Production of liquid nitrogen and liquid oxygen using the Linde-Frankl process

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1. Background:

Two of the most important cryogenic fluids are liquid nitrogen (LN_2) and liquid oxygen (LOX), which have many applications in fields such as medicine, aircraft, food preservation, and metal production. Industries used a variety of production techniques to fulfill the massive demand for these liquids. The most well-known of these are the Linde-Frankl, Pressure Swing adsorption (PSA), Polymeric membrane ion transport, Vacuum pressure swing adsorption (VPSA), and Linde double-column processes. The Linde-Frankl process, which is a cryogenic liquid separation process, was replicated in an open-source and user-friendly program called DWSIM to generate LN2 and LOX, respectively. This variant of the Linde-Double (i.e, Linde-Frankl process) is good for separating the inert particles present in the mixture. Air containing 78.1% of N_2, 20.9% of O_2, and 1% Argon (Ar) is used as feed for this process. Since the Peng-Robinson equation of state well predicts the thermodynamic behavior of actual gases and can successfully manage the Vapour-Liquid Equilibrium (VLE) computations, it was used as a thermodynamic model in this simulation.

2. Operating Conditions:

The feed contains 78.1% N_2, 20.9% O_2, and 1% Argon (Ar), all other components are neglected. The thermodynamic model used for this operation is the Peng-Robinson model

- Ambient Temperature = 298 K
- Ambient Pressure = 1 atm
- Maximum Pressure for Compression = 200 atm
- Mass flow rate = 118451 kg/h
- Volumetric Flow Rate = 100000 m^3/h
- Number of stages of DC-01 = 29 (100% efficient)
- Number of stages of DC-02 = 30 (100% efficient)

3. Process Description:

The first step in this procedure is to dry out the air and eliminate any solid particles, moisture, or other contaminants. Assuming that the air is dry and filtered. The first step is to send the cleaned air, which is at 25 °C and 1.01325 bar, to a compressor i.e, COM-01, where it is adiabatically compressed to a pressure of 6.8 bar. The act of compression raises the air temperature to 290 ºC. The stream is sent to C-01, a cooler, to reduce the air temperature from 290 °C to 38 °C. Now, this stream is split into 2 streams, i.e, a larger stream of 65% mass flow rate and a smaller stream of 35% mass flow rate.

Liquid nitrogen from the DC-01 is used as the cold stream to cool the bigger stream (i.e, 65% mass flow stream) from 38 ºC to -171.2 ºC in HE-01. By using a cooler (C-02) the temperature is further lowered to -174 ºC. The smaller stream (at 38 ºC and 6.8 bar) is compressed in COM-02 adiabatically from 6.8 bar to 202.65 bar. This causes the stream's temperature to rise to 640.408 ºC. The stream is cooled from 640.408 ºC to -100 ºC using a cooler (C-03). With the help of a HE-02, the stream's temperature is further decreased to -160 ºC. The cold stream of the heat exchanger is made up

of the liquid oxygen that comes out of the DC-02. The next step is to push the stream out of the valve's nozzle using an expansion engine valve. The stream undergoes the Joule-Thompson effect and becomes 82.81% liquid as a result of this abrupt expansion to 7.09 bar. Both the larger and smaller streams are mixed which resulting in a 94.47% liquid, which is enough for separation. Next, the stream is sent to a distillation column, i.e, DC-01. Because nitrogen is so easily vaporized, it is retrieved from the upper part of the column while the oxygen-rich stream is retrieved from the bottom. Reusing the liquid nitrogen, it feeds the HE-01 as a cold stream. Cooling the entering air is achieved by using the stream's latent heat. After exiting the heat exchanger, the nitrogen is cooled to a liquid state using a cooler. Liquid oxygen is produced as the bottom product of the DC-02 by sending the oxygen-rich stream obtained from DC-01. This liquid oxygen stream is used as the cold stream for cooling the incoming smaller air stream in the HE-02. A small waste stream containing Nitrogen, Oxygen, and argon will leave as the top product of the DC-02. This stream is purged into the atmosphere as it only contains Nitrogen, Oxygen, and argon.

4. Results:

The product streams contain 99.99% liquid nitrogen and 99% of liquid oxygen. Based on the input mass flow rate, liquid nitrogen and oxygen recovery in the product streams are 95.5% and 99.25%.