Efficient Low Cost Oxygen Generation Technique

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Abstract: *In present situation there is acute shortage of medical oxygen. Producing large volumes of life saving oxygen at high purity and low cost is of utmost importance . Some Methods of oxygen generation are Pressure Swing Adsorption, Cryogenic Air Separation, Ion Transport Membrane. PSA devices are suited for producing small volume of oxygen, on the order of 10 tonnes per day. Cryogenic Air Separation Unit is used for producing for large volume of oxygen but this method involves high cost. As compared with Cryogenic Air Separation method Ion Transport Membrane is more efficient and produces large volume of oxygen at low cost with highest purity oxygen (>99.5%)*

Keywords Medical Oxygen, Ion Transport Membrane, cryogenic Air Separation, Oxygen Production

Description of Oxygen Production Methods

Pressure Swing Adsorption

Pressure swing adsorbers (PSA) devices draw air from the atmosphere into a pressurised tank. Zeolites can be found inside the tank. Zeolites have the ability to distort and produce a dipole when put under strain. This dipole enables for the capture of nitrogen while allowing oxygen to pass depending on the zeolite used. The PSA is normally pressured to a minimum of 1.5 atm for oxygen enrichment. After the certain volume of air has been separated, the zeolite becomes nitrogen-saturated. It is necessary at this time to be rejuvenated This is accomplished by lowering the tank's pressure to atmospheric levels. As a result, the polarity of the zeolite is restored. This allows the nitrogen to escape. The pressure in the tank is reduced to sub-atmospheric levels by vacuum pressure swing adsorbers (VPSA), which improves the regeneration process. While one tank is regenerating in both processes, another tank is normally charging. This enables for continual oxygen generation. While PSAs can approach 99.9% accuracy, the expense of rising above 99.5 percent in a PSA device increases drastically. Furthermore, PSA devices are best suited for producing small volume of oxygen, on the order of 10 tonnes per day. Because the output of oxygen is mostly controlled by bed size in PSA systems, expenses climb linearly as more oxygen is required.

Cryogenic Air Separation

Cryogenic air separation units (ASU) is an old method of producing high purity oxygen in large quantities. The method is based on the fact that the boiling temperatures of air's elements vary. At around -300^{o}F, this separation occurs. Further distillation is required if better purity oxygen or liquid oxygen is required. To chill liquid oxygen even further, nitrogen is employed as a heat transfer fluid.Cryogenic separation is effective when one or more of the following conditions is needed: high purity oxygen (>99.5%), large volumes of oxygen (>10^2 tonnes per day), or both. But only problem with cryogenic separation is its high cost [1]

Low Cost Oxygen Supply Methods

Along with Running costs and purity the intended volume is also a major factor in determining which air separation unit is ideal for a given industry. Fig.1, shows which technology is most suited when all other factors are taken into account.

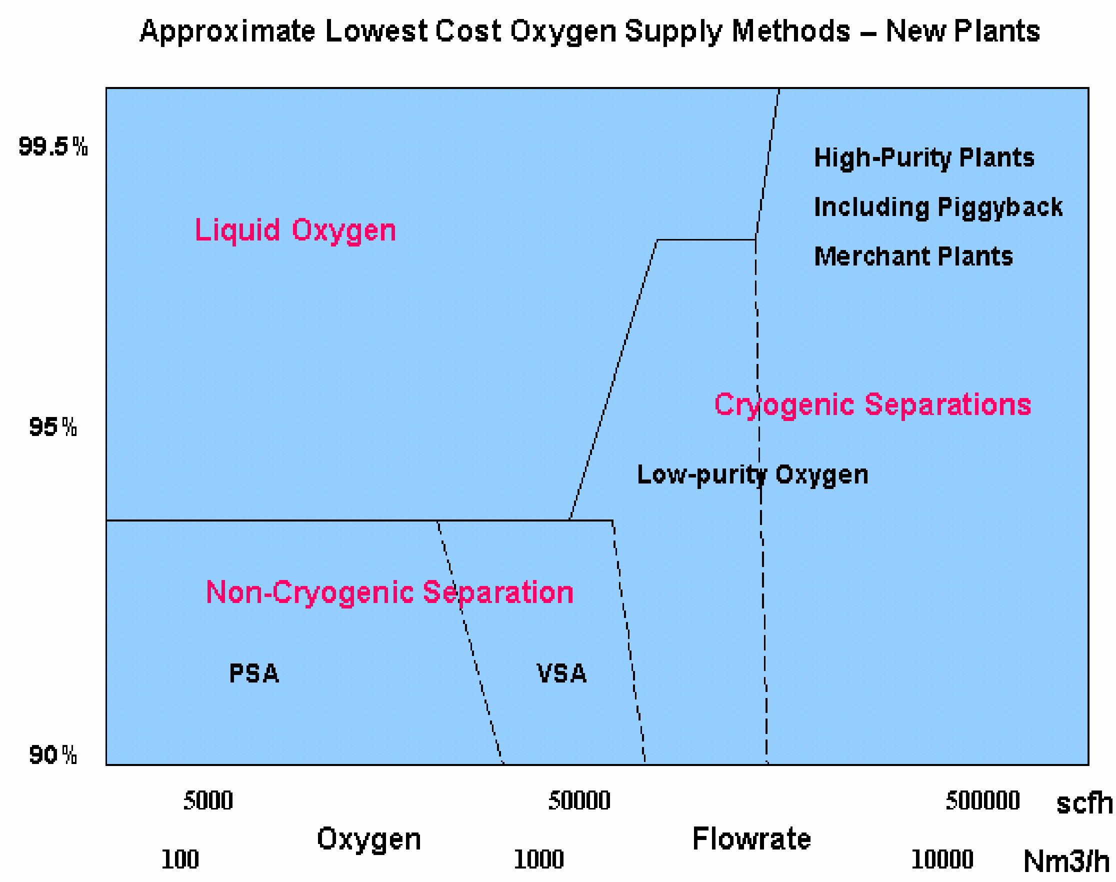

Fig.1 Analysis of Oxygen Supply Methods

Three factors are measured against each other (volume, purity, and cost). It should be emphasised that future improvements in zeolites will very certainly cut the cost of PSA systems [Smith 2001].Because there are few projected breakthroughs in cryogenic air separation, expenses are projected to remain stable. PSA/VPSA is ideal for low volumes and low purity oxygen requirements, as shown in Fig 1. When high flow rate and high purity oxygen are required, cryogenic separation is used. Finally, if the facility requires high purity oxygen at low rates, liquid oxygen supply option. The term "piggyback merchant plants" refers to a plant's ability to create enough high purity oxygen for both itself and local merchants who require it. When the plant only requires small amounts of high-purity oxygen, this is a viable option. But it is not suitable for high volumes of oxygen.

Membrane Technology

Alternative technologies for O_2 production were required due to the substantial efficiency penalty associated with using cryogenic O_2 separation units in oxy-combustion systems. Ion transport membranes (ITMs) are one of these ways for separating O_2 from air. These ITMs can extract oxygen from air at high temperatures (above 700 degrees Celsius). The kind of membrane, thickness, operating temperature, and differential in oxygen partial pressure across the membrane all influence oxygen permeability through ion transport membranes.Air is passed via a membrane filter in traditional membrane technology. Fast gases will pass through the filter, while slow gases will be trapped. Nitrogen and argon are considered slow gases, while oxygen is considered a rapid gas. By adjusting the amount of time the gas spends undergoing filtering, different levels of purity can be attained. Previously, membrane technology could only achieve purity levels of around 50%. Membrane technology provides a fast start-up time and works in close to ambient settings. Air Products and Chemicals, in collaboration with the US Department of Energy and Ceramatec, developed the ion transport membrane (ITM). According to reports, this method can create 99 percent pure O_2 at a fraction of the expense of cryogenic separation. [Dyer,2000] SEOSTM Oxygen Generator, ITM Oxygen, and ITM Syngas are three different ITM technologies that have been created. Electrochemical cell stacks make up the SEOSTM system.

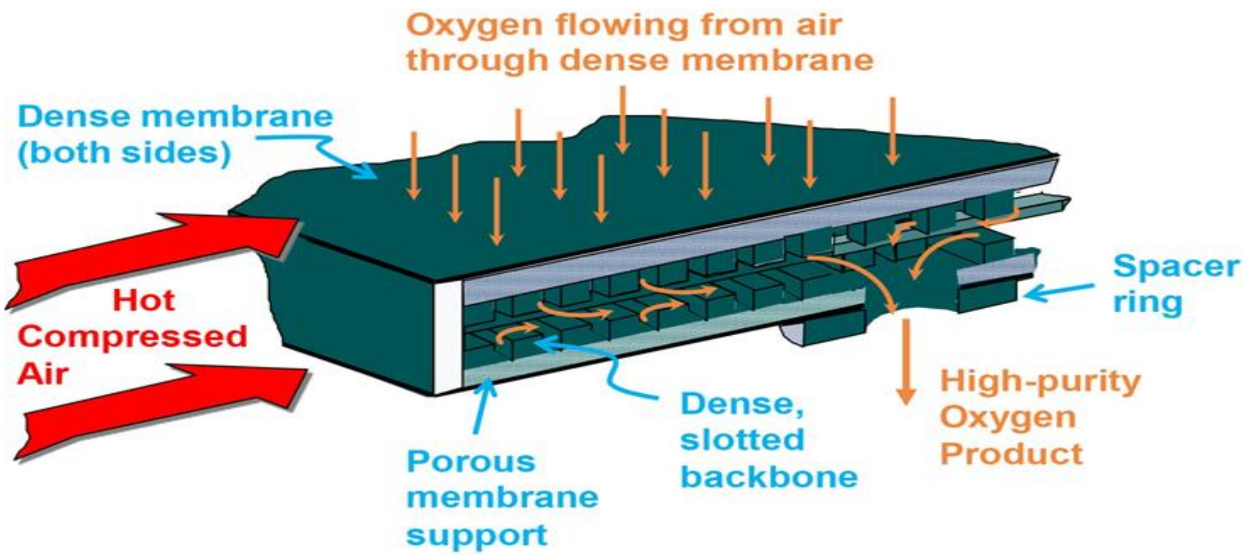

Fig.2. Ion Transport Membrane System

A voltage is delivered to these cell stacks after they have been heated to about 600 ^{0}C. The oxygen in the feed air is ionised, recombined, and collected at an outlet under this electric potential. [Dyer,2000] ITM Oxygen can produce oxygen streams with extremely high purity (above 99.9%) and volume (equal to cryogenic slurry volumetric flow). It takes in air with a high pressure and a high temperature This air passes through a ceramic membrane constructed of oxygen-depleted metals. Because of the difference in oxygen partial pressures across the membrane, the oxygen is ionised and diffuses across the membrane. The procedure solely filters oxygen because the membrane is not drawn to any other chemicals [Allam 2002]. Cryogenic separation units face competition from ITM Oxygen. Air Products connected an ITM Oxygen supply to an IGCC plant and a cryogenic air separation unit to another.

Area Description	Ion Transport Membrane Oxygen Plant	Cryogenic Air Separation Unit
Oxygen Plant	41600	61200
$/metric tonne per Day Oxygen produced	14300	22200

Table 1: Comparison of Ion Transport Membrane System and Cryogenic ASU

(Costs are represented in thousand US Dollars)

The cryogenic air separation unit cost $61.2 million to install, compared to $41.6 million for the ITM technology. Furthermore, the ITM plant produced oxygen for $14,300 per tonne of oxygen per day, in comparison with $22,200 per tonne of oxygen per day for the cryogenic facility.

Conclusion

Immense oxygen flow, high selectivity, and good integration with high-temperature energy applications are all advantages of ITM technology. The installation cost of the Ion Transport Membrane technology cryogenic air separation unit was very low as compared with cryogenic air separation unit .The ITM plant produced oxygen at a low cost in comparison with the cryogenic plant. Advancements in membrane materials will surely lower the costs of all membrane technologies

References

[1] Smith A.R. and J. Klosek. "A Review of air separation technologies and their integration with energy conversion processes", Fuel Processing Technology 70 (2001) p.115-134.

[2] Dyer, Paul N., Robin E. Richards, Steven L. Russek, and Dale M. Troyer. "Ion transport membrane technology for oxygen separation and syngas production", Solid State Ionics 134 (2000) 21-33.

[3]Allam, Rodney J., Edward P. Foster, and VanEric E. Stein. April 2002. "Improving Gasification Economics through ITM Oxygen Integration." For the 5th (IChemE) European Gasification Conference. Noordwijk, The Netherlands.

[4] Ben Mansou., Habib M. Badr H.M., Azharuddin,Nemitallah, ''Characteristics of oxy-fuel combustion in an oxygen transport reactor''. Energy Fuels 26(7), 4599–4606 (2012)

[5] Samart, S. et.al.''Perovskite membrane reactors, ''fundamentals and applications for oxygen production, syngas production and hydrogen processing.''.Woodhead Publishing, Cambridge (2014)

[6] Hashim S.S., Mohamed A.R., Bhatia S, ''Oxygen separation from air using ceramic-based membrane technology for sustainable fuel production and power generation''. Renew. Sustain.Energy Rev. 15(2), 1284–1293 (2011)

[7] Islam M.S., Cherry M., Catlow C., "Oxygen diffusion in LaMnO3 and LaCoO3 perovskite-type oxides: a molecular dynamics study''. J. Solid State Chem. 124(2), 230–237 (1996)

[9] Bouwmeester H.J ., Kruidhof, H., Burggraaf, A.J. "Importance of the surface exchange kinetics as rate limiting step in oxygen permeation through mixed-conducting oxides". Solid State Ionics 72, 185–194 (1994). (part 2)

[10] Steele, B.C "Oxygen ion conductors and their technological applications". Mater. Sci. Eng. B 13(2), 79–87 (1992)

[11] Allam, R.J. "Improved oxygen production technologies". Energy Procedia 1(1), 461–470 (2009)

[12] Gellings, P.J., Bouwmeester H. The CRC Handbook of Solid State Electrochemistry. CRC Press, USA (1997)

[13] Habib M.A., et al. "A review of recent developments in carbon capture utilizing oxy-fuel combustion in conventional and ion transport membrane systems". Int. J. Energy Res. 35(9), 741–764 (2011)

[14] Xu, S.J., Thomson, W.J., "Oxygen permeation rates through ion conductingperovskite membranes". Chem. Eng. Sci. 54(17),3839–3850 (1999)

[15] Sunarso J. et.al., "Mixed ionic–electronic conducting (MIEC)ceramic-based membranes for oxygen separation". J. Membr. Sci. 320(1–2), 13–41 (2008)

[16] Bernardo, P., Drioli, E., Golemme, G."Membrane gas separation:a review/state of the art". Ind. Eng. Chem. Res. 48(10), 4638–4663(2009)

[17] Leo, A., Liu, S., da Costa, J.C. "Development of mixed conducting membranes for clean coal energy delivery". Int. J. GreenhouseGas Control 3(4), 357–367 (2009)

[18]Wang H. Yang,W."Oxygen permeation study in atubular Ba0.5Sr0.5Co0.8Fe0.2O3-d oxygen permeable membrane". J. Membr. Sci. 210(2), 259–271 (2002)

[19] Engels S. et al. "Oxygen permeation and stability investigationson MIEC membrane materials under operating conditions for power plant processes". J. Membr. Sci. 370(1–2), 58–69 (2011)

[20] Li.,et.al. "Enhancing the oxygen permeation rate of Ba0.5-Sr0.5Co0.8Fe0.2O3–d membranes by surface loading Co_3O_4 nanorod catalysts." Surf. Coat. Technol. 276, 47–54 (2015)