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Indoor Air Quality Management under Button Up Conditions

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Abstract: Maintaining the desired Indoor Air Quality under the Button Up Conditions, has always been a challanging task. The present invention provides Indoor Air Quality Management System Under Button Up Conditions[1]. The system is operated in a Normal, Button Up or Filtration mode. The invention comprises computer based fully automated system which include six sub systems i.e., CO2 Removal System, Odour/ TVOC Removal System, Oxygen Replenishment System, Compressed Air System, NBC Filtration System and Facility Management System that operate in coordination with one another to maintain the desired CO2, Oxygen and Positive Pressure levels in facility. CO2 adsorbents which adsorb CO2 from the air by way of not only their chemical reactions but also or only by way of their molecular structure and other properties. Activation of CO2 Removal System is based on the signal from the CO2 sensor that is located in the return air duct of the air handling units serving the buildings. The CO2 Removal System does not depend only on one type of absorbent/adsorbent material. All the six sub systems are fully integrated with one another to always maintain the desired levels of CO2, Oxygen and positive pressure in the facility and filter away any hazardous contaminants from the air under all three modes of operation i.e., Normal Mode, Button Up Mode or Filtration Mode as felt necessary. The Bunkerman absorbents used in the system, showed CO2 absorbent capacity of about 35% to 42% by weight. The adsorbent capacity of the Bunkerman Adsorbents and molecular sieves were observed to be between 15 to 18. An absorbent capacity of 30% and adsorbent capacity of 12% can be safely adopted for CO2 removal filters in the systems. The proposed Bunkerman Indoor Air Quality Management System was effectively able to ensure the recommended levels of CO2 and TVOC [2,3] in the facility tested during Real Button Up Mode.

Keywords: Indoor Air Quality, Button Up Mode, Filtration Mode, CO2 Removal, Oxygen Replenishment, Positive Pressure, NBC, Regenerative Absorption, Adsorption, TVOC, Odour Removal.

INTRODUCTION

It is a well-known fact that normal atmospheric air generally contains 79.03% Nitrogen, 20.94% Oxygen and 0.03% Carbon dioxide by volume. Nitrogen is not absorbed by lungs and in human respiration it goes into lungs and comes out as it was inhaled as part of the air. Exhaled air, however, contains a higher percentage of Carbon Dioxide (an average of 4.38%) as compared to the percentage of CO2 in inhaled air. During inhalation, a small percentage of Oxygen is permanently consumed by lungs and it goes into the blood cells inside the human body.

Therefore, when a facility goes into a Button Up Mode in Closed Up Conditions, the following things happen inside the facility almost simultaneously or in some sequential manner:-

- 1) Oxygen level keeps on depleting with time.
- 2) CO2 level keeps on increasing with time.
- 3) Overall volume of air keeps on reducing with time (since some oxygen is permanently absorbed by lungs).

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- 4) Overall volume of air keeps on reducing with time (since some o2 is permanently absorbed by lungs).
- 5) This fact theoretically and practically creates a negative pressure in the closed chamber.
- 6) Above changes take place inside the facility almost every second as the occupants inhale & exhale the air.

The rate of change in overall composition of air is not a simple phenomenon but it is quite complex in nature and it depends on following factors:-

- *a)* Number and Nature of occupants.
- b) Density and distribution pattern of persons in different areas inside the facility.
- c) Movement and working pattern of occupants inside the facility.



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And hence to monitor and control this highly complex phenomenon, there is always a requirement of having a computerized fully automated Indoor Air Quality Management and Control System which can ensure the desired air quality in the facility under buttoned up conditions. Such a system has been indigenously developed in the present study by Bunkerman[1]. The system is comprised of the following sub systems which are duly integrated with one another:-

- CO2 Removal System.
- Odour/TVOC Removal System
- Oxygen Replenishment System.
- NBC Filtration System.
- Compressed Air System
- Facility Management System.

All these six systems are required to operate not independently but in coordination with one another so as to always maintain the desired CO2, 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.

A. CO2 Removal System

The shelter design should consider carbon dioxide levels when determining the shelter size, and take into account the desired sheltering time and number of people occupying the shelter. Carbon dioxide is present in atmospheric air at about 0.03 percent by volume and acts on the human nervous system to maintain involuntary respiration. At levels in excess of 1 percent it begins to cause hyperventilation, increased oxygen consumption, and increased respiratory carbon dioxide production; concentrations higher than 4 percent are toxic. The recommended levels of carbon dioxide for safe sheltering from various standards are provided below:

- OSHA: The Occupational Safety and Health Administration (OSHA) has set the carbon dioxide permissible exposure limit (PEL) 5000 ppm for an 8-hour period and a short term exposure limit (STEL) of 30000 ppm for 15-minute period.
- 2) *NIOSH:* The National Institute for Occupational Safety and Health (NIOSH) has recommended that carbon dioxide does not exceed 10000 ppm for up to a 10- hour period and a ceiling concentration of 30000 ppm not to exceed a 10-minute period.
- *3) TM* 5-858-7: As per this Technical Manual for Designing Facilities to Resist Nuclear Weapon Effects, the maximum carbon dioxide content of the room exhaust air should not exceed 1 percent and the corresponding concentration in return air should be less than 0.08 percent.
- 4) ASHRAE: According to ASHRAE, the American Society of Heating, Refrigerating and Air Conditioning Engineers, levels of indoor carbon dioxide should be below 700 ppm.
- 5) Many nations, including Japan, Korea, Portugal, France and Norway, have set 1000 ppm of CO2 as the standard for specific indoor environments, including school and office buildings.

Two types of CO2 Removal Systems, one Non-Regenerative Type and the other Regenerative Type were developed in the present invention. In the first phase, the Bunkerman Brand CO2 absorbents, adsorbents and molecular sieves were indigenously developed by conducting several tests and trials on commercially available materials in the Indian market. In the second phase, Bunkerman Filters for CO2 and TVOC removal from the air were developed and optimised. In the third phase, the complete CO2 Removal System was developed by integrating the CO2 Removal Filters, TVOC Removal Filters and other equipment, accessories like valves, vacuum pumps, fans, heating and cooling systems etc.

The optimisation has been achieved in the filters and the systems by making use of the following materials and principles:-

- a) CO2 Absorbents which absorb CO2 from the air by way of their chemical reaction.
- *b)* CO2 adsorbents which adsorb CO2 from the air by way of not only their chemical reactions but also or only by way of their molecular structure and other properties.
- *c)* Molecular Sieves based on adsorbent materials which are Sodium based, Potassium based, Lithium based and/or Zeolite based. Optimisation in shapes and sizes of the molecular sieves and their granules has also been successfully achieved, while designing these filters.
- *d*) Use of moisture absorbing materials has been made in these filters so as to maximise the CO2 absorption and adsorption capacity of the filters.
- e) An effective use of membrane type filters has been made to achieve the optimum efficiency in the filters.



- f) An effective use of special filter material like activated carbon impregnated with one or more of the items shown at Paras 8 (a) to (e) above, has been made with a view to absorb/adsorb the odour and TVOC in addition to CO2. Therefore, the system does not only work as a CO2 Removal System but it works as a CO2 and Odour Removal System.
- g) The presented CO2 Removal System, therefore, does not depend only on one type of absorbent/adsorbent material but it makes use of the latest technology making an optimum use of the properties of various absorbents, adsorbents, molecular Sieves, Moisture absorbing, Odour Removing, TVOC removing and other useful materials to suit the requirement of ensuring the desired indoor air quality in a facility designed to work in Button Up Mode.

B. Control by Sensors

The CO2 Removal System is designed to maintain the permissible exposure limit of CO2 for its occupants not greater than 1000 ppm (0.1%) for the desired Button Up Period as specified by Bhabha Atomic Research Center (BARC) Mumbai. Activation of CO2 Removal System shall be based on the signal from the CO2 sensor located in the return air duct of the air handling units serving the buildings. The threshold value of CO2 to start the CO2 Removal System has been kept at 800 ppm (0.08%), as per recommendations given in TM 5-858-7: Designing Facilities to Resist Nuclear Weapon Effects. As soon as the CO2 content in the indoor air exceeds 800 ppm, the sensor sends the signal to the inbuilt Facility Management System of the CO2 Removal Unit to start filtering the air for CO2 removal and returns it back to the facility through the Air Handling Unit. This way, the contents of CO2 are automatically lowered in the facility. To economise on the use of electricity and filters, the CO2 Removal System automatically stops once the CO2 level comes below 400 ppm or any other value in the facility as desired by users. Therefore, the CO2 level in the facility is always maintained between 400 ppm (or any other such value set by users) and 1000 ppm by the automation system.

C. Odour/TVOC Removal System

In addition to CO2 removal, the Bunkerman Indoor Air Quality management System is also designed to remove TVOC contents from the air (such as body odour, food/drinks smell, toilet odour etc). For this purpose the composition of filters is suitably designed to include the absorbents/adsorbents which can remove TVOC from the air in addition to the CO2 removal.

D. CO2 and Odour Removal System for Toilet Blocks

For toilet blocks, though the duration and strength of occupancy by personnel is much lesser than the other accommodation but the problem of CO2 removal becomes more complex due to requirement of removal of odour and foul gases from the air (which are more predominant) in addition to removal of CO2.

This problem has been resolved in the present system firstly, by installing the ozone generators in the toilet blocks which helps in decomposing the foul gases; and secondly, by designing a combined system for removal of CO2 and the TVOC together. Specially designed filters have been used in the system to achieve this purpose.

The functioning of the CO2 and Odour removal System in places like toilet blocks, are generally governed by monitoring the TVOC contents due to its predominance rather that the CO2. Both types of sensors i.e. CO2 and TVOC are, therefore, essential to be integrated with these systems in toilet blocks.

E. Oxygen Replenishment System

Even though oxygen depletion is a lesser threat than carbon dioxide, most occupants will not be aware of this and may become overly concerned and anxious about the level of oxygen in the shelter. For prolonged Button Up period it becomes mandatory to supply additional oxygen to the occupants after oxygen level drops below 17%.

Oxygen is supplied from pressurized tanks, stored inside the facility. This oxygen is piped to the air handling units and released continuously or in batches by a computerized system that senses the percentage of oxygen in the return air. Periodic checking of the oxygen concentration and manual adjustments of flow rate can also be made. A two stage pressure regulating valve shall be used to set the flow. The variation of oxygen content between <u>17% and 21%</u> is acceptable as per TM5-858-7 "Designing facilities to resist Nuclear weapon effect". The permissible oxygen concentration within the underground facility is provided as under:

The oxygen concentration for the underground facility should preferably be maintained at 21% for heavy work activity and shall not drop below 20% for activity involving light work.

However, considering the desired activities of personnel during the Button Up period it should be acceptable to maintain the oxygen levels in the facility between 21% and 17%.



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Therefore, the Oxygen Replenishment has been designed to consist of the following:-

- 1) Manifold cylinders containing Pressurized Oxygen,
- 2) Oxygen Sensor,
- 3) Control System.

F. Compressed Air System

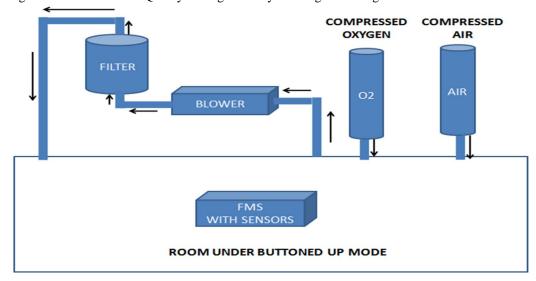
In addition to the above two systems, the third system i.e. Compressed Air System is also integrated so as to always maintain a desired positive pressure in the facility. This is done so that no contaminated air from outside leaks into the facility and the desired level of Indoor Air Quality is always ensured in the facility as per the standards laid down in the Indian and International Codes of Practice.

G. NBC Filtration System

Bunkerman also provides suitably designed NBC filtration system for the facilities which are required to be functional under such emergency conditions. Due to security reasons, more details of NBC Filtration System are excluded from the scope of this document.

H. Facility Management System (FMS)

All the above systems are integrated together with the help of a suitably designed Facility Management System (FMS) by Bunkerman. The Bunkerman FMS includes specially designed hardware and software components assembled and integrated together so as to control and manage the entire Indoor Air Quality Management System automatically with least human intervention. The entire system, therefore, works as an intelligent system based on the concept of Fix and Forget type. The schematic Diagram of the Indoor Air Quality Management System is given in Fig 1 below.



SCHEMATIC DIAGRAM OF INDOOR AIR QUALITY MANAGEMENT SYSTEM

Figure 1

II. RESULTS

A. Test Results

The tests on materials, filters and equipments were conducted in the following sequential manner:-

- 1) Tests on materials (Bunkerman absorbents, Bunkerman Adsorbents, Bunkerman Molecular Sieves etc) developed buy BUNKERMAN for absorption and adsorption of CO2.
- 2) Tests on Bunkerman brand Filters (CO2 Scrubbers) both Regenerative and Non-Regenerative Type.
- 3) Tests on Complete System under **Simulated** Button Up conditions.
- 4) Tests on Complete System under **Real** Button Up conditions.



The test results for testing of materials for Bunkerman Absorbent Type 1, are given below.

SPE		C	MSME UAM NO: A503D ERTIFICATE OF A		
ENTR			Finish Good	d	
TYPE-1	me: BUNKERMAN		A. R. No. SPEA/BUI/QC		2-23
	BU1/005/22-23 as p	er client	Date of intimation: 16.07.		
Batch size:			Date of Receiving: 16.07. Date of Analysis: 16.07		
Sample qua	ntity: 500 gm		Dute of Release: 21.07		
		Gen	eral Characteristics		
_					6 - F
	ppearance		lar-having Irregular spheric	al shape	Complies
1	Solubility		Partially soluble in water		Complies
	St	atic Chemical Ana	alvsis at R&D Laboratory	-Baddi-HP	
Sr. No.	Test	Parameter	Specificati	on	Observation
1	Ph @ 25°C (15	% solution in water	11 - 13		12.42
2		(Percentage by	NLT 30.00 %		33.98 %
	Aero-Dynamic an		ic Analysis at R&D Labo		-HP-tested on
		16th and 1	8th July'2022-28-hours te	st	
Sr. No.	Test Pa	16 th and 1 rameter	8th July 2022-28-hours te Specification	st	Observation
		16 th and 1 rameter	8th July'2022-28-hours te	st	Observation is not hard, but become
Sr. No.	Test Pa	16 th and 1 rameter	8 th July 2022-28-hours te Specification 80.95Kg 899Kg/Cu.m	The material	Observation is not hard, but become
Sr. No.	Test Pa Non-Regenerative	16 th and 1 rameter Test bed weight	8th July 2022-28-hours te Specification 80.95Kg 899Kg./Cu.m 2890min	The material	Observation is not hard, but become
Sr. No. 1 2 3 4	Test Pa Non-Regenerative Material Density Total time of oper Test Bed size	16 th and 1 rameter Test bed weight ation	8 th July '2022-28-hours te Specification 80.95Kg 899Kg./Cu.m 2890min 600mm diax320mm ht.	The material	Observation is not hard, but become
Sr. No. 1 2 3 4 5	Test Pa Non-Regenerative Material Density Total time of open Test Bed size Static Pressure dro	16th and 1 rameter Test bed weight ation op for Air flow	8 th July '2022-28-hours te Specification 80.95Kg 899Kg./Cu.m 2890min 600mm diax/20mm ht. 19tum WC	The material	Observation is not hard, but become
Sr. No. 1 2 3 4 5 6	Test Pa Non-Regenerative Material Density Total time of open Test Bed size Static Pressure dro Air-flow at inlet o	<u>16th and 1</u> rameter · Test bed weight ation op for Air flow f bed	8th July 2022-28-hours te Specification 80.95Kg 899Kg./Cu.m 2890min 600mm diaxJ20trum ht. 19mm WC 263-264cfm	The material	Observation is not hard, but become
Sr. No. 1 2 3 4 5 6 7	Test Pa Non-Regenerative Material Density Total time of open Test Bed size Static Pressure dro Air-flow at inlet o Average Inlet air t	<u>16th and 1</u> rameter Test bed weight ation up for Air flow f bed emp and Humidity	8th July 2022-28-hours te Specification 80.95Kg 899Kg./Cu.m 2890min 600mm diax320trum ht. 19mm WC 263-3264cfm Avg 23.52°C, 73.75%	The material	Observation is not hard, but become
Sr. No. 1 2 3 4 5 6 7 8	Test Pa Non-Regenerative Material Density Total time of oper Test Bed size Static Pressure dr Air-flow at inlet o Average Inlet air t Time Avg. input C at inlet of the bed.	16 th and 1 rameter · Test bed weight ation op for Air flow (bed emp and Humidity 202 Concentration	8th July 2022-28-hours fe Specification 80.95Kg 899Kg./Cu.m 2890min 600mm diax320mm ht. 19mm WC 263-264cfm Avg.23.52°C, 73.75% 790.68ppm	The material	Observation is not hard, but become
Sr. No. 1 2 3 4 5 6 7	Test Pa Non-Regenerative Material Density Total time of oper Test Bed size Static Pressure dro Average Inlet air t Time Avg. input at inlet of the bed. Time Avg. CO2 a 48.16ftrs. Duration	16 th and 1 rameter · Test bed weight ation up for Air flow f bed emp and Humidity 202 Concentration bsorption in bed for h.	8 th July 2022-28-hours te Specification 80:05Kg 899Kg./Cu.m 2880min 600mm dia:20mm hr. 600mm dia:20mm hr. 600mm dia:20mm hr. 600mm dia:20mm hr. 263-264cfm Avg.23.52°C, 73.75% 790.68ppm 360.73PPM	The material	Observation is not hard, but become
Sr. No. 1 2 3 4 5 6 7 8 10	Test Pa Non-Regenerative Material Density Total time of oper Test Bod size Static Pressure dre Average Inlet air Time Avg. coupa at inlet of the bed. Time Avg. Coupa 48.16hrs. Duration Time Avg. coupa Concentration of c	16 th and 1 rameter · Test bed weight ation up for Air flow f bed emp and Humidity 202 Concentration hsorption in bed for hsorption in bed for - of CO2 utlet of the bed.	8 th July 2022-28-hours te Specification 80:05Kg 899Kg./Cu.m 2880min 600mm diac/20mm hr. 600mm diac/20mm hr. 10mm WC 263-264cfm Avg.23.52°C, 73.75% 790.68ppm 360.73PPM 429.95PPM	St The material powder when	Observation is not hard, but become a compressed.
Sr. No. 1 2 3 4 5 6 7 8	Test Pa Non-Regenerative Material Density Total time of oper Test Bod size Static Pressure dro Average Insta iff - Time Avg. input at inlet of the bod. Time Avg. cotput Time Avg. cotput Time Avg. cotput Concernations at Dynamic Wet Effi	16 th and 1 rameter · Test bed weight ation p for Air flow (bed emp and Humidity yo2 Concentration baorption in bed for a. of CO2 wiltet of the bed. kickensy of CO2 oistare during	8 th July 2022-28-hours te Specification 80:05Kg 899Kg./Cu.m 2880min 600mm dia:20mm hr. 600mm dia:20mm hr. 600mm dia:20mm hr. 600mm dia:20mm hr. 263-264cfm Avg.23.52°C, 73.75% 790.68ppm 360.73PPM	Samples beck	Observation is not hard, but become
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The test results for testing of materials for Bunkerman Absorbent Type 2, are given below.

SP	EA	uresh Bhawan, P.O-Ul egd.no-CINU70109AS2	ENTRADE IN ubari, G.S.Road, Guwahati, 016PTC017539, GSTIN: 18A MSME UAM NO: AS031 CERTIFICATE OF A	District- Kamru AXCS6312F1Z 00003825	up, Assam, Pin-78100 Z,		
ENTR	ADE		Finish Goo	d			
Product Na TYPE - 1		RMAN ABSORBENT	A. R. No. SPE	A/BU1/QC/FG	/001/INT/22-23		
		23 as per client	Date of	fintimation: 18.	06.2022		
Batch size	: 30 kg			Dute of Receiving: 18.06.2022			
sample qu	antity: 500 gm			of Analysis: 18.0			
				f Release: 20.0	06.2022		
		G	eneral Characteristics	-			
	ppearance	White Gran	ular having Irregular spheric	al shape	Complies		
	Solubility		Partially soluble in water		Complies		
		Statis Chaminal A	the second second	-			
Sr. No.	_	Test Parameter	nalysis at R&D Laboratory				
SF. 140.			Specification	on .	Observation		
2		C (1% solution in wate rption (% e by weight)	r) 11 - 13 Not less than 30		12.30		
temark:-S	ample complie	s /Does not comply with					
		nic and Thermo-dynam	nic Analysis at R&D Labo	ratory-Baddi-	HP-tested on		
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	Acro-Dynam	nic and Thermo-dynam	nic Analysis at R&D Labo 28 th June'2022-28-hours ter Specification	<u>st</u> .	Observation		
Sr. No. 1	Aero-Dynam To Non-Regene	nic and Thermo-dynamic 27 th and 2 est Parameter rative Test bed weight	nic Analysis at R&D Labo 28 th June'2022-28-hours te Specification 30Kg	<u>st</u> .	observation is not hard, but become		
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Sr. No. 1 2 3 4	Acro-Dynam To Non-Regene Material Der Total time of Test Bed size	tic and Thermo-dynamic 27 th and 2 est Parameter rative Test bed weight naity f operation e	nic Analysis at R&D Labor 28 th June'2022-28-hours te Specification 30Kg 790Kg.Cu.m 1675min 492mm diax200mm ht.	The material is	observation is not hard, but become		
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Sr. No. 1 2 3 4 5	Aero-Dynam To Non-Regene Material Der Total time of Test Bed siza Static Pressu Air-flow at in	tic and Thermo-dynam 27 th and ; est Parameter rative Test bod weight nsity f operation c red for Air flow net of bod	nic Analysis at R&D Labor 28 th June'2022-28-hours ter Specification 30Kg 790Kg Cum 1675min 492mm diac200mm ht. 28mm WC 5805-583cfm	The material is	observation is not hard, but become		
Sr. No. 1 2 3 4 5 6	Aero-Dynam Non-Regene Material Der Total time of Test Bed sizt Static Pressu Air-flow at it Average Inle	tic and Thermo-dynamics 27 ²⁰ and 2 set Parameter rative Test bod weight mainy reperation re drop for Air flow net of bod st air temp and Hamidity put CO2 Concentration	nic Analysis at R&D Labor 25 th June' 2022-28-hours fe Specification 30Kg 790Kg Cum 1675min 492mm diac200mm ht. 28mm WC	The material is	observation is not hard, but become		
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Mr. R. Debnath

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The test results for testing of materials for Bunkerman Adsorbent Type 2, are given below.

SPI	Suresh Bhawan, P.O-Ulu Regd.no-CINU70109AS2	bari, G.S.Road, Guwahati, D16PTC017539, GSTIN :18A MSME UAM NO: AS030 CERTIFICATE OF	District- Kamrup AXCS6312F1ZZ, D0003825	p, Assam, Pin-781007,	
ENTR	ADE	Finish Goo	bd	*	
Product Na TYPE – 2	me: BUNKERMAN ADSORBENT	A. R. No. SPEA/BU2/Q	C/FG/001/INT/22	-23	
Batch No .:	BU2/001/22-23	Date of intimation: 24.07	7.2022		
Batch size:		Date of Receiving: 24.07	.2022		
Sample qu	antity: 500 gm	Date of Analysis: 24.0'	7.2022		
		Date of Release: 30.07.2022			
	Ge	neral Characteristics			
A	ppearance Nearly (niform Granular-light brownish		Complies	
	Solubility	Partially			
	Static Chemical Ar	alvsis at R&D Laborator	v-Baddi-HP		
Sr. No.	Test Parameter	Specification		Observation	
1	Ph @ 25°C (1 % solution in water				
2	CO2 Absorption (Percentage by weight)	Not less than 15.00 %		17 %	
Remark:-S	CO2 concentration is 99.99% from CO ample complies /Does not comply with Aero-Dynamic and Thermo-dynam 25 th and 2	n-house Specification	oratory-Baddi-I	HP-tested on	
Sr. No.	Test Parameter	Specification	0	bservation	
1	Non-Regenerative Test bed weight	60.02Kg	The material is spherical, apparently uniform in size.		
2	Material Density	736Kg.Cu.m			
3	Total time of operation	215min			
4	Test Bed size	492mm diax445mm ht.			
5	Static Pressure drop for Air flow	68mm WC			
6	Air-flow at inlet of bed	570-614cfm			
7	Average Inlet air temp and Humidity	21-23°C, 57.7-75.49%			
8	Time Avg. input CO2 Concentration at inlet of the bed.	818ppm			
	an inter of the own				

8 Time Avg. CO2 adsorption in bed for 191.92PPM 3.58hrs duration. Time Avg. output CO2 626.08ppm Concentration at outlet of the bed. 9 Dynamic Wet Efficiency of CO2 25.7% adsorption with moisture during Material is highly hygroscopic above time period (brought moisture level to 2.22%RH 10 Dynamic dry CO2 Efficiency of CO2 1.88% and very high Exothermic. Maximum adsorption without moisture during temperature at out let air is observed above time period to be 73.2°C. 10 Max Heat Rejection during test 7.75-8.14KW

Mr. S.Debnath I.N.D.bec repare by:

Ms. T. Nath Thath Checked by

SPEA/BU/QC/001-F01-00



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The test results of the complete CO2 Removal System (Non Regenerative Type) tested on 15 Sep 22 under Real Button Up Mode, are given below.

BUNKERMAN ⁸	BUNKERMAN Plot No.20, HIMUDA, Bhatolikalan, Baddi Industrial Area, Solan, Himachal Pradesh-17320 RECORD/CERTIFICATE OF TESTING CO3 REMOVAL SYSTEM NON-REGENERATIVE TYPE						
	Testing: 15th Sep	2022		Absorbents used in each Cartridge			
				Bunkerman Absor	bent Type-1: - 9 Kg		
		Up Mode: - 10 P	ersons		ebent Type-2: - 3 Kg		
No. of	CO ₂ Cartridges u	sed: - 6 Nos.					
Total C	bty, of Absorbent	:: - 13x6 ≈ 78 Kg		Bunkerman Abso	orbent Type-3: - 1Kg		
Total	20,000				Total: - 13 Kg	Each	
Timet	o Start Button U	p Mode: -					
			TVOC	01	Pressure	Remarks	
Time	AHU	CO ₂ (ppm)	(ppb)	(%)	(pascal)		
	ON/OFF	(ppm) (420	3	20.15	35146.28		
:38	OFF	570	28	20.10	95149. 43		
140	OFF	705	45	2011	95141.10		
150	ON	800.	\$3	40.04	95158.19 981 44.96		
1085.	00	-749	37	20.18	98144.37	-	
80:08	ON	625	20	20.08	35947.52		
0:12	OFF	600	30	20.01	95143.64		
0:15	OFF	S80	29	20.04	98143.71		
0:18	OFF	2.62	1111	and the second division of the second divisio	20110		
0. 10.			Sandiza	621			
		0.00	680	20.10	95137.49		
0:25	OFF	665	521	19:99	95142.91		
0:35	ON	795	35.2	20.02	95132132		
10:36	ON		200	19.95	951 29-13		
10:45	ON	665	181	20.03	95128 . 08	-	
10:47	ON	600	174	20.01	35132.74		
10:48	OFF	- BVD					
					-		
				_			
						17	
				0		-H	
Bunker	rman 22 scoubt	2	- m	Pvt. Ltd.	e lowe car 2-lests twi 2 co2 leve 5 x the cyst	Lat aido	
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The test results of the complete CO2 Removal System (Non Regenerative Type) tested on 05 Nov 22 under Real Button Up Mode, are below

No. of P No. of C	Testing: 5 th Nove ersons in Button			BUNKERMAN Plot No.20, HIMUDA, Bhatolikalan, Baddi Industrial Area, Solan, Himachal Pradesh-173205 RECORD/CERTIFICATE OF TESTING CO; REMOVAL SYSTEM NON-REGENERATIVE TYPE					
No. of P No. of C		mber. 2022							
No. of C				Absorbents	used in each Cartrie	dge			
			ersons	Bunkerman Absor	rbent Type-1: - 9 Kg				
Total Q	O2 Cartridges us	sed: - 6 Nos.			rbent Type-2: - 3 Kg				
	ty. of Absorbent	- 13×6 - 70 1/-							
		- 15x0 - 78 Kg		Bunkerman Abso	orbent Type-3: - <u>1 Kg</u>				
Time to	Start Button Up	Mode: -			Total: - 13 Kg				
Time	AHU ON/OFF	CO ₂ (ppm)	TVOC (ppb)	O2 (%)	Pressure (pascal)	Remarks			
2:05	OFF	980	47	19.94	96077.88				
2:10	OFF	495	46	28,61	96042.49				
2:15	OFF	530 S70	47	19.84 BF. PL	96063.39				
2:25	OFF	SRS	65	25.61	96069-17				
2:30	OFF	635	57	19.78	96066·97				
2:35	CEF	670		19.00	960S7-91				
2:35	CFF	60,5	- 53	19.74	36069.70				
	OFF	21F	52	19.71	96067.95				
2:50	OFF	745		19.72	9606696				
2:55	OEF	775	<u> </u>	19.72	36063.53				
2:58	ON	805	60	19.79	96062.57				
3:00	001	785	5241	19.73	F2.22028				
3:05	OFF	600	3433	19.70	96064.77				
		-							
Bunkern	da-	SPEA En	trode Pvt. L	M.	Dr. A. R. Moha Profes Dept. of Mechan Indian Institute of Kharagpur-72130 mail : amohanty@r	anty, FNAE isor ical Engineer of Technology 02, INDIA			

III. DISCUSSION

The tests on materials developed for absorption/adsorption of CO2 and TVOC were performed under ambient conditions of temperature and pressure. The Bunkerman absorbents showed CO2 absorbent capacity of about 35% to 42% by weight. The adsorbent capacity of the Bunkerman Adsorbents and molecular sieves were observed to be between 15 to 18%. It was revealed from the test results that an absorbent capacity of 30% and adsorbent capacity of 12% can be safely adopted for design purposes for filters for CO2 removal in the systems.

The adsorbents and molecular sieves could also adsorb/absorb a reasonable amount of TVOC in addition to their CO2 adsorption capacity. The tests on filters made with combinations of absorbents, adsorbents and molecular sieves (arrived after several trials), revealed even better results for CO2 and TVOC removal from the indoor and outdoor air.

The tests on the system conducted during Buttoned Up Mode revealed that the system is able to efficiently remove the CO2 and TVOC from the indoor air and ensured to always maintain the air quality inside the facility as per laid down standards [2,3,4].



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IV. CONCLUSIONS

The Bunkerman absorbents showed CO2 absorbent capacity of about 35% to 42% by weight. The adsorbent capacity of the Bunkerman Adsorbents and molecular sieves were observed to be between 15 to 18. An absorbent capacity of 30% and adsorbent capacity of 12% can be safely adopted for CO2 removal filters in the systems. The proposed Bunkerman Indoor Air Quality Management System was effectively able to ensure the recommended levels of CO2 and TVOC [2,3] in the facility tested during Real Button Up Mode.

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