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Experimental Study of Vortex Diffusers

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Summary

This report documents experimental research performed on vortex diffusers used in ventilation and air-conditioning systems. The main objectives of the research were (1) to study the flow characteristics of isothermal jets issuing from vortex diffusers, (2) to compare the vortex diffuser's performance with that of a conventional diffuser, and (3) to prepare a report that disseminates the results to designers of ventilation and air-conditioning systems. This information is not available in the current technical literature.

To accomplish the research objectives, the researchers constructed a test platform and used diffusers donated by the manufacturers. Three diffusers were considered: a conventional round ceiling diffuser and two different styles of vortex diffusers. The researchers also used (experimental) equipment and instruments that they already had.

Measurements were taken of each diffuser to obtain a velocity map, velocity profile, and velocity decay. Flow visualization experiments were undertaken to capture the general behavior of jets issuing from the diffusers. A fog machine was used to enable whole-field visualization. This is a new and significant approach because the nontoxic fog, which meets stringent safety requirements, was produced easily in large quantities suitable for this application. A videotape of the flow visualizations was also produced.

Researchers found that, overall the vortex diffusers create slightly more induction (mixing) of ambient air in comparison to the conventional diffuser. This is caused by the turbulence resulting from the rotational motion of the air near the outlet of the vortex diffuser. The rotational motion disappears within three outlet diameters and the flow becomes radial. The vortex diffusers require larger duct static pressure at a given flow rate compared with the conventional diffuser.

Acknowledgments

During the course of this research, the first author was partially supported by a Faculty Sabbatical Fellowship granted by Associated Western Universities, Inc., and the U.S. Department of Energy. He would like to extend special thanks to Dr. Ahmad Pesaran and Dr. Robert Farrington, the scientists who were his initial hosts, and Dr. Ren Anderson, Buildings Program manager.

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Nomenclature

A	area
Ak	diffuser area factor, calculated (Q/Vk)
An	diffuser neck area, calculated ($\pi D^2/4$)
CD	conventional diffuser (round ceiling diffuser)
D	diffuser neck diameter
H	vertical distance from diffuser
K	proportionality constant for jet zone III
Q	flow rate
R	radial distance from diffuser center
V	velocity
Vk	Average outlet velocity, velocity measured with standard instrument in specified location
Vn	neck velocity, calculated (Q/An)
VD1	vortex diffuser #1
VD2	vortex diffuser #2

1. Introduction

Air diffusers are important components of ventilation and air-conditioning systems. The comfort level of occupants and the efficient delivery of air in a building depend on, among other factors, properly designed and selected diffusers. Many kinds of diffusers are manufactured to meet specific requirements and, quite often, each kind is available in different styles. For example, one common kind is the round ceiling diffuser, which is available in both adjustable and fixed geometries.

Another kind of diffuser is the vortex (swirl) diffuser. The jet issuing from this diffuser has both translational and rotational velocity. The rotation is imposed on the main flow as the air passes through a series of angled vanes located in the diffuser. Some manufacturers of vortex diffusers claim that, because of the rotational component, the diffusers have significantly higher induction (mixing) than do conventional diffusers. However, the effect of this rotational component has not been well documented.

Although vortex diffusers have been manufactured since the 1960s, information available on vortex jet characteristics and performance is limited. The *ASHRAE Handbook of Fundamentals* did not even mention this type of diffuser until its most recent revision (ASHRAE 1993). A literature search did not identify a specific study of vortex diffusers used in air conditioning.

However, that vortex motion in the occupant zone has been investigated as a means of ventilation, [see Nagasawa and Matsui (1988), Nagasawa et al. (1990), Yamaguchi et al. (1991), and Nagasawa (1992)]. For example, in one experimental study (Nagasawa et al. 1990), air was distributed through holes in four columns situated near the perimeter of a table of five smokers to create a vortical circulation around the table. The return duct was above the table. Results showed that the contaminants (i.e., cigarette smoke particles) were not transported to the rest of the room, but they were instead contained to a space around the vortex axis.

Because of the lack of technical information on vortex diffusers, and in accord with ongoing research at NREL's Ventilation and Indoor Air Quality Laboratory, we decided that an experimental investigation of vortex diffusers was appropriate. The objectives set for the research were (1) to study the flow characteristics of isothermal jets issuing from two different styles of vortex diffusers, (2) to compare the vortex diffuser's performance with that of a conventional diffuser, (3) to see if the standard test methods could be used to obtain the characteristics of vortex diffusers, and (4) to prepare a report that would disseminate the results to designers of ventilation and air-conditioning systems.

2. Experiments

In this section, we first describe the experimental setup and method and follow that with a list of measurement uncertainties.

2.1 Experimental Setup

To accomplish the research objectives, the researchers designed and assembled a test apparatus as shown schematically in Figure 1. It consists of a 3.7 m x 3.7 m (12 ft x 12 ft) plywood platform (or table) with a center opening to support a diffuser in an up-side-down (jet issuing upward) arrangement, flush with the surface. This arrangement was selected for convenience of assembly and measurements. The test apparatus was housed in a large warehouse.

The up-side-down arrangement in this study differs from the one prescribed in standard test methods (e.g., ANSI-ASHRAE 70-1991), in which a diffuser is installed in a ceiling-type arrangement. Note that the direction of air flow upstream of the diffuser in this study is against gravity which should not pose a problem as long as the flow is isothermal. This was verified by testing a conventional diffuser in the up-side-down arrangement and comparing results with published data from the manufacturer's catalog.The manufacturer used the standard method of test. The details of this validation are presented later with the results.

The air-flow loop was comprised of an air blower, a mass flow transducer with a readout device, 20 cm (8in) diameter sheet metal duct, and the diffuser. There is about 60 cm (25 in.) of straight vertical duct upstream of the diffuser. A window screen is used at the last elbow fitting to help straighten the flow.

Other instruments used in this study include an omnidirectional hot-wire anemometer (TSI-1640) for velocity measurements, a thermocouple (type J) with a readout device, a velometer (Alnor Series 6000) for average outlet velocity measurements, and a pressure sensor (Alnor CompFlow 8530D-1) for duct static pressure measurements. To minimize the intrusiveness of the measuring probe, the telescopic hot-wire anemometer probe is attached vertically to the end of a 60-cm horizontal rod supported by a laboratory stand. One pressure tap is installed in the duct 1.5 diffuser neck diameters (1.5D) upstream of the diffuser.

2.1.1 Flow Visualization

In addition to the velocity point measurements, researchers conducted several tests to visualize the jets issuing from the diffusers and to observe the induction of ambient air into the jets.

A fog machine is used to visualize the jet flow, and smoke from three burning punks is used to observe the motion of the ambient air near the diffuser. The contrast between the fog produced by the machine and the smoke generated by the punks is especially useful for the flow visualization. The fog is introduced into the duct upstream of the diffuser at the point shown in Figure 1. The punks are positioned above the test platform at selected vertical and radial locations.

The fog machine is typically used for special effects in movie and stage productions. A nontoxic liquid is pumped into the machine and atomized to a very fine fog, which can easily be produced in a large, controllable quantity. This is a new and significant approach to flow visualization, considering the stringent safety requirements that must be observed. After each run, distilled water is circulated

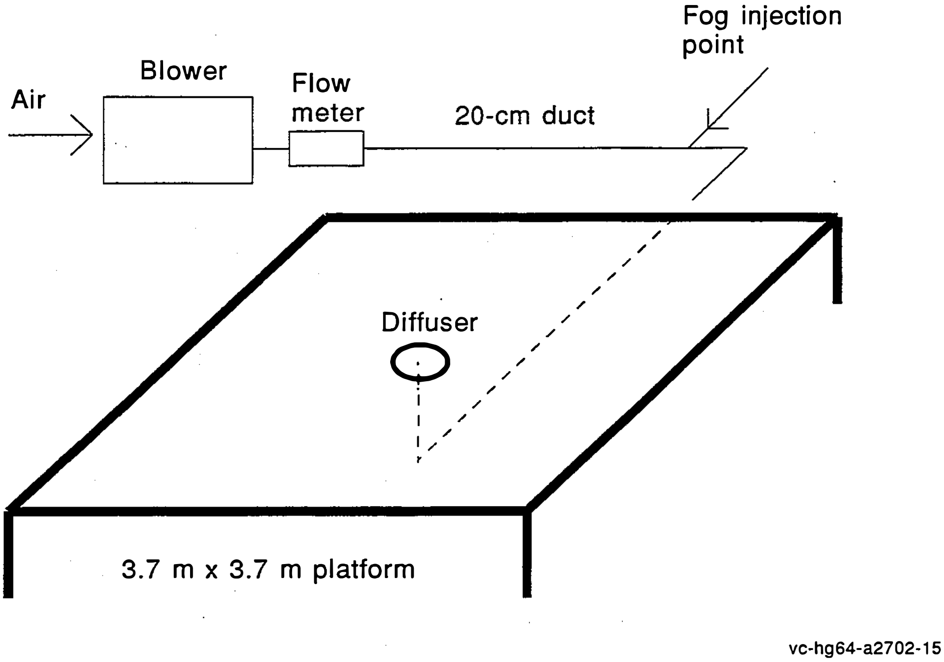

Figure 1. Test apparatus

through the machine to clear the fog fluid. A more detailed description of the fog machine and the Material Safety Data Sheet (MSDS) for the fog liquid are included in the appendix.

A photographic camera, attached to the test platform on one side, and a video camera are used to record flow visualizations. The video camera is positioned either 1.5 m (5 ft) above the center of the test platform or on the side. It is operated with a remote control device. Special lighting is not necessary, but the platform is covered by black felt fabric to provide proper contrast in the background for most of the tests. Black and white film (Kodak TriX Pan, 400 ASA) is used for still photography.

In addition to the whole-field visualization, the researchers observed the flow direction at several locations around the diffuser, using a fine strip of mylar taped to the tip of a long slender rod supported by a laboratory stand.

2.1.2 Diffuser Styles Tested

A round ceiling diffuser (hereafter called the "conventional diffuser") and two different styles of vortex diffusers were tested in this study (see Figure 2). These diffusers are designed for ceiling installation. A short description of each follows.

The conventional diffuser has a neck diameter of 15 cm (6 in.) and two fixed cones [Figure 2(A)]. This diffuser was tested to validate the up-side-down test arrangement and also to compare it's performance with that of the vortex diffusers.

As shown in Figure 2(B), vortex diffuser #1 has 12 identical, fixed radial vanes in a fan-type arrangement at the center of the diffuser face plate [61 cm x 61 cm (24 in. x 24 in.)]. The neck diameter is 18 cm (7.1 in.). Each vane has a slanted surface followed by a horizontal section. This

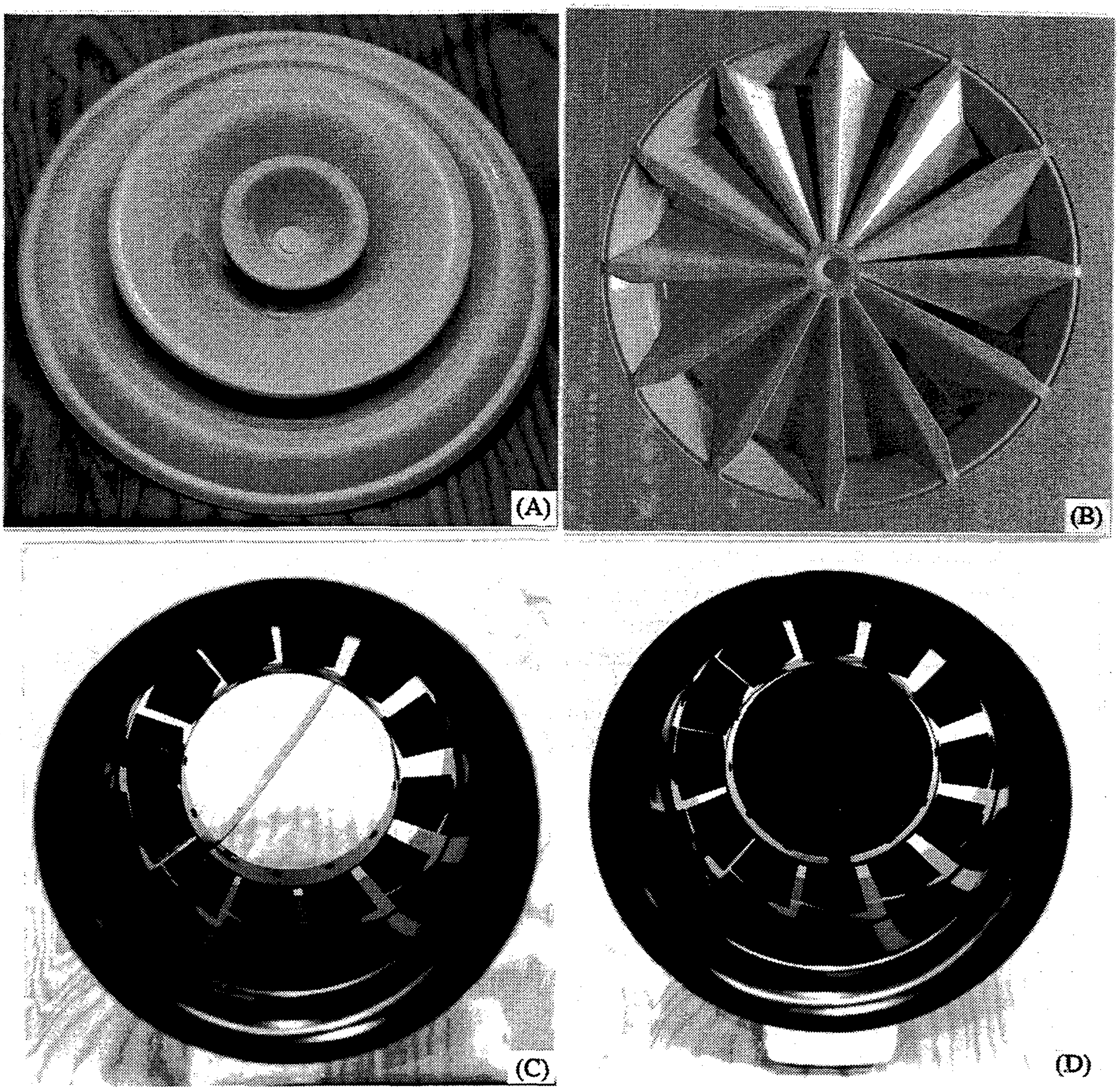

Figure 2. Diffusers tested: (A) conventional diffuser, (B) vortex diffuser #1, (C) vortex diffuser #2 with blank-off plate open, (D) vortex diffuser #2 with blank-off plate closed

particular shape forces air to rotate around a vertical axis as the air flows horizontally out of the diffuser.

Vortex diffuser #2 [Figures 2(C) and 2(D)], has a neck diameter of 20 cm (8 in.) and a cylindrical shape with a smooth, rounded outlet. The diffuser is divided into a central and an annular passageway. There are 12 straight vanes with adjustable angles positioned in the annulus. These vanes create rotation in the flow. The central passageway is equipped with a blank-off plate, which can be used to control the outflow direction. The air flow is vertical (parallel to the diffuser axis) when the blank-off plate is open, and it is horizontal when the blank-off plate is fully closed, which was the only configuration of current interest.

The last portion of the duct (i.e., between the last elbow and the diffuser) was sized to match the neck size of the diffuser being tested.

2.2 Test Method

Each diffuser was tested at several different flow rates. Some of the runs were repeated to investigate the repeatability in data. The flow rate was measured for three minutes and then averaged. A typical flow rate measurement is shown in Figure 3. At a given flow rate, researchers took numerous velocity point measurements in the radial, angular, and axial directions obtained with the omnidirectional hot-wire anemometer. They used a 3-minute observation interval to obtain the average velocity for each measurement point. Figure 4 shows a typical velocity measurement.

Temperature was measured at the diffuser outlet and the blower inlet. Barometric pressure was measured in a nearby laboratory. The barometric pressure and ambient air temperature are needed for correcting the velocity and flow rate readings from the standard condition (instrument setting) to the test condition in Denver, Colorado at an elevation of 1610 m (5283 ft) elevation.

2.3 Measurement Uncertainty

Researchers estimated the following uncertainties from repeated measurements, comparisons among results obtained from different instruments measuring the same quantity, and their own judgment:

Flow rate	5% of reading
Velocity	0.1 m/s (20 fpm)
Temperature	1.1°C (2°F)
Pressure	2% of reading
Radial distance	1.3 cm (1/2 in.)
Vertical distance	0.16 cm (1/16 in.)

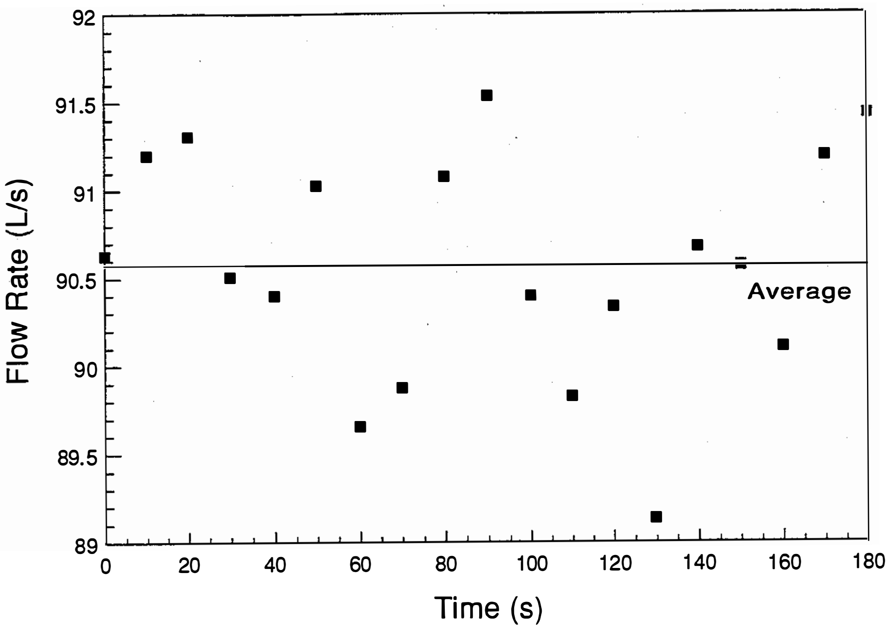

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Figure 3. Typical flow rate measurement

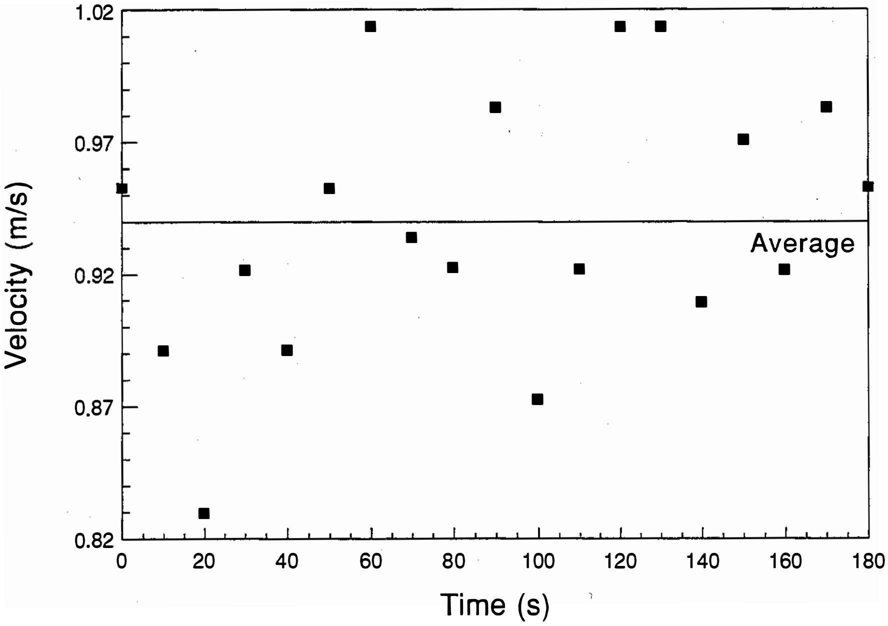

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Figure 4. Typical velocity measurement

3. Results and Discussion

The results of this study include validation of the test apparatus, the performance data for vortex diffusers, and comparison with the conventional diffuser.

3.1 Validation of Test Apparatus

As stated earlier, the diffusers were tested in an up-side-down arrangement. Presumably, the up-side-down test and the standard test (where a diffuser is installed in a ceiling) should produce the same results as long as airflow is isothermal. The researchers verified this using a conventional diffuser in the apparatus.

Velocity at the outlet was measured with an Alnor Velometer according to the procedure specified by the manufacturer. This measurement was used to determine the velocity factor, which was later used to produce velocity decay information.

Figure 5 shows, in the standard format, the velocity decay obtained from this study and that from the diffuser manufacturer for the same style of conventional diffuser. As expected, the data fall on the slope of zone III of jet expansion. Note that the data in the manufacturer's catalog are rounded to the nearest foot. The catalog data were extended to cover 0.5 ft on each side of the data points, shown by a series of horizontal bars in Figure 3. The data obtained for validation compare favorably with the manufacturer's data, especially considering the experimental uncertainty, the manufacturing variations for the same diffuser, and the variability of testing at different laboratories (Miller and Ball 1983). Hence, the use of and up-side-down test arrangement produces valid results.

For completeness, the velocity map and velocity profile for the conventional diffuser are shown in Figures 6 and 7, respectively. Figure 6 shows that the diffuser provides a uniform radial velocity distribution. The low velocity points match the locations of the three radial ribs that support the cones in this diffuser. As expected, and as shown in Figure 7, the point of maximum velocity was within 2 cm (1 in.) of the platform's surface.

3.2 Vortex Diffusers

Each of the vortex diffusers were tested under three different flow rates. Figures 8-13 show the results in terms of the velocity map, velocity profile, and velocity decay for the vortex diffusers.
Figures 8 and 9 show that the velocity distribution is radially uniform for both diffusers. However, careful and time-consuming individual vane adjustments were necessary in the case of vortex diffuser #2 before the uniform velocity distribution was established. Vortex diffuser #1 had fixed vanes.

The flow rate specifications for the diffusers are:

CD: 80-315 cfm (size 6 in.)
VD1: 94-150 cfm (size 180 mm)
VD2: 125-300 cfm (size 8 in.)

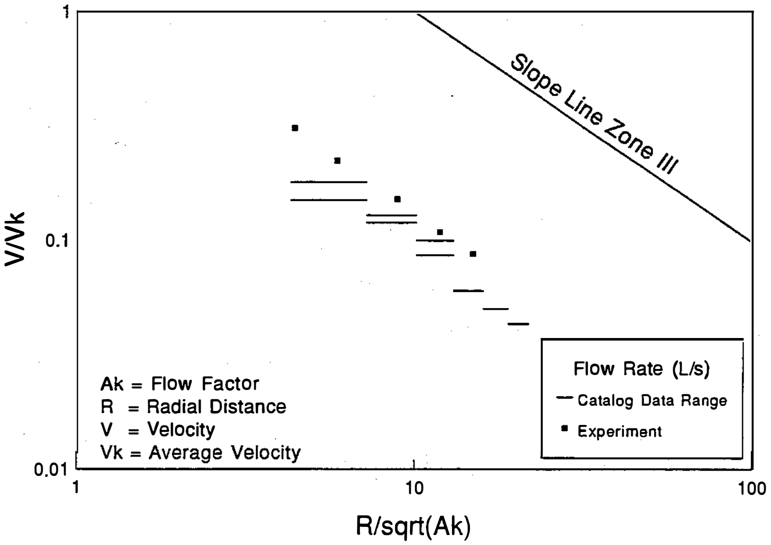

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Figure 5. Velocity decay for conventional diffuser tested in up-side-down orientation compared with manufacturer's catalog data

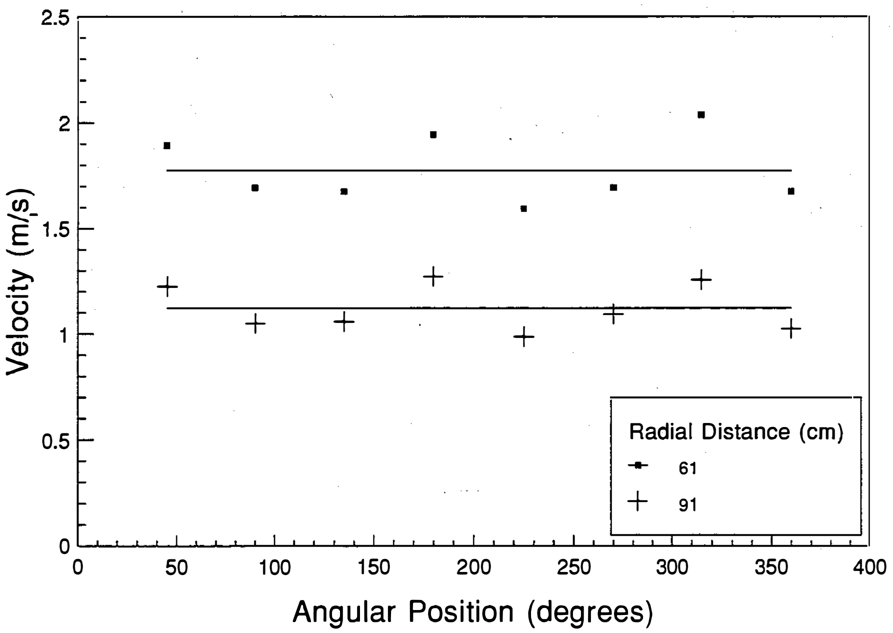

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Figure 6. Velocity map for conventional diffuser (Q = 71 L/s)

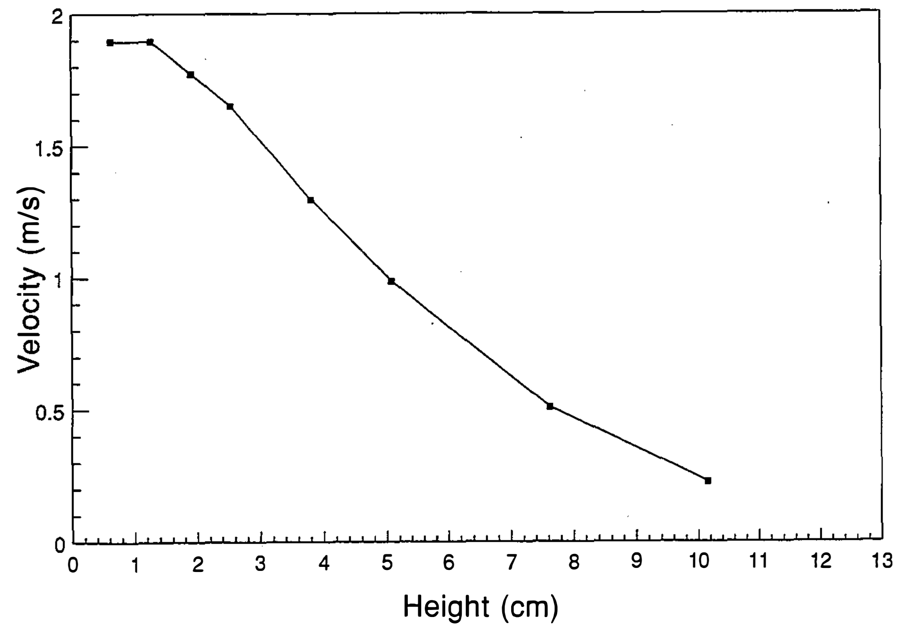

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Figure 7. Velocity profile for conventional diffuser (Q = 71 L/s, R = 76 cm)

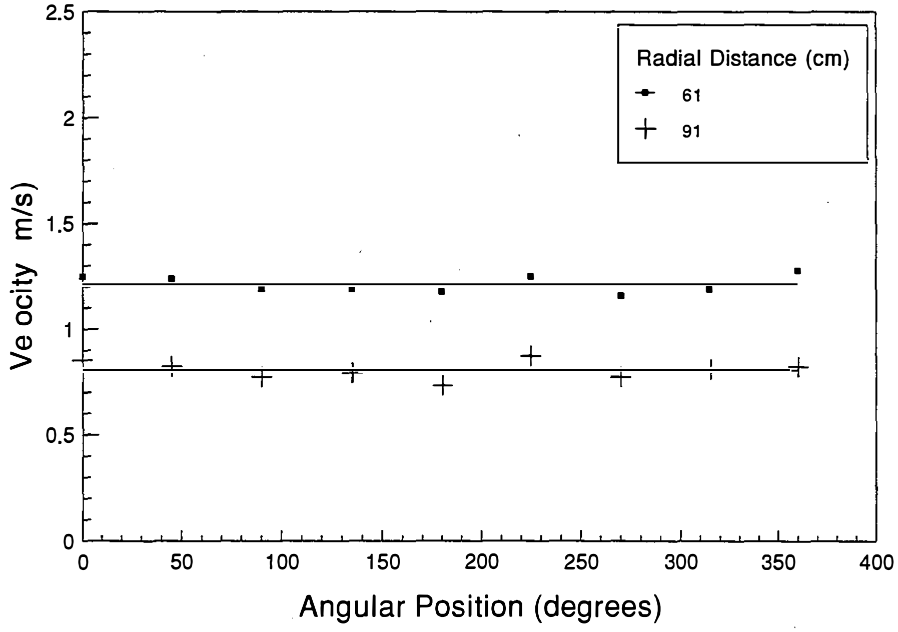

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Figure 8. Velocity map for vortex diffuser #1, (Q = 57 L/s)

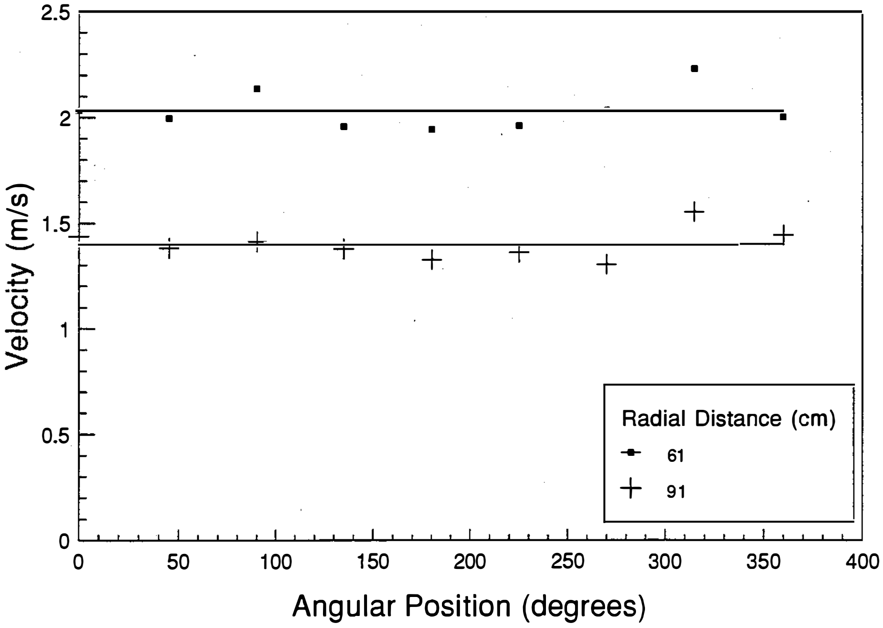

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Figure 9. Velocity map for vortex diffuser #2 (Q = 93 L/s)

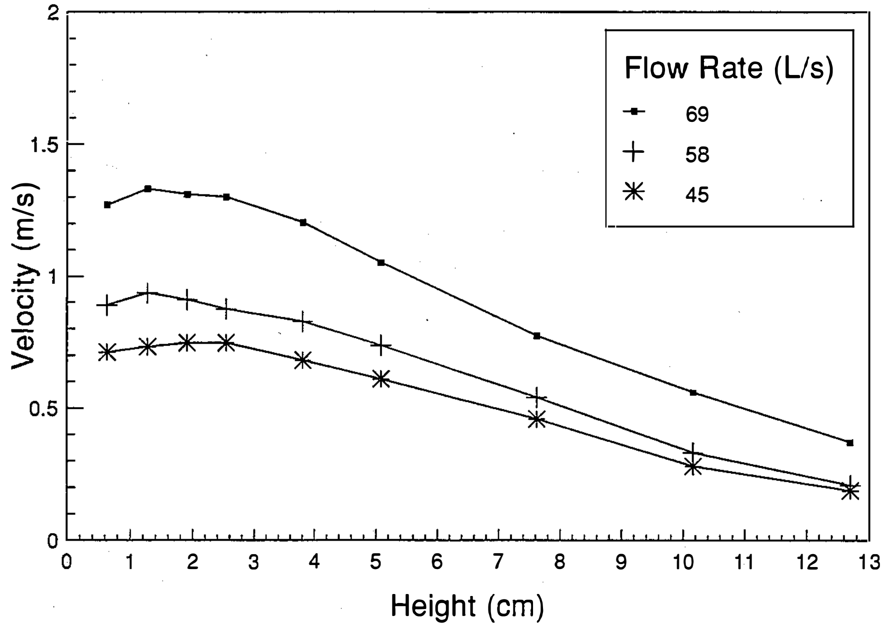

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Figure 10. Velocity profile for vortex diffuser #1 (R = 76 cm)

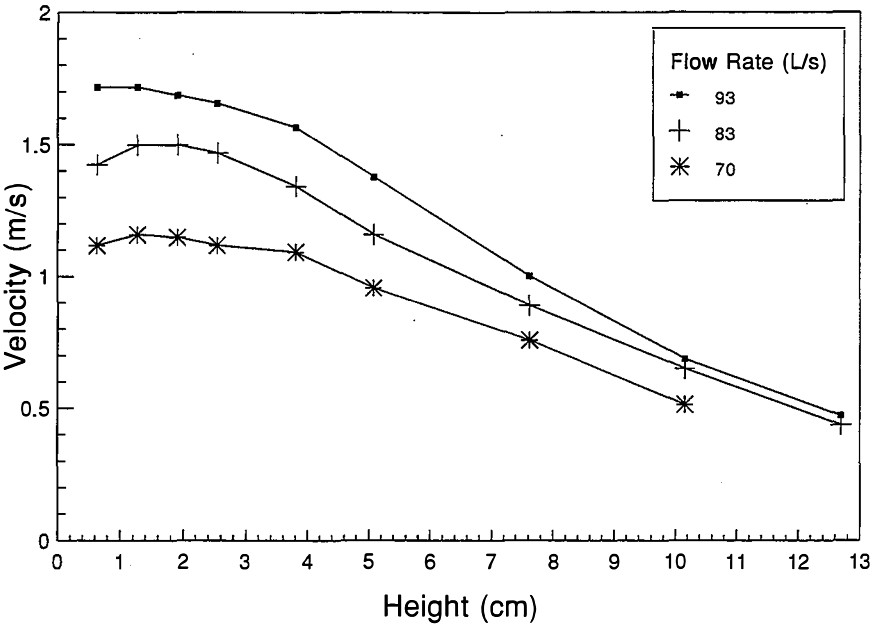

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Figure 11. Velocity profile for vortex diffuser #2 (R = 76 cm)

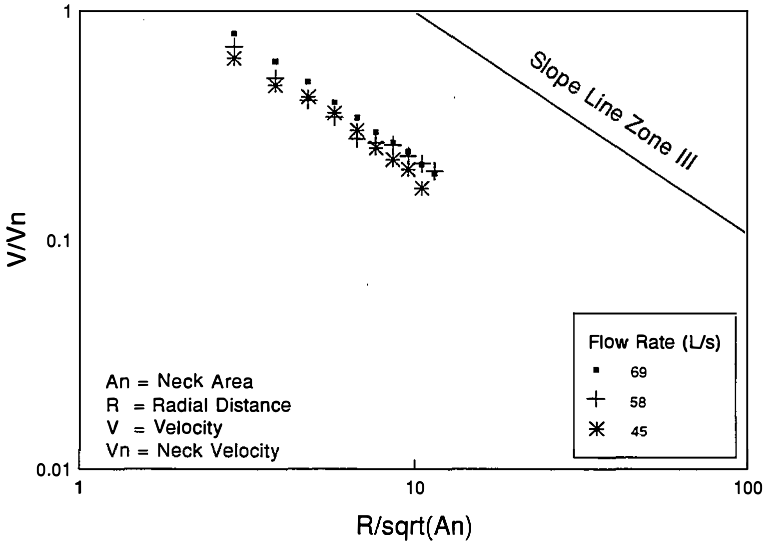

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Figure 12. Velocity decay for vortex diffuser #1

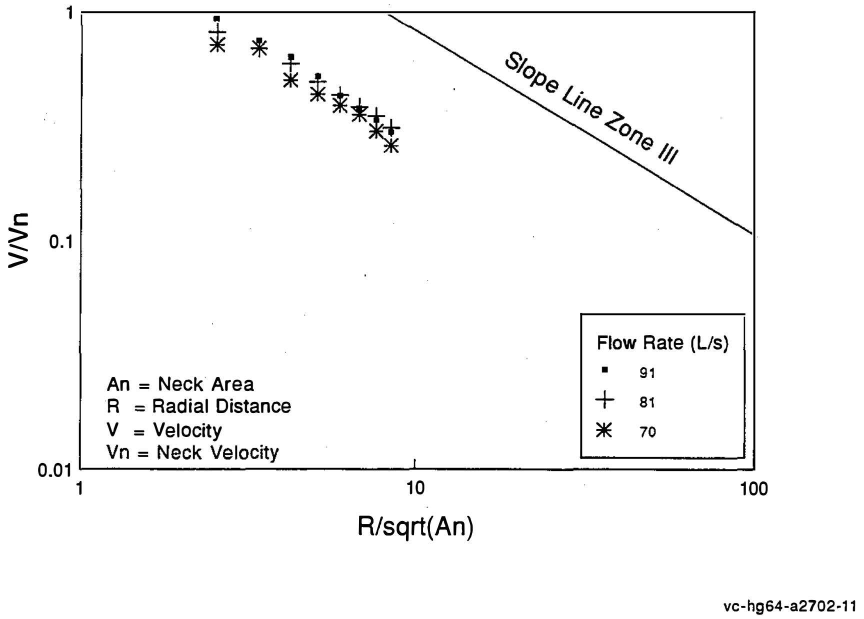

Figure 13. Velocity decay for vortex diffuser #2

Figures 10 and 11 show the velocity profiles for the two vortex diffusers at a radial distance of 76 cm (30 in). The maximum point of velocity is within 2 cm (0.8 in.) of the surface for all the cases shown which is similar to established performance of conventional diffusers (Koestel, 1957).

Figures 12 and 13 show velocity decay data and that the typical zone III of jet expansion is established for each of the vortex diffusers, analagous to the conventional diffuser. The format of Figures 12 and 13 differs from the standard format in that the neck velocity and neck area are used for normalization, whereas the average outlet velocity (measured with a specified instrument and method) and area factor are used for normalization in the standard format (ASHRAE 70-91). For vortex diffuser #1, the standard normalization approach was not used because the average outlet velocity could not be measured; we were unable to arraive at a meaningful area factor—it was dependent on the flow rate. In the case of vortex diffuser #2, it was impractical to use the standard specified instrument to measure the velocity because of the long throat of the diffuser.

Figure 14(A) presents a composite of velocity decay data for the three diffusers tested; the best (least squares) fits to the same data are shown in Figure 14(B). The main insight obtained from Figure 14(B) is that the data for the vortex diffusers show a slightly higher value of K. The numerical value of K is found at the intersection of the best-fit curve and the horizontal line at which V/Vn = 1. The significance of K is apparent in the following well-known equation (ASHRAE, 1993):

$$\frac{V}{Vn}=K\frac{\sqrt{An}}{R}$$

Figure 14-A

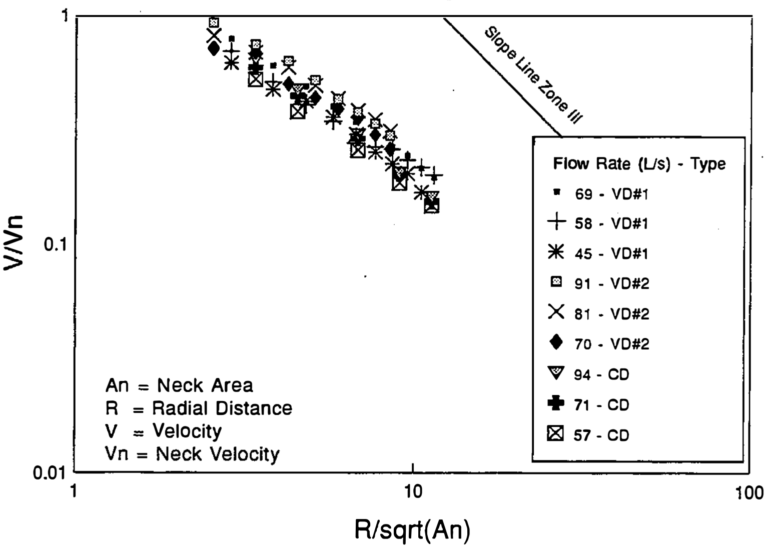

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Figure 14-B

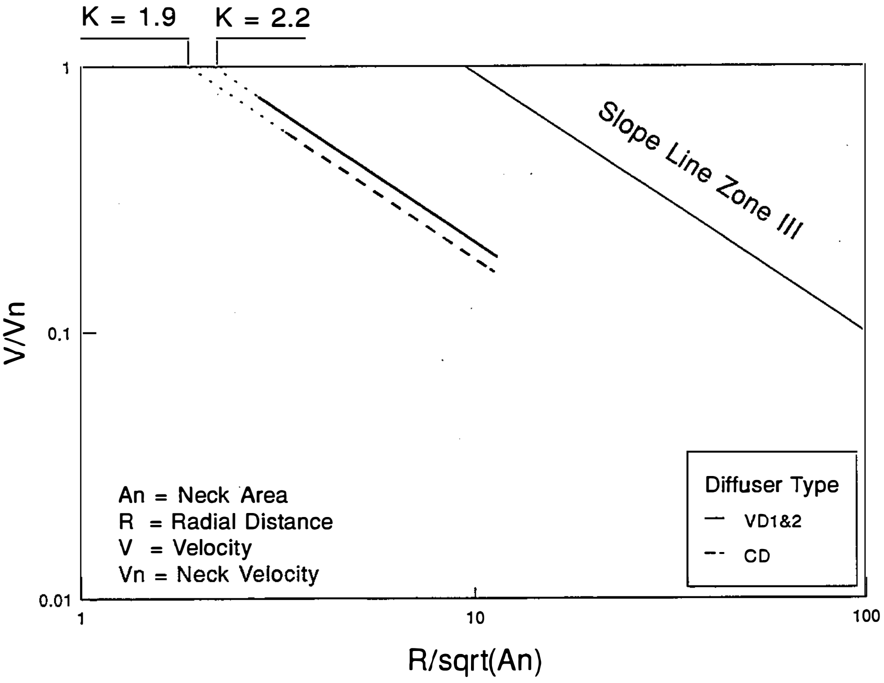

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Figure 14. Composite velocity decay for three diffusers; (A) data, (B) best-fit lines

For a given diffuser diameter and flow rate, the diffuser with a higher K will produce a jet at a higher velocity, at a given radial distance. Under these circumstances, a diffuser with a higher K will cause more ambient air to be mixed with its jet. Thus, the vortex diffusers create somewhat more induction when compared with the conventional diffuser, which is attributable to the turbulence created at the outlet by the rotational component of the jet. However, additional research is needed to quantify this effect. It is not clear whether the induction is high enough to have a significant effect on the motion of room air.

Static pressure data, measured at 1.5D upstream of each diffuser, are presented in Figure 15. Both vortex diffusers require higher static pressure at a given flow rate than does the conventional diffuser to force the air flow through the vortex diffuser vanes. Of course, this results in a higher operational cost.

It should be noted that several of the runs for vortex diffuser #1 were repeated after 1 month, and the results were within 4% of the first series.

3.3 Observations and Flow Visualizations

Three sets of information pertain to the airflow patterns. First, the general motion of air from each diffuser jet was observed. Second, a series of flow visualization photographs were obtained to show the ambient air motion near the diffuser jet. And third, whole-field visualization photographs are presented. All photographs were taken from the side of the test platform, approximately 1.8 m (6 ft) away from the center.

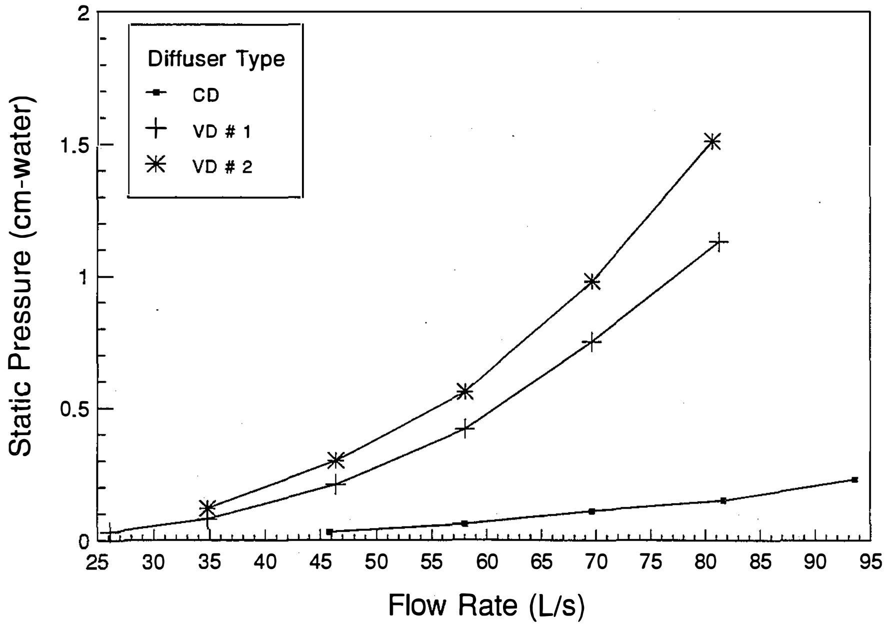

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Figure 15. Duct static pressure for three diffusers

Numerous observations were made to determine the direction of air flow around each of the diffusers by placing a thin mylar strip in the airstream. In the case of the conventional diffuser, the direction of outflow was radial, as expected. For the vortex diffusers, a strong rotation was seen at the diffuser outlet area, but this rotational motion decayed to produce a straight radial flow within 3D of the diffuser center. In another independent test for vortex diffuser #1, colored oil drops were placed on the diffuser face plate at different radial and angular positions, and their traces confirmed this observation.

Examples of the air motion near the diffuser jet for the conventional diffuser and for vortex diffuser #2 at the same flow rate are shown reproduced in Figures 16 and 17. The motion is made visible by the smoke generated by three punks taped together and placed above the test platform. The white horizontal lines in the photographs are strings stretched across the platform to mark the vertical distance from the diffuser face at 30 cm (1 ft), 46 cm (1.5 ft), and 61 cm 9(2 ft). A general description of these photographs follows.

Depending on where the smoke was produced, it rose (because of its buoyancy) a short distance, and then it was pulled downward into the diffuser jet, clearly showing the motion of the air near the jet. The distance the smoke rises and the amount of smoke that is pulled into the diffuser jet depend on the diffuser, and these values could be used as a qualitative measure of the mixing between the ambient air and the jet issuing from the diffuser. For example, in Figure 17(B) there is no initial rise, and all the smoke is pulled into the diffuser jet, indicating greater mixing when compared with the case shown in Figure 16(B).

From other photographs shown in Figures 16 and 17, larger mixing is apparent for the vortex diffuser for the locations observed in this study. Note that the smoke from the punks is generated by burning, and thus its use as a tracer would underestimate the downward motion of isothermal ambient air. Nevertheless, a downward motion of smoke (which is indicative of the downward motion of air) is seen in most of the photographs shown in Figures 16 and 17.

The whole-field flow visualization runs (using two visualization media—fog and smoke) were recorded on a videotape for completeness. Some photographs of the same runs are reproduced in Figures 18 and 19 for the conventional diffuser and vortex diffuser #2 at two different flow rates. The visualizations of vortex diffuser #1 were similar to those of vortex diffuser #2. The diffuser jet, which was made visible by the fog, is the horizontal cloud-like portion of the photographs. The motion of the air near the diffuser jet was visualized by the smoke, which was generated by burning punks located abovethe diffuser center. The white horizontal line marks the height of 30 cm (1 ft) above the diffuser.

As seen in Figure 18(A), the smoke for the conventional diffuser is initially dispersed upward, and then a portion of it moves downward, whereas for the vortex diffuser at approximately the same flow rate, all the smoke moves downward [see Figure 19(A)]. This indicates a greater mixing between the air and the jet for the vortex diffuser. At the higher flow rate shown in Figures 18(B) and 19(B), the results are qualitatively comparable between the diffusers; i.e., the induction at the outlet is not obviously greater for the vortex diffuser.

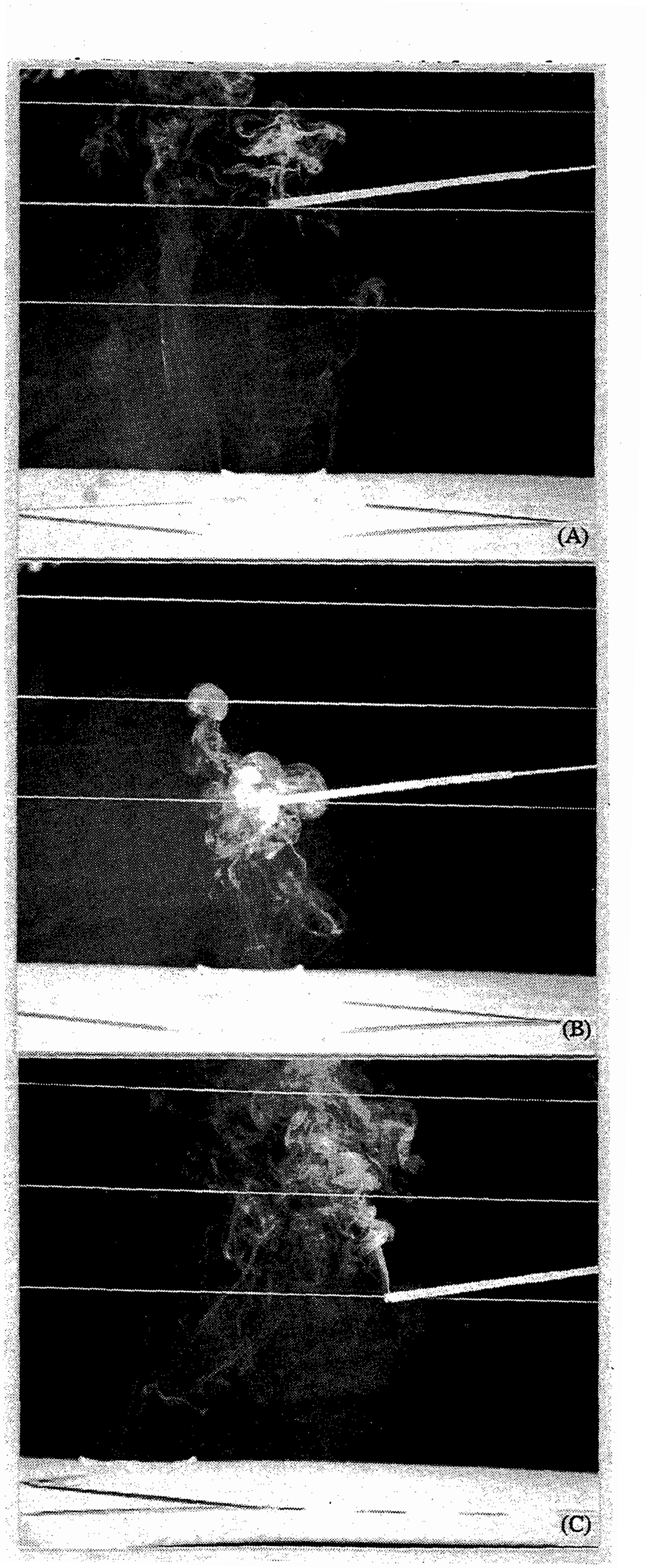

Figure 16. Ambient air motion near jet for conventional diffuser (Q = 71 L/s): (A) R = 0, H = 46 cm; (B) R = 0, H = 30 cm; (C) R = 61 cm, H = 30 cm

Figure 17. Ambient air motion near jet for vortex diffuser #2 ($Q = 71$ L/s): (A) $R = 0$, $H = 46$ cm; (B) $R = 0$, $H = 30$ cm; (C) $R = 61$ cm, $H = 30$ cm

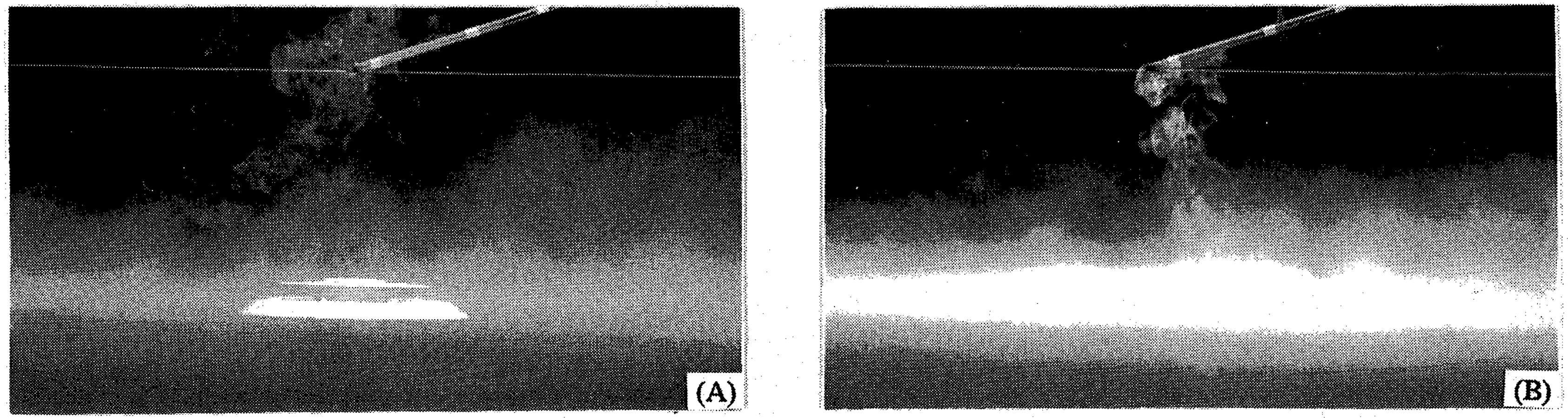

Figure 18. Whole-field flow visualization for conventional diffuser

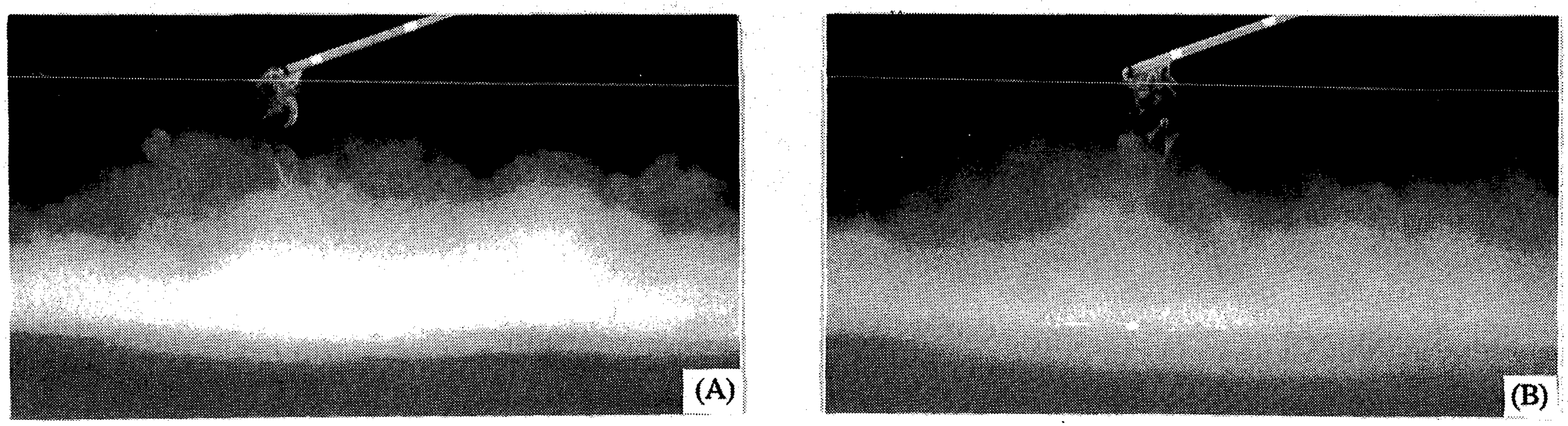

Figure 19. Whole-field flow visualization for vortex diffuser #2

4. Conclusions

Diffuser manufacturers can and should provide standard performance data for their vortex diffusers. The performance of these diffusers can be expressed by standard parameters of throw and pressure drop, at least. The following conclusions are based on the quantitative measurements and qualitative observations made in this study of vortex diffusers.

1. The jets issuing from the vortex diffusers are rotational at the outlet but turn into straight, radial flows within 3D of the center.

2. The maximum velocity at a given radial position occurs within 2 cm (1 in.) of the surface, as with a conventional diffuser.

3. Circumferentially uniform flow over 360^0 is produced by both conventional and vortex diffusers, but, for vortex diffuser #2, the flow's uniformity is dependent on careful vane adjustment.

4. The jet velocity decay for the vortex diffusers resembles that of the typical zone III.

5. Somewhat more induction is observed near the vortex diffuser outlet compared with that of the conventional diffuser. However, the significance of this effect on room air motion remains to be quantified.

6. The up-side-down test produces valid results as long as isothermal air is used.

7. The vortex diffusers require higher static pressure than the conventional diffusers.

8. A fog machine can be a useful device for a whole-field flow visualization in air-conditioning applications. It can easily produce a large, controllable amount of nontoxic fog.

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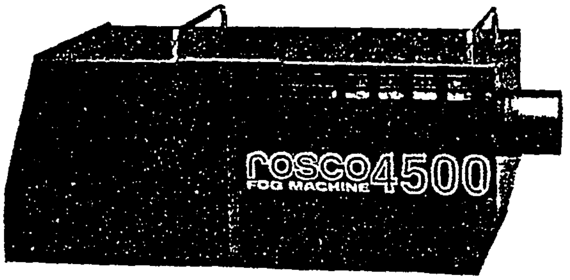
Appendix

Theatrix, Inc.
1630 West Evans, Unit C
Englewood, CO 80110
(303) 922-0505

model 4500 fog machine

WHEN BILLOWING CLOUDS OF DENSE FOG ARE NEEDED, THE 4500 FOG MACHINE IS THE ANSWER

- High volume, dense fog
- Internal/external tank capabilities
- Volume control
- Uses proven Rosco Fog Fluid



Controls and indicator lights for the Model 4500 are protected by a metal cover at the rear of the 40 pound (18.2 Kg) machine.

Rosco's Model 4500 Fog Machine is the latest in the growing line of Rosco fog systems. The machine has an output of 4500 cubic feet per minute, three times the output of the Model 1500.

The Model 4500 utilizes most of the quality components which have proven so reliable in the 1500. The high volume of smoke is generated by combining three heat exchangers fed by a powerful peristaltic pump. The speed of the pump is controlled electronically, thus controlling the volume of the fog.

The Model4500 features an internal 1½ liter tank for fluid. The fluid level in the internal tank can be monitored from outside the machine. Users who prefer to supply fluid from larger external containers can do so easily with a simple hose connection.

The 4500 has an extensive array of controls and indicator lights on the back of the machine, secured under metal cover. There is a remote control included as standard equipment with the machine which permits operation from as far away as 100 feet. Also available is an optional Super Remote that includes a programmable sequencer. The machine is available in both 120 volt and 240 volt models.

The Model 4500, like all Rosco Fog Products, uses Rosco Fog Fluid exclusively. Rosco Fog Fluid is a unique chemical formulation. As reported in a National Institute of Occupational Safety and Health (NIOSH) study (HETA 88-117): "Two main advantages to the Rosco system are the low toxicity of the components which comprise the liquid smoke solutions and the fact that the aerosol generated has no unpleasant odor, leaves no residue and does not irritate the eyes or mucous membranes."

* Rosco's Model 1500 was used in the study reported here.

11/89 (5.4)

Rosco Laboratories, Inc.
36 Bush Ave., Port Chester, NY 10573 (914) 937-1300 FAX: (914) 937-5984 Telex: 131472
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Rosco Laboratories, Ltd.
1271 Denison St. #66, Markham, Ontario, Canada L3R 4B5 (416) 475-1400 FAX: (416) 475-3351
Roscolab Ltd.
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(01) 659-2300 Telex: 8953352

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Attn: 42-00802
Rosco Portuguese Lda.
Trv Bento Gonclaves, 6B Bairro de Angola, Camarate, Portugal 2685 Sacaven

TECHNICAL SPECIFICATIONS: MODEL 4500

POWER REQUIREMENTS: 240 volts, 50/60 Hz, 12.5 amps
120 volts, 50/60 Hz, 20 amps

MAXIMUM FLUID CONSUMPTION: 5.25 liters per hour

SMOKE OUTPUT: 4500 cu. ft. per minute

PARTICLE SIZE: 0.5-60 microns

WARM UP TIME: 10 minutes (approx.)

WEIGHT: 40 lbs.

DIMENSIONS: 24.5" x 9.0" x 9.75"

MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION

Manufacturer's Name:	ROSCO LABORATORIES INC.
Regular Telephone No:	(914) 937-1300 Eastern Time (213) 462-2233 Pacific Time
Emergency No: (nights/weekends)	(914) 738-9169 (203) 327-3244
Address:	36 Bush Avenue, Port Chester, New York 10573
Product Name:	ROSCO FOG FLUID
Synonyms:	Rosco Fog and Smoke Fluid, Rosco Smoke Simulation Fluid, Rosco Stage and Studio Fluid

II HAZARDOUS INGREDIENT

Material or Component

The fog fluid, which is unique in the marketplace, is a proprietary mixture of very low toxicity ingredients. All major components are essentially non-toxic when ingested, are "Generally Regarded as Safe" by the U.S.Food and Drug Administration (FDA), and have been individually approved by FDA for use either in foods, food additives, pharmaceutical preparations, or food packaging. Proprietary information is available at any time to licensed physicians solely for treatment of their patients.

Occupational exposure limits (PELs or TLVs) have not been established for any of the components of this product.

III PHYSICAL DATA

Boiling Point (760 mmHg) : 212-470 F

Melting Point: not applicable

Specific Gravity ($H_2 0=1$) : 1.12

Vapor Pressure: 8.4 mmHg

Vapor Density (air=1) : 2.9

Solubility in water:
Complete @ 70 F

% Volatiles by Vol. : 16%

Evaporation Rate (N=1): 0.01
(N=butyl acetate)

Molecular Weight : Range (18-150)

Molecular Composition:
Trade Secret

Appearance & Odor: Green or colorless liquid with pleasant mild odor.

IV FIRE AND EXPLOSION DATA

Flash Point: no flash point by Cleveland Open Cup and Penskey-Martin Closed Cup

Autoignition Temp.: Not Determined

Flammable Limits in Air % by Vol.: Not Determined

Extinguishing Media: WATER FOG, ALCOHOL FOAM, DRY CHEMICAL

Special Fire Fighting Procedures: NONE

Unusual Fire and Explosion Hazard: NONE

V HEALTH HAZARD INFORMATION

Routes of Exposure

Inhalation: (Vapor)
The low volatility of the compounds in this formulation makes it highly unlikely that significant quantities of vapor could be absorbed during exposure either to the liquid or to the fog.

Inhalation: (Aerosol)
The fog includes liquid particles which may be inhaled and subsequently exhaled, p absorbed or swallowed.

Skin Absorption:
The fluid can be very slowly absorbed through intact skin. Significant exposures could only be acquired by immersion in fluid or prolonged contact with saturated clothing.

Effects of Over-exposure

Ingestion:
Very low toxicity. Central nervous system depression (stupor) in children and drowsiness or dizziness in adults at doses of 2 - 3 ounces. Rapid heart rate and breathing rate in response to decrease in blood pH.

Inhalation:
Acute vapor exposure is difficult to achieve at ambient temperature. There is little likelihood of adverse effects. Sensitive persons (such as those with asthma or other reactive airway disorders) including employees or spectators, should be warned that they may experience asthma-like effects from aerosol exposures.

Skin contact:
Fluid may cause slight irritation after prolonged contact. Incidental skin contact with the fog should produce no adverse effect.

Eye contact:
May cause mild irritation.

Chronic:
No long term effects are known to result from exposure by inhalation or by contact with intact skin.

Emergency and First Aid Procedures

Eyes: In case of eye contact with liquid, flush immediately with large amounts of water and seek aid of a physician.

Skin: Short term contact causes no adverse effects.
Wash off with water and remove saturated clothing.

Inhalation: Remove person to fresh air. If breathing has stopped, administer cardio-pulmonary resuscitation (CPR).

Ingestion: Very low in toxicity. Consult physician if symptoms of intoxication appear. Do not induce vomiting if patient is not fully conscious. Small amounts of fluid are metabolized or excreted without adverse effect.

Note to Physician: Ingestion of several ounces by a child (proportionally more in an adult) could result in metabolic (lactic) acidosis. The pH imbalance has been successfully treated with bicarbonate. Treat respiratory effects symptomatically.

VI REACTIVITY DATA

Conditions Contributing to Instability: Stable Compound

Incompatibility: Oxidizing Materials (strong acids or peroxides)

Hazardous Decomposition Products: None

Conditions Contributing to Hazardous Polymerization: Does not occur

VII SPILL OR LEAK PROCEDURES

Steps to be Taken if Material is Released or Spilled

Small Spills: Soak up with absorbent material and sweep into drum.

Large Spills: Dam to prevent run-off to storm sewers or waterways. Use vacuum system to recover.

Neutralizing Chemicals: not applicable

Waste Disposal Method: Contact commercial chemical waste company to dispose of waste in accordance with federal, state, and local regulations.

VIII SPECIAL PROTECTION INFORMATION

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Ventilation Requirements

Special ventilation is not required where ambient indoor air quality is adequate (see ASHRAE Standard 62-1981). For applications in totally enclosed, unventilated spaces see OSHA, Notice of Proposed Rulemaking; 1910.146 dated June 6, 1989: Confined space.

Specific Personal Protective Equipment

Respiratory :
None required for intermittent, short-term exposures. Organic vapor respirators with particulate filters can be used to decrease exposure.

Eye:
Chemical face shields or goggles are recommended to prevent eye contact with the fluid.

Skin:
Aprons and/or gloves made of neoprene, rubber, or other impervious material can be used to prevent exposure.

Other Clothing and Equipment:
Practice reasonable caution to minimize skin contact.

IX SPECIAL PRECAUTIONS

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Precautionary Statements: not applicable

Other Handling and Storage Requirements: not applicable

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SUPERFUND AMENDMENT REAUTHORIZATION ACT (SARA)

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SARA Title III Emergency Planning and Community Right-to-Know Act (EPCRA) Section 313:

Since they are individually listed by the US Food and Drug Administration as substances "Generally Regarded as Safe" for use in Food or in Food Packaging, components of this product are exempt from the reporting requirements of Section 313 of EPCRA.

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13. ABSTRACT ***(Maximum 200 words)***

This report documents experimental research performed on vortex diffusers used in ventilation and air-conditioning systems. The main objectives of the research were (1) to study the flow characteristics of isothermal jets issuing from vortex diffusers, (2) to compare the vortex diffuser's performance with that of a conventional diffuser, and (3) to prepare a report that disseminates the results to the designers of ventilation and air-conditioning systems. The researchers considered three diffusers: a conventional round ceiling diffuser and two different styles of vortex diffusers. Overall, the vortex diffusers create slightly more induction of ambient air in comparison to the conventional diffuser.

14. SUBJECT TERMS

vortex diffusers, ventilation, air-conditioning, isothermal jets, diffuser area factor, diffuser neck area, diffuser neck diameter, average outlet velocity, neck velocity, rotational velocity, translational velocity

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