Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 5, Issue 06, June -2018

SWIRL DIFFUSER DESIGN FOR AIR FLOW IN AIR CONDITIONING OF AN AUTOMOBILE

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ABSTRACT:- *Swirl diffusers used in air-conditioning system for automobiles can create better air mixing to enhance inside air quality and help in achieving better human comfort. The variation in temperature in air conditioning system depends strongly on the flow characteristics produced by the diffuser outlet that vary considerably between different modelling set ups. In automobile sector it is very important to calculate the effect of variation in temperature of diffused air through swirl diffuser from a.c. with and without heat load In this dissertation work, I have tried to reduce the variation in temperature of conditioned air and improvement in thermal human comfort by adopting different models of car swirl diffuser designed on pro-E software. After that I have made prototype wooden model of the car swirl diffuser to check its performance under different operating and flow conditions experimentally. The experiment has been performed inside an Alto 800 car with swirl diffuser model installed at the car a.c. outlet. The variation in temperature of diffused air form car swirl diffuser at different altitude and along longitudinal axis of car with the effect of heat load on temperature variation is determined. This experiment has been performed on three different models of car swirl diffuser having different slot angles of 120, 130 and 140.*

1. 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. When an even air flow is maintain, draft and hotspot in room are eliminated, providing greater comfort to occupants, while increase energy efficiency. A ceiling is the most common location for an air diffuser. One is also sometimes installed on walls or window. 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 [31]. The desired look and function of air conditioning diffuser will also affect how and where it is placed. 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. This is especially beneficial in areas that have a high degree of humidity during a day. For home use an aid diffuser that fit over a register can be employed. This type is usually expensive and easy to install.
Swirl diffusers are designed to provide effective indoor air diffusion through specially designed swirl deflection blades to produce a highly turbulent radial air flow pattern that will induce better mixing of room air. This also results in rapid temperature equalization to give stable room conditions with minimum temperature gradients. The excellent high qualities of air from swirl diffusers enable designers to aim for a high value of Air Change Effectiveness (ACE) [21]. Swirl diffusers have recently become very popular because they generate radially high induction swirl airflow by drawing room air up into the supply air pattern to induce superior air mixing. Better mixing means better ACE.

2. Types of floor Swirl Diffuser

2.1 Floor "Swirl" Diffuser

Floor "Swirl" Diffusers are designed for use in raised access floor air distribution systems, where the floor cavity is used as a pressurized supply air plenum. The NFD core design produces a low velocity helical "swirl" discharge air pattern. The design achieves high induction rates of room air which optimizes mixing for maximum comfort conditions. An architecturally appealing face design compliments any contemporary decor and is available as standard in a gray or black finish as well as a

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wide variety of custom colors [13]. Allowing extreme flexibility in space planning, the diffuser, once installed in the access floor panel, can be quickly relocated to accommodate changing conditions and floor layouts.

Fig.1 Floor Swirl Diffuser

Fig.2 Aluminium Floor Swirl Diffuser

2.2 Aluminum Floor "Swirl" Diffuser

Aluminum Floor "Swirl" Diffusers are designed for use in raised access floor air distribution systems, where the floor cavity is used as a pressurized supply air plenum. The specially designed ANFD core produces a low velocity helical "swirl" air pattern [20]. This design achieves high induction rates of room air which optimizes mixing for maximum comfort conditions. An architecturally appealing face design compliments any contemporary decor and is available as standard in a gray or black textured finish as well as a wide variety of custom colors [20]. Allowing extreme flexibility in space planning, the diffuser, once installed in the access floor panel, can be quickly relocated to accommodate changing conditions and floor layouts.

2.3 VAV Floor "Swirl" Diffuser with Actuator

Floor "Swirl" Diffusers with actuators are designed for use in raised access floor air distribution systems, where the floor cavity is used as a pressurized supply air plenum. An integral modulating actuator provides variable air volume control in cooling applications for precise zone temperature control. The NFD-VAV core design produces a low velocity helical "swirl" discharge air pattern [16]. The design achieves high induction rates of room air, which optimizes mixing for maximum comfort conditions. An architecturally appealing face design compliments any contemporary decor and is available as standard in a gray or black finish as well as a wide variety of custom colors. Allowing extreme flexibility in space planning, the diffuser, once installed in the access floor panel, can be quickly relocated to accommodate changing conditions and floor layouts [9].

Fig.3 VAV Floor Swirl Diffuser with Actuator

2.4 VAV Aluminum Floor "Swirl" Diffuser with Actuator

Aluminum Floor "Swirl" Diffusers with actuators are designed for use in raised access floor air distribution systems, where the floor cavity is used as pressurized supply air plenum. An integral modulating actuator provides variable air volume control in cooling applications for precise zone temperature control. The core design produces a low velocity helical "swirl" discharge air pattern [16]. The design achieves high induction rates of room air, which optimizes mixing for maximum comfort conditions. An architecturally appealing face design compliments any contemporary decor and is available as standard in a gray or black textured finish as well as a wide variety of custom colors.

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Fig.4 VAV Aluminium Floor Swirl Diffuser with Actuator

3. Diffuser oulet location and selection

3.1 Selection by Comfort Criteria - ADPI

ADPI (Air Diffusion Performance Index) statistically relates the space conditions of local or traversed temperatures and velocities to occupants' thermal comfort. This is similar to the way NC relates local conditions of sound to occupants' noise level comfort. High ADPI values are desirable as they represent a high comfort level, and also increased probability of ventilation air mixing [34]. Acceptable ADPI conditions for different diffuser types are shown in (Fig. 3.4) for velocities less than 70 fpm and velocity-temperature combinations that will provide better than the 80% occupant acceptance.
The curves in (Fig. 3.4) summarize some of the tests which established ADPI and the relationships from which this selection procedure originates.

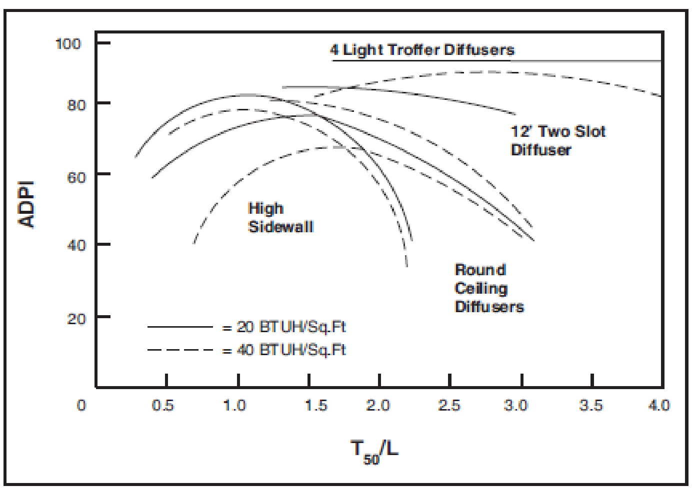

Fig. 5 Through Vs. Characteristics room length

The curves show relative comfort for:
1. Four different outlet types
2. Catalog throws and space characteristics
3. Loading (one cfm/sq. ft. with a 20°F differential is a load of about 20 Btuh/sq. ft.)
4. Flow rate (variable volume)

4. Factors affecting diffuser performance

4.1 Swirling blades angle

The effect of blades angle on the diffuser performance is shown in Fig. 3.5. As depicted in the figure, the evacuation time is minimized at the angle of 32◦ and the diffuser shows the best performance, consequently. In addition, the sensitivity of the evacuation time to the blades angle is surprisingly significant in the range of 30–35◦. The diffuser maximum discharge velocity is also illustrated in Fig. 3.5. As shown in the figure, with an increase in the blades angle, the maximum velocity decreases continuously due to increment of the effective outlet area. As a major conclusion, the optimum blades angle has no

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meaningful relationship with the diffuser discharge velocity. To describe the effect of swirling blades on the resultant airflow pattern, three cases are assessed in details:
1. Diffuser with no swirling blade;
2. Diffuser with blades angle of 32◦;
3. Diffuser with blades angle of 40◦.
The indoor airflow distribution in three cases is shown in Fig. 3.6.
As depicted in Fig. 3.6a, when the diffuser has no blade, air enters the room without any rotation just like a jet which may reduce the diffuser entrainment effect considerably. As a result, the presence of swirling blades has a key role in making the air to rotate and in improving the diffuser mixing effect. The airflow patterns through the room are also illustrated in Fig. 3.6b and c. at the blades angle of 32◦ and 40◦, respectively. As shown in the above mentioned figures, the velocity distribution is remarkably different from the previous case and the blades cause the flow to swirl. At the optimum blades angle, namely 32◦, the discharge air is well attached to the ceiling due to Coanda effect and distributed through the room almost uniformly [34]. Such a well distributed pattern caused by an impressive Coanda effect, improves the indoor air mixing and the resultant induction effect. At the same time, the air velocity does not go over 0.25 m/s through the room, except near the diffuser where is not important for the residents comfort

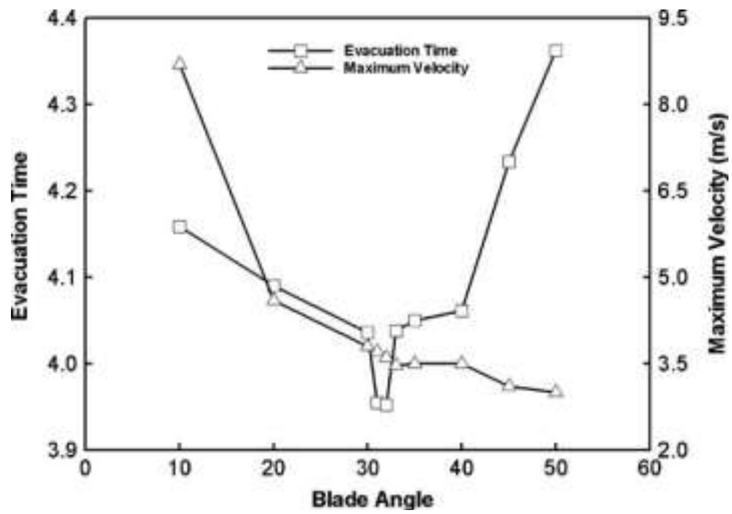

Fig.6 The effect of blades angle on the evacuation time and the maximum discharge velocity. [6]

4.2 Diffuser jet indexes

The swirling jet performance may be characterized by an index, namely jet decay coefficient, which is introduced by Hu as:

$$K = \frac{V_x}{V_o} \cdot \frac{x + x_p}{\sqrt{A_o}}$$

Where K is the jet decay coefficient, V_x is the centerline velocity at the distance x. V_o and A_o are the effective outlet velocity and area, respectively and x_p is the distance between the jet virtual origin and the diffuser centerline.

5. Modelling

Modelling of 12º, 13º and 14º diffuser has been done using PRO-E software. Step by step procedure has been explained while modelling

6. Experimental Investigation and Results

6.1 Experimental Analysis

It consists of three different models of swirl diffuser installed in the car for air distribution inside the car space. The conditioned air from air conditioner is supplied through the diffuser. A bulb of 1000W is placed inside the car to provide a heat load. Bulb is placed near the location Y2. A temperature sensing instrument with six thermocouple wires is placed inside the car to measure the temperature at six locations vertically at a distance of 0.7 feet.

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There are six locations inside the car where readings of temperature have to be noted and the variatin in temperature of air is to be studied.
The various components and parts of the experimental set-up are shown in following figures.

Fig.7 12⁰ Swirl Diffuser

Fig.8 13⁰ Swirl Diffuser

Fig.9 13⁰ Swirl Diffuser

6.2 Experimental set up

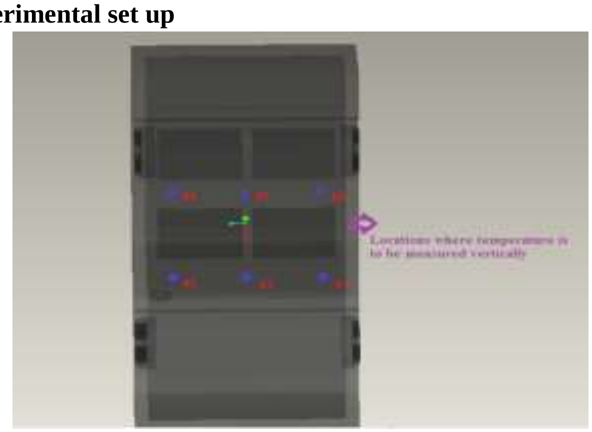

Fig.10

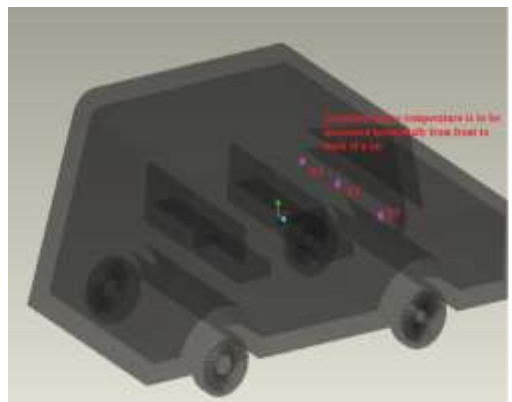

Fig.11

6.3 Graphical Representation of Results in given conditions:

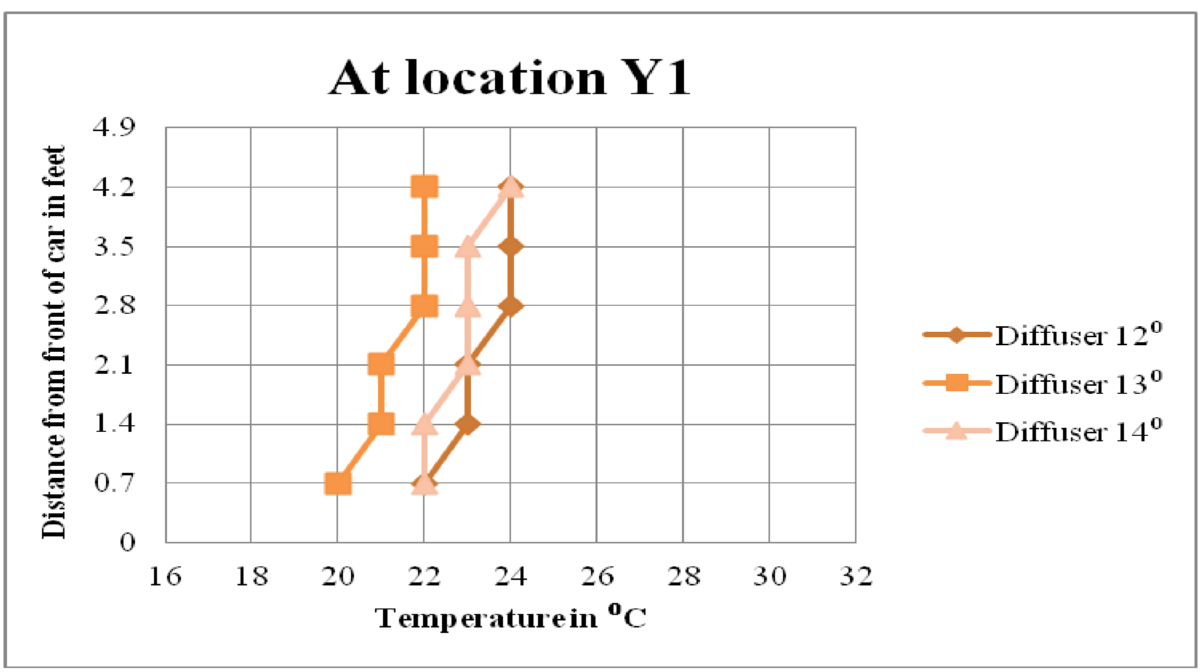

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Fig. 12 Variation in temperature vs. distance from front of car in feet at location Y1 without load.

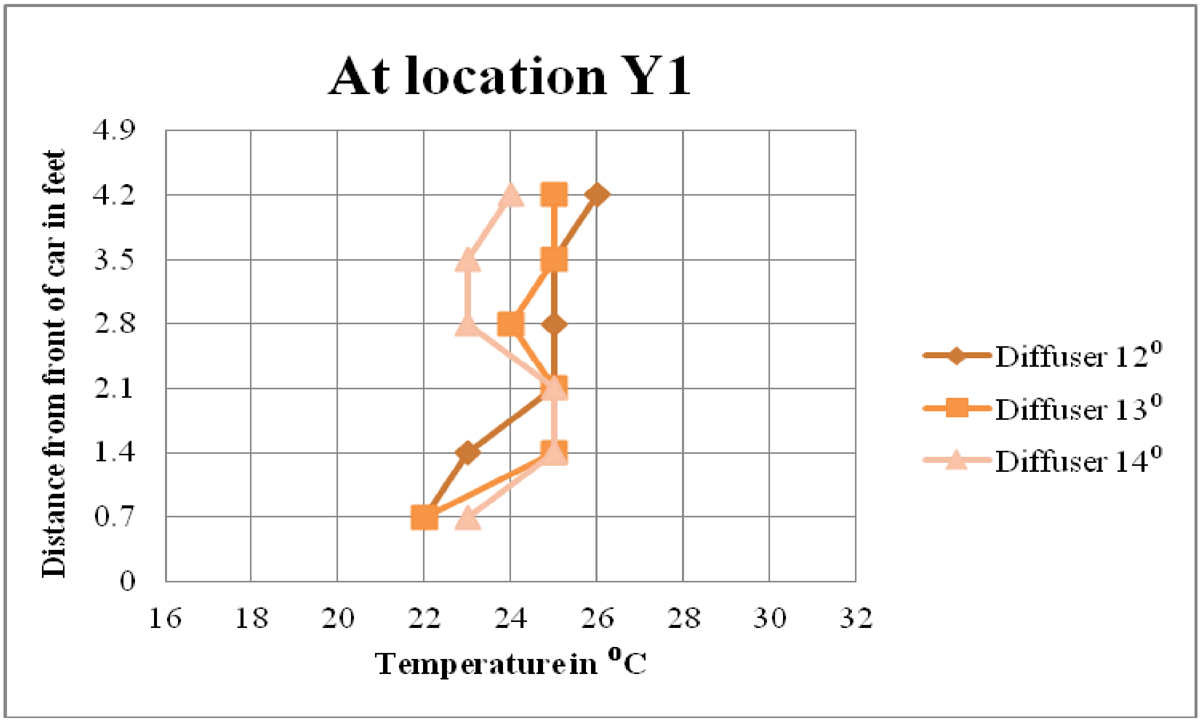

Fig.13 Variation in temp. vs. distance from front of car in feet at location Y1 with load 100

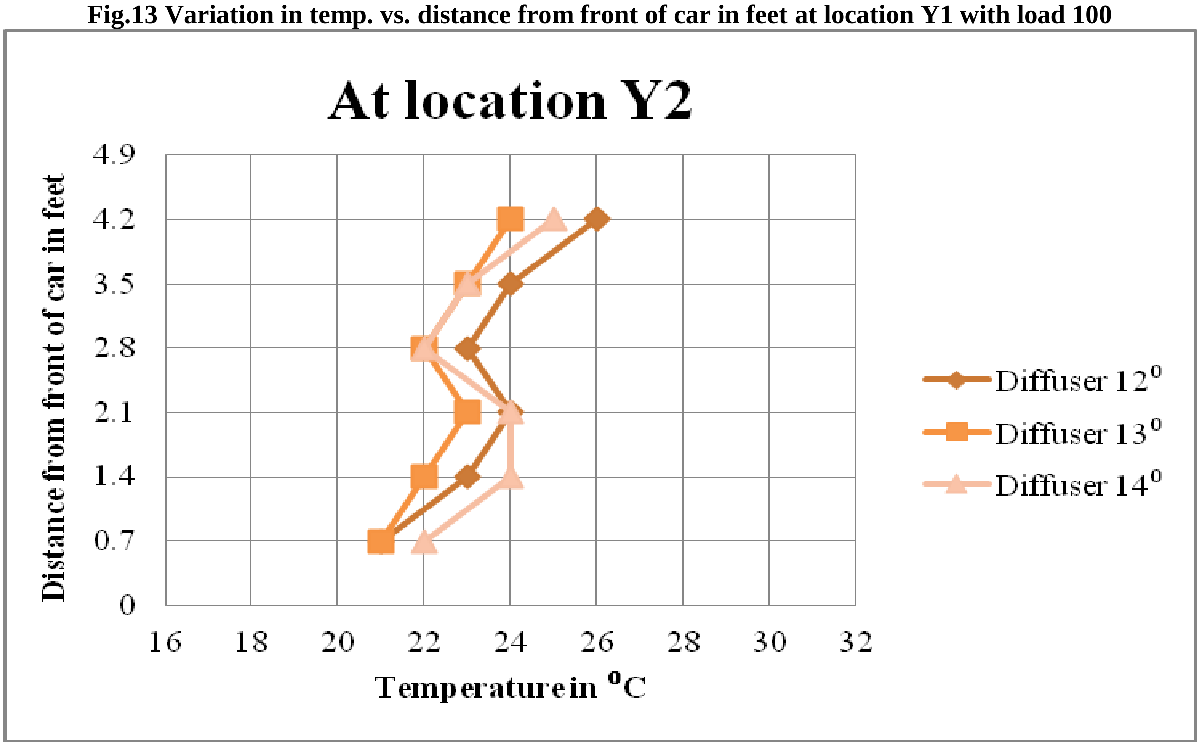

Fig.14 Variation in temperature vs. distance from front of car in feet at location Y2 without load.

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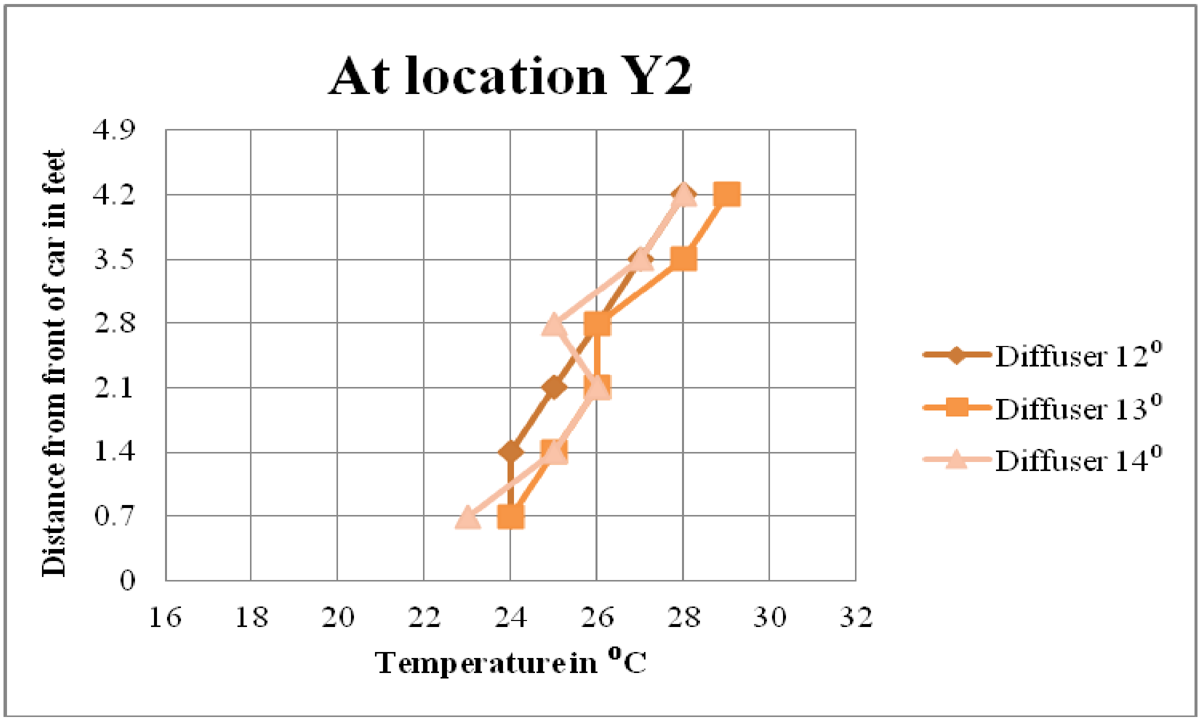

Fig.15 Variation in temp. vs. distance from front of car in feet at location Y2 with load 1000W.

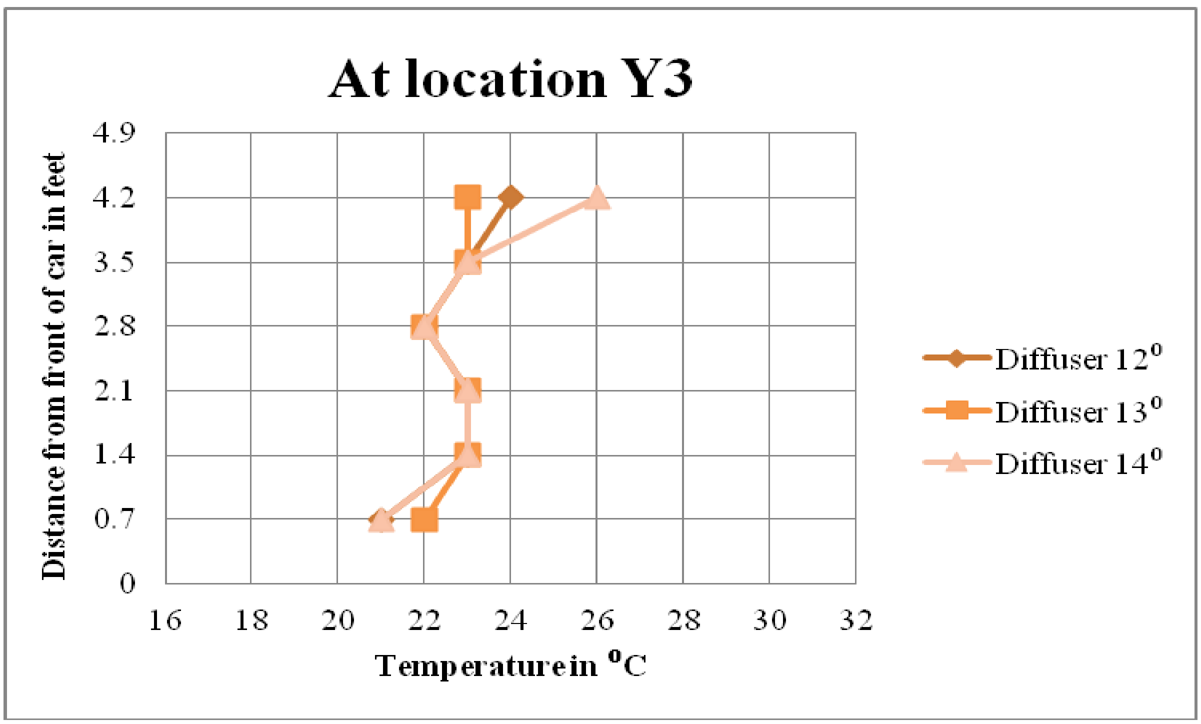

Fig.16 Variation in temperature vs. distance from front of car in feet at location Y3 without load.

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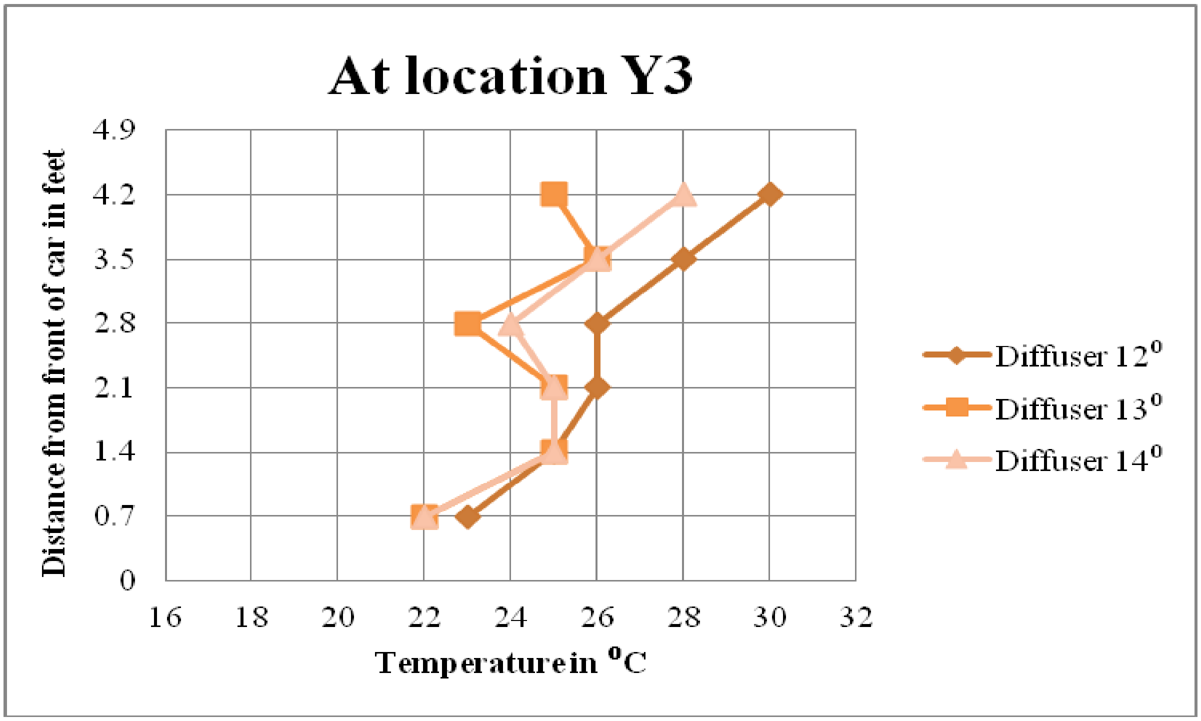

Fig.17 Variation in temp. vs. distance from front of car in feet at location Y1 with load 1000W.

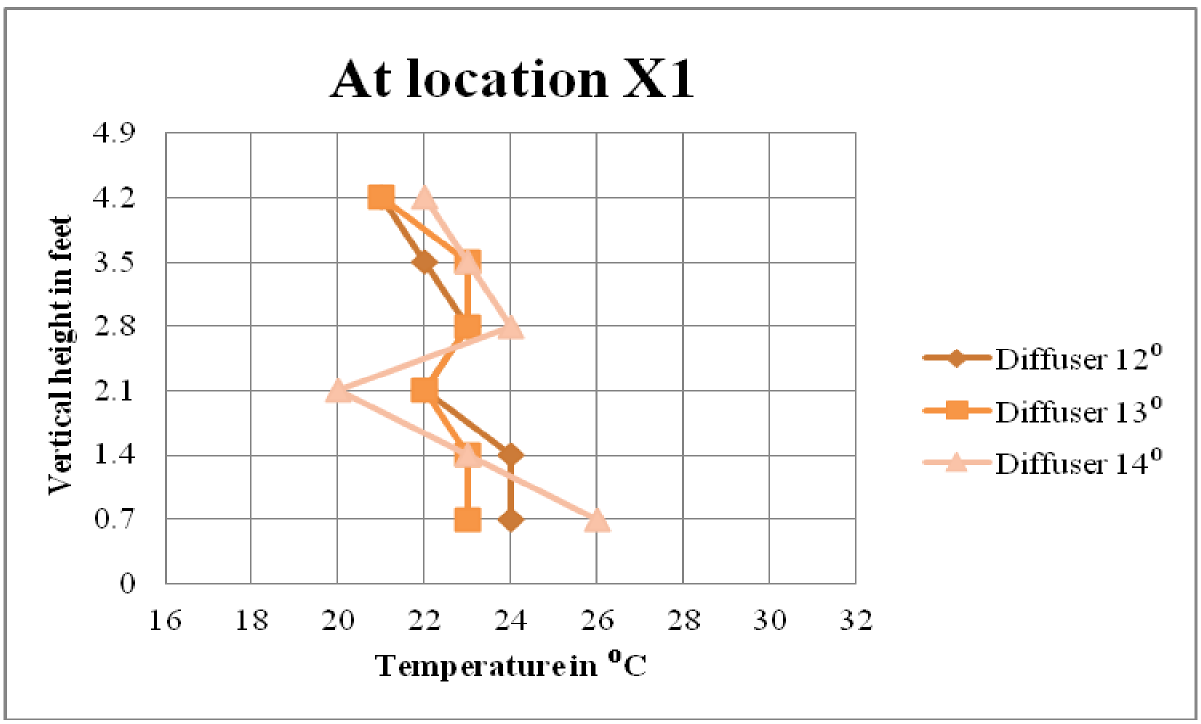

Fig.18 Variation in temperature vs. height at location X1 without load.

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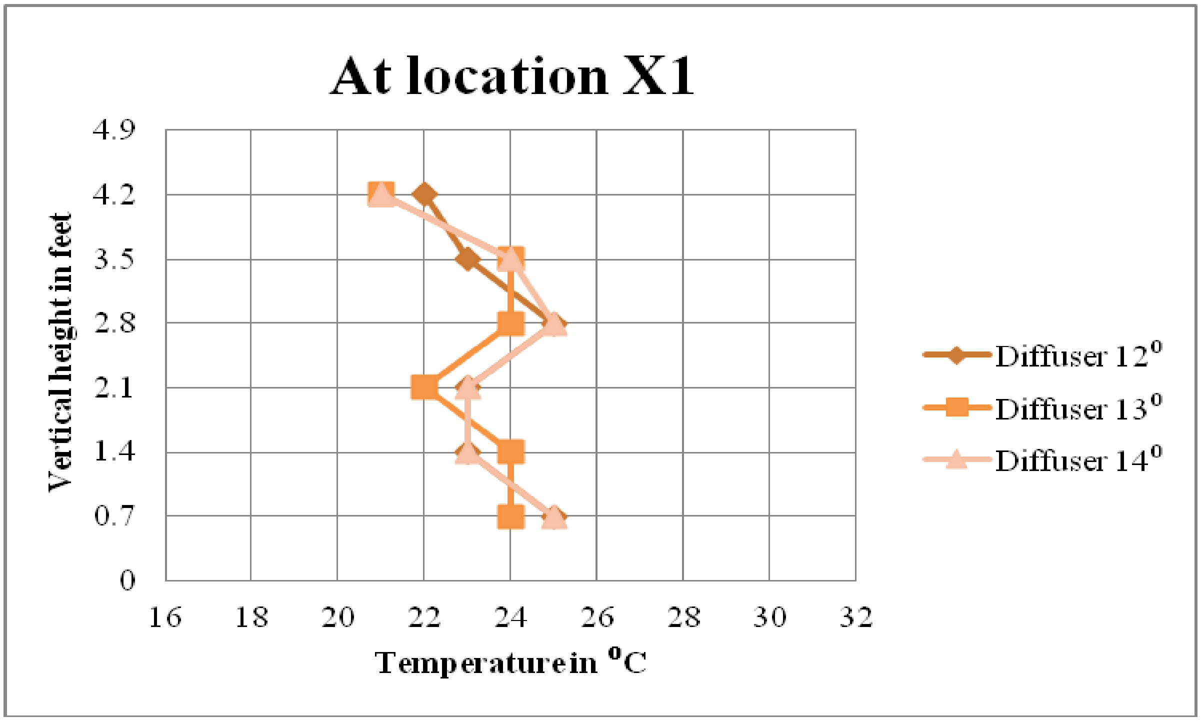

Fig.19 Variation in temperature vs. height at location X1 with load 1000W.

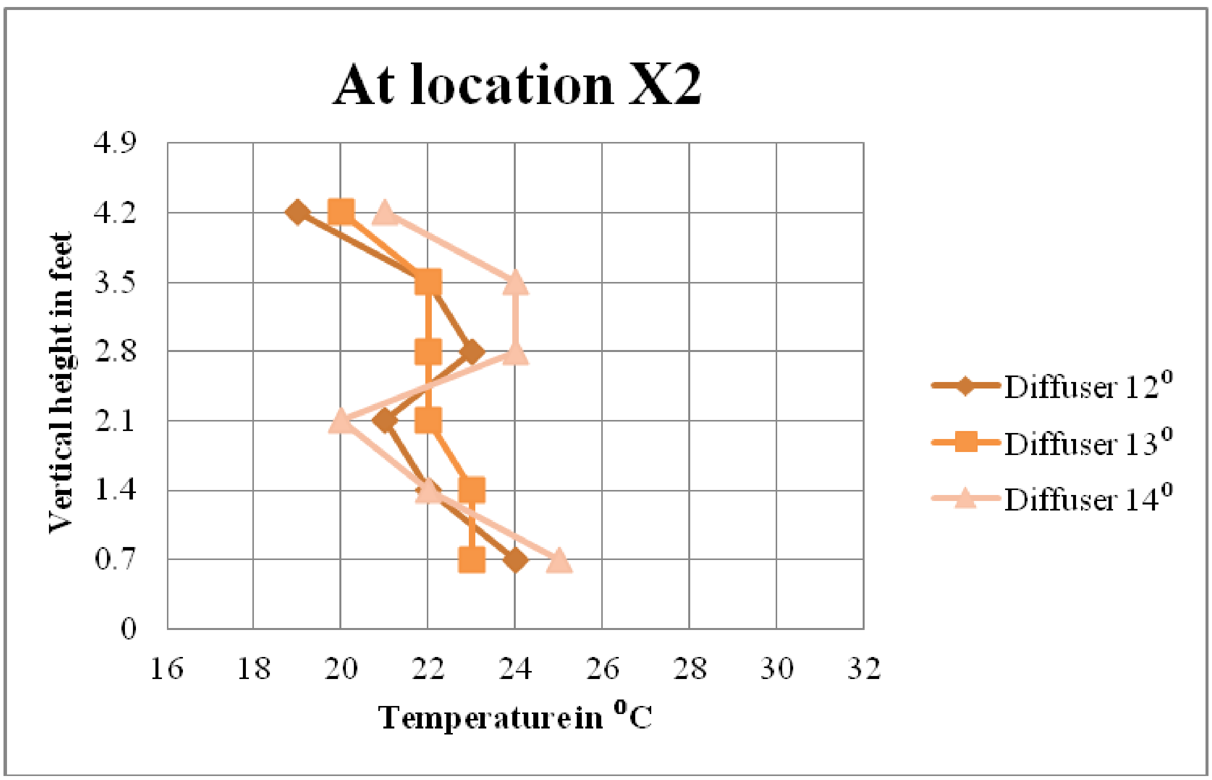

Fig.20 Variation in temperature vs. height at location X2 without load.

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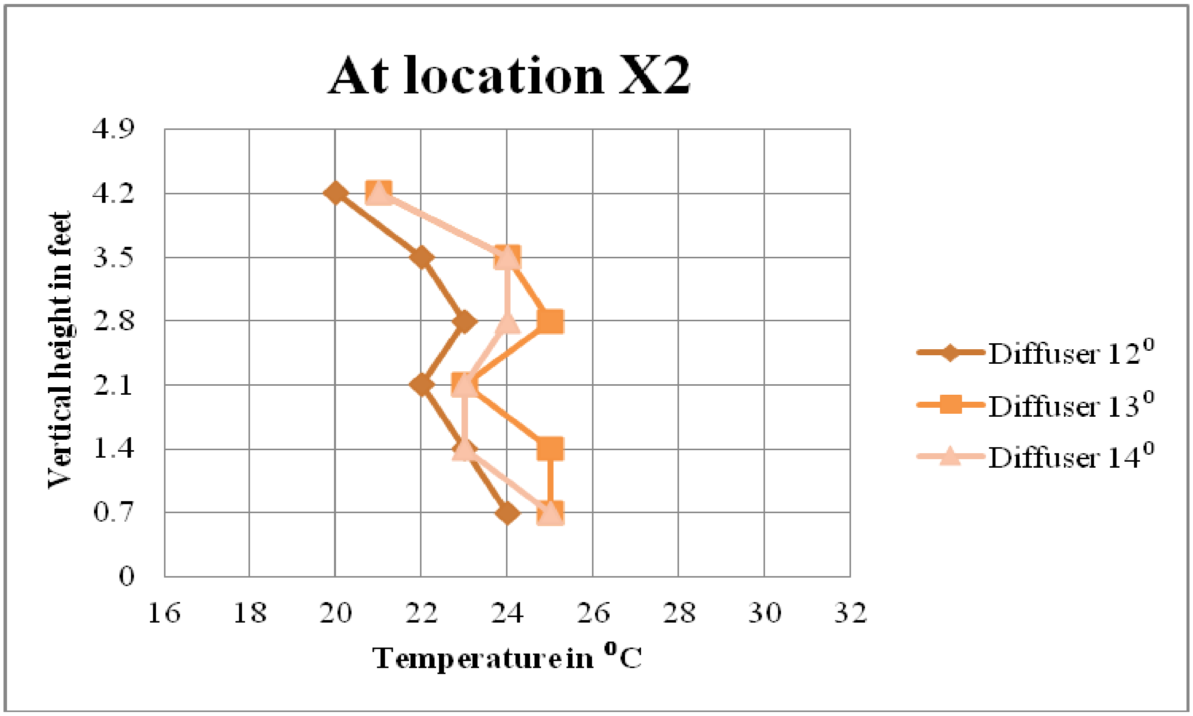

Fig.21 Variation in temperature vs. height at location X2 with load 1000W.

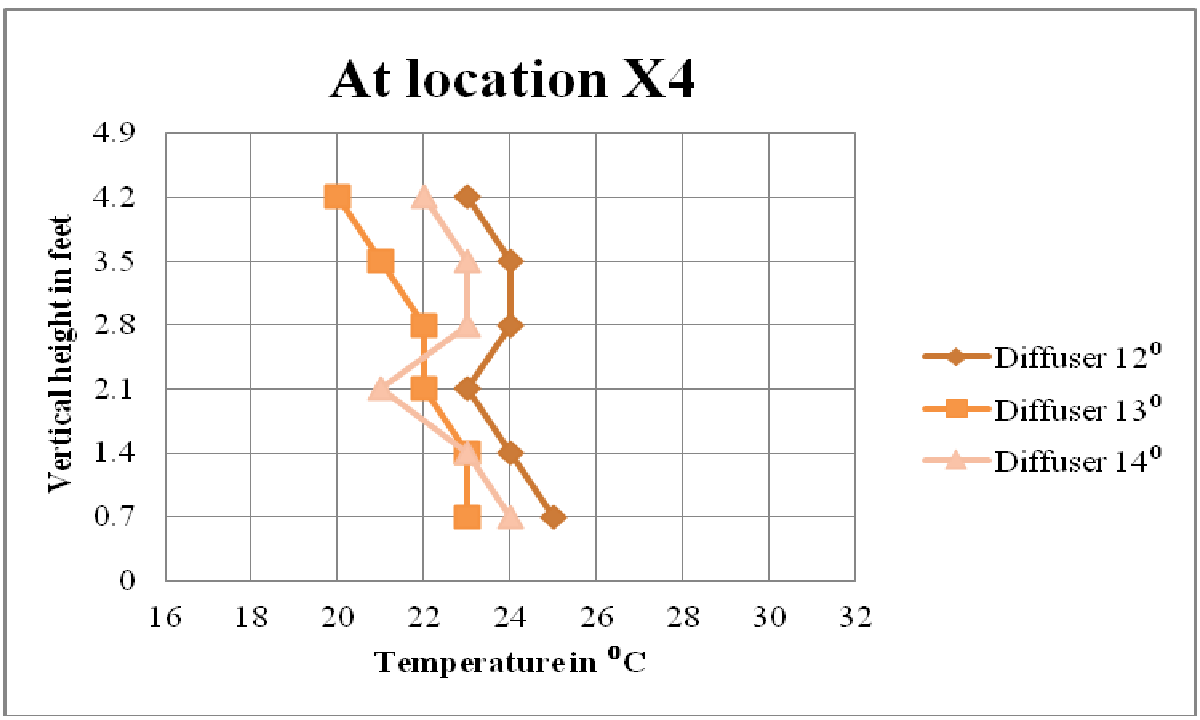

Fig.22 Variation in temperature vs. height at location X4 without load.

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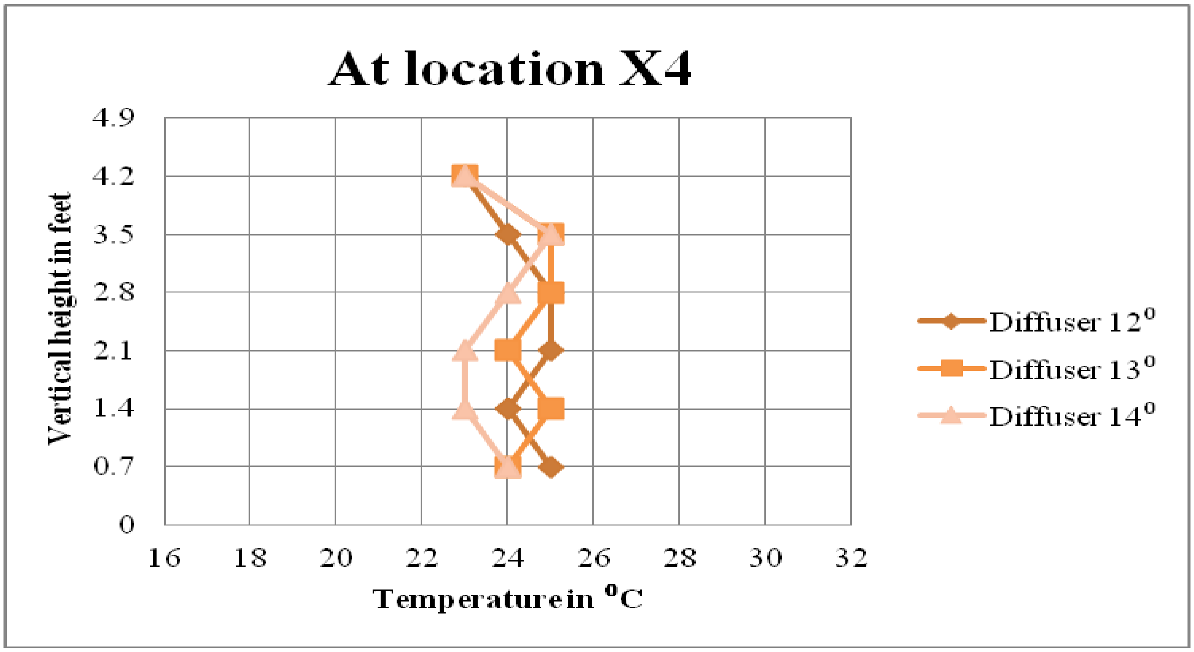

Fig.23 Variation in temperature vs. height at location X4 with load 1000W.

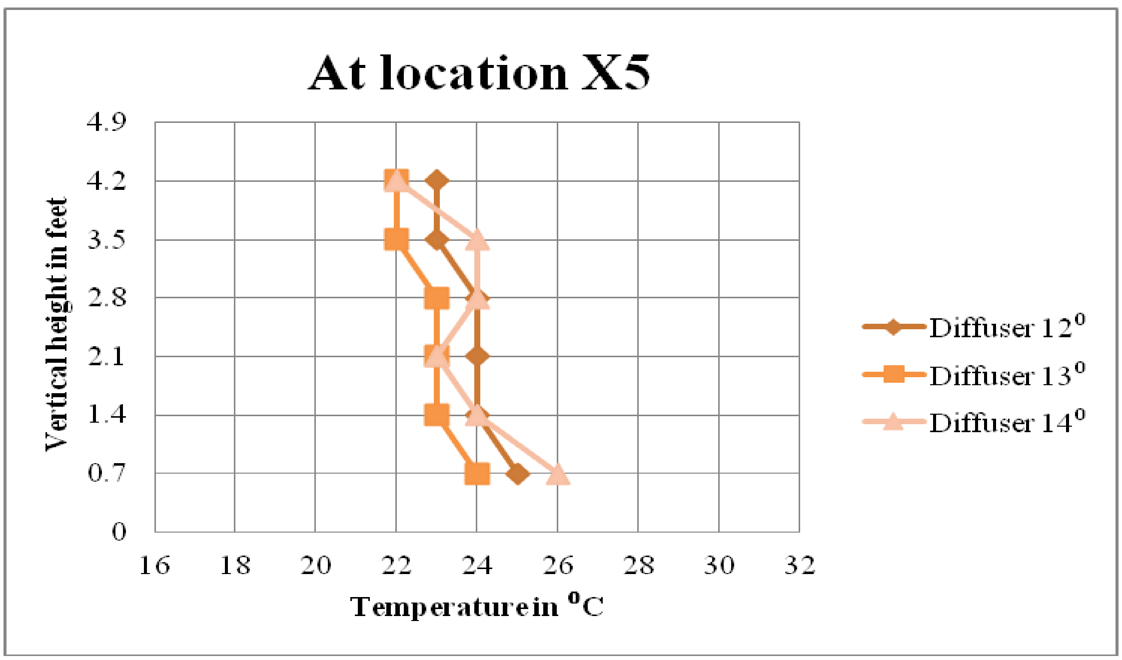

Fig.24 Variation in temperature vs. height at location X5 without load.

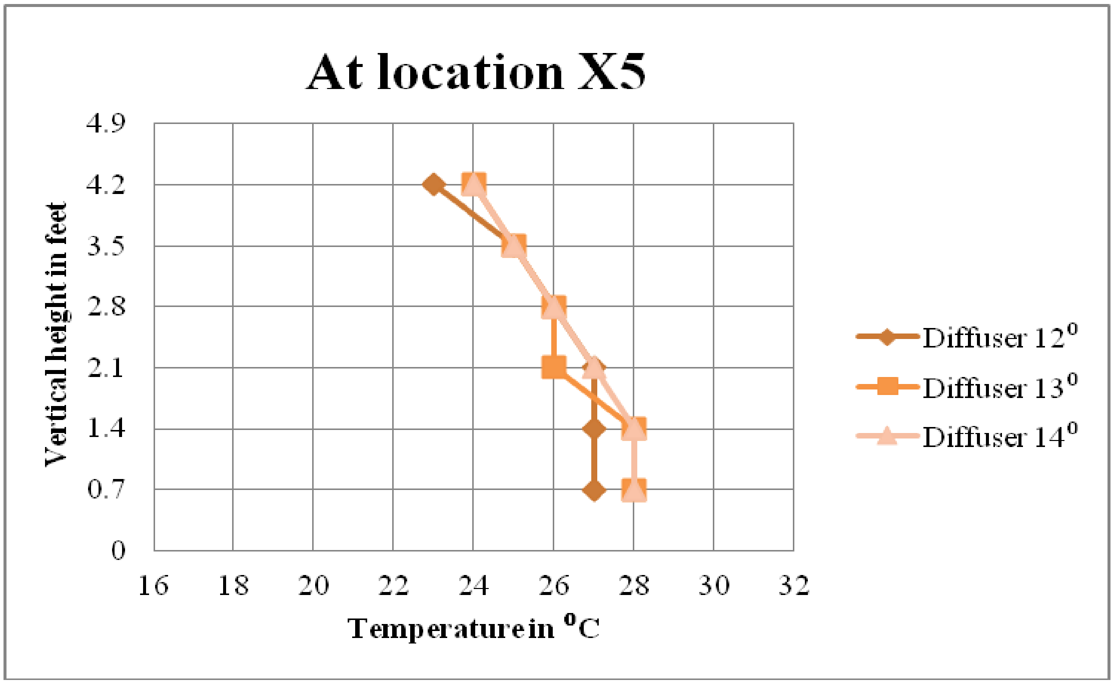

Fig.25 Variation in temperature vs. height at location X5 with load 1000W.

7.1 Conclusion:

The results from this dissertation work show that a car installed with swirl diffuser at the outlet of a.c. can improve air quality because the contaminant concentration in the breathing zone is lower than that of mixing system. It helps us in comparing the performance of three different 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 floor-supply ventilation and the risk of cross contamination can be effectively reduced. The system with the swirl diffusers can provide a better comfort level than that with the perforated panels due to the mixing by the diffusers.

The maximum variation in temperature is obtained at location Y2. This happens due to presence of bulb of load capacity 1000W near location Y2. 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 12º, 13º and 14º under different operating conditions and the best performance is obtained with 13º swirl diffuser.

This study helps in selecting optimum models of 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 car and the variation in temperature of air inside a car will be reduced. We can achieve better human comfort and proper ventilation by using swirl diffuser.

7.2 Limitations

While conducting the experiment it has been observed that if we perform this experiment using higher degree diffuser angles there will be heat losses and efficiency of diffuser will be reduced.

7.3 Future scope:

In the present dessertation work investigation are made on the thermal behaviour produced by the diffused air from swirl diffuser installed at the outlet of car air- conditioner. In this work we have observed the variation in temperature of air from air conditioner at various locations with and without heat load.

It is proposed that the effect of air flow rate and air velocity on the indoor thermal environment inside a car 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 inside a car can be analyzed by varying the supply air conditions in future.

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