

From the annular passage, the flow entered the test section—the annular diffuser. The annular diffuser, shown in Figure (9) consisted of two cones, total expansion angle of each cone being 40°. The cones were machined from laminated pieces of basswood and were assembled out of four cone sections, thereby, allowing the study of four annular diffusers, of the same divergent angle but of different lengths. The lengths were chosen, to give area ratios of 1.25, 1.50, 2.0 and 3.0.

At the diffuser inlet, the inner diameter of the outer pipe was 8.0 inches and the inner pipe had an outer diameter of 5.0 inches, resulting in an annular height of 1.5 inches. The hub to tip radius ratio was 0.6., typical of turbine outlet annuli.

The following table gives the area ratios and the corresponding non-dimensional length for the diffusers tested.

<table>
<thead>
<tr>
<th>Total Expansion Angle</th>
<th>L/h</th>
<th>AR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.60</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>3.13</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>6.35</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>12.65</td>
<td>3.00</td>
</tr>
</tbody>
</table>

TABLE 3-1

3.2.0. Experimental Procedure

The following measurements were made for each diffuser,
the largest diffuser being analyzed first.

Each annular diffuser was studied for five different swirl conditions, approximately zero swirl to a maximum swirl of about 25°. For each swirl condition, pressure variations along the diffuser and the flow conditions at the inlet and the outlet of the diffuser were measured. The degree of swirl was set, by turning the external control knob, which rotated all of the twenty-four vanes simultaneously through the same angle (0° to 45°).

Initially, the airfoils were turned to a neutral position, allowing zero swirl or axial flow to be introduced into the flow. Two inches upstream of the diffuser inlet, a yaw probe was inserted, and measurements were made at ten positions, radially across the annular gap. The probe also allowed measurements of static pressure and total pressure at these positions. It should be noted that first, the probe was rotated to the null direction and then swirl angle and pressure readings were taken.

The inlet flow conditions were measured at three different radial locations 120° apart, by rotating the plexiglass section about the inner pipe.

The flow was adjusted for each swirl condition by adjustment of the damper, to ensure a constant flow rate of approximately 1900 cfm at a Reynolds Number of 2x10^5.
Following the inlet swirl and pressure measurements, the yaw probe was removed and replaced by a hot wire probe to measure the inlet turbulence level. Care was taken to locate the hot wire at the same position as the yaw probe and for each position to rotate the hot wire to the same angle as was measured, with the yaw probe at the corresponding position. Once the hot wire was properly aligned, average D.C. voltage and RMS voltage readings were recorded.

Care was taken not to bring the hot wire probe too close to the wall, in order to reduce the chances of damaging the hot wire. This precaution allowed turbulent measurements only at eight positions, instead of ten.

At the exit, another yaw probe was mounted and similar measurements were made at ten positions; however, only one traverse was made. No static pressure measurements were made, assuming that the exit static pressure was atmospheric. Also, no turbulence measurements were made at the exit.

The pressure variations in the diffuser were noted by means of three rows (120° apart) of static pressure taps, fourteen per row, along the diffuser wall. These pressure taps were hooked up to a thirty-six tube sloping bank manometer.

In Figure (10), the stations at which measurements were taken are shown.
3.3.0. Instrumentation

The inlet conditions were measured with a probe that contained a cobra yaw probe, a circular stainless steel hypodermic tube (0.06 in. D.) to measure total pressure and a similar hypodermic tube of the same outer dimensions with two small holes on the side to measure static pressure. The yaw probe was aligned for zero swirl by placing it in a uniform velocity field of a windtunnel. The static pressure and total pressure tubes were calibrated with a standard Kiel Probe in a windtunnel.

Outlet conditions were measured with another cobra yaw probe, whose central hypodermic tube measured the total pressure. The probe was aligned and calibrated in the windtunnel. Static pressure was assumed atmospheric at the exit.

Thirty static pressure taps, 0.040 in. diameter, were drilled into the outer wall and allowed measurement of the static pressure rise in the diffuser.

A NPL-Type Multitube Tilting Manometer was utilized in making all pressure measurements.

The relative inlet turbulence was measured with a Disc, Constant-Temperature Anemometer, 55A01, using a Type 55A36 Miniature Hot Wire Probe. The cold resistance of this probe was approximately 3.40 ohms. Calibration of the hot wire was done periodically in the windtunnel and the test apparatus itself.
CHAPTER 4

RESULTS AND DISCUSSION

4.1.0. Experimental Results

Before measurements were taken, it was shown that the flow, for zero swirl, was fully developed. Since the length of the annulus was 80 times the hydraulic diameter, it was reasonable to assume that the flow at the diffuser inlet was fully developed. Also the velocity profile at the diffuser inlet was compared with the velocity profiles of Brighton and Jones (ref. 1) for fully developed turbulent flow, Figure 11, showing very good agreement. It was observed that the inlet velocity profile could be repeated well and at zero swirl did not vary considerably for different flow rates. The last observation showed that the Reynold's Number effects were quite small, within the range of experimentation.

4.2.0. Inlet Conditions

Inlet measurements, taken at three traverses, 120° apart, indicated a good circumferential uniformity. The flow was, therefore, assumed to be a function of radial distance only (axisymmetric).
In order to check the magnitude of three-dimensional effects, a three-dimensional five-hole yaw probe was employed and a traverse made at the diffuser inlet. The pressure difference in the pitch plane was small; therefore, the flow in the radial direction was considered to be negligibly small.

Inlet data and calculated results are given in Table I.

4.2.1. Swirl and Tangential Velocity Distributions

Figure (13) shows the various inlet swirl distributions at which the diffusers were tested. It is seen that for low and medium swirl, the swirl angle is nearly constant across the core of the annulus. At higher swirl, the swirl angle increases toward the outer wall; the slope of the profile increasing as the swirl angle increases. The same trend is evident for all four diffusers.

Figure (14) shows the various inlet tangential velocity distributions for the four diffusers. A trend similar to the swirl angle distributions is evident. For low and medium swirl, the profiles are flat, the tangential velocity being nearly constant across the core of the annulus. At higher swirl, the tangential velocity increases towards the outer wall.

From the tangential velocity profiles across the annulus, it is evident that the inlet swirl distribution does not follow a free vortex pattern. This can be
attributed to the fact that the flow is fully developed at the entry to the diffuser and also that the annulus is quite small. Therefore, the whole flow region is affected by shear stresses and hence there is no non-viscous flow region for the free vortex pattern of swirl to develop.

At higher swirl angles, the slope of the swirl angle and the tangential velocity distributions increase, because the flow is being shifted outwards.

4.2.2. Velocity and Dynamic Pressure Distributions

Figure (15) shows the dynamic pressure distributions for the four diffusers, and Figures (16 and 17) show the absolute and axial velocity profiles are almost identical. As the swirl angle increases, the absolute velocity profile becomes increasingly affected by both the tangential velocity and the axial velocity. The figures show, however, that the trend of the axial velocity distribution is also dominant in the corresponding absolute velocity distribution. Both profiles show that with increasing swirl, the profile becomes more skewed towards the outer wall (the point of maximum velocity shifts toward the outer wall). This trend becomes even more pronounced in the dynamic pressure distributions where the velocity is squared and plotted.

4.2.3 Static Pressure Distribution

The inlet static pressure distribution for the four diffuser studied are shown in Figure (18).
It is seen that as the swirl increases the static pressure decreases, becoming more negative at the diffuser inlet. Note that this condition is a favorable condition, for it causes the diffuser to be more efficient. A decreasing static pressure at the inlet increases the flow rate.

The static pressure distributions show the static pressure to be generally constant near the inner wall and increasing towards the outer wall. In the outer region, the static pressure becomes increasingly affected by a combination of the boundary layer effects and the centrifugal forces created by the swirl flow.

As the diffuser length increases, it is observed that the inlet static pressure decreases. This could be explained by the fact that the exit static pressure for all diffusers is equal to ambient pressure.

4.3.0. Diffuser Duct and Outlet

Outlet data and calculated results are given in Table II.

4.3.1. Swirl and Tangential Velocity Distributions

Swirl angle and tangential velocity distributions at the diffuser outlet are shown in Figures (19 and 20). The profiles are not as smooth as the inlet profiles; however, do show the same trend as was evident for high inlet swirl, the swirl angle increasing towards the outer wall. For all swirl conditions, the mass-weighted swirl angle decreases from the diffuser inlet
to the diffuser outlet.

For low and medium swirl the reduction in mean swirl angle, from inlet to the outlet, is accompanied by a change in distribution from a relatively uniform rotation in the inlet to a non-uniform gradient with maximum swirl angle at the outer wall at the exit.

The tangential velocity distributions show the tangential velocity to be constant across the core of the annulus for all swirl conditions.

4.3.2. Velocity and Pressure Distributions

Dynamic pressure and velocity distributions for the diffuser outlet are presented in Figures (21, 22, and 23). The distributions for the dynamic pressure, absolute velocity and axial velocity show similar trends, greater skewness towards the outer wall as the swirl angle increases. The outward shift is more pronounced at the diffuser exit. For low swirl, the maximum velocity is near the inner wall; and at high swirl, it has shifted considerably towards the outer wall. Comparison of the curves of the dynamic pressure at the diffuser inlet to that at the outlet, shows the curves to be steeper at the exit, having a more pronounced maximum point. The diffuser magnifies any distortion of the flow parameters. This amplification is due to the diffusing action which occurs.

With increasing swirl, the absolute velocity distribution changes significantly; static pressure and
flow-angle distributions on the contrary were essentially constant from inlet to exit of the diffuser.

4.3.3. Static Pressure Rise in Diffuser

The static pressure distribution along the diffuser length is shown in figure (24) for the four annular diffuser investigated. It is seen that as the diffuser length increases the static pressure rise increases accordingly. Swirl appears to have no appreciable effect on the distributions.

4.4.0. Effect of Turbulence

Kline (ref.7) his associates have done extensive investigations on plane walled diffusers and they concluded that for Mach number less than unity and for Reynolds Number greater than $5 \times 10^5$, the most important inlet conditions affecting performance are inlet velocity profile and turbulence level. Other researchers have also mentioned turbulence as a prime influence on diffuser performance.

In turbomachines, the boundary layer builds up and often occupies a considerable portion of the annular space of the flow. In swirl flow, because of the tangential mean velocity, neither the turbulence level nor the radial pressure variation need be small in the boundary layer.

Yeh (ref. 17) investigated the development of incompressible turbulent boundary layers along concave and convex stationary annular walls, analytically and experimentally for a swirling flow. He concluded that large-scale turbulence eddies "roam" radially back and forth.
in the outer half of the annular passage; while, such motion is very much reduced in the inner half. The strong radial turbulent motion near the outer wall pulls the immediate adjacent mean velocity taut, creating a larger velocity gradient and shear stress at the outer wall.

For flow with swirl, the boundary layer near the inner wall is very much like the one for flow with no swirl—approaching the equilibrium profile for fully-developed turbulent flow without swirl. For the outer wall region, the boundary layer departs much more than for flow with no swirl. The turbulence intensity is generally larger near the outer wall. This is shown to be true for the results found in the present investigation, as shown in Figure (15). The transverse component of turbulence intensity is produced near the outer or concave wall (where the tangential velocity decreases with radius) but is suppressed near the inner or convex wall (where the tangential velocity increases with radius), resulting in a larger intensity near the outer wall.

At the inlet to the annular pipes, the swirl generator sets up a swirling flow; that is, flow with both tangential and axial mean velocities. The turbulence present in the flow decays the turbulent swirl in the flow and also evens out the velocity profile. Kreith and Sonju (ref. 8) observed that swirl in a turbulent pipe flow decays to about 10-20% of its initial value in a distance of about 50 pipe diameters. In the present investigation it was found that a swirl of
45° set up by the swirl generator at the inlet of the annulus, decayed to 26° at the diffuser inlet and to 18° at the diffuser exit. This trend was true for all swirl conditions.

4.5.0. Discussion of Performance Parameters

The performance of the four annular diffusers and the effect of inlet swirl on the performance was determined by plotting the parameters—the diffuser effectiveness and the pressure recovery factor. The plots were also compared to the findings of other researchers.

4.5.1. Pressure Recovery Factor

For the four diffusers, the pressure recovery factor was plotted against the non-dimensional length for different inlet swirl conditions, shown in Figure (26). In order to find an optimum swirl angle, if possible, the pressure recovery factor was plotted against mass weighted average swirl angle $\Psi$, Figure (27), for each diffuser.

The plots show that the introduction of a certain amount of swirl into the flow has an effect on the performance of the diffuser.

In the plot of CPR versus the non-dimensional diffuser length, the curves are approximately parallel to the curve for zero swirl, indicating that the general trend of the CPR variation with the non-dimensional length is not affected by the swirl. The pressure recovery factor increases as the diffuser length increases and levels off
at higher values of non-dimensional diffuser length.

Srinath who investigated an equiangular divergent convergent annular diffuser, found that the curves of constant swirl angle levelled off and then decreased at higher non-dimensional diffuser lengths, Figure (24). The curves of the $C_{P_{R}}$ versus $L/h$ plot were also quite flat, compared to the ones of this investigation.

Sovran and Klomp conducted an extensive investigation of a wide variety of annular diffuser configurations, for flow with no inlet swirl. The geometric characteristics were specified by four parameters—the two wall angles, the inlet radius ratio and a non-dimensional length. From their results, several types of diffusers were chosen, and a plot of pressure recovery factor versus area ratio was made, shown in Figure (28).

Each curve in this plot represents a set of diffusers of the same wall angle but of different lengths. The particular type of annular diffuser is identified by its outer wall angle (which has a positive value if the cone is diverging, negative if the cone is converging), the inner wall angle, the inlet radius ratio and the non-dimensional diffuser length. For comparison, the four diffusers of the present investigation have also been plotted. Note that the identification expression for this set of diffusers is $20°, 20°, 0.6, (1.25, 1.50, 2.00, 3.00)$. 

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Two sets of diffusers studied by Sovran and Klomp, (30°, 29\frac{1}{2}°, 0.7, L/h and 15°, 15°, 0.7, L/h) have a geometry similar to those of the present investigation and show a similar performance trend. Results of the current investigation, for the case of flow with no swirl, are supported strongly by the results of Sovran and Klomp.

Referring to Figure (28) again, it is observed that if the outer wall angle is left at 20°, as the inner wall angle becomes less divergent, the pressure recovery factor for a constant value of area ratio decreases. The profile of pressure recovery factor versus area ratio, tends to become flatter.

Sovran and Klomp unfortunately did not include any results for a set of diffusers, which had a diverging outer cone and a converging inner cone. The trend of Figure (26) and the results obtained by Srinath predicts that such a set would have had a flat profile.

In the second performance plot Figure (27) pressure recovery factor is plotted against mass-weighted swirl angle for constant diffuser length. For the largest diffuser, swirl apparently has no effect on the pressure recovery factor, for smaller diffuser lengths, however, the inlet swirl has a small effect on the pressure recovery factor. When a small amount of swirl is introduced into the flow, the pressure recovery factor decreases, and as more swirl is added, the pressure recovery factor slowly increases. For the two shorter diffuser lengths the
increased swirl produces pressure recovery factors greater than for no-swirl flow. The diffuser with non-dimensional diffuser length equal to 6.35 (Diffuser B) shows the same trend.

The point of minimum pressure recovery factor shifts to a higher swirl angle as the non-dimensional diffuser lengths increases. The curves of $C_{PR}$ versus $\bar{\psi}$ flatten out as the diffuser length increases.

In general, an increase in swirl angle causes sharp radial pressure gradients to develop which will cause better mixing of the outer wall boundary layer with fluid having higher kinetic energy. This delays or even washes off completely the stall or flow separation from the outer wall. The divergence of the flow is thus brought closer to an ideal flow process. The pressure recovery therefore tends to increase.

The profiles, Figure (30), obtained by Srinath for $C_{PR}$ versus $\bar{\psi}$ for the equiangular divergent-convergent annular diffuser show an opposite trend. When swirl is introduced into the flow, the pressure recovery increases to a maximum value and then further increase in swirl decreases it. Srinath concluded that any increase in inlet swirl beyond the optimum value will bring down the diffuser performance.

The geometry of the present annular diffuser; that is the divergence of the inner cone, favors also the divergence of the flow. In the diffuser studied by Srinath, the converging inner cone, allowed early flow separation

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on the inner wall, especially at higher swirl angles. Here, the radial pressure gradients also lead to an adverse condition resulting from the centripetal flow of low energy air which in turn causes separation of the flow on the inner wall. This separation of flow on the inner wall causes considerable losses especially in the exit portions of the diffuser.

4.5.2. Diffuser Effectiveness

Two additional plots have been included in the performance plots, to show the distribution of the diffuser effectiveness, which has been redefined for the case of flow with inlet swirl. These plots are shown in Figures (31 and 32). The effect of inlet swirl is evident in both plots.

First consider the plot of diffuser effectiveness versus non-dimensional diffuser length. For low swirl, the trend is similar to that shown in the plot of pressure recovery factor versus non-dimensional diffuser length. As the diffuser length increases the diffuser effectiveness increases and tends to flatten out.

For higher swirl, it appears that as the diffuser length increases the diffuser effectiveness decreases sharply, reaches a minimum and then with further increase the effectiveness increases again. The effect of the inlet swirl becomes more pronounced in the plot of diffuser effectiveness versus mass-weighted inlet swirl angle for constant non-dimensional diffuser length.
For the largest diffuser, the diffuser effectiveness remains constant, swirl having no effect. For the other three diffusers, the presence of some swirl decreased the diffuser effectiveness and reached a minimum value. As the inlet swirl was further increased the effectiveness also increased, the increase being more rapid as the diffuser became shorter.
CHAPTER 5

CONCLUSIONS

1. The Pressure Recovery Factor, $C_{PR}$, increases with diffuser length, $L/h$, and tends to flatten out at higher values of diffuser length.

2. For a given Equiangular Divergent Annular Diffuser, $C_{PR}$ initially decreases with swirl, $\bar{\Omega}$, and then increases.

3. The effect of swirl on Diffuser Effectiveness is similar to its effect on $C_{PR}$. However, the swirl effect on Diffuser Effectiveness, $\eta$, is more pronounced for shorter diffuser lengths.

4. Equiangular Divergent Annular Diffusers perform better than Equiangular Divergent-Convergent Annular Diffusers, the diffuser effectiveness of the Divergent Annular Diffuser being considerably higher at increased inlet swirl.
<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0155</td>
<td>33 CONTINUE</td>
</tr>
<tr>
<td>0156</td>
<td>35 CALL LINE (PAPAY, VAPPA, 10, 1, 1, K)</td>
</tr>
<tr>
<td>0157</td>
<td>50 CONTINUE</td>
</tr>
<tr>
<td>0158</td>
<td>55 CALL PLOT (7, 6, 1, 3)</td>
</tr>
<tr>
<td>0159</td>
<td>60 CONTINUE</td>
</tr>
<tr>
<td>0160</td>
<td>90 CALL SYMBOL (P, 1, 14, 22)</td>
</tr>
<tr>
<td>0161</td>
<td>100 CALL PLOT (1, 1, 1, 1, 3)</td>
</tr>
<tr>
<td>0162</td>
<td>200 CALL PLOT (9, 1, 1, 1, 999)</td>
</tr>
<tr>
<td>0163</td>
<td>300 CALL EXIT</td>
</tr>
</tbody>
</table>

APPENDIX

A-3 continued
C INLET TURBULENCE PROFILE
DEFINITION TRIP (X,2), DADFRAY(1C), TARRAY(10)

13 CALL PLOTS (18,1,15,0)
20 CALL PLOT (-2,5,12,5,2)

21 CALL AXIS (-10,0), O, 0, X (P-RINR)/(ROTR-RINR), -2C, 5, 0, 9, 0, DARRAY(9), D

22 CALL AXIS (-1,0,0), 21H PERCENTAGE TURBULENCE, +21, 6, 9, 9, TARRAY(9)
1, TARRAY(11)

25 CALL SYMBOL (1, 5, 6, 5, 0, 14, 16) HAMILT TURBULENCE, +0, 0, 16)
33 CALL SYMBOL (1, 5, 25, 2, 14, 12) HPR DISTRIBUTION, 0, 0, 12)

16 FORMAT (4H, DIFFUSER)
5 DO 6, K, 1, 5
6 PRINT 17

17 FORMAT (3H, SWIRL ANGLE SETTING)
DO 19, I = 1, 9
PRINT 10, TARRAY, VNC, VRMS

19 FORMAT (7F, 5)
CORT = VNC(1)/VNC(1)/5, 27
VRMS(1) = TARRAY(11)/VRMS
VRMS(1) = VRMS(1)/VRMS, SOCT, PERCU

15 FORMAT (7F, 3)
I = 5

36 CALL LIP (DARRAY, TARRAY, 1, 1, 1, K)

CONTINUE

35 CONTINUE

55 CALL PLOT (18,5, 0, 6, -3)
54 CONTINUE

51 CALL SYMBOL (P, 14, 0, 6, 14, 22)
54 CONTINUE

1 CALL PLOT (10, 14, 1, 21)
1 CALL PLOT (10, 14, 1, 21)
1 CALL PLOT (10, 14, 1, 21)

11 CALL EXIT
APPENDIX

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APPENDIX B.

DIFFUSER EFFECTIVENESS

The diffuser effectiveness is defined as the ratio of the actual pressure recovery factor to the ideal pressure recovery factor.

\[ n = \frac{C_{FR}}{C_{FR_{I}}} \quad (B-1) \]

The actual pressure recovery factor is defined as the ratio of the mass weighted static pressure rise from the inlet to the diffuser outlet to the average dynamic pressure at the inlet.

\[ C_{FR} = \frac{P_{2} - P_{1}}{P_{D_{dyn}}_{1}} = \frac{\text{STATIC PRESSURE RISE}}{\text{DYNAMIC HEAD AT INLET}} \quad (B-2) \]

In the present study, the ideal pressure recovery factor has been defined on three assumptions. First, the flow is considered to be a free vortex. The streamlines in a free vortex flow are concentric circles about the center of the vortex and the velocity at any point in such a flow field is given by the following two components.

\[ \nu_{r} = \frac{K}{r} \quad (B-3) \]

\[ \nu_{\theta} = 0 \]

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The free vortex motion is irrotational except at the centre, where \( V_t \) approaches infinity. Secondly, the flow is in radial equilibrium and, thirdly, there are no losses. Then from continuity

\[
A_1 V_0 = A_2 V_{a_2} \tag{3-4}
\]

from Bernoulli

\[
\frac{P_1}{\gamma} + \frac{1}{2} V_1^2 = \frac{P_2}{\gamma} + \frac{1}{2} V_{a_2}^2 = C \tag{3-5}
\]

from Free Vortex Condition

\[
r_1 V_{r_1} = r_2 V_{r_2} \tag{3-6}
\]

The absolute velocity can easily be written in terms of its components: the axial velocity and the tangential velocity. The axial velocity is independent of radius; (assuming uniform flow); the tangential velocity is dependent on radius. Therefore,

\[
V_c^2 = V_0^2 + V_{r_0}^2 \tag{3-7}
\]

Equation 3.5 becomes,

\[
\frac{P_1(r)}{\gamma} + \frac{1}{2} (V_0^2 + V_{r_0}^2) = \frac{P_2(r)}{\gamma} + \frac{1}{2} (V_{a_2}^2 + V_{r_2}^2) \tag{3-8}
\]
Rewritting,
\[ \frac{P_2(r)-P(r)}{\gamma} = \frac{1}{2} \left\{ \left( V_{a1}^2 - V_{a2}^2 \right) + \left( V_{t1}(r)^2 - V_{t2}(r)^2 \right) \right\} \]  \hspace{1cm} (B-9)
\[ = \frac{1}{2} \left\{ V_{a1}^2 \left( 1 - \frac{r^2}{R_a^2} \right) + \frac{V_{t1}(r)^2}{V_{t1}} \left( 1 - \frac{r^2}{R_{t1}^2} \right) \right\} \]  \hspace{1cm} (B-10)

From Equation (B-9):
\[ V_{a2} = \frac{P_1}{P_2} \cdot V_{a2} \]

From Equation (B-4):
\[ V_{t2}(r) = \frac{r_1}{r_2} \cdot V_{t1}(r) \]

Substituting these values into Equation (B-10):
\[ \frac{P_2(r)-P(r)}{\gamma} = \frac{1}{2} \left\{ V_{a1}^2 \left( 1 - \frac{r^2}{R_a^2} \right) + \frac{V_{t1}(r)^2}{V_{t1}} \left( 1 - \frac{r^2}{R_{t1}^2} \right) \right\} \]  \hspace{1cm} (B-11)

The mass-weighted and non dimensional form of Equation (B-11) is
\[ \frac{\tilde{P}_2(r)-\tilde{P}(r)}{\tilde{V}_{a1}^2 \cdot \tilde{V}_{t1}^2} = \left\{ \left( \frac{\tilde{V}_{a1}}{\tilde{V}_{t1}} \right)^2 \left( 1 - \frac{r^2}{R_a^2} \right) + \left( \frac{\tilde{V}_{t1}(r)}{\tilde{V}_{t1}} \right)^2 \left( 1 - \frac{r^2}{R_{t1}^2} \right) \right\} \]  \hspace{1cm} (B-12)
where \( r_{im} \) and \( \tilde{r}_{im} \) are mean radii.

From the typical velocity triangle shown in Figure, where \( \psi \) is defined as a swirl angle, it is readily shown that
\[ V_a = V \cos \psi \]  \hspace{1cm} (B-13)
\[ V_t = V \sin \psi \]  \hspace{1cm} (B-14)
Substituting these values into Equation (8.12)

\[
\frac{\bar{P}(r) - \bar{P}(\infty)}{\frac{1}{2} \rho \bar{V}^2} = \cos^2 \psi \left(1 - \frac{P_a^2}{P_c^2}\right) + \sin^2 \psi \left(1 - \frac{r_{1m}^2}{r_{2m}^2}\right) \quad (8.15)
\]

Equation 8.15 is the final expression for the ideal pressure recovery factor, based on the condition of a free vortex flow. The expression differs considerably from the one for ideal one-dimensional flow, because it is not expressed wholly in terms of the diffuser geometry, but also contains the mass-weighted inlet swirl angle. However, at zero-swirl, the expression reduces to the expression for ideal one-dimensional flow.

\[
\frac{\bar{P}(r) - \bar{P}(\infty)}{\frac{1}{2} \rho \bar{V}^2} = 1 - \frac{1}{r_{1m}^2} \quad (8.16)
\]

In order to be able to apply the expression, an expression has to be found for the mean radii, \(r_{1m}\) and \(r_{2m}\).

Consider the variation in the radial direction, in a typical cross-sectional plane.

From Bernoulli,

\[
\frac{\bar{P}(r)}{\rho} + \frac{1}{2} \bar{V}^2 = \text{constant} = C \quad (8.17)
\]

From which

\[
\bar{P}(r) = C \bar{V} - \frac{1}{2} \bar{V}^2 = C \bar{V} - \frac{1}{2} (V_0^2 + I_c(r)^2) \quad (8.18)
\]

From Free Vortex Flow

\[
I_c(r) = K \quad (8.19)
\]
Substituting Equation B.9 into Equation B.15,

\[ P(r) = C \rho - \frac{\rho}{2} \left( \frac{\kappa^2}{r^2} + \frac{\kappa^2}{r^2} \right) \]

\[ = C \rho - \frac{\rho}{2} \frac{\kappa^2}{r^2} - \frac{\rho}{2} \frac{\kappa^2}{r^2} \]

\[ = \frac{C \rho}{2} - \frac{\rho}{2} \left( \frac{\kappa^2}{r^2} + \frac{\kappa^2}{r^2} \right) \]  \hspace{1cm} (B-20)

Defining

\[ M = C \rho - \frac{\rho}{2} \frac{\kappa^2}{r^2} \]  \hspace{1cm} (B-21a)

\[ N = \frac{\rho}{} \frac{\kappa^2}{2} \]  \hspace{1cm} (B-21b)

Equation B.20 then becomes

\[ P(r) = \frac{M - N}{2} \]  \hspace{1cm} (B-22)

The mass-weighted value of \( P(r) \) is found in the plane,

\[ \bar{P} = \frac{\int_{r_{in}}^{r_{out}} P(r)2\pi r \, dr \, \rho}{\int_{r_{in}}^{r_{out}} 2\pi r \, dr \, \rho} \]

\[ = \frac{\int_{r_{in}}^{r_{out}} (M - \frac{\rho}{2} \frac{\kappa^2}{r^2}) \, r \, dr}{\int_{r_{in}}^{r_{out}} 2\pi r \, dr \, \rho} \]

\[ = \frac{2\pi}{\pi} \int_{r_{in}}^{r_{out}} (M - \frac{\rho}{2} \frac{\kappa^2}{r^2}) \, r \, dr \]

\[ = \frac{M - N}{2} \frac{2\pi}{\ln(r_{out}/r_{in})} \frac{\kappa^2}{(r_{out}^2 - r_{in}^2)} \]  \hspace{1cm} (B-24)

However from Equation B.22,

\[ \bar{P} = M - N \frac{\rho}{r_{in}^2} \]  \hspace{1cm} (B-25)

Equating Equations B.24 and B.25,

\[ \frac{r_{in}^2}{2} = \frac{(r_{out}^2 - r_{in}^2)}{2 \ln(r_{out}/r_{in})} \]  \hspace{1cm} (B-26)

Therefore, summarizing

\[ C_{PMF} = \frac{\bar{P} - \bar{P}}{\frac{r_{in}^2}{2}} = \cos^2 \epsilon \left( 1 - \frac{r_{in}^2}{r_{out}^2} \right) + \sin^2 \epsilon \left( 1 - \frac{r_{in}^2}{r_{in}^2} \right) \]

\[ \text{where } r_{in}^2 = \frac{(r_{out}^2 - r_{in}^2)}{2 \ln(r_{out}/r_{in})} \]  \hspace{1cm} (B-27)
APPENDIX C

DESIGN OF THE SWIRL GENERATOR

The swirl in the annulus is created by a set of vanes arranged radially at the inlet to the annulus. The vanes have an NACA 0012 cross-section and a three inch chord. The angle of the airfoils to the incoming flow may be varied from 0 degrees (no swirl) to 45 degrees. The vane arrangement and the inlet contours are shown in the figure on the next page. This type of arrangement introduces a vortex, similar to a free vortex, into the entering flow.

The vanes have a maximum tip diameter of twenty-four inches.

In order to establish a well behaved swirl or vortex, it was necessary to design a flow contour block. The incoming flow must be continuously accelerated up to the annulus velocity in order to avoid separation and consequent disruption of the swirl.

An analysis was carried out and was subsequently modified by United Aircraft of Canada Limited.

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**DESIGN ANALYSIS**

The Schneider Analysis

Design Conditions: Using geometric conditions required for the annulus.

(a) hub radius \( r_{1,\text{HUB}} = 2.5" \)

(b) tip radius \( r_{1,\text{TIP}} = 4.0" \)

(c) mass flow rate \( Q = 1867 \text{ cfm} \)
By the continuity equation \( \nabla \cdot \mathbf{v} = \nabla \cdot (\mathbf{V} \cdot \mathbf{A}) \)

\[
\frac{1667}{60} = \nabla \cdot (4.5^2 - 2.5^2) \quad (C-1)
\]

\[
V = \frac{1667 \times 14.1}{60 \times 30.7} = 14.0 \text{ ft/sec} \quad (C-2)
\]

Thus the velocity at the exit plane is to be 14.0 ft/sec.

From these conditions and supposing an inlet radius \( r_2 \) of 11" the angular momentum and continuity equations are used to find the inlet opening "3".

\[
T = rQ \left( r_2 V_2 \cos \alpha_2 - r_1 V_1 \cos \alpha_1 \right) \quad (C-3)
\]

where \( T \) becomes zero as in passages where there are no vanes.

\[
\therefore \quad rQ r_2 V_2 \cos \alpha_2 = rQ r_1 V_1 \cos \alpha_1 \quad (C-4)
\]

with

\[
\alpha_2 = \alpha_1 = 0^\circ \quad (\alpha \text{ is the swirl angle})
\]

\[
r_2 V_2 = r_1 V_1 \quad (C-5)
\]

This \( rV \) = constant, which is free vortex motion with the tangential component of velocity varying inversely with radius.

Taking the mean value for \( r_2 \) of 3.25"

\[
V_1 = 3.25 \times 14.1 \times 12 / (11 \times 12) = 4.3 \text{ ft/sec}
\]

and

\[
A = \frac{Q}{V} = \frac{1467 \times 14.1}{60 \times 30.7} = \approx 77 \text{ in}^2 \quad (C-6)
\]

with \( r = 11" \)

\[
\frac{1467 \times 14.1}{60 \times 30.7 \times 14.1 \times 12 / (11 \times 12} = 277 \text{ in}^2
\]

\[
= 1.50 \text{ inches}
\]

Similar calculations for \( r = 13" \) yield \( \beta = 1.503" \).

The dust profile submitted by the writer (called "Schneider analysis") was put through the U.A.S.I.
computer without any changes. The program used was UACL-D1118: MULTIPLE PLANE COMPLETE RADIAL EQUILIBRIUM.

From the program output the velocity and pressure distributions were plotted versus sweep angle $0^\circ$ for various planes as seen on profile (1), Figure (12A). The velocity distribution, for $0^\circ$ swirl, Figure (12B), shows a fairly smooth acceleration along the tip contour which by itself would be acceptable. The hub velocity, on the other hand shows a peak at plane 4 and a sharp drop at plane 5. This drop is accompanied by a sharp increase in static pressure at plane 5 as seen in Figure (12C). The increase in static pressure is due mostly to the high curvature change from plane 4 to 5 (increase in curvature) hence the velocity in this region is lower (decreased).

Although the acceleration along the tip contour is smooth, the diffusion factor, defined as

$$D_{\text{tip}} = 1 - \frac{\text{Velocity out}}{\text{Velocity max}}$$

has a value of 0.0232.

This in itself is far from critical but in view of the flow conditions at the hub there is a possibility of flow distortion in the exit portion of the duct.

In the case of $45^\circ$ swirl at the inlet, with the same profile, the flow conditions are greatly improved. As can be seen from Figure (12D), the velocity along both walls increases smoothly and the hump on the duct hub contour
velocity curve disappears resulting in much improved flow conditions.

The Modified Analysis by United Aircraft Limited

The analysis in this case considers the same flow parameters and geometric conditions as in the Schneider analysis but differs in the duct profile. It was felt that the Schneider profile did not turn the flow early enough upstream but rather turned very late, as shown by the high curvatures at planes 4 and 5.

A comparison of the UACL profile, Profile 2, Figure (12F), and Profile 1, Figure (12A), show earlier turning in Profile 2 resulting in a continuous acceleration throughout the entire length of the duct. The advantage of early turning of the flow is that if any imperfections in the contours occur in a region of high curvature, the flow will feel these effects much more than in a region where curvatures are low. Therefore, with early turning, the flow can use the rest of the duct to stabilize itself, whereas when the flow is turned in the late stages there is no time for stabilization. Again this analysis was done for both 0° and 45° swirl angles at the inlet.
APPENDIX D
ERROR ANALYSIS

Accuracy of Measurements

The multitube tilting manometer used in the present investigation had a reading accuracy of 0.10 inches of water, and the radial position of the probe could be read to an accuracy of 0.01 inch. From wind tunnel calibration tests, using the test probe and a standard pitot static probe calibration curves were obtained for the static pressure and total pressure readings taken with the two probes.

Due to some inevitable fluctuations of the manometer readings, it was sometimes necessary to select an average reading. Secondly the manometer had sometimes slow response to the applied pressures. Care was taken to wait for some time before taking the readings. The static pressure tube was susceptible to greater error as non-alignment with the flow could cause greater error. It was more sensitive to non-alignment than the total pressure tube. It was estimated that the accuracy of the total pressure measurements was ± 0.20"H2O and that of the static pressure measurements was ± 0.30"H2O.

The error in the pressure recovery factor is analyzed below by incorporating the Uncertainty Analysis Standard Equation:

\[
\omega_p = \left\{ \left( \frac{\partial \omega_r}{\partial x_1} \omega_r \right)^2 + \left( \frac{\partial \omega_r}{\partial x_2} \omega_r \right)^2 + \cdots + \left( \frac{\partial \omega_r}{\partial x_n} \omega_r \right)^2 \right\}^{\frac{1}{2}} \tag{D-1}
\]

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where $R$ is a given function of the independent variable $x_1, x_2, x_3 \ldots x_n$.

$w_R$ is the uncertainty in the result.

$w_1, w_2, w_3 \ldots w_n$ are the uncertainties in the independent variables.

Equation for the Pressure Recovery Factor:

$$C_{PR} = \frac{P_{S2} - P_{S1}}{P_{dyn}} = \frac{P_{S2} - P_{S1}}{P_{T1} - P_{S1}} \quad (D-2)$$

Since $P_{S2}$ was assumed to be equal to the ambient pressure,

$$P_{S2} = 0 \text{ gauge}$$

Therefore,

$$C_{PR} = -\frac{P_{S1}}{P_{T1} - P_{S1}} \quad (D-3)$$

Then, applying the General Equation for the Uncertainty Analysis,

$$w_{C_{PR}} = \left\{ \left( \frac{\partial C_{PR}}{\partial P_{S1}} w_{P_{S1}} \right)^2 + \left( \frac{\partial C_{PR}}{\partial P_{T1}} w_{P_{T1}} \right)^2 \right\}^{1/2} \quad (D-4)$$

Upon differentiation:

$$\frac{\partial C_{PR}}{\partial P_{S1}} = -\frac{P_{S1}}{(P_{T1} - P_{S1})^2} \quad (D-5)$$

$$\frac{\partial C_{PR}}{\partial P_{T1}} = \frac{P_{S1}}{(P_{T1} - P_{S1})^2} \quad (D-6)$$

As an example, consider Diffuser A at maximum swirl condition: $P_{S1} = -6.017''$ H$_2$O, $P_{S2} = 0$, and $P_{T1} = 2.433''$ H$_2$O. Then

$$\frac{\partial C_{PR}}{\partial P_{S1}} = \frac{-2.433(7.07)}{[(2.433)(7.07) - (-6.017)(7.07)]^2} = -\frac{24.33}{50.5}$$

$$\frac{\partial C_{PR}}{\partial P_{T1}} = \frac{(-6.017)(7.07)}{[(2.433)(7.07) - (-6.017)(7.07)]^2} = -\frac{44.26}{50.5}$$
And the Uncertainty Values are:

\[ \omega_{PS} = \pm 0.10 \pm 1.20 = \pm 1.30 \]  
\[ \omega_{PT} = \pm 0.10 \pm 1.10 = \pm 1.20 \]

The error in the Pressure Recovery Factor is

\[ \omega_{PR} = \left\{ \left( -\frac{2.433}{50.5} \times 30 \right)^2 + \left( -\frac{4.24}{50.5} \times 20 \right)^2 \right\}^{\frac{1}{2}} \]

\[ = 2.2 \% \]

From windtunnel calibration tests it was found that the accuracy of the yaw probes was approximately \( \pm 2.0^\circ \).

A similar error analysis was carried out for the axial velocity.

\[ V_a = V \cos \alpha \]

\[ = \left( \frac{2g}{12} \left( \frac{P_T - P_S}{P_{air}} \right) \left( \frac{T_{in}}{T_{ref}} - 1 \right) \right)^{\frac{1}{2}} \cos \alpha \]

\[ = 70 \left( P_T - P_S \right)^{\frac{1}{2}} \cos \alpha \]

where \( P_T \) and \( P_S \) were measured in inches of water in a manometer.

Applying the Uncertainty Analysis, one obtains

\[ \omega_{V_a} = \left\{ \left( \frac{\alpha V_a}{\alpha P_S} \omega_{P_S} \right)^2 + \left( \frac{\alpha V_a}{\alpha P_T} \omega_{P_T} \right)^2 + \left( \frac{\alpha V_a}{\alpha \alpha} \omega_{\alpha} \right)^2 \right\}^{\frac{1}{2}} \]

where

\[ \frac{\alpha V_a}{\alpha P_S} = -70 \cos \alpha \left( \frac{1}{2} \right) \left( P_T - P_S \right)^{-\frac{1}{2}} \]

\[ \frac{\alpha V_a}{\alpha P_T} = 70 \cos \alpha \left( \frac{1}{2} \right) \left( P_T - P_S \right)^{-\frac{1}{2}} \]

\[ \frac{\alpha V_a}{\alpha \alpha} = -70 \left( P_T - P_S \right)^{\frac{1}{2}} \sin \alpha \]

Considering again Diffuser A at maximum swirl condition it is found that
\[ \frac{\partial V_3}{\partial P_3} = -12.8 \quad \frac{\partial V_4}{\partial P_T} = 12.8 \quad \frac{\partial V_5}{\partial \alpha} = -48.0 \]

And the Uncertainty Values are
\[ u_{P_3} = \pm 0.30 \]
\[ u_{P_T} = \pm 20 \]
\[ u_{\alpha} = \pm 2 \]

The error in the Axial Velocity is
\[ u_{V_6} = \left\{ (-12.8 \times 0.30)^2 + (12.8 \times 20)^2 + (-48.0 \times 2.0)^2 \right\}^{1/2} \]
\[ = 5.2\% \]
APPENDIX-E

MASS-WEIGHTED AVERAGES

The mass weighted average $Q$ is defined as

$$
\overline{Q} = \frac{\int_0^{2\pi} \int_{r_i}^{r_o} Q \, dm}{\int_0^{2\pi} \int_{r_i}^{r_o} dm} \quad (E-1)
$$

where $Q$ could be $\rho$, $P$, or $\psi$ and $m$ is the mass flow across any section.

$$
\overline{Q} = \frac{\int_A \gamma(VQ) \, dA}{\int_A \gamma V \, dA} \quad (E-2)
$$

or

For incompressible and axisymmetric flow

$$
\overline{Q} = \frac{\int_{r_i}^{r_o} VQ \, r \, dr}{\int_{r_i}^{r_o} V \, r \, dr} \quad (E-3)
$$

where $V$ is the velocity in the axial direction.

From the measured value of $\rho$, $P$, and $\psi$, the mass weighted averages were obtained by a step by step numerical integration. A computer program was prepared to carry out this integration.
REFERENCES

(1) Brighton, J.A. Jones, J. B. Fully Developed Flow in Annuli ASME Paper # 64 PE2

(2) Cockrell, David J. King, A. L. Flow Through Diffusers Ruhr - Universität Fochum Lehrstuhlfür Strömungs maschinen

(3) Eiffel, G. Notes on the Calculation of the Efficiency Coefficients of Air Channels, Paris, 1918


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<td>Fox, R. W.</td>
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(17) Yeh, H. Boundary Layer Along Annular Walls in Swirl Flow
### Inlet Experimental Data

**Diffuser:** D/L = 1.266

- **Flow Temperature:** 66°F
- **Room Temperature:** 54°F
- **Barometric Pressure:** 28.62" Hg

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<th>DIST FROM INNER SURF (INCHES)</th>
<th>SWIM ANGLE</th>
<th>PS STATIC PRESSURE INCHES WATER 45° F CAP SLOPE</th>
<th>PT TOTAL PRESSURE INCHES WATER 45° F CAP SLOPE</th>
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### Inlet Calculated Results

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<th>REL VEL (FT/SEC)</th>
<th>TUR VEL (FT/SEC)</th>
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### EXPERIMENTAL DATA

**Differential Flow Temperature** = 10°F

**Rock Temperature** = 69°F

**Barometric Pressure** = 28.67" Hg

### INLET

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<th>Static Pressure, Inches Water</th>
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### EXIT CALCULATED RESULTS

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INLET TURBULENCE DATA

DIFFUSER A

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<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
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<th>RMS VOLTAGE MILLIVOLTS</th>
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RELATIVE TURBULENCE

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INLET EXPERIMENTAL DATA

DIFFUSER A, L/H = 0.66
FLOW TEMPERATURE = 60°C
ROOM TEMPERATURE = 20°C
BAROMETRIC PRESSURE = 29.65" Hg

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INLET CALCULATED RESULTS

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<th>ABS. VELOCITY</th>
<th>AXIAL VELOCITY</th>
<th>TAN VELOCITY</th>
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<tr>
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<td>FT/SEC</td>
<td>FT/SEC</td>
<td>FT/SEC</td>
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<td>152.592</td>
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<td>112.446</td>
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Diffuser:

Flow Temperature = 110°F
Room Temperature = 68°F
Barometric Pressure = 29.6 inHg

<table>
<thead>
<tr>
<th>Exit</th>
<th>Up Angle</th>
<th>Static Pressure</th>
<th>Total Pressure</th>
</tr>
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<tr>
<td></td>
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<td>Inches Water</td>
<td>Inches Water</td>
</tr>
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</tr>
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</tr>
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<td>0.72</td>
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</tr>
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Exit Calculated Results:

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<th>Down Velocity</th>
<th>Total Velocity</th>
</tr>
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<tr>
<td></td>
<td>Max</td>
<td>Min</td>
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<td>0.24</td>
<td>67.2</td>
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<td>0.48</td>
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<td>1.20</td>
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<td>5.5</td>
</tr>
</tbody>
</table>

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## INLET TURBULENCE DATA

**Diffuser** A, L/H 12.45  
**Flow Temperature** 110.0°F  
**Room Temperature** 60.0°F  
**Barometric Pressure** 29.60" Hg  
**Mass Weighted Swirl Angle** 3.532°  

<table>
<thead>
<tr>
<th>Distance from Inner Surface (Inches)</th>
<th>DC Voltage (Volts)</th>
<th>RMS Voltage (Millivolts)</th>
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</thead>
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<tr>
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<td>0.610</td>
<td>9.700</td>
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<tr>
<td>0.760</td>
<td>9.750</td>
<td>0.097</td>
</tr>
<tr>
<td>0.910</td>
<td>9.750</td>
<td>0.090</td>
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<td>9.750</td>
<td>0.109</td>
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<td>1.180</td>
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<td>0.137</td>
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<td>9.550</td>
<td>0.197</td>
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## RELATIVE TURBULENCE

<table>
<thead>
<tr>
<th>Distance from Inner Surface (Inches)</th>
<th>Percentage Turbulence</th>
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<tbody>
<tr>
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<tr>
<td>0.450</td>
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</tr>
<tr>
<td>0.610</td>
<td>6.965</td>
</tr>
<tr>
<td>0.760</td>
<td>5.719</td>
</tr>
<tr>
<td>0.910</td>
<td>5.306</td>
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<td>1.050</td>
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<tr>
<td>1.180</td>
<td>8.236</td>
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<tr>
<td>1.310</td>
<td>12.082</td>
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COLD RESISTANCE OF HOT WIRE 3.40 OHMS
### INLET EXPERIMENTAL DATA

**DIFFUSER F, L/H = 12.65**

- **FLOW TEMPERATURE** = 110.0°F
- **ROOM TEMPERATURE** = 82.0°F
- **BAROMETRIC PRESSURE** = 28.92" Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF. INCHES</th>
<th>SWIRL ANGLE</th>
<th>PS STATIC PRESSURE INCHES WATER 45 DEG SLOPE</th>
<th>DT TOTAL PRESSURE INCHES WATER 45 DEG SLOPE</th>
</tr>
</thead>
<tbody>
<tr>
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<td>8.733</td>
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<td>5.067</td>
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<td>9.733</td>
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<td>9.933</td>
<td>5.550</td>
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<td>5.755</td>
<td>2.617</td>
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<td>15.667</td>
<td>5.883</td>
<td>2.617</td>
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<td>5.967</td>
<td>2.617</td>
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<td>1.180</td>
<td>11.067</td>
<td>5.717</td>
<td>2.617</td>
</tr>
<tr>
<td>1.310</td>
<td>11.067</td>
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<td>1.350</td>
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<td>5.317</td>
<td>1.047</td>
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</table>

### INLET CALCULATED RESULTS

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF. INCHES</th>
<th>ABS VELOCITY FT/SEC</th>
<th>AXIAL VELOCITY FT/SEC</th>
<th>TANGENTIAL VELOCITY FT/SEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.500</td>
<td>132.694</td>
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<td>24.37</td>
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<td>29.68</td>
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### Exit Experimental Data

**Diffused Flow**
- Flow Temperature: 10.0°F
- Flow Temperature: 88.0°F
- Barometric Pressure: 29.62" Hg

<table>
<thead>
<tr>
<th>Flow Temperature</th>
<th>Static Pressure</th>
<th>Total Pressure</th>
</tr>
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<tbody>
<tr>
<td>10.0°F</td>
<td>4.5&quot; Hg Water</td>
<td>76.5&quot; Hg Water</td>
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<td>88.0°F</td>
<td>76.7&quot; Hg Water</td>
<td>84.7&quot; Hg Water</td>
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### Exit Calculated Results

<table>
<thead>
<tr>
<th>Flow Temperature</th>
<th>Static Pressure</th>
<th>Total Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0°F</td>
<td>4.5&quot; Hg Water</td>
<td>76.5&quot; Hg Water</td>
</tr>
<tr>
<td>88.0°F</td>
<td>76.7&quot; Hg Water</td>
<td>84.7&quot; Hg Water</td>
</tr>
</tbody>
</table>

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INLET TURBULENCE DATA

DIFFUSER A, L/H 12.65
FLOW TEMPERATURE 110.0°F
ROOM TEMPERATURE 82.0°F
BAROMETRIC PRESSURE 29.62" Hg
MASS WEIGHTED SWIRL ANGLE 10.267°

COLD RESISTANCE OF HOT WIRE = 3.40 OHMS

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
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<td>9.650</td>
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<td>1.180</td>
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<td>0.280</td>
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RELATIVE TURBULENCE

<table>
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<tr>
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<th>PERCENTAGE TURBULENCE</th>
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### INLET EXPERIMENTAL DATA

**DIFFUSER**

- **A**
- **L/M = 18.65**

**Flow Temperature** = 110.0°F

**Room Temperature** = 82.0°F

**Barometric Pressure** = 23.62 in Hg

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<th>SWEEP ANGLE</th>
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<th>TOTAL PRESSURE INCHES WATER 45° SLOPE</th>
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<td>6.533</td>
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### INLET CALCULATED RESULTS

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<th>GAS VELOCITY</th>
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<th>TANGENTIAL VELOCITY</th>
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</table>

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### EXPERIMENTAL DATA

**Diffuser R:** 12.65
**Flow Temperature:** 110.6°F
**Total Temperature:** 82.0°F
**Barometric Pressure:** 28.63" Hg

<table>
<thead>
<tr>
<th>Toe Inlet / Exit</th>
<th>T.S.P. &amp; Static</th>
<th>T.S.P. &amp; Static w/ Wing Slope</th>
<th>Total Pressure &amp; Static w/ Wing Slope</th>
</tr>
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<tbody>
<tr>
<td>0.20</td>
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<td>0.21</td>
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<tr>
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### CALCULATED RESULTS

<table>
<thead>
<tr>
<th>Exit</th>
<th>T.S.P. &amp; Static</th>
<th>T.S.P. &amp; Static w/ Wing Slope</th>
<th>Total Pressure &amp; Static w/ Wing Slope</th>
</tr>
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<tbody>
<tr>
<td>0.20</td>
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<td>0.75</td>
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<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
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INLET TURBULENCE DATA

DIFFUSER A, L/H 12.45
FLOW TEMPERATURE 110.0°F
ROOM TEMPERATURE 88.0°F
BAROMETRIC PRESSURE 29.62 "Hg
MASS WEIGHTED SWIRL ANGLE 15.603 °

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.750</td>
<td>0.145</td>
</tr>
<tr>
<td>0.450</td>
<td>9.850</td>
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</tr>
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<td>0.610</td>
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<td>0.760</td>
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RELATIVE TURBULENCE

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>PERCENTAGE TURBULENCE</th>
</tr>
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<tbody>
<tr>
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<td>0.910</td>
<td>6.074</td>
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<tr>
<td>1.180</td>
<td>9.460</td>
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<tr>
<td>1.310</td>
<td>15.329</td>
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INLET EXPERIMENTAL DATA

DIFFUSER \( A \), \( L/H = 12.67 \)
FLOW TEMPERATURE, \( 110.0 \)°F
ROOM TEMPERATURE, \( 88.0 \)°F
BAROMETRIC PRESSURE, \( 29.62 \) in. Hg

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE (INCHES)</th>
<th>SWEEP ANGLE</th>
<th>STATIC PRESSURE (INCHES WATER)</th>
<th>TOTAL PRESSURE (INCHES WATER)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ACROSS SLOPE</td>
<td>AROUND SLOPE</td>
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<tr>
<td>0.0690</td>
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<td>3.443</td>
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<td>2.217</td>
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<tr>
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<td>26.033</td>
<td>5.917</td>
<td>1.997</td>
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INLET CALCULATED RESULTS

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE (INCHES)</th>
<th>AVG. VELOCITY (FT/SEC)</th>
<th>ANGLE VELOCITY (FT/SEC)</th>
<th>DAV. VELOCITY (FT/SEC)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>FT/SEC</td>
<td>FT/SEC</td>
<td>FT/SEC</td>
</tr>
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<td>14.842</td>
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<td>75.31</td>
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<td>75.36</td>
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<td>76.96</td>
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<td>76.36</td>
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<td>147.47</td>
<td>74.45</td>
</tr>
</tbody>
</table>

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### DETERMINED EXPERIMENTAL DATA

- **Flow Temperature:** 116.0 °F
- **Room Temperature:** 68.0 °F
- **Barometric Pressure:** 29.62" Hg

### Distances from Inner Slit (Inches) vs. Static Pressure (Inches of Water Apeco Slide)

<table>
<thead>
<tr>
<th>Dist from Inner Slit (Inches)</th>
<th>Static Pressure (Inches of Water Apeco Slide)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>1.5, 1.6</td>
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<tr>
<td>0.45</td>
<td>3.0, 3.1</td>
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<tr>
<td>0.55</td>
<td>14.3, 15.4</td>
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<tr>
<td>0.65</td>
<td>1.0, 1.0</td>
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<tr>
<td>0.85</td>
<td>1.6, 1.7</td>
</tr>
<tr>
<td>1.05</td>
<td>1.6, 1.7</td>
</tr>
<tr>
<td>1.15</td>
<td>1.7, 1.8</td>
</tr>
<tr>
<td>1.25</td>
<td>2.1, 2.2</td>
</tr>
<tr>
<td>1.45</td>
<td>2.6, 2.6</td>
</tr>
</tbody>
</table>

### EXIT: CALCULATED RESULTS

<table>
<thead>
<tr>
<th>Dist from Inner Slit (Inches)</th>
<th>Static Pressure (Inches of Water Apeco Slide)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>6.5, 6.7</td>
</tr>
<tr>
<td>0.45</td>
<td>5.9, 6.0</td>
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<tr>
<td>0.55</td>
<td>4.7, 4.8</td>
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<tr>
<td>0.65</td>
<td>4.6, 4.7</td>
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<tr>
<td>0.85</td>
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<td>1.25</td>
<td>5, 5</td>
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</table>

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INLET TURBULENCE DATA

DIFFUSER A, L/H 12.45
FLOW TEMPERATURE 110.0 °F
ROOM TEMPERATURE 82.0 °F
BAROMETRIC PRESSURE 29.42 "Hg
MASS WEIGHTED SWIRL ANGLE 87.045 °

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.750</td>
<td>0.168</td>
</tr>
<tr>
<td>0.450</td>
<td>9.850</td>
<td>0.121</td>
</tr>
<tr>
<td>0.610</td>
<td>9.850</td>
<td>0.105</td>
</tr>
<tr>
<td>0.760</td>
<td>9.900</td>
<td>0.098</td>
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<tr>
<td>0.910</td>
<td>9.900</td>
<td>0.112</td>
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<td>9.900</td>
<td>0.125</td>
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<td>9.850</td>
<td>0.155</td>
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<tr>
<td>1.310</td>
<td>9.800</td>
<td>0.255</td>
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RELATIVE TURBULENCE:

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>PERCENTAGE TURBULENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
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<td>0.450</td>
<td>6.999</td>
</tr>
<tr>
<td>0.610</td>
<td>6.074</td>
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<td>0.760</td>
<td>5.616</td>
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<td>0.910</td>
<td>6.418</td>
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<td>1.050</td>
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<td>8.966</td>
</tr>
<tr>
<td>1.310</td>
<td>14.891</td>
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</tbody>
</table>

COLD RESISTANCE OF HOT WIRE = 3.70 OHMS

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### Inlet Experimental Data

**Diffuser**
- 
- Flow Temperature: 110.0°F
- Room Temperature: 80.0°F
- Barometric Pressure: 29.82" Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>SWIRL ANGLE</th>
<th>PS STATIC PRESSURE INCHES WATER 45° SLOPE</th>
<th>PS TOTAL PRESSURE INCHES WATER 45° SLOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.200</td>
<td>1.233</td>
<td>3.617</td>
<td>1.340</td>
</tr>
<tr>
<td>0.250</td>
<td>1.767</td>
<td>3.667</td>
<td>2.283</td>
</tr>
<tr>
<td>0.450</td>
<td>1.600</td>
<td>3.217</td>
<td>3.217</td>
</tr>
<tr>
<td>0.610</td>
<td>1.800</td>
<td>3.967</td>
<td>3.045</td>
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<td>0.760</td>
<td>2.023</td>
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</tr>
<tr>
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<td>1.210</td>
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<td>2.267</td>
</tr>
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<td>1.310</td>
<td>1.167</td>
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<td>4.630</td>
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<td>1.440</td>
<td>1.510</td>
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### Inlet Calculated Results

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<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>ABS VELOCITY</th>
<th>AXIAL VELOCITY</th>
<th>TAN VELOCITY</th>
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<td>0.450</td>
<td>158.476</td>
<td>159.469</td>
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<tr>
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<td>156.619</td>
<td>156.619</td>
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<td>1.440</td>
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<td>118.659</td>
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EXIT EXPERIMENTAL DATA

DIFFUSER

FLOW TEMPERATURE = 110.6°C
ROOM TEMPERATURE = 88.0°F
BAROMETRIC PRESSURE = 28.60°Hg

<table>
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<tr>
<th>DIST FROM INNER SURF</th>
<th>DRY AIR</th>
<th>STATIC PRESSURE</th>
<th>TOTAL PRESSURE</th>
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<tbody>
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<td>INCHES WATER</td>
<td>INCHES WATER</td>
<td>INCHES WATER</td>
</tr>
<tr>
<td>0.080</td>
<td>0.570</td>
<td>0.300</td>
<td>0.550</td>
</tr>
<tr>
<td>0.250</td>
<td>0.600</td>
<td>0.300</td>
<td>0.700</td>
</tr>
<tr>
<td>0.420</td>
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<td>0.700</td>
</tr>
<tr>
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<td>0.600</td>
<td>0.300</td>
<td>0.700</td>
</tr>
<tr>
<td>0.720</td>
<td>0.600</td>
<td>0.300</td>
<td>0.700</td>
</tr>
<tr>
<td>0.870</td>
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<td>0.300</td>
<td>0.700</td>
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<tr>
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<td>0.300</td>
<td>0.700</td>
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<td>1.320</td>
<td>0.600</td>
<td>0.300</td>
<td>0.700</td>
</tr>
<tr>
<td>1.470</td>
<td>0.600</td>
<td>0.300</td>
<td>0.700</td>
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EXIT CALCULATED RESULTS

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<th>DIST FROM INNER SURF</th>
<th>DRY AIR</th>
<th>TOTAL VOLUME</th>
<th>TOTAL VOLUME</th>
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</thead>
<tbody>
<tr>
<td>INCHES</td>
<td>FT³/SEC</td>
<td>BTU/SEC</td>
<td>BTU/SEC</td>
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<td>12.557</td>
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<td>1.657</td>
<td>11.437</td>
<td>12.557</td>
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<td>1.657</td>
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<td>12.557</td>
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<td>12.557</td>
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<tr>
<td>1.000</td>
<td>1.657</td>
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<tr>
<td>1.470</td>
<td>1.657</td>
<td>11.437</td>
<td>12.557</td>
</tr>
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</table>

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INLET TURBULENCE DATA

DIFFUSER B, L/H 6.35
FLOW TEMPERATURE 116.6°F
ROOM TEMPERATURE 80.0°F
BAROMETRIC PRESSURE 29.20 "Hg
MASS WEIGHTED SWIRL ANGLE 1.272°

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.750</td>
<td>0.145</td>
</tr>
<tr>
<td>0.450</td>
<td>9.800</td>
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<tr>
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<tr>
<td>0.760</td>
<td>9.820</td>
<td>0.094</td>
</tr>
<tr>
<td>0.910</td>
<td>9.800</td>
<td>0.122</td>
</tr>
<tr>
<td>1.050</td>
<td>9.720</td>
<td>0.155</td>
</tr>
<tr>
<td>1.180</td>
<td>9.650</td>
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</tr>
<tr>
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<td>0.255</td>
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RELATIVE TURBULENCE

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>PERCENTAGE TURBULENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>8.549</td>
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<tr>
<td>0.450</td>
<td>6.307</td>
</tr>
<tr>
<td>0.610</td>
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<tr>
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<td>0.910</td>
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<td>1.050</td>
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</tr>
<tr>
<td>1.310</td>
<td>15.483</td>
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### INLET EXPERIMENTAL DATA

**DIFFUSER**

- **Flow Temperature:** 110.0°F
- **Room Temperature:** 70.0°F
- **Bargometric Pressure:** 22.43 "Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>SWIRL ANGLE</th>
<th>STATIC PRESSURE INCHES WATER</th>
<th>TOTAL PRESSURE INCHES WATER</th>
<th>LDRG SLOPE</th>
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<tbody>
<tr>
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<td>3.850</td>
<td>1.583</td>
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</tr>
<tr>
<td>0.093</td>
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<td>4.138</td>
<td>3.000</td>
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</tr>
<tr>
<td>0.096</td>
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<td>4.267</td>
<td>3.252</td>
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<tr>
<td>0.096</td>
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<tr>
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<td>4.559</td>
<td>3.483</td>
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<tr>
<td>0.093</td>
<td>4.667</td>
<td>4.567</td>
<td>3.247</td>
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</tr>
<tr>
<td>0.093</td>
<td>4.667</td>
<td>4.433</td>
<td>2.582</td>
<td></td>
</tr>
<tr>
<td>0.093</td>
<td>4.500</td>
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</tr>
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<td>0.093</td>
<td>4.457</td>
<td>3.793</td>
<td>1.952</td>
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</tbody>
</table>

### INLET CALCULATED RESULTS

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>ABS. VEL.</th>
<th>TOTAL VELOCITY</th>
<th>TAN VELOCITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.090</td>
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<td>120.167</td>
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<tr>
<td>0.096</td>
<td>167.583</td>
<td>169.807</td>
<td>126.612</td>
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**EXIT EXPERIMENTAL DATA**

**DIFFUSION**  
$1.11 = 6.35$

**FLOW TEMPERATURE** = $115.0\,^\circ F$

**ROOM TEMPERATURE** = $76.0\,^\circ F$

**DIASTOMIC PRESSURE** = $20.0\,\text{ repeat}^2$

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**EXIT CALCULATED RESULTS**

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INLET TURBULENCE DATA

DIFFUSER $B$, L/H 4 25
FLOW TEMPERATURE $110.0^\circ F$
ROOM TEMPERATURE $78.0^\circ F$
BAROMETRIC PRESSURE 23.43 "Hg
MASS WEIGHTED SWIRL ANGLE 0.285^

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<th>RMS VOLTAGE MILLIVOLTS</th>
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RELATIVE TURBULENCE

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### INLET EXPERIMENTAL DATA

**Diffuser B**

- **Flow Temperature:** 118°F
- **Room Temperature:** 86°F
- **Barometric Pressure:** 29.41" Hg

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### INLET CALCULATED RESULTS

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<th>AXIAL VELOCITY</th>
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## EXPERIMENTAL DATA

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## CALCULATED RESULTS

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<td>FT/SEC</td>
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INLET TURBULENCE DATA

DIFFUSER $B$, $L/H = 0.35$
FLOW TEMPERATURE $118^\circ C$
ROOM TEMPERATURE $84^\circ F$
BAROMETRIC PRESSURE $29.24^\prime Hg$
MASS WEIGHTED SWIRL ANGLE $11.4^\circ$

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<th>DISTANCE FROM INNER SURFACE INCHES</th>
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<th>RMS VOLTAGE MILLIVOLTS</th>
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<td>0.165</td>
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<td>9.870</td>
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<td>0.760</td>
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RELATIVE TURBULENCE

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COLD RESISTANCE OF HOT WIRE = 5.74 OHMS

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## INLET EXPERIMENTAL DATA

**Diffuser** $D$, $L/H = 0.85$

**Flow Temperature** = 119.6°F

**Rock Temperature** = 62.0°F

**Barometric Pressure** = 22.44" Hg

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## INLET CALCULATED RESULTS

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**EXIT EXPERIMENTAL DATA**

FLOW TEMPERATURE = 110.0°F
ROOM TEMPERATURE = 64.0°F
BAROMETRIC PRESSURE = 29.44

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**EXIT CALCULATED RESULTS**

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**INLET TURBULENCE DATA**

**DIFFUSER** 2, L/H 5.55

FLOW TEMPERATURE 67.5°F

ROOM TEMPERATURE 70°F

BAROMETRIC PRESSURE 29.44°Hg

MASS WEIGHTED SWIRL ANGLE 17.24°

<table>
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<th>DISTANCE FROM INNER SURFACE (INCHES)</th>
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<th>RMS VOLTAGE (MILLIVOLTS)</th>
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<td>0.117</td>
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<td>9.900</td>
<td>0.175</td>
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<tr>
<td>1.310</td>
<td>9.850</td>
<td>0.250</td>
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**RELATIVE TURBULENCE**

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE (INCHES)</th>
<th>PERCENTAGE TURBULENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>8.445</td>
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<tr>
<td>0.450</td>
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<tr>
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<tr>
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<td>14.461</td>
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</table>

COLD RESISTANCE OF HOT WIRE = 8.2 OHMS

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**INLET EXPERIMENTAL DATA**

DIFFUSER \( B \) = 1.0
FLOW TEMPERATURE = 115.5°F
ROOM TEMPERATURE = 87°F
BAROMETRIC PRESSURE = 29.41" Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF. (INCHES)</th>
<th>SWIFT ANGLE (DEGREES)</th>
<th>PS (INCHES WATER)</th>
<th>STATIC PRESSURE (INCHES WATER)</th>
<th>TOTAL PRESSURE (INCHES WATER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.090</td>
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</tr>
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<td>26.667</td>
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</table>

**INLET CALCULATED RESULTS**

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF. (INCHES)</th>
<th>ABS VELOCITY (FT/SEC)</th>
<th>AXIAL VELOCITY (FT/SEC)</th>
<th>TANGENTIAL VELOCITY (FT/SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.090</td>
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<td>14.432</td>
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<td>3.043</td>
</tr>
<tr>
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<td>17.476</td>
<td>14.432</td>
<td>3.043</td>
</tr>
</tbody>
</table>

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**EXIT EXPERIMENTAL DATA**

**DIFFUSER \( D \), L/min: 6.35**

**FLOW TEMPERATURE: 118.6°F**

**FAN TEMPERATURE: 87.0°F**

**GAGE METER PRESSURE: 26.42 in Hg**

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF.</th>
<th>SMALL ANGLE</th>
<th>STATIC PRESSURE</th>
<th>TOTAL PRESSURE</th>
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<tbody>
<tr>
<td>INCHES</td>
<td>DEGREES</td>
<td>INCHES WATER</td>
<td>INCHES WATER</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ABOVE SLIP.</td>
<td>ABOVE SLIP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>INCHES WATER</td>
<td>INCHES WATER</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ABOVE SLIP.</td>
<td>ABOVE SLIP.</td>
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<tr>
<td>0.075</td>
<td>16.00°</td>
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<td>0.250</td>
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<td>15.00°</td>
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<td>3.420</td>
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<tr>
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<td>17.00°</td>
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<tr>
<td>0.875</td>
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<td>1.350</td>
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**EXIT CALCULATED RESULTS**

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF.</th>
<th>LPS VEL.</th>
<th>AXIAL VEL.</th>
<th>-rad/SEC.</th>
<th>FT/SEC.</th>
<th>FT/SEC.</th>
</tr>
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<tbody>
<tr>
<td>INCHES</td>
<td></td>
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<tr>
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</tr>
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<td>47.24</td>
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<td>47.24</td>
</tr>
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<td>3.070</td>
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<td>3.070</td>
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<tr>
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<td>3.680</td>
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<td>3.070</td>
<td>47.24</td>
<td>47.24</td>
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<td>3.070</td>
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<td>47.24</td>
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<td>47.24</td>
<td>47.24</td>
</tr>
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</table>

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INLET TURBULENCE DATA

DIFFUSER $D$, L/H 6.35
FLOW TEMPERATURE 119.5°F
ROOM TEMPERATURE 77.0°F
BAROMETRIC PRESSURE 29.31" Hg
MASS WEIGHTED SWIRL ANGLE 22.35°

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.900</td>
<td>0.148</td>
</tr>
<tr>
<td>0.450</td>
<td>9.970</td>
<td>0.108</td>
</tr>
<tr>
<td>0.610</td>
<td>10.000</td>
<td>0.096</td>
</tr>
<tr>
<td>0.760</td>
<td>10.000</td>
<td>0.098</td>
</tr>
<tr>
<td>0.910</td>
<td>9.970</td>
<td>0.105</td>
</tr>
<tr>
<td>1.050</td>
<td>9.950</td>
<td>0.125</td>
</tr>
<tr>
<td>1.180</td>
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<td>9.900</td>
<td>0.235</td>
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RELATIVE TURBULENCE

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>PERCENTAGE TURBULENCE</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>0.450</td>
<td>6.110</td>
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<td>0.760</td>
<td>5.514</td>
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<td>0.910</td>
<td>5.940</td>
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<tr>
<td>1.050</td>
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<td>1.180</td>
<td>8.403</td>
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<td>13.457</td>
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COLD RESISTANCE OF HOT WIRE = 3.42 OHMS
### Inlet Experimental Data

**Diffuser C**  
L/H = 3.03

**Flow Temperature** = 100.0°F  
**Room Temperature** = 78.0°F  
**Barometric Pressure** = 28.60" Hg

<table>
<thead>
<tr>
<th>Dist From Inner Surface (Inches)</th>
<th>Squirrel Angle</th>
<th>Static Pressure (Inches Water 45° CG Slope)</th>
<th>Total Pressure (Inches Water 45° CG Slope)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.060</td>
<td>1.733</td>
<td>2.553</td>
<td>2.467</td>
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<tr>
<td>0.280</td>
<td>0.943</td>
<td>2.663</td>
<td>3.783</td>
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<td>0.450</td>
<td>0.833</td>
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<td>4.367</td>
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<tr>
<td>0.640</td>
<td>0.667</td>
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<td>4.483</td>
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<tr>
<td>0.766</td>
<td>0.833</td>
<td>3.167</td>
<td>4.683</td>
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<tr>
<td>0.945</td>
<td>0.833</td>
<td>3.117</td>
<td>4.653</td>
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<td>5.517</td>
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<tr>
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<td>2.850</td>
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<tr>
<td>1.440</td>
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<td>1.953</td>
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</table>

### Inlet Calculated Results

<table>
<thead>
<tr>
<th>Dist From Inner Surface (Inches)</th>
<th>Abs Velocity (FT/SEC)</th>
<th>Axial Velocity (FT/SEC)</th>
<th>Tangent Velocity (FT/SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.060</td>
<td>1.211</td>
<td>1.310</td>
<td>1.750</td>
</tr>
<tr>
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<td>1.479</td>
<td>1.479</td>
<td>1.659</td>
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<td>0.450</td>
<td>1.554</td>
<td>1.554</td>
<td>1.654</td>
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<tr>
<td>0.640</td>
<td>1.594</td>
<td>1.652</td>
<td>1.493</td>
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<td>0.766</td>
<td>1.626</td>
<td>1.626</td>
<td>1.546</td>
</tr>
<tr>
<td>0.945</td>
<td>1.626</td>
<td>1.626</td>
<td>1.546</td>
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<tr>
<td>1.170</td>
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<td>1.556</td>
<td>1.596</td>
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<td>1.484</td>
<td>1.596</td>
</tr>
<tr>
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<td>1.399</td>
<td>1.599</td>
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</table>

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**Exit Experimental Data**

**Diffused** $C$, $L/ft^2 = 2.83$

<table>
<thead>
<tr>
<th>Distance from Vent Supply</th>
<th>Static Pressure</th>
<th>Total Pressure</th>
</tr>
</thead>
<tbody>
<tr>
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<td>30.65&quot;</td>
<td>42.61&quot;</td>
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<tr>
<td>0.25&quot;</td>
<td>33.45&quot;</td>
<td>45.41&quot;</td>
</tr>
<tr>
<td>0.50&quot;</td>
<td>36.25&quot;</td>
<td>48.21&quot;</td>
</tr>
<tr>
<td>0.75&quot;</td>
<td>39.05&quot;</td>
<td>51.01&quot;</td>
</tr>
<tr>
<td>1.00&quot;</td>
<td>41.85&quot;</td>
<td>53.81&quot;</td>
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<tr>
<td>1.25&quot;</td>
<td>44.65&quot;</td>
<td>56.61&quot;</td>
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<tr>
<td>1.50&quot;</td>
<td>47.45&quot;</td>
<td>59.41&quot;</td>
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**Exit Calculated Results**

<table>
<thead>
<tr>
<th>Distance from Vent Supply</th>
<th>Velocity</th>
<th>Exit Vel. + Static Pressure</th>
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<td>0.0&quot;</td>
<td>125.53&quot;</td>
<td>152.53&quot;</td>
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<tr>
<td>0.25&quot;</td>
<td>144.73&quot;</td>
<td>171.73&quot;</td>
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<tr>
<td>0.50&quot;</td>
<td>163.93&quot;</td>
<td>190.93&quot;</td>
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<tr>
<td>0.75&quot;</td>
<td>183.13&quot;</td>
<td>210.13&quot;</td>
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<td>1.00&quot;</td>
<td>202.33&quot;</td>
<td>230.33&quot;</td>
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<tr>
<td>1.25&quot;</td>
<td>221.53&quot;</td>
<td>250.53&quot;</td>
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<tr>
<td>1.50&quot;</td>
<td>240.73&quot;</td>
<td>269.73&quot;</td>
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INLET TURBULENCE DATA

DIFFUSER C, L/H 3.13
FLOW TEMPERATURE 100.0°F
ROOM TEMPERATURE 70.0°F
PAROMETRIC PRESSURE +3.65 KPA
MASS WEIGHTED SWIRL ANGLE 10.75

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.800</td>
<td>0.128</td>
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<tr>
<td>0.450</td>
<td>9.850</td>
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<td>0.610</td>
<td>9.850</td>
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<tr>
<td>0.760</td>
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<td>0.110</td>
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<tr>
<td>0.910</td>
<td>9.800</td>
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<td>9.700</td>
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<td>1.180</td>
<td>9.600</td>
<td>0.255</td>
</tr>
<tr>
<td>1.310</td>
<td>9.500</td>
<td>0.260</td>
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</table>

RELATIVE TURBULENCE

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>PERCENTAGE TURBULENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>7.424</td>
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<tr>
<td>0.450</td>
<td>5.264</td>
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<tr>
<td>0.610</td>
<td>5.932</td>
</tr>
<tr>
<td>0.760</td>
<td>6.363</td>
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<tr>
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<tr>
<td>1.310</td>
<td>16.109</td>
</tr>
</tbody>
</table>

COLD RESISTANCE OF HOT WIRE = 3.33 OHMS
### INLET EXPERIMENTAL DATA

DIFFUSER C  
FLOW TEMPERATURE = 106.0 °F  
ROOM TEMPERATURE = 73.0 °F  
BAROMETRIC PRESSURE = 29.51 "Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>STATIC ANGLE</th>
<th>STATIC PRESSURE INCHES WATER 45° SLOPE</th>
<th>TOTAL PRESSURE INCHES WATER 45° SLOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.064</td>
<td>2.500</td>
<td>2.450</td>
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### INLET CALCULATED RESULTS

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<th>DIST FROM INNER SURF INCHES</th>
<th>ABS. VELOCITY FT/SEC</th>
<th>AXIAL VELOCITY FT/SEC</th>
<th>LAY VEL. FT/SEC</th>
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### Experimental Data

**Diffuser** C; L/H = 3.13
**Flow Temperature:** 196.8°F
**Tight Temperature:** 196.0°F
**Barometric Pressure:** 23.31" Hg

<table>
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<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>SMALL AREA</th>
<th>PS STATIC PRESSURE INCHES WATER</th>
<th>TOTAL PRESSURE INCHES WATER</th>
<th>PS CORRECTED SLOW</th>
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### Calculated Results

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<th>TAN VELOCITY</th>
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<td>2.948</td>
<td>4.540</td>
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<td>1.937</td>
<td>3.93</td>
<td>3.094</td>
<td>4.684</td>
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INLET TURBULENCE DATA

DIFFUSER C, L/H 3.13
FLOW TEMPERATURE 766.0 °F
ROOM TEMPERATURE 73.0 °F
BAROMETRIC PRESSURE 29.87 "Hg
MASS WEIGHTED SWIRL ANGLE 3.532°

<table>
<thead>
<tr>
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<th>RMS VOLTAGE MILLIVOLTS</th>
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<td>9.700</td>
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<td>9.750</td>
<td>0.086</td>
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<tr>
<td>0.760</td>
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<tr>
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RELATIVE TURBULENCE

<table>
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<tr>
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<th>PERCENTAGE TURBULENCE</th>
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### INLET EXPERIMENTAL DATA

**Diffuser:** $C = \frac{L}{H} = 3.43$

**Flow Temperature:** $104.0$°F

**Room Temperature:** $50.0$°F

**Barometric Pressure:** $29.47$ in Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURFACE INCHES</th>
<th>SWING ANGLE</th>
<th>STATIC PRESSURE INCHES WATER</th>
<th>TOTAL PRESSURE INCHES WATER</th>
<th>FT/SEC</th>
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<tbody>
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<td>2.333</td>
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</tr>
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<td>2.667</td>
<td>0.00</td>
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<tr>
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### INLET CALCULATED RESULTS

<table>
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<td>204.977</td>
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<td>212.977</td>
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EXIT EXPERIMENTAL DATA

FLOW TEMPERATURE = 105.0°F
ROOM TEMPERATURE = 70.0°F
BAROMETRIC PRESSURE = 29.47" HG

<table>
<thead>
<tr>
<th>DIST FROM INLET SURF. INCHES</th>
<th>SWIVEL ANGLE</th>
<th>STATIC PRESSURE INCHES WATER Column Slope</th>
<th>TOTAL PRESSURE INCHES WATER AERODYNAMIC SLOPE</th>
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<td></td>
<td>°</td>
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<tr>
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<td>2.7</td>
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<td>6.5</td>
<td>3.2</td>
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EXIT CALCULATED RESULTS

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<th>GAS VELOCITY</th>
<th>TOTAL VELOCITY</th>
<th>CURRENT VELOCITY</th>
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<td>3.3, 1.5</td>
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<td>27.9, 6.0</td>
<td>3.9, 3.0</td>
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<td>29.0, 8.0</td>
<td>5.0, 6.0</td>
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<td>5.5, 7.5</td>
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<td>7.0, 12.0</td>
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# INLET TURBULENCE DATA

**Diffuser C, L/H 3.13**

Flow Temperature: 104.0°F

Room Temperature: 74.0°F

Barometric Pressure: 29.6" Hg

Mass Weighted Swirl Angle: 7.69°

<table>
<thead>
<tr>
<th>Distance from Inner Surface (Inches)</th>
<th>DC Voltage (Volts)</th>
<th>RMS Voltage (Millivolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.600</td>
<td>0.175</td>
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<tr>
<td>0.450</td>
<td>9.700</td>
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<td>0.610</td>
<td>9.750</td>
<td>0.105</td>
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<td>0.760</td>
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<tr>
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**Relative Turbulence**

<table>
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<th>Percentage Turbulence</th>
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Cold Resistance of Hot Wire: 3.34 Ohms
### INLET EXPERIMENTAL DATA

**Diffuser C:** L/m = 3.43

- Flow Temperature = 104.0 °F
- Room Temperature = 74.0 °F
- Barometric Pressure = 28.46 "Hg

<table>
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<tr>
<th>Dist. From Inner Surf. (Inches)</th>
<th>Skill Angle</th>
<th>Static Pressure (Inches Water gage Slope)</th>
<th>Total Pressure (Inches Water gage Slope)</th>
</tr>
</thead>
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<td>0.640</td>
<td>12.967</td>
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<td>0.660</td>
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<td>4.650</td>
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### INLET CALCULATED RESULTS

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<td>167.758</td>
<td>157.869</td>
<td>45.130</td>
</tr>
</tbody>
</table>

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### EXPERIMENTAL DATA

**Diffusion**

\[ G = 1.14 \times 2.13 \]

**Flow Temperature**

\[ 100.0\,^\circ\text{C} \]

**Romm Temperature**

\[ 70.0\,^\circ\text{C} \]

**Barometric Pressure**

\[ 23.66\,\text{in. Hg} \]

#### Table: Static Pressure

<table>
<thead>
<tr>
<th>DIST FROM INLET</th>
<th>STATIC PRESSURE</th>
<th>TOTAL PRESSURE</th>
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</thead>
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#### Calculated Results

<table>
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<tr>
<th>DIST FROM INLET</th>
<th>ABS. VELOCITY</th>
<th>AXIAL VELOCITY</th>
<th>TANG. VELOCITY</th>
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<tbody>
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<td>7.73</td>
<td>5.24</td>
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<td>5.24</td>
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<td>7.73</td>
<td>5.24</td>
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INLET TURBULENCE DATA

DIFFUSER C, L/H 3.13
FLOW TEMPERATURE 104.0°F
ROOM TEMPERATURE 77.0°F
BAROMETRIC PRESSURE 29.45"Hg
MASS WEIGHTED SWIRL ANGLE 142.56°

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE (INCHES)</th>
<th>DC VOLTAGE (Volts)</th>
<th>RMS VOLTAGE (Millivolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.670</td>
<td>0.185</td>
</tr>
<tr>
<td>0.450</td>
<td>9.750</td>
<td>0.130</td>
</tr>
<tr>
<td>0.610</td>
<td>9.800</td>
<td>0.102</td>
</tr>
<tr>
<td>0.760</td>
<td>9.800</td>
<td>0.092</td>
</tr>
<tr>
<td>0.910</td>
<td>9.800</td>
<td>0.100</td>
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<tr>
<td>1.050</td>
<td>9.800</td>
<td>0.115</td>
</tr>
<tr>
<td>1.180</td>
<td>9.800</td>
<td>0.140</td>
</tr>
<tr>
<td>1.310</td>
<td>9.750</td>
<td>0.170</td>
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RELATIVE TURBULENCE

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE (INCHES)</th>
<th>PERCENTAGE TURBULENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
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<td>7.664</td>
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<td>5.956</td>
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<td>0.760</td>
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<td>0.910</td>
<td>5.839</td>
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<tr>
<td>1.050</td>
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<td>1.310</td>
<td>10.023</td>
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</table>

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### Inlet Experimental Data

**Diffuser C**  
**L/1n = 2.48**

- **Flow Temperature:** 68.0°C
- **Rock Temperature:** 72.0°C
- **Barometric Pressure:** 26.37" Hg

<table>
<thead>
<tr>
<th>DIST. FROM INNER SURF. (INCHES)</th>
<th>SWFT ENGL.</th>
<th>STATIC PRESSURE (INCHES WATER 45DEG SLOPE)</th>
<th>TOTAL PRESSURE (INCHES WATER 45DEG SLOPE)</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>2.817</td>
<td>3.917</td>
</tr>
<tr>
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<td>1.8733</td>
<td>2.957</td>
<td>4.017</td>
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<td>4.95°</td>
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<td>1.75</td>
<td>2.5667</td>
<td>3.957</td>
<td>4.982</td>
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<td>2.6505</td>
<td>3.799</td>
<td>4.617</td>
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<td>2.7333</td>
<td>3.333</td>
<td>3.732</td>
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### Inlet Calculated Results

<table>
<thead>
<tr>
<th>DIST. FROM INNER SURF. (INCHES)</th>
<th>FLOW VELOCITY (FT/SEC)</th>
<th>EXD. VELOCITY (FT/SEC)</th>
<th>EXP. VELOCITY (FT/SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>159.30</td>
<td>123.70</td>
<td>62.0°</td>
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<tr>
<td>0.25</td>
<td>163.20</td>
<td>144.935</td>
<td>74.9°</td>
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<tr>
<td>0.5</td>
<td>171.33</td>
<td>151.29</td>
<td>78.2°</td>
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<tr>
<td>0.75</td>
<td>175.20</td>
<td>152.172</td>
<td>78.643°</td>
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<td>1.0</td>
<td>171.88</td>
<td>152.819</td>
<td>78.761°</td>
</tr>
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<td>1.25</td>
<td>172.285</td>
<td>153.156</td>
<td>79.127°</td>
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<td>1.5</td>
<td>172.610</td>
<td>153.232</td>
<td>79.23°</td>
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<td>1.75</td>
<td>172.120</td>
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<td>79.44°</td>
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<td>77.67°</td>
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<tr>
<td>2.25</td>
<td>158.69</td>
<td>137.16</td>
<td>71.32°</td>
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### EXPERIMENTAL DATA

**DIFFUSION** \( C \), \( L/H = 2.18 \)

<table>
<thead>
<tr>
<th>Dist</th>
<th>Dept. Ave</th>
<th>Static Pressure Inches Water After Slump</th>
<th>Total Pressure Inches Water After Slump</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>16.373</td>
<td>6.820</td>
<td>6.752</td>
</tr>
<tr>
<td>0.026</td>
<td>16.554</td>
<td>6.624</td>
<td>6.556</td>
</tr>
<tr>
<td>0.042</td>
<td>17.377</td>
<td>6.626</td>
<td>6.558</td>
</tr>
<tr>
<td>0.058</td>
<td>18.058</td>
<td>6.527</td>
<td>6.459</td>
</tr>
<tr>
<td>0.074</td>
<td>18.710</td>
<td>6.421</td>
<td>6.353</td>
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<tr>
<td>0.083</td>
<td>21.555</td>
<td>5.841</td>
<td>5.773</td>
</tr>
<tr>
<td>0.097</td>
<td>22.503</td>
<td>5.826</td>
<td>5.758</td>
</tr>
<tr>
<td>0.135</td>
<td>23.550</td>
<td>5.802</td>
<td>5.734</td>
</tr>
<tr>
<td>0.438</td>
<td>26.077</td>
<td>5.778</td>
<td>5.710</td>
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### CALCULATED RESULTS

<table>
<thead>
<tr>
<th>Dist</th>
<th>Gas Vol./100c</th>
<th>Axial Vol./100c</th>
<th>Total Vol./100c</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
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<td>138.57</td>
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<td>106.59</td>
<td>247.16</td>
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<td>0.083</td>
<td>141.37</td>
<td>108.60</td>
<td>250.17</td>
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<td>0.097</td>
<td>142.37</td>
<td>110.61</td>
<td>253.28</td>
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<td>0.438</td>
<td>159.37</td>
<td>127.63</td>
<td>286.90</td>
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**INLET TURBULENCE DATA**

**DIFFUSER C, L/H 3.53**

**FLOW TEMPERATURE 123.5°F**

**ROOM TEMPERATURE 72.0°F**

**BAROMETRIC PRESSURE 29.37" Hg**

**MASS WEIGHTED SWIRL ANGLE 23.86°**

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE (INCHES)</th>
<th>DC VOLTAGE (VOLTS)</th>
<th>RMS VOLTAGE (MILLIVOLTS)</th>
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<tbody>
<tr>
<td>0.280</td>
<td>9.700</td>
<td>0.195</td>
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<tr>
<td>0.450</td>
<td>9.820</td>
<td>0.127</td>
</tr>
<tr>
<td>0.610</td>
<td>9.850</td>
<td>0.100</td>
</tr>
<tr>
<td>0.760</td>
<td>9.850</td>
<td>0.097</td>
</tr>
<tr>
<td>0.910</td>
<td>9.820</td>
<td>0.107</td>
</tr>
<tr>
<td>1.050</td>
<td>9.820</td>
<td>0.117</td>
</tr>
<tr>
<td>1.180</td>
<td>9.800</td>
<td>0.140</td>
</tr>
<tr>
<td>1.310</td>
<td>9.770</td>
<td>0.170</td>
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</tbody>
</table>

**RELATIVE TURBULENCE**

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE (INCHES)</th>
<th>PERCENTAGE TURBULENCE</th>
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<tbody>
<tr>
<td>0.280</td>
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<td>7.388</td>
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<td>0.610</td>
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<td>0.760</td>
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<td>0.910</td>
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<td>1.050</td>
<td>6.806</td>
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<td>1.180</td>
<td>8.175</td>
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<td>1.310</td>
<td>9.984</td>
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</table>
INLET EXPERIMENTAL DATA

DIFFUSER D = 1.68
FLOW TEMPERATURE = 106.0°F
ROOM TEMPERATURE = 72.0°F
BAROMETRIC PRESSURE = 29.96" Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>SWIFT ANGLE</th>
<th>STATIC PRESSURE INCHES WATER ABS. SLOPE</th>
<th>TOTAL PRESSURE INCHES WATER ABS. SLOPE</th>
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</thead>
<tbody>
<tr>
<td>0.092</td>
<td>0.507</td>
<td>1.567</td>
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<tr>
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<td>0.507</td>
<td>1.517</td>
<td>30.633</td>
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<td>1.692</td>
<td>50.717</td>
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<td>0.617</td>
<td>0.067</td>
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<td>50.933</td>
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<tr>
<td>0.769</td>
<td>0.267</td>
<td>1.947</td>
<td>50.850</td>
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<tr>
<td>0.915</td>
<td>0.267</td>
<td>2.017</td>
<td>50.817</td>
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<tr>
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<td>0.267</td>
<td>1.958</td>
<td>50.183</td>
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<tr>
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<td>1.440</td>
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<td>1.707</td>
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INLET CALCULATED RESULTS

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>ABS VELOCITY FT/SEC</th>
<th>AXIAL VELOCITY FT/SEC</th>
<th>TANGENT VELOCITY FT/SEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
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### EXIT EXPERIMENTAL DATA

**Diffuser L/D = 1.00**
- Flow Temperature = 106.0°F
- Room Temperature = 70.0°F
- Barometric Pressure = 28.03" Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>SWIRL ANGL</th>
<th>PS STATIC PRESSURE INCHES WATER AND G SLOP</th>
<th>PT TOTAL PRESSURE INCHES WATER AND G SLOP</th>
</tr>
</thead>
<tbody>
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<td>1.028</td>
<td>3.137</td>
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<tr>
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<td>1.031</td>
<td>3.377</td>
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<td>1.033</td>
<td>3.537</td>
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### EXIT CALCULATED RESULTS

<table>
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<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>GAS VELOCITY</th>
<th>AXIAL VELOCITY</th>
<th>TANGENTIAL</th>
<th>GAS VELOCITY</th>
<th>AXIAL VELOCITY</th>
<th>TANGENTIAL</th>
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<tr>
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<td>10.000</td>
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<tr>
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<td>10.600</td>
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<tr>
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<td>11.400</td>
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<td>11.400</td>
</tr>
</tbody>
</table>

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### INLET TURBULENCE DATA

**Diffuser** $D = 1.60$

**Flow Temperature** $105.0^\circ F$

**Room Temperature** $72.0^\circ F$

**Barometric Pressure** $27.65'' Hg$

**Mass Weighted Swirl Angle** $\theta = 5.7^\circ$

<table>
<thead>
<tr>
<th>Distance from Inner Surface (inches)</th>
<th>DC Voltage (Vols)</th>
<th>RMS Voltage (Millivolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.750</td>
<td>0.152</td>
</tr>
<tr>
<td>0.450</td>
<td>9.800</td>
<td>0.112</td>
</tr>
<tr>
<td>0.610</td>
<td>9.870</td>
<td>0.087</td>
</tr>
<tr>
<td>0.760</td>
<td>9.870</td>
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</tr>
<tr>
<td>0.910</td>
<td>9.820</td>
<td>0.115</td>
</tr>
<tr>
<td>1.050</td>
<td>9.750</td>
<td>0.147</td>
</tr>
<tr>
<td>1.180</td>
<td>9.700</td>
<td>0.175</td>
</tr>
<tr>
<td>1.310</td>
<td>9.520</td>
<td>0.255</td>
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</table>

### Relative Turbulence

<table>
<thead>
<tr>
<th>Distance from Inner Surface (inches)</th>
<th>Percentage Turbulence</th>
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<tbody>
<tr>
<td>0.280</td>
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<tr>
<td>0.450</td>
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<tr>
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<tr>
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<td>1.050</td>
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<td>15.421</td>
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</table>

COLD RESISTANCE OF HOT WIRE = 3.37 OHMS
### INLET EXPERIMENTAL DATA

**Diameter** $D$, $L/H = 1.05$
**Flow Temperature** = 106.5°F
**Room Temperature** = 35.8°F
**Barometric Pressure** = 29.79" Hg

<table>
<thead>
<tr>
<th>Distance from Inner Surf (Inches)</th>
<th>Angle</th>
<th>Static Pressure (Inches Water 45° Slope)</th>
<th>Total Pressure (Inches Water 45° Slope)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
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<td>0.00</td>
<td>0.00</td>
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<td>0.25</td>
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<tr>
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<td>3.00</td>
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<tr>
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<td></td>
<td>3.00</td>
<td>2.91</td>
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<tr>
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<td></td>
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<td>2.87</td>
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<tr>
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<td>3.00</td>
<td>2.67</td>
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### INLET CALCULATED RESULTS

<table>
<thead>
<tr>
<th>Distance from Inner Surf (Inches)</th>
<th>Axial Velocity (FT/SEC)</th>
<th>Axial Velocity (FT/SEC)</th>
<th>Axial Velocity (FT/SEC)</th>
<th>Axial Velocity (FT/SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
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<td>0.25</td>
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<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
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<td>0.00</td>
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</tr>
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<td>0.00</td>
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</tr>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
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## EXIT EXPERIMENTAL DATA

<table>
<thead>
<tr>
<th>DIFFUSED D</th>
<th>L/H=660</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOW TEMPERATURE</td>
<td>108.5°F</td>
</tr>
<tr>
<td>ROOM TEMPERATURE</td>
<td>76.0°F</td>
</tr>
<tr>
<td>BAROMETRIC PRESSURE</td>
<td>28.18&quot;Hg</td>
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<table>
<thead>
<tr>
<th>FLOW INNER DIA.</th>
<th>STATIC</th>
<th>TOTAL</th>
</tr>
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<tbody>
<tr>
<td>INCHES</td>
<td>PRESSURE</td>
<td>INCHES</td>
</tr>
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<td></td>
<td>WATER</td>
<td>ASP. G.</td>
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<td>9.62</td>
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<tr>
<td>2.840</td>
<td>5.66</td>
<td>9.64</td>
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<td>9.66</td>
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<td>2.860</td>
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<tr>
<td>2.880</td>
<td>5.67</td>
<td>9.66</td>
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## EXIT CALCULATION RESULTS

<table>
<thead>
<tr>
<th>DIST</th>
<th>GAS VELOCITY</th>
<th>TOTAL VELOCITY</th>
<th>AIR VELOCITY</th>
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<tbody>
<tr>
<td></td>
<td>FT/SEC</td>
<td></td>
<td>FT/SEC</td>
</tr>
<tr>
<td>2.35</td>
<td>340.400</td>
<td>240.575</td>
<td>99.825</td>
</tr>
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<td>2.36</td>
<td>340.500</td>
<td>240.775</td>
<td>99.225</td>
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<td>240.975</td>
<td>98.625</td>
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<td>2.38</td>
<td>340.700</td>
<td>241.175</td>
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<td>2.39</td>
<td>340.800</td>
<td>241.375</td>
<td>97.425</td>
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INLET TURBULENCE DATA

DIFFUSER $D$, L/H 1.60
FLOW TEMPERATURE 104.0°F
ROOM TEMPERATURE 79.0°F
BAROMETRIC PRESSURE 29.42 "Hg
MASS WEIGHTED SWIRL ANGLE 3.32°

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.800</td>
<td>0.152</td>
</tr>
<tr>
<td>0.450</td>
<td>9.850</td>
<td>0.105</td>
</tr>
<tr>
<td>0.610</td>
<td>9.900</td>
<td>0.092</td>
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<tr>
<td>0.760</td>
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<td>0.094</td>
</tr>
<tr>
<td>0.910</td>
<td>9.900</td>
<td>0.102</td>
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<tr>
<td>1.050</td>
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<td>0.117</td>
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<tr>
<td>1.180</td>
<td>9.850</td>
<td>0.132</td>
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<tr>
<td>1.310</td>
<td>9.850</td>
<td>0.175</td>
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COLD RESISTANCE OF HOT WIRE = 3.37 OHMS

RELATIVE TURBULENCE

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>PERCENTAGE TURBULENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>8.876</td>
</tr>
<tr>
<td>0.450</td>
<td>6.074</td>
</tr>
<tr>
<td>0.610</td>
<td>5.272</td>
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<tr>
<td>0.760</td>
<td>5.387</td>
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<tr>
<td>0.910</td>
<td>5.845</td>
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<tr>
<td>1.050</td>
<td>6.730</td>
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<tr>
<td>1.180</td>
<td>7.635</td>
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<tr>
<td>1.310</td>
<td>10.123</td>
</tr>
</tbody>
</table>
### DIFFUSER, D = 0.25, L/H = 1.60

**Flow Temperature:** 100.0 °F

**Room Temperature:** 70.0 °F

**Barometric Pressure:** 29.12 in.Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>SWING ANGLE</th>
<th>PS STATIC PRESSURE INCHES WATER 45° DEG SLOPE</th>
<th>PT TOTAL PRESSURE INCHES WATER 45° DEG SLOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.090</td>
<td>7.566</td>
<td>1,467</td>
<td>3,583</td>
</tr>
<tr>
<td>0.095</td>
<td>7.633</td>
<td>1,571</td>
<td>3,683</td>
</tr>
<tr>
<td>0.090</td>
<td>7.567</td>
<td>1,487</td>
<td>3,573</td>
</tr>
<tr>
<td>0.080</td>
<td>7.563</td>
<td>1,467</td>
<td>3,583</td>
</tr>
<tr>
<td>0.075</td>
<td>7.567</td>
<td>1,487</td>
<td>3,573</td>
</tr>
<tr>
<td>0.070</td>
<td>8.667</td>
<td>2,067</td>
<td>5,967</td>
</tr>
<tr>
<td>0.065</td>
<td>8.667</td>
<td>2,067</td>
<td>5,967</td>
</tr>
<tr>
<td>0.060</td>
<td>8.833</td>
<td>1,951</td>
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<td>0.060</td>
<td>8.833</td>
<td>1,951</td>
<td>4,660</td>
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</table>

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### INLET, CALCULATED RESULTS

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF INCHES</th>
<th>MPS VELOCITY FT/SFC</th>
<th>AXIAL VELOCITY FT/SFC</th>
<th>TAN VELOCITY FT/SFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.090</td>
<td>155.648</td>
<td>15.784</td>
<td>72.885</td>
</tr>
<tr>
<td>0.095</td>
<td>155.949</td>
<td>15.921</td>
<td>72.916</td>
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<tr>
<td>0.090</td>
<td>155.648</td>
<td>15.784</td>
<td>72.885</td>
</tr>
<tr>
<td>0.080</td>
<td>163.968</td>
<td>16.548</td>
<td>75.832</td>
</tr>
<tr>
<td>0.075</td>
<td>163.968</td>
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<td>0.070</td>
<td>165.185</td>
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<td>16.874</td>
<td>76.933</td>
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<td>0.060</td>
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<td>72.703</td>
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<td>148.025</td>
<td>14.710</td>
<td>72.703</td>
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<tr>
<td>0.060</td>
<td>148.025</td>
<td>14.710</td>
<td>72.703</td>
</tr>
</tbody>
</table>

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### Experimental Data

**Diffuser:**
- Diameter: 1.25 in
- Flow Temperature: 100.0°F
- Room Temperature: 70.0°F
- Barometric Pressure: 29.12 in Hg

<table>
<thead>
<tr>
<th>Dist From Inner Surface (inches)</th>
<th>Skirt Angle</th>
<th>Static Pressure (inches water gauge slope)</th>
<th>Total Pressure (inches water gauge slope)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>30.0</td>
<td>34.0</td>
<td>36.0</td>
</tr>
<tr>
<td>0.75</td>
<td>30.0</td>
<td>34.0</td>
<td>36.0</td>
</tr>
<tr>
<td>0.50</td>
<td>30.0</td>
<td>34.0</td>
<td>36.0</td>
</tr>
<tr>
<td>0.25</td>
<td>30.0</td>
<td>34.0</td>
<td>36.0</td>
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</tbody>
</table>

### Calculated Results

<table>
<thead>
<tr>
<th>Dist From Inner Surface (inches)</th>
<th>Mass Velocity (ft/sec)</th>
<th>Axial Velocity (ft/sec)</th>
<th>Tangential Velocity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>5.0</td>
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<td>2.0</td>
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<tr>
<td>0.75</td>
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<td>5.0</td>
<td>3.0</td>
<td>2.0</td>
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### INLET TURBULENCE DATA

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.750</td>
<td>0.165</td>
</tr>
<tr>
<td>0.450</td>
<td>9.820</td>
<td>0.132</td>
</tr>
<tr>
<td>0.610</td>
<td>9.850</td>
<td>0.100</td>
</tr>
<tr>
<td>0.760</td>
<td>9.900</td>
<td>0.083</td>
</tr>
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<td>0.910</td>
<td>9.870</td>
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</tr>
<tr>
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<td>9.850</td>
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### RELATIVE TURBULENCE

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>PERCENTAGE TURBULENCE</th>
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<tr>
<td>0.280</td>
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<td>1.180</td>
<td>10.140</td>
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<tr>
<td>1.310</td>
<td>11.608</td>
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</table>
INLET EXPERIMENTAL DATA

DIFFUSER: D : L/H = 1.66
FLOW TEMPERATURE = 130.0°F
ROOM TEMPERATURE = 70.0°F
BAROMETRIC PRESSURE = 29.18 in Hg

<table>
<thead>
<tr>
<th>DIST FROM INNER SURF</th>
<th>STATIC PRESSURE INCHES WATER 45DEG SLOPE</th>
<th>TOTAL PRESSURE INCHES WATER 45DEG SLOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>2.050</td>
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<td>5.867</td>
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<td>5.633</td>
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INLET CALCULATED RESULTS
### EXPERIMENTAL DATA

**Diffuser:** 3

**Flow Temperature:** 188.6°F

**Room Temperature:** 76.8°F

**Barometric Pressure:** 29.16" Hg

<table>
<thead>
<tr>
<th>Dist from Inlet Surt. (inches)</th>
<th>Static Angle (degrees)</th>
<th>Static Pressure (inches Water Column Above Sump)</th>
<th>Total Pressure (inches Water Column Above Sump)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>2.50</td>
<td>1.50</td>
<td>3.00</td>
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<td>0.25</td>
<td>3.60</td>
<td>1.56</td>
<td>5.16</td>
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<td>0.45</td>
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<td>1.56</td>
<td>7.10</td>
</tr>
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<td>9.10</td>
</tr>
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<td>1.55</td>
<td>8.29</td>
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<tr>
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</tr>
<tr>
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<td>8.63</td>
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<tr>
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<td>11.07</td>
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<tr>
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<td>1.85</td>
<td>13.42</td>
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### CALCULATION RESULTS

<table>
<thead>
<tr>
<th>Dist from Inlet Surt. (inches)</th>
<th>Static Pressure (inches Water Column Above Sump)</th>
<th>Total Pressure (inches Water Column Above Sump)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.50</td>
<td>3.00</td>
</tr>
<tr>
<td>0.25</td>
<td>1.56</td>
<td>5.16</td>
</tr>
<tr>
<td>0.45</td>
<td>1.56</td>
<td>7.10</td>
</tr>
<tr>
<td>0.69</td>
<td>1.56</td>
<td>9.10</td>
</tr>
<tr>
<td>0.74</td>
<td>1.55</td>
<td>8.29</td>
</tr>
<tr>
<td>0.79</td>
<td>1.55</td>
<td>9.47</td>
</tr>
<tr>
<td>0.87</td>
<td>1.58</td>
<td>10.21</td>
</tr>
<tr>
<td>1.07</td>
<td>1.55</td>
<td>11.07</td>
</tr>
<tr>
<td>1.37</td>
<td>1.55</td>
<td>12.12</td>
</tr>
<tr>
<td>1.43</td>
<td>1.85</td>
<td>13.42</td>
</tr>
</tbody>
</table>

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INLET TURBULENCE DATA

DIFFUSER D, L/H 1.60
FLOW TEMPERATURE 100.0°F
ROOM TEMPERATURE 72.0°F
BAROMETRIC PRESSURE 29.12 "Hg
MASS WEIGHTED SWIRL ANGLE 5.29°

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.800</td>
<td>0.157</td>
</tr>
<tr>
<td>0.450</td>
<td>9.870</td>
<td>0.115</td>
</tr>
<tr>
<td>0.610</td>
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<td>0.094</td>
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<td>0.760</td>
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<td>0.180</td>
</tr>
<tr>
<td>1.310</td>
<td>9.770</td>
<td>0.260</td>
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</table>

RELATIVE TURBULENCE

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>PERCENTAGE TURBULENCE</th>
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</thead>
<tbody>
<tr>
<td>0.280</td>
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<tr>
<td>0.610</td>
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<td>0.760</td>
<td>5.640</td>
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<tr>
<td>0.910</td>
<td>5.763</td>
</tr>
<tr>
<td>1.040</td>
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<td>1.150</td>
<td>10.511</td>
</tr>
<tr>
<td>1.310</td>
<td>15.270</td>
</tr>
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### INLET EXPERIMENTAL DATA

**DIFFUSER:**  
**L/H = 1.60**

**FLOW TEMPERATURE:** 104.0°F

**ROOM TEMPERATURE:** 79.0°F

**BARTHEL'S PRESSURE:** 29.46" Hg

<table>
<thead>
<tr>
<th>FROM INNER SURF</th>
<th>SWEEP PRESS</th>
<th>STATIC PRESSURE</th>
<th>TOTAL PRESSURE</th>
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<tbody>
<tr>
<td>INCHES</td>
<td>INCHES WATER</td>
<td>INCHES WATER</td>
<td>INCHES WATER</td>
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<tr>
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<td>45° SLOPE</td>
<td>45° SLOPE</td>
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<td>2.783</td>
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<td>5.467</td>
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<td>0.761</td>
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<tr>
<td>0.910</td>
<td>24.833</td>
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<td>5.467</td>
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<tr>
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<td>25.646</td>
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<td>5.467</td>
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<td>2.783</td>
<td>5.467</td>
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<tr>
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</tr>
<tr>
<td>1.440</td>
<td>25.005</td>
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<td>5.467</td>
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### INLET CALCULATED RESULTS

<table>
<thead>
<tr>
<th>FROM INNER SURF</th>
<th>MACH VELOCITY</th>
<th>AXIAL VELOCITY</th>
<th>TANGENT VELOCITY</th>
<th>ANGULAR VELOCITY</th>
</tr>
</thead>
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<tr>
<td>INCHES</td>
<td>FT/SEC</td>
<td>FT/SEC</td>
<td>FT/SEC</td>
<td>FT/SEC</td>
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<td></td>
<td></td>
<td>142.578</td>
<td>182.578</td>
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<td>0.281</td>
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<td>149.568</td>
<td>73.591</td>
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</tr>
<tr>
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<td>166.462</td>
<td>150.373</td>
<td>76.135</td>
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<td>74.783</td>
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<td>151.672</td>
<td>74.783</td>
<td></td>
</tr>
<tr>
<td>1.311</td>
<td>166.627</td>
<td>151.672</td>
<td>74.783</td>
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<tr>
<td>1.440</td>
<td>166.272</td>
<td>150.162</td>
<td>72.578</td>
<td></td>
</tr>
</tbody>
</table>

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### Exit Experimental Data

**Diffuser**
- \( D = 1.60 \)
- \( L/H = 1.40 \)

**Flow Temperature** = 104.0°F

**Room Temperature** = 79.0°F

**Barometric Pressure** = 28.66 in Hg

<table>
<thead>
<tr>
<th>Dist from Inner Side (inches)</th>
<th>Swirl Angle</th>
<th>Static Pressure</th>
<th>Total Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.090</td>
<td>7° 70'</td>
<td>1.067</td>
<td>2.075</td>
</tr>
<tr>
<td>0.280</td>
<td>5° 40'</td>
<td>1.063</td>
<td>4.350</td>
</tr>
<tr>
<td>0.470</td>
<td>4° 50'</td>
<td>1.064</td>
<td>5.665</td>
</tr>
<tr>
<td>0.759</td>
<td>13° 20'</td>
<td>1.060</td>
<td>6.487</td>
</tr>
<tr>
<td>0.949</td>
<td>14° 60'</td>
<td>1.070</td>
<td>6.970</td>
</tr>
<tr>
<td>1.139</td>
<td>15° 50'</td>
<td>1.065</td>
<td>6.630</td>
</tr>
<tr>
<td>1.419</td>
<td>17° 20'</td>
<td>1.059</td>
<td>5.976</td>
</tr>
<tr>
<td>1.689</td>
<td>19° 0'</td>
<td>1.069</td>
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<td>1.929</td>
<td>21° 60'</td>
<td>1.072</td>
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</table>

### Exit Calculated Results

<table>
<thead>
<tr>
<th>Dist from Inner Side (inches)</th>
<th>Exit Velocity</th>
<th>Axial Velocity</th>
<th>Total Velocity</th>
</tr>
</thead>
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<tr>
<td>0.090</td>
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<td>0.759</td>
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<td>1.752</td>
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<td>1.977</td>
<td>5.934</td>
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</tbody>
</table>

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### INLET TURBULENCE DATA

**DIFFUSER** D, L/H 1.60  
**FLOW TEMPERATURE** 109.0°F  
**ROOM TEMPERATURE** 76.0°F  
**BAROMETRIC PRESSURE** 29.14" Hg  
**MASS WEIGHTED SWIRL ANGLE** 25.46°

<table>
<thead>
<tr>
<th>DISTANCE FROM INNER SURFACE INCHES</th>
<th>DC VOLTAGE VOLTS</th>
<th>RMS VOLTAGE MILLIVOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.280</td>
<td>9.800</td>
<td>0.157</td>
</tr>
<tr>
<td>0.450</td>
<td>9.850</td>
<td>0.100</td>
</tr>
<tr>
<td>0.610</td>
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<td>0.090</td>
</tr>
<tr>
<td>0.760</td>
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<td>0.100</td>
</tr>
<tr>
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### RELATIVE TURBULENCE

<table>
<thead>
<tr>
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</tr>
</thead>
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<td>10.005</td>
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<td>1.310</td>
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<td>SWIRL CONDITION</td>
<td>DIFFUSER A</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>Minimum Swirl</td>
<td>$\bar{\psi}$</td>
</tr>
<tr>
<td>$\circ$</td>
<td>$\frac{P_c}{V_t}$</td>
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<tr>
<td></td>
<td>$\frac{V_t}{V_t^*}$</td>
</tr>
<tr>
<td></td>
<td>$\bar{v}_t$</td>
</tr>
<tr>
<td>$\triangle$</td>
<td>$\bar{\psi}$</td>
</tr>
<tr>
<td></td>
<td>$\frac{P_c}{V_t}$</td>
</tr>
<tr>
<td></td>
<td>$\frac{V_t}{V_t^*}$</td>
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<tr>
<td></td>
<td>$\bar{v}_t$</td>
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<tr>
<td>$\perp$</td>
<td>$\bar{\psi}$</td>
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<tr>
<td></td>
<td>$\frac{P_c}{V_t}$</td>
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<tr>
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<td>$\frac{V_t}{V_t^*}$</td>
</tr>
<tr>
<td></td>
<td>$\bar{v}_t$</td>
</tr>
<tr>
<td>$\times$</td>
<td>$\bar{\psi}$</td>
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<td>$\frac{P_c}{V_t}$</td>
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<td></td>
<td>$\frac{V_t}{V_t^*}$</td>
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<td>$\bar{v}_t$</td>
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<tr>
<td>Maximum Swirl</td>
<td>$\bar{\psi}$</td>
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<td>$\diamond$</td>
<td>$\frac{P_c}{V_t}$</td>
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<td>$\frac{V_t}{V_t^*}$</td>
</tr>
<tr>
<td></td>
<td>$\bar{v}_t$</td>
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TABLE IV
MASS WEIGHTED VALUES

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<table>
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<th>SWIRL CONDITION</th>
<th>DIFFUSER C</th>
<th>DIFFUSER D</th>
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<td>EXIT</td>
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<td></td>
</tr>
<tr>
<td>Minimum Swirl</td>
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<td></td>
</tr>
<tr>
<td>Ω</td>
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<td>(\frac{U}{V_s})</td>
<td>-2.107</td>
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</tr>
<tr>
<td>(\frac{V}{V_a})</td>
<td>150.530</td>
<td>118.449</td>
</tr>
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<td>(\frac{V}{V_t})</td>
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<tr>
<td>Δ</td>
<td>3.532</td>
<td>2.697</td>
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<td>(\frac{U}{V_s})</td>
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<td>-1.078</td>
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<td>(\frac{V}{V_a})</td>
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<td>(\frac{U}{V_s})</td>
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<td>116.170</td>
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<td></td>
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<tr>
<td>Maximum Swirl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>◊</td>
<td>23.808</td>
<td>20.790</td>
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<tr>
<td>(\frac{U}{V_s})</td>
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<td>-1.965</td>
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<tr>
<td>(\frac{V}{V_a})</td>
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<td>123.370</td>
</tr>
<tr>
<td>(\frac{V}{V_t})</td>
<td>151.742</td>
<td>115.132</td>
</tr>
</tbody>
</table>

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**TABLE V**

**DIVERGENT-DIVERGENT ANNULAR DIFFUSER**

**EXPERIMENTALLY MEASURED \(C_P, \Psi, \eta\) VALUES**

<table>
<thead>
<tr>
<th>SWIRL CONDITION</th>
<th>L/h</th>
<th>1.60 DIFFUSER</th>
<th>3.13 DIFFUSER</th>
<th>6.35 DIFFUSER</th>
<th>12.65 DIFFUSER</th>
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</thead>
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<tr>
<td>Minimum Swirl</td>
<td></td>
<td>(\Psi)</td>
<td>(\psi)</td>
<td>(\psi)</td>
<td>(\psi)</td>
</tr>
<tr>
<td>(\bigcirc)</td>
<td>0.151</td>
<td>0.793</td>
<td>1.582</td>
<td>1.976</td>
<td></td>
</tr>
<tr>
<td>(\Delta)</td>
<td>3.349</td>
<td>3.531</td>
<td>4.582</td>
<td>5.077</td>
<td></td>
</tr>
<tr>
<td>(\bigtriangleup)</td>
<td>8.280</td>
<td>7.697</td>
<td>11.688</td>
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<td></td>
</tr>
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<td>(\times)</td>
<td>14.274</td>
<td>14.564</td>
<td>17.269</td>
<td>15.603</td>
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</tr>
<tr>
<td>Maximum Swirl</td>
<td>23.463</td>
<td>23.808</td>
<td>25.357</td>
<td>24.065</td>
<td></td>
</tr>
</tbody>
</table>

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FIGURE 2 SCHEMATIC DIAGRAM OF THE TEST FACILITIES

A - BLAST PLATE
B - BLOWER
C - FLOW-CALIBRATION PIPE
D - EXPANSION CONE
E - PLENUM CHAMBER
F - FILTER
G - HONEYCOMB
H - SCREENS
I - SWIRL VANE UNIT
J - ANNULAR PIPES
K - ROTATABLE OUTER PIPE
L - ANNULAR DIFFUSER
FIGURE 3 APPARATUS LAYOUT

FIGURE 4 CENTRIFUGAL BLOWER
FIGURE 5  DIFFUSER TEST
SECTION

FIGURE 6  YAWPROBE AT DIFFUSER EXIT
FIGURE 7 SETTLING CHAMBER

FIGURE 8 SWIRL VANE UNIT

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**FIGURE 9 DIFFUSER GEOMETRY**

- $r_1$ = hub radius
- $r_o$ = tip radius
- $\theta_i$ = inner wall angle
- $\theta_o$ = outer wall angle
- $A_t$ = throat area = $A_1$
- $A_L$ = area at $L = A_2$

For this investigation:

- $\theta_i = \theta_o = 20^\circ$
- $\pi r_1 = 0.6$ at 1
- $r_0 = 0.6$ at 1
- $A_2/A_1 = 1.25, 1.50, 2.00$, $3.00$
There are 10 Measuring Stations at each one of the 3 Traverse Stations. The Measuring Stations are located at the midpoints of ten equal ring area elements.

DIFFUSER WALLS - 3 rows of 10 Static Pressure Taps are located on the outer wall at 0°, 120°, and 240°.

FIGURE 10 MEASUREMENT STATIONS
FIGURE 11

COMPARISON OF MEAN VELOCITY DISTRIBUTION WITH RESULTS OF BRIGHTON & JONES

Laminar Flow
 Brighton & Jones

Turbulent Flow, Reynolds' Number = 146,000
 Brighton & Jones

Mean Velocity Distribution for No Swirl Case for Present Investigation.
Figure 12G

LEVERS ANALYSIS
WITH A CHANGED

$\alpha = 0^\circ$

VELOCITY DISTRIBUTION

VS.
SWEEP ANGLE $\theta$

VELOCITY VS.

$0$  $10$  $20$  $30$  $40$  $50$  $60$  $70$  $80$  $90$  $100$

Sweep Angle $\theta$
FIGURE 12-H

NEVERS ANALYSIS
WITH 8 CHANGED

$\alpha_{in} = 0^\circ$

STATIC PRESSURE $P_s$

VS

SWEPT ANGLE $\theta$

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FIGURE 13A
INLET SWIRL ANGLE PROFILES
DIFFUSER A

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FIGURE 13B
INLET SWIRL ANGLE PROFILES
DIFFUSER B

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FIGURE 13C
INLET-SWIRL ANGLE PROFILES
DIFFUSER C
FIGURE 13D.
INLET SWIRL ANGLE PROFILES
DIFFUSER D

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FIGURE 14A.
INLET TANGENTIAL VELOCITY PROFILES
DIFFUSER A

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FIGURE 14B
INLET TANGENTIAL VELOCITY PROFILES
DIFFUSER B
FIGURE 14C.
INLET TANGENTIAL VELOCITY PROFILES
DIFFUSER C
Figure 14D.

Inlet Tangential Velocity Profiles

Diffuser D
FIGURE 15A
INLET DYNAMIC PRESSURE PROFILES
DIFFUSER A
FIGURE 15B
INLET DYNAMIC PRESSURE PROFILES
DIFFUSER B
FIGURE 15C
INLET DYNAMIC PRESSURE PROFILES
DIFFUSER C
FIGURE 15D
INLET DYNAMIC PRESSURE PROFILES
DIFFUSER D

DYN PRES/MAX DYN PRES
0.00 0.20 0.40 0.60 1.00

(R-RINA) / (ROTR-RINA)
0.00 0.20 0.40 0.60 0.80 1.00

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FIGURE 16A
INLET ABSOLUTE VELOCITY PROFILES
DIFFUSER A

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FIGURE 16B.
INLET ABSOLUTE VELOCITY PROFILES
DIFFUSER B
FIGURE 16C
INLET ABSOLUTE VELOCITY PROFILES
DIFFUSER C
FIGURE 17A.
INLET AXIAL VELOCITY PROFILES
DIFFUSER A
FIGURE 17B
INLET AXIAL VELOCITY PROFILES
DIFFUSER B

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FIGURE 17C
INLET AXIAL VELOCITY PROFILES
DIFFUSER C
FIGURE 17 D
INLET AXIAL VELOCITY PROFILES
DIFFUSER D

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FIGURE 18A
INLET STATIC PRESSURE PROFILES
DIFFUSER A

STATIC PRESSURE (IN H₂O)

0.00 0.20 0.40 0.60 0.80 1.00
(R-RINR) / (ROT-RINR)

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FIGURE 18B
INLET STATIC PRESSURE PROFILES
DIFFUSER B

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FIGURE 18C
INLET STATIC PRESSURE PROFILES
DIFFUSER C

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FIGURE 18D
INLET STATIC PRESSURE PROFILES
DIFFUSER D

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FIGURE 19A. 
EXIT SWIRL ANGLE PROFILES 
DIFFUSER A
FIGURE 20A
EXIT TANGENTIAL VELOCITY PROFILES
DIFFUSER A

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FIGURE 20B
EXIT TANGENTIAL VELOCITY PROFILES
DIFFUSER B

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FIGURE 20C
EXIT TANGENTIAL VELOCITY PROFILES
DIFFUSER C
EXIT TANGENTIAL VELOCITY PROFILES

DIFFUSER D

[Graph showing velocity profiles with axes indicating velocity (ft/sec) and (R-RINR)/(ROT-RINR).]

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FIGURE 21A
EXIT DYNAMIC PRESSURE PROFILES
DIFFUSER A
Figure 21B
Exit Dynamic Pressure Profiles
Diffuser B
FIGURE 21C
EXIT DYNAMIC PRESSURE PROFILES
DIFFUSER C
FIGURE 21D
EXIT DYNAMIC PRESSURE PROFILES
DIFFUSER D
FIGURE 22A
EXIT ABSOLUTE VELOCITY PROFILES
DIFFUSER A

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FIGURE 22B
EXIT ABSOLUTE VELOCITY PROFILES
DIFFUSER B
Figure 22C

Exit Absolute Velocity Profiles

Diffuser C

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FIGURE 22 D
EXIT ABSOLUTE VELOCITY PROFILES
DIFFUSER D

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FIGURE 23A
EXIT AXIAL VELOCITY PROFILES
DIFFUSER A
FIGURE 23B
EXIT AXIAL VELOCITY PROFILES
DIFFUSER B

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FIGURE 23C
EXIT AXIAL VELOCITY PROFILES
DIFFUSER C
FIGURE 23D
EXIT AXIAL VELOCITY PROFILES
DIFFUSER D

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FIGURE 24B
STATIC PRESSURE RISE

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FIGURE 24D
STATIC PRESSURE RISE

DISTANCE (IN.)

STATIC PRESSURE (IN. H₂O)

-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
-9.00
-10.00

0.00  4.00  8.00  12.00  16.00  20.00

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FIGURE 25A
INLET TURBULENCE
DIFFUSER A
FIGURE 25c
INLET TURBULENCE
DIFFUSER C
Figure 25D

Inlet Turbulence

Diffuser D

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FIGURE 26

$C_{PR}$ VERSUS $L/h$
CONSTANT $\varphi$ (SWIRL ANGLE)

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FIGURE 27

$C_{PR}$ VERSUS $\bar{\Psi}$
CONSTANT $L/h$

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FIGURE 28

COMPARISON OF PRESENT RESULTS TO
RESULTS OF SOVRAN & KLOMP

TYPES OF DIFFUSERS

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>$\theta_o$</th>
<th>$\theta_t$</th>
<th>$r_h/r_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>30.0°</td>
<td>29.5°</td>
<td>0.70</td>
</tr>
<tr>
<td>X</td>
<td>20.0</td>
<td>20.0</td>
<td>0.60</td>
</tr>
<tr>
<td>□</td>
<td>15.0</td>
<td>15.0</td>
<td>0.70</td>
</tr>
<tr>
<td>◆</td>
<td>20.0</td>
<td>15.0</td>
<td>0.70</td>
</tr>
<tr>
<td>●</td>
<td>20.0</td>
<td>5.0</td>
<td>0.70</td>
</tr>
<tr>
<td>○</td>
<td>20.0</td>
<td>0.0</td>
<td>0.55</td>
</tr>
</tbody>
</table>

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FIGURE 29
ANNULAR EQUIANGULAR DIFFUSER
PRESSURE RECOVERY FACTOR VARIATION WITH LENGTH FOR VARIOUS SWIRL DISTRIBUTIONS
UNIVERSITY OF WATERLOO

$2\theta = 15^\circ$
$h = 0.875''$

<table>
<thead>
<tr>
<th>SWIRL NO</th>
<th>$\bar{\psi}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0°</td>
</tr>
<tr>
<td>III</td>
<td>11.2°</td>
</tr>
<tr>
<td>IV</td>
<td>14.2°</td>
</tr>
<tr>
<td>VI</td>
<td>23.0°</td>
</tr>
</tbody>
</table>
FIGURE 30
ANNULAR EQUIANGULAR DIFFUSER
PRESSURE RECOVERY FACTOR VARIATION WITH
INLET SWIRL FOR CONSTANT LENGTH
UNIVERSITY OF WATERLOO

2θ = 20°
h = 0.875"

S - S: OPTIMUM SWIRL ANGLE LINE

L/h = 16.5
L/h = 13.2
L/h = 9.8
L/h = 4.9
L/h = 8.2

CPR

0.5
0.3
0.3
0.5
0.3
0.5
0.3
0.5
0.3

0 5 10 15 20 25 30 Ψ (Deg)
FIGURE 31

$\eta$ VERSUS $L/h$ CONSTANT $\phi$ (SWIRL ANGLE)

- $\bigcirc$ -- LOW SWIRL -- 1°
- $\bigtriangleup$ -- 5°
- $\bigtriangledown$ -- 10°
- $\times$ -- 15°
- $\diamond$ -- HIGH SWIRL 25°

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FIGURE 32

\( \eta \) VERSUS \( \bar{\psi} \)
CONSTANT \( \frac{L}{h} \)

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VITA AUCTORIS

1946  Born in Frankfurt am Main, West Germany on May 17.
1965  Completed High School at Vincent Massey Collegiate Institute, Windsor, Ontario in June.
1969  Received the Degree of Bachelor of Applied Science in Mechanical Engineering from the University of Windsor, Windsor, Ontario.
1971  Currently a candidate for the Degree of Master of Applied Science in Mechanical Engineering at the University of Windsor.