Natural Refrigerants based Automobile Air Conditioning System

Sohail Bux, A.C. Tiwari

Abstract-Air conditioning of automobile is essential for modern luxurious life. Today's automobile air conditioning system is based on vapour compression refrigeration cycle and refrigerant R134a is used for this purpose. In this paper Lithium Bromide-water, Aqua-ammonia and Lithium Chloride -water refrigeration systems is run by waste exhaust heat or low grade energy of four cylinder four stroke diesel engine situated at mechanical department at Rajeev Gandhi technical university Bhopal. The capacity of refrigeration system is one ton and five litres kirlosker diesel engine is used for this purpose . A common counter flow shell and tube type generator or heat exchanger is used for all three vapour absorption refrigeration systems. The performance of all refrigeration systems depends on performance of diesel engine exhaust. This automobile air-conditioning system is run by waste heat or low grade energy, required minimum maintenance, used environment friendly refrigerants and reduce the mileage of the vehicle.

Key words: Waste heat recovery, LiBr-H_2O, NH_3-H_2O, LiCl-H_2O Refrigeration system, shell and tube heat exchanger, Diesel engine.

I. INTRODUCTION

Today world wise problem is best way to use minimum energy and develop method of reduce pollution problem. This problem also consider in research and development area where alternative source of energy, cost reduction method of energy and reuse of different forms of wasted energy. The rate of energy rises continuously, thus energy utilization management is essential in every small to multinational company. The energy available in may in company are the form of heat energy from low temperature to high temperature. This heat energy is captured the help of heat exchanger, which waste heat energy is recovered from low range temperature to high range temperature. In present automobile air conditioning only 30% fuel energy is used and remaining 70% energy is waste in atmosphere and artificial refrigerant used in automobile air conditioner is responsible for global warming and ozone depletion potential(ODP). Existing automobile air conditioning system and compare of vapour compression and vapour absorption refrigeration system are given.

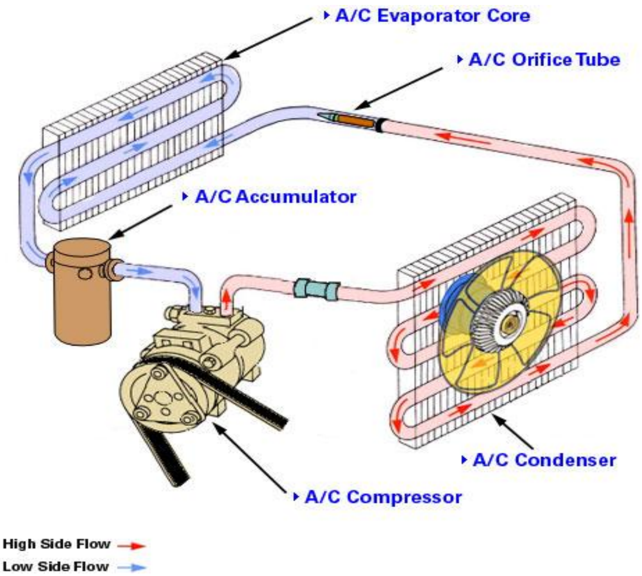

Fig.1 Existing Automobile Air Conditioning System

Table1. Comparison between Vapour Absorption and Vapour Compression Refrigeration System

No.	Vapour Absorption system	Vapour Compression System
1.	Uses low grade energy like heat. Therefore, may be worked on exhaust systems from I.C engines, etc.	Using high-grade energy like mechanical work.
2.	Moving parts are only in the pump, which is a small element of the system. Hence operation is smooth.	Moving parts are in the compressor. Therefore, more wear, tear and noise.
3.	The system can work on lower evaporator pressures also without affecting the COP.	The COP decreases considerably with decrease in evaporator pressure.
4.	No effect of reducing the load on performance.	Performance is adversely affected at partial loads.
5.	Liquid traces of refrigerant present in piping at the exit of evaporator	Liquid traces in suction line may damage the compressor
6.	Automatic operation for controlling the capacity is easy.	It is difficult.

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Objective

- Developed a system of automobile air-conditioning of single stageLiBr-H_2O, NH_3-H_2O and LiCl`-H_2O vapour absorption system run by low grade energy or Exhaust waste heat of diesel engine.
- Calculated different parameters of 4 stroke 4cylinder diesel engine.
- Design a Shell and Tube exchanger or generator of vapour absorption systems which resist the back pressure of exhaust gases of diesel engine .
- Compare LiBr-H_2O ,NH_3-H_2O and LiCl-H_2O vapour absorption systems with existing 134a compression refrigeration system of automobile.

II. LITERATURE REVIEW

More than 150 papers associated with absorption technology have been reviewed to classify current research problem. Some very important papers given by different scientists, researcher and academicians are given. Morcos [1] has studied the performance of shell and dimpled tube heat exchangers for waste heat recovery. The exchanger heat duty, overall heat transfer coefficient, effectiveness and tube side friction factor are investigated as functions of the tube surface geometry (plain or dimpled), the flow pattern (counter or parallel) and tube Reynolds number .**Talbi and Agnew** [2] have examined the interfacing of turbocharged diesel engine with an absorption refrigeration unit and estimated the performance enhancement due to the energy recovery from the engine exhaust gas.. **Anderson and Robert Nation** [3] have done work in waste heat recovery system for an internal combustion engine exhaust gas and coolant using two different liquids operating at different pressure and temperature in two separate circuit path . **S. Wang at. el** [4], observed that In the exhaust gases of motor vehicles, there is enough heat energy that can be utilised to power an air-conditioning system. Once a secondary fluid such as water or glycol is used, the aqua-ammonia combination appears to be a good candidate as a working fluid for an absorption car air-conditioning system.**K.Balaji And R.Senthil Kumar** [6], illustrates the sugar industry steam turbine exhausts carry a considerable amount of thermal energy. This energy can be set in to positive use as a heat source for vapour absorption system to serves as cooling system. This paper shows the thermal and fiscal advantages of using single effect lithium bromide water absorption by means of waste heat. The objective of this work is to hypothetical design of lithium bromide water absorption Refrigeration system using waste heat from sugar industry steam turbine exhaust. **Ghassemi [7]** presented his worked Ammonia water absorption refrigeration system for automobile application. This setup show the condenser is situated top of the automobile and evaporator is inside of the fuel cost and capital cost of the system decreases and overall COP are 0.29[9]**. Keatin**g[9] invented absorption refrigeration system for mobile application and had a patent in 1954. This system is applicable for vehicle, boats, railways cars. **MeNamara [10]** designed a diesel, steam I.C. engine or turbine operated absorption machine and had patent 1972. This system was using a mixture of water ammonia helium three fluid systems **Akerman[11]** investigated a automobile air-conditioning system using exhaust of internal combustion engine. His worked basically used two different absorption cycles with different refrigerant pairs .**Vicent et. al. [12]** presented a tuck refrigeration system using waste heat of exhaust gases available at tail pipe of internal combustion engine additionally the main feature which given by Vincent is used as a eutectic plate storage system for slow aped or parking condition of truck. **Horuz's[13]** presented by experimental investigation of exhaust gas operated ammonia-water absorption refrigeration system **.Salim M[14]**. simulated theoretically automobile Lithium Bromide water single stage absorption refrigeration system taken heat from internal combustion engine exhaust gases. This system is also useful for water cooled and air cooled condition and ABSIM software is used for calculation purpose. S**hah Alam[15]** presented three fluid vapour absorption refrigeration system, run by four cylinder, four stroke passenger car. The capacity of car air conditionor is one ton. He shows that the heat required for air conditioner is more than double amount are available on engine exhaust.**Talom, Beyene[16]** study on a project in which a 10.55 kW (three ton) absorption chiller was modified for hot gas intake and matched to a 2.8 L V6 internal combustion engine. Mathematical model and experimental test results suggest that the concept is thermodynamically feasible and could significantly enhance system performance depending on part-load of the engine. **Ramanathan *et al.*[17]** simulated an automotive air-conditioning system based on absorption refrigeration cycle. By developing a steady-state simulation model performance analysis of vapor absorption refrigeration system is done. The water lithium bromide pair is used as a working mixture for its favorable thermodynamic and transport properties compared to the conventional refrigerants utilized in vapor compression refrigeration applications. The pump power required for the proposed vapor absorption refrigeration system is found lesser than the power required operating the compressor used in the conventional vapor compression refrigeration system. A possible arrangement of the absorption system for automobile application is proposed. In this paper **Boonnasaa *et al.*** [18] studied the means to improve the capacity of the combined cycle (2 gas turbines and 1 steam turbine unit) power plant. The most popular way is to lower intake air temperature to around 15 deg. C and 100% RH before entering the air compressor of a gas turbine (GT). This research proposes a steam absorption chiller (AC) to cool intake air to the desired temperature level. Cooling inlet air would increase air mass flow, and then increase the power output[19]. **Pise et al[19]**.carried out extensive investigation on the enhancement of heat and mass transfer in absorbers of LiBr-H2O refrigerating system. It is showed that the heat and mass transfer in the absorber can be improved by creating wavy and turbulent flows by means of introducing extended surfaces, splashing using additives or simply by increasing the solution flow Reynolds No. Schmidt No.

III. VAPOUR ABSORPTION REFRIGERATION SYSTEM

Vapour absorption refrigeration system same as vapour compression refrigeration system but compressor is Replace by a generator or Desorber and absorber. The two fluid type single stage vapour Absorption refrigeration systems are given. In aqua ammonia absorption refrigeration system ammonia is a refrigerant and water is a absorbent and LiBr-H2O, LiCl-H2O both absorption refrigeration cycle are same refrigerant water but absorbent solution are different.

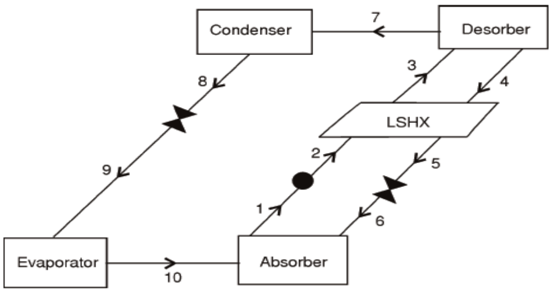

Fig.2 Single Stage LiBr-H2O Vapor Absorption System.

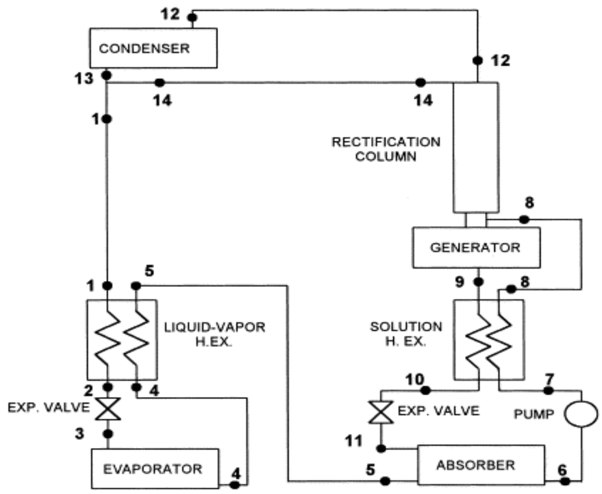

Fig3. Single Stage NH3-H2O Absorption Refrigeration System.

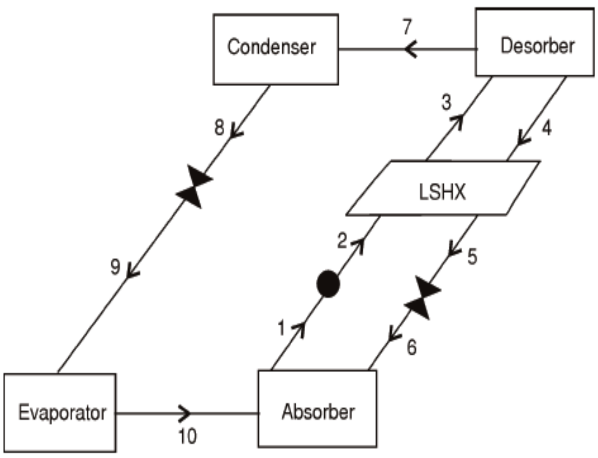

Fig4. Single Stage LiC1-H2O Absorption Refrigeration System.

IV. MATERIAL AND METHOD

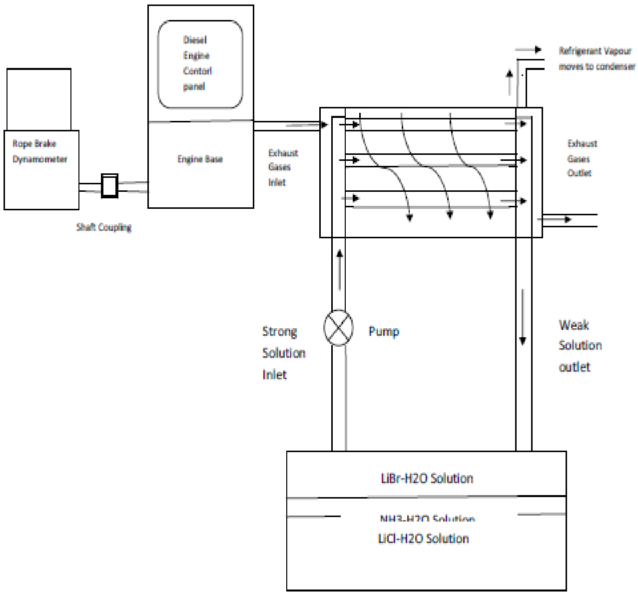

Fig5.Exprimetal Set Up in Mechanical Department UIT RGPV Bhopal

First we developed a experimental set up in mechanical department in UIT RGPV Bhopal. This set up mainly two parts one is four stroke four cylinder diesel engine coupled with rope brake dynamometer. The exhaust pipe (tail pipe) of diesel engine connected to shell and tube type heat exchanger after catalytic convertor for LiBr-H2O, NH3-H2O, and LiCl-H2O refrigeration system. In this system water as a refrigerant and Lithium Bromide and Lithium Cloride is absorbent and other case ammonia is a refrigerant and water is a absorbent. Exhaust pipe is connected to shell side and refrigerant flow in the tube side of heat exchanger and with help of pump and solution of refrigerant and absorbent is collected in the reservoir which is situated in bottom of the pump . The shell and tube type heat exchanger used as a generator of absorption refrigeration system .Temperature and pressure measurement of inside and outside of heat exchangers with help of thermocouples and u tube manometer .From this experimental set up we measure the different parameters of diesel engine and its performance effect on performance of LiBr-H2O,NH3-H2O and LiCl-H2O absorption refrigeration systems.

Fig 6: Diesel Engine Setup in Mechanical Department of UIT RGPV

Table 2 Specification of Diesel Engine

Name of Manufacturer	Kirlosker
Rated Speed	2500 rpm
Brake Power	25 KW
Fuel Used	Diesel
Stroke Length	92 mm
Diameter of Cylinder	78 mm
Compression Ratio	18
Anemometer Diameter	68 mm
No of Cylinder	Four
No of Stroke	Four
Dynamometer	Hydraulic
Capacity	5 Liters

Table 3(a)

S.NO.	LOAD (Kg)	SPEED (rpm)	FUEL (Kg/Sec)	MEP (Bar)	AIR (Kg/Sec)	C.V. (MJ/Kg)
1	5	2240	0.00197	4.2	0.034	38
2	10	2200	0.00209	5.0	0.034	38
3	15	2160	0.00256	6.3	0.034	38
4	20	1990	0.00305	7.4	0.034	38

Table3 (b)

S.NO	IP (Kw)	BP (Kw)	η_m (%)	η_v (%)	η_{ith} (%)	η_{bth} (%)	ISFC Kg/Kwhr	BSFC Kg/Kwhr	A/F
1	13.4	5.6	42	84.5	17.36	7.4	0.518	1.34	15.6
2	16.5	12	66.8	88.65	20.4	13.74	0.437	0.65	16
3	20.06	16.4	80.7	92.6	21.96	18.25	0.399	0.493	14.4
4	21.95	19.9	90.24	95.4	22.6	19.8	0.410	0.454	12.9

V. Shell and Tube Generator or Heat Exchanger

Shell and Tube heat exchanger is common type heat exchangers. These are reliable design method and shop facility is available for successful design or construction method. This heat exchanger are design for high pressure relative to environment and high pressure difference between the fluid streams .These heat exchanger are used as a condenser, feed water heater, steam generator and refrigeration and air conditioning purpose .The major components of this heat exchanger are tube bundle, shell .front head end, rear head end, baffles and tube sheet. TEMA (Tubular Exchanger Manufacturers Association) standards are used for designing of generator of automobile air conditioning purpose. Thermal stress, mechanical stress, vibration problem and erosion are important parameters consideration when designing shell and tube heat exchanger. High pressure, corrosion fouling and high heat transfer fluid flow (water or ammonia) are used in tube side and low heat transfer fluid or exhaust gases of diesel engine are used in shell side. Dimension of heat exchanger are given in tabulated form after calculation.

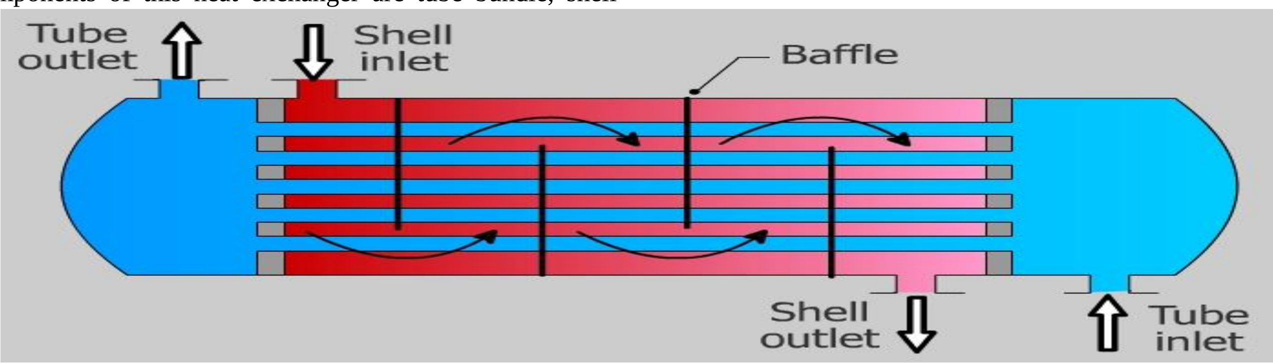

Fig.7

Table 4: Shell and Tube Heat Exchanger

Sr	Load (Kg)	Speed (Rpm)	Cooling capacity of LiBr-H_2O Heat Exchanger (Kw)	Cooling capacity of NH3-H_2O Heat Exchanger (Kw)	Cooling capacity of LiCl-H_2O Heat Exchanger (Kw)	Pressure Drop in LiBr-H_2O Heat Exchanger (Pa)	Pressure Drop in NH_3-H_2O Heat Exchanger (Pa)	Pressure Drop in LiCl-H_2O Heat Exchanger (Pa)	Heat Recovered From Exhaust Gas (Kw)
1	5	2237	8.2	7.0	8.3	6.5	15	6.4	18
2	10	2200	7.5	6.8	7.8	6.2	22	6.0	17.5
3	15	2165	6.9	5.9	7.0	5.5	20	7.1	16
4	20	1980	6.0	4.5	6.8	5.1	18	6.9	14

VI. RESULT AND DISCUSSION

From Table 3(a) and Table3(b)of diesel engine drawn different types of characteristic curves like Load vs. Exhaust temperature, exhaust gas flow rate, air consumption, power, exhaust gas flow rate, specific fuel consumption. When Load of engine increases all these parameters are decreases, Other characteristic curves are Load vs. engine back pressure, engine efficiency, cooling capacity, heat input vs. cooling capacity, heat transfer at the generator vs. cooling capacity. Back pressure increases when speed increase if surface area of generator is less and back pressure reduce when surface area is more, engine efficiency increase as well as increase automobile air conditioning has advantages of reducing the dedicated internal combustion engine, refrigerant compressor, unit weight, capital cost, fuel cost, maintenance, atmospheric pollution and noise pollution. One difficulty may occur when automobile is in very slow moving condition or it rest. The eutectic plate is provided for shell and tube heat exchanger or generator.

VII. CONCLUSION

The Lithium Bromide –Water, Aqua-Ammonia and Lithium Chloride-Water system based as a automobile air conditioner have following advantages and limitations.

- Generator designing is based on minimum back pressure and maximum heat transfer capacity.
- Balance the fluctuation in cooling capacity of automobile cabin due to changing of speed, traffic speed and cruse speed.
- Generator or Shell and Tube heat exchanger is made from stainless steel or galvanized steel due to reduce the corrosion problem.
- The crystallization occurs in Lithium Bromide -Water ,Lithium Chloride –Water absorption refrigeration system and toxic properties of ammonia keep in mind when designing these air conditioning systems.
- Additional energy source is available for automobile air conditioner, when the vehicle in parking i.e. eutectic plate or solar energy.
- This air conditioning system is totally eco- friendly in nature or used only natural refrigerants as well as increases the mileage of automobile.

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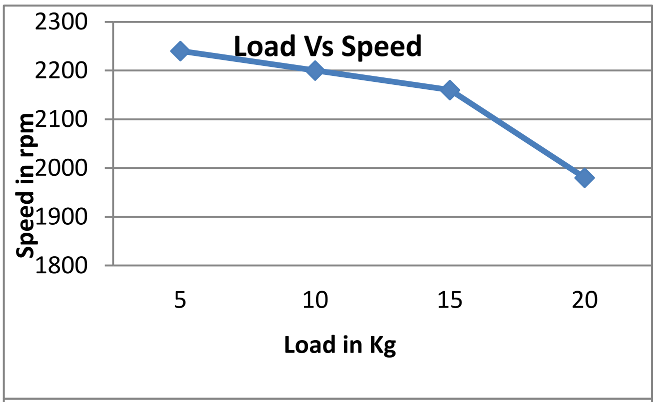
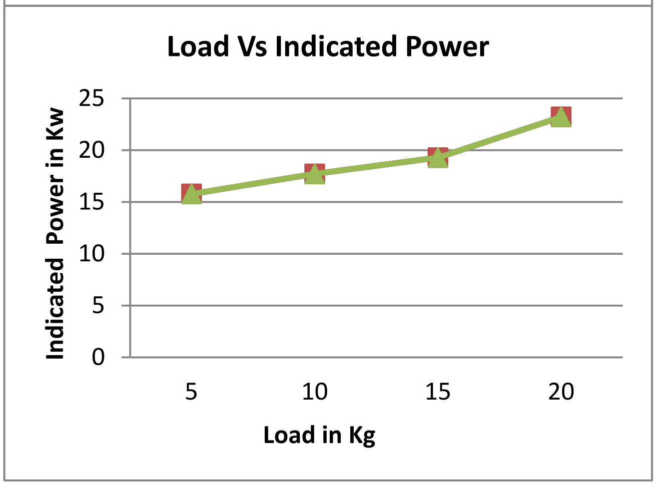
Performance Curves of Experimental Set up

Fig.8





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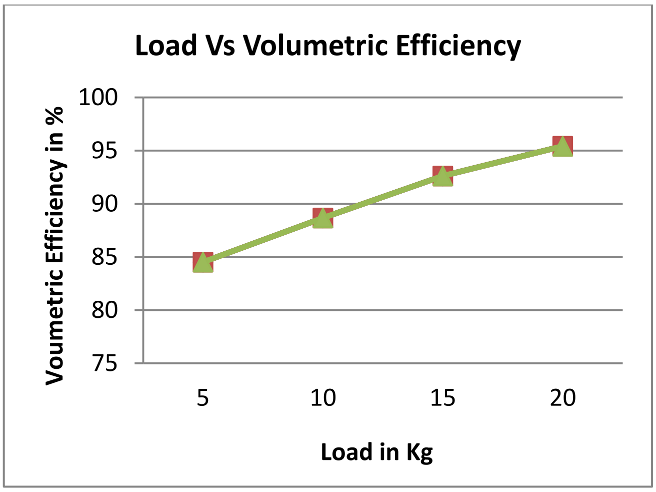

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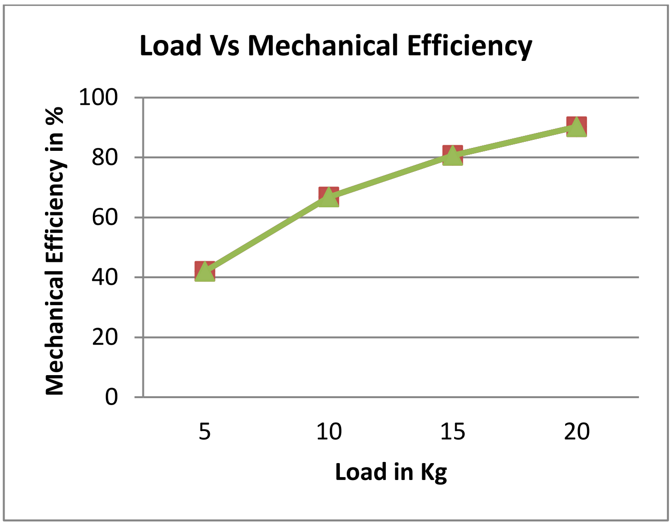

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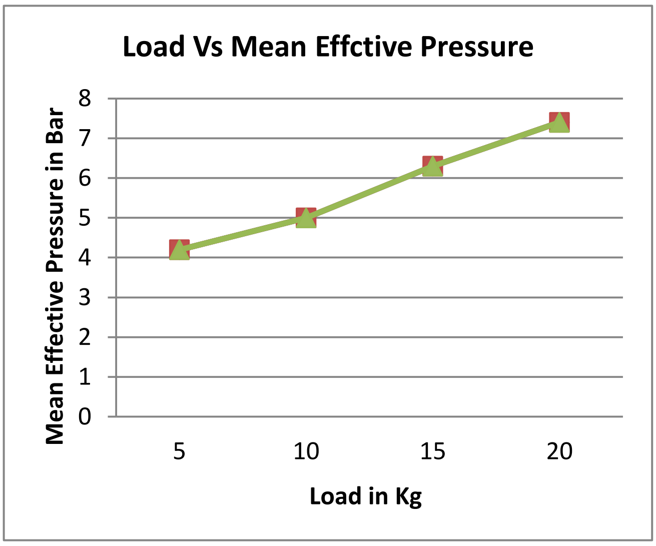

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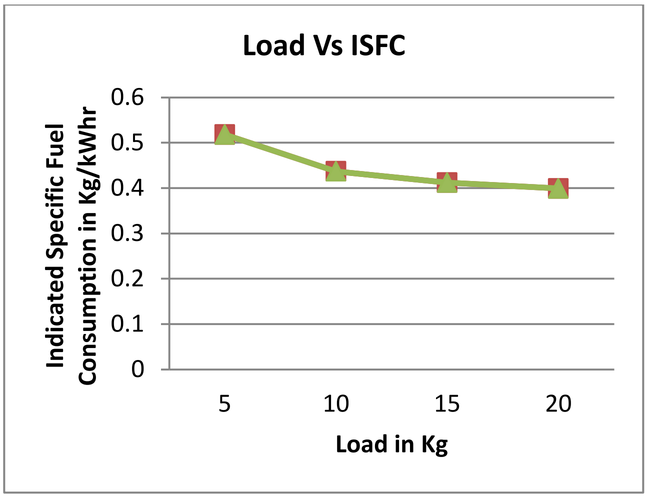

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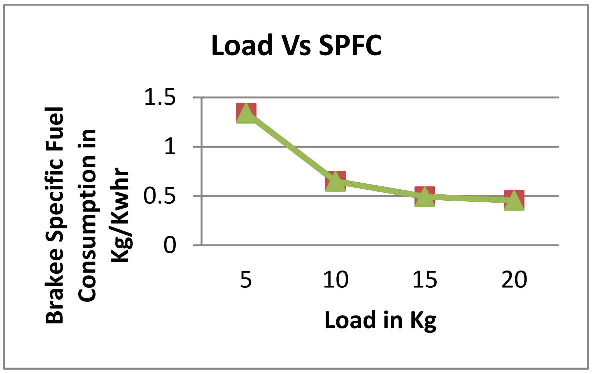

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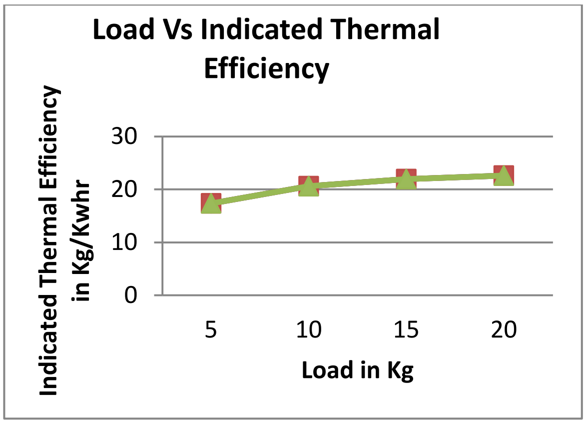

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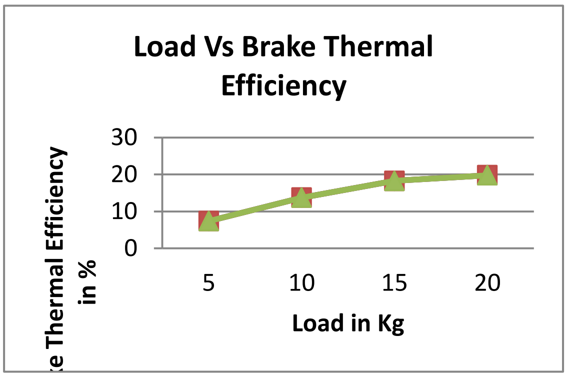

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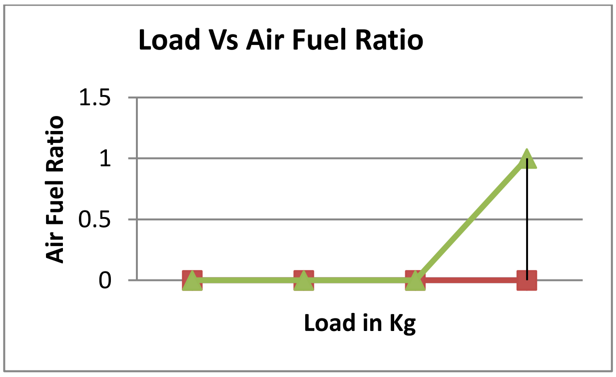

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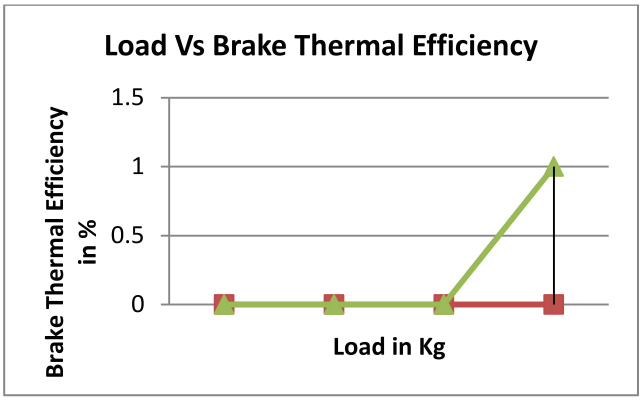

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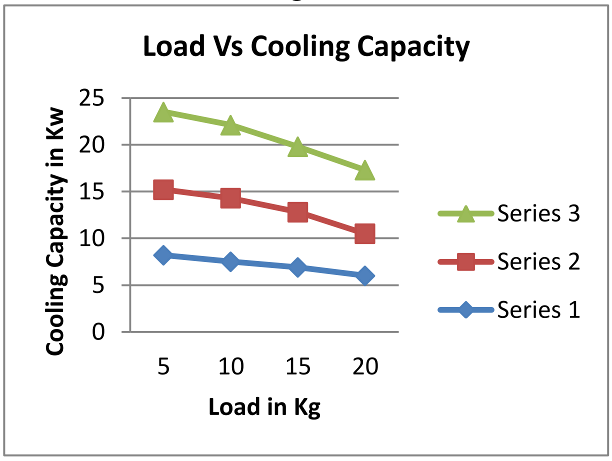

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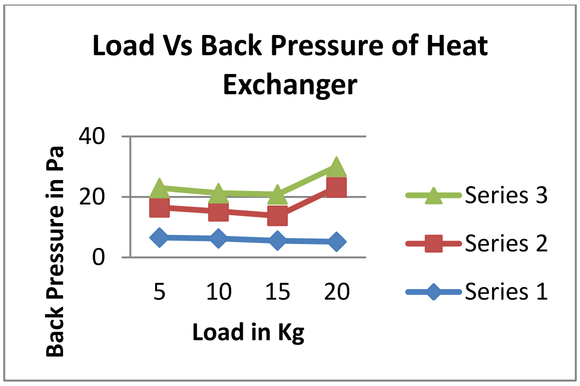

Fig :19

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