Properties and Applications

Sodasorb absorbent is a proprietary mixture of hydrated lime ($Ca(OH)_2$) and a small quantity of sodium hydroxide (NaOH), with carefully controlled moisture content and porosity to maximize absorptive capacity.

Properties

Sodasorb absorbent is specially processed into porous, uniform pellets in order to expose the maximum absorbent surface area. The hardness of Sodasorb's pellets gives it high resistance to powdering and breakage.

As a result of its carefully designed physical composition, Sodasorb is an ideal absorbent for removal of carbon dioxide and other acidic contaminants from gas streams of air. In addition to the wide-ranging anesthesia applications previously discussed in this manual, here are a few other uses.

Applications

Medical Equipment
    Anesthetic rebreathing systems, metabolators, and oxygen therapy.
Underwater Breathing Systems
    Rebreathing systems for commercial and recreational diving and hyperbaric chambers.
Submarines
    Carbon dioxide removal for naval, research, civilian, and tourist submarines.
Safety Equipment
    Personal closed circuit rebreathers for mine, fire, and other safety rebreathing systems.
Industrial Uses
    Absorbs acid gases, aids purification, and functions as an aldol condensation catalyst.

HP Sodasorb Absorbent characteristics: Underwater Diving Experiment

Dewey and Almy Chemical Division, W. R. Grace & Co.-Conn. ©1979

Overview

High Performance (HP) Sodasorb Absorbent was developed primarily to remove carbon dioxide (CO_2) from underwater breathing systems and habitats for the United States Navy. This study examines some of the criteria that affect the ability of HP Sodasorb to remove CO_2, such as increased air flow through an absorbent bed, absorbent moisture content, particle size, and absorbent canister size. Absorbent reaction chemistry is reviewed with respect to pH of the moisture in the stream exiting the absorbent bed. Test data were also generated to show the maximum temperature reached in an absorbent bed using pure CO_2 versus 4.0% CO_2 in nitrogen and the flow resistance due to CO_2 absorbent. The methods used for determining these factors are described along with the results.

W. R. Grace & Co.-Conn. continually seeks to improve the quality of its Sodasorb CO_2 Absorbent. While originally developed for use in gas masks, Sodasorb moved on to gain wide-spread acceptance in the medical community, being used in surgical procedures requiring inhalation anesthesia. New uses for Sodasorb are continuously explored.

Today, Sodasorb is used to absorb carbon dioxide not only in the traditional medical industries, but also in tourist submarines, scuba apparatus, commercial diving, hyperbaric chambers, and even to absorb certain acid-gases, acting as an aldol condensation catalyst.

The underwater diving industry represents a key area for which the company has developed a technically improved product, High Performance Sodasorb.[1] In response to a series of customer questions within the diving industry, and in order to “fine-tune” our High Performance Sodasorb, a series of studies were undertaken. Today, these tests continue to yield improved absorbent capacity and more effective packaging/delivery systems.

In terms of High Performance Sodasorb, these studies were designed to address the following issues:

- The effect of differing flow rates on HP Sodasorb efficiency and the back pressure generated by the absorbent.
- The effect of HP Sodasorb moisture content on efficiency at a constant flow rate.
- The effect of absorbent particle size on pressure drop and efficiency through a fixed bed configuration.
- The effect of canister size on efficiency.
- The maximum temperature reached in the absorbent bed during a reaction.
- The pH of water in the gas stream exiting the absorbent bed.

The set-up for determining time efficiency, air flow resistance, and reacted gas temperature utilized a modified Navy Mark VI canister. Holding approximately 600 grams of absorbent, a gas stream consisting of 4.0% CO_2 in nitrogen was routed through a humidifier device to moisturize the gas to 100% relative humidity. This gas stream was then passed through the absorbent canister which was submerged in a constant temperature water bath (20°C). A manometer measured the differential pressure across the canister (back pressure), and a telethermometer electrode inserted into the top of the canister monitored the gas temperature exiting the absorbent bed. Gas exiting the canister was analyzed by an infrared detector, which was calibrated before and after each test with pure nitrogen (baseline) and 0.5% CO_2 in nitrogen (end point). Absorption data was recorded on a strip chart device. For checking flow rate accuracy, a gas totalizer recorded the amount of gases passing through the system.

Efficiency Test Protocol

Analysis of the test results consisted of determining time (in hours) from the start of gas flow to the point where carbon dioxide concentration in the exit stream reached 0.5%. This span was recorded as the absorbent time efficiency rating. While this level of carbon dioxide indicates impending breakthrough, practical experience shows that a diver begins to experience sensory losses above 1% carbon dioxide concentration.[2]

All efficiency tests, unless otherwise specified, were run under the following conditions: bath temperature 20°C, inlet gas at 100% relative humidity, and flow rate of 10.41 liter per minute (22 cu.ft./hr.). This flow rate was chosen since it approximated the generation rate of CO_2 by an average adult male at a normal breathing rate.[3,4] All time efficiency results were normalized to a 1,000 gram dry sample size. Back pressure was measured by observing the difference, in inches of water, between canister inlet and outlet gas pressures.

Experiment Description

Employing this test apparatus at varying flow rates, analysis revealed that HP Sodasorb efficiency decreases when flow rate is increased. This may be explained by a reduction in contact time between the absorbent and gas. At 22 cubic feet per hour, the high performance product showed a minimum efficiency of five hours to CO_2 breakthrough and a lesser time efficiency at flow rates above this level. Conversely, absorber unit back-pressure increased with higher flow rates. Some of the change was also due to apparatus design and particle flow resistance.

Table 1. Time Efficiency/Back Pressure Results Under Various Flow Rates

Efficiency (hours)	Flow Rates Avg. (cu.ft./hr.)	Back Pressure (inches of water)
5.0	22.0	0.4
3.0	25.0	0.6
1.4	26.5	1.0

Several HP Sodasorb lots were moistened to obtain samples containing between 6%-19% water. We found that efficiency was relatively constant within this range. This correlated well to medical experience where the desired moisture level is 12%-19%. If the moisture content is too low, the reaction with carbon dioxide will not be initiated. Conversely, if the moisture content is too high, the absorption sites become saturated with water which hinders the reaction.

Although with our experimental design, efficiency was constant for absorbent moisture content between 6%-10%, certain applications may require a higher or lower moisture content. For example, our work with the U.S. Navy indicated that a moisture range of 18.5%-21.5% was required for optimal absorbent efficiency with their Mark XI system due to the flow rate and the design of the absorber unit.

Granule size of the absorbent has a marked effect on the rate of carbon dioxide absorption due to the surface area. Our data shows that increased efficiency is experienced when particle size is progressively reduced. An absorbent of finer mesh, as noted, exposes greater active surface area, resulting in more efficient absorption rates. Back pressure was found to be relatively constant for granules ranging from 6-16 mesh; less than 16 mesh, there was a significant pressure increase.

Table 2. Back Pressure per Particle Mesh Size

Particle Mesh Size	Back Pressure (inches of water)
6	.2
8	.3
10	.4
12	.4
16	.4

There have been numerous attempts to reduce flow resistance by perfecting absorbent canisters and breathing systems. A reduction of flow resistance through technical improvements of canister design could allow the use of absorbent granules finer than 16 mesh.

To further demonstrate how canister design affects efficiency, the absorbent canister was increased in length from 1 to 2 feet. Based on 1,000 grams of HP Sodasorb removing 4.0% CO_2 from a gas flow, efficiency times of 4.9 hours per 1,000 grams were obtained from the one foot canister and 7.5 hours per 1,000 grams from the 2 foot canister. Doubling length per diameter ratio increased the time efficiency by 53% per 1,000 grams of absorbent. This suggests that canister designs should maintain a length per diameter ratio as high as possible to obtain maximum efficiency.

In all tests, the temperature of the reacted gases leaving the absorbent canister was monitored. There were no appreciable temperature differences observed. With the absorbent canister submerged in a constant temperature water bath (20°C), and the gas stream humidified to 100% relative humidity, the highest exit gas temperature monitored was 37°C. This correlates well with previous work where temperature conditions within face masks have been measured.[5] It should be noted that in certain diving environments, an increase in heat from the breathing apparatus may have a debilitating effect on the diver's ability to function normally underwater. Therefore, temperature should be monitored.

The reaction of Sodasorb with CO_2 generates heat and causes the exit gas temperature to rise as described above. Obviously, the absorbent bed temperature also rises. In addition, the exit gas contains moisture which has passed over the caustic absorbent. We decided to measure the absorbent bed temperature and the pH of the water contained in the exit stream, the latter prompted by concern in the diving industry that exit moisture may contain caustic which could burn the user.

A temperature probe was placed in one side of the U-tube and a cotton wad inserted in the center of the tube at the bottom. The half of the U-tube containing the probe was then filled with absorbent. Pure CO_2 was passed through the U-tube, and reaction temperatures were monitored from the absorbent bed. Once the HP Sodasorb was exhausted, the cotton was removed and the water pressed from it for pH determination. The condensate from the empty side of the U-tube was also tested with calibrated pH paper. The pH of the water and the condensate from the empty side of the U-tube were neutral, indicating no caustic was being carried over. Although the exit stream gas was neutral, care must be taken to ensure that the absorbent itself does not come in direct contact with the user, as it will cause skin irritation.

The observed bed temperature was dependent upon where the temperature probe was placed. Temperature results averaged 95°C pure CO_2, with a maximum temperature of 101°C. Prior work had shown that, in the canister of a to-and-fro apparatus, the temperature of the absorbent bed ranged from 50° to 55°C when subjected to a gas stream that contained CO_2 levels similar to human respiratory production.

Summary

Sodasorb absorbent has been used for over sixty years as a carbon dioxide absorbent for inhalation anesthesia. The introduction of High Performance Sodasorb several years ago was the first major attempt at designing a product specifically for use outside the conventional medical area. Continued experiments with this absorbent, coupled with a better understanding of its end uses, have shown that significant improvements in performance are achievable. Future work in the areas of absorbent and system design should further improve absorption efficiency.

Various experiments have demonstrated that higher efficiency involves several factors: absorbent selection, mesh distribution, moisture content, canister design and configuration, gas flow, and velocity. For undersea application, absorption improvement involves several evaluations. And, based on operating conditions, a concept suitable for one system may not be applicable with another set of conditions.

While maximizing efficiency is, to some extent, a trial and error procedure, the results of our experiments suggest the following approaches towards maximizing absorbent efficiency:

- Utilization of smaller particle size absorbent.
- Reduction of air flow velocity through the canister.
- Maintenance of a high length to width ratio canister design.
- Proper moisture level selection for the absorbent. Moisture should be in the range of 12%-16%, if high velocity air flow is not a problem.

As a final note, we should also mention the effect of bed temperature on efficiency. While not included in this series of experiments, a previous study has shown that efficiency decreases as the temperature drops.[7] In those instances where the canister will be subjected to low or below freezing conditions, the unit should be insulated or protected with a heat exchanger device. While the significantly higher porosity of HP Sodasorb offsets the low temperature effect to some extent, efficiency at temperatures below freezing does suffer. Basically, what occurs is that the free moisture freezes and inhibits the reaction process.

References

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