ISSN 2395-1621

Evaluation for Replacement of R22 as R161 in the Vapour Compression Cycle through Aspen Plus Software

[#1]A. N. Korshetti, [#2]Dr. V. N. Raibhole

[1]ashok.korshetti1@gmail.com
[2]vnraibhole@mescoepune.org

1. G.S. Moze COE Balewadi,, Pune-411045, India
2. M.E.S. College Of Engg, Pune-411005, India

ABSTRACT

As per the scientific study of environmental pollution extensively, there is an significant need to phase out R22 earlier than that prescribed by Montreal protocol. Any alternative to R22 has to possess all desirable properties of refrigerants like thermodynamic efficiency, non-flammable and non-toxic, thermal and chemical stability, compatibility and low cost. There are other concerns such as Ozone Depletion Potential (ODP) & Global Warming Potential (GWP) of a refrigerant. The R161 is a zero ODP and low GWP refrigerant with excellent thermo physical properties and was neglected with contention that flammable fluids are not safe to be used as refrigerants. With the technological development, refrigeration industry has started working on flammable refrigerants. In this paper theoretical performance study on an ideal vapour compression refrigeration system with refrigerant R161 and R22 was done for a range of evaporating temperature ranging between -15^0C to 10^0C and constant condensation temperature of 55^0C. Environmental properties, thermo-physical properties and chemical properties of R161 and R22 are compared. Theoretical results showed that R161 is more energy efficient than R22.The discharge temperatures are lower than that of R22.Thus the study is an attempt to suggest an eco-friendly alternative refrigerant to R22.It gives better graphical interface with direct access because the refrigerant R161can be an excellent replacement for refrigerant R22 for medium temperature applications. In this paper theoretical cycle performance of both the refrigerants for the evaporator temperature range of -15°C to 10°C shows that R161 is a promising alternative refrigerant to R22. COP values are higher and discharge temperature is lower for R161 compared to R22. COP value with R161 can be improved by designing a refrigeration system especially for R161.

Keywords:- **COP- Coefficient of Performance, GWP-Global Warming Potential, ODP-Ozone Depletion Potential, R- Refrigerant**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

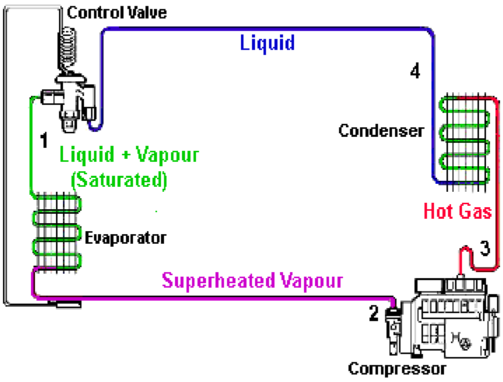
I.NTRODUCTION

R161, a hydro fluro carbon, (ethyl fluoride) is chlorine free and has been neglected due to its flammability, but expected improvement in performance of a refrigeration system using this refrigerant makes it attractive. Very little work has been reported in the literature. At international level, some research on R161 has been reported in China. Some researchers have worked on system performance with mixtures of R-161 and other refrigerants. Most of the research on R161 has been carried out in China. In India, very little, that too theoretical work has been reported. No experimental work has been reported yet. From literature review one can say, this is the time to develop a small scale refrigeration system for R161 and to test its performance. Yongmei Xuanet. Al. [11] suggested ternary mixture of HFC-161, HFC-125 and R143a as an alternative refrigerant to R502. Xuan et al [12] used ternary mixture of R161/R125/R134a (10/45/45% by weight) as drop-in for R404A in refrigeration application and found COP was nearly equivalent to R404A.Han et al [2]used ternary non-zoetrope mixture of R32/R125/R161 as an alternative to R407C and found that refrigeration capacity as well as coefficient of performance was superior to R407CGuo (2009) compared the properties of R161 and R290 as a replacement to R22 and it was found that R161 posses excellent properties than R290 in the field of R22 replacement. Padalkar et.al.[8]in his simulation work for

5.27kW air conditioner split unit, observed that R161 has higher energy efficient, comparable cooling capacity, lower discharge temperature, lower power consumption and smaller refrigerant charge than R22 refrigeration system. Xiao-hong Han et al [12] have experimented refrigerant R161 as an alternative refrigerant to R410A in a small scale refrigeration system. Results of this experimentation show that R161 is a promising alternative refrigerant to R410A for small scale refrigeration system, which supply a valuable reference for the development of actual system of R161.Yingwen Wu etal have investigated the feasibility of R161 in comparison with R22 and R290, in residential air-conditioner. He studied the performance of 3.5kW residential air-conditioner, theoretically as well as experimentally. Results showed that R161 has better thermodynamics performance than R290. Peng LI et. al. analysed experimentally heat transfer and pressure drop characteristics of R161 in a horizontal smooth tube and observed that the evaporation heat transfer coefficient of R161is about 10% to 25% higher than that of R22 when vapour quality exceeds 0.4. Most of the research on R161 has been carried out in China. In India, very little, that too theoretical work has been reported. No experimental work has been reported yet at national level.

II. CURRENT THEORY & PRACTICE- NUMERICAL APPROACH:

With increasing recognition of environment protection, a great deal of attention has been devoted to the negative environmental effect of CFCs and HCFCs refrigerant. Based on scientific findings, regulatory requirements and market pressure, the governing selection criteria for the new alternative refrigerants are changing. New long term alternative refrigerant should have not only zero ODP but it should have low GWP value – initially 150 or less with old requirements of suitability, safety, and material compatibility. At the same time it should have short (but not too short) atmospheric life. Most important, new alternative must offer high efficiency to reduce indirect contribution to the greenhouse effect. In refrigeration and air-conditioning industries, R22 is the most widely used refrigerant as far as now. Complying with Montreal Protocol, R22 is being phased out in developed and developing countries. In recent years, R134a refrigerant has been recommended and applied in actual equipment to replace R22 by most researchers and refrigerant manufacturers. However, R134a has high global warming potential (GWP=1300). Therefore, R134a can be a long term alternative and can only be used as one of transitional candidates. Recently, the natural refrigerant R290 have been recommended as one of the refrigerant alternative. Thus, as on date, R290 and R161 are the two refrigerants for evaluation as a replacement to R22.Now we have sufficient information to build a real circuit. By taking the components shown below and connecting those with tubing and adding refrigerant first remove all air and moisture a real cooling system can be built.



By using fans to circulate air over the evaporator (the air will be cooled), and condenser (the air will be heated), switch on the compressor and we have a refrigeration machine. Sounds simple, but careful design and specification of components is needed. The control valve is a key component. Usually named as "Expansion Valve" this device regulates the superheat at the outlet of the evaporator. The temperature sensor at the outlet of the evaporator is connected to the valve to provide feedback on the adjustment of the valve. Most valves work automatically by means of a diaphragm, and are termed Thermostatic Valves, whilst other types are electronic.

It is really quite simple in principle. The properties of the Refrigerant or Working Fluid are known to a high level of accuracy and by measuring the pressure and temperature at points 1, 2, 3, 4 the P-h diagram can be established. In practice only two pressure measurements 2 and 3 are required. Instrumentation and computer techniques are now available which allow fast diagnostics of almost any system.

III. CALCULATION METHOD

For Cycle analysis the following Parameters of Vapour compression cycle are used.

1) *Pressure ratio is calculated by using*

$$\text{Pressure ratio} = P_{Cond}/P_{evap}$$

2) *Compressor work is calculated by using*

$$Wc = P = \gamma/(\gamma-1)\, P_1 V_1 \left\{ \left(P_2/P_1\right)^{\gamma-1/\gamma} - 1 \right\}$$

3) *Refrigerating effect is calculated by using*

$$R.E. = h_1 - h_4$$

4) *Volumetric refrigeration Capacity is calculated by using*

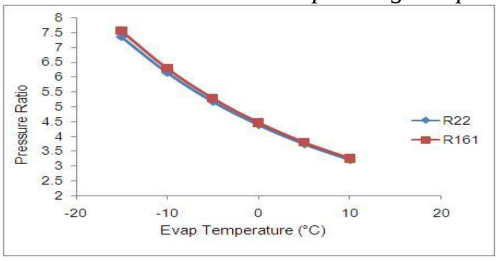
$$V.R.C. = \rho 1.RE$$

5) *Coefficient of Performance is calculated by using*

$$C.O.P. = RE/P$$

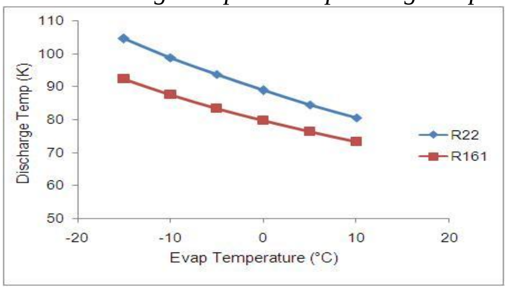
IV. RESULTS DISCUSSIONS WITH GRAPHS

IV.1 Pressure Ratio Vs Evaporating Temp.



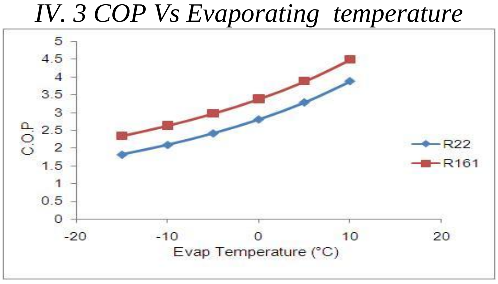
Above graph shows that pressure ratio decreases with increase in evaporating temperature. For R161, pressure ratio is slightly higher compared to R22. That difference in Pressure ratio decreases from 2.5% to 1.4% with increase in evaporator temperature in the given range.

IV.2 Discharge temp. Vs Evaporating temp.



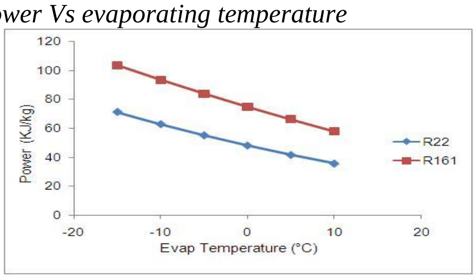
Above graph shows that discharge temperature of a refrigerant decreases with increase in evaporating temp. Discharge temp. for R161 is lower than that of R22 by 11.6% to 9% .

IV. 3 COP Vs Evaporating temperature



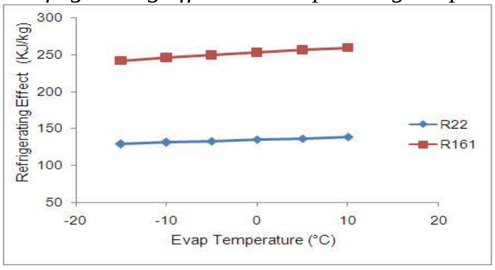
Above graph shows, COP for R161 is higher than that of R22 by 29% to 15.3% in the evaporator range with increase in evaporator temp. Improvement in COP with R161 can be achieved by reducing power required which is much higher compared to R22.

IV. 4 Power Vs evaporating temperature



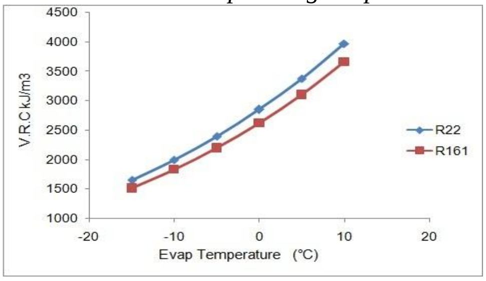
Above graph shows, Power requirement with R161 is higher by 45% to 61% with increase in evaporator in the given evaporator range.

IV.5 Refrigerating effect Vs Evaporating temperature



Above figure shows, refrigerating effect for R161 is 87.4% higher than that of R22 at - 10°C evaporating temperature.

IV.6 C.O.P.Vs Evaporating temperature



In above graph it can be seen that, volumetric refrigerating capacity increases with evaporating temperature. It is lower for R161 compared to R22.

V. Evaluation of Refrigerant R22 & R161

V.1 Thermo Physical Properties

Thermo Physical Properties					
REFRIGERANT	MOL. WEIGHT G/MOLE	Normal B.P. 0C	Critical Temp. Tc 0C	Critical press. Pc MPa	Latent heat of Evap KJ/Kg
R22	86.47	- 40.7	96.2	4.99	233.7
R161	48.06	-37.1	102.2	4.70	421.3

Molecular weight of R161 is lower than molecular weight of R22 by 45%.Latent heat of evaporation of R161 is 82% higher than R22 at normal boiling point. This indicates that per KW of cooling capacity, charge required of R161 is less by about 55% than that of R22.Also due to higher heat capacity; discharge temperature of R161 will be lower compared to R22.Normal boiling point of R161 is slightly lower than that of R22. Saturated pressure of R161 is slightly lower than that of R22 and it is similar to R290. Lower saturation pressure of refrigerant allows ease in manufacturing of refrigeration system and at low cost also.

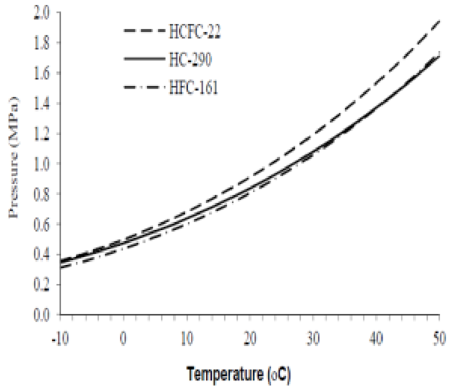


Fig.2 vapour pressure curve for R22 and R161

V.2 Environmental Properties

Environmental Properties			
ODP(R 11=1)	GWP100yr(CO2=1)	Atm. life (Years)	POCP
0.055	1800	11.9	~1
00	12	0.21	5.5

R161 is a non-ozone depleting refrigerant whereas R22 is a non-zero ODP refrigerant. GWP value of R161 is 12 which is very low value compared to R22. Photo Chemical Ozone Creation Potential (POCP) value of R161 compared to R290 is much lower.More recently hydrocarbons have beeZcompared in terms of their photochemical ozone creation potential or POCP.

V.3 Safety characteristics:

Safety Properties					
LFL by mass Kg/m3	LFL by volume%	Burning Velocity Cm/s	Combustion heat MJ/Kg	Toxicity PPM	Safety Class
---	---	---	---	1000	A1
0.038	3.8	38.3	26.6	1800	A3

For the development of R161, flammability and toxicity are very important parameters due which it was neglected alternative for so many years. R22 is non-flammable and non-toxic. R290 and R161 are classified as A3 as per ASHRE34-2010.However lower flammability limit (LFL) for R161 is 0.075Kg/m3 by mass whereas for R290 it is 0.038Kg/m3.LFL value of R161 is approximately double the LFL value of R290.To avoid risk due to flammability, charge in the system should be well below the LFL.The European standard EN378 gives the safety requirements for the use of flammable refrigerants in various applications. As per the EN378 and ASHRAE15, the charge limit is about 15g/m3 for R161and for R290 it is 8g/m3. This shows the more scope for mass of R161 in a system.Burning velocity and combustion heat of R161 are lower than R290. Toxicity safe index for R161 is higher than R22 and R290. From toxicity tests it has been observed that Occupational exposure limit (OEL) of R161 is 1822 ppm when mouse sucks the refrigerant for 28days.The OELs for R22 and R290 are 1000.

VI. Theoretical cycle performance of R22 and R161 at condensing temperature of 55°C and evaporating temperature of – 10°C.

Refrigerant	PR	RE kJ/Kg	P kJ/Kg	VRC kJ/m3	Td °C	COP
R22	6.14	131.04	62.92	1997	98.85	2.08
R161	6.28	245.60	93.42	1832	87.67	2.62
% deviation of R161 from R22	2.2	87.4	- 48.4	-8.29	-11.4	26.3

VII. CONCLUISION

In order to great deal of attention has been devoted to the negative environmental effect of CFCs and HCFCs refrigerant. Based on scientific findings with regulatory requirements The refrigerant R161 may use as excellent replacement for refrigerant R22 for medium temperature applications. In this paper, Theoretical cycle performance of both the refrigerants for the evaporator temperature range of -15°C to 10°C shows that R161 is a promising alternative refrigerant to R22.COP values are higher and discharge temperature is lower for R161 compared to R22. COP value with R161 can be improved by designing a refrigeration system especially for R161 extensively as per the nature of work.

ACKNOWLEDGEMENT

Authors would like to thank Dr. V. N. Raibhole,
Dr. S.N. Sapali, , Dr. A.S. Padalkar, Prof. C.S. Chaudhari,
Prof .M.M. Dange, Prof. M.R. Jagdale for the needful
support and guidance.

REFRENCES

[1] Chen qi, hongrong-hua, chenguang-ming "Measurement of gaseous PVT properties of ethyl

Fluoride at temp. 371.21 to 413.29K", journal of Zhejiang university science, 2006.
[2] Han X H, Q. Wang,Z.W.Zhu, G.M.Chen" Cycle performance study on R32/R125/R161 as an alternative refrigerant to R407C", Applied thermal engineering 2007.
[3] HanXH ,Q. Wang, Z.W.Zhu and G.M.Chen "HFC161 as an alternative refrigerant to HFC410A in a small scale refrigeration" 2011.
[4] Hundet. al. Refrigeration and Air conditioning book.
[5] James M. calm, "The next generation of refrigerants-historical review, considerations, and outlook, international journal of Engineering" 22nd international congress of refrigeration. Beijing. 2008.
[6] Yingwen Wu, iangfei Liang, Xiaoping Tu, RongZhuang, "Study of HFC161 refrigerant for Residential Air Conditioning Applications" 2012.
[7] James calm and Glenn Hourahan, Refrigerant Data summery, engineered systems, Nnov.2001
[8] Padalkar A.S., K.V. Mali, S. Devotta "Prospective of HFC-161 as an alternate to HCFC-22 in air conditioners", 23rd IIR international congress of Refrigeration, August 21-26, 2011.
[9] Pearson. New, Natural and Alternative Refrigerants by of Star Refrigeration limited
[10] Peng Li, XueHui Wang, Xiao Hong HAN and Guang Ming CHEN "Experimental investigation on Evaporation heat transfer and pressure drop characteristics of HFC161 in a horizontal smooth tube "International Refrigeration and air Conditioning Conference at Purdue, July16-19-2012.
[11] YongmeiXuan and Guangmingchen, "Experimental study on HFC-161 mixture as an alternate refrigerant to R502" 2004.
[12] Xiao-hong Han, Yu Qiu,Peng Li, Ying-jieXu,Qin Wang, Guang-ming Chen, "Cycle Performance studies on HFC161 in a small scale refrigeration system as an alternative refrigerant to HFC410A"Energy and Buildings 2011.
[13] Xuan "Ternary mixture of R161/R125/R134a as drop-in for R404A in refrigeration application". 2004.
[14] Chaudhari C.S. & Dr. Sapali S.N. "Evaluation of a Refrigerant R161 as a Replacement to HCFC22" international conference on Advances in Mechanical Engineering at College of Engg, Pune during 29th – 31st May 2013.
[15] Refrigeration & Air Conditioning, CP Arora, Tata Macraw-Hill, 2006.
[16] Refrigeration system, P.2 Ballaney Khanna publishers, 2009
[17] Refrigeration & Air Conditioning, Manohar Prasad
[18] Refrigeration & Air Conditioning, Dr. S.N. Sapali, PHI Publications
[19] Aspen Plus Software manual (10.2) & software

