LOW-COST PORTABLE OXYGEN CONCENTRATOR USING PRESSURE SWING ADSORPTION TECHNIQUE

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Introduction:

An oxygen concentrator using Pressure Swing Adsorption (PSA) is a medical device designed to deliver high concentrations of oxygen to patients requiring supplemental oxygen therapy. The PSA technology leverages the ability of certain adsorbent materials, such as zeolite/sodium based, to preferentially absorb nitrogen from the air, allowing concentrated oxygen to be collected and delivered to the user.

The process begins with ambient air being drawn into the concentrator via a compressor. The air is then passed through a series of filters to remove dust and other impurities. Next, the filtered air enters the PSA chambers, typically two columns filled with zeolite/sodium material. In the first column, nitrogen is adsorbed onto the zeolite/sodium under high pressure, allowing oxygen to pass through. This oxygen-rich air is collected and directed to the patient.

While the first column is adsorbing nitrogen, the second column undergoes regeneration. During this phase, the pressure is reduced, causing the zeolite/sodium to release the adsorbed nitrogen, which is then expelled from the system. The columns alternate between adsorption and regeneration phases, ensuring a continuous supply of oxygen.

Objectives

I. To Design and develop portable oxygen concentrator using pressure swing adsorption technique.
II. This product will be based on compact footprint design for emergency use at primary healthcare center in villages.
III. Enhance Oxygen Supply: Provide a continuous and reliable supply of oxygen for medical and industrial use by concentrating oxygen from ambient air.
IV. Cost-Effective Operation: Offer a more economical alternative to compressed oxygen cylinders, reducing recurring expenses.

V. Portability: Ensure the system is portable and user-friendly, facilitating home and field use.

VI. Energy Efficiency: Optimize energy consumption to ensure the device is efficient and cost-effective to operate.

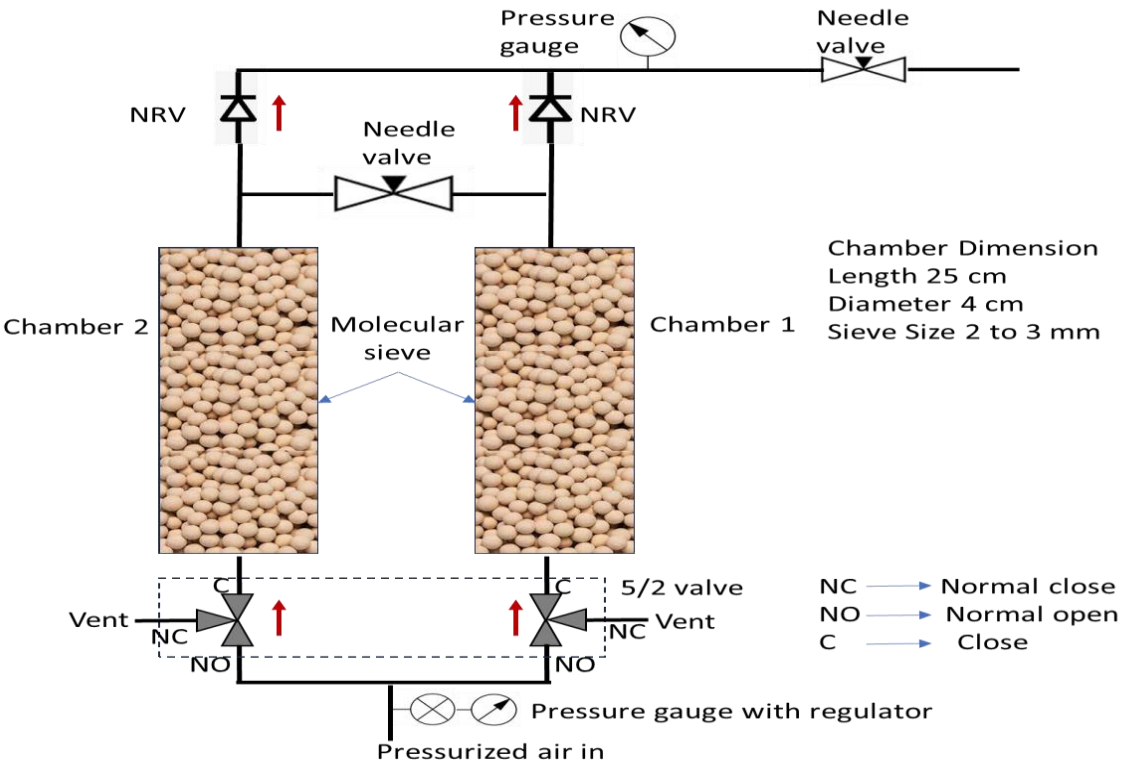
VII. Longevity: Design for durability and minimal maintenance, ensuring a long operational lifespan.

VIII. Ease of Use: Simplify operation with intuitive controls and minimal required training for users.

IX. Environmental Impact: Minimize environmental footprint by reducing reliance on delivery and storage of traditional oxygen tanks.

Methodology

- Nitrogen in atmospheric air is adsorbed at high pressure in a special grade molecular sieve and desorbed at atmospheric pressure. This process is done alternatively using two sets of adsorption / desorption chambers.
- PSA works in two cycles. In cycle 1, nitrogen is adsorbed in chamber 1 at high pressure (~3 bar). The concentrated oxygen is released from chamber 1, which is split into 2 parts. While one part goes to the concentrator outlet, the other part is used to regenerate the molecular sieves in chamber 2. The nitrogen gets desorbed (adsorbed nitrogen from previous cycle) from the molecular sieve in chamber 2 at low pressures and is ready for the next cycle.
- The whole cycle is automated using a timer, flow splitter and flow control valves.



Representation of oxygen concentrator

MATERIALS USED

- **5/2 Valve:** is a directional control valve with five ports and two positions, commonly used to control the flow of air or hydraulic fluid in pneumatic or hydraulic systems.
- **Non return valve:** A non-return valve allows fluid to flow in one direction only, preventing backflow.
- **Push fit connector:** A push fit connector is a type of plumbing fitting that allows quick and secure joining of pipes without the need for soldering or special tools.
- **Timer:** A timer is a device that counts down or up to measure and signal the 5/2 valve to open and close at a specific amount of time.
- **PSA Chamber:** A PSA chamber is a vessel where ambient air undergoes pressure swing adsorption to separate nitrogen, thereby concentrating oxygen for various applications.
- **Pressure Regulator with Gauge**: A pressure regulator is a device that maintains and controls the output pressure of gases or liquids to a desired constant level despite variations in input pressure.
- **Needle Valve:** A needle valve is a type of valve with a small port and a threaded, needle-shaped plunger, designed to precisely control the flow of fluid.
- **Piping:** It is a tube made of poly urethane used to move pressurized air around the system.

METHOD ADOPTED

Pressure Swing Adsorption (PSA) technology is a gas separation process used primarily to produce high-purity gases. It operates by adsorbing certain gases onto a solid adsorbent material under high pressure and then releasing them under lower pressure. By cycling between these pressure levels, PSA systems can selectively separate gases from a mixture. This technology finds extensive use in various industries, including the production of oxygen, nitrogen, and hydrogen. PSA offers advantages like low energy consumption, compact size, and ease of operation, making it a preferred choice for gas separation applications.

Results

This project aims to design and develop a portable oxygen concentrator using pressure swing adsorption technique.

1. This can be used in rural primary health care centers for emergency use.

2. Similar design can be used for zero air generation in industries.

3. Pressure swing adsorption (PSA), offers a cost-effective and efficient solution for oxygen generation.

4. Flow Rate: The device demonstrated the capability to deliver a stable flow rate of oxygen within the therapeutic range required for various medical applications, from low to high flow requirements.

5. Durability and Reliability: Long-term stability tests indicated that the PSA oxygen concentrator exhibited robustness and reliability, with minimal maintenance requirements, ensuring continuous operation over extended periods.

6. Portability and Accessibility: The compact design of the oxygen concentrator, coupled with its ease of operation, enhances accessibility to oxygen therapy, particularly in resource-limited settings and during emergencies.

7. Cost-effectiveness: Cost analyses demonstrated that the PSA oxygen concentrator offers significant cost savings over conventional oxygen supply systems, making it an attractive option for healthcare facilities and individual users.

INNOVATION IN THE PROJECT

The fabricated oxygen concentrator is a portable, cost-effective device working on Pressure swing adsorption technique, which can be used as an emergency device in primary health care centres in rural areas.

Conclusion

In conclusion, the utilization of pressure swing adsorption technology in oxygen concentrators presents a promising solution for oxygen generation with high purity, reliability, and cost-effectiveness. The results of this study underscore the potential of PSA oxygen concentrators to address the growing demand for oxygen therapy, particularly in healthcare settings, homecare environments, and emergency situations. Further advancements in design and optimization could enhance the performance and accessibility of PSA oxygen concentrators, contributing to improved healthcare outcomes globally.

Scope Of the Project

Oxygen concentrators utilizing pressure swing adsorption (PSA) technology are pivotal in providing medical-grade oxygen in various healthcare settings, especially during emergencies and in regions with limited access to traditional oxygen cylinders. PSA works by selectively adsorbing nitrogen from ambient air, thereby enriching the oxygen content for inhalation. These concentrators operate by cycling compressed air through a molecular sieve bed, where oxygen is retained while nitrogen is vented out.

The scope of oxygen concentrators employing PSA encompasses:

Medical Applications: Primarily used to treat respiratory conditions like COPD, asthma, and during surgeries, PSA oxygen concentrators offer a reliable and continuous source of oxygen therapy.

Portable Solutions: With advancements, portable PSA concentrators have emerged, enabling patients to maintain their oxygen therapy regimen while on the move, fostering greater mobility and independence.

Emergency Preparedness: In disaster management scenarios, PSA oxygen concentrators serve as essential life-saving devices, providing oxygen therapy to patients in need when conventional oxygen supplies are disrupted.

Home Healthcare: PSA concentrators are increasingly being used in home healthcare settings, allowing patients to receive oxygen therapy in the comfort of their homes, reducing hospital admissions and healthcare costs.

Remote Areas and Developing Countries: In regions lacking access to centralized medical oxygen supplies, PSA concentrators offer a cost-effective and sustainable solution to address oxygen therapy needs, especially in rural and remote areas.

Military and Aviation: PSA technology finds applications in military operations, aircraft, and submarines, ensuring oxygen supply in confined spaces and remote locations where traditional oxygen cylinders may be impractical.

Industrial Use: Beyond medical applications, PSA oxygen concentrators are utilized in industrial processes like wastewater treatment, glassmaking, and metal fabrication, where a controlled oxygen environment is required.

Environmental Benefits: Compared to traditional methods of oxygen production like cryogenic distillation, PSA technology is more energy-efficient and environmentally friendly, reducing carbon emissions and energy consumption.

Research and Development: Ongoing research aims to enhance the efficiency, reliability, and affordability of PSA oxygen concentrators, making them more accessible to a broader range of users worldwide.

Global Health Initiatives: PSA oxygen concentrators play a crucial role in global health initiatives aimed at improving access to essential medical equipment, particularly in low-resource settings, contributing to efforts to combat diseases like pneumonia and COVID-19.

Overall, the scope of PSA oxygen concentrators is vast and encompasses various sectors, from healthcare to industry, addressing critical oxygen needs efficiently and sustainably.