International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: V Month of publication: May 2022

DOI: https://doi.org/10.22214/ijraset.2022.43615

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

A Review of Portable Oxygen Concentrator

Anshul Mathur[1], Geetanjali Kapil[2], Deora Mukesh[3], Dinesh Chaudhary[4], Ishant Jangir[5], Gaurav Sharma[6], Yash Gotan[7]
[1]Assistant Professor, Department of Mechanical Engineering, Maharishi Arvind Institute of Engineering and Technology, Jaipur
[2,3,4,5,6,7] Students, Final Year, Department of Mechanical Engineering, Maharishi Arvind Institute of Engineering and Technology, Jaipur

Keywords: Zeolite, Silica Gel, HEPA Filter

I. INTRODUCTION

As we all have seen the pandemic situation in the world and the sudden oxygen crisis during the second and third waves of COVID-19, the Oxygen Concentrators came with hope for the patients struggling for oxygen during the crisis. Also, the number of patients with lungs diseases is increasing day by day due to air pollution. So, patients with respiratory problems are also in need of some efficient method of artificial oxygen production. But the oxygen concentrators available in the market were imported from other countries. Along with this, their prices were also sky-high, which makes them difficult to afford for the country's common man. A COVID-19 infected patient might need 5-16 liters of oxygen per minute. The oxygen concentrators use atmospheric air freely available in unlimited quantity in our surroundings and are also relatively safe. The ones which are available in the market contain zeolite pellets which are quite expensive. So, we are intended to develop an oxygen concentrator that uses silica gel, zeolite capsules, and a HEPA filter as the main components. The process of oxygen making through this system will be somewhat equally effective as the ones which are available on the market, and also it will be affordable to a good proportion of society.

An oxygen concentrator is a device that concentrates the oxygen from ambient air by selectively removing nitrogen to supply an oxygen-enriched produced gas stream. They are used industrially and also as medical devices for oxygen therapy for patients having lung infections and other respiratory diseases. (1)

Benefits offered by oxygen concentrators are: -

- Improves survival rates for respiratory conditions
- Improves mental attentiveness
- Increases stamina

Two methods commonly used are pressure swing adsorption and membrane gas separation. Pressure swing adsorption (PSA) concentrators make the use of multiple molecular sieves consisting of zeolite minerals that adsorb pressurized nitrogen in fast cycles. (1)

II. HISTORY

Home medical oxygen concentrators were invented in the early 1970s, with the produced output of these devices increase in the late 1970s. Union Carbide Corporation and Bendix Corporation were both the early manufacturers of oxygen concentrators. Before this, home medical oxygen therapy required the use of heavy high-pressure oxygen cylinders or small cryogenic liquid oxygen systems. Both of these oxygen delivery systems required regular home visits by the suppliers to replenish oxygen supplies. In the United States of America, Medicare switched from fee-for-service payment to a flat monthly rate for home oxygen therapy in the mid-1980s, causing the durable medical equipment (DME) industry to rapidly embrace concentrators as a way to control costs. This reimbursement change dramatically decreased the number of primary high pressure and liquid oxygen delivery systems in use in homes in the United States at that time. Oxygen concentrators became the preferred and most common means of delivering home oxygen. The number of manufacturers entering the oxygen concentrator market increased exponentially as a result of this change. 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. (1)

III. COMPONENTS OF PORTABLE OXYGEN CONCENTRATOR

The portable oxygen concentrator system is an assembly of several components like PVC cylinders, silica gel, zeolite capsules, HEPA filter, storage tank, oxygen sensor, and timer in a particular order and they are interlinked to each other.

The overall construction of this system is based on these components, which are briefly described as given below:

A. Silica Gel

Silica gel is a highly porous and non-crystalline form of silica that is used to remove moisture from gases and liquids, thicken liquids, provide a dull surface to paints and synthetic films, and for other purposes.

Silica gel was known as early as 1640, but it remained a curiosity until its adsorbent properties were found useful in gas masks during World War I. It is generally prepared by acidification of a solution of a silicate; the resulting silicic acid forms either a rigid mass or a gelatinous precipitate. Soluble materials are removed from it by washing it with water. The water present is removed by heating, leaving a glassy, granular solid. For the highest activity as a desiccant, the gel is not made completely dehydrated, instead, it is left with a small percentage of combined water. (2)

Fig.1 Silica Gel

B. Zeolite Capsules

Zeolites have unique and outstanding physical and chemical properties. These properties make them a lot useful in a variety of applications including agronomy, ecology, certain manufacturing, industrial processes, medicine, and cosmetics.

By origin, zeolites can be natural or synthetic (man-made) materials. They are aluminosilicate minerals with rigid anionic frameworks containing channels and cavities of a well-defined structure.

The variety of zeolites' application is originally a consequence of their porous structure: pores become negatively charged channels and cavities, which are occupied with positively charged alkali, and alkali earth monovalent (i.e., Na^+, K^+), and divalent (i.e., Ca^{2+}) ions, OH-groups or H_2O molecules, which can be easily exchanged by other molecules and cations from the surroundings.

13X zeolite is one of the microporous crystalline hydrophilic FAU and the sodium X zeolite type with large super cages and windows aperture pores of around 13 and 7.4 Å. Generally, the 13X zeolite is prepared by sodium aluminosilicate gels, using a wide range of silica and alumina sources via the hydrothermal synthesis route. Several researchers used 13X zeolite as adsorbent for CO_2, N_2, CH_4, and H_2 separation, as binderless 13X zeolite beads for bindery CO_2/CH_4 mixture separation, as CO_2 adsorbent in its modified state by amine-grafting, and as high-grade detergents due to its high magnesium ion exchange/removal capacity from water. (3)

Fig.2 Zeolite 13X Pallets

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C. HEPA Filter

HEPA filters or High-Efficiency Particulate Air filters are the primary technology used for particulate removal in individual and collective protection applications. HEPA filters are usually thought to be impenetrable, but they are 99.97% efficient at collecting the most-penetrating particle (approx. 0.3 micrometer).

"HEPA air cleaners, which are not commonly used in all hospitals, are a cheap and easy way to reduce risk from airborne pathogens," says David Fisman, an epidemiologist at the University of Toronto, Canada. (4)

The HEPA filter is made up of borosilicate microfibers in the form of pleated sheets. The HEPA filter media is a glass and polymer blend and is pleated to provide more filter material in a smaller space. The sheet is pleated to increase the overall filtration surface area needed for the filtration. The pleats are separated by serrated Aluminium baffles or stitched fabric ribbons, which direct the airflow through the filter. This whole combination of pleated sheets and baffles acts as a filtration medium. It is installed into an outer frame made of fire-rated particleboard which is made up of Aluminium, or Stainless Steel. The frame-media junctions are permanently glued or pot-sealed to ensure a leak. (5)

Fig.3 HEPA Filter

IV. WORKING

The purpose of an Oxygen Concentrator is to extract oxygen from the atmospheric air and supply it to the patient at an appreciable rate. So, the process employed in the system is achieved through the given procedure.

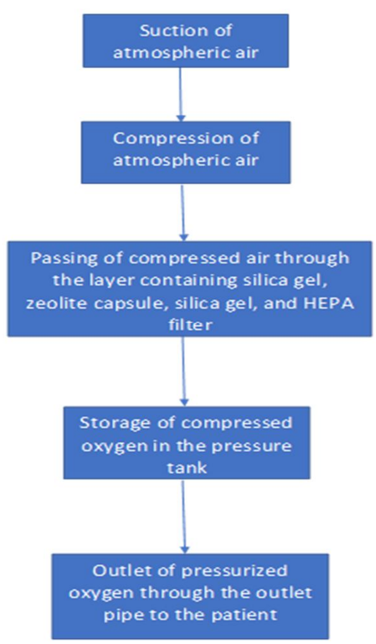

Fig.4 Flow Chart of Process Employed

The suction pump employed will be used for the intake of atmospheric air into the system. The air compressor will compress the air to the pressure of 4-5 bar. There will be a two-cylinder arrangement system in which silica gel, zeolite capsules, and HEPA filters are arranged in this series in both cylinders. The compressed air will pass through one of these cylinders at a time. The moisture gets separated from the air through silica gel. Silica gel does it by adsorption, that is, the water molecules adhere to its surface. Then the moisture-free air passes through the zeolite capsules. It helps oxygen to get separated from the rest of the constituents of the air. The separated oxygen needs to be filtered from all the impurities it is having. For this, it needs to be passed through the HEPA filters. They extract the dissolved impurities and make them pure. The obtained oxygen needs to be stored in a storage tank, where it gets a suitable environment to stay, being unreactive and stable. So, it gets stored in a storage tank. At the end of the outlet from the storage tank, there will be an oxygen mask through which the patient will be getting the appropriate amount of oxygen in the form of pulses.

V. APPLICATIONS

Medical oxygen concentrators are used in hospitals or at home to concentrate and supply oxygen for patients. PSA generators provide a cost-effective source of oxygen. They are safer, less expensive, and more convenient alternatives to tanks of oxygen or pressurized cylinders. They can be used in various industries including medical, pharmaceutical production, water treatment, and glass manufacture. PSA generators are particularly useful in remote areas or parts of the world that are not easily accessible or mobile medical facilities (military hospitals, disaster facilities). (6)

VI. CONCLUSION

It is an initiative to help people with medical problems, who find it difficult to respirate as a normal human being. It’s not just about the medical care, but also to make something that allows every citizen of this nation to get this medical facility at a pocket-friendly price, which doesn’t stop them to treat themselves and their loved ones due to monetary issues. The oxygen concentrators which are available in the market are imported from other countries. It is a step taken to reduce the dependency of the nation for such an essential facility and to reduce the load on the pocket of the common man of the nation. The motive is to provide an efficient and effective alternative to the imported oxygen concentrators and cryogenic oxygen cylinders used.

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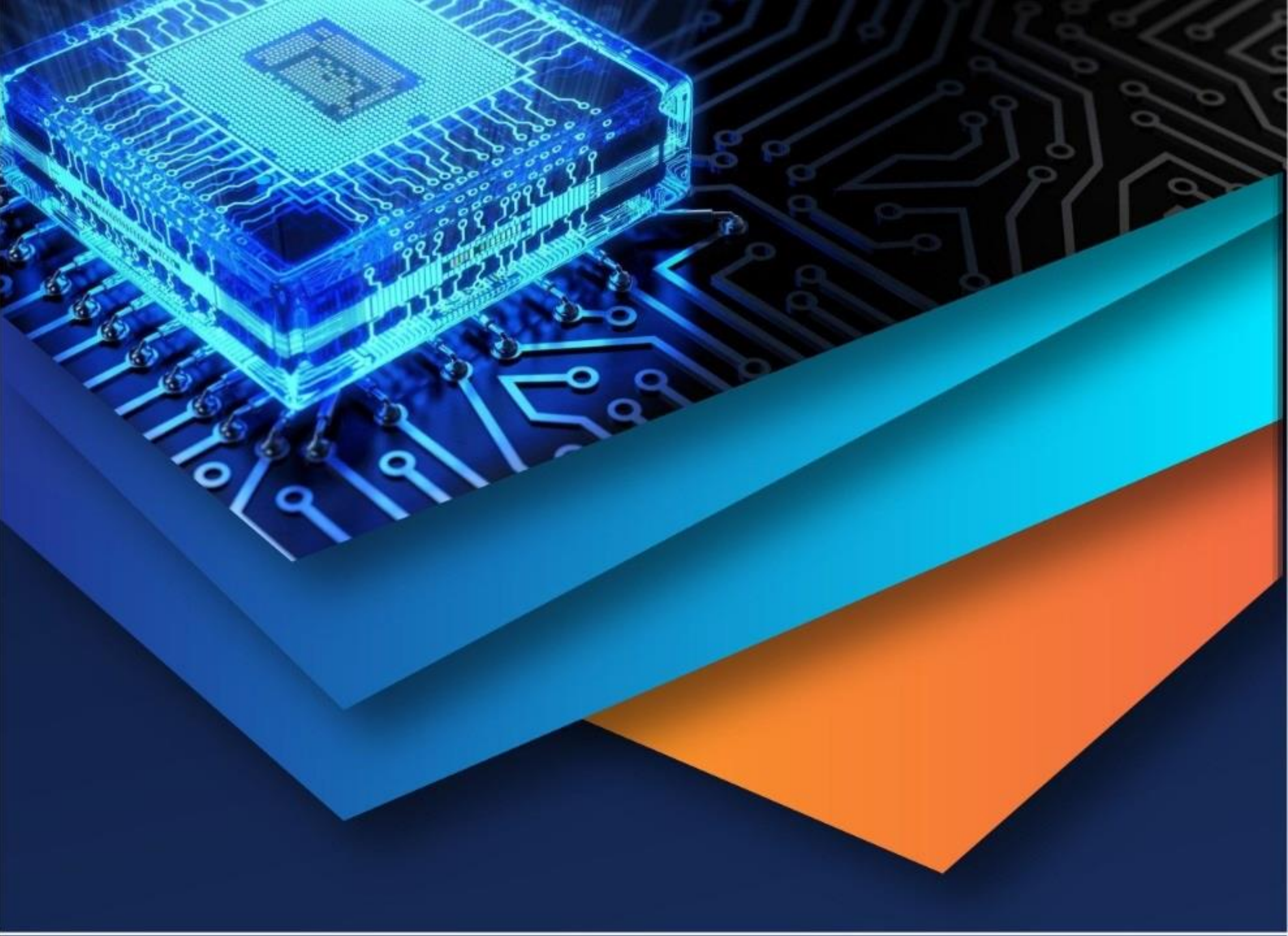

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