PERFORMANCE EVALUATION OF CEILING BASED SWIRL DIFFUSER PLACEMENT IN INDOOR ENVIRONMENT FOR HUMAN THERMAL COMFORT

[1]Ravi Pratap Singh, [2]Sachin Kumar Nikam, [3]Deenoo Pawar
[1]ME Scholar, [2]Assistant Professor, [3]Assistant Professor
[1]Department of Mechanical Engineering,
[1]Lakshmi Narain College of Technology, Bhopal, India

Abstract: Human thermal comfort is most important consideration while placing an air diffuser in indoor space. Velocity of air and swirl produce by diffuser is also put an impact for obtain thermal comfort in indoor space. In this work we have evaluated performance by placing ceiling diffuser in indoor space with the diffuser angle 100,110,120 to obtain better swirl effect and analysis the temperature distribution inside the indoor space. Swirl produce by diffuser depends on it angle and proper swirl mixing with air produce better temperature distribution inside the room to obtain thermal comfort so by this experimental work we just want to evaluate and analysis the proper flow of air by swirl diffuser to design more angle validated ceiling diffusers.

IndexTerms - **Swirl diffuser, indoor environment, comfort condition**

I. INTRODUCTION

Air diffuser is device that is designed to prove uniform air flow to throughout a room. It works to increase the efficiency of air conditioning units by dividing and distributing cooled air. It provides greater comfort to occupants when the even air flow is maintained. Air diffuser is mostly mounted on ceilings and sometimes on walls. The type, size and location of the diffuser depend on many factors. This includes the layout of building or room, location of doors and windows and a type of air conditioning system being used. The concept of air diffuser is relatively simple, air flows naturally through a duct. The diffuser capture this air, as it come through the air conditioning system and splits the forced air into smaller streams. The tiny current of air is then directed in an even flow throughout the room. This stream cannot typically be the felt while the air is circulating. When this air conditioning devices is placed in a room, the temperature will usually drop faster than when one is not used. Since the room can be cooled quickly, the thermo state may be turned up more at night in order to save energy. It is important for a humid weather. It is bit costly but easily installable. It is customizable and can be made in any colour as per the décor. It is the common air diffuser to be installed at home. Those that cover vents in walls are somewhat larger than other residential type and are preferred when and air conditioning vent is along the lower edge a wall. Air diffuser helps air conditioning units more efficiently. They do not need a power source in order to operate. They are large any looking to efficiency of an air conditioning unit and provide even air temperatures in both commercial and residential environment.

Air diffusers are device that suffer as the end point for HVAC unit. Diffusers circulate fresh air into rooms and are found in both residential and commercial buildings. Common referred to as air diffusers to as air vents. Diffuser comes in several shapes and size are often found in floors and ceiling. Diffuser is also sometimes referred to registers. According to Alantsupply.com .they can be made of metal or wood, though wood is less common are usually found in the home.

II. LITERATURE REVIEW

Mohammed A. Aziz in 2012 investigates airflow characteristics (vortex, round and square ceiling diffuser) and the effect on the thermal comfort in a room which is fully ventilated. Experimentally, a sub-scale room is set-up to measure the temperature field in the room. {1}B. Sajadi in 2011 investigated the effect of geometric parameters on the performance of a specific type of swirling air diffuser. The results also reveal that it extremely depends on the blades angle and the angle i.e. between 30◦ and 35◦ for the diffuser performance and the resultant indoor airflow distribution {2} P. K. Sinha and B. Majumdar in 2011 investigated the distribution of mean velocity, static pressure and total pressure experimentally on an annular curved diffuser of 37.5° angle of turn with an area ratio of 1.284. {3} Suraj and V N Bartaria (2013) offered in their technical paper the experimental work to decrease the variation in temperature of system and development in thermal human consolation with the aid of adopting design of ground swirl diffuser modeled on 3D modeling software. The prototype wood model of the ground swirl diffuser turned into fabricated and designed to check its performance below unique operating and flow situations experimentally. {4}

III. THERMAL COMFORT

Definition of Thermal comfort is defined in British Standard BS EN ISO 7730 as:
‘That condition of mind which expresses satisfaction with the thermal environment.’

So the term 'thermal comfort' describes a person's psychological state of mind and is usually referred to in terms of whether someone is feeling too hot or too cold.
There are six factors which affect the thermal comfort both environmental and personal. These factors may be independent of each other, but together contribute to a worker's thermal comfort.

Environmental factors:

- Air temperature
- Radiant temperature
- Air velocity
- Humidity

Personal factors:

- Clothing Insulation
- Metabolic heat

The recommended temperature range to optimize indoor thermal comfort for most people is 19°C to 28°C. This temperature range is appropriate for the sedentary or near sedentary physical activity levels that are typical of general office work. This recommendation assumes that people dress appropriately to the external seasonal demands.

IV. MODELING OF DIFFUSER

The reference for the modelling is taken from the journal paper "Performance and flow characteristics of floor swirl diffuser under different operating and flow parameters" by Suraj, International Journal of Mechanical Engineering and Technology (IJMET), ISSN0976 – 6340(Print), ISSN 0976 – 6359(Online) Volume 4, Issue 4, July - August (2013)",specified as ground swirl diffuser modelled on 3D modelling software. The prototype wood model of the ground swirl diffuser turned into fabricated and designed to check its performance below unique operating and flow situations experimentally. The research was executed inner an acrylic sheet timber room with ground 14 swirl diffuser fashions mounted on the roof. The variant in temperature of subtle air shape ground swirl diffuser at distinctive degrees and the impact of warmth load on temperature version was received. This test has been finished on three distinctive models of ground swirl diffuser having unique slot angles of 10^0,11^0,12^0

V. EXPERMENTAL SETUP

The experiment is performed in open space inside the workshop area of department of Mechanical engineering LNCT, Bhopal Campus. The objective of this study is to find out the air flow pattern and its distribution downward height through different swirl diffusers installed at the ceiling in an air-conditioned room. The experiment is based on predicting the nature and behaviour of air diffused by three different types of swirl diffusers having slots with draft angle of 100,110,120, respectively under different operating and flow conditions. An experiment is performed to evaluate the thermal comfort produced in a room equipped with heat load of 1500W load capacity with different swirl diffusers and compare their performance graphically. The graphs are plotted between temperature of diffused air inside the room and vertical height from the floor level.
In the early design stage, without experimental data support, some assumptions have to be taken based on the experience and similar studies done in this field. Following assumptions are applied in the investigation of experimental and numerical analysis. Metabolic rate and preference of closing in the office varies from the people to people. The standard values for metabolic rate and closing factor are to be considered. The activity of a sedentary occupant is estimated to be 1.2 met and the clothing insulation is 1.0 clo in winter and 0.5 clo in summer. Ventilation effectiveness for DCV is estimated to be 1.0, as it is for the mixing ventilation. The experimental set-up is situated in a clean area with excellent air quality. Acrylic sheet wooden room is closed while performing the experiment and heat transfer from room door due to leakage is neglected. We have assumed that the position of the room with respect to sun direction and altitude is identical for heat load calculation. So no effect has been considered. Only sensible heat of air is measured for calculation neglecting latent heat. It contains an acrylic sheet wooden room of size 4 by 4 by 5 feet with dissimilar models of swirl diffuser installed at the ceiling level. The conditioned air from air conditioner is supplied from the bottom through a duct of reducing cross-section to increase the air flow velocity through the diffuser. A heater of 1500W is placed inside the room to provide a heat load. Heater is placed near the location x2. .

Fig.1 10^0 swirl diffuser

Fig.2 11^0 swirl diffuser

Fig.3 12^0 swirl diffuser

Fig.4 Back side showing air-conditioner and duct

Fig.5 Duct of reducing cross- section

Fig.6 Back view of the experimental set-up

Fig.7 Digital Temperature Indicator

Fig.8 Temperature sensing instrument

Fig.9 Heater of heat load capacity 1500W

Fig.10 Top view of various locations inside the room

3-D view of the experimental set-up and actual front view of the experimental set-up is shown in Fig.11, Fig.12 and Fig.13 respectively.

Fig.11 Front view of the experimental set-up

Fig.12 Air distribution pattern through 10^0 ceiling Swirl Diffuser

Fig.13 Air distribution pattern through 11^0 ceiling Swirl Diffuser

Fig.14 Air distribution pattern through12^0 ceiling Swirl Diffuser

VI. EXPERIMENTAL INSTRUMENTATION

Transparent Acrylic Sheet Wooden chamber-The test facility is located at the workshop of LNCT College. The test chamber has the inner dimension (length x width x height): 4 x 4 x 5 ft. The swirl air diffuser is located at the centre of ceiling. At the ceiling a hole of diameter 280mm and depth 280mm is made to place the diffuser. The diffusers used are 280mm in diameter and 280mm height with curved slots cut at the upper surface. These curved slots are drafted through an angle of 100, 110 and 120. Rectangular slots of size 20mm x 200mm are cut on the cylindrical vertical surface of diffuser to capture the air coming out through the air-conditioner. The walls of test chamber are insulated. Four exhaust vents of size 5cm x 5cm are cut on the ceiling for ventilation. The exhaust air is exhausted directly to the surrounding. Inlet air comes from the air conditioner through a reducing cross-sectional area duct and captured in the diffuser at the floor level.

Air temperature measurement-Thermocouple Type k is used to measure the air temperature at inlet, exhaust and along a measuring stand. 13 thermocouples at different heights (0.2m, 0.4m, 0.6m, 0.8m, 1m, 1.2m, 1.4m, 1.6m, 1.8m, 2.0m 2.2m 2.4m 2.6m), are mounted on a stand to measure the air temperatures. Each thermocouple on the stand is attached by the insulated tapes the thermocouples produce an electric voltage that is converted to temperature in the temperature indicator. The reading accuracy for the thermocouples is expected to be 0.3% which can be neglected because the overall accuracy is dominated by the data processed in temperature indicator. A common reference point in the temperature indicator is used and this results in an accuracy of ±1 K. By averaging the measured results, it is expected the accuracy can reach up to ±0.5 K.

Fig.15 Air temperature measurement with thermocouple

Thermocouple -A thermocouple has two conductors of dissimilar materials (typically metal alloys) that produce a voltage in the region of the point at the contact of two conductors. The voltage produced is reliant on, not essentially proportional to, the difference of temperature of the junction to the parts of the conductors. It is used as temperature sensor for controlling measurements and used to exchange temperature gradient to electricity. The main drawback of thermocouples is its accurateness; system errors of less than one degree Celsius (C) can be hard to get. **Wire Calibration-**Thermocouple wire is made to a definite condition, suggestive of its conformance with the NBS tables. This can be improved by calibrating the wire (testing it at known temperatures). Repeated piece of wire on continuous coil will track each other more directly than the lenience. If the wire is calibrated for an attempt to look up its basic condition, it will become even more crucial that all of the aforesaid conditions be heeded in order to avoid deceleration. The thermocouple is a basic component for temperature purposes. This gave a basic overview of thermocouples, shows common challenges faced while design process, and suggesting solutions. The first solution combines both reference-junction recompense and signal conditioning in a single analog IC for ease use; the second solution separates the reference-junction compensation from the signal conditioning to give digital-output temperature to sense with better elasticity and accurateness.

VII. EXPERIMENT RESULTS

The results of experiments are presented in two parts: requirement of the air conditioner size for the particular room condition by the cooling load calculation and thermal comfort environment according to the temperature variation inside the room with different diffusers. Due to different slot angle geometry of swirl diffusers, flow pattern of diffused air inside the room changes. The air is circulated inside the room through different diffusers. As a result the temperature of air inside the room varies which we have recorded at six different locations. The variation in temperature with respects to height is tabulated for each swirl diffuser with and without heat load under two different conditions. The two conditions are when only one exhaust vent is opened and when all the exhaust vents are opened. The study helps in comparing the performance of different swirl diffusers under different operating conditions. From the graphs plotted it is observed that minimum variation in temperature is obtained with 11^0 swirl diffuser and the uniformity in temperature is obtained when all the exhaust ports are opened.

Various data has been recorded with different swirl diffusers under different operating conditions and are tabulated as shown.

Experimental Readings:

Condition1: When exhaust all vent is opened

Initial Room Temperature = 320C

Room Temperature with load 1500W without a.c = 38^0C

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	23	24	22
2	1.0	22	24	23
3	1.5	23	24	22
4	2.0	21	23	21
5	2.5	22	23	23
6	3.0	23	24	22

Table 1.1 Variation in temperature vs. height at location X1 without load.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	28	27	26
2	1.0	27	27	26
3	1.5	28	27	26
4	2.0	27	25	25
5	2.5	27	26	26
6	3.0	26	26	25

Table 1.2 Variation in temperature vs. height at location X1 in condition 1 with load 1500W.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	22	24	22
2	1.0	23	23	22
3	1.5	22	24	23
4	2.0	23	24	23
5	2.5	23	25	22
6	3.0	23	23	21

Table 1.3 Variation in temperature vs. height at location X2 in condition 1 without load.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	27	28	27
2	1.0	28	28	26
3	1.5	27	27	27
4	2.0	28	27	26

5	2.5	26	28	26
6	3.0	28	27	26

Table 1.4 Variation in temperature vs. height at location X2 in condition 1 with load 1500W.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	25	25	24
2	1.0	24	25	24
3	1.5	23	24	23
4	2.0	24	24	23
5	2.5	25	25	23
6	3.0	25	25	24

Table 1.5 Variation in temperature vs. height at location X3 in condition 1 without load.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	28	28	26
2	1.0	27	28	26
3	1.5	27	27	25
4	2.0	25	26	27
5	2.5	26	27	26
6	3.0	26	26	25

Table 1.6 Variation in temperature vs. height at location X3 in condition 1 with load 1500W.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	24	25	23
2	1.0	24	24	24
3	1.5	25	24	24
4	2.0	24	25	23
5	2.5	23	24	24
6	3.0	23	24	23

Table 1.7 Variation in temperature vs. height at location X4 in condition 1 without load.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	27	28	27
2	1.0	27	27	26
3	1.5	28	27	27
4	2.0	27	27	27
5	2.5	28	28	26
6	3.0	28	27	26

Table 1.8 Variation in temperature vs. height at location X4 in condition 1 with load 1500W.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	24	24	22
2	1.0	23	25	24
3	1.5	23	25	23
4	2.0	24	24	22
5	2.5	25	23	24
6	3.0	24	24	23

Table 1.9 Variation in temperature vs. height at location X5 in condition 1 without load.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	28	28	27
2	1.0	27	28	26
3	1.5	28	27	27
4	2.0	27	28	26
5	2.5	26	27	26
6	3.0	27	27	26

Table 1.10 Variation in temperature vs. height at location X5 in condition 1 with load 1500W.

Graphical Representation of Results:

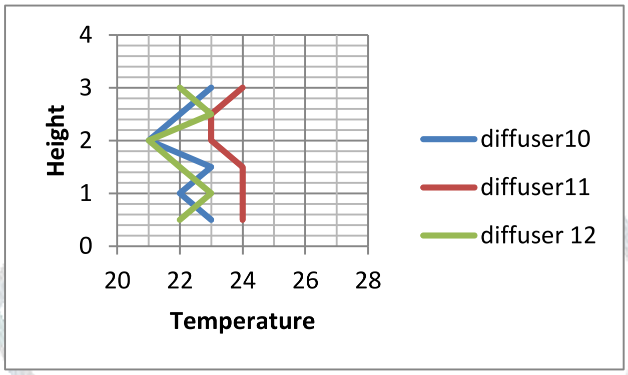

Fig.16 Variation in temperature vs. height at location X1 without load

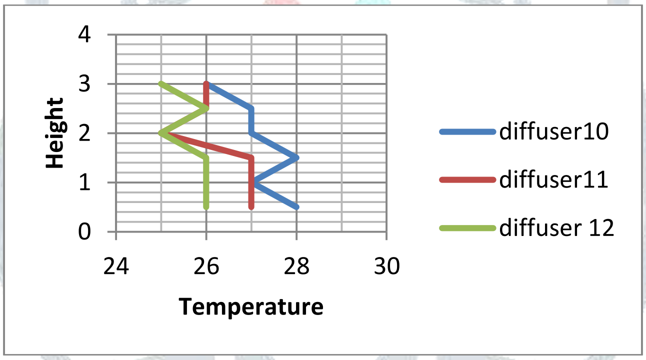

Fig.17 Variation in temperature vs. height at location X1 with load 1500W.

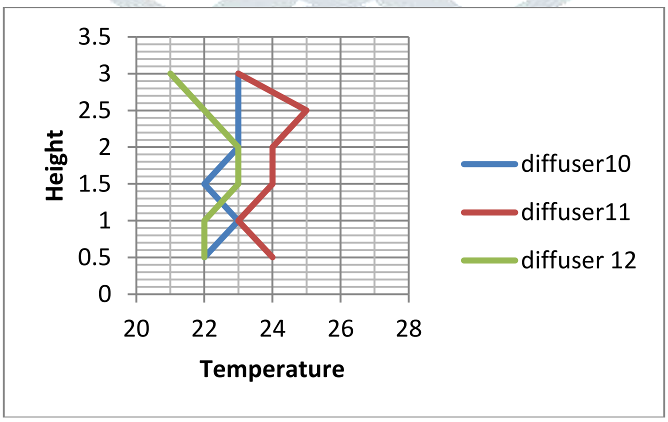

Fig.18 Variation in temperature vs. height at location X2 without load

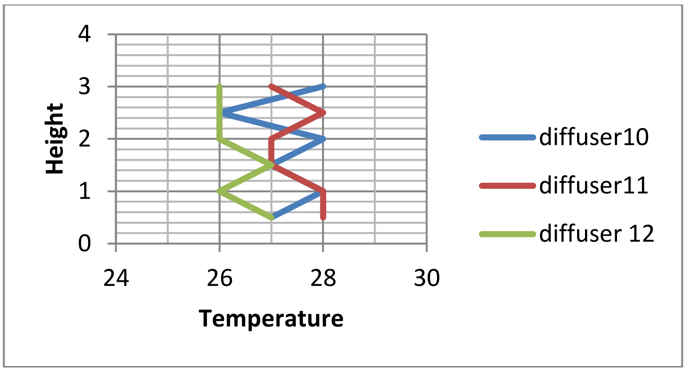

Fig.19 Variation in temperature vs. height at location X2 with load 1500W.

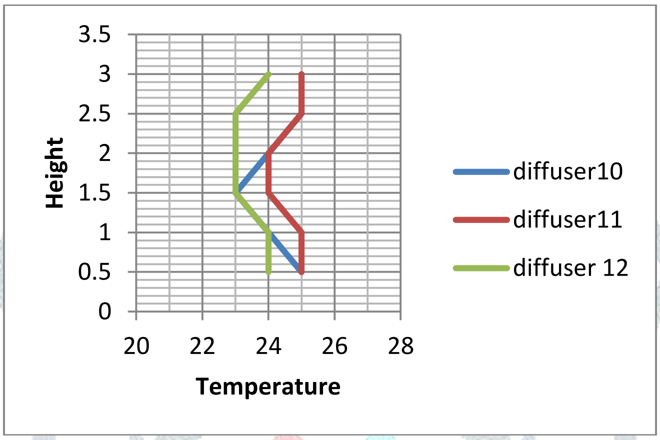

Fig.20 Variation in temperature vs. height at location X3 in without load

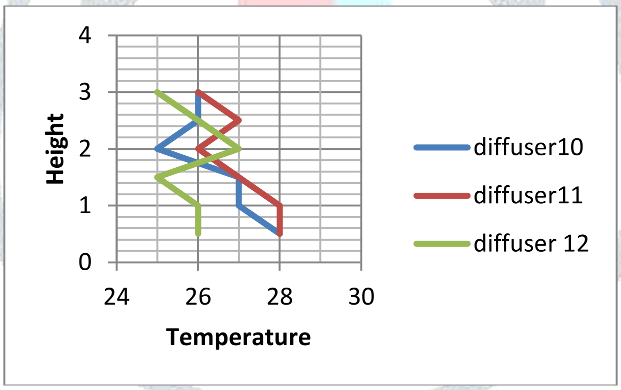

Fig.21 Variation in temperature vs. height at location X3 with load 1500W.

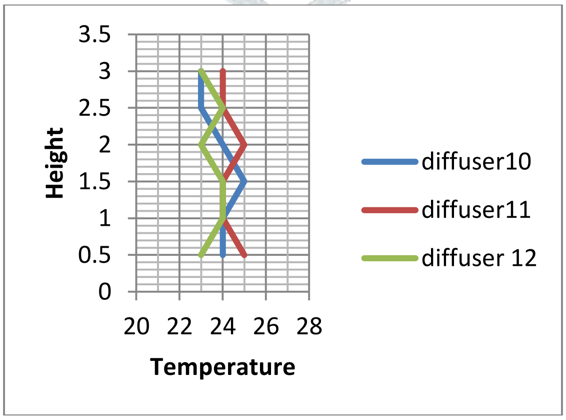

Fig.22 Variation in temperature vs. height at location X4 without load

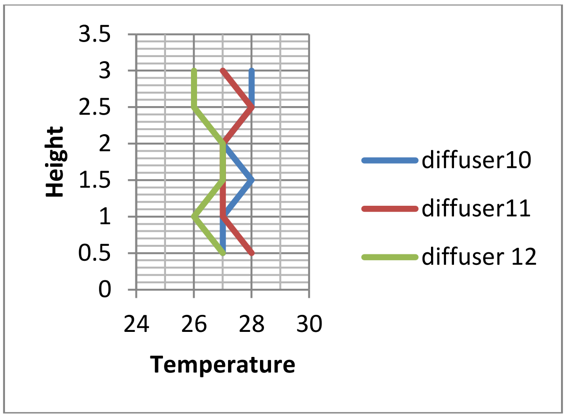

Fig.23 Variation in temperature vs. height at location X4 with load 1500W.

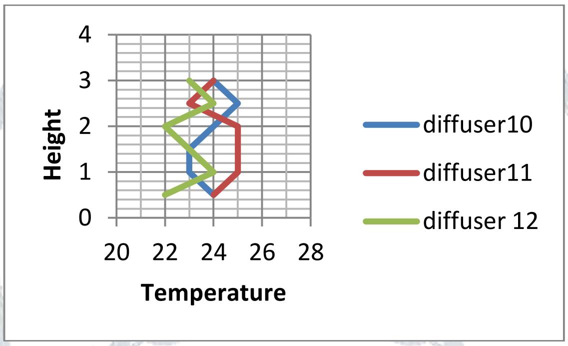

Fig.24 Variation in temperature vs. height at location X5 without load

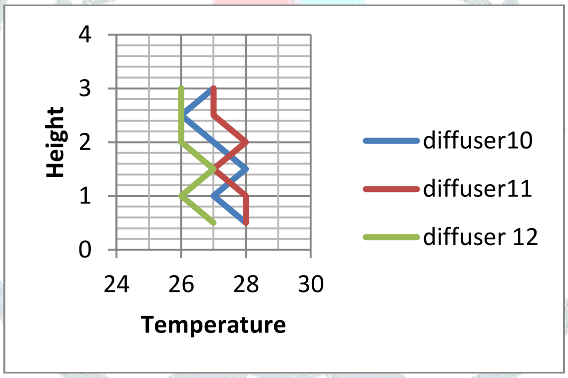

Fig.25 Variation in temperature vs. height at location X5 with load 1500W.

VIII. CONCLUSION AND FUTURE SCOPE

The results from this dissertation work show that a workshop with ceiling-supply displacement ventilation using swirl diffuser can improve indoor air quality because the contaminant concentration in the breathing zone is lower than that of mixing system. It helped us to compare three types of swirl diffuser under different operating and flow conditions. Due to swirl action produced more unidirectional flow was created, the slow recirculation at the occupant zone was eliminated for the ceiling supply ventilation and the risk of cross contamination can be effectively reduced. The maximum variation in temperature is obtained at location X2. This happens due to presence of heater of load capacity 1500W near location X2. As we move away from the heat source variation in temperature reduces and we obtained almost uniform temperature at the upper region of the experimental set-up. We have compared the performance of different swirl diffuser models having slot with draft angle 100, 110 and 120 under different operating conditions and the best performance is obtained with 11^0 swirl diffuser. We have also compared the performance of diffuser when only one exhaust vent is opened and when all the four exhaust vents are opened. The temperature profile is more uniform when all the four exhaust vents are opened. This study helps in selecting optimum models for ceiling swirl diffuser under different operating conditions. We can improve the Air Change Effectiveness and human comfort by varying the slot design angle of diffuser. It will results in better mixing of air inside the room and the variation in temperature of air from floor height will be reduced. We can achieve better human comfort and proper ventilation by using ceiling swirl diffuser. In the present dissertation work investigation are made on the thermal behaviour produced by the diffused air from swirl diffuser installed at the ceiling level. In this work we have observed the variation in temperature of air from air conditioner at various locations with and without heat load. The variation in temperature is also observed when one exhaust vent is opened and when all four exhaust vents are opened. It is proposed that the effect of air flow rate and air velocity on the indoor thermal environment should also be determined experimentally. Velocity distribution pattern can also be made by measuring air velocity at different locations. Humidity percentage can also be measured at different locations. We have kept the supply air conditions constant in the present work. The effect on indoor thermal environment can be analysed by varying the supply air conditions in future.

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