International Journal of Advance Research and Innovation
Vol. 1(1), Jan-Mar 2013, pp.57-61
doi: 10.51976/ijari.111307

Article Info
Received: 01 Jul 2013 | Revised Submission: 15 Jul 2013 | Accepted: 22 Jul 2013 | Available Online: 01 Aug 2013

Thermal Analysis of a Claude system for Liquefaction of Various Gases

Devender Kumar and R. S. Mishra***

ABSTRACT

From various Cryogenics systems a detailed thermo analysis of Claude cryogenic system for various gases is done. A comprehensive Second law analysis of Claude system is carried out by using various properties variables in system to find out the more efficient statics of system included exergy efficiency of system After a applying numerical computational technique to Claude system it find out the Methane gas is more suitable than any other observed gas and 350 and 500 bar is best compressor pressure per kg of gas, other han this it is noticed from analysis that the inlet pressure is kept between in range of 3 to 5 bar and inlet temperature is kept below for high second law efficiency.

Keywords: *Thermodynamics Analysis; Lindesystem; COP; Exergy Efficiency; Exergy Destruction.*

1.0 Introduction

From the introduction of refrigeration in human world, curiosity of find out the least temperature that any material can attain is increases and with effect of time and by human theoretical effort in science field Absolute Zero is find out and considered as the least Temperature, but in practical point of view this absolute temperature (0 Kelvin) seem impossible and it taken as ideal reference, With effect of attaining least temperature a new field is introduce called cryogenics.

Cryogenics is defined as process for producing very low temperature (Below -150 or 123 K) but temperature below from -180 (93.15 K) consider as the dividing line of refrigeration and cryogenics, its coming out from fact that boiling point of various permanent gases like helium, hydrogen, oxygen, nitrogen and air etc. Number of process is design and practically lays to achieve cryo temperature. As per place requirements of cryogenics is called from different name like cryobiology, cryonics, cryo-electronics, cryotrons, cryosurgery etc.

The liquefy gases are store in special containers called Dewar flask. To transfer the liquid from carrier to tank the pump which used are called cryogenics transfer pumps.

Claude system is design to liquefy various particular gases like air, oxygen, nitrogen, feron etc. To achieve high performance of a cyclic process, various analyses is done to identify the inefficient parts of process and upgrade them to their upper level.

2.0 Literature Review

Exergy is defined as the useful part of energy and anergy defined as the unused part or wasted part of energy. In other words Exergy is defining as the availability of maximum useful work that can be obtained from a system. A good exergetic design of a heat exchanger would allow for an increase in the global efficiency of the process, by defining a thermodynamic cycle in which the exergetic losses would be limited [1]. From past few years exergy analysis has used as a power tool to upgrade a system by analyzing there inefficient part or energy destruction parts and with the help of all this optimization of a process is possible.

Exergy and anergy defined the economically feasibility of a procession a given environment conditions. Exergy analysis provides useful information with respect to the theoretical upper limit of the system performance, which cannot be obtained from an energy analysis alone. The analysis allows the determination of the sites with the losses of exergy, and therefore showing the direction for the minimization of exergy losses to approach the reversible COP [2].

In exergy analysis exergy and anergy are noted in various terms for each component. The Bejan [3] work is bseof allexergetic analysis of heat exchangers. Various problems are studied related to exergy analysis which a are mentioning or summarized in [4], From the vast study it noticed that most new methods differ only in the way that entropy generation is non-dimensional [5].

**Corresponding Author: Department of Mechanical Engineering, Delhi Technological University, New Delhi, India (E-mail: devenderdahiya@in.com)*
***Department of Mechanical Engineering, Delhi Technological University, New Delhi, India*

Irreversibility that is just another form of exergy destroyed waste potential. So irreversibility is a factor which try to keep low as possible as an optimizer can do without affecting other properties.

Various components are taken under studied and ASU (air separation unit) using distillation columns are one of the main methods used for separating air components. Exergy analysis, inefficiencies were identified in the distillation system for an efficient cryogenic air separation plant producing large-tonnage quantities of nitrogen [6].

Exergy efficiency of a double diabatic column, with heat transfer all through the length of the column, is 23% higher than that of the conventional adiabatic double columns. In a simple adiabatic distillation column, most of the exergy losses occur in the column itself (57%) [7].

Now as advancement goes on technology switching toward more efficient method of separation; polymeric membrane and membrane on ceramic technology are used for separating oxygen [8].

Number of parameters for optimization are analyzed but still compressor are the main element which determining the energy parameters of low cryogenic technology. So, we have to first eliminate not only compressor part but use of all these type of machines which are not only efficient but also eco friendly too.

In other word : the problem of making a transiting to new cooling principle's is critical and for this one of the most promising alternatives may be electro caloric cooling [9].

Claude cycle is a very is a very useful process in cryo industries but its less exergy efficiency still a major drawback in advancement of Claude cycle. With help of Claude cycle number of gases can be liquefy. It is noticed by experiment that more than half of the exergy loss takes place in the liquefaction part and one-third in the air compression unit.

Minor but prominent exergy losses are taking place in the distillation unit and the main heat exchanger. The major cause of exergy loss is the use of compressors and to a lesser extent the use of turbines [10].

Bye various experimental data It is noticed that the evaporating and condensing temperatures put a strong effects on the exergy losses in the evaporator, condenser, second law of efficiency and COP of the cycle but little effects on the exergy losses in the compressor and the expansion valve.

The second law efficiency and the COP increases, and the total exergy loss decreases with decreasing temperature difference between the evaporator and refrigerated space and between the condenser and outside air [11] and if advance technology like nano fluid include it noticed that Nano fluid and Nano lubricant cause to reduce the exergy losses in the compressor indirectly [12].

3.0 Thermo Analysis of Claude System for Liquefication of Gases

3.1 Compressor work:

Compressor work:

$$\eta_{comp} = \frac{W_t}{W_{comp}} \tag{1}$$

$$W_t = mRT ln\frac{P_2}{P_1} \tag{2}$$

$$W_{comp} = h_2 - h_1 - T_1\,(s_2 - s_1) \tag{3}$$

$$W_{reversible} = W_{actual} - T_0 S_{gen} \tag{4}$$

$$W_{Total} = W_{comp} + W_{Expander} \tag{5}$$

First heat exchanger:

$$m_2(h_2 - h_3) = (m_2 - m_6)(h_1 - h_{10}) \tag{7}$$

Expander:

$$\frac{T_8}{T_3} = (\frac{P_8}{P_3})^{(\frac{Y-1}{Y})\eta_{expander}} \tag{8}$$

$$W_{Expander} = h_8 - h_3 \tag{9}$$

$$(m_4 - m_6 + m_8)h_9 = m_8 h_8 + (m_4 - m_6)(h_7) \tag{10}$$

Second Heat exchanger:

$$m_4(h_3 - h_4) = (m_2 - m_6)(h_{10} - h_9) \tag{10}$$

Throttle valve:

$$h_4 = h_5 \tag{11}$$

Heat Balance of the separator

$$m_4 h_5 = m_6 h_6 + (m_4 - m_6)(h_7) \tag{12}$$

Second law analysis:

$$\eta_{2nd}(\%) = m_6(\frac{h_7 - h_6 - T_0(s_7 - s_6)}{W_c})_{*100} \tag{13}$$

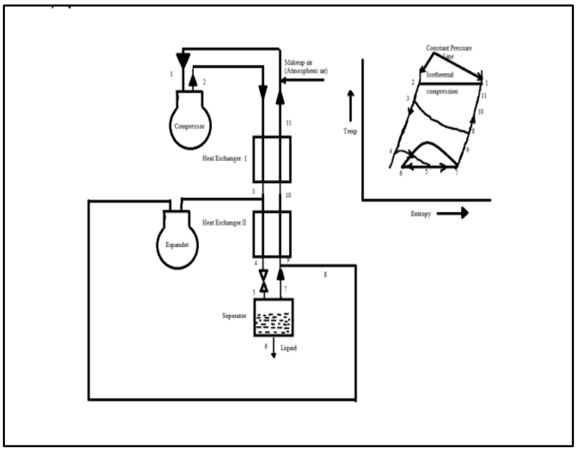
COP (coefficient of performance):

$$COP = \frac{h_1 - h_7}{h_2 - h_1 - T_1\,(s_2 - s_1)} \tag{14}$$

3.2 Claude cycle

A complete analysis of Claude cycle is performing with the help of Engineer equation solver for various gases. Claude cycle as shown in Fig1 is taken for analysis. Claude system consist a compressor, expander, two heat exchangers with throttle valve and separator. The fluid which have to liquefy first fed to compressor in its gaseous form at atmospheric pressure, it is compress isothermally in compressor after that the high pressure gas is partially cooled by passing through the first heat exchanger, at the exits of first heat exchanger a portion if air is bled and called by expansion in expander ,the remaining portion of air passes through the second heat exchanger ,the gas from second heat exchanger is throttled irreversibly at atmospheric pressure. The liquid gas is collect in separator after throttling. The low temp gas from expander is mixed with the unliquefied gas from the separator, producing an effect of increased mass flow rate at feed system.

Fig 1: Claude System



Various results are drawn for particular inlet temperature, pressure and compressor outlet pressure for different gases

4.0 Results and Discussion

Fig: 2. show the variation of Second law efficiency with compressor pressure and from the graph analysis it concluded that after a specific pressure the efficiency start decreasing, for all considered gases ,the pressure ranging from 250 to 450 show highest second law efficiency.

The variation in liquefaction mass with compressor pressure is not always directly proportional to each other, Fig: 3. show that the liquefaction mass after exceeding some range of compressor reverse the directly proportional behavior and pressure become inversely proportional to compressor pressure the pressure at which change of behavior observed is 300 to 400 for gases considered here COP is inversely proportional to the compressor pressure as it increases COP of system decreasing. In Fig: 4. COP vs. compressor pressure show that from 100 to 200 ranger the rate of decreasing COP with comp. pressure is high but as further increase of pressure the rate of decreasing in COP of system is suppress. Fig: 5. show that the rate of increase of liquefaction mass with inlet pressure is very slow and it is almost linear, because increase in mass only infractions. Fig: 6. Show that rate of increase in COP with inlet pressure is in fraction. COP is directly proportional to the inlet pressure and COP behavior with inlet pressure is same for all considered gases. Fig: 7. Show that increase in inlet pressure also reduces the requirement of very low liquefaction temperature. The Inlet pressure increase also increases the liquefaction temperature of gas. Rate of increase of second law efficiency with inlet pressure is very low and it almost linear due increment show only in fraction. Fig: 8. show variation in Second law efficiency with inlet pressure Fig: 9. show variation in Compressor work with respect to Inlet pressure and from graph it observed that inlet pressure have high impact on the compressor pressure as seen from graph I bar increase in inlet pressure decreases approx. 11% compressor pressure. Fig: 10. show decrease in second law efficiency with increase in inlet temperature, natural gas (methane composition 98%) Claude setup show large drop with inlet temperature. Liquefaction mass decreases as the inlet temperature increases, Fig: 11. show decrease in mass rate with respect to inlet temperature. Fig: 12. Show that gas other than methane and fluorine present very marginal increases in COP with increase in inlet temperature whereas fluorine and methane gas inlet temperature is directly proportional to the COP. Fig: 13. show there is increase in work done by compressor with inlet temperature.

Fig 2: Variation of Second Law Efficiency with Compressor Pressure.

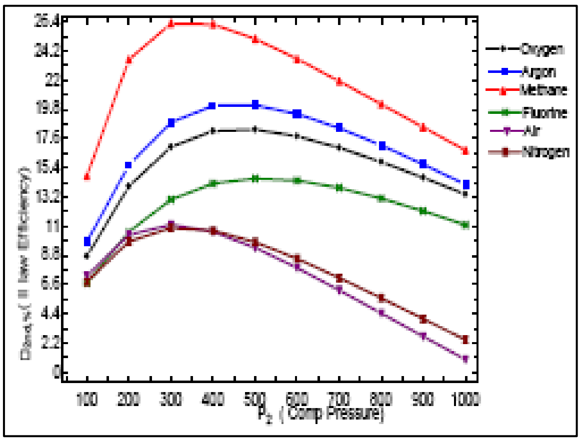


Fig: 3. Variation of Liqufecation Mass with Compressor Pressure.

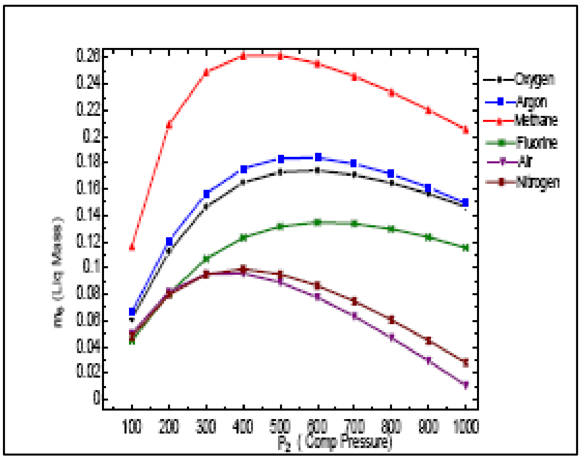


Fig 4: Variation of COP with Compressor Pressure.

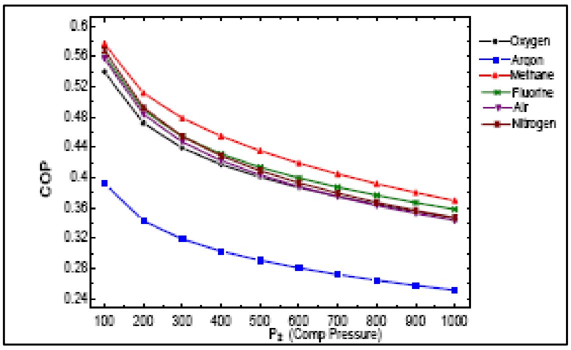


Fig 5: Variation of Liqufecation Mass with Inlet Pressure.

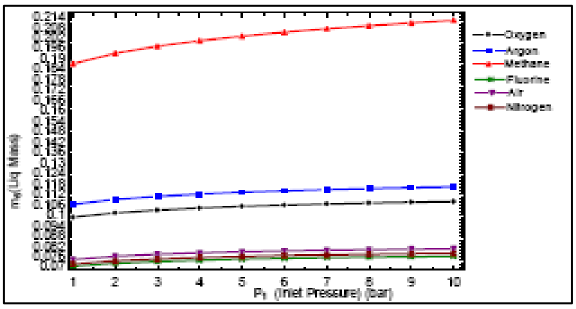


Fig 6: Variation of COP with Inlet Pressure.

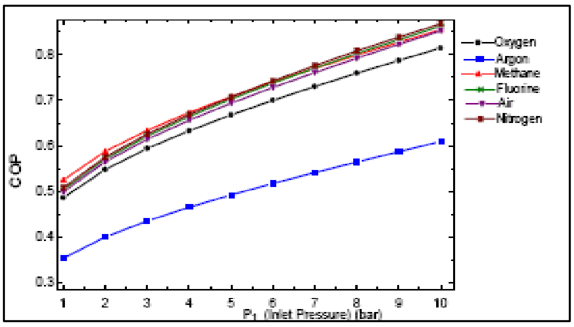


Fig 7: Variation of Liquefication Temperature with Inlet Pressure.

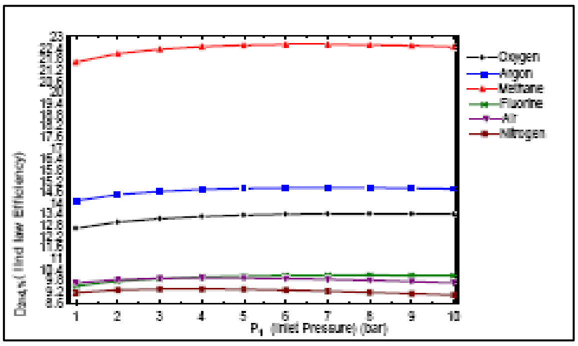


Fig 8: Variation of 2nd Law Efficiency with Inlet Pressure

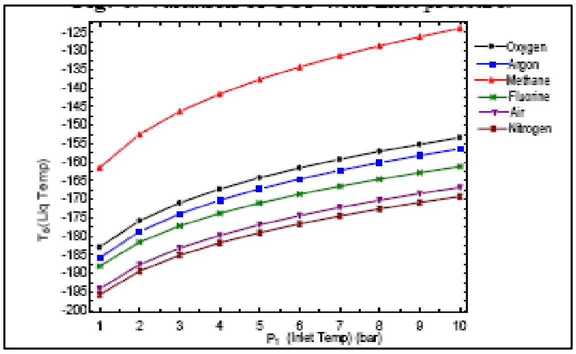


Fig 9: Variation in Wcomp with Inlet Pressure.

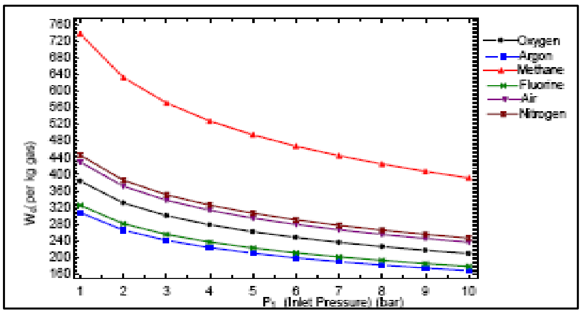


Fig 10: Variation of 2nd Law Efficiency with Inlet Temperature

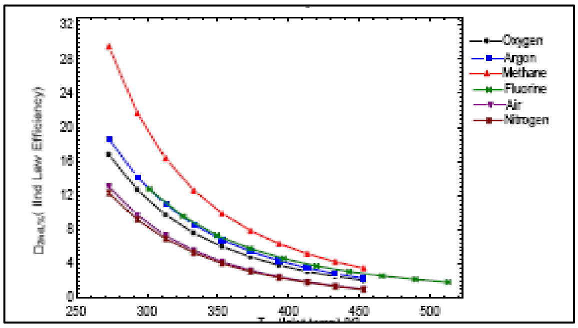


Fig 11: Variation of Liquefaction Mass with Inlet Temperature

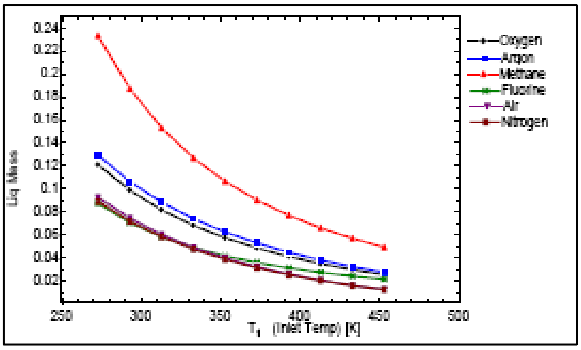


Fig 12: Variation of COP with Inlet Temperature

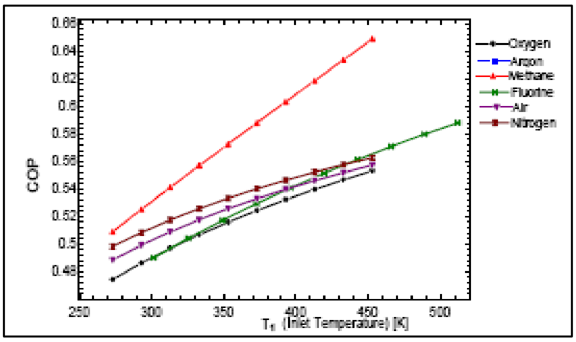
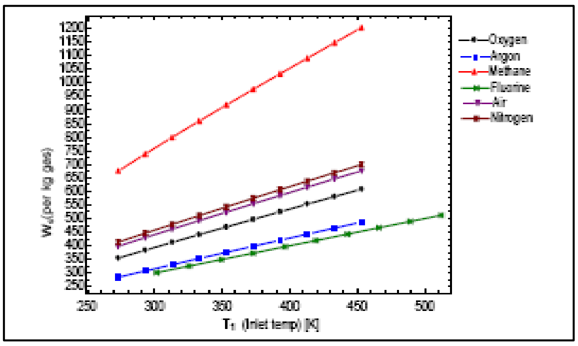


Fig 13: Variation in Wcomp with Inlet Temperature



5.0 Conclusions

- Working with methane gas as compare to other gases are more efficient.
- COP is directly proportional to inlet temperature but show slight slop after some inlet pressure increases

References

[1] T. J. Kotas, "The Exergy Method of Thermal Plant Analysis", 1995 Ed.; Krieger Publishing Company: London, UK, 1985

[2] M. Kanoglu, MeldaOzdinc, Carpınlıoglu and MurtazaYıldırım, "Energy and exergy analyses of an experimental open-cycle desiccant cooling system", Applied Thermal Engineering 24, 2004, 919–932

[3] A. Bejan, "General criterion for rating heat-exchanger performance", Int. J. Heat Mass Transf, 1978, 21, 655–658

[4] M. Yilmaz, O. N. Sara, S. Karsli, "Performance evaluation criteria for heat exchangers based on Second law analysis", Exergy Int. J. 2001, 4, 278–294

[5] S. T. Wu, X. F. Yuan, Y. R. Li, L. Xiao, "Exergy transfer effectiveness on heat exchanger for finite pressure drop", Energy 2006, 32, 2110–2120

[6] R. Agrawal, D. W. Woodward, "Efficient cryogenic nitrogen generators: An exergy analysis, Gas Separation & Purification", 5 (3), September 1991, Pages 139-150, ISSN 0950-4214.

[7] J. Rizk, M. Nemer, D. Clodic, "A real column design exergy optimization of a cryogenic air separation unit", Energy, 37(1), January 2012, Pages 417-429, ISSN 0360-5442

[8] GaëlleGosselin, "Thermodynamic study of oxygen-enhanced combustion: analysis of different techniques of oxidant production", KTH industrial engineering and management, Master of Science Thesis EGI 2012: HT.

[9] Yu. V. Sinyavskii, "Electrocaloric refrigerators: A promising alternative to current low-temperature apparatus", Chemical and Petroleum Engineering, June 1995, 31(6), pp 295-306, ISSN 1573-8329.

[10] R. L. Cornelissen, G. G. Hirs, "Exergy analysis of cryogenic air separation, Energy Conversion and Management", 39(16–18), November–December 1998, Pages 1821-1826, ISSN 0196-8904

[11] RecepYumrutaş, Mehmet Kunduz, Mehmet Kanoğlu, "Exergy analysis of vapor compression refrigeration systems", Exergy, An International Journal, 2(4), 2002, Pages 266-272, ISSN 1164-0235

[12] J. U. Ahamed, R. Saidur, H. H. Masjuki, "A review on exergy analysis of vapor compression refrigeration system", Renewable and Sustainable Energy Reviews, 15(3), April 2011, Pages 1593-1600, ISSN 1364-0321