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"Design and Development of an Oxygen Generator System

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Astract: Some people suffer from healthy problems concerning breathing difficulties, so that it could be hard to take them continuously to the hospital or health facilities. In addition, those who have chronic diseases especially with our polluted atmosphere and dusty, unexpected weather. For that, we design a system to generate Oxygen, and this system is can be easily moved and it is makeable as portable machine.

This device design as continence to the patient. Therefore, it can be easily existed and available at home. In addition, it is smoothly movable.

We show perfect results that could help the patient and reduce his fatigue to transfer from place to other.

Getting the oxygen percentage, which is, should be 90-91%. This is very good percentage. Moreover, the device consists of the compressor ،A compressed air dryer ،Filters، Valves، Regulator، Oxygen tank،The generator، Flow meter ،Stan.

1. Background

Generator Oxygen PSA Generators separates oxygen (O2) from compressed air utilizing pressure swing adsorption technology. Compressed air, which consists of approximately 21% oxygen and 78% nitrogen, is passed through a bed of zeolite molecular sieve (ZMS). The sieve preferentially adsorbs N2 and moisture over O2 allowing the O2 to pass through as a product gas at pressure.

An oxygen generator is a device that produces oxygen by separating it from other gases in the air. The process of oxygen generation is typically based on the principles of pressure swing adsorption (PSA) or membrane technology.

In the PSA process, compressed air is fed into the generator, where it is passed through a molecular sieve bed. The sieve bed contains materials such as zeolite, which adsorbs nitrogen and other gases, allowing pure oxygen to pass through. The oxygen is then collected and stored in a tank for later use.

In membrane oxygen generation, the compressed air is passed through a semi- permeable membrane that allows oxygen to pass through while blocking other gases. The oxygen is then collected and stored in a tank.

Oxygen generators are commonly used in a variety of applications, including medical facilities, industrial processes, and research laboratories. They are often used to provide a reliable and cost-effective source of oxygen in locations where traditional oxygen cylinders or tanks may be impractical or unavailable.

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. 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. 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. Generally, the oxygen concentrator output is measured in LPM (liters per minute)1.

2. Problem statement

One common problem associated with oxygen generators is the potential for system failure, which can lead to a lack of oxygen production and potentially dangerous situations. The failure may be caused by a variety of factors, such as a malfunctioning valve, a clogged filter, or a power outage.

The ongoing coronavirus and its variants are alarming the world inadequately. Extreme reciprocal pneumonia is the primary element of serious COVID-19, and sufficient ventilator help is vital for patient endurance. Supplemental oxygen is the first fundamental stage for the cure of serious COVID-19 patients with hypoxemia. Another issue is the cost and maintenance of the oxygen generator. The equipment can be expensive to purchase, install, and maintain. The molecular sieve bed or membrane may need to be replaced periodically, and the generator requires regular servicing to ensure that it is operating efficiently and safely.

3. Objectives

- To design a portable device of the oxygen generator.
- To implement a portable device of the oxygen generator.

4. Scope of the study

Design and implement a lightweight, portable oxygen generator that can be used in remote or emergency situations.

The delivery of oxygen to patients who suffer from chronic breathing diseases such as lung fibrosis, which affects the movement of oxygen from the lungs to the blood, meaning that the level of oxygen may decrease, and the body's organs, tissues and cells that do not receive an adequate amount of oxygen.

Oxygen therapy helps maintain the level of oxygen in the blood, which reduces shortness of breath and nausea.

5. Application of oxygen generator

Oxygen generators have a wide range of applications in various fields due to the critical role of oxygen in many chemical and biological processes. Here are some common applications of oxygen generators:

1. Medical: Oxygen generators are widely used in the medical industry to provide supplemental oxygen to patients with respiratory conditions, such as COPD, asthma, and pneumonia. They are also used during surgical procedures and in intensive care units.
2. Industrial: Oxygen generators are used in various industrial applications, such as metal cutting and welding, chemical production, and water treatment. They can also be used to enhance combustion efficiency in boilers and furnaces.
3. Aerospace: Oxygen generators are used in aircraft and spacecraft to provide breathable air for crew members and passengers. They are also used in life support systems and as a backup oxygen supply in case of emergencies.
4. Environmental: Oxygen generators can be used in environmental applications, such as wastewater treatment and soil remediation. They can also be used to promote the growth of aerobic bacteria in composting and bioremediation processes.
5. Aquaculture: Oxygen generators are used in aquaculture systems to provide dissolved oxygen to aquatic organisms, such as fish and shellfish. This is important for maintaining optimal water quality and promoting healthy growth.
6. Mining: Oxygen generators can be used in mining operations to improve the efficiency of chemical reactions and reduce the risk of explosions. They are also used to provide breathable air to workers in confined spaces.
7. Sports and fitness: Oxygen generators can be used in sports and fitness training to simulate high-altitude conditions and promote oxygen uptake in the body. This can help improve endurance and performance.

These are just a few examples of the diverse range of applications for oxygen generators. The specific application will depend on the context and requirements of each use.

Literature Review

1. Introduction

Patients who suffer from respiratory problems due to chronic diseases that lead to their urgent need for oxygen and as soon as possible. Their health condition requires the availability of an oxygen generator, provided that it is small in size and easy to carry.

The problems that happen to the patient that require him to use an oxygen generator?

There are many medical conditions that can cause a patient to require supplemental oxygen therapy, which may be provided through the use of an oxygen generator. Some common conditions include:

1. Chronic obstructive pulmonary disease (COPD): A group of lung diseases, including chronic bronchitis and emphysema, that make it difficult to breathe.
2. Pneumonia: An infection of the lungs that can cause inflammation and fluid buildup, leading to breathing difficulties.
3. Asthma: A chronic condition that causes the airways to become inflamed and narrow, making it difficult to breathe.
4. Sleep apnea: A condition in which breathing stops and starts during sleep, leading to low oxygen levels.
5. Heart failure: A condition in which the heart cannot pump enough blood to meet the body's needs, leading to shortness of breath and fatigue.
6. Lung cancer: A type of cancer that can cause breathing difficulties and may require oxygen therapy during treatment.

In all of these cases, oxygen therapy can help to improve oxygen levels in the body, reduce shortness of breath, and improve overall quality of life. An oxygen generator can provide a reliable and continuous supply of oxygen to patients who require supplemental oxygen therapy.

2. Oxygen generator function:

An oxygen concentrator is a medical device that delivers oxygen to a patient who requires supplemental oxygen. The following are the functions that an oxygen concentrator should perform for the patient:

1. Concentrate Oxygen: The primary function of an oxygen concentrator is to take in air from the surroundings, remove other gases such as nitrogen and argon, and concentrate the oxygen to a higher level, typically around 90- 95%.
2. Flow Rate Control: An oxygen concentrator should have the capability to regulate and control the flow rate of oxygen being delivered to the patient. The flow rate can be adjusted depending on the patient's requirements and the severity of their condition.
3. Oxygen Purity Indicator: The oxygen concentrator should have an oxygen purity indicator that displays the concentration of oxygen being delivered to the patient at any given time. This is important because low oxygen purity levels can be harmful to the patient.
4. Power Failure Alarm: The oxygen concentrator should have an alarm that alerts the patient or caregiver in case of a power failure. This is important to ensure that the patient does not run out of oxygen in case of a power outage.
5. Portability: An oxygen concentrator should be portable so that the patient can move around with it. This is especially important for patients who require oxygen therapy while traveling or outside the home.
6. Noise Level: The oxygen concentrator should operate quietly to minimize disturbance to the patient or those around them.
7. Easy Maintenance: The oxygen concentrator should be easy to clean and maintain to ensure that it functions properly and delivers the correct level of oxygen concentration at all times.

Overall, an oxygen concentrator should be reliable, safe, and easy to use, and it should provide the patient with the oxygen they need to improve their health and quality of life.

3. History of Oxygen generator

1. First Oxygen generator invented by carl William Scheele

Oxygen concentrators were first discovered in 1772 by Swedish-born chemist Carl Wilhelm

Scheele, as shown figure below figure (2.1) and (2.2).

Fig (2.1) First Oxygen generator

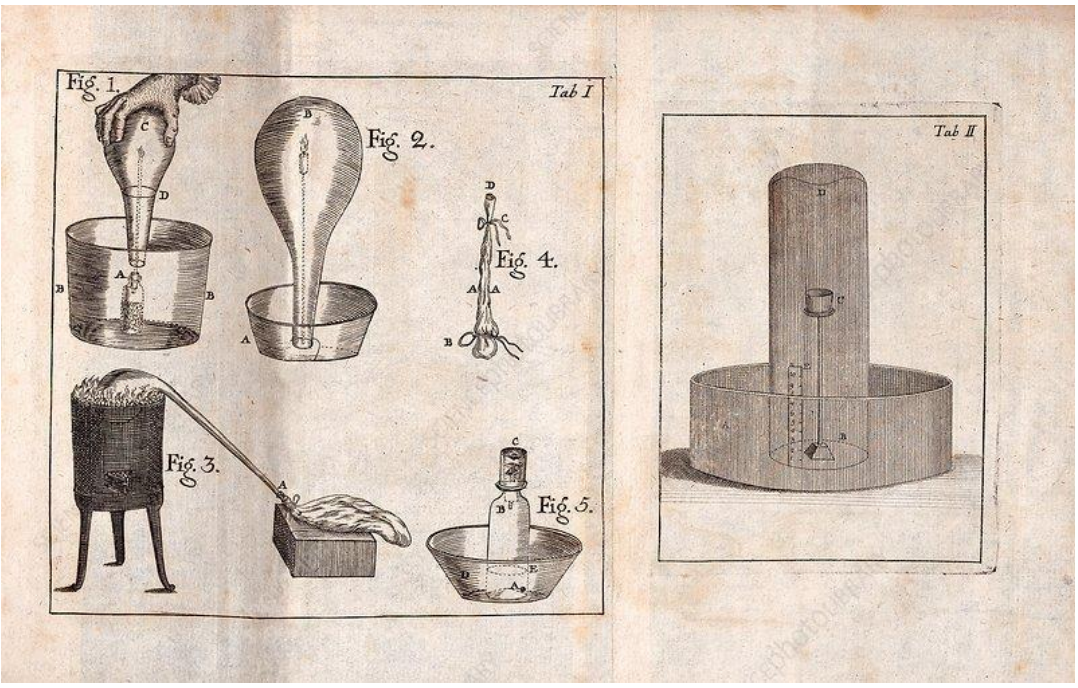


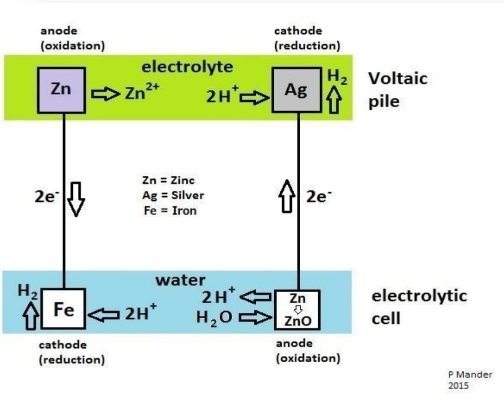
Fig (2.2) the first use of oxygen

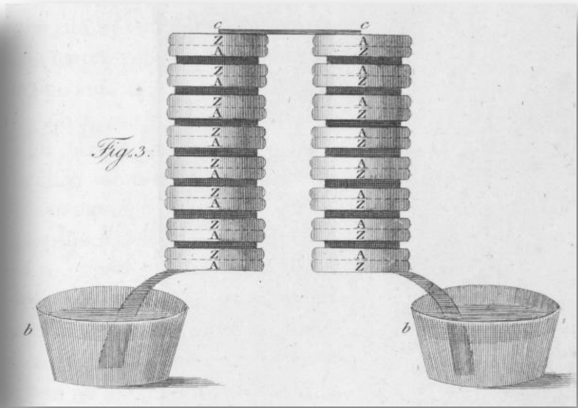
The first use of oxygen was made by Dr George Holtzapple in New York for the treatment of pneumonia as shown figure below figure (2.3).

Fig (2.3) Dr George Holtzapple in New York

2. William Nicholson In 1800

The development of the oxygen generator dates back to the early 19th century, when scientists began to study the properties of gases. In 1800, William Nicholson and Anthony Carlisle discovered that an electric current could decompose water into its constituent gases, hydrogen and oxygen. This discovery led to the development of electrolysis, a process that uses an electric current to separate oxygen from other gases as shown figure below figure (2.4).





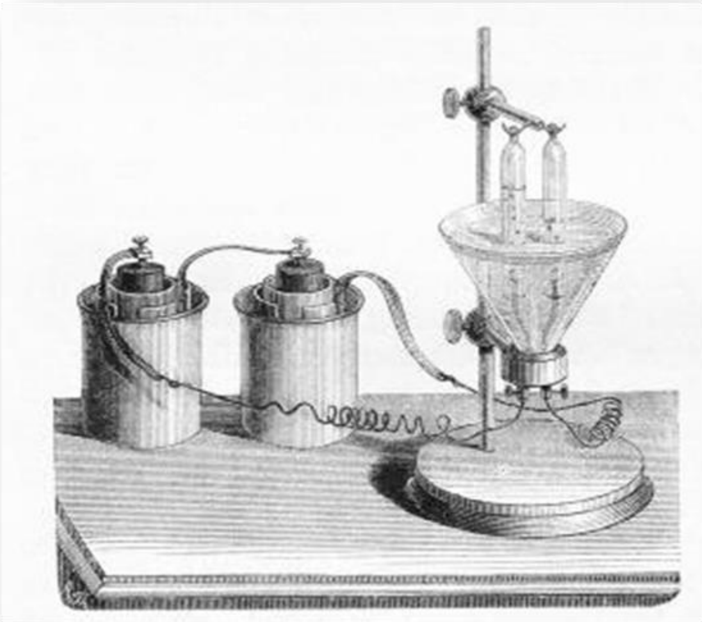


Fig. (2.4) William Nicholson

3. Chemical oxygen generators in 1860

In 1860, Antoine Lavoisier and Pierre-Simon Laplace discovered that oxygen could be produced by heating certain compounds, such as potassium chlorate. This led to the development of chemical oxygen generators, which use a chemical reaction to produce oxygen as shown figure below figure (2.5).

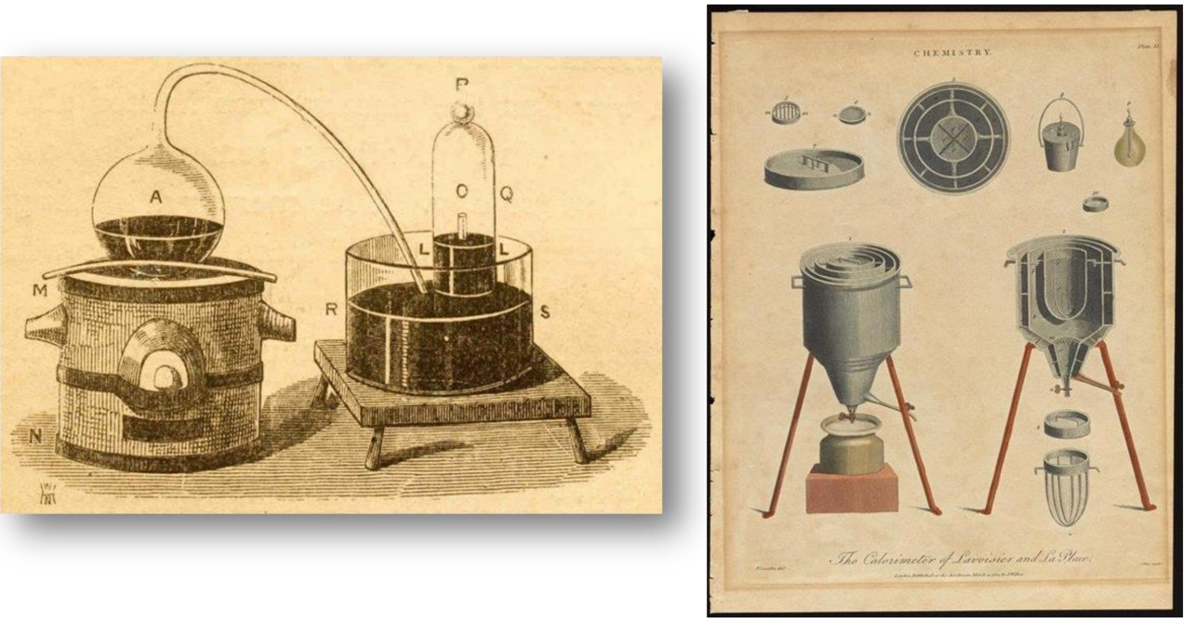


Fig. (2.5) chemical oxygen generators

4. The First World War

During the First World War, an oxygen mask apparatus was designed and used in 1917 for the soldiers who needed clean oxygen. It was the idea of John Scott who developed the oxygen mask apparatus.

Swedish John Scott is an important doctor and scientist who has made many discoveries about the nature of man and gases As shown figure below figure (2.6).

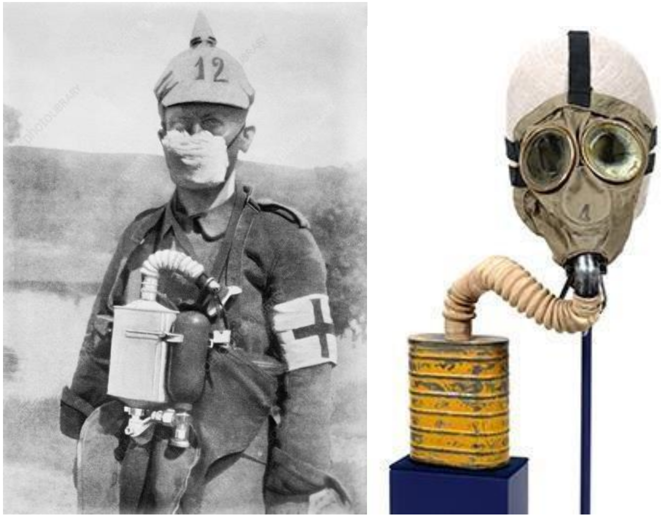


Fig. (2.6) oxygen mask

5. In World War II

During World War II, oxygen generators were used to provide oxygen for pilots at high altitudes. These generators used a chemical reaction between sodium chlorate and iron powder to produce oxygen as shown figure below figure (2.7).

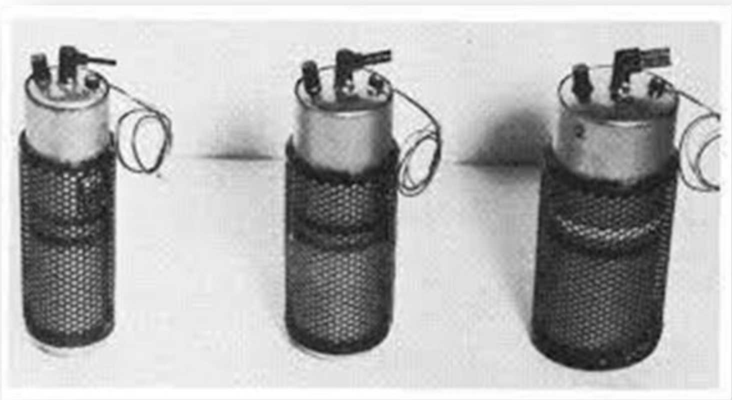


Fig (2.7) Oxygen generators with chemical reactions

6. Membrane oxygen generators

In the 1950s and 1960s, the development of membrane technology led to the development of membrane oxygen generators. These generators use a semipermeable membrane to separate oxygen from air as shown figure below figure (2.8).

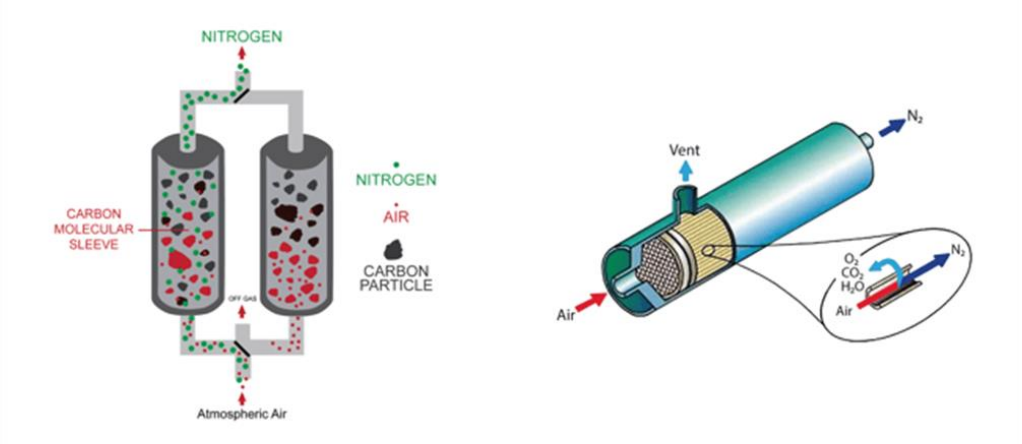


Fig. (2.8) membrane oxygen generators (1950-1960).

Today, oxygen generators are used in a variety of applications, including medical oxygen generators, industrial oxygen generators, and emergency oxygen generators.

4. History of Portable Oxygen Generator

What is a Portable Oxygen Concentrator?

Individuals who require oxygen therapy find it challenging to carry their devices when they wish to travel somewhere. The patient and their families become exhausted as a result of this situation, and the equipment itself wears out. Patients have a psychological barrier as a result of this. The patient is limited in space in the home or in another environment. Therefore, portable oxygen concentrators have been developed. There are models that can be worn on the back or shoulder in the form of a bag, and models with pulls like a suitcase. The weight of such equipment varies between 8 kg and 800 gr depending on the features and capacity of the device. Portable type oxygen concentrators work at flow rates as low as 0.5 liter/minute and 1 liter/minute due to their small and light weight.

Elmaslar Medical analyzed the needs of patients and developed Health time OC5 and Health time OC10 oxygen concentrators with a patient unit design that extends up to 15 meters without loss of pressure and purity in order to increase the mobility of patients in their environment. With this design, the products received the 2010 Good Design Award.

The development of the portable oxygen generator began in the early 20th century, when researchers began to study the use of oxygen in medical applications. In the 1920s and 1930s, researchers developed the first portable oxygen concentrators, which used a process called pressure swing adsorption (PSA) to separate oxygen from air As shown figure below figure (2.9).

Fig(2.9) The pressure swing adsorption

PSA technology was first developed in the 1940s for industrial applications, but it was not until the 1960s that it was adapted for medical use. In 1970, a portable oxygen concentrator was developed for use in space by the National Aeronautics and Space Administration (NASA).

In the 1980s, technological advances in microprocessors and materials led to the development of more efficient and lightweight portable oxygen concentrators. Today, portable oxygen concentrators are widely used in medical settings, as well as for recreational and travel purposes.

5. Zeolites

Zeolites are a family of such molecular sieves that are made up of various compounds, some of which occur naturally, but many of which are synthetically made for industrial applications. For reasons unknown to me, India turns out to be a major producer of zeolite. They are used as catalysts in the fractionation of hydrocarbons and as desiccants for the removal of water and, as in our present case, for the separation of gases.

In particular, for our purpose, two synthetic zeolites, known as zeolites 5A and 13X are suitable for adsorption of nitrogen from air at low temperatures and/or high pressures. Now, all of the gases that make up air are nonpolar; We know from elementary chemistry that oxygen and nitrogen molecules are electrically neutral and that the existence of the molecule itself is due to electronic stability. So why does nitrogen adsorb to 5A or 13X zeolites while oxygen does not?

The reason for this is due to a high level reaction between the zeolite and the air. The positive charge on a zeolite molecule induces a quadrupole moment in both nitrogen and oxygen, but it is three times stronger in nitrogen than in oxygen. Because of this, more nitrogen is attracted to the surface of the zeolite crystal, while oxygen passes through the pores or cage.

However, we know that quadrupole interactions are much weaker than dipole interactions, which is why adsorption (i.e. removal) of nitrogen from the zeolite matrix can also be easily achieved. Much of the process described below in subsection 2.3 on pressure swing adsorption relates to initial adsorption, followed by subsequent adsorption of nitrogen in a cyclic manner to achieve continuous concentrated oxygen generation. Between 5a and 13h zeolites, commercially, zeolites are manufactured, as shown figure below figure (2.10).

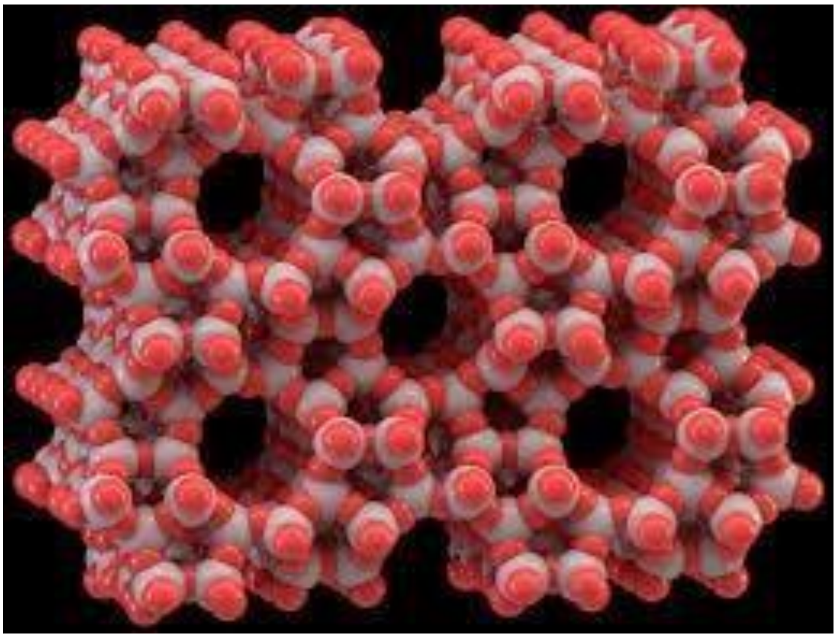


Fig (2.10) Zeolites

Chapter Three

Planning

Planning

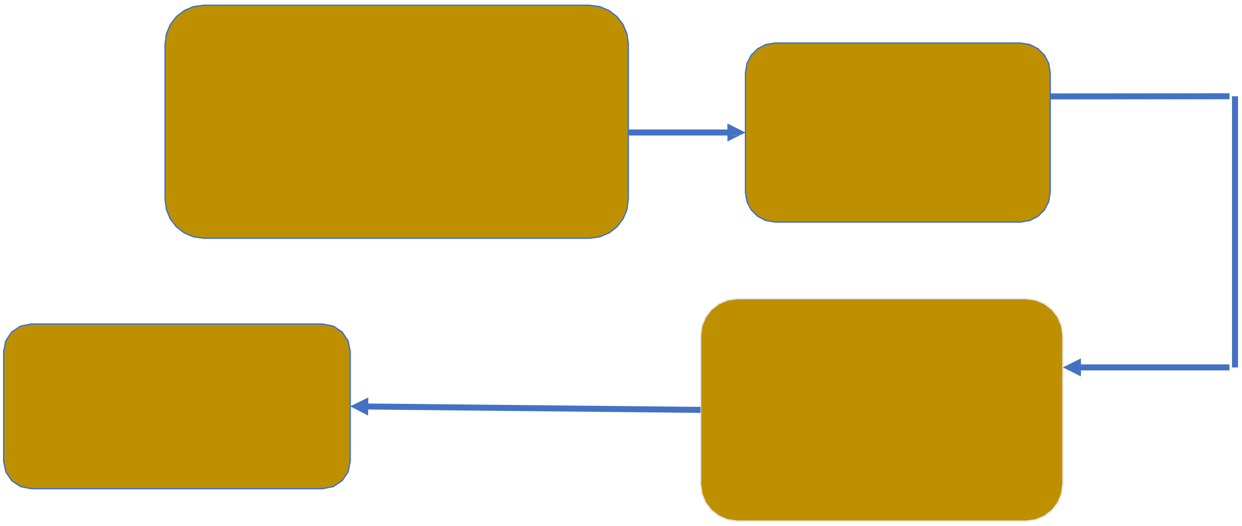


Fig (3.1) System architecture

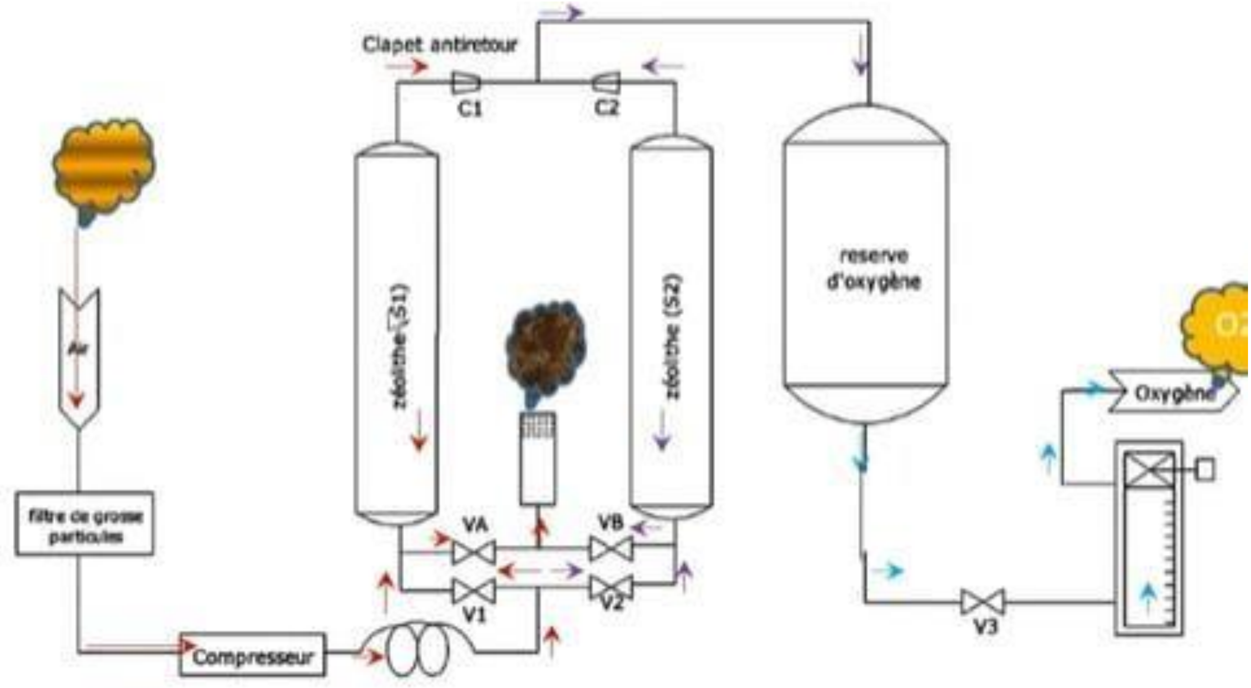


Fig (3.2) Block diagram

1. Device components

1. The compressor

Its operating principle is conversion of rotary motion to linear (reciprocating) motion of a piston moving within a cylinder. The downward stroke of the piston is when intake takes place, and its upward stroke is when compression takes place. It is a compressor that compresses the air until it rises more than the atmospheric pressure. It presses according to the device's needs. There are types of them: 2 bar, 3 bar, 5 bar and 10 bar.

This compressor of ours contains two holes, the first hole contains a filter to prevent the entry of dust and dirt from the air, and at the same time it silences the sound. The second hole is for the air to come out. Of course, the air comes out moist, so we will use the dryer. It is the most important component of this device because it compresses air as shown figure below figure (3.3).

Fig (3.3) The compressor

2. A compressed air dryer

is a piece of equipment designed to separate water vapor or moisture (de- humidify) from industrial process air. In the typical system, a compressor draws in humid air and compresses it, which raises the air temperature and then cooling the air condensing water vapor out of the unit As shown figure below figure (3.4).

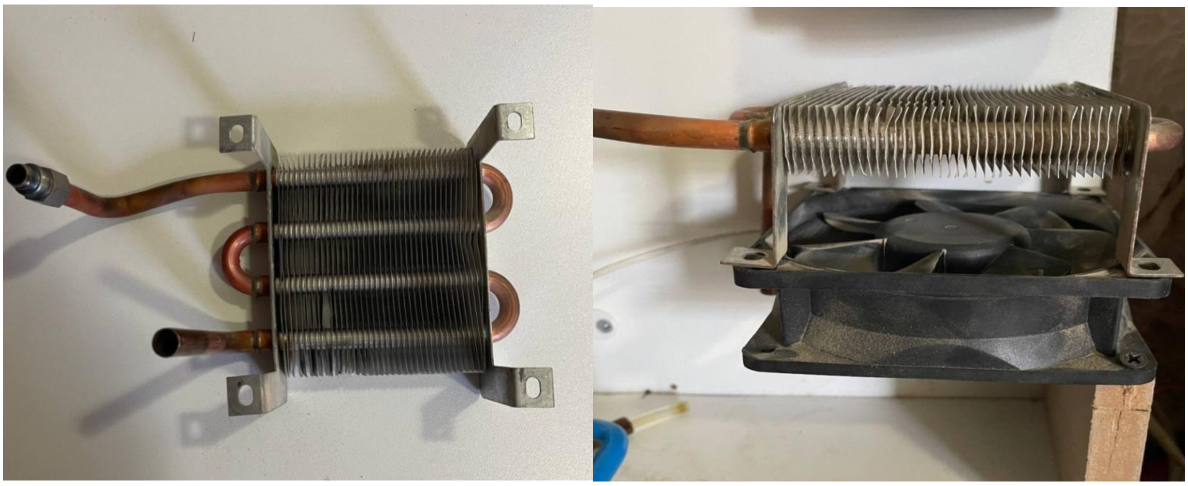


Fig (3.4) A compressed air dryer

3. Filters

Air intake filters are installed in an air compressor to remove any dust or debris the compress may suck in. Dust will cause wear to the compressor element, valves, filters, compressor oil and any moving parts as shown figure below figure (3.5).

Fig (3.5) Types of Filters

4. Valves

Oxygen valves are used to regulate the flow of oxygen in industrial settings. They are an essential piece of equipment in many industries, as they help to ensure that oxygen is only used when and where it is needed.

The pressure is divided into the first and second generators, and it expels nitrogen from the air. It is electronic and electrical as shown figure below figure (3.6).

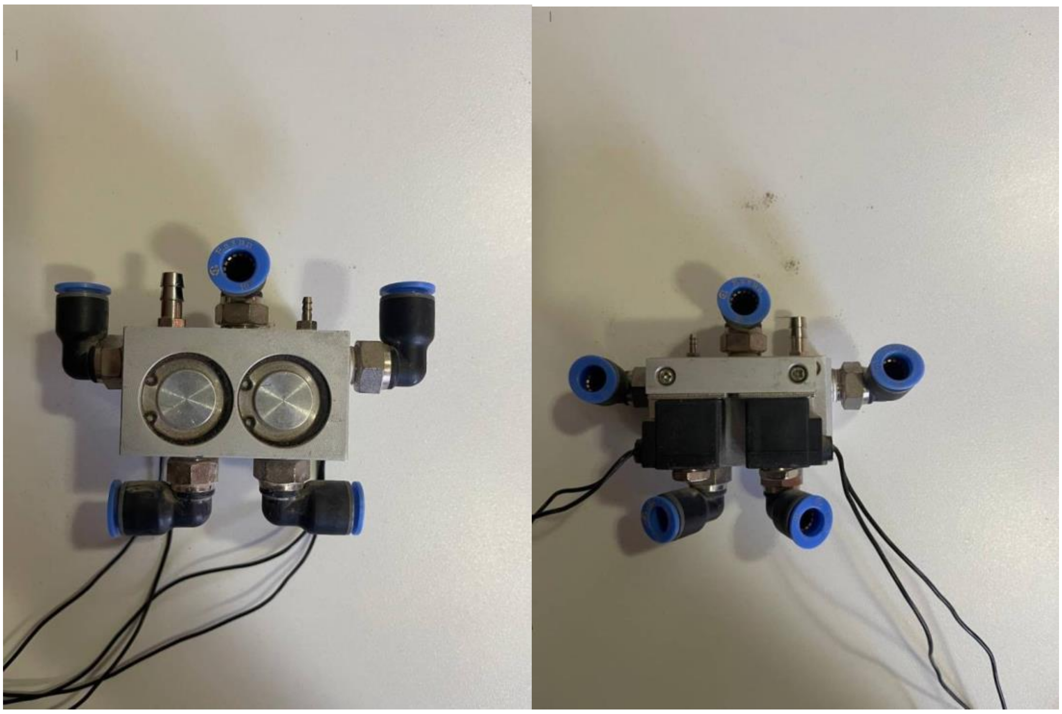


Fig (3.6) valves

5. Regulator

Oxygen regulators are intended for the administration of oxygen to patients that are deemed by a physician to need increased oxygen levels to improve or stabilize their breathing conditions. It is a pressure-reducing device that lowers the pressure of the oxygen from a cylinder to a level that can safely be used.

A gas pressure regulator is a control device that maintains a defined pressure of a system by cutting off the flow of a gas or liquid when it reaches a set pressure. Pressure regulators come in several types and configurations and they provide control in a variety of applications as shown figure below figure (3.7).

Fig(3.7)Regulator

6. Oxygen tank

An oxygen tank is an oxygen storage vessel As shown figure below figure (3.8).

Fig (3.8) Oxygen tank

7. The generator

It contains zeolite granules, and these granules in turn contain soft openings, so that oxygen passes to the top and nitrogen is confined to the bottom, and then it exits from the valve openings as shown figure below figure (3.9).

Fig (3.9) The generator

8. Flow meter

Oxygen flowmeter is equipment used to control oxygen flow delivery in patients undergoing oxygen therapy. Objective: To evaluate accuracy and precision of oxygen flowmeters used in adult care, as shown figure below figure (3.10).

Fig (3.10) Flow meter

9. Stan : As shown figure below Fig(3.11)

Fig (3.11) Stan

2. Working

The first time we installed the compressor, this compressor contains two air holes, and the beginning of this first hole is that there must be a filter, and this filter is itself a silencer.

When the air is drawn, the air enters the compressor and comes out of the compressor compressed, and according to the pressure that we need, which is needed by the device or what the patient needs. Of course, the air that comes out of the compressor is hot, so we will connect directly to the compressor. The dryer device. This dryer device contains a fan so that the dryer device cools and dries the air This work is very important for the zeolite granules so that they do not get damaged and the air for them is dry, As shown figure below Fig (3.12)

Fig (3.12) device work

After the dryer, we will connect a valve, and this valve is considered electronic and electrical, and this valve It contains five entrances. The first entrance is the entry from the dryer device, and now the valve has four exits. The first exit will go to the generator and a special place for the nitrogen exit of this first generator and the second exit is the second generator and an exit for the dryer device, As shown figure below figure (3.13).

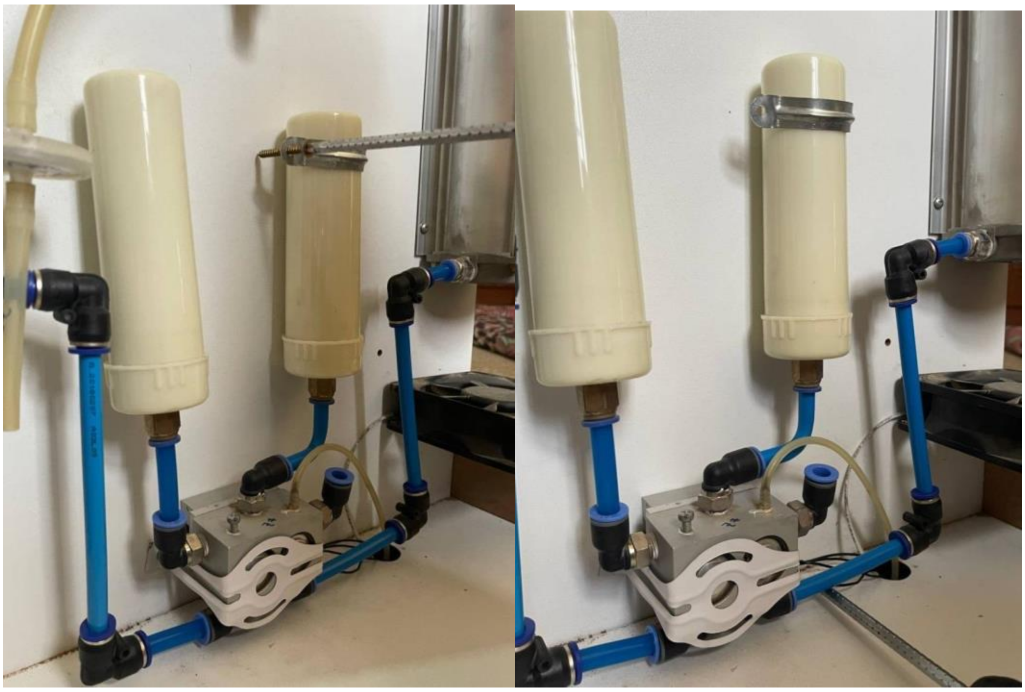


Fig (3.13) device work

Of course, the connectors are hoses that can withstand ten-bar pressure and high temperatures, and their quality is good.

The valve contains five openings; the first opening is for air entry and exit. Its function is to regulate the movement of air inside the generator.

I have 2 generators, so it is not reasonable to let the air pass through a random movement, this valve changes every 30 seconds to the generator, and as we indicated earlier, this valve contains one opening for the entry of air and four for the exit of air, so that there are two openings for the first generator and the other two openings for the second generator.

When the air enters the first generator, it is compressed inside the first generator for 30 seconds, after which it closes and opens on the second generator. During this closure, nitrogen gas is expelled from the nitrogen filter while it is at the bottom, and here the air is compressed inside the second generator during the process of expelling nitrogen from the first generator and then The reverse is done so that the second generator is closed, and the air is compressed inside the first generator, and so the process continues between the first generator and the second generator. Through this process, the air comes out of an opening from the opening of the first generator and from the opening of the second generator, and it exits from each generator to a tank so that there is a tank for the first generator and a tank for the second generator; during this process, oxygen gas was obtained.

Then we connect the rectifier, which in turn regulates the pressure so that I can set the device to a pressure of 2 liter per minute. This is a point.

The second point is that inside the tank, the pressure will be high, which means it reaches 10 litters per minute, and I do not need this amount, so the accelerator is used so that the pressure can be reduced as needed.

Here we put a hose and a filter to filter the air that goes to the patient

It also filters the water, as there can be water at the bottom of the tank through pressure, as shown figure below figure (3.14).

Fig (3.14) Generator work

Then we put the flowmeter, and this flowmeter, in turn, is designed according to the size of the compressor, which gives 5 liters per minute.

Experimental Work

A new device was introduced to measure the percentage of oxygen and measure the flow rate which is:

1. oxygen purity analyzer device

It is a device that measures and analyzes the purity of oxygen and determines its percentage if it is suitable for the patient or not. In addition, it helps doctors to know the percentage of gas inside the oxygen cannula by placing a tube in the sensor through which the oxygen gas passes and reads the purity percentage. In addition, it is possible to measure the percentage of oxygen and the purity of oxygen in the oxygen production device and see if this device gives pure oxygen and is suitable for patients or not, As shown figure below figure(4.1).

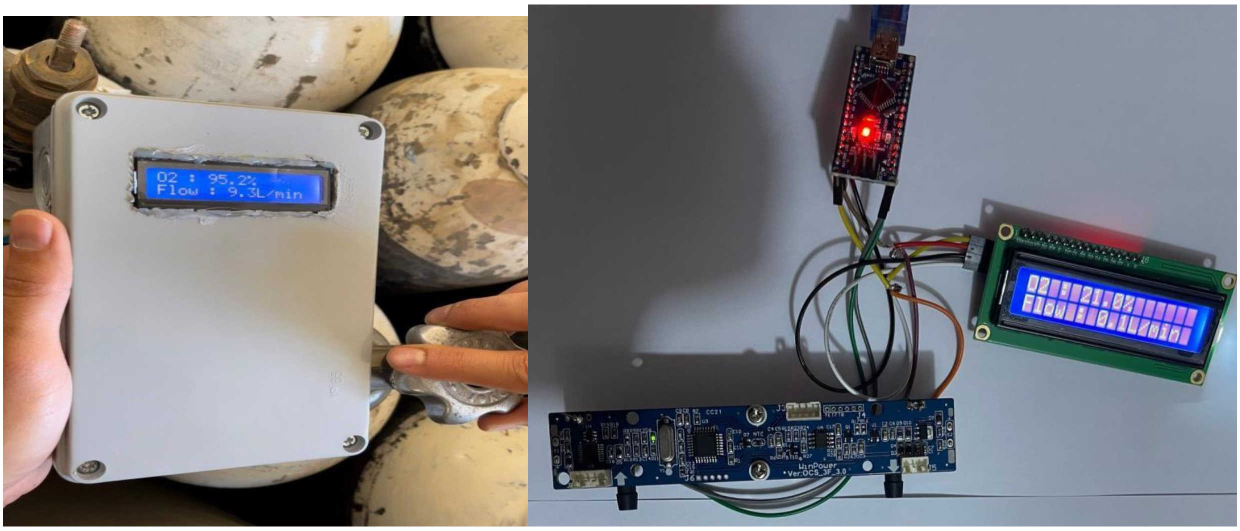


Fig (4.1) oxygen purity analyzer device

2. Results

The two devices were connected together, which is an oxygen generator. We turned it on for about a quarter of an hour until it worked and subtracted the nitrogen and gave us the oxygen. We have a meter called a flowmeter, this flowmeter gives from one to five liters per minute, this device was connected to the flowmeter and we changed it to one liter per minute and we took a reading (the flow reading plus the oxygen percentage reading) and then we changed it to number two and we recorded the readings and so on to number 6 From the stream, this device contains an Arduino and can store the readings, As shown figure below figure (4.2).

Fig (4.2)circuit connection

1. Measurements

Two readings doing to measure the purity of oxygen with the amount of flow. The first reading done without the presence of zeolite granules, and the second reading was made with presence of these granules. We notice that there is a clear difference between the two readings because of these granules. As shown in the tables below.

Measurement without zeolite granules

Reading	The flow (L/min)	O2 Rate
1	2.5	20.3%
2	3.5	21.0%
3	4.8	21.2%
4	6.7	21.0%
5	7.1	21.6%

Measurement with zeolite granules

Reading	The flow (L/min)	O2 Rate
1	2.5	90.3%
2	3.8	90.0%
3	4.5	85.5%
4	6.7	87.6%
5	7.3	84.1`%

3. Discussion

1. Performance Optimization: In the future, it would be beneficial to focus on enhancing the performance of the oxygen concentrator. This could involve exploring advanced technologies and materials to improve oxygen concentration efficiency, reduce power consumption, and increase the overall lifespan of the device. Research efforts could be directed towards optimizing the design of the concentrator's components, such as the compressor, sieve beds, and filters, to achieve greater reliability and efficacy.

2. Portable and Lightweight Design: The development of a portable and lightweight oxygen concentrator is an important area for future exploration. Currently, most oxygen concentrators are relatively bulky and heavy, limiting their mobility and usability for patients who require oxygen therapy on the go. Future research could focus on designing compact and lightweight concentrators without compromising performance, making them more convenient for patients to carry and use in various settings.

3. Noise Reduction: Noise generated by oxygen concentrators can be a significant concern, particularly for patients who require continuous oxygen therapy during sleep or in quiet environments. Future work could involve investigating noise reduction techniques, such as the use of sound-absorbing materials, advanced insulation, or quieter compressor designs, to ensure a more comfortable and peaceful user experience.

4. User-Friendly Interface: Enhancing the user interface and overall user experience of oxygen concentrators should be a priority in future research. This could involve developing intuitive and user-friendly control panels, incorporating visual indicators for easy monitoring of oxygen levels and operational status, and implementing smart features such as remote monitoring and data analysis to aid healthcare professionals in providing better care.

5. Integration of Connectivity and Data Analysis: With the advancement of Internet of Things (IoT) technologies, future oxygen concentrators could be designed to connect to a network, allowing seamless data collection and analysis. This connectivity would enable healthcare providers to remotely monitor patient usage, track oxygen saturation levels, and provide timely interventions when necessary. Additionally, data analysis could help identify patterns and trends in oxygen therapy, leading to improvements in treatment protocols and personalized patient care.

6. Environmental Impact and Sustainability: As the demand for oxygen concentrators increases, it is important to consider their environmental impact and explore sustainable practices. Future

research could focus on developing concentrators with energy-efficient components, using eco-friendly materials, and implementing recycling and disposal programs to minimize waste and reduce the carbon footprint associated with manufacturing and using these devices.

7. Clinical Studies and Validation: Conducting clinical studies and validation tests on oxygen concentrators is crucial for establishing their safety, efficacy, and long-term impact on patient health. Future research should involve extensive
8. Clinical trials involving diverse patient populations to evaluate the performance, durability, and health outcomes associated with oxygen concentrator use. These studies can help refine the device design, optimize therapeutic protocols, and guide regulatory decisions to ensure the highest standards of patient care.

By addressing these areas of future work, researchers can contribute to the continuous improvement and innovation of oxygen concentrators, ultimately enhancing the quality of life for patients who rely on these devices for oxygen therapy.

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