Performance Evaluation of Domestic Refrigerator working with LPG

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Abstract— A project performance study on a VCR system with LPG as refrigerant was conducted and compared with R134a.The VCR system was initially designed to operate R134a .Experimental result showed that the LPG refrigerant with charge of 30g worked well at loaded condition (load A) as it took 24 min. to bring down the temperature of 500g of water from 29 degree Celsius to 7 degree Celsius, at loaded condition (load B) as it took 24 min,to bring down the temperature of 500g of water from 45 degree Celsius to 22 degree Celsius, at unload condition (No load) it took 26 min to bring down the evaporator temperature from 31 degree Celsius to -20.3 degree Celsius, in comparison to 90g of R-134a at loaded condition (load A), which took 30 min, to bring down the temperature of 500g of water from 29 degree Celsius to 9 degree Celsius, at loaded condition (load B), as it took 40 min, to bring down the temperature of 500g of water from 45 degree Celsius to 18 degree Celsius, at unload condition (No load), it took 26 min to bring down the evaporature temperature from 31 degree Celsiuse to -5 degree Celsiuse. While LPG charge of 25g worked well under unloaded condition. It took 15 minutes to bring down evaporator temperature from 31 degree Celsiuse to 0 degree Celsius, in comparison to 90g R-134a which took 14 minutes for the same, under designed project set up.While LPG charge of 35g worked well under unload condition. It took 12 minutes to bring down the evaporator temperature from 31 degree Celsius to 0 degree Celsius in comparison to 90g R-134a which took 15 minutes for the same, under designed project.Ammeter continuously gave reading in the range of 0.6 A to 0.9 A and voltmeter as 210V while working with LPG as refrigerant in comparison to R134a in which ammeter gave reading of 1A and voltmeter as 220V. From here we can easily conclude that power consumed by compressor while working with LPG as refrigerant decreased considerably.

Index Terms – Vapour Compression Refrigeration system, LPG, R-134a.

1 INTRODUCTION

According to the second law of thermodynamics heat cannot spontaneously flow from a colder location to a hotter area, work is required to achieve this. Heat pump and refrigeration cycle can be classified as vapor compression, vapor absorption, gas cycle, or Stirling cycle types.Refrigeration is the process of removing heat from a substance under controlled condition.Refrigerating machine is a device which will either cool or maintain a body at a temperature below that of the surroundings. Hence, heat must be made to flow from a body at low temperature to the surrounding at high temperature. In which the refrigerant undergoes phase change, is one of the many refrigeration cycles and is the most widely used method for air conditioning of buildings and automobiles, it is also used in domestic and commercial refrigerators, large – scale warehouse for chilled or frozen storage of foods and meats, refrigerated trucks and railroad cars and a host of other commercial and industrial services.

2. CLASSIFICATION OF REFRIGERANTS

The refrigerants may, broadly, be classified into the following two groups:
1 – Primary refrigerants, and
2 – Secondary refrigerants.
The refrigerants which directly take part in the refrigeration *system* are called primary refrigerants whereas the refrigerants which first cooled by primary refrigerants and then used for cooling purposes are known as secondary *refrigerants.*
The primary refrigerants are further classified into the following four groups:
1 – Halo- Carbon or organic refrigerants.
2 – Azeotrope refrigerants.
3 – Inorganic refrigerants.
4 – Hydro- Carbon refrigerants.

3. Materials and Methods

According to second law of thermodynamics,a refrigerator is a reversed heat engine or a heat pump which pumps heat from a cold body and delivers it to a hot body or simplyit is a device which cool or maintain a body at a temperature below that of the surrounding.

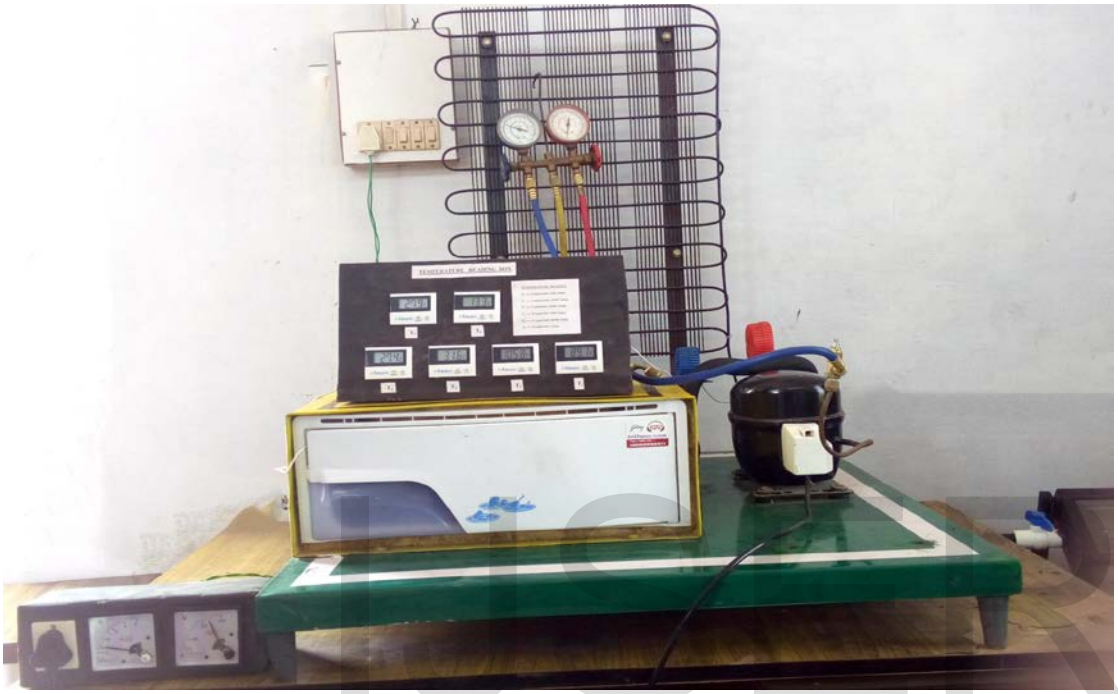
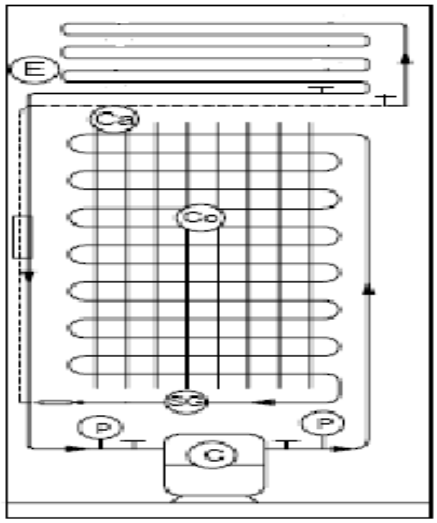


Fig. 1: Photograph of VCR system (Experimental setup)



T - Temperature measuring points
C – Compressor
Co – Condenser
Ca - Capillary tube
E – Evaporator
P – Pressure gauge

Fig.2: Block diagram of experimental Setup

OBSERVATION TABLE

Charge-R134a

No load **Amount of charge-90g**

Table no. 1: Study of performance of 90g R134a as refrigerant.

Time (min)	Evaporator Temp. T6 (°C)	Compressor inlet temp. T1 (°C)	Compressor outlet temp. T2 (°C)	Condenser outlet temp. T3 (°C)	Evaporator inlet temp. T4 (°C)	Evaporator outlet temp. T5 (°C)	LPS (Psi)	HPS (psi)
start	30.2	30.5	30	30	30.1	30.7	66	79
2	26	29.7	33	32.7	28.6	27.9	11	190
4	21.3	28.2	34.9	33.2	26.3	27	10	190
6	17.2	26.5	36.2	35	23.7	22	8	175
8	13.7	24.1	37.8	35.9	19	20.2	7	175
10	8.2	19.3	38.2	37	14.4	19.3	7	170
12	4.1	16	39.1	37.7	14.1	15	6	170
14	1	13.1	41.1	37.9	11.5	12	6	170
16	-1	9.7	42	38.2	9.6	10.3	6	170
18	-2.3	6.2	42.5	38.3	9.2	10	6	170
20	-3.2	3.8	42.8	38.5	9	9.7	6	170
22	-4	2	43	38.5	8.7	9.2	6	170
24	-4.5	1	43.2	38.7	8	8.6	6	170
26	-5.7	-1	43.5	39	7	7.7	6	170

Charge-LPG **Amount of charge-30g**

No load

Table no. 2: study of performance of 30g LPG as refrigerant

Time (min)	Evaporator Temp. T6 (°C)	Compressor inlet temp. T1 (°C)	Compressor outlet temp. T2 (°C)	Condenser outlet temp. T3 (°C)	Evaporator inlet temp. T4 (°C)	Evaporator outlet temp. T5 (°C)	LPS (Psi)	HPS (Psi)
start	31	30.7	30.5	30.6	30.2	31	50	65
2	29.9	29.8	33.4	31.1	28.3	29.2	10	140
4	24.6	82.8	35.3	31.6	26.8	27	9	130
6	14.2	25.8	36.5	31	25.2	26.4	9	130
8	5.8	23.7	37.8	30.9	23.8	24.6	9	120
10	2.8	22.9	38.9	30.9	22.9	23.5	8	120
12	-2.7	20.5	40.1	31	22.1	23.1	8	120
14	-7.9	19.3	40.6	31	21.3	22.4	9	120
16	-11.9	18.5	41.1	31	20.8	21.5	9	120
18	-14.8	17.3	41.4	31.5	19.5	20.6	9	110
20	-17.6	16.2	41.8	31.7	18.7	19.5	9	110
22	-19	15.1	42.3	31.7	17.2	18.2	9	120
24	-20.6	14	42.6	31.9	16.1	17.5	9	120

4 Results

In this project I used liquefied petroleum gas (LPG) as refrigerant in domestic refrigerator of 165 liter, basically designed

for R-134a as refrigerant .No modification has been made by me in the basic design of any component or capillary length of refrigerator . I first of all tested the coefficient of performance, by charging 90g R-134a with no load, then with load 500g of water at different temperature 29 and 45 degree Celsius, after that I charged it with 35g, 30g, 25g, and 20g of LPG, at no load, then with load 500g of water at different temperature 29 and 45 degree Celsius for each of charging respectively, consequently and checked its performance.

My findings are as follows:-

4.1 Charge: R-134a, Amount: 90g

Investigation has been performed first without load, after that under load of 500g water at temperature 29°C kept in steel vessel, then the same amount of water at 45°C .reading from various temperature sensors (fixed at various points), Pressure gauges (fixed at compressor inlet and compressor outlet), ammeter and voltmeter were taken at an interval of two minutes each.

Calculation of COP for R-134a

Table 3: parameter of charging 90g of R-134a

PARAMETER	NO LOAD	Load A (with 500G of water at 29°C)	Load B (with 500g of water at 45°C)
Mix Temp T_6 (°C)	-5.7	2.9	2.3
Mix Temp T_2 (°C)	43	44	44.6
Spend time (min)	26	30	40
LPS (bar)	0.483	0.414	0.345
HPS (bar)	11.73	12.42	11.73
V (volt)	220	220	230
I (ampere)	1	1	1

4.2 Charge: LPG, Amount: 30g

Investigation has been performed first without load, after that under load of 500g water at temperature 29°C kept in steel vessel, then the same amount of water at 45°C .reading from various temperature sensors (fixed at various points), Pressure gauges (fixed at compressor inlet and compressor outlet), ammeter and voltmeter were taken at an interval of two minutes each.

Calculation of COP for LPG, 30g

Table 4: Parameter of charging 30g of LPG

PARAMETER	NO LOAD	LOAD I (with 500g of water at 29°C)	LOAD I I (with 500g of water at 45°C
Mix Temp T_6 (°C)	-20.3	-5	0
Mix Temp T_2 (°C)	42.1	42.7	43.1
Spend time (min)	24	24	24
LPS (bar)	0.621	0.69	0.69
HPS (bar)	8.28	8.97	9.66
V (volt)	210	210	210
I (ampere)	0.8	0.8	0.8

Observation from test rig of refrigerator using LPG, Charge amount 30g as refrigerant

NO LOAD

COP is calculated assuming cycle to be ideal vapour compression cycle and taking dryness fraction as 0.95.

LPS = 9 Psi = 0.621 bar

hf = -22.4 KJ/Kg, hfg = 433.6 KJ/Kg, hg = 411.2 KJ/Kg

h1 = hf + 0.95 hfg = 389.52 KJ/Kg

HPS = 120 Psi = 8.28 bar

Hg = 491 KJ/Kg = h2, hf = 147.1 KJ/Kg = h3 = h4

COP = (h1 – h4) / (h2 – h1) = 2.388

LOAD A

COP is calculated assuming cycle to be ideal vapour compression cycle and taking dryness fraction as 0.95.

LPS = 10 Psi = 0.69 bar

hf = -22.4 KJ/Kg, hfg = 433.6 KJ/Kg, hg = 411.2 KJ/Kg

h1 = hf + 0.95 hfg = 389.52 KJ/Kg

HPS = 130 Psi = 8.97 bar

Hg = 493.8 KJ/Kg = h2, hf = 154 KJ/Kg = h3 = h4

COP = (h1 – h4) / (h2 – h1) = 2.258

LOAD B

COP is calculated assuming cycle to be ideal vapour compression cycle and taking dryness fraction as 0.95.

LPS = 10 Psi = 0.69 bar

hf = -22.4 KJ/Kg, hfg = 433.6 KJ/Kg, hg = 411.2 KJ/Kg

h1 = hf + 0.95 hfg = 389.52 KJ/Kg

HPS = 140 Psi = 9.66 bar

Hg = 495 KJ/Kg = h2, hf = 158 KJ/Kg = h3 = h4

COP = (h1 – h4) / (h2 – h1) = 2.194

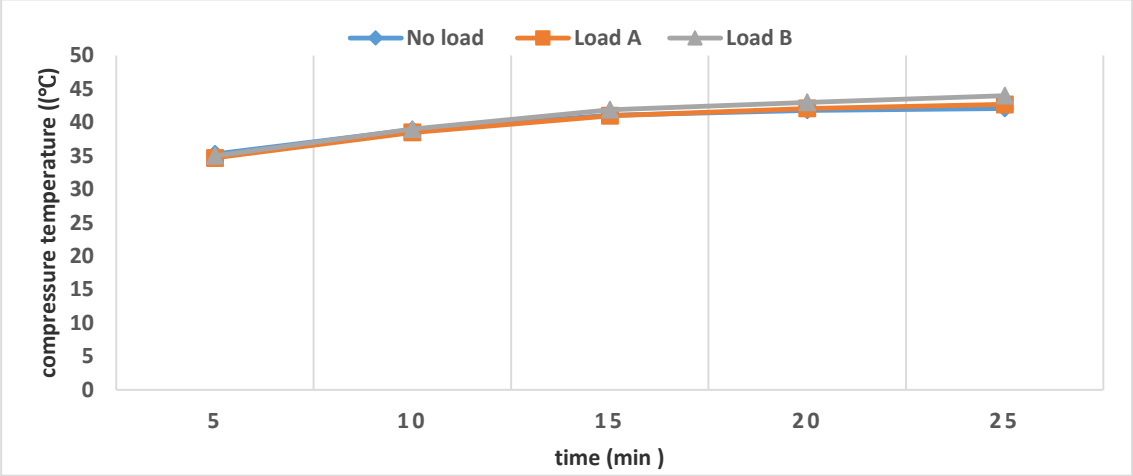


Fig 3: compressure temp. vs time graph of 30g LPG as refrigerant.

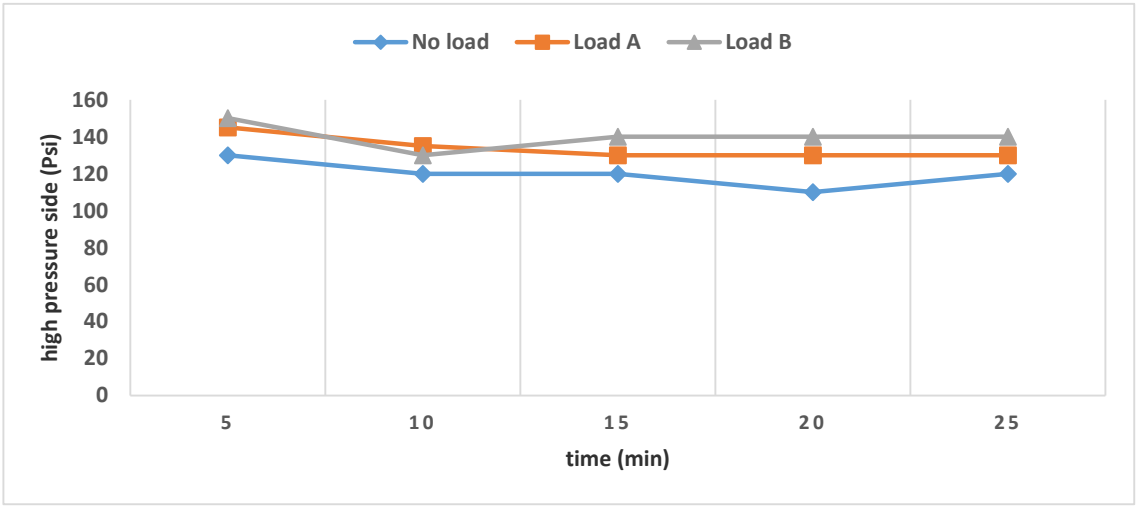


Fig 4: HPS vs time graph of 30g LPG as refrigerant.

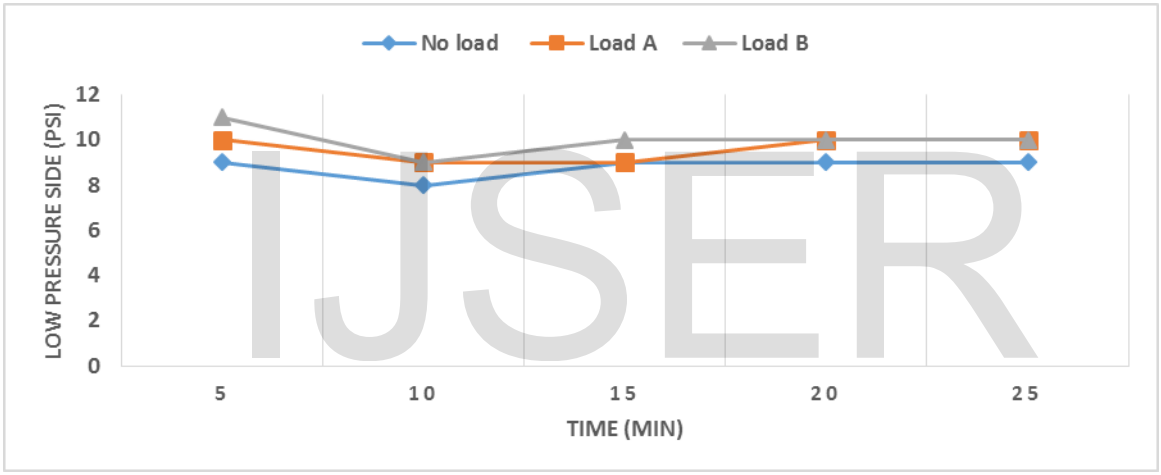


Fig 5: LPS vs time graph of 30g LPG as refrigerant.

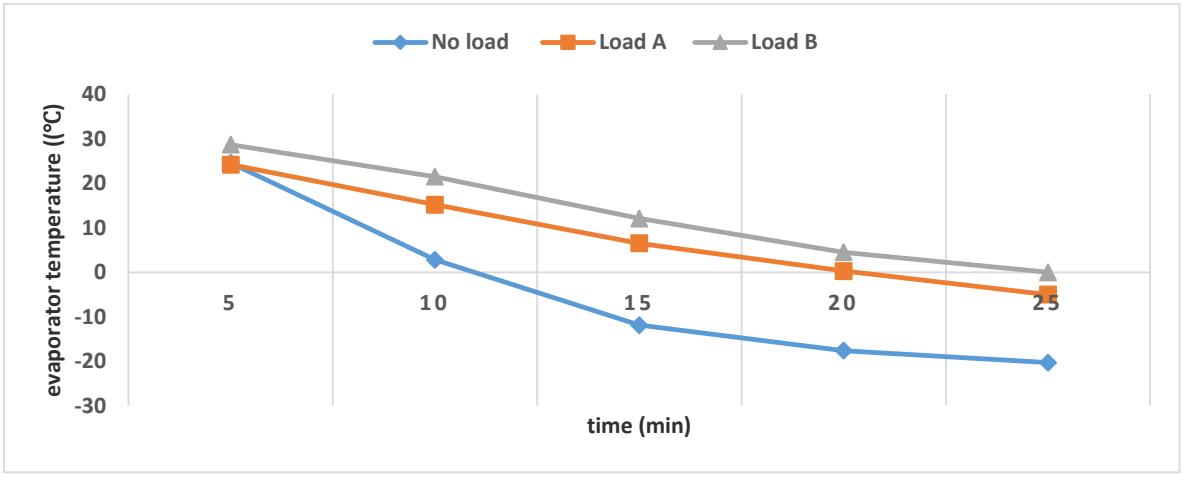


Fig 6: Evaporator temp. vs time graph of 30g LPG as refrigerant.

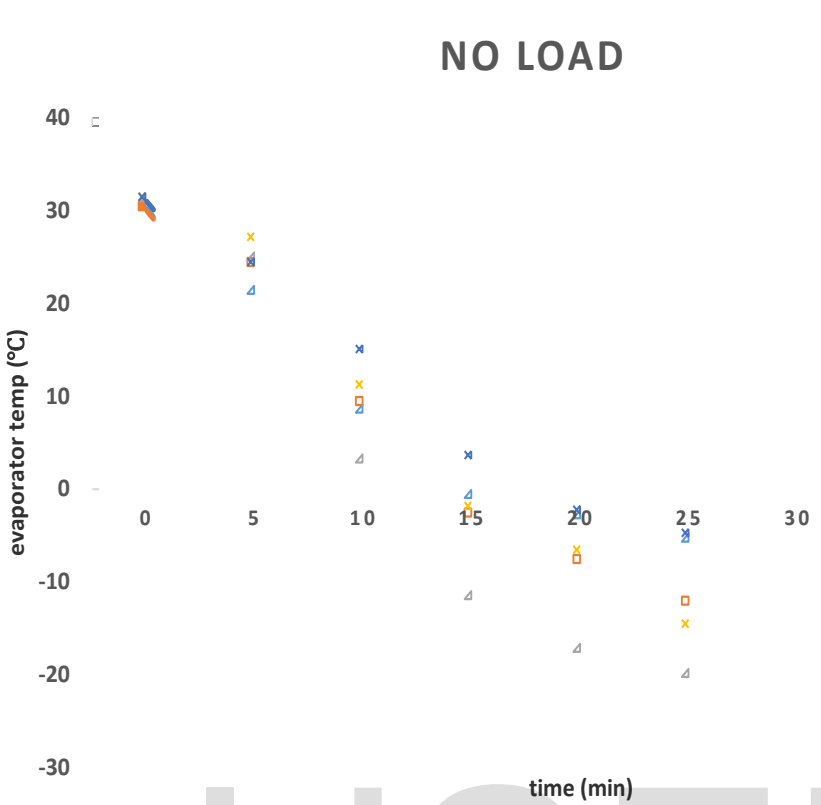


Fig 7: Comparison of evaporator temp. of various refrigerants vs time.

5. Conclusion

The performance of a domestic refrigerator (base refrigerator) was investigated using LPG as refrigerants. Although the base refrigerator has been designed for 105 g R134a, it was capable to work with LPG. Nevertheless, energy consumption analysis indicated that the HFC compressor should be changed to a HC compressor for hydrocarbon refrigerants. The optimum charge amounts for LPG were found to be in between 25g to 35g. Moreover, results showed that energy consumption was reduced, for the refrigerator while working with a HFC type compressor charged with the optimum amount of LPG charge, in comparison with the base refrigerator. The proposed LPG seems to be an appropriate long-term candidate to replace R134a in the existing refrigerator, except capillary tube length and initial charge Literature review on safety analysis showed that in case of a sudden leakage of total amount of hydrocarbon refrigerants, it would not result in explosive conditions. If same experiment was conducted on the refrigerator designed for LPG, better results are expected.

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