International Journal of Scientific Research and Modern Education (IJSRME)
ISSN (Online): 2455 – 5630
(www.rdmodernresearch.com) Volume I, Issue I, 2016

OXYGEN CONCENTRATORS – A STUDY

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Abstract:

Since the first day that life started on planet Earth the one element that has been consumed is Oxygen. Even though 21% of the Earth's atmosphere consists of molecular oxygen, it follows to reason that the demand for clean, pure oxygen must always exceed its supply. But does it? An oxygen concentrator is a device currently in use in various fields to bridge this very gap. Using the simple process of adsorption, oxygen enriched air can be obtained from a supply of ambient air. Current technology advocates the use of the Pressure Swing Adsorption (PSA) method utilizing various adsorbents, mostly zeolites to obtain upto 99% pure oxygen. The applications are endless ranging from small nursing homes to huge industries and of course global environmental improvement.

Key Words: Oxygen Concentrator, PSA, Adsorbents & Global Environmental Improvement.

Introduction:

Oxygen concentrators typically use pressure swing adsorption technology and are used very widely for oxygen provision in healthcare applications, especially where liquid or pressurized oxygen is too dangerous or inconvenient, such as in homes or in portable clinics.Oxygen concentrators could also be used to provide an economical source of oxygen in industrial processes, where they are also known as Oxygen Gas Generators or Oxygen Generation Plants [4].

The major technique currently employed is the Pressure Swing Adsorption (PSA) technique. Pressure swing adsorption processes rely on the fact that under high pressure, gases tend to be attracted to solid surfaces, or "adsorbed". The higher the pressure, the more gas is adsorbed; when the pressure is reduced, the gas is released, or desorbed. PSA processes can be used to separate gases in a mixture because different gases tend to be attracted to different solid surfaces more or less strongly. If a gas mixture such as air, for example, is passed under pressure through a vessel containing an adsorbent bed of zeolite that attracts Nitrogen more strongly than it does Oxygen part or all of the Nitrogen will stay in the bed, and the gas coming out of the vessel will be enriched in oxygen. When the bed reaches the end of its capacity to adsorb nitrogen, it can be regenerated by reducing the pressure, thereby releasing the adsorbed nitrogen. It is then ready for another cycle of producing oxygen enriched air [5].

Detailed Working:

The process operates by using adsorbents to separate air components. The main equipment required in PSA is a compressor, a silica gel bed, two adsorption columns, and a storage tank. A compressor is required to supply the required volume of atmospheric air to produce the desired purity and output flow rate of oxygen. A silica gel bed is used to remove water vapor and impurities such as carbon dioxide and carbon monoxide. Two adsorption columns are used to allow for a semi-continuous supply of product. A storage tank allows for product storage for later use. The two columns operate semi-continuously in four stages to supply the desired purity and flow rate of oxygen. Adsorbents are selectively chosen to provide for the most beneficial design. The PSA stage operation is described in figures as shown below:

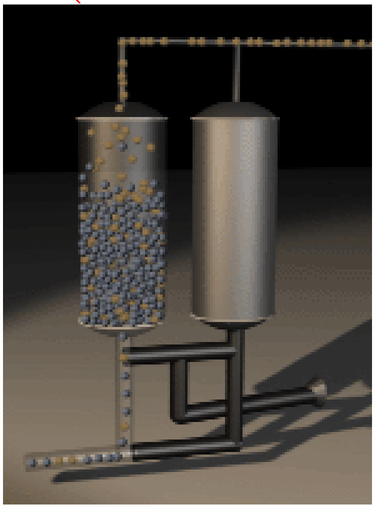

Figure 1: PSA Stage 1

Stage 1: Compressed air is fed into the first bed. Nitrogen and argon molecules are trapped, while oxygen is allowed to flow through.

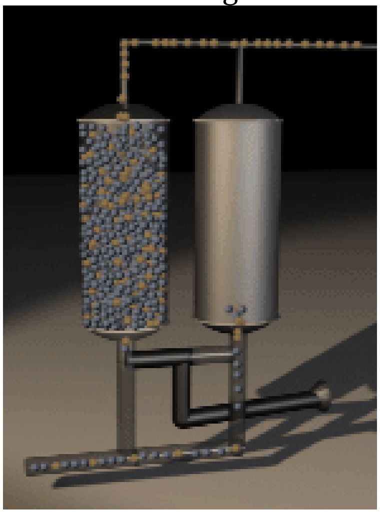

Figure 2: PSA Stage 2

Stage 2: When the adsorbent in the first bed becomes saturated with nitrogen and argon, theairflow feed is directed into the second bed.

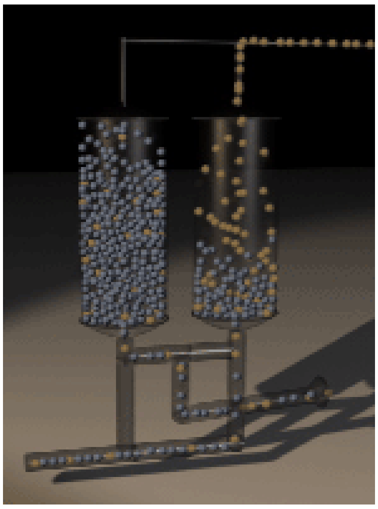

Figure 3: PSA Stage 3

Stage 3: The adsorbent adsorbs nitrogen and argon in the second bed. The first bed isdepressurized allowing argon and nitrogen to be purged out of the system and released to the atmosphere or collected for further use.

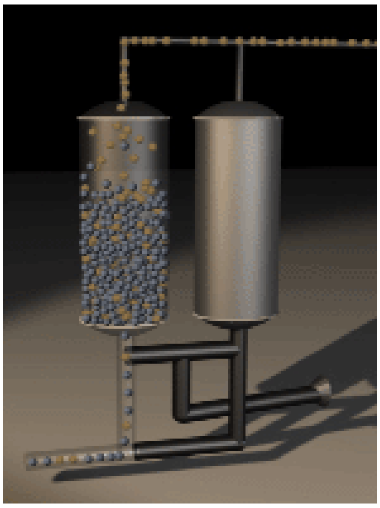

Figure 4: PSA Stage 4

Stage 4: The process starts over. Compressed air is once again fed into the first bed. Thesecond bed is depressurized releasing argon and nitrogen molecules to the atmosphere. The process is repeated continuously producing a constant flow of purified oxygen.

Adsorbents for Pressure Swing Adsorption:

1. Silica Gel:

Silica gel is used in a pretreatment bed to remove water vapor and impurities such ascarbon dioxide and carbon monoxide before the air feed stream enters the adsorbent beds. Water strongly adheres to the cation sites within each zeolite rendering them useless and ineffective. Silica gel beds are necessary to remove water vapor from the air. Air at 100% humidity has approximately 3% of water vapor. Once the bed is saturated with water, the bed is heated with a heating coil to evaporate the water from the silica gel [1].

2. Zeolites:

Zeolitesare microporous crystalline structures that govern the molecules that areadsorbed during the PSA process. The shape-selective properties of zeolites are the basis for their use in molecular adsorption. The different structures of the zeolite indicate the type of molecules that the zeolite will adsorb [1].

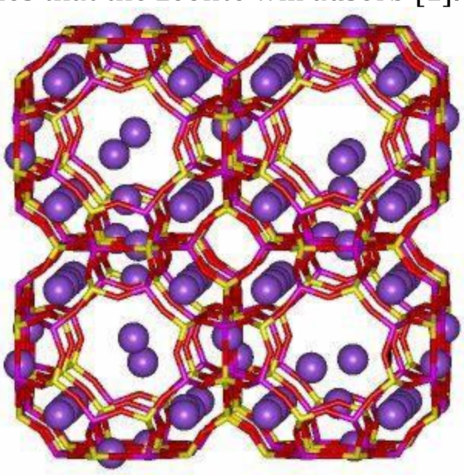

Figure 5: Zeolite structure

Zeolites have various ways of controlling adsorption. The size and shape of pores can control access into the zeolite. In another case different types of molecule enter the zeolite, but some diffuse through the channels more quickly while others are left behind and do not pass through. Cation-containing zeolites, such as silver zeolites, are extensively used in gas separation processes. These cations are indicated as the purple spheres in the figure above. Molecules are differentiated on the basis of their electrostatic interactions with the metal ions. Zeolites can thus separate molecules based on differences of size, shape and polarity.

Ion exchange is another aspect of zeolites that aids in the separation process. Ion exchange involves adding metal cations to the structure of the zeolite to attract certain molecules. Calcium is the most common metal cation exchanged in zeolites, but new studies have found silver exchanged zeolites to be more effective in air separation. For zeolites to be affective, metal cations must be bound to the structure such as calcium, sodium, and in our case silver. Silver exchanged zeolites are a relatively new type of zeolite used in separation. The silver metal cation is placed in the structure of the zeolite structure as shown below. Zeolite structure types of A, X, and Y are the dominant types used in commercial use for adsorption and ion exchange.

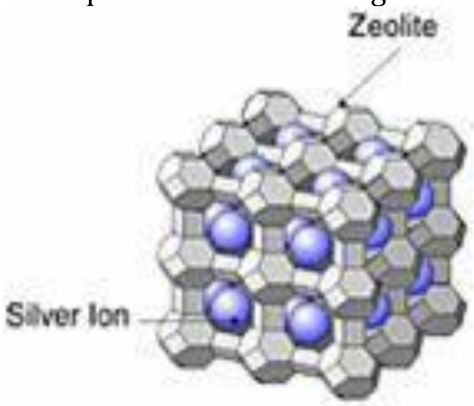

Figure 6: Zeolite A with Silver Ion

With this type of arrangement nitrogen and argon are attracted to the silver ion by electrostatic forces because of their polarization properties.

(i) LiAgX Zeolite:

Research of air separation using PSA shows zeolite LiAgX currently has the bestperformance of removing nitrogen in air separation processes. The LiAgX has structure type X which is shown in the figure below [3].

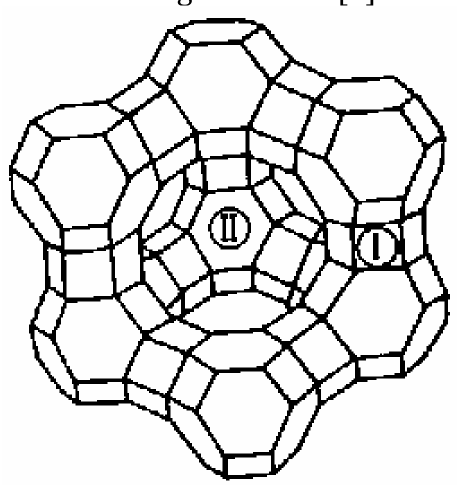

Figure 7: Zeolite X structure

(ii) AgA Zeolite:

Silver-exchanged zeolite A shows a strong adsorption of nitrogen as well as argon. For the separation of oxygen from nitrogen and argon, the zeolite structure A is the best structure. It allows for the best interaction between the ion in the zeolite and the nitrogen and argon molecules [3].

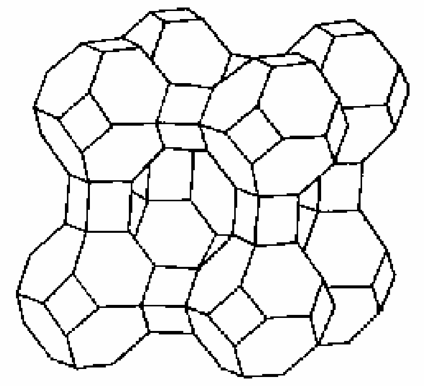

Figure 8: Zeolite a structure

AgA zeolite has a selectivity of argon to oxygen as 1.63 to 1 at atmospheric pressure Nitrogen to oxygen selectivity is lower in this AgA zeolite when compared to the LiAgX zeolite previously discussed [3].

The overall process flow diagram is shown below. The pressure swing adsorption design consists of atmospheric air feed, a compressor, two adsorption columns, a high pressure storage tank, two 3-way valves, and two 2-way valves.

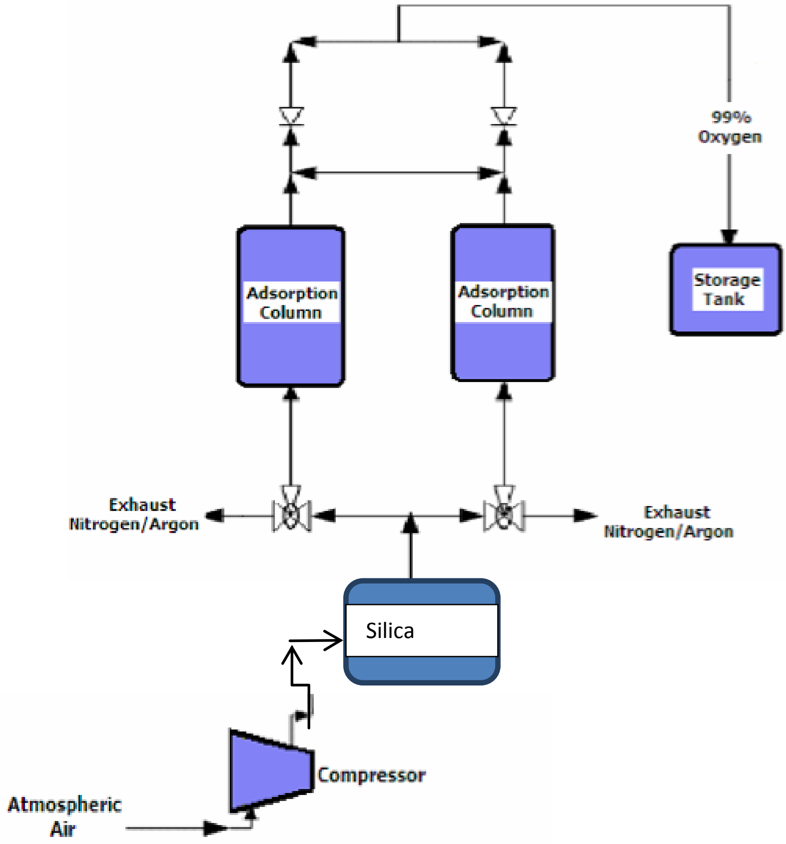

Figure 9: PSA Process Flow Diagram

Applications:

(i) Bio-Medical Application:

Oxygen concentrators running on PSA technology are being widely used to provide pure oxygen to patients in need. It is fast replacing oxygen cylinders for the supply of oxygen in hospitals in the western countries. It is also used to provide a continuous supply of fresh air through masks to military personnel flying at very high altitudes.

(ii) Glass works industries:

In the manufacture of glass, very high temperatures are needed to attain high quality clear glass. Currently bellows/blowers are used to supply ambient air to the furnace. If oxygen concentrators could be used instead, higher temperatures could be attained due to greater rates of combustion as a result of greater availability of oxygen.Not only glass works; it can also be used in any furnace-related operation, if cost permits.

(iii) Lake Regeneration:

Prepared bacterial cultures are generally used in order to break down organic wastes and to reduce the presence of harmful anaerobic microorganisms, which results in dead lakes. Often these bio-cultures are unable to succeed due to presence of heavy competition from the above-mentioned sources. Now, if oxygen concentrators are used to increase the level of oxygen present in these lakes, it will promote the growth of the bio-culture resulting in lake regeneration over the period of time. This method has been successfully implemented to regenerate Lake Tahoe Basin, California USA.

(iv) Ozone Generation:

Air is usually used as feed stream for Ozone Generators. Since air contains only 21% Oxygen by volume, the efficiency of the ozone generators is quite poor. If Oxygen Generators are used to supply highly pure oxygen as the feed, efficiency and performance of these generators will increase greatly. Currently, very high capacity generators are being used to produce ozone, which is let out into the atmosphere at the Antarctic Ozone Hole. Oxygen concentrators are employed in order to supply the feed there.

Conclusion:

The scope of this technology is thus immense in the environmental and the health sectors. It opens up exciting avenues for a country like India where the problems are many and solutions are few.

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