Project Title :- Manufacturing of Oxygen and Nitrogen by Linde and PSA Process.

Group Number :- 19

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Use And Economics

In 1953, the production of high-purity oxygen (99.5% and above) reached 25.3 billion cubic feet, a fivefold increase from 1939. The majority, about 24.5 billion cubic feet, was obtained through air liquefaction, with the rest from water electrolysis. Oxygen shipments in 1952 were valued at $63 million, accounting for 80% of all elemental gases.

The primary use of oxygen is in steel operations like welding, cutting, and scarfing. Lower purity or tonnage oxygen (90-95%) is used in chemical manufacturing and in some steel production processes to raise temperatures and accelerate production. Recent improvements in the Linde, Frankl, and other designs have reduced the minimum economical production from 100 tons per day to smaller amounts.

Nitrogen production in 1952 was 2,699,000,000 cubic feet, mainly used in ammonia synthesis. It is also used as a protective atmosphere in metal annealing, to prevent oxidation in food products and welding areas, as a reagent, and as a grinding aid for hard or heat-sensitive materials.

Introduction

Separation of gas is important in many industries, this allow extraction and purification of gases for range of applications. Two important process for gas separation are Linde process and Pressure Swing Adsorption (PSA).

The Linde process, is method for production of oxygen commercially, this process helps to extract high-purity oxygen and nitrogen from atmospheric air. This process involve compression of air and further purification to remove impurities like CO2, moisture. Then we need to further liquefy air and separate its constituents with help of various methods such as Joule-Thomson effect and adiabatic expansion. This process was developed by Carl von Linde in 1900. This process make use of double-column setup for liquefaction and rectification.

Other method is Pressure Swing Adsorption (PSA), principle of this method is making use of adsorption and desorption of gases on a solid surface. It is used to separate hydrogen, carbon dioxide and methane from air. It comparatively energy efficient and economical. It is used in many industries like petrochemical, food industry etc.

Both the methods are required for efficient and economical way of gas separation. Understanding both methods is necessary for chemical engineers, process designers. This report will include about both processes and their comparison.

Oxygen :_

• Oxygen was independently discovered by Carl Wilhelm Scheele and Joseph Priestley in 1773 and 1774 respectively, but the work was first published by Priestley.
• Antoine Lavoisier named it oxygen in 1777, and his experiments with oxygen helped to discredit the then popular phlogiston theory of combustion and corrosion.
Oxygen is produced industrially by-
• Cryogenic Separation: fractional distillation of liquefied air
• Absorptive Separation: use of zeolites/silica gel with pressure-cycling to concentrate oxygen from air
• Electrolysis of water: used only to an insignificant extent
• Membrane Separation

Nitrogen :-

• Nitrogen is a chemical element that occurs in all living organisms, primarily in amino acids, proteins and in the nucleic acids (DNA and RNA).
• The human body contains about 3% by weight of nitrogen, the fourth most abundant element after oxygen, carbon, and hydrogen.

• Nitrogen was discovered by Daniel Rutherford in 1772, who called it noxious air or fixed air.
• He also explains that nitrogen does not support combustion

Definitions : -

Critical temperature is the temperature above which a substance cannot exist in a liquid state, regardless of the pressure applied .

Critical pressure is the pressure required to liquefy a gas at its critical temperature .

Liquefaction is the process of converting a gas into a liquid state by cooling or increasing the pressure of the gas until it condenses

Joule-Thomson Effect :- If a gas is allowed to expand through a fine nozzle or a porous plug , so that it issues from a region at a higher pressure to a region at lower pressure , there will be a fall in temperature of the gas provided the initial temperature of the gas is sufficiently low

Linde's Process

Linde's process is also known as adiabatic expansion of compressed gas.
The process is based upon Joule-Thomson effect, which states , "When a gas under high pressure is allowed to expand adiabatically through a fine hole into a region of low pressure, it is accompanied by cooling"
History And Development :- The Linde process, developed by Carl von Linde in Germany around 1900, revolutionized the industrial production of oxygen. It can produce high- quality oxygen and nitrogen from atmospheric air.

Process :-

1. **Air Compression**: Atmospheric air is first drawn into the process and compressed to about 200 atmospheres using multistage compressors. This compression increases the air temperature significantly.

2. **Air Cooling and Moisture Removal:** The compressed air is then cooled and the moisture is removed. Cooling is achieved using water-cooling between compression stages and further cooling to around 10 to 30°C using ammonia refrigeration. Any moisture that condenses out during this process is removed by passage through a tower packed with solid KOH or activated alumina.

3. **Further Cooling to Liquefaction**: The air, now at 200 atm and -30°C, is further cooled to its liquefaction temperature. This cooling is critical for the subsequent liquefaction of air components.

4. **Liquefaction and Separation**: The cooled, compressed air is then fed into a combined liquefier and separator unit. Here, the air is liquefied and separated into its constituents, oxygen, and nitrogen. This can be made possible due to difference in the boiling point of both the gases, -183 C for oxygen and -195.8 C for nitrogen.

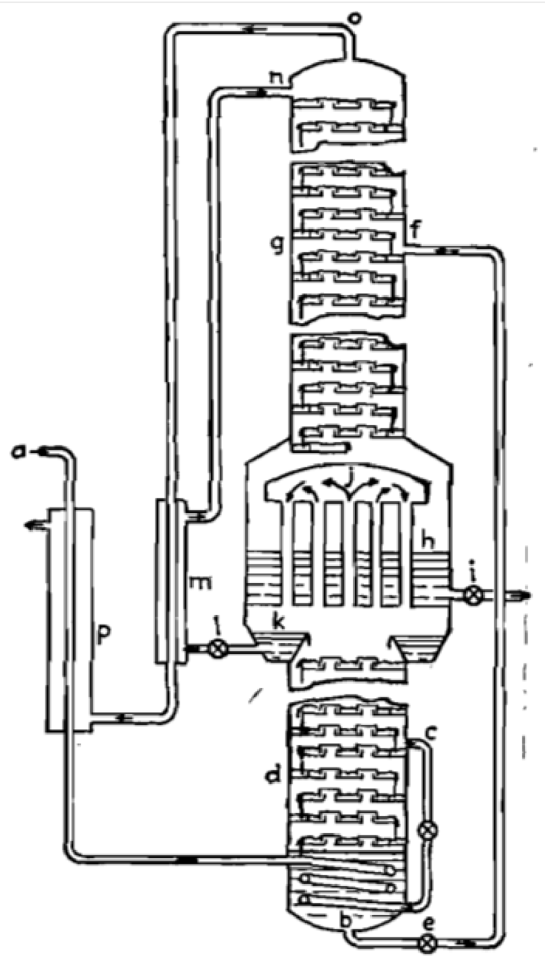
5. **Fractional Distillation**: The air which was liquefied goes under fractional distillation in a distillation column. This allows separation of both the gases because of their different boiling points. Nitrogen being more volatile boils first and is collected at the top, oxygen being less volatile boils later.

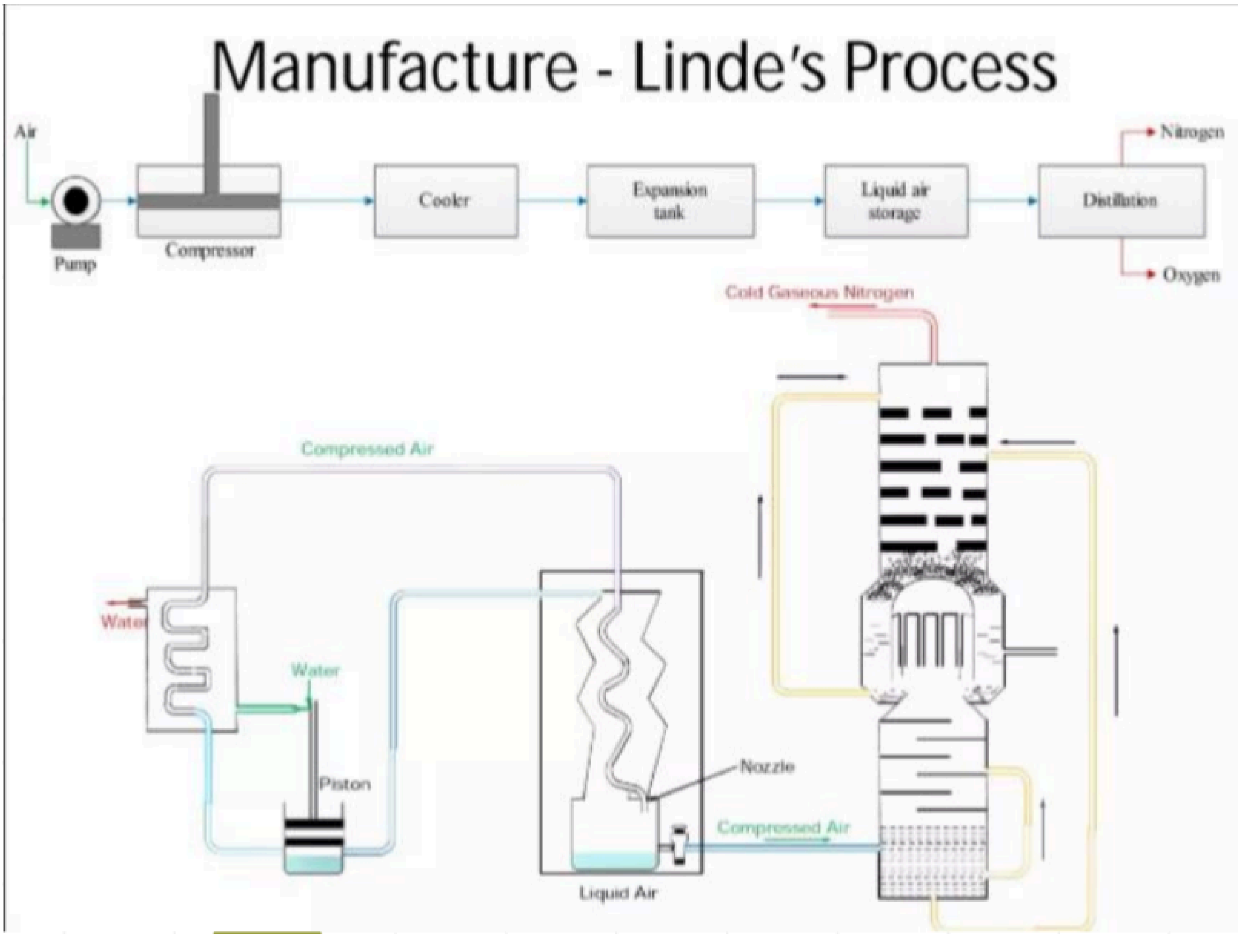
6. **Joule-Thomson Effect**: Joule Thomson plays important role in separation of both gases. This is a cooling effect which result in drop of temperature, when compressed gas expands through a valve.

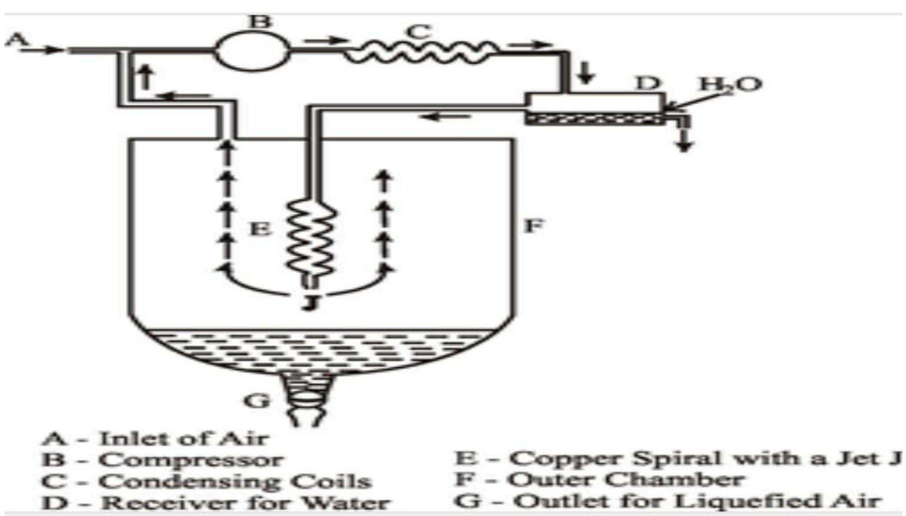
7. **Double-Column System**: This is the most important part of the process, it consists of two columns for rectification. Oxygen and Nitrogen separates out more efficiently.

8. **Storage and Distribution**: Oxygen and Nitrogen which were separated in previous steps are stored in double-wall vacuum containers. Air is continuously fed into the system, gases are then used in various industries.

a. Entrance for compressed air at 200 atm.
b. Accumulated liquid rich in oxygen
c. Cooled and liquefied air entering lower column
d. Lower rectifying column
e. Exit valve for liquid, 40 ± per cent oxygen
f. Liquid entering upper column
g. Upper rectifying column
h. Accumulated oxygen liquid
i. Exit valve for oxygen, 99 + per cent pure
j. Condensing tubes and dome for lower column
k. Condensed overhead from lower column, rich in nitrogen
l. Release valve for flow to upper column
m. Heat exchanger, nitrogen-rich liquid to nitrogen gas
n. Nitrogen-rich liquid entering upper column
o. Cold gaseous nitrogen
p. Heat exchanger, entering air to leaving gaseous nitrogen




Manufacture - Linde's Process
Air
Pump
Compressor
Cooler
Expansion tank
Liquid air storage
Distillation
Nitrogen
Oxygen
Cold Gaseous Nitrogen
Compressed Air
Water
Water
Piston
Nozzle
Compressed Air
Liquid Air


A
B
C
D
H_2O
E
F
J
G
A - Inlet of Air
B - Compressor
C - Condensing Coils
D - Receiver for Water
E - Copper Spiral with a Jet J
F - Outer Chamber
G - Outlet for Liquefied Air

Application :-

1.Cryogenic Cooling: Liquid Nitrogen and liquid Oxygen are produced with the help of this process. This is used for cryopreservation, cryosurgery.

2.Gas Separation: To separate two or more gases.

3.Hydrocarbon Recovery: Used in liquefaction of hydrocarbons, for example natural gas, for storage etc

Pressure Swing Adsorption (PSA)

Pressure Swing Adsorption (PSA) is a widely used gas separation process that operates at near-ambient temperatures. Principle of this process is that gases selectively adsorbed on a solid surface, for example material like zeolite or activated carbon. It is known for its wide application in industries.

History and Development :-
PSA was developed to produce high-purity oxygen and nitrogen. It was developed in early 20th century, it was first used commercially in 1960s.

Process :-

1. **Adsorption Under High Pressure**: In this process gas is passed through a vessel containing an adsorbent bed, like zeolite. This allows adsorption of nitrogen on zeolite under high pressure, while oxygen passes through.

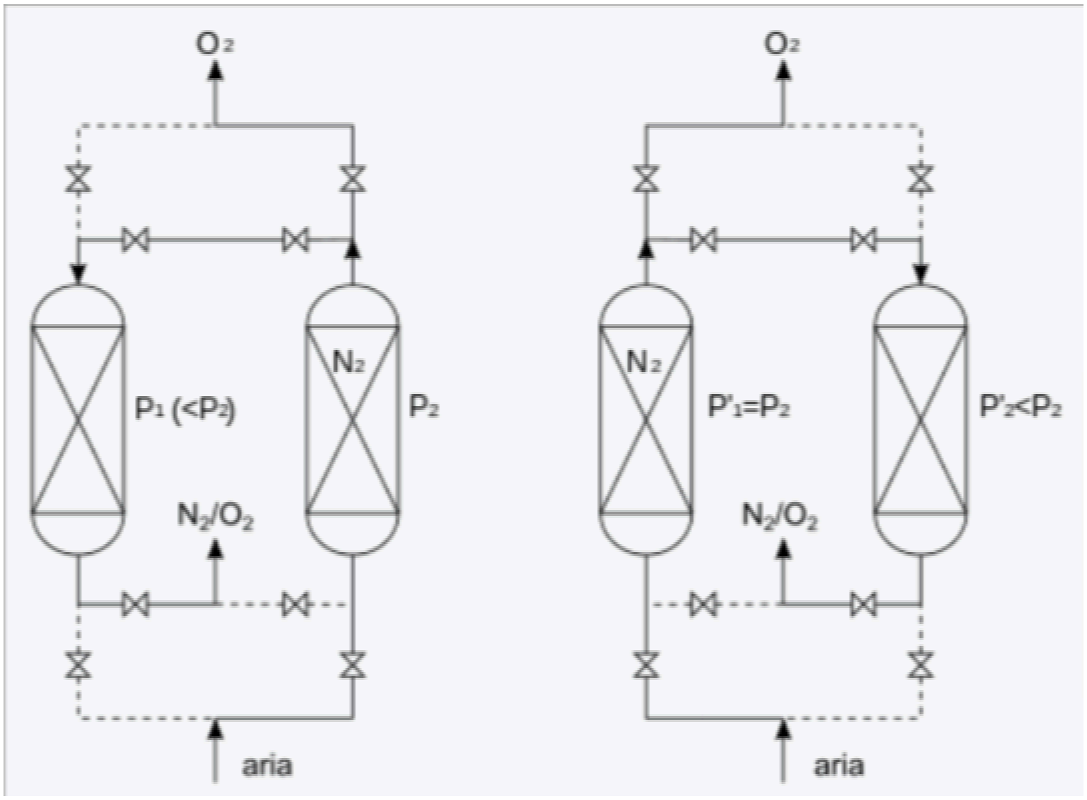
2. **Separation of Gases**:As the gas mixture is passed through vessel, nitrogen gets trapped in the vessel, therefore exiting gas contains more oxygen.

3. **Reaching Adsorption Capacity**: The zeolite bed eventually reaches its capacity to adsorb nitrogen. At this point, the pressure in the vessel is decreased, causing the adsorbed nitrogen to be released, or desorbed, from the zeolite.

4. **Regeneration of Adsorbent Bed**: The desorbed nitrogen is vented out, and the adsorbent bed is regenerated, ready for another cycle. The regenerated bed is then used in the next cycle of producing oxygen-enriched air.

5. **Continuous Production**: To achieve near-continuous production, two adsorbent vessels are used alternately. While one vessel is adsorbing nitrogen, the other is being regenerated. The gas exiting the vessel being depressurized is used to partially pressurize the second vessel, which helps in energy savings.

6. **Energy Efficiency**: This pressure equalization process helps in maintaining a continuous flow of the target gas while minimizing energy consumption, making it a common practice in industrial applications.



Application :-

PSA is used in a variety of industries for gas separation tasks, including:

- To produce high-purity oxygen, nitrogen, hydrogen for various industrial or medical process.
- To remove impurities from natural gas, biogas.

Comparison and Analysis

Both Linde process and PSA are use to separate gas or to purify them, but the have their differences like their operating principles, applications and efficiency.

Operating Principle:

- Linde Process: This process involve liquefaction and rectification of air. Air is compressed and then cooled to liquefy it, then liquefied air is separated in its constituents using fractional distillation.
- PSA Process: PSA uses adsorption of gases onto solid surfaces under high pressure. This allow separation of various gases.

Energy Consumption:

- Linde Process: The Linde process require high energy input to compress and cool the air.
- PSA Process: PSA is generally more energy-efficient compared to the Linde process.

Purity of Products:

- Linde Process: This process can produce high purity gases cause it uses fractional distillation.
- PSA Process: This can also produce very pure gases, but compared to Linde's process purity is less

Cost-Effectiveness:

- Linde Process: Due to high requirement of energy this method is more costly as it requires complex equipment.
- PSA Process: Due to less requirement of energy this method is cost-effective as it requires simpler equipment.

Conclusion

Linde Process:

The Linde process can be used to produce high-purity gases at industrial level. This method is highly effective. But it is only suitable for large scale applications as it require high energy inputs.

Pressure Swing Adsorption (PSA) Process:
On the other hand PSA is less energy intensive and can be used for small-scale production.

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