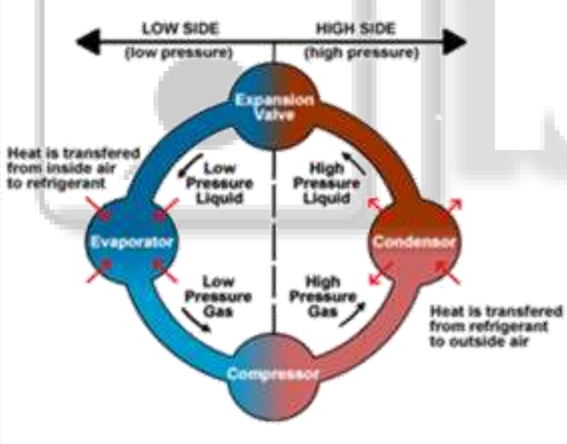
Review Study on LPG Used as a Refrigerant in an Automobile Car and its Feasibility

Ibrahim Hussain Shah[1] Mohammad Shoeb Sheikh[2]
[1]Assistant Professor [2]M.E. Student
[1,2]Department of Mechanical Engineering
[1,2]Institute of Engineering and Technology, Devi Ahilya Vishwavidyalaya, Indore-452017, MP, INDIA

Abstract— In this review we have done studies in two parts, in first part we mentioned the possibilities of LPG as refrigerant and in second part the effects of emissions on automobile engine when use Air conditioner. In first part we investigated the use of LPG in domestic refrigerator and their limitations and safety, this study gave the potential how to use the LPG in refrigerator and in the second part we studied the load of Air Conditioner on an automobile engine and their effects on tail pipe emissions and fuel efficiency. So studies shows that LPG can be used in a car air conditioner as a refrigerant and as a fuel for an automobile engine we designed a system which works on LPG as a refrigerant and a fuel for an automobile engine.
Keywords: refrigerant gas, works on LPG

I. INTRODUCTION

power say electricity is regularly required to drive an air conditioner.It also includes the process of reducing and maintaining the temperature of a body to its comfort zone.



Layout of Vapor Compression cycle [4]

II. MAIN COMPONENTS OF VAPOR COMPRESSION REFRIGERATION CYCLE

A. Compressor:

This is the heart of the air conditioning system. The compressor similar in size to the vehicles electrical alternator can usually be identified as the component sited low down in the engine bay driven by the engine belts via a pulley and connected to the rest of the air conditioning system by two reinforced hoses. When you turn on the air conditioner in your car an electrical circuit operates a clutch in the compressors pulley causing the compressor to start pumping refrigerant gas into the rest of the system under extremely high pressure. By increasing the pressure the refrigerant gas leaving the compressor becomes hot.

B. Condenser:

The condenser can be identified as a second radiator that shares the air flow with the main engine coolant radiator. Usually the condenser will have its own electric cooling fan/s that become/s active when the air conditioning system is switched on. The condenser takes the heated high pressure refrigerant gas from the compressor and cools it. Condensing the refrigerant gas into a liquid releases heat in the process. This heat is expelled into the atmosphere by the air flowing through the condenser.

C. Evaporator:

The evaporator works the opposite of the condenser, here refrigerant liquid is converted to gas, absorbing heat from the air in the compartment. When the liquid refrigerant reaches the evaporator its pressure has been reduced, dissipating its heat content and making it much cooler than the fan air flowing around it. This causes the refrigerant to absorb heat from the warm air and reach its low boiling point rapidly. The refrigerant then vaporizes, absorbing the maximum amount of heat. This heat is then carried by the refrigerant from the evaporator as a low-pressure gas through a hose or line to the low side of the compressor.

III. EXPANSION VALVE

The expansion valve removes pressure from the liquid refrigerant to allow expansion or change of state from a liquid to a vapor in the evaporator.

The high-pressure liquid refrigerant entering the expansion valve is quite warm. This may be verified by feeling the liquid line at its connection to the expansion valve. The liquid refrigerant leaving the expansion valve is quite cold. The molecules contained in the liquid refrigerant are thus allowed to spread as the refrigerant moves out of it. Under a greatly reduced pressure the liquid refrigerant is at its coldest as it leaves the expansion valve and enters the evaporator.

Pressures at the inlet and outlet of the expansion valve will closely approximate gauge pressures at the inlet and outlet of the compressor in most systems. The similarity of pressures is caused by the closeness of the components to each other.

Maclaine-cross, E. Leonardi have done the investigation on performance and safety of LPG and they described the environmental harmful refrigerants in terms of ODP (ozone depletion potential) and GWP (global warming potential). Ozone depletion and global warming require replacement of chlorofluorocarbon refrigerants like R12. The hydro fluorocarbon R134a is nonflammable, difficult to synthesize, has zero ozone depletion and high global warming. LPG refrigerants are highly flammable, occur naturally, have zero ozone depletion and negligible global warming. In Germany, most new refrigerators use R600a and many heat pumps and air conditioners now use R290 with measured energy consumption 10 to 20% lower than R12, R134a or R22. LPG mixtures have successfully replaced R12 and R134a in over 100,000 US car air-conditioners. LPG refrigerants have superior properties often giving 10 to 20% energy savings. [1]

Refrigerant	R12	R22	R134a	R600a	R290
Class	CFC	HCFC	HFC	LPG	HC
Atmospheric Lifetime (years)	130	15	16	<1	<1
Ozone depletion potential	1.0	0.07	0	0	0
Global warming potential	7300	1500	1200	8	8

Maclaine-cross, E. Leonardi have done another investigation on the comparative performance of Hydrocarbon refrigerants in this work they select the R600a as a refrigerant and used in refrigerator and compare with R134a and R12, they found that R600a have shown electricity savings over the other two refrigerants, they performed experiment which shows half the leakage, pressure loss and condenser pressure and double the heat transfer coefficient as compared to other two refrigerants and use of R600a in small heat pumps and air conditioner is attractive but also required design changes.

Hydrocarbon refrigerants have environmental advantages and are safe in small quantities. R290 can replace R22 and HC mixtures replace R12 and R134a in applications using positive displacement compressors.
This explains sometimes over 20% energy savings reported for small refrigerators using R600a. These improvements can be realized in other small application with equipment redesign. [2]

Y.S. Lee, C.C. Su An experimental study on the performance of a domestic vapor-compression refrigeration system with isobutane (R600a) as the refrigerant. The input power of the compressor varied between 230 and 300 W, while the amount of the charged refrigerant was about 150 g. The expansion and heat transfer components of the system were capillary tubes and plate heat exchangers, respectively. The refrigeration temperatures were set at about 4 and -10 ^{0}C to simulate the situations of the cold storage and the freezing applications. Both normal and extreme conditions were investigated in this work.

In the cold storage application, two capillary tubes in parallel gave better performances than a single tube. The proper sizes of the tube are between 4 and 4.5 m in length, and 0.7 mm in internal diameter in the cold storage application, while in the freezing application they are between 4.5 and 5 m in length, and 0.6 mm in internal diameter. The coefficients of performance of the system lie between 1.2 and 4.5 in the cold storage application and between 0.8 and 3.5 in the freezing application, which are comparable with those of the system with R-12 and R-22 as the refrigerant. In general, the refrigeration capacity increases with the refrigeration loads. [3]

Balakrishan, Karuppasamy, Ramakumar, Anu investigated the alternative eco-friendly refrigerant for R134a with a better COP, GWP, ODP and they used the mixture of R32/R600a/R290 in the proportion of 70:5:25 by weight and below there are some more details about their work.

Use alternative eco-friendly refrigerant for R134a with better coefficient of performance (COP) reduced Global Warming Potential (GWP) and Ozone Depletion Potential (ODP). This investigation has been accessed using a hydrocarbon refrigerant mixture composing of R32/R600a/R290 in the ratio of 70:5:25 by weight. The performance characteristics of the domestic refrigerator were predicted using continuous running tests under different ambient temperature and cyclic running (On/Off) tests at the fixed i.e., evaporation temperature (-5˚C) and condensation temperature (30˚C). The obtained results showed that the hydrocarbon mixture has lower values of energy consumption; pull down time and ON time ratio also higher Coefficient of Performance (COP). Thus, the performance of the alternate refrigerant derives the better choice than R134a. [4]

Refrigerants	**Mixing Ratios**	**COP**	**Mass flow Rate (kg/sec)**
R32/R600a/R290	45/5/50	1.90	0.0303
R32/R600a/R290	35/9/56	2.01	0.0286
R32/R600a/R290	30/10/60	1.91	0.0299
R32/R600a/R290	60/5/35	2.01	0.0217
R32/R600a/R290	50/6/44	1.98	0.0203
R32/R600a/R290	65/4/21	2.03	0.0213
R32/R600a/R290	**70/5/25**	**2.21**	**0.0311**
R32/R600a/R290	45/10/45	2.07	0.0295
R32/R600a/R290	50/5/45	1.33	0.0219
R32/R600a/R290	44/6/64	1.93	0.0301
R32/R600a/R290	30/6/64	2.08	0.0233
R32/R600a/R290	72/8/20	1.73	0.0212
R32/R600a/R290	63/7/30	2.04	0.0242
R32/R600a/R290	20/7/73	2.02	0.0227

Zhijing Liu, Imam Haider, Liu, Reinhard investigated their work in two parts in the first one they taken blend of R290/R600 and tested as a drop in substitute in a 20 cubic feet, single-evaporator, auto defrost, top mount, conventional domestic refrigerator/freezer. All the hardware remained the same, only the capillary tube was lengthened to achieve the optimum performance. The best result with an optimized R290/R600 blend was 6% savings compared to the baseline test with R12. In the second part of the work, an 18.0 cubic-feet, auto defrost, top mount, domestic refrigerator was used for experiments. Having tested for the single-evaporator baseline performance, the unit was converted to a two-evaporator modified-Lorenz-Meutzner cycle.

Refrigerant	R12	R290/600
Min. energy consumption [kWh/day]	2.46	2.29
Compressor on-time [min]	12	9.25
Total cycle time [min]	26	28
Additional capillary tube length [ft]	-	5.0
Refrigerant charge [g]	240	70
Average freezer compartment temperature [^{0}C]	-15.6	-16.0
Average food compartment temperature [^{0}C]	3.3	4.1
Average evaporator pressure during on-time [kPa]	123	146
Average condenser pressure during on-time [kPa]	975	1139

Modified Lorenz-Meutzner cycle refrigerator test results

The optimum performance of the modified unit yielded 14.6% and 16.7% energy savings with Binary mixtures R290/C_5H_{12}, and R290/R600, respectively. A ternary mixture R290/R600/C_5H_{12} with 17.3 % energy savings proved to be better than the binary mixtures. The superior transport properties of the hydrocarbon mixtures are believed to be responsible for their better test performance.

The hydrocarbon blend R290/R600 (propane/n-butane) is an attractive substitute for R12. In drop-in tests savings of up to 6.5% could be achieved with a mixture composition of 70/30 and 70gm. of charge.

The experimental results of the binary hydrocarbon mixtures, R290/ C_5H_{12} (propane/n-pentane) and R290/R600, showed 14.6 % and 16.7% energy savings in the modified-Lorenz-Meutzner cycle refrigerator.

The ternary R290/R600/ C_5H_{12} mixture with 17.3 % energy saving has a better performance than the binary mixtures of R290/R600 and R290/ C_5H_{12}.

the promising test performance of hydrocarbons, their commercial refrigeration application is impeded by flammability concerns. [5]

Zainal Zakaria & Zulaikha Shahrum had showed the possibility of using LPG in Domestic Refrigerator Systems and their proposed work have Domestic refrigerators annually consume approximately 17,500 metric tons of traditional refrigerants such as Chlorofluorocarbon (CFC) and Hydro flouro carbon (HFC) which contribute to very high Ozone Depletion Potential (ODP)

And Global Warming Potential (GWP). Good progress is being made with the phase out of CFC 22 from new equipment manufacture by replacing LPG since it possesses an environment friendly nature with no ODP. LPG is expected to results in comparable product efficiencies based on its characteristics. Therefore, this two types of refrigerants (LPG and CFC 22) to be examined using a modified domestic refrigerator in term of their performance characteristics parameters such as pressure and temperature at specified location at the refrigerator and the safety requirements while conducting the experiment. Based on the present work, it is indicated that the successful of using LPG as an alternative refrigerant to replace CFC 22 in domestic refrigerators is possible by getting LPG COP as 13 compared to 10 for CFC22.[6]

Hussin Shah and Kundan Gupta have designed and analyzed a refrigerator using LPG as refrigerant. LPG is available in cylinders at high pressure. When this high pressure LPG is passed through the capillary tube of small internal diameter, the pressure of LPG is dropped due to expansion and phase change of LPG occurs in an isenthalpic process. LPG at a pressure of 12.41 bar in Domestic 14.5 kg cylinder equipped with a high pressure regulator and this pressure has reduced up to 1.41 bar with the help of capillary tube. But if we use a low pressure regulator as is the practice in conventional domestic LPG gas stove, the pressure of LPG after the expansion device and before the burner would be different. So we have calculated the refrigerating effect with the help of changes in properties of LPG (pressure, temperature, and enthalpy) before and after the evaporator using high pressure regulator and the amount of refrigerating effect is 323kJ/Kg. Due to phase change from liquid to gas latent heat is gained by the liquid refrigerant and the temperature drops. In this way LPG can produce refrigerating effect for a confined space and from the experimental investigation they found that the COP of refrigerator which use LPG is higher than a domestic refrigerator. [7]

Dr.P.Srinivas, P.Ravi Chandra, M.Ravi Kumar & N.Yogi Manash Reddy investigated on replacement of R134a with LPG and calculate the performance parameters like Compressor Work, Coefficient of Performance, Refrigerating Effect are evaluated at various operating conditions and compared with R134a. It is found that LPG has higher refrigerating effect which is 76.19% higher than the R134a. Power consumption for R134a as refrigerant is higher than LPG as refrigerant by 9.2%. Coefficient of Performance for LPG is higher than R134a by 34.6 %. It is found that 50gm of LPG is the optimum mass of LPG for higher COP when compared to R134a. It requires lesser work and it possessed all the properties to qualify as refrigerant and there is no issue of safety when mass of LPG used does not exceed to150gm. [8]

Ian Maclaine-cross had suggested the use of Hydrocarbons refrigerant in automobile and the theory: The world needs car air conditioning and the hydrocarbon (HC) refrigerant 290/600a avoids stratospheric ozone depletion and a typical 15% increase in TEWI from R134a leakage and service emissions but total refrigerant emissions from leakage and service releases are typically 0.4 L/year of liquid for regas. If the refrigerant is HFC–134a this adds about 15% to the car's total global warming emissions. For Asia the refrigerant is typically CFC–12 adding about 102% to emissions. HC refrigerants can reduce this warming and ozone depletion to zero and slightly reduce tropospheric ozone. Measurements suggest that R290/600a [55/45] matches the performance of R134a best if ethane impurity is below 0.5%. Batches of HC replacement for R12, 134a, 22 and 502 can be manufactured from natural butane and propane by pumping ethane rich vapor off the propane before mixing. [9]

Haslinda Mohamed Kamar,Mohd Yusoff Senawi and Nazri Kamsah the single largest auxiliary load on an automotive engine is caused by the air-conditioner compressor. During peak load it can draw up to 5 to 6 kW power from the vehicle's engine, and this is equivalent to a vehicle being driven down the road at 56 km/hr, the additional fuel consumed due to air conditioner usage is substantial. A study by Rugh et al. indicate air conditioner usage reduces fuel economy by about 20% and increases emissions of nitrogen oxides (NOx) by about 80% and carbon dioxide (CO_2) by about 70%, although the actual numbers depend on the actual driving conditions.[10]

L. Chaney up to 19.4% of vehicle fuel consumption in India is devoted to air conditioning (A/C). Indian A/C fuel consumption is almost four times the fuel penalty in the United States and close to six times that in the European Union because India's temperature and humidity are higher and because road congestion forces vehicles to operate inefficiently. Car A/C efficiency in India is an issue worthy of national attention considering the rate of increase of A/C penetration into the new car market, India's hot climatic conditions and high fuel costs.[11]

LPG powered Air Conditioning System World's First Oceanair Distribution has teamed with Calor Gas to rollout the world's first LPG-powered heat pump VRF (variable refrigerant flow) air conditioning. The technology operates on the same principle as LPG-powered vehicles and opens up new application areas for air conditioning. The system also provides hot water and generates its own electricity – which can be used in buildings for lighting and other services. The new LPG-powered Sanyo system opens up a big and important new market for air conditioning. It is a major step forward – in terms of both technology and market opportunity.

A modified 2-litre Nissan engine, operating at between 800-2100 rpm, is equipped with conventional engine components, such as spark plugs, oil and air filter, as on a standard car. The system only requires connection to a single-phase power supply to power start-up, a control circuit and inverter-driven fans. The technology is highly efficient, ranging from between 1.4 (140 per cent) to 1.6 (160 per cent) when used as a heating or cooling system respectively. The technology is being promoted as an alternative to oil-fired heating systems, against which it offers immediate cost savings. Due to the efficiency of the system, which delivers both hot water and up to 4kW electricity. [12]

IV. Conclusion

The aforementioned research papers, websites and their thorough study found that the possibility to use LPG as refrigerant in Refrigerator and Air Conditioner of an automobile car and it is already mentioned that the use of Air Conditioner in an automobile car can exceed the tail pipe emissions and reduce the fuel efficiency up to 19%, we used the LPG as refrigerant in an automobile car.

In this project a system is designed for a car which runs on LPG. LPG is used as refrigerant and a fuel in the car, LPG is coming from the cylinder and expand into the capillary tube where its pressure drop and low pressure refrigerant come into evaporator produces refrigerating effect by the phase change process inside the evaporator and the air which is coming from the blower is in contact with evaporator gets cooled and supplied to inside area of car and remaining low pressure LPG will come out from the evaporator coil to the vaporizer of car and then it goes to engine of car as a fuel. We had done several experiments on it which shows that there is strong possibility of use of LPG as a refrigerant in an automobile car. The suggested work is being carried out and will be published soon.

V. References

[1] Maclaine-cross, E. Leonardi, Performance and safety of LPG refrigerants. Conference of the Australian LPG Association Ltd, ISBN 0646248847, pp.149-168, 28th Feb 1995.
[2] Maclaine-cross, E. Leonardi, Comparative Performance of Hydrocarbon Refrigerants. IIF, IIR, Comissionions, Melbourne, 11 Feb 1996.
[3] Y.S. Lee, C.C. Su, Experimental studies of isobutane (R600a) as the refrigerant in domestic refrigeration system,Applied Thermal Engineering 22 (2002) 507–5191.
[4] Balakrishan karuppasamy, Ramakumar,Anu Experimental study of lternative refrigerants to replace R134a in a domestic refrigerator, IJRAM ISSN: 2321-3051.
[5] Zhijing Liu, Imam Haider, Liu, Reinhard ,Test results of Hydrocarbon Mixtures in Domestic Refrigerators/Freezers, CEEE, Maryland.
[6] Zainal Zakaria & Zulaikha Shahrum, The possibility of using LPG in Domestic Refrigeration Systems, IJRRAS-9 ISSURE-3, Dec-2011.
[7] Ibrahim Hussain shah and Kundan gupta, Design of LPG Refrigeration System and Comparative Energy Analysis with Domestic Refrigerator, IJESRT, ISSN: 2277-9655.
[8] Dr.P.Srinivas, P.Ravi Chandra, M.Ravi Kumar & N.Yogi Manash Reddy, Experimental Investigation of LPG as Refrigerant in a Domestic Refrigerator,JMERT, vol-2 NO.-1 (2014).
[9] Ian Maclaine-cross, Hydrocarbon Refrigerants for Car Air Conditioners, Presented at Seminar on ODS phase-out, Solution for the Refrigeration Sector, Indonesioa, 5 May 1999.
[10] Haslinda Mohamed Kamar,Mohd Yusoff Senawi and Nazri Kamsah, Computerized Simulation of Automotive Air-Conditioning System, IJCSI, Vol. 9, Issue 2, No 2, March 2012 ISSN: 1694-0814.
[11] L. Chaney, Fuel Savings and Emission Reductions from Next-Generation Mobile Air Conditioning Technology in India, Conference Paper NREL/CP-540-41154 May 2007.
[12] www.lpgasmagazine.co.uk

