ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Performance Analysis of Vapour Compression Refrigeration System Utilizing Different Refrigerant

Ashish Patidar [1], Amitesh Paul [2]
[1] SSSIST Sehore, [2] RKDF University Bhopal, India

Abstract

The performance of heat transfer is one of the most important research areas in the field of thermal engineering. There are a large number of refrigerants, which are used to transfer heat from low temperature reservoir to high temperature reservoir by using vapour compression refrigeration system. This paper presents a performance analysis of vapour compression refrigeration system with using refrigerants like R-134a & Blend of R-290(propane) (50%) and R-600a (50% Isobutane). Various performance measures like compressor discharge temperature, pressure ratio, volumetric cooling capacity (VCC), volumetric efficiency and mass flow rate are analyzed. The performance in term of coefficient of performance (COP), refrigerating capacity (RC), and compressor work (We) were evaluated for the investigated refrigerants at various evaporating and condensing temperatures. The system performance increases as the evaporating temperature increases, but reduces as the condensing temperature increases. The COP of R134a obtained was lower than those of Blend of R- 290(propane) (50%) and R-600a (50% isobutane).

Keywords: Refrigeration, Propane, Isobutane, Vapour Compression Refrigeration System, R 134a & Blend of R-290(propane) and R-600a (isobutene).

Introduction

Recently, the ozone depleting potential (ODP) and global warming potential (GWP) have become the most important criteria in the development of new refrigerants apart from the refrigerant CFCs and HCFCs, both of which have high ODP and GWP, due to the their contribution to ozone layer depletion and global warming. In spite of their high GWP, alternatives to refrigerant CFCs and HCFCs such as hydro fluorocarbon (HFC) refrigerants with their zero ODP have been preferred for use in many industrial and domestic applications intensively for a decade. HFC refrigerants also have suitable specifications such as non-flammability, stability, and similar vapour pressure to the refrigerant CFCs and HCFCs. Akintunde (2006) also investigated the moisture solubility in R12 and R134a at various temperatures in orders to evaluate the performance of R134a as a substitute for R12 in relation to moisture than R12 at all temperatures. Therefore, R134a system will be more prone to rusting and copper plating due to large moisture content in the refrigerant. For this reason, a more efficient and environment being alternative refrigerant is needed in the refrigeration system. The natural refrigerants are naturally occurring substances such as ammonia, hydrocarbons, carbon dioxide, water and air. In this group, the hydrocarbons are most closely related to the HFCs. Their thermodynamic and transport properties are very similar to most HFCs currently used in refrigeration and air-condition systems, which make them suitable as substitute refrigerants in the existing HCFC and HFC systems without any major changes in the design.

Property	**MU**	**CH3-CH2-CH3 (R290)**	***n-butane CH3-2(CH2) -CH3 (R600)***
Molar Mass	g/mol	44.096	58.125
t_{triple}	˚C	187.62	138.25
t_0(1.013bar)	˚C	42.11	0.49
t_{inf}	˚C	105	60
t_{auto}	˚C	450(A3)	405(A3)
Explosive range LEL./UEL	%vol	2.1/9.5	1.9/8.5

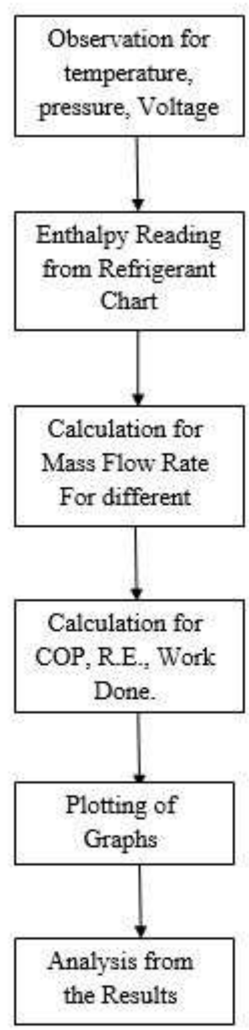
K=cp/cv(1.013bar, x=1)	-	1.1833	1.1191

Methodology

Steps for Analysis

1. Take observation for temperature and pressure from test rig using R-12, R-134a and Hydrocarbon Blend.
2. Take readings for suction temperature, Compressor discharge temperature, condenser discharge temperature and evaporator temperature.
3. Using refrigerant chart (p-h curve) for R-12, R-134a and Hydrocarbon Blend obtain values of enthalpies for different load.
4. Determination of mass flow rate for different loads for R-12, R-134a and Hydrocarbon Blend.
5. Calculation of Refrigerating effect, work done and COP for different loads.
6. Plotting of graphs for:
   a. COP Vs Power.
   b. R.E. Vs Evaporator Temperature.
   c. R.E. Vs Condenser Temperature.
   d. Mass flow Rate Vs Evaporator Temperature.
   e. Mass Flow Rate Vs Condenser Temperature.
7. Comparison for the performance by the results.

Flow chart



Compatibility of R290 and R600 and their mixtures as refrigerant

In order to establish if the mixtures between R290 and R600 are suitable as refrigerants, a comparative study of their individual thermo-physical properties has been carried out. Thus, based on the data presented, one can notice that the two fluids investigated have close values for the molar mass, triple point temperature (t *triple*), critical point pressure (p) and also for temperature (t *min* , t *max*), pressure (p *max*) and density (ρ *max*) in regard with their range of application. Both fluids present several desired refrigerant properties such as: critical pressure over 35 bar, critical temperature (t K) over 95°C, evaporating temperature ($t0$) below zero and increased latent heat of vaporization (q $v0$), both at atmospheric pressure,

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

and also a small adiabatic exponent (*k*). Regarding the evaporating temperature at the atmospheric pressure one can notice that R290 presents a lower value making it suitable for refrigeration applications while R600 has a higher value being suitable for air conditioning (AC) applications. At the same time both substances have an almost double latent heat of vaporization compared to CFCs, HCFCs and HFCs refrigerants. This is a very important advantage concerning R290, R600 and their mixtures in order to use them as refrigerants. Besides their thermodynamic properties which make R290 and R600 suitable as refrigerants, various papers on their use in domestic, commercial and industrial applications prove as well that these two substances are compatible with the commonly used materials in VCRS. The suitability as refrigerants, from a thermodynamic and functional points of view suggest that R290 and R600, as natural substances having ODP=0 and GWP<20, are an viable solution as eco refrigerants for the substitution of pollutant synthetic refrigerants like CFCs, HCFCs and HFCs. Table 1 shows that although R290 and R600 are not toxic, they are flammable and classified according to ASHRE as A3 substances having low explosive range (lower explosive limit - LEL/upper explosive limit UEL=1.9/8.5 % vol.). Under these circumstances, in case of their use as refrigerants, measures concerning operational safety, sealing and explosion prevention equipment have to be adopted.

Cycle Description and Model

A vapour compression refrigeration system consists of five components such as evaporator, liquid vapour heat exchanger, compressor, condenser and expansion valve. These components connected in a closed loop through piping that has heat transfer with the surrounding. At state 11, refrigerant leaves the evaporator at a low pressure, low temperature, saturated vapour and enter the liquid vapour heat exchanger where it absorbs the heat from high pressure- temperature refrigerant flows from condenser. The refrigerant from the liquid-vapour heat exchanger enter into compressor through the suction line in which both temperature and pressure increased at state 1. At state 2, it leaves the compressor as a high pressure, high temperature, superheated vapour and enter the condenser where it reject heat to surrounding medium at constant pressure after undergoing heat transfer in the discharge line. Refrigerant leaves the condenser at state 3, as high pressure, medium temperature, saturated liquid and enters the liquid-vapour heat exchanger at state 33. The expansion valve allows to flowing the high pressure liquid at constant enthalpy from high pressure to low pressure. At state 4, it leaves the expansion valve as a low temperature, low pressure, and liquid vapour mixture and enters the evaporator where it absorbs the heat at constant pressure, changed into saturated vapour and cycle is completed.

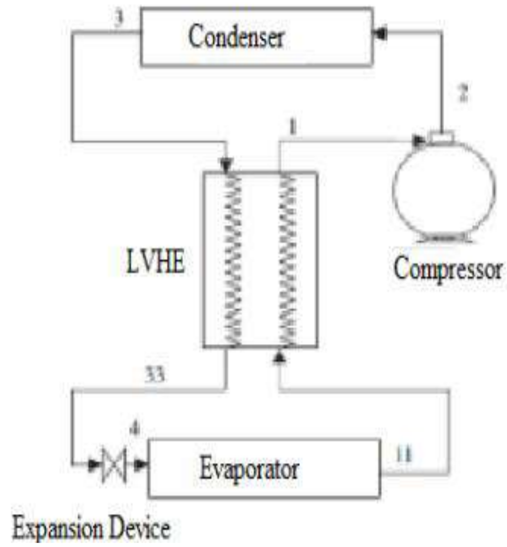


Fig. Vapour compression refrigeration system with a liquid –vapour heat exchanger

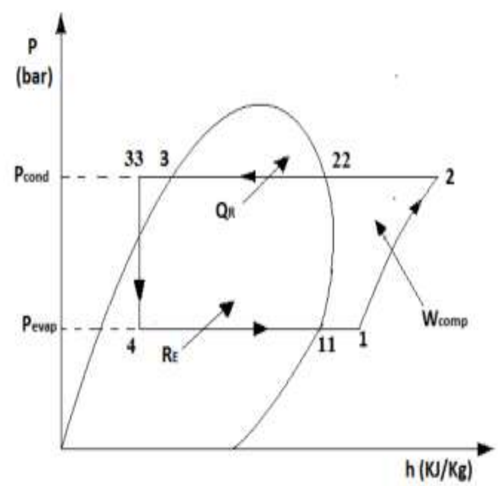


Fig. Pressure-Enthalpy Diagram

Calculation for R-134a

PARAMETER	NO LOAD	LOAD I	LOAD II
T_1 (°C)	-1.0	-0.6	-0.3
T_2 (°C)	67	69	71.2
T_3 (°C)	52.3	54	55.2
T_4 (°C)	-10.1	-9.1	-8.9
h_1 (KJ/kg)	397.51	398.25	398.20
h_2 (KJ/kg)	428.25	428.89	429.10
h_{f3} (KJ/kg)	274.71	277.86	281.04
h_4 (KJ/kg)	186.78	189.40	189.56
V (volt)	230	230	230
I (ampere)	0.90	0.90	0.90
P_d (bar)	11.2	11.2	11.4
P_s (bar)	0.35	0.42	0.42

Observation from test rig of refrigerator using R-134a as refrigerant

1. NO LOAD

Power, P = V×I×COSØ
P = 230×0.90×0.85
P = 171.81 J/sec
But P = mr (h2-h1)
171.81 = mr (428.25-397.51)
mr = 5.589 gm/sec
Refrigerating Effect,
R.E = mr (h1-hf3)
R.E = 5.589× (397.51-274.71)
R.E = 686.32 J/sec
Work done,
W.D = mr (h2-h1)
W.D =5.589×(428.25-397.51)
W.D = 171.80 J/sec
Coefficient of Performance,
COP = RE/ WD
COP = 686.32/171.80
COP = 3.99

2.LOAD I

Power, P = V×I×COSØ
P = 230×0.90×0.85
P = 171.81 J/sec
But P = mr (h2-h1)
171.81 = mr (428.89-398.25)
mr = 5.607 gm/sec
Refrigerating Effect,
R.E= mr (h1-hf3)
R.E = 5.607×(398.25- 277.86)
R.E = 675.02J/sec
Work done,
W.D = mr (h2-h1)
W.D =5.607×(428.89-398.25)
W.D = 171.79 J/sec
Coefficient Of Performance,
COP = RE/ WD
COP = 675.02/171.79
COP = 3.93

3. LOAD II

Power, P = V×I×COSØ
P = 230×0.90×0.85
P = 171.81 J/sec
But P = mr (h2-h1)
171.81 = mr (429.10-398.20)
mr = 5.56gm/sec
Refrigerating Effect,
R.E= mr (h1-hf3)
R.E= 5.56×(398.20- 281.04)
R.E = 651.40 J/sec
Work done,
W.D = mr (h2-h1)
W.D = 5.56×(429.10- 398.20)
W.D = 171.8 J/sec
Coefficient Of Performance,
COP = RE/ WD
COP = 651.40 /171.8
COP = 3.79

Conclusion

In this study, an ideal vapour compression refrigeration system is used for the performance analysis of alternative new refrigerant mixtures as substitutes for R- 134a & Blend of R-290(propane) (50%) and R-600a (50%) (isobutane). Considering the

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

comparison of performance coefficients (COP) and load ratios of the tested refrigerants and also the main environmental impacts of ozone layer depletion and global warming, refrigerant blends of Blend of R-290(propane) (50%) and R-600a (50%) (isobutane)are found to be the most suitable alternatives. The refrigeration efficiency, the performance coefficient.

- Single capillary tube having smaller inner diameter is suitable for freezing applications, whereas parallel capillary tubes having more inner diameter are suitable for cold storage or air conditioning applications.
- For reducing the harmful effects on environment, it is necessary to use and research about the new refrigerants with low GWP and ODP.
- To study the effect of new efficient, minimum GWP, minimum ODP and environmental friendly refrigerants.
- Innovation of new refrigerant mixture having high COP with less environmental impact.
- To develop a mathematical model by considering multiple factors so that experimental investigation can be minimized.

References

1. Ji J, Chow TT, Pei G, Dong J, He W. "Domestic air-conditioner and integrated water heater for subtropical climate" *Applied Thermal Engineering*. Vol23 Issue 5 pp:581-592, 2003
2. Inan C, Gonul T, Tanes MY, "X-ray investigation of a domestic refrigerator. Observations at 25°C ambient temperature". *International journal of Refrigeration* Vol 26 Issue 2 pp:205-213, 2003.
3. Jung D, Kim CB, Song K, Park B, "Testing of propane/isobutane mixture in domestic refrigerators" ". *International journal of Refrigeration*, Vol 23 Issue 7 pp :517-527, 2000.
4. Hoffman, J. S., "Assessing the Risks of Trace Gases that can modify the Stratosphere, Office of Air and Radiation",*U.S. Environmental Protection Agency, Washington DC*, 1987.
5. Molina, M. J. and Rowland, F. S., 1974, Stratospheric sink for chlorofluoro methanes: chlorine atom catalyzed destruction of ozone, Nature, Vol. 249, June 28, pp. 808–812.
6. R. Radermacher, K. Kim, "Domestic refrigerator: recent development", *International journal of refrigeration* vol 19 (1996) pp 61-69.
7. S.J.Sekhar, D.M.Lal, "HFC134a/HC600a/HC290 mixture a retrofit for CFC12 system", *International journal of refrigeration* Vol 28, pp 735-743, 2005.
8. Bansal PK, Martin A, "Comparative study of vapour compression", *thermoelectric and absorption refrigerators* 2000; 24(2):93-107.
9. S. Devotta, A. V. Wagmare, N. N. Sawant, B.M. Domkundwar, Alternatives to HFC-22 for air conditioners, Applied Thermal Engineering 21(2001) 703-715.
10. Dossat RJ, Horan TJ (2002). Principle of refrigeration. Prentice Hall, New Jersey, USA. Fifth edition, ISBN 0-13-027270-1 pp1-454.
11. Y.S.Lee, C. C. Su, Experimental studies of isobutene (R600a) as refrigerant in domestic refrigeration system. Applied Thermal Engineering 22 (2002) 507-519.
12. B. A.Akash, S.A. Said, Assessment of LPG as a possible alternative to R-12 in domestic refrigerators. Energy conversion and Management 44 (2003) 381-388.
13. Kornhauser, A. A., "The Use of an Ejector as a Refrigerant Expander", Proc. ASHRAE-Purdue CFC Conference, Int. Inst. Refrig., Paris, pp. 10-19, 1990.