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Research Article

Effect of Compressor Outlet Pressure on Liquefaction and Refrigeration Capacity

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Abstract

The main components of a helium liquefier which determines the performance of the HRL for a given compressor flow rate are Turbine, Heat exchanger and JT valve. Turbine and JT valve produces cooling effect of helium gas by isentropic and isenthalpic expansion process respectively. Different components can be made to have different thermodynamic cycle configuration. For each configuration main components can have different operating process parameters leading to different performance of HRL. This project involves the analysis and optimization of these process parameters for a given configuration. This analysis and optimization work will also involve different practical factors and in efficiencies of main components.

Keywords: *Liquefaction, Helium, process parameters, Optimization, Turbine, heat exchanger.*

1. Introduction

Helium liquefier as the name suggest is used for the liquefaction process of Helium gas. The cold box shown below is used for the cool down and liquefaction purpose of Helium gas coming out of the Tokomak. Cold box contains total 8 heat exchangers and 3 turbines which expand isentropically and one JT valve which expands isenthalpically. Process parameters of heat exchanger are effectiveness or UA, mass flow rate, Temperatures and for turbine are temperatures, mass flow rate, inlet outlet pressure; efficiency has to be optimized to get maximum liquefaction of LHe with minimum refrigeration load.

Normally JT valve is kept at the lowest temperature followed by the performance of other components and hence optimization of its process parameter is not considered here. One of the optimum cycle configurations is provided here that gives the higher cooling effect with a lower capital investment and operating cost of different HRL components. This configuration has three turbines and eight heat exchangers which produces liquid helium at 4.5 K. 1st and 2nd turbines operates at warmer temperature compared to 3rd turbine which has process flow paths connected in series. Helium stream coming out of the 1st turbine passes to the heat exchanger which will reduce its temperature before entering the 2nd turbine. Helium mass flow rate supplied by the compressor system is 140 g/s at pressure of 14 bars and 310 k temperature. A part of this mass flow rate passes through a 1st and 2nd turbine for isentropic expansion and then this low pressure helium stream comes back to compressor suction through different heat exchangers to transfer cooling effect to the hot stream coming from the compressor. 3rd turbine will expand the remaining part of the main helium stream will further passes through a heat exchanger before entering the JT valve for liquid helium production.

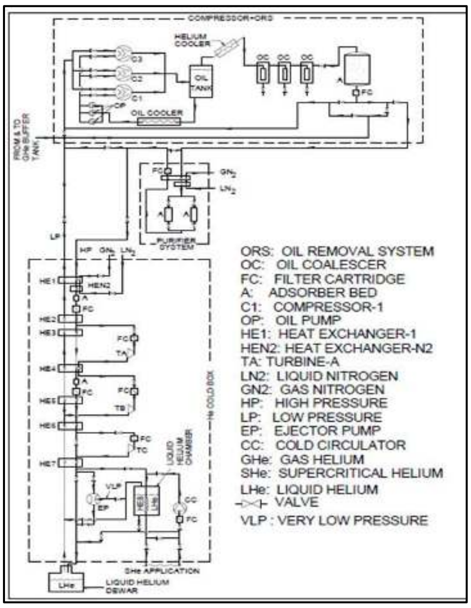

Figure 1.1 Typical Schematic of the cold box along with the warm and cold end components for Helium plant of Tokamak

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2. Effect of Compressor Outlet Pressure on Liquefaction and Refrigeration Capacity

Developed procedure for 2 compressors, 140.7 g/s is at compressor outlet pressure of 14 bar. At different compressor outlet pressures liquid formation at JT outlet and refrigeration capacity is calculated and tabulated below. Graph of liquid formation at JT outlet and refrigeration capacity against compressor outlet pressure has been plotted below which shows that both liquid formation and refrigeration capacity increases as compressor outlet pressure is increasing.

Table 2.1: Liquid formation at JT outlet, Refrigeration capacity and JT inlet temperature at different compressor outlet pressure for 2 compressor system with 3rd turbine

Pressure	JT Inlet	liquefaction	Refrigeration load
Pa	k	g/s	W
1200000	5.761282527	29.33742534	436.55
1400000	5.255432267	42.91480427	701.90
1600000	4.885541404	49.2079059	824.89
1800000	4.687424143	52.03264347	880.10
2000000	4.583452649	53.40708397	906.96
2200000	4.525941217	54.13970546	921.28

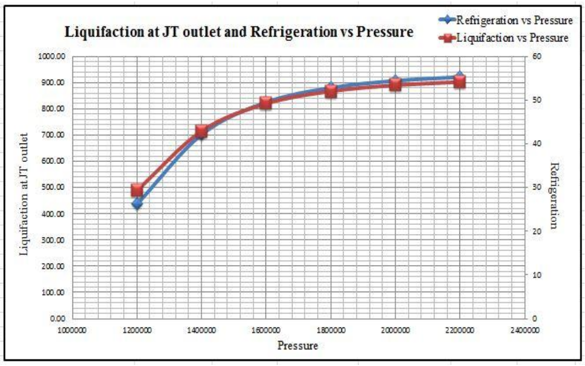


Figure 2.1: Liquid formation at JT outlet, Refrigeration capacity VS pressure for 2 compressor system with 3rd turbine

3. Validation Using Aspen Hysys

3.1Process Flow Diagram of Helium Liquefier in Aspen Hysys

Figure shows the process flow diagram that drawn in Hysys. Table shows the steady state properties of all the streams in the PFD, material stream 49 gives the helium liquefaction rate

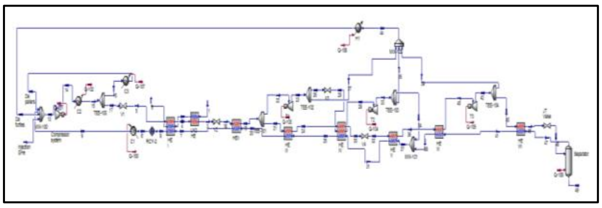
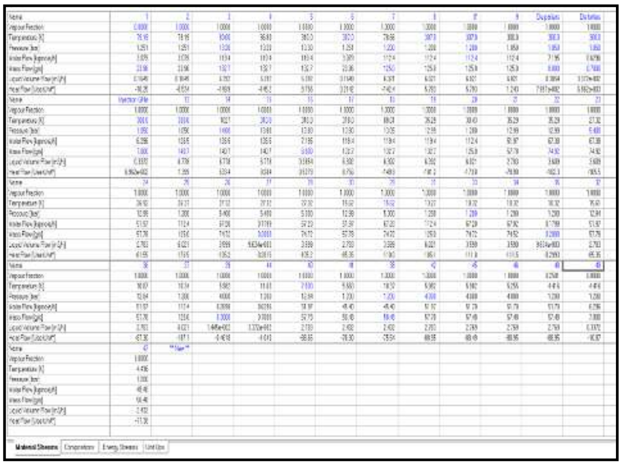


Figure 3.1.1: PFD of Helium Liquefier

3.2 Material Streams

Table 3.2.1: Material streams in Helium Liquefier



Conclusion

Among all analyzed methods steady state approach is effectively used for the optimization of process parameters of turbine and heat exchanger such as mass flow rate, temperature, inlet outlet turbine pressures, effectiveness or UA.

Analytically developed procedure for 2 compressors has been validated using Aspen HYSYS. Optimization of process parameters like compressor outlet pressure is done using analytical method which comes out to be 14 bar.

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