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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.*

I. 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).
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.

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:-

- CO_2 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 CO_2, 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. CO_2 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:

1) *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 CO_2 as the standard for specific indoor environments, including school and office buildings.

Two types of CO_2 Removal Systems, one Non-Regenerative Type and the other Regenerative Type were developed in the present invention. In the first phase, the Bunkerman Brand CO_2 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 CO_2 and TVOC removal from the air were developed and optimised. In the third phase, the complete CO_2 Removal System was developed by integrating the CO_2 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) CO_2 Absorbents which absorb CO_2 from the air by way of their chemical reaction.
b) CO_2 adsorbents which adsorb CO_2 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 CO_2 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 17% and 21% 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%.

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

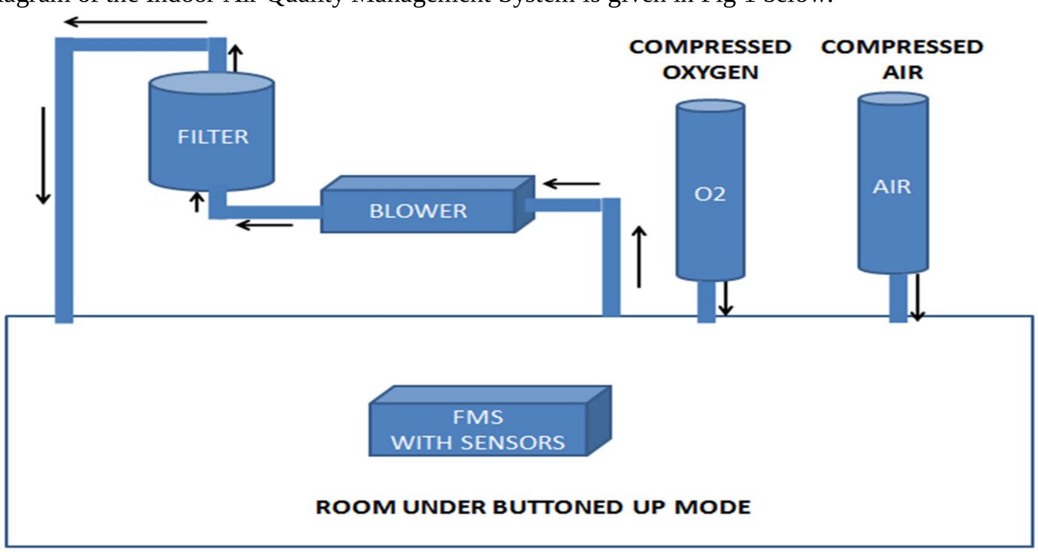
In addition to the above two systems, the third system i.e. Compressed Air System is also integrated so as to always maintain a desired positive pressure in the facility. This is done so that no contaminated air from outside leaks into the facility and the desired level of Indoor Air Quality is always 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 CO_2.
2) Tests on Bunkerman brand Filters (CO_2 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.

SPEA ENTRADE

SPEA ENTRADE INDIA PVT LTD

Suresh Bhawan, P.O-Ulubari, G.S.Road, Guwahati, District- Kamrup, Assam, Pin-781007,
Regd.no-CINU70109AS2016PTC017539, GSTIN :18AAXCS6312F1ZZ,
MSME UAM NO: AS03D0003825

CERTIFICATE OF ANALYSIS

Finish Good

Product Name: BUNKERMAN ABSORBENT TYPE – 1	A. R. No. SPEA/BU1/QC/FG/005/INT/22-23
Batch No.: BU1/005/22-23 as per client	Date of intimation: 16.07.2022
Batch size: 80 kg	Date of Receiving: 16.07.2022
Sample quantity: 500 gm	Date of Analysis: 16.07.2022
	Date of Release: 21.07.2022

General Characteristics

Appearance	White Granular-having Irregular spherical shape	Complies
Solubility	Partially soluble in water	Complies

Static Chemical Analysis at R&D Laboratory-Baddi-HP

Sr. No.	Test Parameter	Specification	Observation
1	Ph @ 25°C (1 % solution in water)	11 - 13	12.42
2	CO_2 Absorption (Percentage by weight)	NLT 30.00 %	33.98 %

Note: Input CO2 concentration is 99.99% from CO2 Cylinder.
Remark:-Sample complies /~~Does not comply~~ with In-house Specification.

Aero-Dynamic and Thermo-dynamic Analysis at R&D Laboratory-Baddi-HP-tested on 16th and 18th July'2022-28-hours test

Sr. No.	Test Parameter	Specification	Observation
1	Non-Regenerative Test bed weight	80.95Kg	The material is not hard, but become powder when compressed.
2	Material Density	899Kg./Cu.m	
3	Total time of operation	2890min	
4	Test Bed size	600mm diax320mm ht.	
5	Static Pressure drop for Air flow	19mm WC	
6	Air-flow at inlet of bed	263-264cfm	
7	Average Inlet air temp and Humidity	Avg.23.52°C, 73.75%	
8	Time Avg. input CO2 Concentration at inlet of the bed.	790.68ppm	
10	Time Avg. CO2 absorption in bed for 48.16hrs. Duration.	360.73PPM	
	Time Avg. output of CO2 Concentration at outlet of the bed.	429.95PPM	
11	Dynamic Wet Efficiency of CO2 absorption with moisture during above time period	17.23%	Samples become very hard and brittle. When hammered, it is broken into pieces
12	Maximum Heat Rejection during test	1.80KW	

Mr. S.Debnath Prepare by:	Ms. T.Nath Checked by	APPROVED BY Mr.R.Debnath SPEA ENTRADE (I) PVT. LTD. Approved By:

SPEA/BU/QC/001-F01-00

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

SPEA ENTRADE

SPEA ENTRADE INDIA PVT LTD

Suresh Bhawan, P.O-Ulubari, G.S.Road, Guwahati, District- Kamrup, Assam, Pin-781007,
Regd.no-CINU70109AS2016PTC017539, GSTIN :18AAXCS6312F1ZZ,
MSME UAM NO: AS03D0003825

CERTIFICATE OF ANALYSIS

Finish Good

Product Name: BUNKERMAN ABSORBENT TYPE – 1	A. R. No. SPEA/BU1/QC/FG/001/INT/22-23
Batch No.: BU1/001/22-23 as per client	Date of intimation: 18.06.2022
Batch size: 30 kg	Date of Receiving: 18.06.2022
Sample quantity: 500 gm	Date of Analysis: 18.06.2022
	Date of Release: 20.06.2022

General Characteristics

Appearance	White Granular having Irregular spherical shape	Complies
Solubility	Partially soluble in water	Complies

Static Chemical Analysis at R&D Laboratory-Baddi-HP

Sr. No.	Test Parameter	Specification	Observation
1	Ph @ 25°C (1 % solution in water)	11 - 13	12.30
2	CO_2 Absorption (% e by weight)	Not less than 30.00 %	36.25 %

Note: Input CO2 concentration is 99.99% from CO2 Cylinder.
Remark:-Sample complies /~~Does not comply~~ with In-house Specification.

Aero-Dynamic and Thermo-dynamic Analysis at R&D Laboratory-Baddi-HP-tested on 27th and 28th June'2022-28-hours test

Sr. No.	Test Parameter	Specification	Observation
1	Non-Regenerative Test bed weight	30Kg	The material is not hard, but become powder when compressed.
2	Material Density	790Kg.Cu.m	
3	Total time of operation	1675min	
4	Test Bed size	492mm diax200mm ht.	
5	Static Pressure drop for Air flow	28mm WC	
6	Air-flow at inlet of bed	580-583cfm	
7	Average Inlet air temp and Humidity	Avg.26.48°C, 52.8-58.37%	
8	Time Avg. input CO2 Concentration at inlet of the bed.	755ppm	
9	Time Avg. CO2 absorption in I Bed in 27.91hrs duration	106.37PPM	
9	Time Avg. output CO2 Concentration at outlet of the bed.	648.63PPM	
10	Dynamic Wet Efficiency of CO2 absorption with moisture during above time period	17.45%	Samples become very hard and brittle. When hammered, it breaks into pieces
11	Max. Heat Rejection during test	0.81KW	

Mr. S.Debnath Prepare by:	Ms. T.Nath Checked by	APPROVED BY Mr.R/ Debnath SPEA ENTRADE (I) PVT. LTD. Approved By:

SPEA/BU/QC/001-F01-00

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

SPEA ENTRADE

SPEA ENTRADE INDIA PVT LTD

Suresh Bhawan, P.O-Ulubari, G.S.Road, Guwahati, District- Kamrup, Assam, Pin-781007,
Regd.no-CINU70109AS2016PTC017539, GSTIN :18AAXCS6312F1ZZ,
MSME UAM NO: AS03D0003825

CERTIFICATE OF ANALYSIS

Finish Good

Product Name: BUNKERMAN ADSORBENT TYPE – 2	A. R. No. SPEA/BU2/QC/FG/001/INT/22-23
Batch No.: BU2/001/22-23	Date of intimation: 24.07.2022
Batch size: 60 kg	Date of Receiving: 24.07.2022
Sample quantity: 500 gm	Date of Analysis: 24.07.2022
	Date of Release: 30.07.2022

General Characteristics

Appearance	Nearly uniform Granular-light brownish	Complies
Solubility	Partially	

Static Chemical Analysis at R&D Laboratory-Baddi-HP

Sr. No.	Test Parameter	Specification	Observation
1	Ph @ 25°C (1 % solution in water)	--	--
2	CO_2 Absorption (Percentage by weight)	Not less than 15.00 %	17 %

Note: Input CO2 concentration is 99.99% from CO2 Cylinder.
Remark:-Sample complies /~~Does not comply~~ with In-house Specification. .

Aero-Dynamic and Thermo-dynamic Analysis at R&D Laboratory-Baddi-HP-tested on 25th and 26th July'2022-3-4-hours test

Sr. No.	Test Parameter	Specification	Observation
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	
8	Time Avg. CO2 adsorption in bed for 3.58hrs duration.	191.92PPM	
	Time Avg. output CO2 Concentration at outlet of the bed.	626.08ppm	
9	Dynamic Wet Efficiency of CO2 adsorption with moisture during above time period	25.7%	Material is highly hygroscopic (brought moisture level to 2.22%RH and very high Exothermic. Maximum temperature at out let air is observed to be 73.2°C.
10	Dynamic dry CO2 Efficiency of CO2 adsorption without moisture during above time period	1.88%	
10	Max Heat Rejection during test	7.75-8.14KW	

Mr. S.Debnath	Ms. T. Nath	APPROVED BY Mr. R. Debnath
Prepare by:	Checked by	Approved By:

SPEA/BU/QC/001-F01-00

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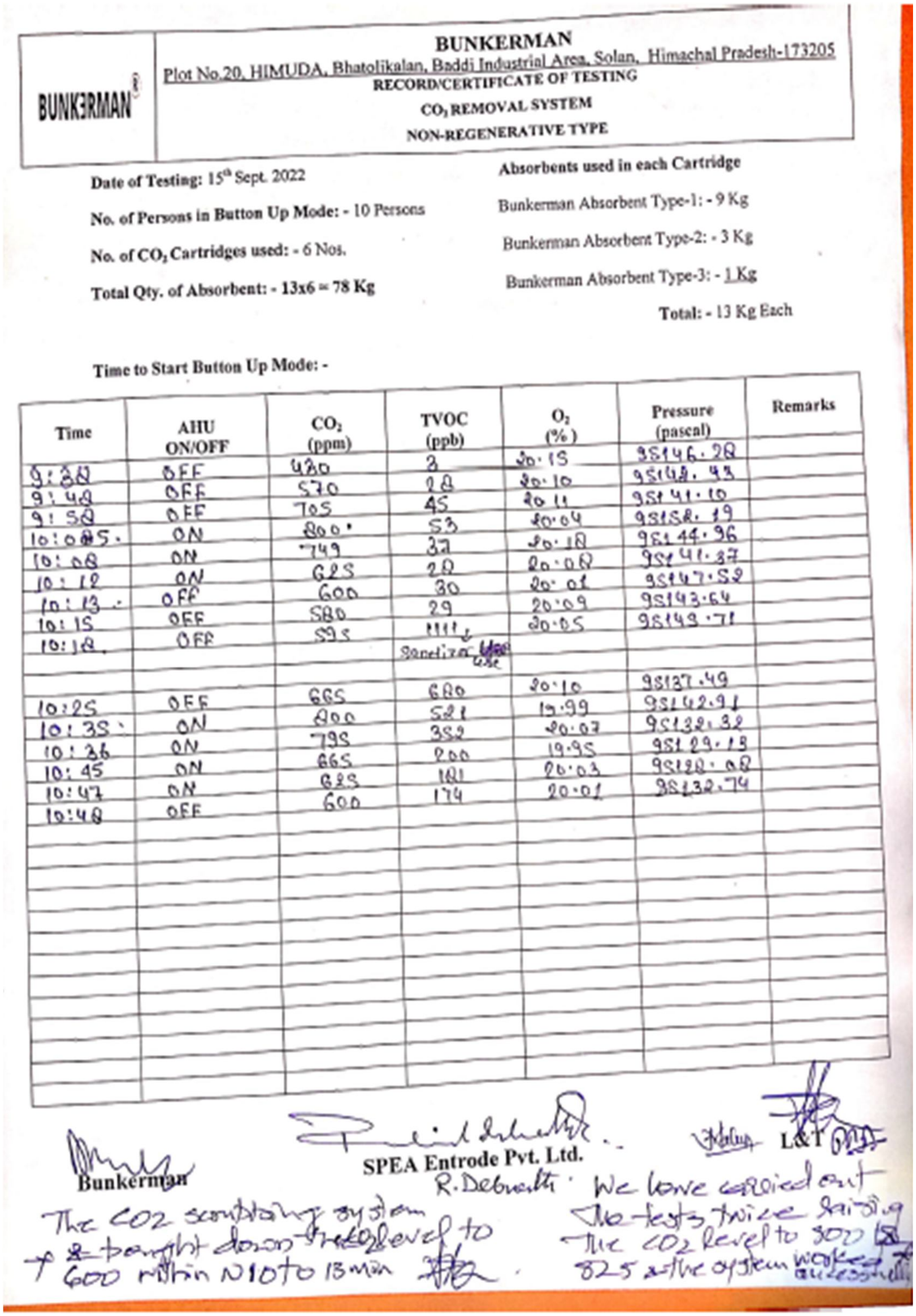
The test results of the complete CO2 Removal System (Non Regenerative Type) tested on 15 Sep 22 under Real Button Up Mode, are given below.



BUNKERMAN

Plot No.20, HIMUDA, Bhatolikalan, Baddi Industrial Area, Solan, Himachal Pradesh-173205

RECORD/CERTIFICATE OF TESTING

CO_2 REMOVAL SYSTEM

NON-REGENERATIVE TYPE

Date of Testing: 15th Sept. 2022

No. of Persons in Button Up Mode: - 10 Persons

No. of CO_2 Cartridges used: - 6 Nos.

Total Qty. of Absorbent: - 13x6 = 78 Kg

Absorbents used in each Cartridge

Bunkerman Absorbent Type-1: - 9 Kg

Bunkerman Absorbent Type-2: - 3 Kg

Bunkerman Absorbent Type-3: - 1 Kg

Total: - 13 Kg Each

Time to Start Button Up Mode: -

Time	AHU ON/OFF	CO_2 (ppm)	TVOC (ppb)	O_2 (%)	Pressure (pascal)	Remarks
9:38	OFF	430	3	20.15	95146.28	
9:48	OFF	570	28	20.10	95148.43	
9:58	OFF	705	45	20.11	95141.10	
10:05	ON	800	53	20.04	95158.19	
10:08	ON	749	37	20.18	95144.96	
10:12	ON	625	28	20.08	95141.37	
10:13	OFF	600	30	20.01	95147.52	
10:15	OFF	580	29	20.09	95143.64	
10:18	OFF	595	111 & Sanitizer use	20.05	95149.71	
10:25	OFF	665	680	20.10	95137.49	
10:35	ON	800	521	19.99	95142.91	
10:36	ON	795	352	20.07	95132.32	
10:45	ON	665	200	19.95	95129.13	
10:47	ON	625	181	20.03	95128.08	
10:48	OFF	600	174	20.01	95132.74	

Bunkerman

SPEA Entrode Pvt. Ltd.

R. Debnath

L&T

The CO2 scrubbing system brought down the CO2 level to 600 within 10 to 15 min

We have carried out the tests twice raising the CO2 level to 800 & 825 & the system worked successfully

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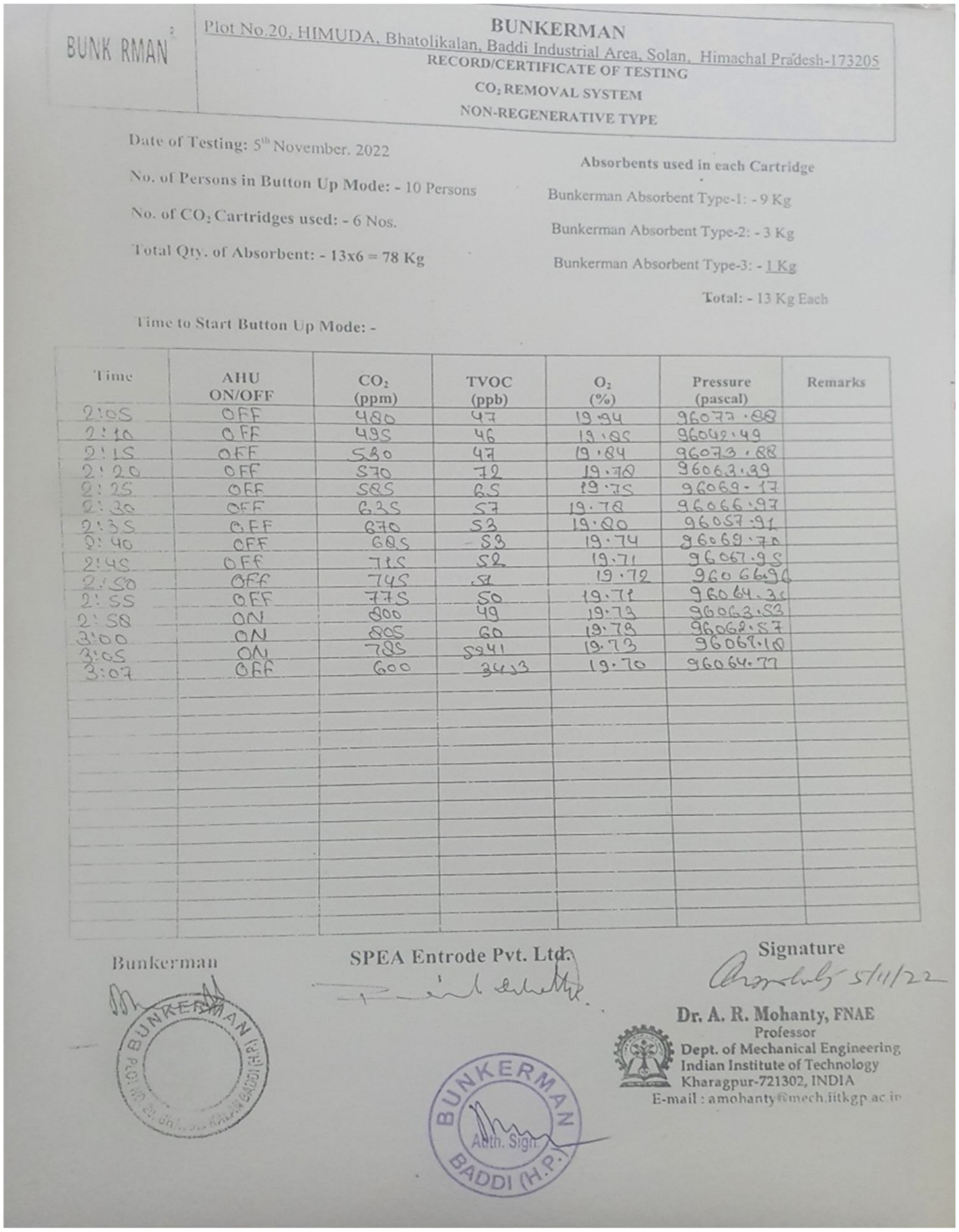
The test results of the complete CO2 Removal System (Non Regenerative Type) tested on 05 Nov 22 under Real Button Up Mode, are below



BUNKERMAN
Plot No.20, HIMUDA, Bhatolikalan, Baddi Industrial Area, Solan, Himachal Pradesh-173205
RECORD/CERTIFICATE OF TESTING
CO_2 REMOVAL SYSTEM
NON-REGENERATIVE TYPE

Date of Testing: 5th November, 2022

No. of Persons in Button Up Mode: - 10 Persons

No. of CO_2 Cartridges used: - 6 Nos.

Total Qty. of Absorbent: - 13x6 = 78 Kg

Absorbents used in each Cartridge
Bunkerman Absorbent Type-1: - 9 Kg
Bunkerman Absorbent Type-2: - 3 Kg
Bunkerman Absorbent Type-3: - 1 Kg
Total: - 13 Kg Each

Time to Start Button Up Mode: -

Time	AHU ON/OFF	CO_2 (ppm)	TVOC (ppb)	O_2 (%)	Pressure (pascal)	Remarks
2:05	OFF	480	47	19.94	96077.88	
2:10	OFF	495	46	19.85	96042.49	
2:15	OFF	530	47	19.84	96073.88	
2:20	OFF	570	72	19.78	96063.99	
2:25	OFF	585	65	19.75	96069.17	
2:30	OFF	635	57	19.78	96066.97	
2:35	OFF	670	53	19.80	96057.91	
2:40	OFF	685	53	19.74	96069.70	
2:45	OFF	715	52	19.71	96067.95	
2:50	OFF	745	51	19.72	96066.96	
2:55	OFF	775	50	19.71	96064.3	
2:58	ON	800	49	19.73	96063.53	
3:00	ON	805	60	19.79	96062.57	
3:05	ON	785	5941	19.73	96067.10	
3:07	OFF	600	3433	19.70	96064.77	

Bunkerman | SPEA Entrode Pvt. Ltd. | Signature 5/11/22

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BUNKERMAN BADDI (H.P.) Auth. Sign

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].

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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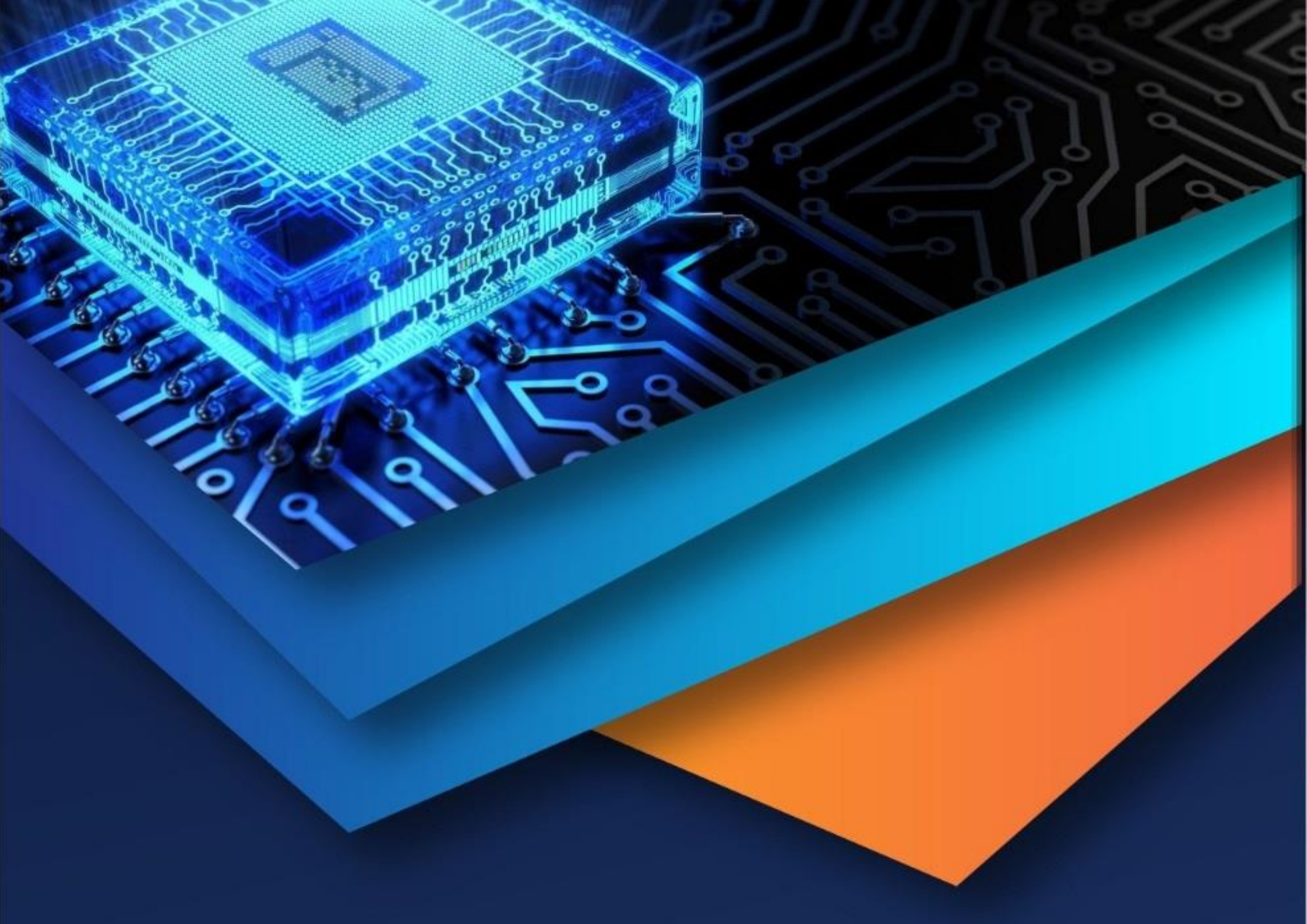

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