MAJOR PROJECT REPORT

ON

OXYGEN CONCENTRATOR USING PRESSURE SWING ADSORPTION

Submitted in partial fulfillment for the award of the Degree of

Bachelor of Technology

In

Mechanical Engineering

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CERTIFICATE

This is certified that the Major Project report on "**Oxygen Concentrator using Pressure Swing Adsorption"** submitted by **N. Suneel Kumar(R170126), N. Raju(R170264), P. Devi Manisha(R170026), G. Ludhiya (R171206). R. Kedarnath Sarma(R170124), S. Yousuf(R170785), A. Vandana(R170407)** is the bonafide record of the work carried out by ours, is accepted as the major project report submitted in partial fulfillment for the award of the Degree of Bachelor of Technology in Mechanical Engineering during (2022-23) at IIIT-RK Valley, RGUKT – AP.

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ABSTRACT

Oxygen is used in a variety of chemical processes and for medical purposes throughout the world. Pressure swing adsorption (PSA) has become a viable alternative to cryogenic distillation for the separation of oxygen from air with the development of advanced adsorbents like zeolites. PSA processes are inherently complex because it is a dynamic process. Efficient operation of a PSA process is necessary in order to utilize the capacity of the adsorbent as much as possible and reduce the power requirements of the process.

Long-term oxygen therapy (LTOT) is one of the several methods increasing the duration of survival in chronic obstructive pulmonary disease (COPD), with the oxygen concentrators being the most appropriate and economical choice for this treatment. Studies so far conducted show that a significant amount of oxygen concentrators in Turkey are used wrongly by patients, technical services are inadequate, no periodical maintenance is being done for devices requiring regular maintenance and control, and some devices do not yield the expected oxygen purity in long-term use. These problems in the oxygen concentrators are the most important factors causing delays in the treatment process because the patients are unable to receive oxygen at sufficient purity levels during the scheduled period. Therefore, it has become a necessity that oxygen concentrators are rearranged as devices fulfilling medical requirements and minimizing patient/device-based problems in parallel with the developments in the field of medical electronics. In this study, a low-cost oxygen concentrator with a GPRS-based fault transfer system is designed for patients receiving LTOT and the practical application of this device is realized on a prototype. The most important feature of the designed oxygen concentrator is the ability to detect the fault cases occurred in itself, and then to send them to the related technical service and hospital authority through the GPRS-based fault transfer system without reliance on the patient's statement. This ensures the prevention of delays during the treatment period caused by the functional problems of the device. Keywords: Oxygen concentrator; microcontroller-based system design; GPRS-based fault transfer system; chronic obstructive pulmonary disease; long-term oxygen therapy.

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INTRODUCTION

Oxygen plays a vital role in the breathing processes and in the metabolism of the living organisms.

Home medical oxygen concentrators were invented in the early 1970s, with the manufacturing output of these devices increasing in the late 1970s.Union Carbide Corporation and Bendix corporation were both early manufacturers. Union Carbide Corporation invented the molecular sieve in the 1950s which made these devices possible. It also invented the first cryogenic liquid home medical oxygen systems in the 1960s.The COVID-19 pandemic increased the demand for oxygen concentrators. During the pandemic opensource oxygen concentrators were developed, locally manufactured -with prices below imported products and used, especially during a COVID-19 pandemic wave in India.

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. Two methods in common use are Pressure Swing Adsorption and Membrane Gas Separation. Pressure Swing Adsorption (PSA) concentrators utilize multiple molecular sieves consisting of zeolite minerals that absorbs pressurized nitrogen in fast cycles.

Air is 78.08% nitrogen and 20.95% oxygen and a concentrator that works by plugging into a source of electricity delivers air that is up to 95% oxygen. The technology is known as Pressure Swing Adsorption technology or PSA Technology. It is used for situations where bottled gas supply is impractical or expensive, and can be used by patients in the hospitals or the home. Generally, the oxygen concentrator output is measured in LPM (Liters per minute).

WHAT IS AN OXYGEN CONCENTRATOR:

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 replace that oxygen. Generally, you can't buy an oxygen concentrator over the counter. A doctor must prescribe it after they've completed a thorough medical evaluation. The doctors will also typically show the patients how to effectively use these concentrators while traveling and in their homes.

Oxygen concentrators filter surrounding air, compressing it to the required density and then delivering 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. 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.

You generally measure the oxygen concentrator output in LPM (liters per minute). Your doctor will determine what level of oxygen you need, which may vary at rest, during sleep, and when you exercise.

WHAT ARE THE TYPES OF OXYGEN CONCENTRATORS:

In general, there are two types of oxygen concentrators: stationary and portable.

1.STATIONARY:

Most stationary oxygen concentrators weigh less than 27 kg and have wheels so that they are easily movable by the user. They are self-contained devices that supply an economical, continuous stream of oxygen at flow rates up to 10 liters per minute (LPM). Very low flows, down to 0.1 LPM, may be delivered via the built-in flowmeter or with additional accessories. Most concentrators that are appropriate for health facilities can deliver at least 5 LPM and operate on alternating current electricity, and consume approximately 280 - 600 watts (W), depending on the model (Refer below table). Separate models for 110 - 120 VAC (typically 60 Hz) and 220 - 240 VAC (typically 50 Hz) is generally available from the manufacturer to match the voltage and frequency of the local grid power.

2.PORTABLE:

Portable oxygen concentrators have a lower output capacity (3 LPM or less), consume less power than their stationary counterparts (approximately 40 - 130 W) and are used by individual patients as ambulatory oxygen systems. They may contain batteries capable of operating on direct current (DC).

Portable oxygen concentrators are for patients on the go. They do not usually require highest oxygen concentrations. Not for Covid patients. These are light weight in nature.

USAGE OF OXYGEN CONCENTRATOR:

➢ For acute conditions

- **Asthma:** This condition is where your airways become inflamed and begin producing a lot of mucus, which makes it harder to breathe. While there are a number of pharmaceuticals that can treat and control asthma, an oxygen concentrator can pump high levels of oxygen into the bloodstream of the patient while they're having or have already had an asthma attack.
- **Pneumonia:** Pneumonia is an infection where you develop inflammation in either one or both of your lungs' air sacs and in many cases, fill them up with fluid. Many pneumonia patients have been prescribed oxygen therapy and have seen good clinical outcomes.
- **Respiratory distress syndrome (RDS):** RDS is a breathing disorder mostly affecting newborns, particularly those who are born six or more weeks before their delivery date. Newborns suffering from RDS don't create enough surfactant (a lung coating liquid), causing their lungs to collapse and making them work harder to breathe. Oxygen therapy using oxygen concentrators help pump oxygen into the babies' bloodstream and lungs to reduce further complications.
- **Bronchopulmonary dysplasia (BPD):** Newborns suffering from RDS also have a higher risk of developing BPD. This is a severe lung condition requiring long-term breathing support.

➢ For chronic diseases:

- **Chronic obstructive pulmonary disease (COPD):** COPD affects around 16 million people, but an oxygen concentrator can be an effective treatment. When you have COPD, you have chronic lung damage which makes it difficult for your lungs to absorb enough oxygen. As a result, you can have difficulty breathing, and oxygen therapy through a concentrator can help.
- **Cystic fibrosis:** You inherit this life-threatening condition. It causes digestive system and lung damage. It's a rare condition that affects the body's cells responsible for producing mucus, sweat, and digestive juices. The fluids are changed which results in a stickier, thicker solution that plugs the ducts, tubes, and passageways of the individual infected.
- **Sleep Apnea:** Sleep apnea is a sleeping disorder that can be serious and cause the individual's breathing to sporadically stop and start during their sleep. Usually, treatment for this condition is continuous positive airway pressure (CPAP), weight loss, and physical exercise, though some people with sleep apnea may require oxygen therapy.
- **COVID-19:** Patients with moderate pneumonia induced by COVID-19, with oxygen saturations less than 94-can benefit from supplemental oxygen given through oxygen concentrator, but only till they get hospital admission. However, patients using it themselves without a suitable medical advice can be harmful.

ADVANTAGES:

Following is some of the advantages of using oxygen concentrators for oxygen therapy:

- They provide an unlimited supply of oxygen, unlike cylinders, given a consistent power source. They do not need to be taken elsewhere to be refilled.
- They are more cost-effective when needed for long-term use than some other methods.
- Whether stationary or portable, they are easier to transport compared to oxygen cylinders.
- They require a one-time installation only.
- While some regular cleaning by the user or caregiver is required, they do not require extensive maintenance.

DISADVANTAGES:

Following is some of the disadvantages of using oxygen concentrators for oxygen therapy:

- Regular use of nasal cannula can result in irritation in the nose.
- It is dependent on power supply at all times, which may be difficult to obtain in remote areas.
- A reserve compressed oxygen tank needs to be kept on hand in case of power failure.
- There is a warm-up period since the machine is turned on until it can be used.
- Filters may need to be changed pretty frequently.
- Some older models make noise and produce a vibration while operating.
- Water vapour in the room can compromise the functioning of the machine over time.

METHODOLOGY FOR OXYGEN CONCENTRATOR:

PRESSURE SWING ADSORPTION(PSA) TECHNOLOGY:

WHAT IS PRESSURE SWING ADSORPTION**(PSA)?**

PSA is short for Pressure Swing Adsorption.

Pressure: Elevated pressures are needed for the process, usually 4-8 bar(g).

Swing: While one vessel is being pressurized, the other vessel is being depressurized.

Adsorption: Separation of atmospheric air is done with a PSA principle; oxygen is separated from the air through adsorption process.

Pressure swing adsorption or PSA is a process that separates single gases from a gas mixture. PSA is a non-cryogenic air separation process that is commonly used in commercial practice.

- It is an economic and reliable method for separating many gases and achieving a very high purity level for them.
- PSA is mainly employed in the chemical and petrochemical processes.
- It is used to recover hydrogen from coking or conversion gases, or to separate oxygen and nitrogen from air.
- In the process, gases are separated under pressure based on the species' molecular characteristics and affinity for an adsorbent material.
- It operates at near-ambient temperatures which is in contrast to the cryogenic distillation techniques of gas separation, which takes place at very low temperatures.
- Specific adsorbent materials (e.g., zeolites, molecular sieves, activated carbon, etc.) are used as a trap, preferentially adsorbing the target gas species at high pressure. The process then swings to low pressure to desorb the adsorbed material.
- The adsorption process is based on gas molecules binding to an absorbent material.
    - The adsorbent bed is specially selected depending on the gas to be absorbed.
    - Ideally, only the gas to be separated is adsorbed, while all other gases in the mixture pass through the adsorbent bed.

PRESSURE SWING ADSORPTION WORKING PRINCIPLE:

First, air from the ambient atmosphere is compressed into high-pressure air. This gas is then transferred into a vessel or column which is filled with the adsorbent material (activated carbon, zeolite, etc.). The selection of the adsorbent depends on the gas to be extracted. This system is then pressurized and depressurized cyclically, wherein the low sorbing gas will gradually leave the column first, followed by the other gases.

There are four main phases of the pressure swing adsorption process:

1. Adsorption: The adsorber starts off pressurized with pure gas. The impure gas is fed into the column which contains the adsorber. Adsorption takes place and the pure gas is released from the top of the column. This takes place until the adsorber has reached its adsorption capacity.
2. Depressurization: The adsorber is depressurized over in several small steps to recover additional pure gas still in the adsorber. Once all pure gas has been recovered, the desorbed impurities are dumped into the PSA off-gas line.
3. Regeneration: The adsorbent is purged with high-purity gas at constant off-gas pressure to further regenerate the adsorbent bed.
4. Repressurization: The adsorber is repressurized with pure gas and is now ready to receive more feed gas to start the process over.

PSA APPLICATION:

The PSA process is used in several applications across several industries. It is used in hydrogen recovery and purification, oxygen production, carbon dioxide removal and purification, helium recovery, nitrogen generation, methane recovery, etc. It is used in the chemical industry, the petrochemical industry, iron and steel industries and refining.

PSA IN OXYGEN GENERATION:

The process is being used to generate medical oxygen to supply to hospitals. It is used as a substitute for bulk cryogenic or compressed-cylinder storage, which is the primary oxygen source for any hospital. Hospitals and medical applications require oxygen purity to be between 95 – 99%, and the PSA process can produce oxygen at this purity level.

In the wake of the severe oxygen shortage in the country in the ongoing COVID-19 pandemic, the government has approved the allocation of funds for setting up 551 Pressure Swing Adsorption medical oxygen generation plants at public health facilities across the country.

HOW OXYGEN CONCENTRATOR WORKS:

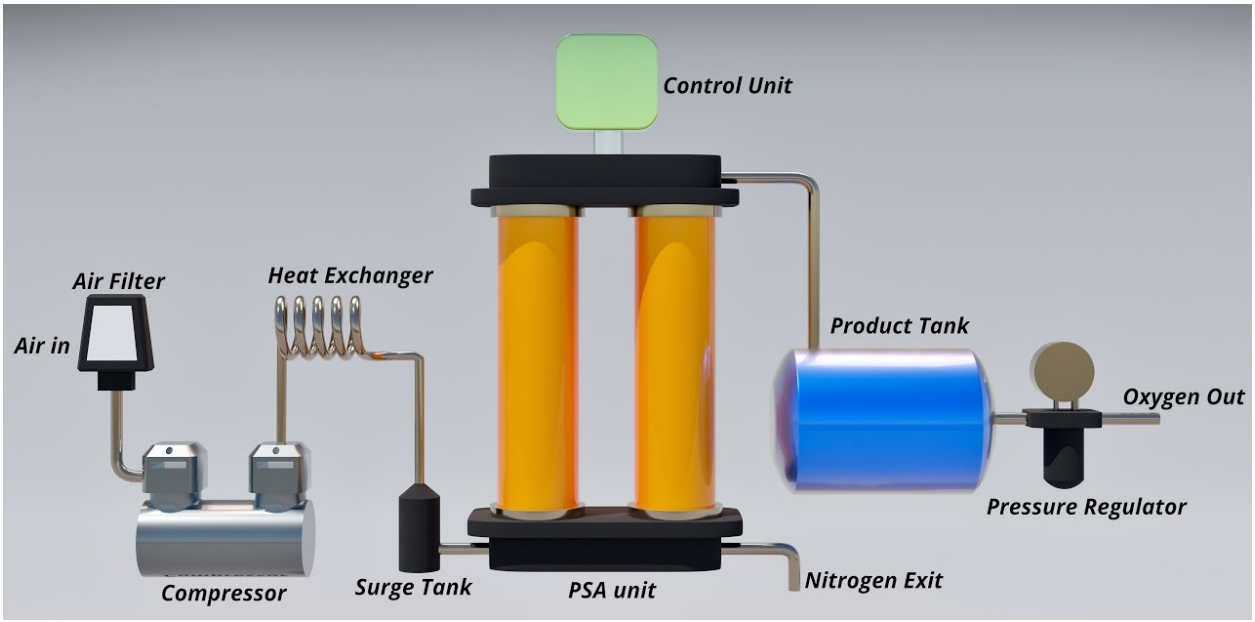


Fig-1: Schematic diagram of oxygen concentrator

An oxygen concentrator is a self-contained, electrically powered medical device designed to concentrate oxygen from ambient air. Utilizing a process known as pressure swing adsorption, an oxygen concentrator produces up to 95.5% concentrated oxygen6.

Atmospheric air is drawn through a gross particle and intake filter before moving through a compressor.

The pressurized air passes through a heat exchanger to reduce the temperature before entering sieve beds that contain zeolite, a mineral material that preferentially adsorbs nitrogen gas (N2) at high pressures. As each sieve bed is depressurized, N2 is released.

Valves open to deliver concentrated oxygen into a reservoir where it accumulates, and from which a flowmeter can be used for measured and continuous release of oxygen to the patient at a specified flow rate.

COMPONENTS -THEIR FUNCTIONS:

1.AIR FILTER:

- To clean the air, before it is supplied to conditioned space.
- Protection of human health and comfort: By removing dust particles related to serious respiratory problems such as asthma.
- Protection of equipment's: Some equipment's may not operate properly or may wear out faster, if air is not clean. Some manufacturing processes are particularly sensitive to atmospheric contaminants.
- Protection of the air conditioning machinery.
- To maintain cleanliness of room surfaces and furnishings.

2.COMPRESSOR:

- The compressor compresses air that is filtered into the concentrator, then delivers the air in a continuous stream.
- The compressed air moves to the sieve bed filter.

3.HEAT EXCHANGER:

- A heat exchanger is a device that facilitates the process of heat exchange between two fluids that are at different temperatures.
- An air-to-air heat exchanger is used on some units to lower the temperature of the compressed air to enhance the adsorption process.
- The compressed air is then directed through one of the two molecular sieve beds. Here, the nitrogen in the air is absorbed.

4.SURGE TANK:

- Surge tank is used to absorb the surges, caused by the water in penstock, due to the sudden loading and unloading of generator.

5.PRESSURE SWING ADSORPTION(PSA) UNIT:

- PSA is a process that separates single gases from a gas mixture.
- PSA is a non-cryogenic air separation process that is commonly used in commercial practice.

6.ZEOLITE MOLECULAR SIEVES:

- Zeolite performs the chemistry of separating oxygen from nitrogen in the air.
- Being highly porous, zeolite beads have a surface area of about 500 square meters per gram.
- At high pressures in the column, nitrogen is in a tight embrace, chemically speaking, with the zeolite.
- Interaction between the negatively charged zeolite and the asymmetric nucleus (quadrupole moment) of nitrogen causes it to be preferentially adsorbed on the surface of zeolite.

- Oxygen remains free and is thus enriched.
- Once nitrogen is under arrest, what flows out from the column is 90% plus oxygen.
- After this, lowering the pressure in the column releases the nitrogen, which is flushed out, and the cycle is repeated with fresh air.

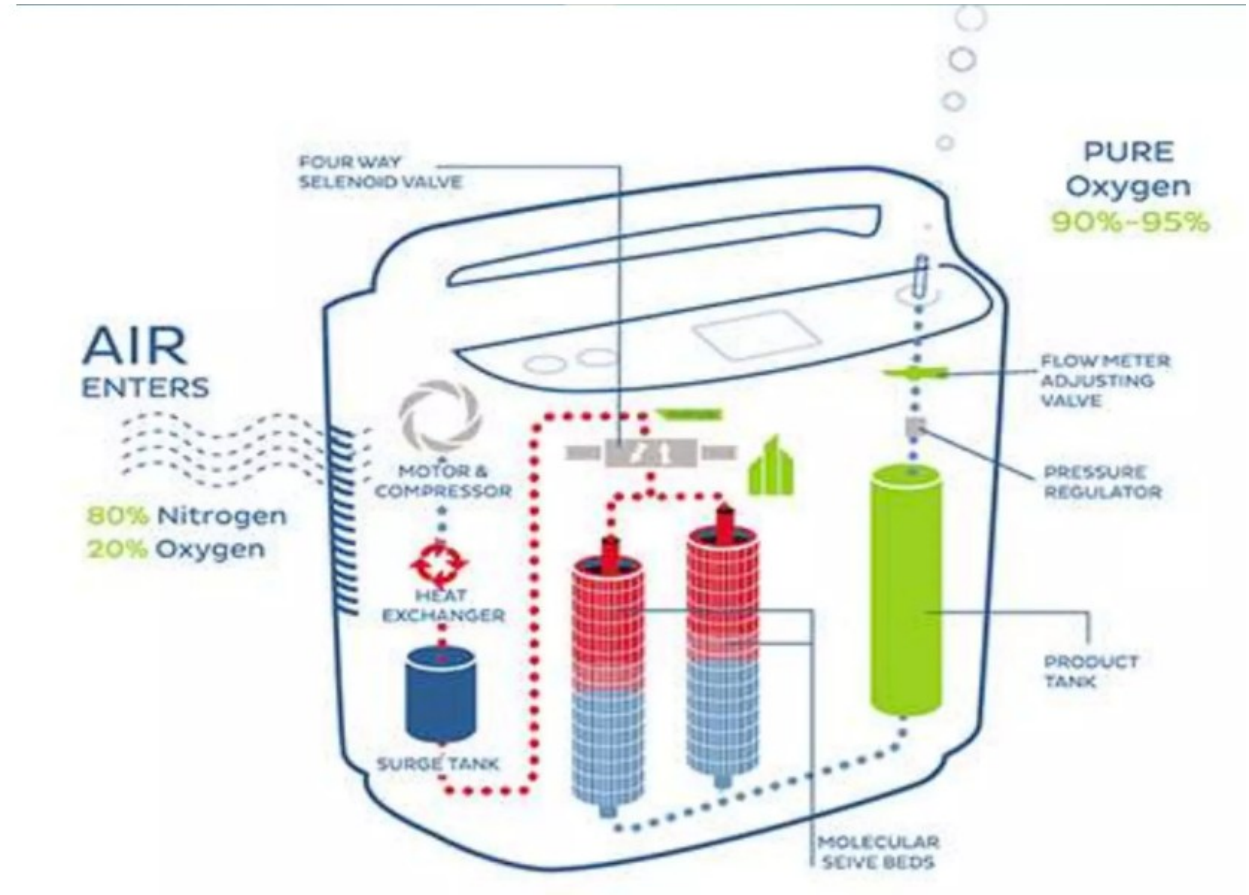
7.PRESSURE REGULATOR:

- Pressure regulators reduce a supply (or inlet) pressure to a lower outlet pressure and work to maintain this outlet pressure despite fluctuations in the inlet pressure.
- The reduction of the inlet pressure to a lower outlet pressure is the key characteristic of pressure regulators.

8.SOLENOID VALVES:

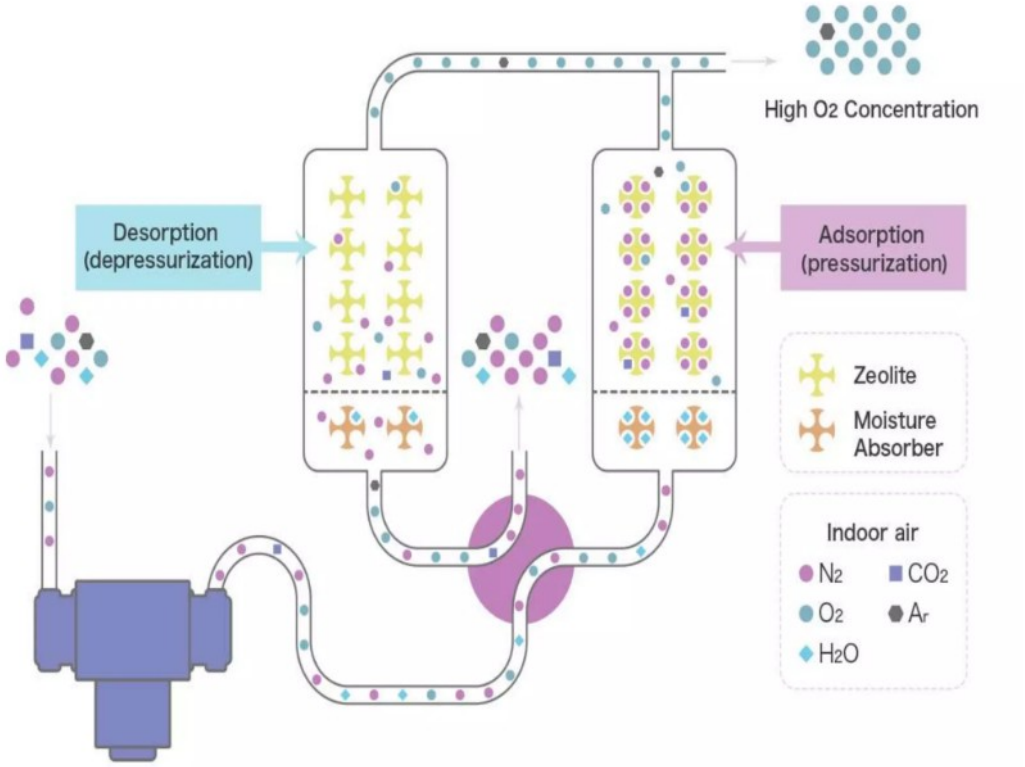
- Solenoid valve function involves either opening or closing an orifice in a valve body, which either allows or prevents flow through the valve. A plunger opens or closes the orifice by raising or lowering within a sleeve tube by energizing the coil. Solenoid valves consist of a coil, plunger and sleeve assembly.

OPERATION OF OXYGEN CONCENTRATOR:



- The concentrator draws in room air and passes it through a series of filters that remove dust, bacteria, and other particulates.
- Two-part cycle:
  - A high-pressure intake phase
  - Depressurizing exhaust phase

PROCESS:



STAGE-1:

- Compressed air is fed into the first bed.
- Nitrogen and argon molecules are trapped, while oxygen is allowed to flow through.

STAGE-2:

- The absorbent in the first bed becomes saturated with nitrogen and argon molecules.
- The air flow feed is directed into the second bed.

STAGE-3:

- The adsorbent adsorbs nitrogen and argon in the second bed.
- The first bed is depressurized allowing argon and nitrogen to be purged out of the system and released to the atmosphere.

STAGE-4:

- The process starts over.
- Compressed air is once again fed into the first bed.
- The second bed is depressurized releasing argon and nitrogen molecules to the atmosphere.

CONCLUSION:

In this project, a low-cost oxygen concentrator was designed and its practical application was realized on a prototype. A GPRS based fault transfer system for the proposed oxygen concentrator was developed to eliminate the problems arising from the information relying on patient's statement.in this way, it was aimed to minimize the delays that may occur during the treatment period. The sending circuits on the control card were arranged in such a manner that gives a digital output for eliminating the analog digital converter and providing the fault detection with short program codes. The experimental results showed that the proposed system supplied the oxygen at the purity of about 94.7% for the flow velocities of 1-3L/min. It is concluded that the system provides a good performance when considered that a patient with the COPD should take the oxygen at the purity of 90% or more the flow velocities 0f 2-3L/min.

FUTURE SCOPE:

- India held a market share of nearly **2.7%** in the global portable oxygen concentrators market in 2021 and it is expected to grow at a healthy pace during the next ten years.
- In 2020, the COVID-19 epidemic has benefited the portable oxygen concentrators market in India. These oxygen concentrators were utilized more frequently during the pandemic to provide supplemental oxygen to patients receiving care at home or dealing with respiratory symptoms linked to COVID-19. Thus, the rising cases of COVID- 19 infections in India has led to the growth of India portable oxygen concentrators market and the trend is likely to continue during the forecast period.
- For instance, in June 2020, the Indian government in Delhi provided around 2,000 oxygen concentrators for the treatment of patients suffering from COVID-19.
- Similarly, easy availability of better-quality portable oxygen concentrators at lower prices and increasing health awareness are expected to boost market in India during the forecast period.

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