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"Experimental Analysis and Estimation of Air Distribution Quantity Using UFAD in Air Conditioned Space with Straight Blade Grill"

Mritunjay Singh[a], Surendra Bharti[b]

1 Research Scholar, Department of Mechanical Engineering, Millennium institute of Technology Bhopal,
2 Asst. Professor, Department of Mechanical Engineering, Millennium institute of Technology Bhopal, (M.P), India

Abstract: In this paper, recent research is reviewed on air conditioning systems and indoor air quality control for human health. The problems in the existing research are summarized. A further study is suggested on air-conditioning systems and indoor air quality control for healthy indoor air environment and also presents an experimental and theoretical investigation evaluate an under floor air distribution (UFAD) system existed in an office building working on hot climate. Air temperature distribution measured in two measuring stations; each consists of 14 temperature sensors which were installed to measure room air temperatures along different height and locations. The obtained data compared with the conventional ceiling based air distribution system. The result compared at various load condition.Experimental results shown and there effect on the vertical temperature profile alsoThe main objectives of this work is to see the characteristics of associate existing UFAD system in associate edifice working on a hot atmosphere throughout season (peak and off-peak months); to outline the setting that produces the simplest operated UFAD system victimization simulation analysis. Thus, assessing and upthe existed system are dole out byscrutiny it against the simplest UFAD system. Additionally a quantitative comparison between simulated UFAD and standard CBAD systems is performed to explore their standing. Obtained data shows an efficient operation of the UFAD system which gives advantages of energy saving and compare it with the conventional ceiling based air distribution (CBAD) system. It shows that UFAD is more efficient then CBAD in low load condition. Temperature measurements show that the indoor vertical temperature profile is influenced highly by the distance away from the supply diffuser position.

Keywords: UFAD system; Penetrative entrainment; Turbulent plume; Turbulent fountain; Displacement ventilation; Mixing ventilation

Introduction:

In many commercial buildings, thermal conditions are not controlled well, due to insufficient cooling or heating capacity, high internal or external loads, large thermal zones, improper control-system design or operation, and other factors. Thermal conditions inside buildings vary considerably, both with time, e.g., as outdoor conditions change, and spatially. While the effects of temperature on comfort are broadly recognized, the effects on worker productivity have received much less attention.

Increased evidence shows that indoor environmental conditions substantially influence health and productivity. Building services engineers are interested in improving indoor environments and quantifying the effects. Potential health and productivity benefits are not yet generally considered in conventional economic calculations pertaining to building design and operation. Only initial cost plus energy and maintenance costs are typically considered.

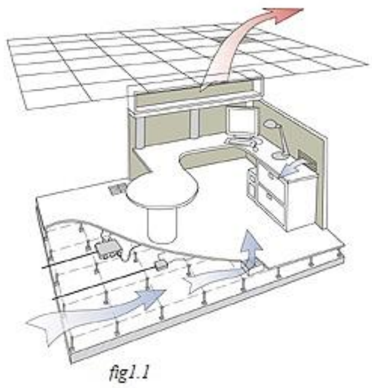

fig1.1

Room temperature could influence productivity indirectly through its impact on the prevalence of SBS symptoms or satisfaction with air quality; however, for cost-benefit calculations it is most feasible to use the available data linking directly temperature, or thermal state, to productivity. IN UFAD (under floor air distribution) systems, thermal stratification within the zone happens due to the low rate of the air offer from the beneath floor; this can change the dynamics of warmth transfer among the zone. Based on this new dynamics of the air, the temperature at the ceiling becomes higher than the temperature at the availability plenum, unlike the conventional air distribution wherever the temperatures are assumed to be uniform everywhere the house. However, the air temperature variation along height within the occupied zone (which is between ankles joint to head levels, 0.2–1.8 m) shouldn't exceed the utmost limit of 3 computer (5^0F) as given by ASHRAE. Sculptural and valid UFAD system that was integrated later among the Energy Plus building energy simulation program.The most plan of UFAD is to produce air at moderate temperatures and flow rates through a raised floor to the occupants' space permitting the air to require zone thermal load and then stratify upward to come back purpose. Noticeably, the UFAD might be organized by totally different layouts in coincident with the building type, usage, and construction kind.

Literature Survey:

Pawel Wargocki*, David P. Wyonet al.[1999]

The pollutionsource was a 20-year-old used carpet which was introduced on a rack behind a screen so that it was invisible to the occupants. Five groups of six female subjects each were exposed to the conditions in the office twice, once with the pollution source present and once with the pollution source absent, each exposure being 265 min in the afternoon, one group at a time. They assessed the perceived air quality and SBS symptoms while performing simulated office work. The subject-rated acceptability of the perceived air quality in the office corresponded to 22% dissatisfied when the pollution source was present, and to 15% dissatisfied when the pollution source was absent.In the former conditionthere was a significantly increased prevalence of headaches (P=0.04) and significantly lower levels of reported effort (P=0.02) during the text typing and calculation tasks, both of which required a sustained level of concentration. In the text typing task, subjects worked significantly more slowly when the pollution source was present in the office (P=0.003), typing 6.5% less text than when the pollution source was absent from the office. Reducing the pollution load on indoor air proved to be an effective means of improving the comfort, health and productivity of building occupants.

R. Kosonen a, ∗, F. Tanb,1 [2004]

This study represented a theoretical reports on the impact of perceived indoor air quality for productivity loss in air-conditioned office buildings. In this study a new derivation of productivity calculation model based on pollution loads and contaminant removal effectiveness was applied and the effect of the improved ventilation efficiency on productivity was estimated. The results show that the proportion dissatisfied is a good predictor of productivity loss due to indoor air quality in different kinds of office work. It is possible to calculate the proportion dissatisfied from olf and decipol units. Productivity had improved by increasing outdoor airflow rate, decreasing emissions and improving ventilation efficiency e.g. with displacement ventilation. With displacement ventilation, it has improved indoor air quality in a manner that significantly increases productivity compared with traditional mixing system. The effect of the contaminant removal effectiveness on the productivity loss was about 0.5–2% between these systems using the same airflow rate.

Y.J.P. Lina,*, P.F. Lindenb [2005]

They presented a simplified model of an underfloor air distribution (UFAD) system consisting of a single source of heat and a single coolingdiffuser in a ventilated space. Laboratory experiments were carried out to simulate the flow and a model for the flow in that space. The model was based on plume theory for the heat source and a fountain model for the diffuser flow, and predicts a steady-state two-layer stratification in the room. The governing parameters were shown to be the buoyancy flux of the heat source, and the volume and momentum fluxes of the cooling diffuser. The results were suggested ways to optimize UFAD design and operation.

Olli Seppänen1, William J Fisk2 [2006]

Theyhad focused on the effects of temperature on performance at office work. . They included those studies that had used objective indicators of performance that were likely to be relevant in office type work, such as text processing, simple calculations (addition, multiplication), length of telephone customer service time, and total handling time per customer for call-center workers. They excluded data from studies of industrial work performance. They calculated from all studies the percentage of performance change per degree increase in temperature, and statistically analyzed measured work performance with temperature. There results showed that performance increased with temperature up to 21 22 ^{o}C, and decreased with temperature above 23-24 ^{o}C. The highest productivity was at temperature of around 22 ^{o}C. For example, at the temperature of 30 ^{o}C the performance was only 91.1% of the maximum i.e. the reduction in performance is 8.9%.

Lau, J. and Chen, Q. [2007].

They reported the investigation of the performance of floor-supply displacement ventilation with swirl diffusers or perforated panels under a high cooling load (nearly 90W/m2). The experiment was carried out in a full-scale environmental chamber to obtain reliable data on the floor-supply displacement ventilation for the validation of a computational-fluid-dynamics (CFD) program. Numerical simulations using CFD program were to evaluate the performance of the system for a large workshop. The impacts of several parameters, such as the air change rate, number of diffusers, diffuser location, occupant location, furniture arrangement, partition location, and arrangement of exhausts, on the indoor environment were investigated based on the thermal comfort level and indoor air quality. They ranked the impacts of these parameters on indoor environment.

Riikka Antikainen, 1 Sanna Lappalainen,2 [2008]

This paper identified the pitfalls of designing such studies by examining several research projects. The methodological challenges include obtained valid measurement data and taking into account the productivity impact of different components ofindoor environments and other business factors, for example. As conclusions, solutions such as choosing case organizations carefully and applying indirect productivity measures were proposed to overcome the problems.

B.F. Yua,*, Z.B. Hua,[2009]

In this paper, recent research was reviewed on air conditioning systems and indoor air quality control for human health. The problems in the existing research were summarized. A further study was suggested on air-conditioning systems and indoor air quality control for healthy indoor air environment.With the improvement of standard of living, air-conditioning had widely been applied.However, health problems associated with air conditioning systems and indoor air quality appear more frequently.

Mariusz Dalewski 1, Michal Vesely 1, Arsen Melikov 1 [2012]

An experiment with 28 human subjects was performed to examine effects of using a local air cleaning device combined with ductless personalized ventilation (DPV) on perceived air quality. Experiments were performed in a test room with displacement ventilation. The DPV at one of two desks was equipped with an activated carbon filter installed at the air intake, while the DPV at the second desk was without such a filter. The air temperature in the occupied zone (1.1 m above the floor) was 29 °C. The pollution load in the room was simulated by PVC floor covering. The subjects assessed acceptability of air quality, odour intensity and air freshness at both desks in random order. Lower odour intensity and higher air freshness was reported at the desk with DPV with the activated carbon filter. The results suggested that using local air cleaning devices integrated with DPV may improve perceived air quality.

Yan Xue1 and Qingyan Chen2, 1 [2014]

The heat transfer through the floor slab in buildings with Under-Floor Air Distribution (UFAD) systems had a negative impact on the energy performance of these buildings, although very few studies had been reported in the literature. By using an energy simulation program, Energy Plus, this investigation compared the energy use in a Philadelphia office building with a UFAD system to that with a well-mixed ventilation system. When the heat transfer through the floor slab was taken into consideration, the thermal load of the building with the UFAD system was higher than with the well-mixed system. On the other hand, the higher supply air temperature of the UFAD system enables the use of more free-cooling. The annual energy consumption by the chillers in the building with the UFAD system was 16%-27% lower than with the well-mixed system, but energy consumption by the boiler was 12%-30% higher, and the energy consumption by the fan was 22-50% higher, depending on the manner in which the heat was supplied to the floor plenum. When the UFAD system was used with an UN ducted floor plenum and without heating coils under the diffusers, it consumed slightly more energy than the well-mixed system.

Paul Raftery[a],*, Fred Bauman[b][2015]

The purpose of this study was to characterize the stratification performance of a previously unstudied type of floor diffuser that discharges air horizontally, with almost no vertical velocity component, and that aims to combine the benefits of both UFAD and displacement ventilation (DV) strategies. They performed 19 full scale laboratory experiments in which they varied the number of diffusers and the internal loads over a range of values typically found in office spaces. They quantified the amount of thermal stratification by measuring the dimensionless temperature at ankle height and found a degree of stratification that is typical of DV systems – higher than is typical in UFAD systems. They developed a model based on these results that can be used to simulate these systems in whole building energy simulation tools, such as Energy Plus, and simplified UFAD design tools.

S.A. Nada,⁎ H.M. El-Batsh, [2016]

A 3D-CFD investigation of airflow, temperature distribution and thermal comfort in high rise ceiling theaters air conditioned with underfloor air distribution (UFAD) system is presented for different operating and geometric conditions. Numerical simulations are implemented, using a commercial CFD package (Fluent 6.3), to understand the effects of supply air temperature, supply air velocity, space height and number of supply air diffusers on the performance of the air conditioning system and thermal comfort. For UFAD system evaluation, the traditional overhead mixing air distribution (OHAD) system are also modelled and compared with the UFAD system. The results showed that (i) the used numerical technique could accurately predict the airflow and temperature distribution in the high rise conditioned space, (ii) UFAD system is capable of creating smaller vertical variations of air temperature and a more comfortable environment and energy saving than OHAD system, (iii) the supply air velocity and temperature, number of diffusers and height of the space have a significant impact on thermal comfort, (iv) the optimum system performance and thermal comfort obtained at 18 °C supply air temperature, 0.8 m/s supply air velocity and proper numbers and distributions of supply diffusers, (v) the percentage of energy saving due to using UFAD system increases with increasing the theater height. The simulation results are validated with the available experimental data and good agreement are obtained.

WeiWei 1 and Ling-Yun He 2. [2017]

This study establishes an appropriate accounting method of building energy to present the BEC situation in China and lays the foundation for policymakers to develop appropriate energy saving policies. Meanwhile, this study attempts to clarify the BEC to help policymakers assess the effect of environmental policies. Using the method in that document, they find that the energy consumption of buildings just accounts for 15%–16% of the final total energy consumption in China; by compare, the previous studies usually have double accounting through a top-down approach if central heat supply of buildings was taken into additional consideration.

Experimental Details

In new construction, under floor air distribution can achieve a 5to10% reduction in floor to floor heights compared to projects with ceiling based air distribution. The measurements were carried out in a mock-up of an open plan room 10ft.* 10ft. * 10ft.(i.e. length, width and height). All areas of the room were made of plywoodwhich were coated with insulation i.e. Thermacole for making system isolated. The floor and the main ceiling were insulated by 15 cm Thermacole and covered by a layer of plastic sheet to reduce air infiltration. The room was placed in a large HE laboratory hall with steady temperature condition of 40.5^0C ± 0.3^0C. Since room is taken under summer condition of40^0C average temperature.

Material Used For Making Experimental Setup

S.No	MATERIAL USED	SPECIFICATION	QUANTITY
1	Plywood	Hardwood $(34*72)ft^2$	38
2	Thermacole Sheet	Heavy density 15mm thickness	
3	Air conditioner	1.5 ton	1
4	Duct	Rectangular	1
5	Grill	Straight vane	1
6	Plastic Sheet	Air seal sheet (4.5ft*10ft)	3

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INSTRUMENT USED FOR MEASURING READING IN EXPERIMENTAL

S.No	INSTRUMENT USED	SPECIFICATION	QUANTITY
1.	THERMOCOUPLE	K-TYPE	14
2.	DATA LOGGER	DL-35W	1
3.	HOT WIRE ANEMOMETER	YK2004AH	1
4.	HYGROMETER	MEXTECH TM-1	1

Experimental Analysis:

By using DATA LOGGER DL-35 we get 14 reading simultaneously in different position with different plane. This is only we do for finding temperature variation along all position and plane.In this experiment we use different load (i.e. 100W, 500W, 1000W) in different position in system and also we use different velocities air conditioned air (i.e. 0.6m/s, 0.3m/s, 0.1m/s) along this we find time by the Air Conditioner to reach the comfort condition in observatory system. The reading has recorded in data logger for load 100 W, 500 W and 1000 W at the velocity of conditioned air 0.6 m/s, 0.3 m/s and 0.1 m/s shown on the thesis work.Final variation of humidity along height with different velocity of air for load 100 W, 500 W and 1000 W as shown below

1) FOR LOAD 100W

HEIGHT	HUMIDITY FOR 0.6 M/S	HUMIDITY FOR 0.3 M/S	HUDITY FOR 0.1 M/S
0	51.5	52.8	53.1
0.5	51.5	52.3	52.6
1	51	52.1	52.3
1.5	50.5	51.2	51.8
2	49.5	50.8	51.1
2.5	49	49	50.6
3	48.7	48.7	48.9
4	48	48.4	48.5
5	47.5	48.1	48
6	47	47.8	47.8
7	45	47.6	47.6
8	44	46.8	46.9
9	43	44	44.2
10	42	43.2	43.4

2) FOR LOAD 500W

HEIGHT	HUMIDITY FOR 0.6 M/S	HUMIDITY FOR 0.3 M/S	HUDITY FOR 0.1 M/S
0	50.4	51.2	52.1
0.5	50.2	51	51.9
1	50	50.7	51.6
1.5	49.7	50.3	50.8
2	49.5	50.1	50.3
2.5	49	49.8	50.1
3	48.7	49.1	49.7
4	48.4	48.8	49.3
5	48	48.4	49.1
6	47.6	48.1	48.7
7	47.3	47.9	48.1
8	46	47.3	47.8
9	45.2	46	47.4
10	44	44.8	46

3) FOR LOAD 1000W

HEIGHT	HUMIDITY FOR 0.6 M/S	HUMIDITY FOR 0.3 M/S	HUDITY FOR 0.1 M/S
0	50.2	51.2	51.4
0.5	49.8	50.8	51.1
1	49.5	50.6	50.9
1.5	49	50.4	50.6
2	48.3	49.8	50
2.5	47.8	49.2	49.7
3	47.5	48.7	49.3
4	47.2	48	49.1
5	46.9	47.4	48.5
6	46.4	46.9	48.3
7	45.6	45.8	47.6
8	44.8	45	46.9
9	43.2	43.6	44.2
10	42	42.8	43.4

Percentage saving energy of UFAD with respect to OHAD system with different load, velocity of conditioned air.

S.No.	Time taken to maintain comfort temperature (minute)	Velocity (m/s)	Load (watt)	% of energy saving at 100 W	% of energy saving at 500 W	% of energy saving at 1000 W
1.	100	0.6	100	20	27.14	9.81
2.	140	0.3	500	21.42	17.64	17.71
3.	220	0.1	1000	11.5	11.1	8.1

Straight Vane Grill Used

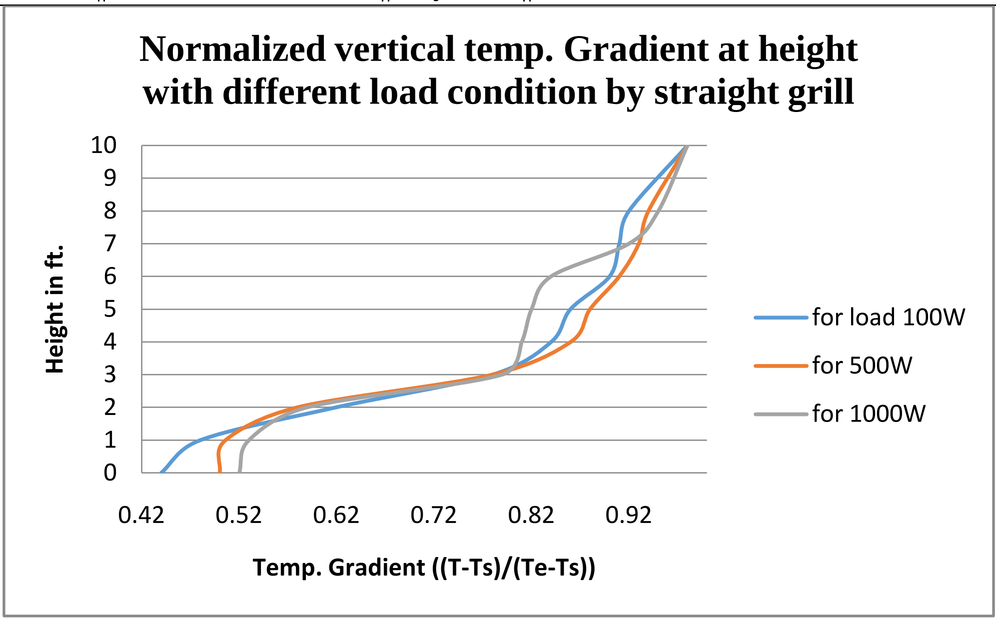
Straight vane grill was used to deliver the supply air into the room. Apparently the air flow pattern was affected by the grill type due to the different throw heights and initial velocities that were produced. The supply air had a higher elevation for the straight-vane grill is good. Sandberg and Etheridge [34]characterized a pure jet or a pure plume property according to its momentum flux M or buoyancy flux B which are defined as follows:

$$M_o=Q_o*u_o$$
$$B_o=(g*Q_o*\Delta T_0)/T_r$$
$$I_m=M_o^{3/4}/B_o^{1/2}$$

where $\mathbf{Q_0}$ is the initial volume flux of the supply air, u_0 the supply air velocity, g the gravitational acceleration, □ $\mathbf{T_0}$ the temperature difference between the supply air of the cooling diffuser and the temperature in the enclosure, $\mathbf{T_r}$ the reference air temperature and $\mathbf{l_m}$ the buoyant jet length scale or thermal length. For the same internal load, changing the diffuser caused different momentum flux and buoyant jet scale as well.

For straight vane grille we finding zone of comfort by using normalize temperature gradient along the height.

height	(T-Te)/(Te-Ts) for 100W	(T-Te)/(Te-Ts) for 500W	(T-Te)/(Te-Ts) for 1000W
0	0.44	0.5	0.52
1	0.48	0.506	0.58
2	0.62	0.58	0.59
3	0.78	0.78	0.79
4	0.84	0.86	0.81
5	0.86	0.88	0.82
6	0.9	0.91	0.84
7	0.91	0.93	0.9
8	0.92	0.94	0.92
10	0.98	0.98	0.97



In this study the ratio between the throw length and the enclosure height was varied. Indicate that more mixing condition was created by straight-vane grills since the normalized temperature near the floor was increased. Above 2.0 ft. Over the floor-level the same growth rate occurred for the cases.

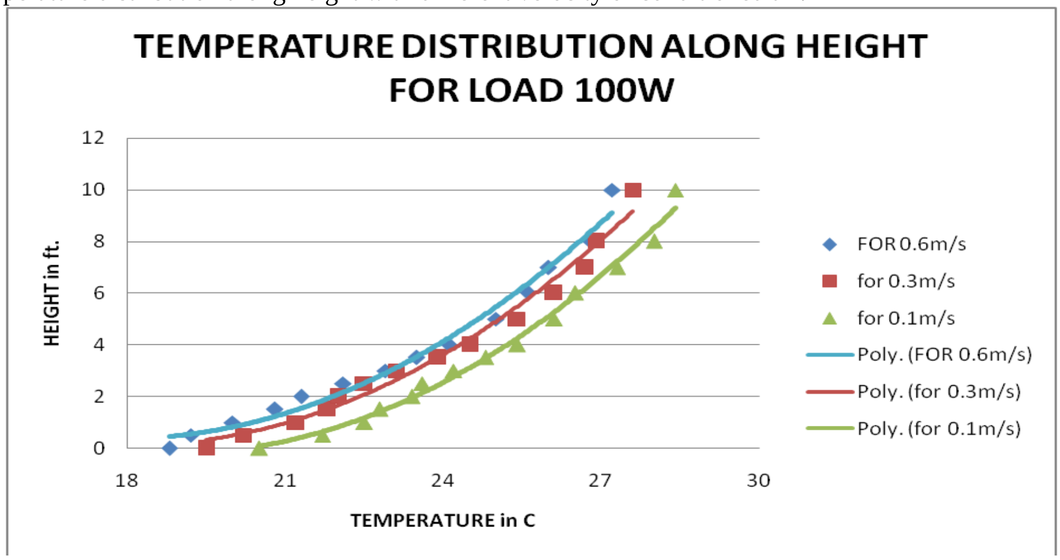
Another parameter caused thermal discomfort is vertical air temperature gradient. As it can be seen from vertical temperature gradient between the ankle and head level in the occupied zone was more than 3^0C for all load cases, regardless of the grill or air flow. Therefore, due to the large temperature gradient especially up to 3.5 ft. above the floor. This problem became more noticeable when either the supply air temperature decreased or the air flow rate increased. Both cases led to higher draught rate and steeper vertical temperature gradients. One possibility to address the problem is to increase the number of inlets in the room and consequently the velocity over the floor would drop.

Results and Discussion:

From this experiment present the predicted variation of temperature and humidity along with variable height on different type of load as well as on different velocity of conditioned air. And also predicting temperature and humidity distribution relation and correlation along heights with respect to time, velocity of conditioned air on different load.

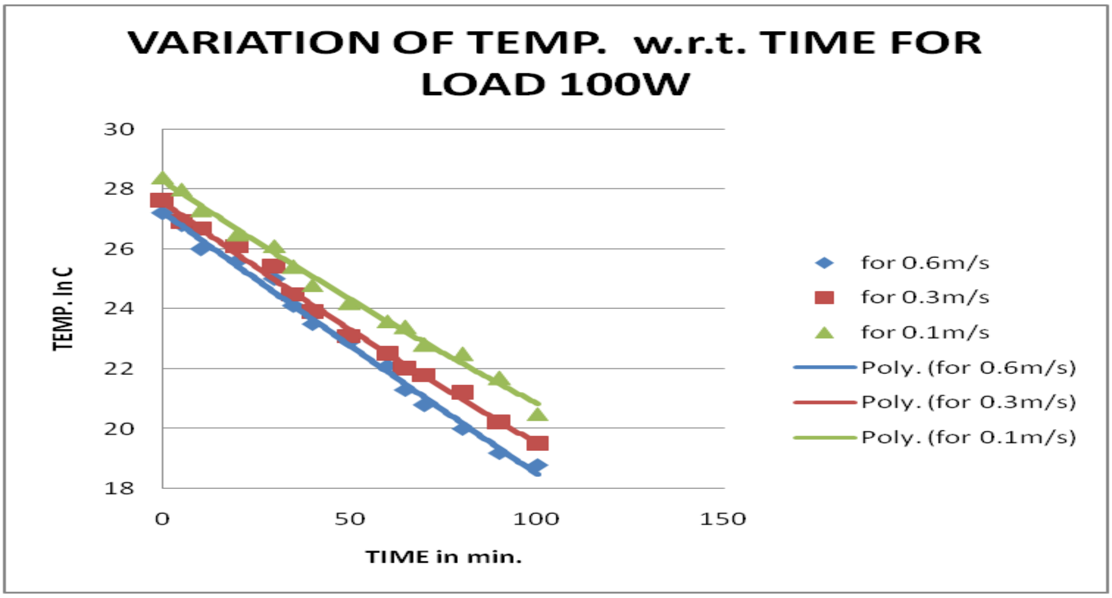
FOR LOAD 100W

1) Temperature distribution along height with different velocity of conditioned air.

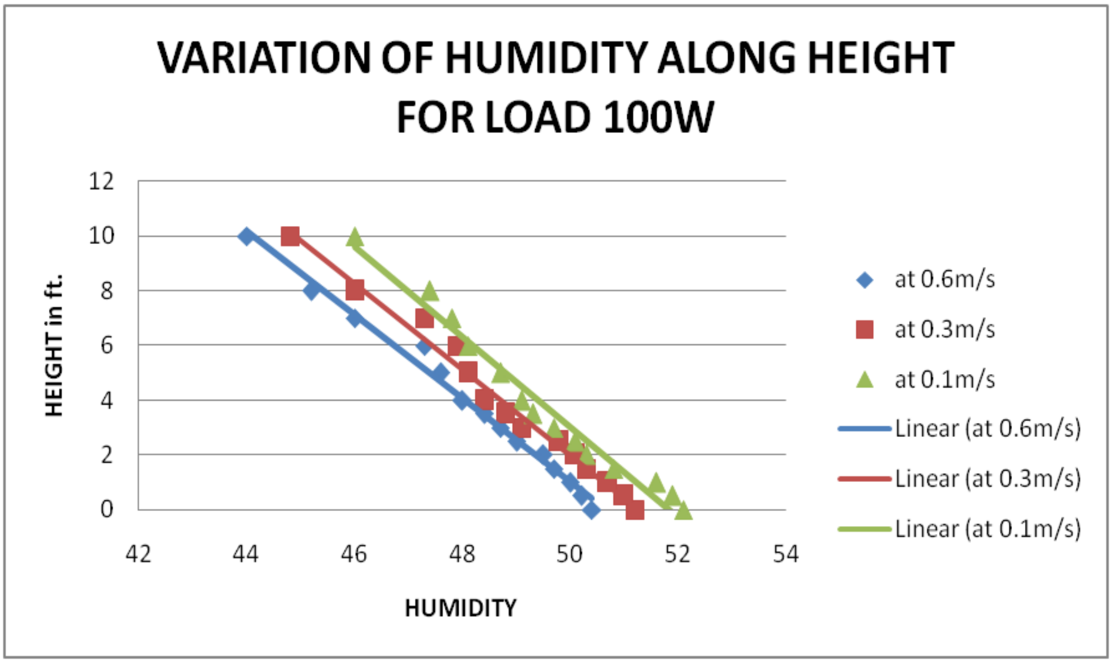


From this graph we get different temperature distribution profile empirical relation with height for load 100W these are

2) TEMPERATURE DISTRIBUTION CURVE w.r.t. TIME

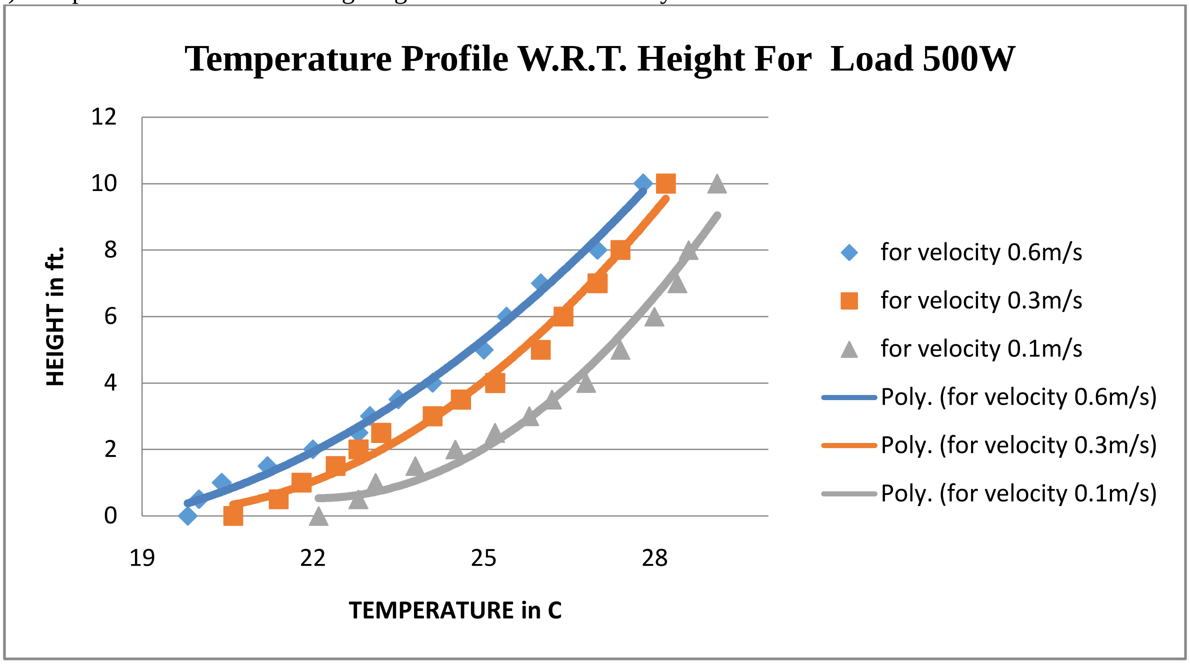


3) HUMIDITY DISTRIBUTION ALONG HEIGHT

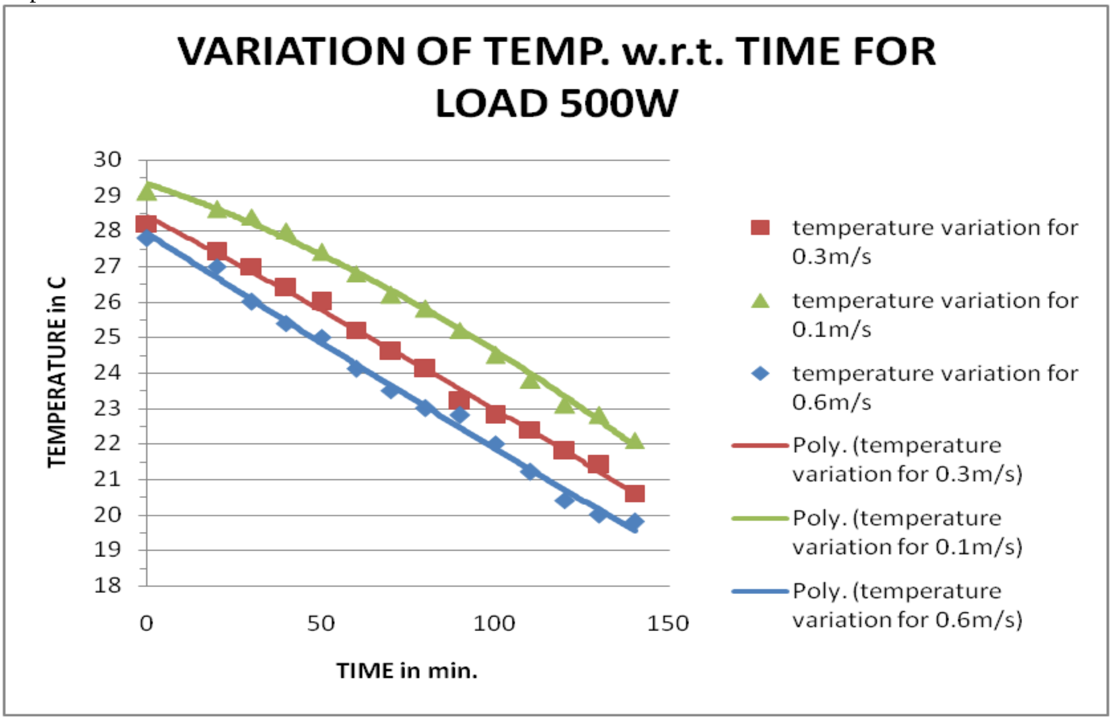


FOR LOAD 500W

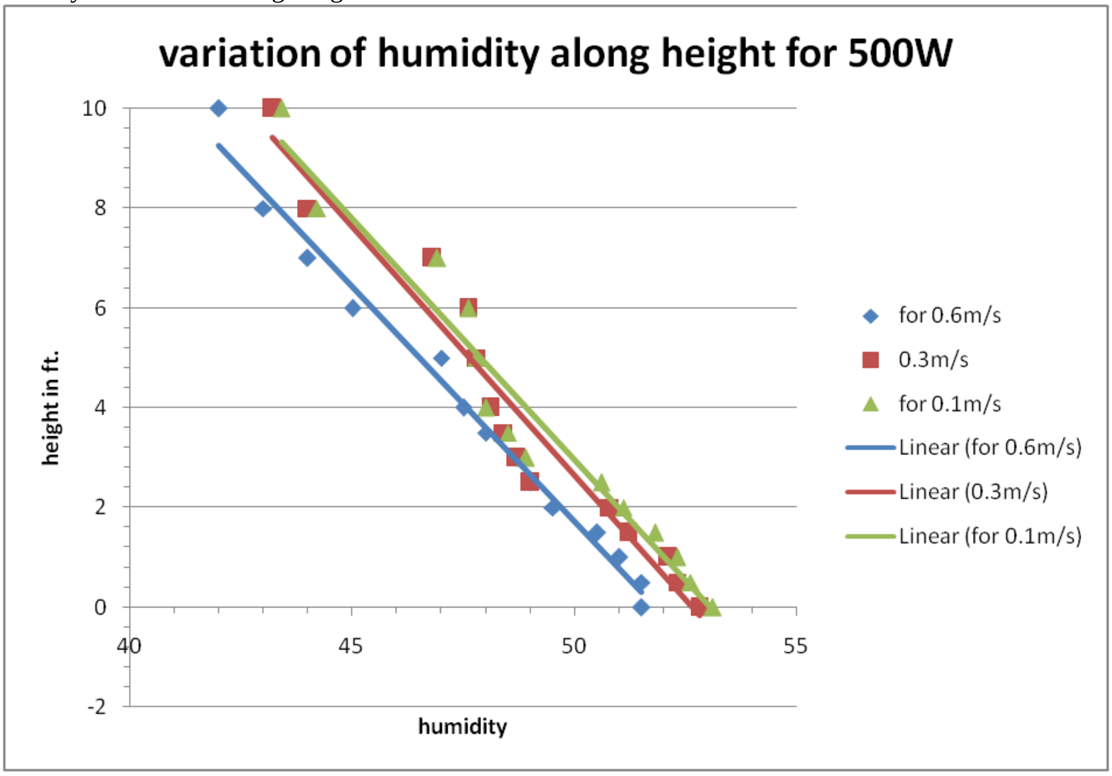
1) Temperature distribution along height with different velocity of conditioned air.



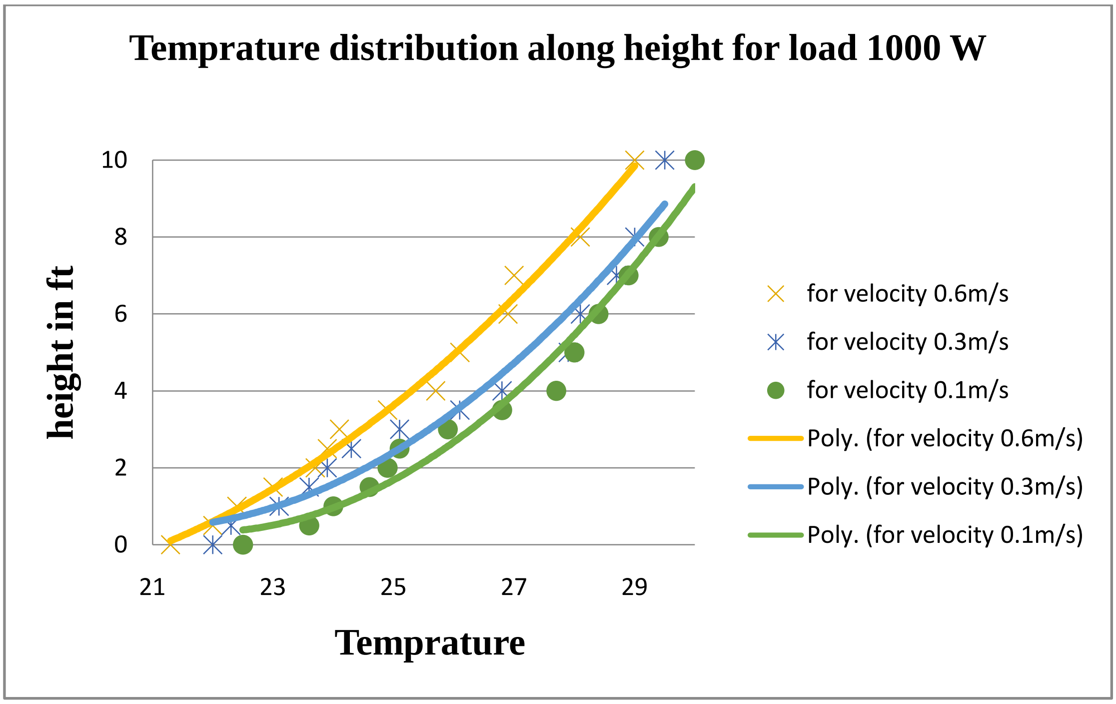
2) Temperature Distribution Curve W.R.T. Time

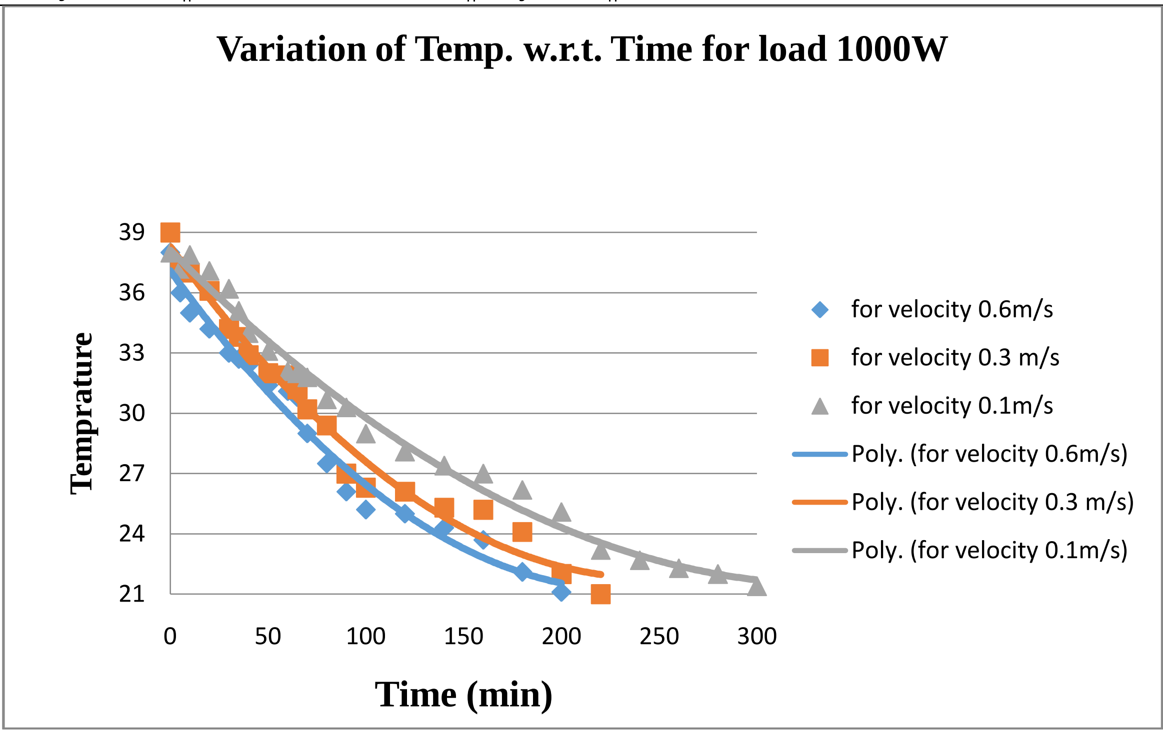


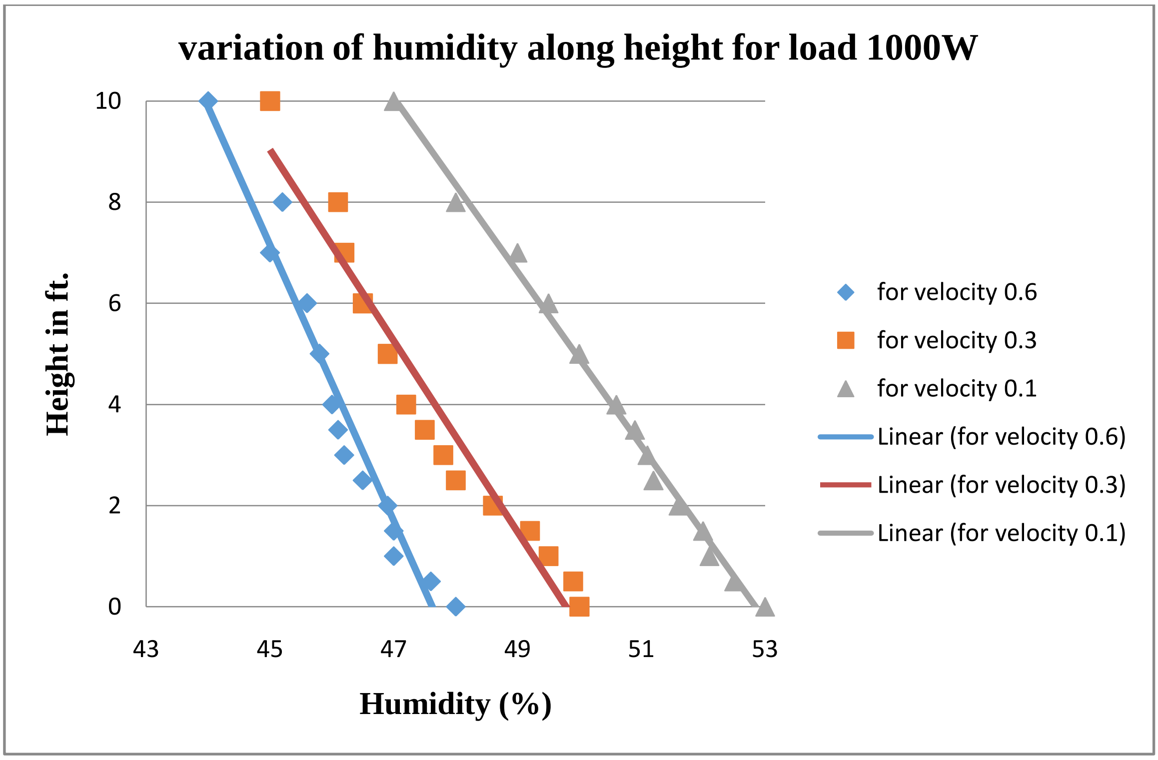
3) Humidity Distribution along Height



FOR LOAD 1000W







Conclusion

Cold feet and draft discomfort. Under floor systems are perceived by some to produce a cold floor, and because of the close proximity of supply outlets to the occupants, the increased possibility of excessive draft. These conditions are primarily indicative of a poorly designed or operated under floor system.In straight vane grille thevertical temperature gradient between the ankle and head level in the occupied zone was more than 3^0C for all load case due to the large temperature gradient especially up to 3.5 ft. above the floor which cause uncomforted. This uncomfort is overcome by using more than one duct or by using good ventilation system or by using different type of grille. As the height increase, humidity decrease accordingly. Up to a height of 6 feet, there lies a proper existence of specific humidity (usually lies between 45 to 50 %) in the comfort zone. Temperature distribution along height is be parabolic in nature but humidity variation along height is linear in nature for all type of load and different type of velocity of air.Conditioned air flowing with the velocity 0.3m/s is found to be more efficient in entire range of load condition then 0.6m/s and 0.1m/s in UFAD system.

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