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Analysis of Indoor Air Quality and PMV-PPD Model in Dynamic Conditioned Car Cabin

Daniel Lawrence I[1], Thiruneelakandan G[2], Dr.Jayabal S[3], Thirumal P[4]

[1]Faculty, Department of Mechanical Engineering, Anna University Regional Office, Madurai, Tamil Nadu, India.

[2]PG student, Department of Mechanical Engineering, Anna University Regional Office, Madurai, Tamil Nadu, India.

[3]Faculty, Department of Mechanical Engineering, Alagappa chettiar college of engineering and technology, Karaikudi, Tamil Nadu, India.

[4]Faculty, Department of Mechanical Engineering, Government college of engineering, Bargur, Tamil Nadu, India.

ABSTRACT: Air conditioning in general is a technology adopted to improve the quality of comfort in automobiles. But poor indoor air quality (IAQ) caused due to introduction of human load and surrounding in new generation automobiles reported adverse effect on the quality of passenger cabin. Excessive carbon dioxide (CO_2) exposure can cause several health effects and even sudden infant death. Hence there is need to meet out quality of air conditioned cabin. This proposed investigation is focused on improving the indoor air quality by controlling the vital parameters like carbon dioxide, carbon monoxide, oxygen, Relative temperature, relative humidity and relative velocity which were used as indicators for IAQ and comfort levels in various systems functional and living environment. The above stated parameters have to be studied under various rates of air flow volume, fresh air supply and human load. These IAQ parameters are to be continuously monitored by a direct reading instrument and predicted thermal comfort index. This paper will improve the indoor air quality of passenger compartments and also improve thermal comfort and human comfort of indoor occupants.

KEYWORDS: indoor air quality, oxygen, carbon dioxide, temperature, relative humidity, relative velocity.

I INTRODUCTION

Air conditioning systems are an accessory component of vehicles whose utilization provides comfort to vehicle occupant. The occupants are concerned about Indoor Air Quality (IAQ). The air-conditioning system in the vehicle cabin is good or not decides the degree of comfort, traffic safety as well as health. In Asia Vehicles equipped with an air-conditioning system accounted for around 10% in early 1970, and which been increased to 99.5% in 2012, so that an air-conditioning system is already.

One of the more unfortunate aspects of modern global development has been the introduction and wide spread acceptance of the use of mechanical means for providing desired comfortable indoor air quality (IAQ) for automobiles. This phenomenon has led to huge energy consumption in the automobiles, and nowadays, around one third of fossil fuel is consumed in automobiles. In this regard, IAQ boundaries are limitations which help automobiles physicists to estimate to what extent automobiles should be heated or cooled. Indoor air quality (IAQ) is a term which refers to the air quality within and around the automobiles, especially as it relates to the health and comfort of occupants.Thermal comfort is defined as that condition of mind which expresses satisfaction with the thermal environment. The experiments are carried out in ASHARE [10] standards so the comfort conditions can maintained to the level.

The following papers are taken into account for the experimental work in which each paper have a different results on their experimental condition. To minimize the entire work those paper conditions are taken to proceedthe process. David et al [1] the air flow management deals a major problem in making the comfort conditions of the passengers and drivers it deals with that process. Alahmer et al [2] the manikins are used in the process to know the exact thermal variation in the process. Sheper et al [3] the thermal and ventilation loads are taken into account. Noe [4] the manikins actual variation in thermal and human comfort are found by the mathematical modeling. Mezrhab et al [5]the material compostion inside the cabin are taken into account for their thermal variation inside the cabin. Yadollah et al [6]it explains about the feedback system importance over the system. Omer et al [7] various climatic conditions are taken into account. Alpaslan et al [8]the enegy consumption process are taken into account for saving the energy Rameshkumar et al [9] the process is carried in an experimental way and were analyzed computationally. However, it is exciting that some comfortable and healthy air-conditioning systems were proposed in the past few years. In order to control the concentration level of indoor pollutants and to improve IAQ, many researchers have investigated the control methods of IAQ. In this paper, be study on air-conditioning systems indoor air quality control and energy consumption in automobiles.References for ASHRAE standard parameters for indoor Environment are Carbon-dioxide 0 to1000ppm, Carbon-monoxide 0 to9ppm, oxygen 19(±.2 ppm), Temperature 20°C to 26.1°C and Relative humidity 38-48 %.

1.1 METHODOLOGY

This project is focused on improving the indoor air quality by controlling the vital parameters like carbon dioxide, oxygen, Relative temperature, relative humidity, carbon monoxide which were used as indicators for IAQ and comfort levels. The above stated parameters have to be studied under various Air flow volume, fresh air supply and load condition. These IAQ parameters are to be continuously monitored by a direct reading instrument which has to be calibrated before each measurement and predict thermal comfort index by using fanger model.

All sampling and observation were developed and described as per ashare standards. The sampling of air to test for gaseous pollutants temperature relative humitity and oxygen was carried out by the below instruments. This investigation will improve the human comfort in the air conditioned living atmosphere and ensure safety and healthy car cabin environment on dynamic condition.

1.1.1 Instruments used for measurements

Digital Thermo Hygrometer (Range: Temp -50°C to +70°C, RH 10% to 99%, Accuracy :Temp ±1°C,RH ±5%)
Anemometer (Range: 0.4-45 m/sec, Accuracy: ±2%+0.1m/s)
CO Meter (Range: 0 to1000ppm, Accuracy : ±5%+2ppm)
CO2 Meter (Range: 0 to 4000ppm, Accuracy : ±40ppm)
O2 Meter (Range: 0 to 30%, Accuracy: ±1%+0.2%)

1.1.2 Passive Experimental observation

Effective indoor air quality requires that support the selection of thermal and human comfort measures which are viable and occupants friendly. The impact of space air quality are causes indoor environment. The data shows that space air quality. The optimal indoor environment in a car cabin depends on its outdoor environment and climate in which it's placed.

This field study observed outdoor air quality and also indoor air quality about without fresh air supply on car cabin. The average values of various parameters are temperature, relative humidity, carbon dioxide, carbon monoxide, oxygen, and relative air velocity observed from space air quality.

Time (AM)	Temp (°C)	RH (%)	CO_2 (ppm)	CO (ppm)	O_2 (%)	RAV (m/s)	Mode
9.00	32	45	460	2	19.1	0.8	Outdoor Environment
10.00	34.6	42	480	1	19.2	1.2	

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11.00	35.4	40	482	1	19.1	1.8	
12.00	35.8	40	473	1	19.2	1.7	

Table 1.1 Space air Environment

Meanwhile the above stated parameters are measured in indoor environment about without fresh air supply.The average summer climatic condition outdoor environment results showed for the above stated parameters. On the other hand, the indoor environment results showed for the above stated parameters while the fresh air supply is closed in dynamic conditioned vehicle.

Time (AM)	Temp (°C)	RH (%)	CO_2 (ppm)	CO (ppm)	O_2 (%)	RAV (m/s)	Mode
9.00	30.2	32	597	2	19.1	0.8	2 Human load /450 cfm
10.00	24.4	38	2163	1	19.1	0.8	
11.00	23.9	40	3860	0	19.2	0.8	
12.00	23.7	46	6482	0	19.1	0.8	
9.00	32	38	741	2	18.9	0.8	2 Human load /600 cfm
10.00	22	44	2248	1	19.1	0.8	
11.00	21.8	49	4107	0	19.1	0.8	
12.00	21.5	52	6874	0	19.1	0.8	

Table 1.2 cabin air quality about without fresh air supply for Partial human load

Cabin indoor obtained for partial load of two human loads and full load of five human loads. The obtained data's are express the poor indoor air quality in both loads because of the variable value of carbon dioxide, Temperature, Relative humidity.

Time(AM)	Temp(°C)	RH (%)	CO_2(ppm)	CO (ppm)	O_2 (%)	RAV (m/s)	Mode
9.00	31.5	37	680	2	19.1	0.8	5 Human load /450 cfm
10.00	24.5	41	2557	1	19.1	0.8	
11.00	24.2	46	4326	0	19	0.8	
12.00	23.9	49	7994	0	19	0.8	
9.00	33.2	35	545	2	19.2	0.8	5 Human load /600 cfm
10.00	21.1	39	2768	1	19.1	0.8	
11.00	22	49	4587	0	19.0	0.8	
12.00	21.8	49	8176	0	18.7	0.8	

Table 1.3 cabin air quality about without fresh air supply for Full human load

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The necessary of the indoor air quality for occupants, this paper observed the better comfort parameters in cabin on dynamic condition.

II.RESULTS AND DISCUSSION

2.1 cabin air quality about with fresh air supply for partial load

Time(AM)	Temp(°C)	RH (%)	CO_2(ppm)	CO (ppm)	O_2 (%)	RAV (m/s)	Mode
9.00	31.2	35	517	2	19.2	0.8	2 Human load /450 cfm / 10% fresh air supply
9.15	26.6	38	2915	0	19.2	0.8	
9.30	25.2	39	3148	0	19.1	0.8	
9.45	24.5	40	2972	0	19.1	0.8	
10.00	23.1	41	3270	0	19.2	0.8	
10.15	21.8	41	3016	0	19.1	0.8	
10.30	21.7	42	3142	0	19.1	0.8	
10.45	21.7	43	3523	0	19.2	0.8	
11.00	22.7	44	3535	0	19.2	0.8	
11.15	22.1	44	3190	0	19.2	0.8	
11.30	21.7	43	3168	0	19.1	0.8	
11.45	21.2	43	3290	0	19.1	0.8	
12.00	21.8	44	3558	0	19.2	0.8	
9.00	31.4	36	570	2	19.2	0.8	2 Human load /450 cfm / 20% fresh air supply
9.15	26.8	37	2041	1	19.2	0.8	
9.30	26.2	36	681	0	19.2	0.8	
9.45	24.4	39	1984	0	19.1	0.8	
10.00	25.2	38	703	0	19.1	0.8	
10.15	23.2	41	1870	0	19.2	0.8	
10.30	23.1	40	760	0	19.2	0.8	
10.45	22.8	40	1868	0	19.2	0.8	
11.00	23.3	40	680	0	19.2	0.8	
11.15	23.6	41	1983	0	19.1	0.8	
11.30	23.4	39	765	0	19.1	0.8	
11.45	22.5	41	1856	0	19.1	0.8	
12.00	23.1	39	727	0	19.1	0.8	
9.00	31.5	35	585	2	19.2	0.8	2 Human load /450 cfm / 30% fresh air supply
9.15	28.1	36	680	0	19.2	0.8	
9.30	26.8	37	988	0	19.2	0.8	
9.45	25.8	38	930	0	19.2	0.8	
10.00	26.2	37	648	0	19.2	0.8	
10.15	24.8	37	672	0	19.1	0.8	
10.30	24.1	37	977	0	19.1	0.8	
10.45	23.3	39	956	0	19.1	0.8	
11.00	25.8	37	627	0	19.1	0.8	
11.15	24.4	37	645	0	19.1	0.8	
11.30	23.2	38	927	0	19.1	0.8	
11.45	23.6	38	886	0	19.1	0.8	
12.00	25.1	37	656	0	19.1	0.8	

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2.2 cabin air quality about with fresh air supply

Time(AM)	Temp(°C)	RH (%)	CO_2(ppm)	CO (ppm)	O_2 (%)	RAV (m/s)	Mode
9.00	31.2	35	570	2	19.2	0.8	2 Human load /600 cfm / 10% fresh air supply
9.15	26.6	38	2764	0	19.2	0.8	
9.30	25.2	39	3058	0	19.2	0.8	
9.45	24.5	40	3165	0	19.2	0.8	
10.00	23.1	41	3338	0	19.2	0.8	
10.15	21.8	41	3147	0	19.2	0.8	
10.30	21.2	42	3186	0	19.2	0.8	
10.45	21.6	43	3428	0	19.2	0.8	
11.00	22.4	44	3612	0	19.2	0.8	
11.15	21.8	43	3237	0	19.2	0.8	
11.30	22.3	44	3362	0	19.2	0.8	
11.45	20.6	43	3186	0	19.2	0.8	
12.00	21.2	44	3474	0	19.2	0.8	
9.00	31.8	35	563	2	19.2	0.8	2 Human load /600cfm / 20% fresh air supply
9.15	26.2	37	1976	1	19.2	0.8	
9.30	26.4	37	623	0	19.2	0.8	
9.45	23.6	40	1928	0	19.1	0.8	
10.00	24.1	40	664	0	19.1	0.8	
10.15	23.8	41	1780	0	19.2	0.8	
10.30	25.3	40	728	0	19.2	0.8	
10.45	23.3	41	1814	0	19.2	0.8	
11.00	24.7	40	690	0	19.2	0.8	
11.15	22.6	41	1844	0	19.1	0.8	
11.30	23.4	40	753	0	19.2	0.8	
11.45	21.5	41	1746	0	19.1	0.8	
12.00	22.1	41	784	0	19.1	0.8	
9.00	32.2	35	558	2	19.2	0.8	2 Human load /600 cfm / 30% fresh air supply
9.15	28.4	37	630	0	19.2	0.8	
9.30	25.8	37	926	0	19.2	0.8	
9.45	24.8	38	932	0	19.2	0.8	
10.00	25.2	37	582	0	19.2	0.8	
10.15	23.5	37	718	0	19.1	0.8	
10.30	22.6	38	884	0	19.1	0.8	
10.45	21.3	39	896	0	19.1	0.8	
11.00	23.4	39	727	0	19.2	0.8	
11.15	23.3	37	695	0	19.1	0.8	
11.30	21.2	39	837	0	19.1	0.8	
11.45	22.6	40	856	0	19.0	0.8	
12.00	21.1	38	726	0	19.0	0.8	

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2.3 cabin air quality about with fresh air supply

Time	Temp	RH	CO_2	CO	O_2	RAV	Mode
9.00	31.5	32.3	574	2	19.2	0.8	5 Human load /450 cfm / 10% fresh air supply
9.15	27.2	39	3160	0	19.2	0.8	
9.30	26.4	40	3783	0	19.2	0.8	
9.45	26.2	41	3664	0	19.2	0.8	
10.00	25.8	40	3828	0	19.2	0.8	
10.15	25.3	40	4020	0	19.2	0.8	
10.30	24.8	41	3768	0	19.2	0.8	
10.45	25.4	44	4215	0	19.1	0.8	
11.00	24.6	43	4328	0	19.1	0.8	
11.15	24.4	45	4466	0	19.1	0.8	
11.30	24.7	43	3780	0	19.1	0.8	
11.45	24.2	44	4173	0	19.1	0.8	
12.00	24.2	44	4384	0	19.0	0.8	
9.00	31.9	36	540	2	19.2	0.8	5 Human load /450 cfm / 20% fresh air supply
9.15	27.5	39	1980	0	19.2	0.8	
9.30	25.2	40	2120	0	19.1	0.8	
9.45	26.3	41	988	0	19.1	0.8	
10.00	24.6	40	1886	0	19.2	0.8	
10.15	25.4	41	1264	0	19.0	0.8	
10.30	24.3	41	2174	0	19.0	0.8	
10.45	25.2	40	1170	0	19.1	0.8	
11.00	24.8	41	1859	0	19.1	0.8	
11.15	24.1	41	1930	0	19.1	0.8	
11.30	24.6	40	1047	0	19.1	0.8	
11.45	24.2	40	1872	0	19.1	0.8	
12.00	25.3	42	1064	0	19.1	0.8	
9.00	31.6	35	610	2	19.2	0.8	5 Human load /450 cfm / 30% fresh air supply
9.15	27.3	38	1120	0	19.2	0.8	
9.30	26.6	39	1086	0	19.2	0.8	
9.45	24.5	39	1212	0	19.1	0.8	
10.00	25.4	40	1165	0	19.1	0.8	
10.15	25.8	40	864	0	19.1	0.8	
10.30	24.6	40	1053	0	19.1	0.8	
10.45	24.1	41	1178	0	19.1	0.8	
11.00	24.7	41	1036	0	19.1	0.8	
11.15	24.5	41	1219	0	19.1	0.8	
11.30	24.9	40	1105	0	19.1	0.8	
11.45	25.3	40	992	0	19.1	0.8	
12.00	24.6	41	1137	0	19.1	0.8	

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2.4 cabin air quality about with fresh air supply

Time	Temp	RH	CO_2	CO	O_2	RAV	Mode
9.00	31.8	34	574	2	19.2	0.8	5 Human load /600 cfm / 10% fresh air supply
9.15	28.2	36	3160	0	19.2	0.8	
9.30	27.1	39	3783	0	19.2	0.8	
9.45	26.4	40	3664	0	19.2	0.8	
10.00	25.6	41	3828	0	19.2	0.8	
10.15	24.7	41	4020	0	19.2	0.8	
10.30	25.8	40	3768	0	19.2	0.8	
10.45	24.0	42	4215	0	19.1	0.8	
11.00	25.5	43	4328	0	19.1	0.8	
11.15	24.8	43	4466	0	19.1	0.8	
11.30	23.4	42	3780	0	19.1	0.8	
11.45	23.9	43	4173	0	19.1	0.8	
12.00	24.2	45	4384	0	19.0	0.8	
9.00	31.7	37	540	2	19.2	0.8	5 Human load /600 cfm / 20% fresh air supply
9.15	27.8	39	1980	0	19.2	0.8	
9.30	26.4	41	2120	0	19.1	0.8	
9.45	25.6	40	988	0	19.1	0.8	
10.00	25.4	40	1886	0	19.2	0.8	
10.15	25.5	40	1264	0	19.0	0.8	
10.30	26.2	42	2174	0	19.0	0.8	
10.45	25.1	41	1170	0	19.1	0.8	
11.00	24.6	43	1859	0	19.1	0.8	
11.15	25.8	42	1930	0	19.1	0.8	
11.30	24.7	41	1047	0	19.1	0.8	
11.45	25.3	40	1872	0	19.1	0.8	
12.00	24.4	41	1064	0	19.1	0.8	
9.00	31.5	34	610	2	19.2	0.8	5 Human load /600 cfm / 30% fresh air supply
9.15	27.1	37	1120	0	19.2	0.8	
9.30	26.4	40	1086	0	19.2	0.8	
9.45	25.2	39	1112	0	19.1	0.8	
10.00	24.3	42	1165	0	19.1	0.8	
10.15	24.8	41	864	0	19.1	0.8	
10.30	23.1	40	1053	0	19.1	0.8	
10.45	23.7	42	1178	0	19.1	0.8	
11.00	24.0	41	1036	0	19.1	0.8	
11.15	24.8	42	1219	0	19.1	0.8	
11.30	23.6	41	1105	0	19.1	0.8	
11.45	24.3	40	992	0	19.1	0.8	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

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This investigation done to control the co_2 variation inside the cabin and makes the affordable thermal comfort to the cabin atmosphere, this paper will discuss about both the thermal comfort and human comfort of the cabin during the dynamic condition. The thermal comfort of the car cabin is found by the fanger model. The experimental analysis is obtained continus monitoring on morning 9AM to 12PM

The following Tables helps to know the variation of temperature, carbon dioxide, carbon monoxide, oxygen, relative humidity and relative velocity on inside the car cabin with the inner circulation of air inside the cabin. The variable air flow are considered, but 350cfm air flow is not yet provide thermal comfort and human comfort in variable fresh air supply, so on the experimental measurements are measured and presented for 450cfm and 600cfm in tabulation.

The analyse the effects of cabin in dynamic condition on thermal and human comfort, the average indoor and outdoor particulars were obtained and the PMV and PPD were calculated in two different human loads, three different air flow volume, and three different fresh air supply. The predicted results is presented in Table 2.1 ,2.2, 2.3, and 2.4. The thermal and human comfort parameters observed from the presented tables.

The indoor air quality predicted from the above mentioned data's about various fresh air supply human load and air flow rate on dynamic condition. Current situations show that cabin air quality widely done without fresh air supply while in long journey in dynamic condition because of the variation of carbon dioxide typically limited such as human load fresh air supply and air flow rate.

The huge variation of carbon dioxide in cabin is more significant issue on human comfort in without fresh air supply mode. But the significant error are identified and rectified through this problem by regulating fresh air supply, human load, and air flow volume. Because of this system are having to spent energy according to actual needs. Meanwhile, the method provided more detailed information about variations of ventilation with the help of real-time measurement instruments and also that the ventilation does not vary over the measurement period. More systematic research is still needed to disclose the characteristics of indoor air pollution, and characterize human exposure to various air pollutants and related health risk.

For example, more details are needed about the transport of air pollutants between indoor and outdoor environments with variations of air exchange under controlled conditions. Considering high ambient air pollution concentration levels, proper ventilation methods and strategies should be adopted to prevent the transport of outdoor air pollution into the indoor environment, mitigate air pollution emitted from indoor sources, and keep enough fresh air indoors at the same time.

2.1 THERMAL COMFORT INDEX:

According to ASHRAE-55, thermal comfort has been defined as the condition of mind which illustrates satisfaction with the thermal environment, and thermal sensation is related to heat balance between the human body and its ambient thermal condition. Depending on the heat transfer, via heat gain or loss, the Thermoregulation system in a human brain regulates skin temperature to maintain a constant core body temperature of 36.5° C. meanwhile indoor temperature 22°C to 24°C, Relative humidity 42% to 48%, Carbon monoxide 0 to 9ppm, carbon dioxide 0 to 1000ppm and Oxygen 19.0±0.2% As per ASHARE. Thermal comfort index of the model are calculated using the fanger model. The volume of data obtained from the experimental value helps to find the comfort condition in high level accuracy.

The fanger model of thermal comfort is calculated by predicted mean vote and predicted percentage dissatisfied. The PMV and PPD model is based on the combined influence of relative humidity, air temperature, mean radian t temperature, air movement to that of clothing and activity level.

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$$PMV=3.155(0.303e^{-0.114M}+0.028)\ L$$
$$PPD = 100 - 95 \exp[-(0.03353\ PMV\ 4 + 0.2179\ PMV2)]$$

The experimental values are calculated to find the PPD and the results are been plotted below, to find the comfort condition. As per fanger model the thermal comfort index calculated. Normally the low bound that PMV>0 was recommended in summer and the up bound that PMV<0 was recommended in winter.

SI.NO	AIR FLOW	LOAD	FRESH AIR SUPPLY	PMV (-3 to+3)	PPD(%)
1	450	2	10	-0.55	11.3
2	450	2	20	-0.16	5.5
3	450	2	30	-0.03	5
4	600	2	10	-0.55	11.3
5	600	2	20	-0.4	12.3
6	600	2	30	-0.65	13.9
7	450	5	10	0.15	5.5
8	450	5	20	0.41	8.6
9	450	5	30	0.26	6.4
10	600	5	10	0.16	5.5
11	600	5	20	0.15	5.4
12	600	5	30	-0.02	5

2.5 PMV-PPD model of cabin

III. CONCLUSION

Providing comfort environment inside the cabin is very complex because of subjective nature. This investigation presented the suitable comfort environment for two and five human load in car cabin on dynamic condition. The results are presented in tabulation. The presented tabulation are expressed the temperature, relative humidity, carbon monoxide, carbon dioxide oxygen and relative velocity about variable loads, air flow rate, and fresh air supply. In general the value of CO_2 in more compare from indoor to outdoor because of increasing human load. To summarize, From our experimental results 600cfm air flow with 30% fresh air supply for 5 human loads and 450cfm air flow with 30% fresh air supply for 2 human loads are the comfort environment in car cabin. The result shows that parameters are clearly. The carbon monoxide and oxygen and relative velocity are may be same because of observed values are same in maximum observation. But carbon dioxide temperature and relative humidity are changed in each and every frequency of variable climatic conditions.

As per fanger model the thermal comfort index calculated. Normally the low bound that PMV>0 was recommended in summer and the up bound that PMV<0 was recommended in winter. Recommended ranges of indoor air design parameters were determined for car cabin was 600cfm air flow with 30% fresh air supplies for 5 human loads obtained PMV value -0.02 and PPD 5%and 450cfm air flow with 30% fresh air supply for 2 human loads obtained PMV value -0.03 and PPD 5% are also the comfort environment as per thermal comfort index.

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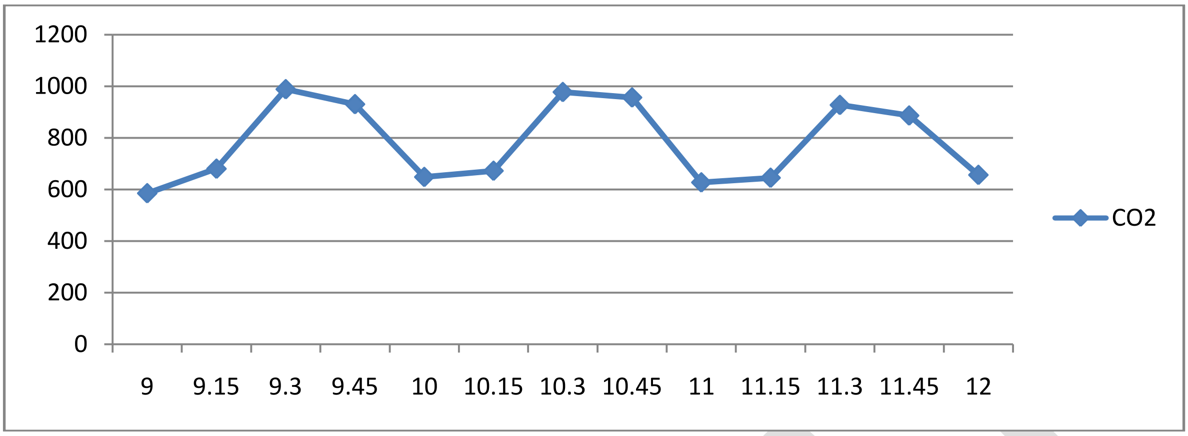

Fig 3.1 Partial Human load /450 cfm / 30% fresh air supply

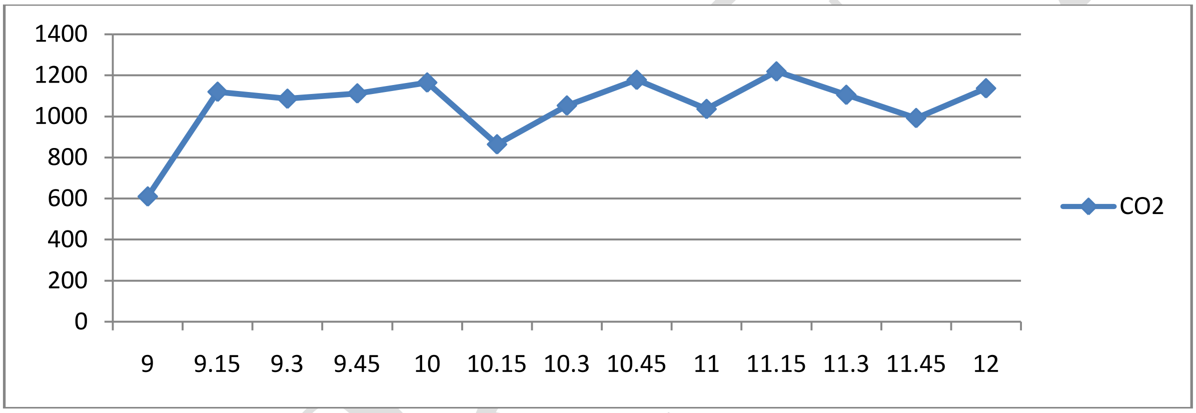

Fig 3.2Full Human load /600 cfm / 30% fresh air supply

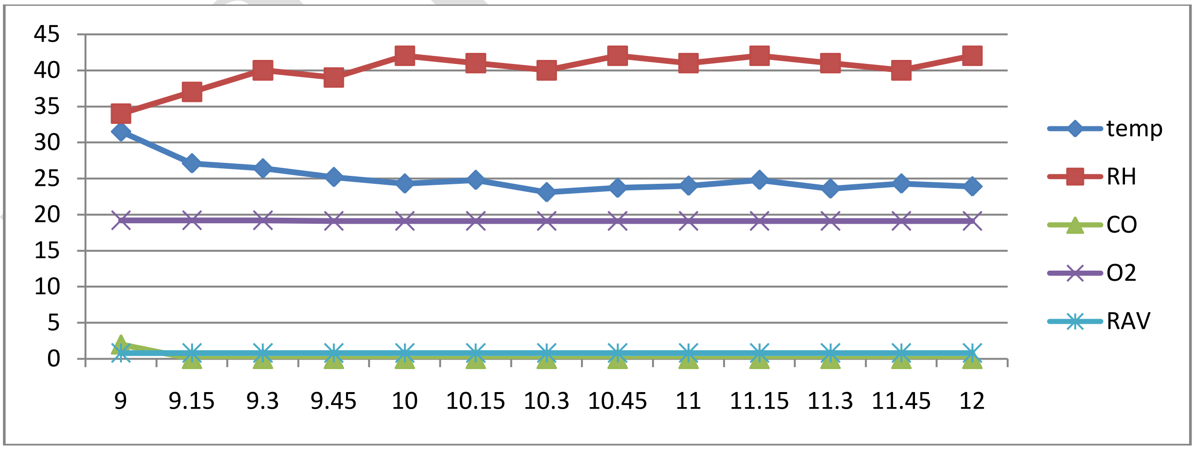

Fig 3.3 Partial Human load /450 cfm / 30% fresh air supply

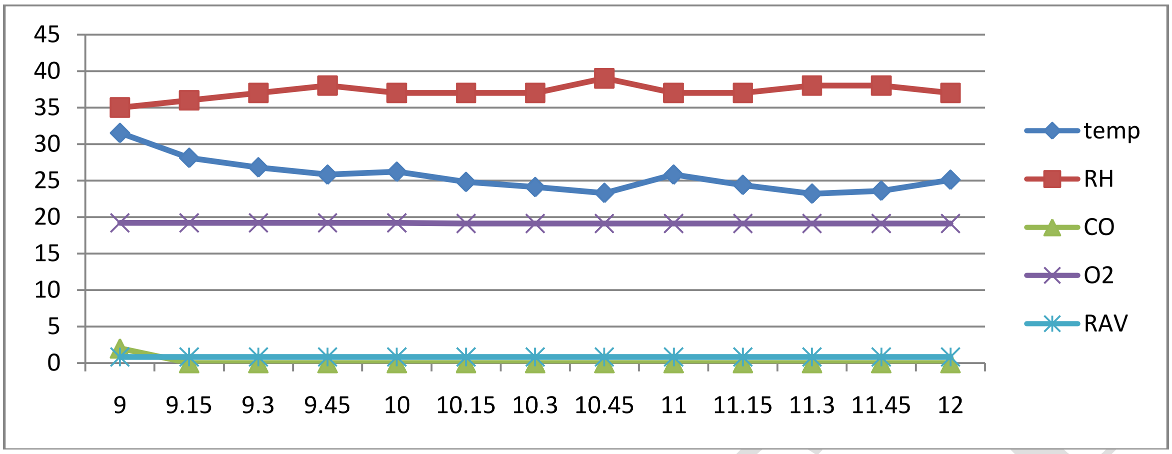

Fig 3.4 Full Human load /600 cfm / 30% fresh air supply

Concluding from these experimental results the quality of indoor air parameters are observed about variable climatic condition in different fresh air supply. The experimental results and thermal comfort index are point out the comfort environment in cabin were both of the results are same, so on the predicted results are provide the human and thermal comfort with healthy environment. The results showed the PMV and PPD values are surprisingly closed to zero and the human and thermal comfort parameters are also the limit of ASHARE standard in the cabin on the dynamic condition.

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