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Research Paper

The Comparison Based on The Characteristics of Various Hydrocarbon Refrigerants of Vapour Compression Refrigeration System Using Suction Line Heat Exchanger

Engineering

KEYWORDS : refrigeration, ODP, GWP, HC1270 (propylene), HC1150 (ethylene), HC600a (isobutene), HC290 (propane)

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ABSTRACT

IN this up-to-the minute comradeship it is decidedly to capitalize those refrigerants having minimal ozone depletion layer potential (ODP) and global warming potential (GWP) by virtue of ozone depletion potential and global warming potential is overshadowing origin to uppermost environmental crisis. In order to dodge the crisis hydrocarbons are pre owned rather than chlorofluorocarbons. Our foremost heading was testing HC290, HC1270, HC1150, HC600a etc.as refrigerants in vapor compression refrigeration system and pronouncing their performance. In testing performance of vapor compression refrigeration system was scrutinize of each refrigerants. Theoretically result showed that all of the HC refrigerants investigated in the analysis have a zero ODP and GWP of HC1150 and HC1270 is same found to be 0.01 whereas HC290 has 0.0011 GWP for the condensation temperature of 60°C and evaporating temperatures ranging between -30°C and 10°C. the effect of prime parameters of performance analysis such as degree of sub cooling and superheating on the refrigeration effect , work input, coefficient of performance, suction vapor flow rate, volumetric refrigeration effect , pressure ratio , power per TR are also investigated for various evaporative temperatures. The HCs refrigerants are best alternatives of various CFCs, HCFCs, refrigerants which are recently used in our domestic refrigeration system and cause harmful effect on our environment.

Introduction

The earth's ozone layer in the upper atmosphere is needed for the absorption of harmful ultraviolet rays from the sun. In 1985, the world was shocked to find a gaping hole above Antarctic in the ozone layer that protects the earth from ultraviolet rays. These rays can cause skin cancer. CFCs have global warming potential (GWP) been linked to the depletion of this ozone layer. They have varying degrees of ozone depletion potential (ODP). In addition, they act as greenhouse gases. Accordingly to an international agreement(Montreal protocol), the use of fully halogenated CFCs, that are considered to have high ODP, viz. the commonly used refrigerants R-11, R-12 ,R-113,R-114 and R-502 ,have been phased out from the year 2000A.D. HCFCs have much lower ODP. They have some GWP. They have to be phased out by 2030.But until 2030, they can be used. R-22 is HCFCs. Its ODP is only 5% of that of R-12. It will be phased out by the year 2030A.D.But R-22 continues to remain very popular as a refrigerant. Even with the measure taken so far, late as 2008, a 2.7 million square kilometres ozone layer hole was detected above Antarctic.

In 1974, two scientists including a radiochemist S. Rowland postulated that CFCs, because they are so stable, have a long life in the lower atmosphere. And in spite of CFCs being heavier than N_2 and O_2, these slowly migrate into the upper atmosphere by molecular diffusion caused by partial pressure difference. It was hypothesized that the chlorine atoms from the molecule would be split off by the action of sunlight, and the free chlorine will react with ozone in the stratosphere, according to the following reactions:

$$CCl_2F_2 \xrightarrow{\text{sunlight}} CClF_2 + Cl$$

$$O_3 + Cl \xrightarrow{\text{sunlight}} ClO + O_2$$

Thus, O_3 will be depleted to O_2 .The problem with CFC is that of chain is that of chain reaction. A single atom of Cl released from CFC reacts taking out 100,000 O_3 molecules. That is why, even small concentration of CFC also become important.

Hydrocarbons provided alternatives to fully halogenated CFC refrigerants. They contain no chlorine atom at all and, therefore, have zero ODP. Even hydro-chlorofluorocarbons like R-122 and R-123 which do contain chlorine atom/s, but in association with H-atoms allows them to dissociate faster in the lower atmosphere of the earth. Chlorine, thus realized gets absorbed by rain water etc., like the chlorine used in the chlorination of water. So fewer Cl- atoms reach the ozone layer in the upper atmosphere. However, HCFCs have a level of ODP in addition to GWP. Hence these also have to be phased out ultimately. Till then, they can be used as transitional refrigerants.

Although HC refrigerants have a highly flammable characteristics according to the standards of ASHRAE (American Society of Heating Refrigeration And Air conditioning Engineers) as a negative specification, they have not only several preferable specifications such as zero ODP, very low GWP, non-toxicity, and higher performance than others types but also high miscibility with the minerals oil and good accordance with the existing refrigerating systems.

refrigeration system

Working principle: - Refrigeration is defined as "the process of cooling of bodies or fluids to temperatures lower than those available in the surroundings at a particular time and place". There are two statement related to second law of efficiency as follows-

1. The Kelvin- Plank statement which is related to heat engine.

2. The clausius statement which is related to refrigeration system and heat pump, which is as follows:

"It is impossible to construct a device which operate on cycle and produce no effect other than the transfer of heat from a low temperature body to high temperature body."

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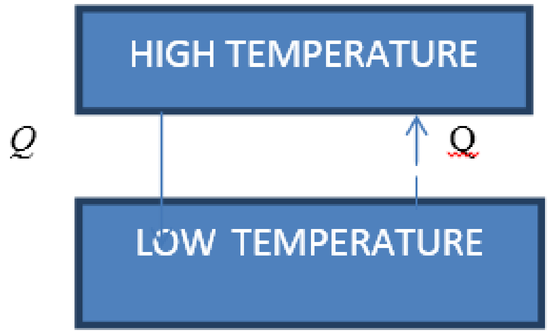

atm	Atmosphere
CFCs	Chlorofluorocarbons
COP	Coefficient of performance
GWP	Global warming potential
h	Enthalpy, kg kj^{-1}
h_{fg}	Latent heat of condensation , kj kg^{-1}
HCFCs	Hydro chlorofluro carbons
HCs	Hydrocarbons
HFCs	Hydro fluorocarbons
ODP	Ozone depletion potential
P	Pressure , MPa
RE_in	Refrigeration effect
SVFR	Suction vapour flow per KW of refrigeration , Ls^{-1}
T	Temperature, °C or K
W_in	Isentropic compression work, KNm kg^{-1}
VRC	Volumetric refrigeration system, kj m^{-3}
PTR	power consumption per ton
Subscripts	
cond	Condenser/Condensing
evap	Evaporator/Evaporating
comp	Compressor

CONSTRUCTION

The Vapor Compression Refrigeration Cycle is a process that cools an enclosed space to a temperature lower than the surroundings. To accomplish this, heat must be removed from the enclosed space and dissipated into the surroundings. However, heat tends to flow from an area of high temperature to that of a lower temperature. During the cycle refrigerant circulates continuously through four stages. The first stage is called Evaporation and it is here that the refrigerant cools the enclosed space by absorbing heat. Next, during the Compression stage, the pressure of the refrigerant is increased, which raises the temperature above that of the surroundings. As this hot refrigerant moves through the next stage, Condensation, the natural direction of heat flow allows the release of energy into the surrounding air. Finally, during the Expansion phase, the refrigerant temperature is lowered by what is called the auto refrigeration effect. This cold refrigerant then begins The Evaporation stage again, removing more heat from the enclosed space. Each of the four stages will now be revisited in detail, explaining the physical changes that occur in the refrigerant and the devices used to accomplish these changes. A visual representation of the cycle is displayed below with the explanation of each stage.

Evaporation:- During this stage, the refrigerant travels through a device called an evaporator that has a large surface area and typically consists of a coiled tube surrounded by aluminium fins. The cold fluid is a mixture of liquid and vapour refrigerant as it begins this stage. While flowing through the evaporator, all the liquid evaporates and absorbs heat from the enclosed space. The energy absorbed is used to change the state of the refrigerant from liquid to vapour. This lowers the temperature of the space, along with whatever food or beverages are stored in it. The refrigerant exits this stage as a saturated vapour. Vapour Compression Refrigeration Cycle Compression The heat that was absorbed in the Evaporation stage must be released into the surroundings, but this will not happen unless the temperature of the refrigerant is higher than the outside air. This is the purpose of the Compression stage. A device, predictably called a compressor, raises the pressure of the refrigerant vapour. Due to basic thermodynamic principles, this causes the temperature of the refrigerant to rise, leaving the stage as a superheated vapour. Energy is needed to power the compressor, which is why electricity is required to operate a refrigerator.

Condensation: - Now that we have increased the temperature of the refrigerant above that of the surroundings, we can dissipate the heat necessary to continue the process. This is accomplished with a device very similar to the evaporator. It also uses a coiled tube with aluminium fins, but may have different dimensions than the evaporator to accommodate the different state of the refrigerant. As the hot vapour flows through the condenser, the outside air removes energy and the refrigerant becomes a saturated liquid. At this point the slightest drop in pressure will initiate evaporation, which is the basis for the final stage of the process.

Expansion:- To begin a new cycle, all that must happen is a lowering of the refrigeration temperature to below that of the enclosure. This is the key to the entire cycle, because this was the problem that we started with. However, in this situation we can utilize what is called the auto-refrigeration effect. When a saturated liquid experiences a sudden drop in pressure, a small amount of liquid is instantly vaporized and the temperature of the mixture is drastically reduced. This cold liquid-vapour mixture can now begin a new cycle. The pressure drop is accomplished by the simplest, yet most important, part of the system – a simple flow restriction. This part is commonly called a throttle or expansion valve.

Montreal Protocol:- The United Nations environment programme conference held in Montreal in September 1987 the decision taken to phase out ozone depleting substances (ODS) within a fixed time period is known as Montreal Protocol. Some of the feature of MP is as follows.

1) Developed countries will phase out CFCs by 1996.

2) Developing countries will phase out CFCs by 2010 with freeze in 1999 and gradual reduction thereafter. Developed Countries will phase out HCFCs by 2030 while developing Countries have been provided a grace period of ten years i.e. Phase out by 2040.

3)Global warming is another serious issue. Some naturally occurring substances mainly cause this but CFCs have very large global warming potential

REFRIGERATION PROPERTIES

SPECIFIC PROPERTIES

Hydrocarbon Refrigerants are natural, nontoxic refrigerants that have no ozone depleting properties and absolutely minimal global warming potential. The most efficient and environmentally safe refrigerants in the world are the five natural refrigerants which are Air, Water, Carbon Dioxide, Ammonia and Hydrocarbons. We call them 'The Famous Five'.

Hydrocarbon Refrigerants are not just good for the environment; they can also save you up to 54% on your energy costs. Air-conditioning systems are the largest consumers of electricity for any building. The energy used in cooling generally accounts for 60% of buildings total energy consumption. By converting to hydrocarbon refrigerants, substantial energy savings can become a reality.

Hydrocarbon Refrigerants are 50% more efficient conductors of heat than Fluorocarbon Refrigerants and their operating pressures are about 20% lower than that of Fluorocarbon Refrigerants. These lower operating discharge pressures reduce the work that the compressor has to do thus reducing wear and tear. There is less pressure on pipe work, joints, hoses, fittings and the like reducing the likelihood of leaks. This can and will extend the working life of your equipment. All these advantages equate to an energy saving of between 17% and 54%. Every year approximately 8 million hydrocarbon based refrigerators are produced in Europe, each using around 30% less energy than refrigerators using fluorocarbon refrigerants.

General Properties
The following types of hydrocarbons are commonly used as refrigerants:

R290 Propane, R600a Isobutene and R1270 Propylene

A number of other hydrocarbons, such as blends containing ethane, propane or butane, are also used as refrigerants.

Safety
Hydrocarbons are highly flammable and must be handled with care. If they are used responsibly, hydrocarbons can be employed in a variety of refrigeration and air conditioning applications. In order to ensure safety, hydrocarbon applications are governed by various international, regional and national standards and regulation. Hydrocarbons can only pose an explosion risk if the concentration is between the lower and upper flammability limits.

When following the safety standards the concentration of leaked refrigerant will not get above LFL where ignition sources can ignite it, even in extreme situations. The necessary safety precautions and system design depend on the refrigerant charge. In general ignition sources inside the application must be avoided. Most hydrocarbons are non-toxic, with the main safety risk coming from their flammability, although gaseous hydrocarbons is heavier than air and will displace air in lungs.

Only authorized persons certified for the installation and maintenance of refrigeration systems containing flammable refrigerants should engage in installation and maintenance.

	R600a		R290	
Lower flammability limit (LFL)	1 .8%	approx. 38 g/m³	2 .1%	approx. 38 g/m³
Upper flammability limit (UFL)	8 .5%	approx. 203 g/m³	9 .5%	approx. 171 g/m³
Auto-ignition temperature	494 °C		470 °C	
Lower and upper flammability limits				

Pressure and Temperature
The refrigeration properties of hydrocarbons, such as pressures, pressure ratios and discharge temperatures, are quite similar to those of HCFCs or HFCs in many respects.

Chemical Properties
The most commonly used hydrocarbons (propane and isobutene) are compatible with standard oils and materials used with HFCs. One exception is propene (propylene), which is not compatible with neoprene. Consequently, special O-rings must be used with this refrigerant.

Economic Aspects
The relative cost of a system using hydrocarbons largely depends on the application. In domestic and light commercial applications, the cost of the system is similar to that of systems with HFCs. In commercial and industrial refrigeration applications, systems with HCs tend to be relatively expensive due to the need for explosion-proof enclosures for electrical equipment, though for chillers placed outdoors the added cost for safety is more modest.
In this paper, for a vapor compression refrigeration cycle, is used in order to obtain better performance present study mostly concentrate on theoretical investigation of the performance of the vapor compression refrigeration cycle. R290, R600a, R1270 are used as the working fluid and compared the performance of the vapor compression cycle. The effect of the main parameter of the performance analysis such as refrigeration type and degree of sub cooling and superheating on refrigerating effect, COP,VRC, are investigated for various evaporating temperature ranging from -30°C to 10°C and constant condensation temperature of 60°C.

METHOD OF ANALYSIS AND CALCULATON
The software EES (engineering equation solver) vapour compression design program was used for the performance analysis of the system.

SYSTEM COOLING CAPACITY (kW) = 1.00
COMPRESSION ISENTROPIC EFFICIENCY = 1.00
COMPRESSION VOLUMETRIC EFFICIENCY = 1.00
ELECTRIC MOTOR EFFICIENCY = 1.00
PRESSURE DROP IN SUCTION LINE = 0.0
PRESSURE DROP IN DISCHARGE LINE =0.0
EVAPORATOR TEMPERATURE RANGE = -20 to 20⁰C
CONDENSER TEMPERATURE = 55⁰C
DEGREE OF SUPERHEATING = 5⁰C
DEGREE OF SUB COOLING = 5⁰C

The pressure –enthalpy diagram in figure 2 is ideal vapor compression refrigeration cycle and is considered for the working substance that change phase during cycle.it is known that the actual vapor compression refrigeration cycle have some changes from the ideal vapour compression refrigeration cycle due to pressure losses during flow of refrigerants through pipes and heat transfer between system and surrounding . The superheating and sub cooling are shown in fig.-3.In the case of superheating state of vapour of refrigerant exists at the inlet part of the compressor , the pressure of liquid at the exit part of condenser is lower than the pressure at the inlet part of it , there is a pressure drop greater than the ideal one between the condenser and expansion valve and also a larger pressure drop occurs on the evaporation line.

So now we have to be taken some assumption to ease the theoretical calculation as following: neglect of the pressure drops and heat transfer between system and surrounding.

1. The refrigeration capacity (RC): The rate of heat transfer of evaporator (Q_{evp}_dot_in), is calculated as follow:

RE_dot_in=Q_{evp}_dot_in =h_1-h_6

2. The power input: The rate, at which work is given to the compressor, is calculated as follows:

W_dot_in=m_dot *(h_2-h_1)

3. Coefficient of performance (COP): It is ratio of refrigeration capacity to the power input, is calculated as follow:

COP=RE__dot in / W_dot_in

In the vapor compression refrigeration cycle in fig.-1(a) ,volumetric refrigeration capacity (VRC) is given as :

VRC= (density of vapour at the state of inlet to the compressor)*RE

Figures and Table

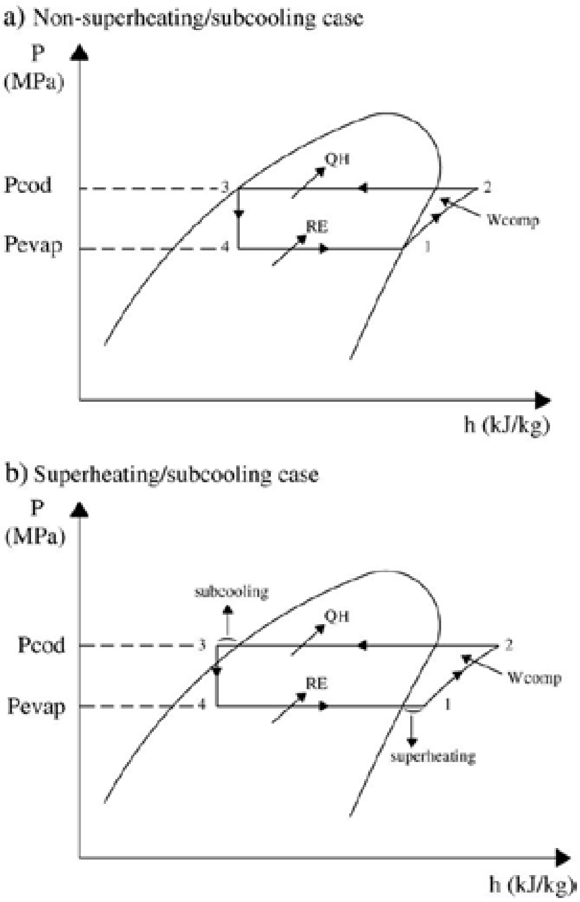

Figure-1 P-h curve .a) simple vapor compression cycle b) vapor compression cycle with sub cooling and superheating

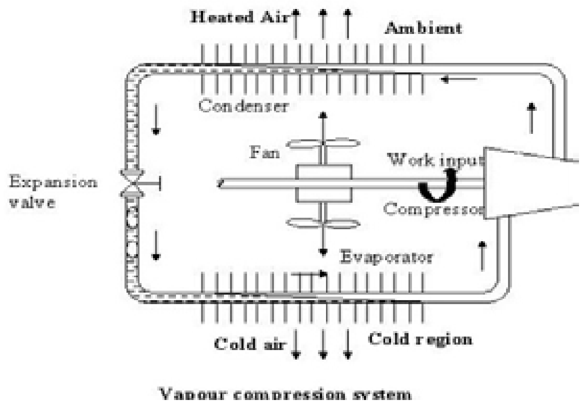

Table-1
Operation on a standard vapour- compression cycle using various refrigerants at T_{cond}=55^{0}c and T_{evap}= -10^{0}c with superheating 5^{0}c and sub cooling 5^{0}c

Refrigerant	P_{evap} (bar)	P_{cond} (bar)	Pressure ratio	W_{comp} (kj/kg)	RE (kj/kg)	Power per ton refrigeration (kw/TR)	VRC (kj/m^3)	Comp. power (kw)	COP
R-290	3.426	19.074	5.523	82.44	234.6	1.11	1747	0.3515	2.845
R-600a	1.090	7.8170	6.235	71.3	240	0.938	698.7	0.2971	3.366
R-1270	4.2	22.286	5.325	85.27	242.4	1.11	2162	0.3818	2.842
R-134a	2.006	14.919	7.434	43.04	125.4	1.084	1229	0.3433	2.913

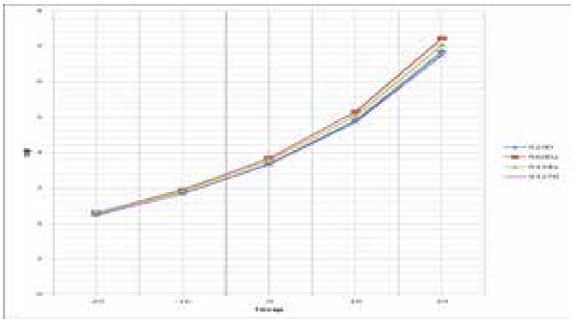

Figure -3 variation in COP with evaporation temperature (T_{evap})

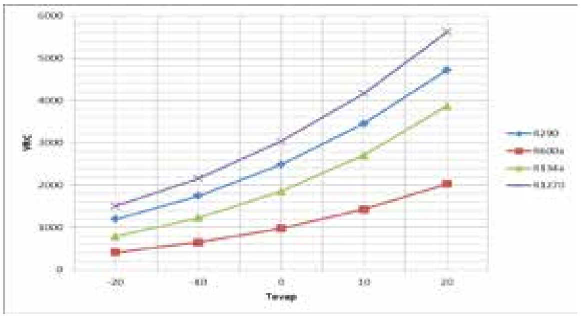

Figure -4 variation in VRC with evaporation temperature (T_{evap})

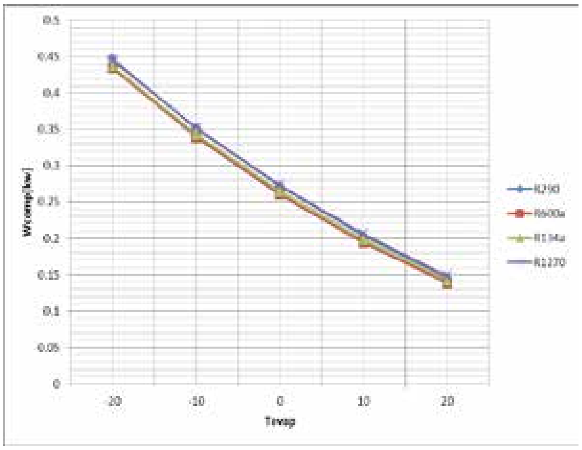

Figure – 5 variation in W_{comp} (kW) with evaporation temperature (T_{evap})

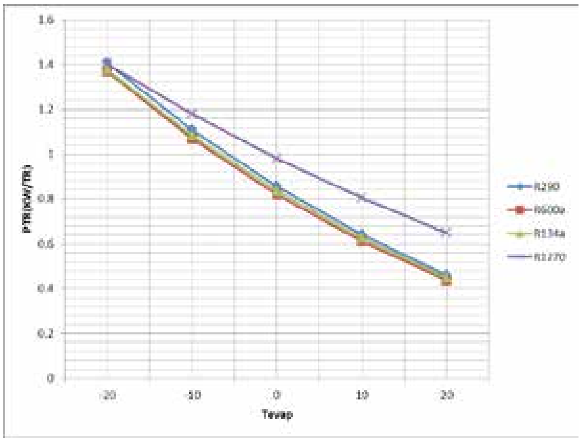

Figure-6 variation in PTR with evaporation temperature (T_{evap})

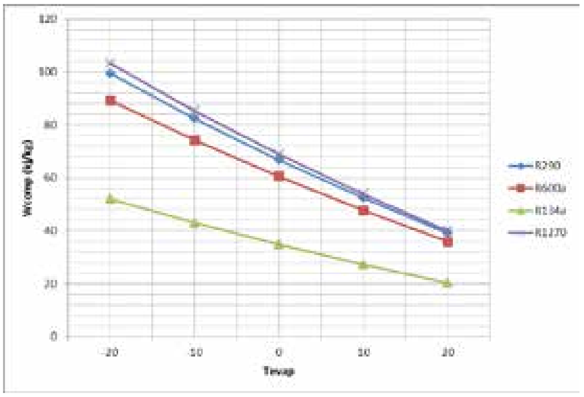

Figure -7 variation in W_{comp} with evaporation temperature (T_{evap})

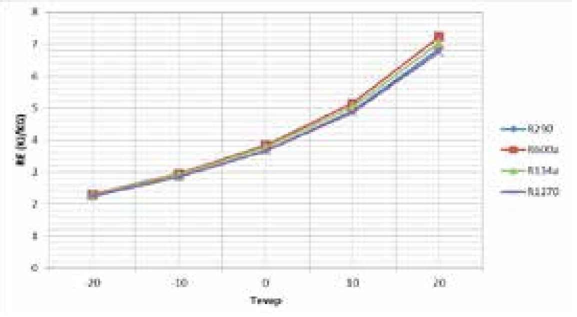

Figure -8 variation in RE with evaporation temperature (T_{evap})

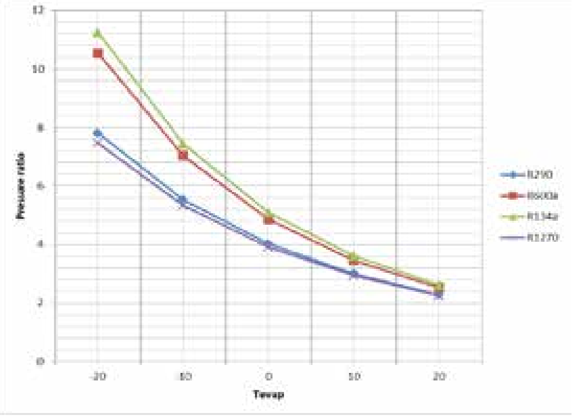

Figure -9 variation in pressure ratio with evaporation temperature (T_{evap})

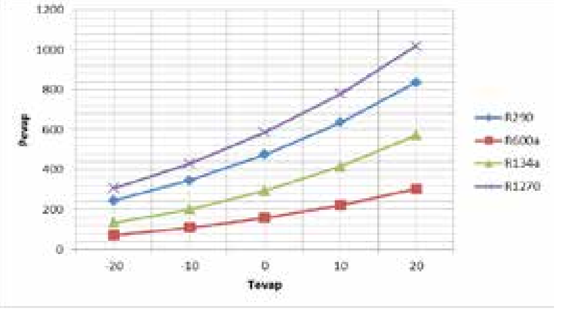

Figure-10 variation in P_{evap} with evaporation temperature (T_{evap})

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Result and discussion

The variation in cop with various value of evaporation temperature is shown in figure -4.From this figure , the coefficient of performance (COP) increases as the evaporation temperature (T_{evap}) increase for the constant condensation temperature of 55^0c and evaporation temperature ranging from -20^0c to 20^0c. The variation in volumetric refrigeration capacity with evaporation temperature is shown in figure-4. Figure- 8 shows that the refrigeration effect (RE) increases with increasing evaporation temperature ($\mathbf{T_{evp}}$) while the compressor power ($\mathbf{W_{comp}}$) decrease with increasing $\mathbf{T_{evp}}$ for the constant condensation temperature and taken rang of evaporation temperature.

CONCLUSION:-

From all of the above study it can be clearly be made out that an ideal vapour compression system which is in practice for the performance analysis of alternatives. Now a day refrigerants in place of CFC's , HCFC's.. Keeping in mind the difference of performance coefficient (COP) and pressure ratio of the analyzed refrigerants and also the important environmental aspects of ozone layer depletion and global warming .refrigerant R600a was evaluated out to be the most effective and suitable among various refrigerants tested. All system including various refrigerants were enhanced by undertaking the effect of the superheating/sub cooling case evolved as a result of optimization.

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