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Experimentation on the sub-cooling, superheating effect, and performance of a low-cost refrigeration system using R1270 as a refrigerant

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ABSTRACT

R1270, also known as CARE 45, is **refrigerant** grade propylene (propene), a natural, or "not in kind", **refrigerant** suitable for use in low and medium temperature **refrigeration** applications. It is non-toxic, with zero ODP (Ozone Depletion Potential) and very low GWP (Global Warming Potential). This paper researches the effect of a test examination completed to decide the exhibition of local icebox when a melted oil gas (LPG) is locally accessible. The performance of a standard VCRS cycle can be obtained by varying evaporator and condensing temperatures over the required range. The effects of evaporator and condensing temperatures on specific and volumic refrigeration effects of a standard VCRS cycle. As shown in the figure, for a given condenser temperature as evaporator temperature increases the specific refrigeration effect increases marginally. It can be seen that for a given evaporator temperature, the refrigeration effect decreases as condenser temperature increases. These trends can be explained easily with the help of the P-h diagram. It can also be observed that the volumetric refrigeration effect increases rapidly with evaporator temperature due to the increase in specific refrigeration effect and decrease in specific volume of refrigerant vapour at the inlet to the compressor. Volumetric refrigeration effect increases marginally as condenser temperature decreases.

Keywords: Refrigerant (R1270), Evaporator, Refrigerating effect, COP. Vapour Compression Refrigeration, COP, Domestic Refrigerator, Eco-Friendly Refrigerants, Sub- Cooling, and Super Heating.

1. INTRODUCTION

Due to the massive demand for electricity over the world, we think of recovering the energy already spent but not being utilized further to overcome this crisis with less investment. The climatic change and global warming demand accessible and affordable cooling systems in refrigerators and air conditioners. Henceforth, we suggest COST-FREE Cooling Systems. LPG is stored in liquefied state in a cylinder before its utilization as fuel. According to the energy survey, the refrigerator is one of the

heaviest power consumers amongst household appliances. It works on the principle that the expansion of LPG will occur during the conversion of liquid LPG into gaseous form. As a result of this, LPG gas pressure drops, and the volume of gas will increase this will result in a decrease in gas temperature and acts as the refrigerant. According to the second law of thermodynamics, this cooling process can only be performed with the aid of some external work. Hence, the power supply is regularly required to drive a refrigerator. The substance that works in a refrigerator to extract heat from a cold body and deliver it to a hot body, i.e. to, surrounding, is called refrigerant. Globally 17500 metric tons of conventional refrigerants are consumed by domestic refrigeration like CFC, HFC which causes high depletion of the ozone layer (ODP), and Global Warming Potential (GWP). The use of LPG instead of CFC 22 has made better progress since it has an environment-friendly orientation with no ODP. Good product efficiency is resulted from the use of LPG because of its characteristics. It indicates LPG can be used as an alternative refrigerant to CFC 22. After performing new system, an experimental analysis is done in CFD. M. Mohanraj et al. [1] have studied experimentally the drop-in substitute for R1270 with the environment friendly, energy-efficient hydrocarbon (HC) mixture, which consists of 45% HC290 and 55% R600a at various mass charges of 50g, 70g, and 90g in a domestic refrigerator. The experiments were carried out in 165 liters domestic refrigerator using R1270 with POE oil as a lubricant. The discharge temperatures of HC mixtures are found to be lower than R1270 by 13.76%, 6.42%, and 3.66% for 50g, 70g, and 90g, respectively. The power consumption of HC mixture at 50g and 70g are lower by 10.2% and 5.1%, respectively, and 90g shows higher power consumption by 1.01%. The percentage reduction in pull-down time is 18.36%, 21.76%, and 28.57% for 50, 70, and 90g mass charges, respectively, compared to R1270. The HC mixture, because of its high energy efficiency, will also reduce indirect global warming. In conclusion, the HC mixture of 70g is an effective alternative to R1270 in 165 liters domestic refrigerator. B.O.Bolaji et al. [2] has an Experimental study of R152a/R32 to replace R1270 in a domestic refrigerator and find out that COP obtained by R152a is 4.7% higher than that of R1270. COP of R32 is 8.5% lower than R1270, and Propane is an attractive and environmentally friendly alternative to CFCs currently used. R.W.James & J.F.Missenden [3] have used Propane in domestic refrigerators and concluded that using Propane in domestic refrigerators is examined about consumption, compressor costs, availability, and energy lubrication, environmental factors, and safety propane is an attractive and environmentally friendly alternative to CFCs used currently. S.K. Kalla et al. [4] the purpose of this paper is to identify the best available alternative for replacing the existing refrigerant R22 with minimal or no changes to the air conditioning system. Both theoretical and experimental studies in this area of research have been reviewed for this purpose. The most common HFC, R410A, has a lower critical temperature, which limits its use in compression-based systems operating at higher condensing temperatures, whereas R407C requires a change to synthetic lubricant and HC-290 is flammable. E. Bellos et al. [5] the goal of this work is to compare various cascade refrigeration systems with CO₂ in the low-temperature circuit. A total of 18 different cascade refrigeration systems, including the CO₂/CO₂ cascade system, are investigated. The analysis is carried out for four different evaporator temperatures (35, 25, 15, and 5 degrees Celsius), while the condenser temperature is varied from 10 to 45 degrees Celsius. The systems are compared energetically and using the total equivalent warming impact (TEWI) for yearly operation in Athens weather conditions (Greece). The final results show that all of the cascade systems investigated are more efficient than the CO₂/CO₂ cascade system.

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1.1 Objectives

- To obtain the characteristic benefits of LPG refrigerant.
- To determine the COP of the refrigerator using LPG as a refrigerant.
- To benefit from the Cooling effect free of cost by eliminating the compressor.
- To produce an eco-friendly refrigeration system by green technology that eliminates the use of ozone-depleting refrigerants.

1.2 Properties of R1270

- Colorless.
- Odorless (It's normal to odorize LPG by adding an odorant before supply to the user, to aid detection of any leaks).
- Heavier than air.
- Liquid LPG is half the weight of water.
- Non-toxic.
- LPG expands upon release, and 1 liter of liquid will form approximately 250 liters of Vapour.

1.3 Scope of Work

- It can be helpful in remote parts where electricity is not available.
- It can play an essential role in restaurants where continuously cooling and heating are required.
- It can be used in automobiles running on LPG or other Gaseous fuels for air conditioning.

2. METHODOLOGY

1.1 Working principle

The vapor absorption refrigeration system comprises all the vapor compression refrigeration system processes like compression, condensation, expansion, and evaporation. In the vapor absorption system, the refrigerant used is ammonia, water, or lithium bromide. The refrigerant gets condensed in the condenser, and it gets evaporated in the evaporator. The refrigerant produces a cooling effect in the evaporator and releases the heat to the atmosphere via the condenser. The refrigerant enters the condenser at high pressure and temperature and gets condensed. The condenser is of water-cooled type. When the refrigerant passes through the expansion valve, its pressure and temperature reduce suddenly. This refrigerant (ammonia in this case) then enters the evaporator. The refrigerant at external pressure and temperature enters the evaporator and produces the cooling effect. In the vapor compression cycle, this refrigerant is sucked by the compressor. Still, this refrigerant flows to the absorber in the vapor absorption cycle that acts as the suction part of the refrigeration cycle.

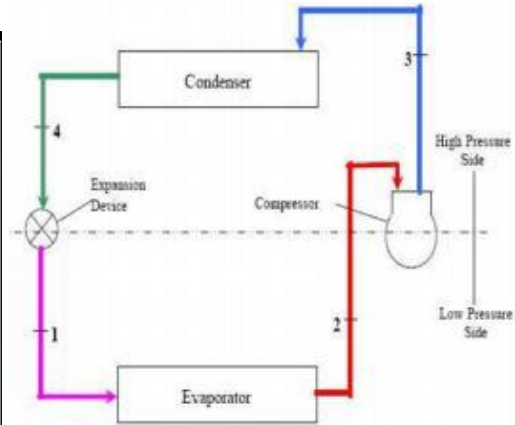
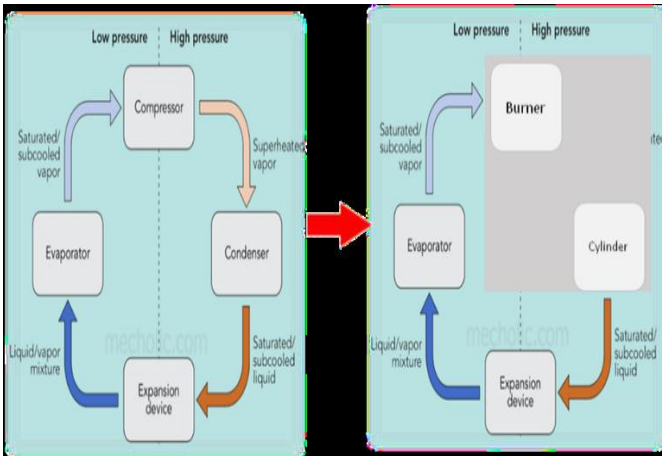


Fig.1 Schematic diagram of simple VCR Fig.2 ACTUAL SYSTEM Modification of VAC

2.2 Effect of sub cooling and super heating on r1270

Sub-cooling is beneficial as it increases the refrigeration effect by reducing the throttling loss at no additional specific work input. Also sub cooling ensures that only liquid enters into the throttling device leading to its efficient operation. Figure 11.4 shows the VCRC cycle without and with sub cooling on P-h and T-s coordinates. It can be seen from the T-s diagram that without sub-cooling the throttling loss is equal to the hatched area $b-4'-4-c$, whereas with sub-cooling the throttling loss is given by the area $a-4''-4'-b$. Thus the refrigeration effect increases by an amount equal to $(h_4-h_4') = (h_3-h_3')$. Another practical advantage of sub cooling is that there is less vapour at the inlet to the evaporator which leads to lower pressure drop in the evaporator.

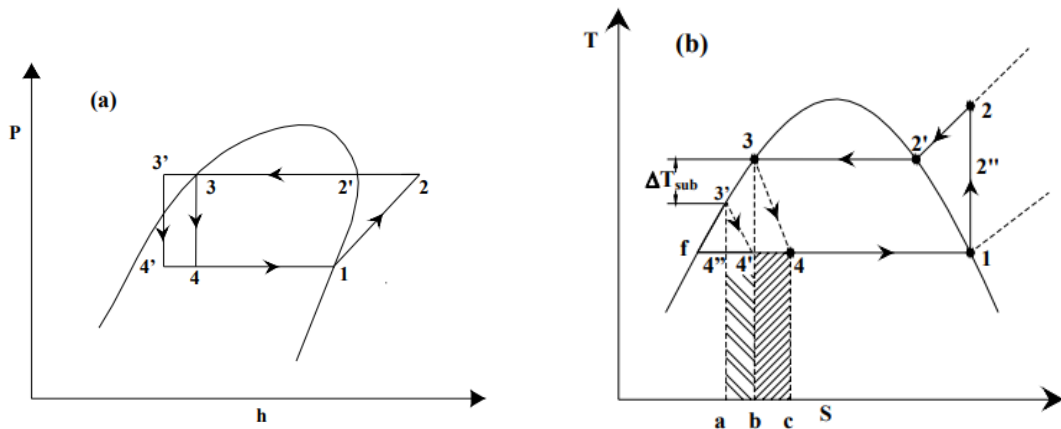


Fig.3 Comparison between a VCRC cycle without and with sub-cooling as refrigeration R1270 (a) on P-h diagram (b) on T-s diagram

Useful superheating increases both the refrigeration effect as well as the work of compression. Hence the COP (ratio of refrigeration effect and work of compression) may or may not increase with superheat, depending mainly upon the nature of the working fluid. Even though useful superheating may or may not increase the COP of the system, a minimum amount of superheat is desirable as it prevents the entry of liquid droplets into the compressor. Figure 11.5 shows the VCRC cycle with superheating on P-h and T-s coordinates. As shown in the figure, with useful superheating, the

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refrigeration effect, specific volume at the inlet to the compressor and work of compression increase. Whether the volumic refrigeration effect (ratio of refrigeration effect by specific volume at compressor inlet) and COP increase or not depends upon the relative increase in refrigeration effect and work of compression, which in turn depends upon the nature of the refrigerant used. The temperature of refrigerant at the exit of the compressor increases with superheat as the isentropic in the vapour region gradually diverge.

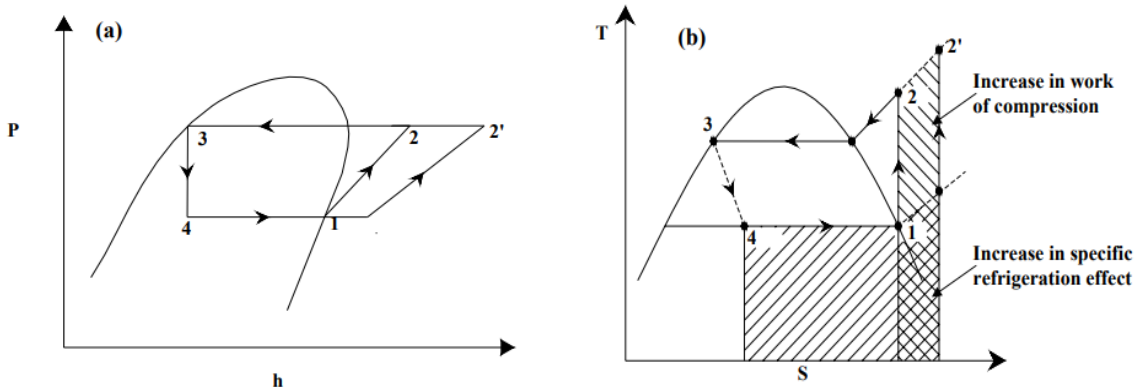


Fig.4 Effect of superheat on specific refrigeration R 1270 effect and work of compression (a) on P-h diagram (b) on T-s diagram

3. MODELING AND ANALYSIS

Design the block diagram on Auto CAD

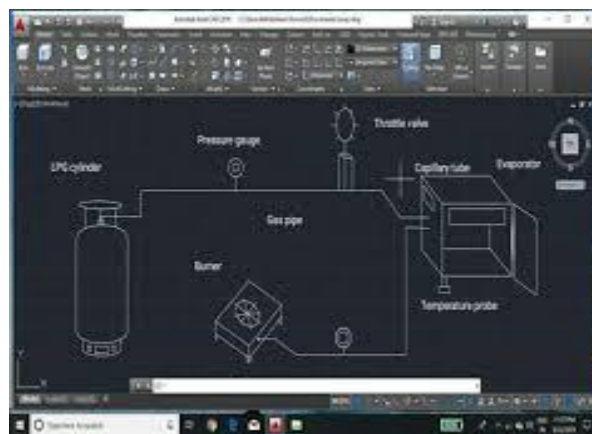


Fig.5 view of Zero Cost Green Refrigerator

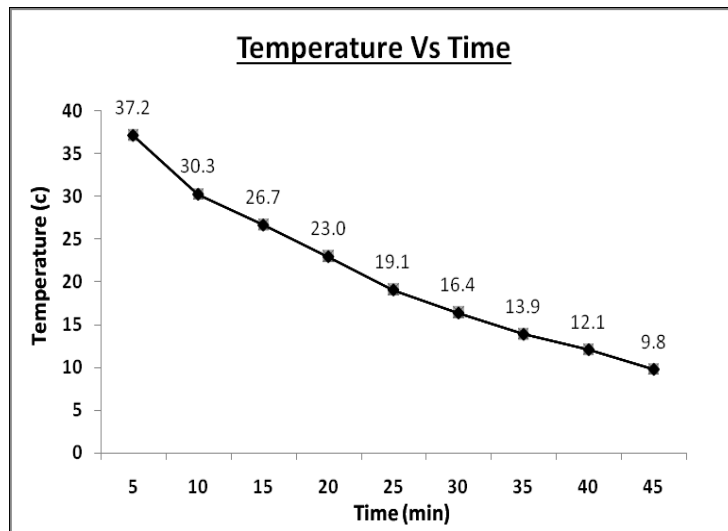
Specifications

- Refrigeration Box : Thermo coal Insulated
 L=270mm W=250mm
 H=380mm T=40mm

- Evaporator Sheet : L=1000mm H=330mm
- LPG Cylinder : 14.2kg
- Capillary Tube : D=0.031mm L=3000mm
- Pressure Gauge : 500psi & 250psi
- Filter : D=44.5mm H=60mm
- Regulator : D=4mm up to 250psi
- Pressure Pipes : 1500mm*2no
- Thermocouple : Digital
- L=Length W=Width H=Height
- T=Thickness D=Diameter Kg=Kilogram

4. EXPERIMENTAL OBSERVATION AND RESULTS

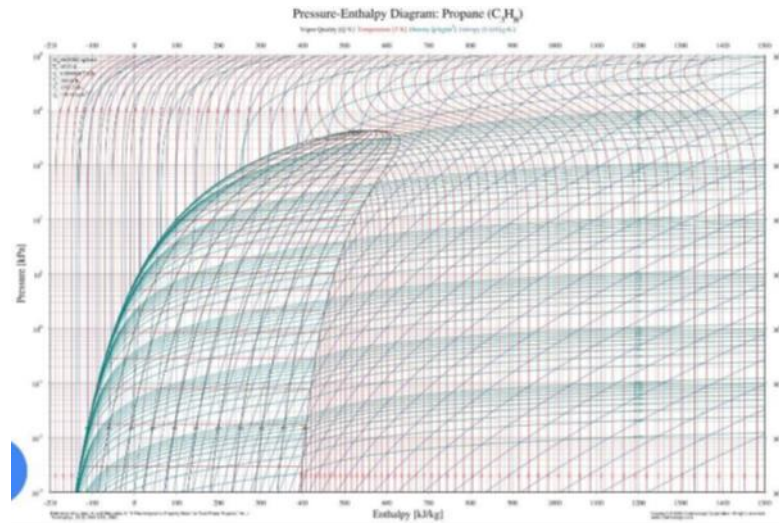
As we experimented with the system of initial pressure of 110 psi from LPG cylinder and the output pressure of 40 psi to obtain refrigeration effect. The observations have been tabulated as shown in below Table 1, and also a graphical representation of the experiment, i.e., **Temperature vs. Time**, is shown below the graph



Graph.1 Temperature vs. Time

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Fig.6 Pressure Enthalpy chart of Propane



Time	Initial Pressure	Delivery Pressure	Temperature
Min	psi	psi	Celsius
5	110	41	37.2
10	110	40	30.3
15	110	41	26.7
20	110	40	23.0
25	110	40	19.1
30	110	36	16.4
35	110	40	13.9
40	110	38	12.1
45	110	40	9.8

Table.1 Initial & Delivery Pressures concerning the time

LPG (Propane) Cylinder Pressure Chart			
Temperature		Vapour Pressure	
C	F	kPa	PSIG
54	130	1794	257
43	110	1358	197
38	100	1186	172
32	90	1027	149
27	80	883	128
16	60	637	92
-1	30	356	51
-18	0	152	24
-29	-20	74	11
-43	-45	0	0

Table.2 Pressure vs. Temperature of Propane

5. COMPARE WITH DOMESTIC REFRIGERATOR

Cop of a domestic refrigerator is generally up to 2.95, which is lesser than the LPG refrigerator. Domestic refrigerators required high input power than LPG refrigerators. Also, there are more moving parts in the domestic refrigerator and not eco-friendly. A household refrigerator requires more maintenance, and operation is noisy.

5.1 ADVANTAGES OF R1270

- The use of LPG (R1270) as a refrigerant additionally improves the average efficiency of via 10.0 to 20.0%.
- The ozone depletion capacity (ODP) of LPG is zero, and international warming capacity (GWP) is 8 that is extensively negligible as examine to the different refrigerant.
- A component from environment friendly, use of LPG also gives us lot of fee blessings.
- LPG does not shape acids, and there with the aid, gets rid of the hassle with blocked capillaries.
- There is a 60% discount on the system's weight because of the better density of LPG.
- This refrigerator works while strength is off.
- The components are efficaciously silent in operation.
- Running cost is zero
- Eliminates the compressor and condenser.

5.2 APPLICATIONS OF R1270

- It may play a crucial function in eating places which constantly cooling, and heating is required.
- It can be utilized in chemical industries for refrigeration purposes.
- It could be beneficial in far-flung elements in which strength is not to be had.
- It can be used in refineries wherein intake of LPG is excessive.

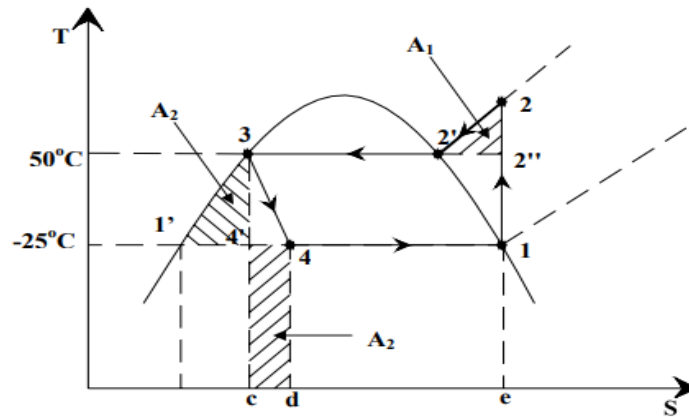
Using refrigerant R1270 property data, required properties at various state points are:

State Point	T (°C)	P (bar)	h (kJ/kg)	s (kJ/kg.K)	Quality
1	-25.0	1.064	383.4	1.746	1.0
2	<u>60.7</u>	13.18	436.2	1.746	Superheated
3	50.0	13.18	271.6	1.237	0.0
4	-25.0	1.064	271.6	1.295	0.4820
1'	-25.0	1.064	167.2	0.8746	0.0
2'	50.0	13.18	423.4	1.707	1.0
2''	50.0	10.2	430.5	1.746	Superheated
4'	-25.0	1.064	257.1	1.237	0.4158

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a) $COP = (h_1 - h_4) / (h_2 - h_1) = 2.1174$

b) Work input to compressor, $W_c = (h_2 - h_1) = 52.8 \text{ kJ/kg}$



6. CONCLUSION

The performance of a vapour compression refrigeration system with various alternative refrigerants is investigated in this paper. R1270 is the refrigerants considered during the analysis. The results were compared to the traditional R134a refrigerant. Various parameters such as evaporating pressure, pressure ratio, power per ton of refrigeration, volumetric cooling capacity, compression work, coefficient of performance, and so on were considered during the analysis.

- There is appreciable change in COP by using R1270 refrigerant.
- Quality of refrigerant at evaporator inlet is significantly lower.
- Discharge temperature is significantly high.
- For refrigerant R1270, the evaporator performs better due to the lower vapour fraction at its inlet.
- From the apparatus setup, the coefficient of performance of the refrigerator using LPG as refrigerant is which is comparable to a domestic refrigerator.
- Though the COP is less than the Domestic refrigerator, the cooling effect or Refrigeration effect is observable and efficacious.
- To reach 10 °C within 45min, this is good enough to preserve the consumable products.
- Hence the LPG-based refrigerator can be used as an alternative for cooling instead of a domestic refrigerator.

FUTURE SCOPE

In the future we may expect further research, regulation changes, the design of new systems suitable for the use of newly developed and natural refrigerants, the optimization of the system in the sense of compensating the lower efficiency of some refrigerants, but with keeping cost within acceptable limits.

Conclusion is always the same: “No ideal refrigerant”, but proper applications suitable for different refrigerants can be found. The chance for “closing the circle” and return to natural refrigerants at a new, high technology level exists and should not be missed.

The system can further be improved and implemented in the air conditioning of vehicles where LPG is fuel. The project can be implemented in restaurant and community program hall, mobile canteen, and mid-day meals to preserve food products like vegetables, milk, etc.

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