

REVIEW PAPER ON OXYGEN CONCENTRATOR

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ABSTRACT: - Medical oxygen concentrators (MOCs) are used for supplying medical grade oxygen to prevent hypoxemia-related complications related to COVID-19, chronic obstructive pulmonary disease (COPD), chronic bronchitis and pneumonia. MOCs often use a technology called pressure swing adsorption (PSA), which relies on nitrogen-selective adsorbents for producing oxygen from ambient air. MOCs are often designed for fixed product specifications, thereby limiting their use in meeting varying product specifications caused by a change in patient's medical condition or activity. To address this limitation, we design and optimize flexible single-bed MOC systems that are capable of meeting varying product specification requirements. Specifically, we employ a simulation-based optimization framework for optimizing flexible PSA- and pressure vacuum swing adsorption (PVSA)-based MOC systems. Detailed optimization studies are performed to benchmark the performance limits of LiX, LiLSX and 5A zeolite adsorbents. The results indicate that LiLSX outperforms both LiX and 5A, and can produce 90% pure oxygen at 21.7 L/min. Moreover, the LiLSX-based flexible PVSA system can manufacture varying levels of oxygen purity and flow rate in the range 93–95.7% and 1–15 L/min, respectively. The flexible MOC technology paves way for transitioning to an envisioned cyber-physical system with real-time oxygen demand sensing and delivery for improved patient care.

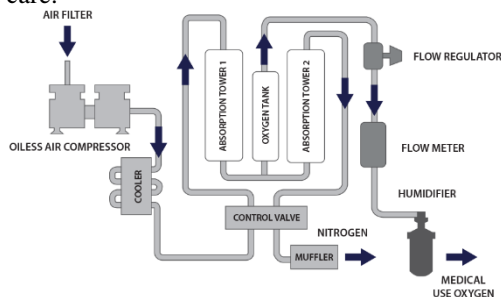


FIGURE 1. WORKING OF THE OXYGEN CONCENTRATOR

1. INTRODUCTION

An oxygen concentrator is a type of medical device used for delivering oxygen to individuals with breathing-related disorders. Individuals whose oxygen concentration in their blood is lower than normal often require an oxygen concentrator to replenish the oxygen.

These devices also come with an electronic user interface so you can adjust the levels of oxygen concentration and

delivery settings. You then inhale the oxygen through the nasal cannula or special mask.

Oxygen concentrators filter surrounding air, compressing it to the required density and then deliver purified medical grade oxygen into a pulse-dose delivery system or continuous stream system to the patient. It's also equipped with special filters and sieve beds which help remove Nitrogen from the air to ensure delivery of completely purified oxygen to the patient.

1.1 ON DEMAND OXYGEN GENERATION

Some of the most crucial metrics that are used for judging the performance of a PSA-based MOC are bed size factor (BSF) and oxygen recovery. BSF is computed by obtaining the amount of adsorbent required to produce 1 ton of oxygen per day (TPD), and is represented with the unit kg ads. O₂ TPD⁻¹. Therefore, minimizing the BSF leads to lower adsorbent inventory levels and smaller MOC units. On the other hand, oxygen recovery is computed by calculating the fraction of oxygen recovered in the product outlet relative to the amount of oxygen fed during a PSA cycle at a cyclic steady state. Consequently, for a given product specification, a higher oxygen recovery leads to lower compression costs and lower ambient air feed flow rates. As MOC is a small-scale device with limited adsorbent amount and rapid cycling, there is high energy consumption due to frequent pressure variation as compared to conventional PSA operation. However, for small-scale applications, the relative simplicity and reliability of MOC play a more significant role as compared to energy consumption. Overall, the key design goals while developing PSA-based MOC are increasing adsorbent productivity, enhancing oxygen recovery and developing compact and lightweight units.



FIGURE 2. (PORTABLE OXYGEN CONCENTRATOR)

2. LITERATURE REVIEW

The focus of this study was the ability of three contemporary POC devices to detect inhalation and deliver a corresponding pulse, a fundamental objective of pulsed oxygen delivery. Portable oxygen concentrators are necessarily limited in their oxygen production and battery reserve, hence efficient use of oxygen is paramount. Any portion of the pulse which does not reach the user's alveoli may represent waste. A POC's output setting may be increased to compensate for such wastage, but then the battery operating duration will suffer. So regardless of a device's oxygen production capacity or dosing scheme, the correct alignment of the pulse with inhalation can be critical. Inspiratory synchrony is the alignment of the pulse start and pulse finish relative to the user's inspiratory flow, Note that inspiratory synchrony is just one of numerous elements of pulse delivery that may affect efficacy. It is the area of the pulse waveform reaching the alveoli that determines the functional oxygen volume delivered per breath, dictated by factors, such as pulse amplitude, pulse duration and how the oxygen output is rationed as breath rate changes. These important issues are not the subjects of this triggering study, beyond noting that trigger timing can also have implications for these issues. Inspiratory synchrony -- pulse termination If we are to avoid wasting oxygen in the anatomic dead space the pulse must be fully delivered within the alveolar portion of the breath, irrespective of pulse volume. For a normal subject at rest, the anatomic dead space represents about one third of the tidal volume and the 'alveolar' duration represents about the first 60% of the inspiratory duration. If a subject's breathing becomes shallower than typical, multiple factors can affect pulsed oxygen efficacy: (a) triggering may be delayed due to the weaker inspiratory flow, (b) tidal volume is reduced but the anatomic dead space is not, hence the 'alveolar' duration is shorter, and (c) if the oxygen pulse flow exceeds inspiratory flow, oxygen may be wasted due to pooling. Issues (a) and (b) both contribute to late pulse termination and associated wastage, and both may be countered by triggering the pulse early within inspiration. Inspiratory synchrony -- pulse initiation (triggering) Delivering the pulse early within inspiration is facilitated by sensitive and responsive triggering. But care is needed to avoid introducing a problem: false triggering. False triggering not only wastes oxygen, but risks loss of synchrony on subsequent breaths. So the objectives for a trigger should consider both sensitivity and robustness, such as: – Compatible with a wide range of users, large and small, Maintain synchrony with the user across a wide range of behaviours, from sleep to rest to vigorous activity. – Minimal spurious triggering. – Be as early as possible within the above constraints. Inspiratory synchrony performance during exertion and rest Our bench testing of these three contemporary POCs during vigorous breathing and at rest revealed all devices showed excellent pulse alignment at all POC settings. Each breath is rewarded with a pulse, and the pulse terminates approximately within the first 60% of the start of the breath. The exertion scenario confirms these devices successfully track dynamically changing breath rates up to the highest rate simulated

(34/min), albeit with the proviso of 100% nasal breathing. There are limitations to the bench research presented here. The scope was limited only to the POC's ability to detect inspiration and trigger a pulse, with no consideration of other pulse parameters such as the pulse's amplitude, pulse volume, or how much of that volume was successfully delivered within the 'alveolar' duration. The tests were conducted in a controlled static laboratory environment free of drafts and ambient vibration. It employed a single bench 'nose' with stable cannula positioning. These simplifications allowed us to focus on repeatable and accurate comparison of device triggering, but lack the complexities of real patient breathing and ambient effects, and the results may not relate directly to efficacy of oxygenation.

3. CONCLUSION

Portable oxygen concentrators are expanding in popularity, and may have potential to act as a single oxygen therapy device (as opposed to a stationary system and an ambulatory system). Success as a single device will depend on the confidence that pulsed oxygen delivery is efficacious across the breadth of patient breathing behaviours. These behaviours may span from quiet breathing (during sleep and at rest) through to vigorous activity, and a variety of oronasal breath partitioning across these activities. A wide variety of nasal geometries also exist which can influence the ability to detect inspiratory flow, as can sub-optimal positioning of the cannula. Such factors can affect the efficiency of pulsed oxygen delivery in an individual user and across users, and suggest there may be clinical benefit in a sensitive yet robust trigger. In this study, all devices performed well with the simulated COPD patient at rest and at elevated breath rates. Performance diverged during oronasal breathing due to differences in trigger sensitivity. Sensitive triggering may offer practical advantage in various scenarios, given the diversity in factors such as patient size, nasal geometry, nocturnal breathing, and the partitioning of ventilation between nose and mouth across patient activity. Factors such as these may contribute to the variability in efficacy observed across pulse oxygen devices.

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