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Optimisation of Heating, Ventilation and Air Conditioning (HVAC) with CO_2 Removal System

Shri Pal[1*], R. Debnath[2]
[1]*Managing Partner, Bunkerman, Baddi, India*
[2]*Director, SPEA Entrade Pvt. Ltd., Gurugram, India*

Abstract**: Maintaining the Indoor Air Quality while designing Heating, Ventilation and Air Conditioning (HVAC) in the buildings, has always been a challenging task. In a usual design, the indoor air quality is maintained by ensuring certain numbers of air changes in the buildings per hour, in which we add the fresh air into the HVAC system of the building from the outside environment. The study presented in this paper differs from this usual design approach for HVAC in the concept that it does not take the outside air (which is generally at a significantly higher or lower temperature than that of the inside air) for maintaining the desired CO_2 and oxygen levels inside the air-conditioned space but it makes use of the Indoor Air Quality Management System recently invented by BUNKERMAN [1, 2] to achieve this purpose. With a result, a considerable reduction in Peak Heat Load (20 to 30% approximately) is achieved as illustrated in the calculations presented in this study. The proposed approach also helps in electrical load balancing in a city in peak load hours and it mitigates the harmful effects of the split air conditioners which lack the provisions of ensuring the desired levels of CO_2 and Oxygen in the indoor air-conditioned space.**

Keywords**: Indoor air quality, Button up mode, CO_2 removal, Oxygen replenishment, Positive pressure, TVOC, Odour removal.**

1. Introduction

Maintaining the Indoor Air Quality while designing Heating, Ventilation and Air Conditioning (HVAC) in the buildings, has always been a challenging task for engineers and architects. The increasing global warming, ever increasing pollution levels in big cities, changing world environment due to threats of global wars, epidemics like corona, spread of terrorism etc, world over; are forcing us to give a fresh look to this problem with a view to derive a sustainable, economical and yet a practical solution to this problem. The present study describes an optimised and economical approach by combining the current HVAC system designs with CO_2 Removal System recently invented by BUNKERMAN [1].

The National Air Quality Index (IAQ) adopted in India and most of the other countries takes care of only 8 types of pollutants in air i.e. PM2.5, PM10, Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Ground Level Ozone (O_3), Ammonia (NH_3) and Lead (Pb). It does not measure and accounts for the contents of CO_2, and other harmful gases like Methane, Formaldehyde, foul or undesirable odour from human perspiration, toilets, kitchens and other sources etc. These are generally described in a single factor termed as Total Volatile Organic Compounds (TVOC). AQI also does not give any indication whether the desired level of oxygen is present in the air or not.

The HVAC engineers and professional institutions like ASHRAE and ISHRAE are well aware of the requirements of maintaining the desired levels of oxygen and limiting the levels of CO_2 within the prescribed limits in the designed buildings. This is, however, being done presently by ensuring certain numbers of air changes in the buildings per hour, in which we add the fresh air into the HCAV system of the building from the outside environment. The study presented in this paper differs from this usual design approach for HVAC in the concept that it does not take the outside air (which is generally at a significantly higher or lower temperature than that of the inside air) for maintaining the desired CO_2 and oxygen levels inside the air-conditioned space but it makes use of the Indoor Air Quality Management System recently invented by BUNKERMAN [1, 2] to achieve this purpose. With a result, a considerable reduction in heat load (20 to 30% approximately) is achieved as illustrated in the calculations presented in this study.

Also in actual practice, the situations may arise where it may not be possible to use the air from outside environment for maintaining the Indoor Air Quality and as a supplement of oxygen and controlling the levels of CO_2 and other harmful gases in the indoor environment. Such situations are mainly faced in Spacecrafts, Submarines, Nuclear Bunkers, Emergency Shelters and other such facilities which are required to operate in Button Up or Filtration Modes. In such situations, in addition to the AQI, it becomes necessary to monitor the levels of CO_2, Oxygen, TVOC and other toxic and harmful contents including Nuclear, Biological and Chemical (NBC) Warfare Agents suspected to be present in the air. The approach presented in this study facilitates and provides an efficient and practical solution under such circumstances. The BUNKERMAN system proposed such facilities comprises of following sub systems:

a) CO_2 Removal System
b) Odour/TVOC Removal System
c) Oxygen Replenishment System
d) NBC Filtration System
e) Compressed Air System

*Corresponding author: drshripal55@gmail.com

f) Facility Management System.

However, for most of the houses and buildings in civil, only following sub systems should suffice to be integrated with the HVAC System:

a) CO_2 Removal System.
b) Odour/TVOC Removal System
c) Facility Management System.

The proposed HVAC System for buildings for civil population may be used in the following two modes of operation i.e. Normal Mode and Button Up Mode.

A. Normal Mode

This mode is used under normal conditions when the outside air is having only normal type of air pollution and it is not contaminated by any Biological, Chemical or Radiological contaminant. In this mode of operation only CO_2 Removal System should suffice to be integrated with the HVAC System for most of the buildings. However, TVOC Removal System and Oxygen Replenishment System may also be added for integration, wherever felt necessary in such buildings. The method of integration are illustrated in Figures 1and 2 below.

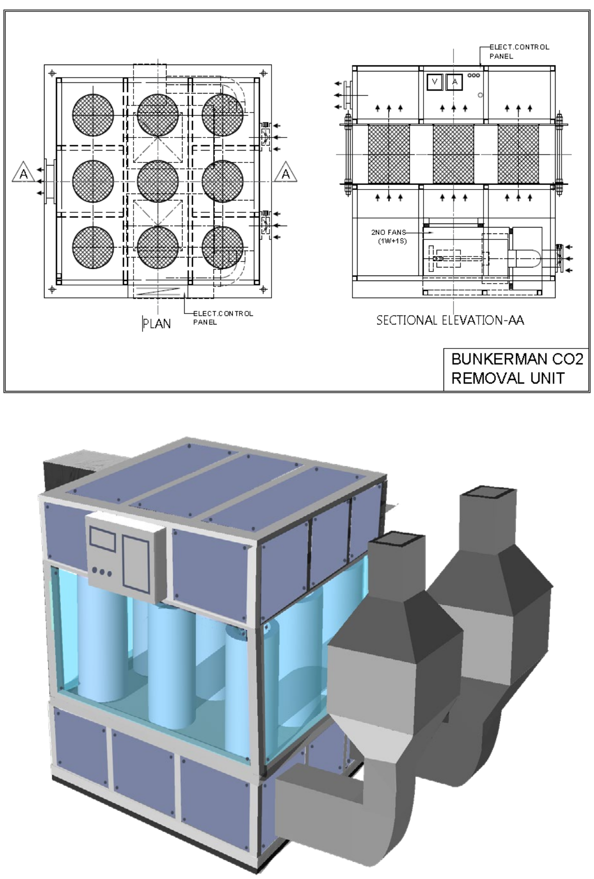

Fig. 1. BUNKERMAN CO_2 removal unit

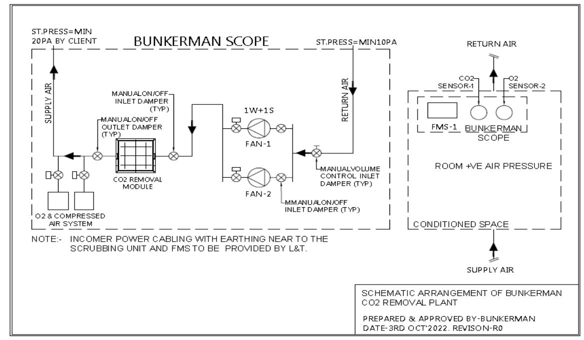

Fig. 2. Typical arrangements of HVAC system integrated with CO_2 removal unit in normal mode

B. Button Up Mode

A Button Up Mode or Period is defined as a period in a habitat during which no outdoor air is permitted to be used for human inhalation (being contaminated). In such a situation, the occupants of the habitat, have to survive only on the available indoor air with some additional provisions for Indoor Air Quality Management which becomes necessary for the safe survival of the occupants. Such situations may arise even for civil population in times of any pandemic like corona or in case of any threat of Biological, Chemical or Nuclear attack.

Under Button Up Conditions, the following six sub systems which are duly integrated with one another, may be necessary for the civil population:

a) CO_2 Removal System.
b) Odour/TVOC Removal System
c) Oxygen Replenishment System.
d) Compressed Air System
e) Facility Management System.

All these five systems are required to operate not independently but in coordination with one another so as to always maintain the desired CO_2, TVOC, Oxygen and Pressure levels in the facility for human inhalation and not to allow any inward leakage of contaminated air from outside environment by maintaining a positive pressure inside the facility. The typical arrangements under such conditions are shown in Figure 3 below.

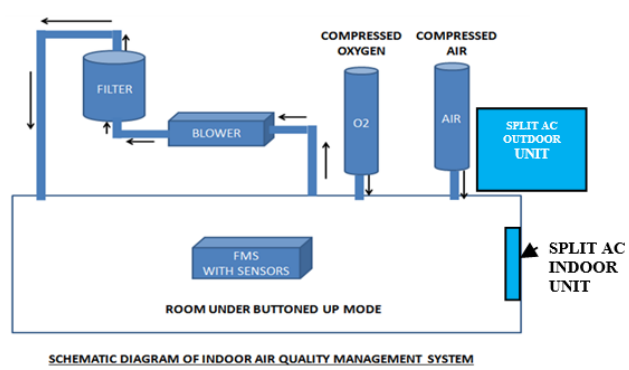

Fig. 2. Typical arrangements of HVAC system integrated with CO_2 removal unit in button up mode

2. Results

As per ASHRAE Standard 62.1-2010 [10], following parameters of the Indoor Air Quality (IAQ) are recommended inside the HVAC rooms:

a) Room dry bulb temperature and Relative humidity.
b) Minimum ventilation rate recommended in ASHRAE standard should be as per Table 6-1. For example, for office building, minimum fresh air of 5-cfm per person plus 0.06 cfm per sq. ft of floor area have been recommended.
c) Appendix 'C' of the above standard suggests maintaining a steady-state CO_2 concentration in a space no greater than about 700 ppm above outdoor air levels."
d) To control other gases and pollutants like PM10, PM2.5, Ozone, and Organism by using various type of filters.
e) Above standard is silent about recommended oxygen level inside the HVAC space.

A. The new integrated system

The new integrated system in which the above five sub systems are combined or integrated with HVAC system, will have the following useful provisions:-

a) The outdoor air is not required to be taken into the ventilation system on continuous basis, without compromising the ASHRAE and ISHRAE mandates.
b) The inbuilt Facility Management System (FMS) automatically controls the indoor climate by ensuring the desired levels of oxygen, CO_2, Positive Pressure and TVOC as per laid down standards and required by the users; and eliminating other harmful gases, if so required.
c) It also reduces the heat load of HVAC building substantially to save capital cost, power and space of the building.
d) This technology is especially useful in buildings like Emergency Isolation Rooms and other rooms in the hospital, Apartments, Institutes, PUBs, Restaurant, Hotel, Bunker, Tunnel, Submarine, Mines, Cinema Hall/Theatre, Community halls etc.
e) In case of any virus suspected in air like Corona or in case of any Nuclear, Biological or Chemical (NBC) environment suspected or encountered outside, the building or facility can immediately be switched on to the Button Up Mode to safeguard the life of the people inside.
f) Monitor the Dry Bulb Temperature and Relative Humidity inside the room.

1) Reduction achieved in HVAC load of the building

The calculations of heat loads in a typical building (ICU of a Hospital) under the two conditions (one with normal design with fresh air change and another with CO_2 Removal System without using any air change) for three different stations, are compared in Table 1 below. It may be concluded from this comparison that an saving of approx. 20 to 30 % in Peak Heat Load can be achieved for air conditioning if we combine the proposed CO_2 Removal System with the air conditioning plant and dispense away the current design concept of adding fresh air of a higher or lower temperature into the air-conditioned space. the expenditure of electricity consumed by the small fan unit of the CO_2 Removal system is almost negligible as compared to the electricity consumption of the air conditioning plant. Therefore, following important conclusion can be made by this comparison:

a) The current procedure of air changes requiring addition of the fresh air from outside environment may be totally dispensed away. The outside air is generally either at a higher or a lower temperature than inside air and it is also generally more contaminated than the inside air; and it therefore, unnecessarily adds to the extra heat load and the contamination to the inside environment.
b) A saving of approx 20 % to 30 % can be achieved in Peak Heat Load for the HVAC system by integrating or combining the above proposed CO_2 Removal System and other sub systems with the air conditioning system in a building.

Table 1
Comparison of estimated heat load

ESTIMATED HEAT LOAD COMPARISION												
SL NO	LOCATION	ODU TEMP	ODU TEMP	Area-ICU room	ESTIMATED HEAT LOAD WITH FRESH AIR AS PER STANADRD		ESTIMATED HEAT LOAD WITH CO2-REMOVAL SYSTEM		HEAT LOAD DIFFERENCE WITH CO2-REMOVAL SYSTEM		%REDUCTION IN PEAK HEAT LOAD WITH CO2-REMOVAL SYSTEM.	
		SUMMER	MONSOON		SUMMER	MONSOON	SUMMER	MONSOON	SUMMER	MONSOON	SUMMER	MONSOON
		DEG C/% RH	DEG C/% RH		TR	TR	TR	TR	TR	TR		Peak Heat Load
						Peak Ht Load		Peak Ht Load		Peak Ht load reduction		% Peak Ht load reduction
1	DELHI	43.3/20%	35/60%	1400sqft,ht 3.5m height with underdeck Insulation-15 Patients.	8.56	9.47	7.51	7.51	1.05	1.96	12.3%	20.7%
2	MUMBAI	35/60%	29.4/88%		7.25	7.3	5.39	5.39	1.86	1.91	25.7%	26.2%
3	GUWAHATI	34.6/51.2%	31.3/81.7%		6.73	7.31	5.31	5.31	1.42	2.00	21.1%	27.4%
4	Peak Heat Load reduction range											20-30%

3. Discussion and Conclusion

The calculations of heat loads in the examples explained above, clearly explains that a saving of approx 20 to 30 % in Peak Heat Load can be achieved for air conditioning if we combine the proposed CO_2 Removal System with the air conditioning plant and dispense away the current design concept of adding fresh air of a higher or lower temperature into the air-conditioned space. The expenditure of electricity consumed by the small fan unit of the CO_2 Removal system is almost negligible as compared to the electricity consumption of the air conditioning plant. Therefore, following important conclusion can be made by this comparison:

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b) A saving of approx 20 % to 30 % can be achieved in Peak Heat Load for the HVAC system by integrating or combining the above proposed CO_2 Removal System and other sub systems with the air conditioning system in a building.

A. *Electric Load Balancing*

A great advantage of the above heat load reduction concept is that this can be used in balancing the peak load and the normal load in a day. The climatic conditions in India are such that the average air conditioning load in a day is generally low during morning and evening hours and it generally peaks up in the afternoon hours say approximately around 3 pm to 5 pm, particularly so during summer and monsoon seasons. With a result, in many cities particularly industrial cities, the electricity department has to resort to a compulsory shut down in some areas during such peak hours. It is at such peak hours that the use of CO_2 Removal System can be made compulsory during such peak hours to reduce the AC load and balance of the time CO_2 Removal System may be switched off and outdoor may be taken into the HVAC System to compensate for the reduced levels of oxygen and increased CO_2 concentration inside the rooms. Thus the CO_2 Removal System and Oxygen Replacement Systems can be used to effectively achieve such type of load balancing during the day.

B. *Split Air Conditioners: The Silent Killers*

The Split Air Conditioners generally used in India and other countries, only cool and circulate the air inside the rooms without having any provisions of supplying fresh air to the room. With a result, in most of the cases, the CO_2 levels in such rooms goes down below the permissible limits of 800 ppm and the oxygen level may also decrease below permissible value of 17 %. Such situations are very dangerous and these are certainly a health hazard for the occupants. It has a sort of slow poisoning effect on the occupants of the room.

Therefore, it is recommended that it should be made compulsory to provide a suitable CO_2 Removal System and Oxygen Replenishment System if Split Air Conditioners are used in a building or a room. In addition to issuing suitable guideline by ISHRAE and ASHRAE in this respect, the concerned Govt authorities should be approached to make a law by legislation in this respect in the interest of safety and health of its general public.

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