AUGMENTATION OF HEAT UTILIZATION SUPPLIED TO FOUR STROKE DIESEL ENGINE USING Li-Br VAPOUR ABSORPTION REFRIGERATION SYSTEM.

A project report submitted in partialfullfilment of therequirement for the award of the Degree of

BACHELOR OF TECHONOLOGY

IN

MECHANICAL ENGINEERING

By

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K. BRAHMA	(315126520090)
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DEPARTMENT OF MECHANICAL ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY &SCIENCES (A)

(Affiliated to Andhra University, approved by AICTE, Accredited by NBA)

SANGIVALASA, VISAKHAPATANAM-531 162

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CERTIFICATE

This is to certify that the project Report entitled "**AUGMENTATION OF HEAT UTILIZATION SUPPLIED TO FOUR STROKE DIESEL ENGINE USING Li-Br VAPOUR ABSORPTION REFRIGERATION SYSTEM**" has been carried out by **M. AJAYKUMAR (31512620143), K BRAHMA (315126520090), K PRUDHVIRAJU (315126520075), K GOUTHAM (315126520097), M UDAYHARSHAVARDHAN (315126520125)** under my guidance in partial fulfillment of the requirements for the award of Degree of Bachelor of mechanical Engineering of Andhra University, Visakhapatnam.

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THIS PROJECT IS APPROVED BY THE BOARD OF EXAMINERS

INTERNAL EXAMINER: 13/4/19

EXTERNAL EXAMINER: 13/4/19

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ABSTRACT

Depleting fossil fuels is a future challenge. Internal combustion engines are major consumer of fossil fuels. Large amount of energy from internal combustion engine is wasted into the environmentthrough exhaust gases. This low grade energy can actually be recovered for useful purpose. This project mainly focuses on the recovery of the waste heat from the exhaust gases of IC engine. Conventionally, automobile Air Conditioning works on Vapour Compression Refrigeration cycle which consumes mechanical energy and reduces fuel economy. This Vapour Compression Refrigeration system can be replaced by a Vapour Absorption Refrigeration system by utilizing exhaust waste heat. By using this waste heat from IC engine a theoretical Li-BrVapour absorption refrigeration system is developed and feasibility of the waste heat recovery is studied by using basic thermodynamic laws. A normal four stroke diesel engine will have Brake thermal efficiency of 35-40% at its rated output. This value decreases with the ageing of the engine. By augmenting the engine system, it is observed that the overall efficiency of the combined diesel engine and the vapour absorption refrigeration system enhanced by an amount of 10-20%. The C.O.P of the vapour absorption refrigeration system obtained is 0.83.

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NOMENCLATURE

SYMBOL	DESCRIPTION
B.P	Brake power
C_P	Specific heat of water at constant pressure
C_{Pg}	Specific heat of gases at constant pressure
C.O.P	co-efficient of performance
H_g	Heat carried away by exhaust gases
h	Enthalpy
i	Current(amperes)
m_1	Mass flow rate of water
m_a	Mass flow rate of strong LiBr-water solution
m_f	Mass flow rate of weak LiBr-water solution
m_{f1}	Mass flow rate of fuel
m_g	Mass flow rate of gases
η	Efficiency
ε	Effectiveness of the combined system
Q	Heat supplied to the engine by the fuel
Q_a	Heat rejected by the absorber
Q_c	Heat rejected by the condenser
Q_g	Heat supplied to the generator
Sp.gr	Specific Gravity
T_a	Ambient temperature
T_1	Inlet temperature of cooling water to the engine and calorimeter

T_2	Outlet temperature of water from engine
T_3	Outlet temperature of water from calorimeter
T_4	Exhaust gas inlet temperature to calorimeter
T_5	Exhaust gas outlet temperature to calorimeter
t	Time taken for consuming 10cc of fuel
V	Voltage
W_1	Rate of flow of water through calorimeter
x	Concentration(Kg LiBr/Kg Solution)
R Y B	3 Phases of an supply
RY YB BR	Voltage between two phases

CHAPTER 1

INTRODUCTION

INTRODUCTION

1.1INTERNAL COMBUSTION ENGINE:

The internal combustion engine is an engine in which the burning of a fuel occurs in a confined space called a combustion chamber. This exothermic reaction of a fuel with an oxidizer creates gases of high temperature and pressure, which are permitted to expand. Useful work is performed by the expanding hot gases acting directly to cause movement, for example by acting on pistons, rotors. Thus converting chemical energy into mechanical energy.

The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar four stroke and two stroke piston engines, along with variants, such as the six stroke piston engine and the Wankel rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same prinicipal.

Internal combustion engines are quite different from external combustion engines, such as steam or stirling engines, in which the energy is delivered to a working fluid not consisting of, mixedwith,or contaminated by combustion products.working fluids can be air, hot water, pressrised water or even liquid sodium, heated in aboiler. Internal combustrion engine is usually powered by energy-dense fuels such as gasoline or diesel, liqiuds derived from fossil fuels. While there are many stationary applications, most ICEs are used in mobile applications and are the dominant power supply for cars, aircraft and boats.

Typically an ICE is fed with fossil fuels like natural gas or petroleum products such as, gasoline, diesel fueloil. There is a growing usage of renewable fuels like biodiesel for CI (compression ignition) engines and bioethanol or methanol for SI (spark ignition) engines. Hydrogen is sometimes used, and can be obtained from either fossil fuels or renewable energy.

1.2DIESEL ENGINE:

Four-stroke cycle (Diesel)

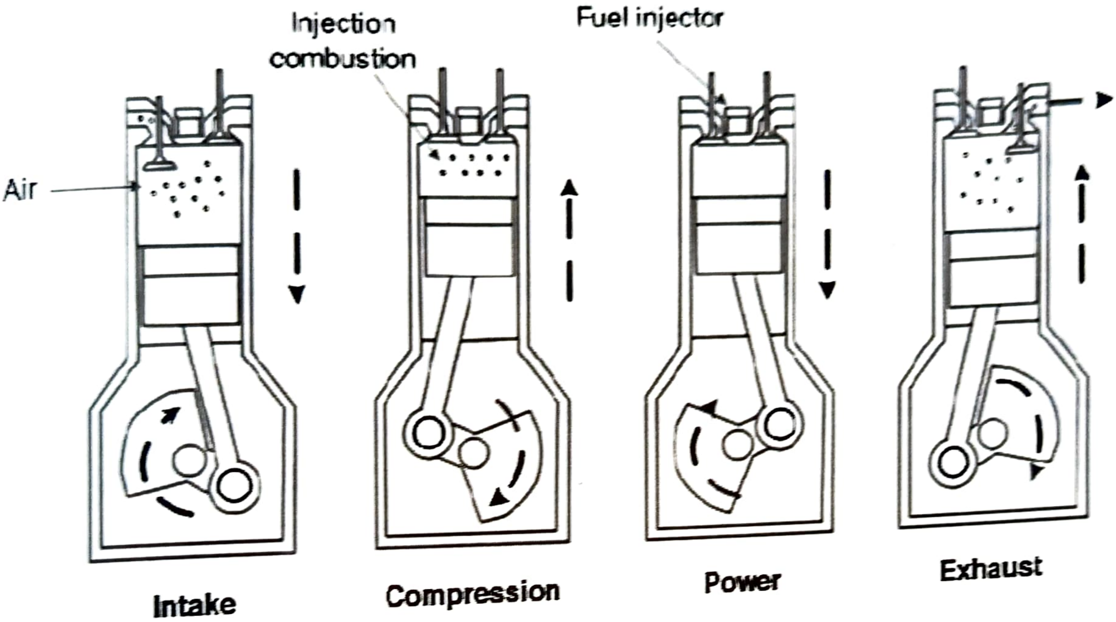

Fig 1.1 Four stroke diesel engine

The diesel engine (also known as a compression-ignition engine) is an internal combustion engine in which ignition of the fuel has been injected into the combustion chamber is initiated by the high temperature which a gas achieves when greatly compressed (adiabatic compression). This contrasts with spark-ignition engines such as petrol engine (gasoline engine) or gas engine (using a gaseous fuel as opposed to gasoline), which use a spark plug to ignite an air-fuel mixture.

The diesel engine has the highest thermal efficiency of any standard internal or external combustion engine due its very high compression ratio and inherent lean burnwhich enables heat dissipation by the excess air. A small efficiency loss is also avoided compared to two-stroke non-direct-injection gasoline engines since un burnt fuel is not present at valve overlap and therefore no fuel goes directly from the intake /injection to the exhaust. Low-speed diesel engines (as used in ships and other) applications where overall engine weight is relatively unimportantly can have a thermal efficiency that exceeds 50%.

Diesel engines are manufactured in two-stroke and four-stroke versions. They were originally used as a more efficient replacement for stationary steam engines. Since the 1910's they have been used in submarines and ships. Use in locomotives, trucks, heavy equipment and electricity generation plants followed later. In the 1930's they slowly began to be used in few automobiles. Since the1970's, the use of diesel engines in larger on-road and off-road vehicles in the USA increased. According to the British Society of Motor Manufacturing and Traders, the EU average for diesel cars account for 50% of the total sold, including 70% in France and 38% in the UK.

The world's largest diesel engine is currently a Wartsila-Sulzer RTA96-C Common Rail marine diesel, which produce a peak power output of 84.42 MW (113,210 hp) at 120 r.p.m.

1.3 PARTS OF DIESEL ENGINE:

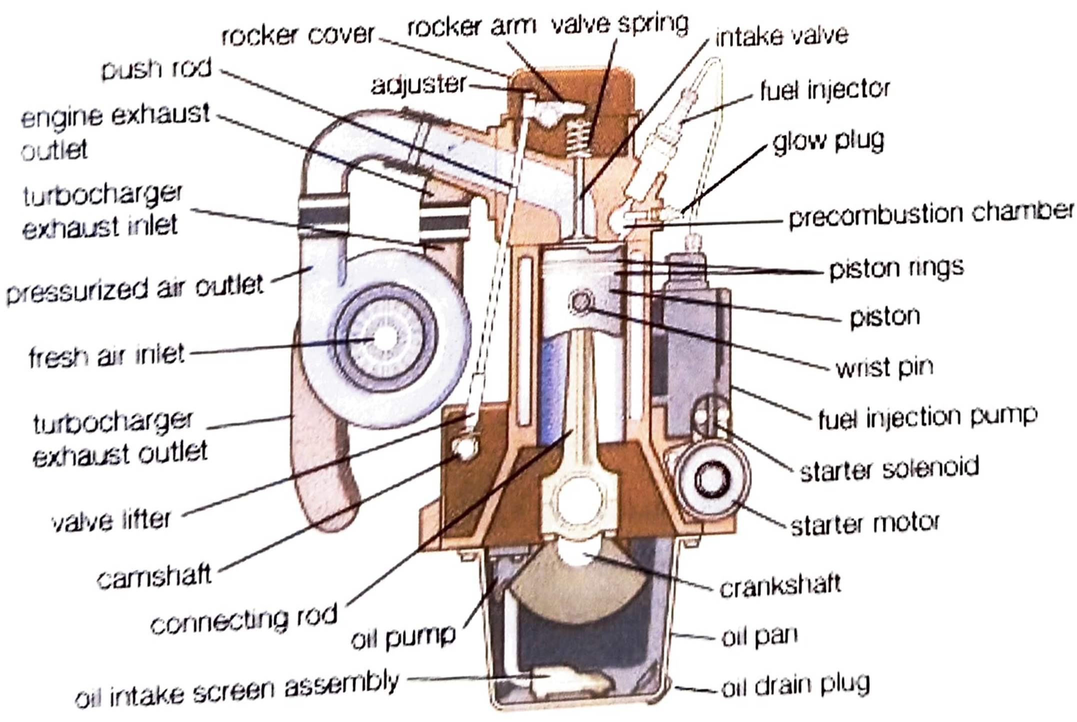

Fig 1.2 Parts of diesel engine

For a four-stroke engine, key parts of the engine include the crankshaft, connecting rod, one or more camshafts and valves. For a two-stroke engine, there may simply be an exhaust outlet and fuel inlet instead of a valve system. In both types of engines there are one or more cylinders and for each cylinder there is a sparkplug (gasoline engines only), a piston, and a crankpin. A single sweep of the cylinder by the piston in an upward or downward motion is known as a stroke. The downward stroke that occurs directly after the air-fuel mix passes from the carburettor or fuel injector to the cylinder (where it is ignited) is also known as a power stroke.

A Wankel engine has a triangular rotor that orbits in an epitrochoidalchamber around an eccentric shaft. The four phases of operations (intake, compression, power and exhaust) take place in what is effectively a moving, variable-volume chamber.

Valves

All four-stroke internal combustion engines employ valves to control the admittance of fuel and air into the combustion chamber. Two-stroke engines use ports in the cylinder bore, covered and uncovered by the piston, though there have been variations such as exhaust valves.

Piston engine valves:

In the piston engines, the valves are grouped into ‘inlet valves’ which admit the entrance of fuel and air and ‘outlet valves’which allow the exhaust gases to escape. Each valve opens once per cycle and the ones that are subject to extreme accelerations are held closed by springs that are typically opened by rods running on a camshaft rotating with the engines’ crankshaft.

Control valves:

Continuous combustion engines as well as piston engines usually have valves that open and close to admit the fuel and /or air at the start up and shutdown. Some valves feather to adjust the flow to control power or engine speed as well.

Exhaust systems:

Internal combustion engines have to effectively manage the exhaust of the cooled combustion gas from the engine. The exhaust system frequently contains devices to control pollution, both chemical and noise pollution. In addition, for cyclic combustion engines the exhaust system is frequently tuned to improve emptying of the combustion chamber. The majority of exhaust also have systems to prevent heat from reaching places which would encounter damage from it such as heat-sensitive components, often referred to as Exhaust Heat Management.

For the propulsion internal combustion engines, the 'exhaust system' takes the form of a high velocity nozzle, which generates thrust for the engine and forms a collimated-jet of gas that gives the engine its name.

Cooling systems:

Cooling systems usually employ (air cooled) or liquid (usually water) cooling, while some very hot engines using radiative cooling (especially some rocket engines). Some high-altitude rocket engines use ablative cooling, where the walls gradually erode in a controlled fashion. Rockets in particular can use regenerative cooling, which uses the fuel to cool the solid parts of the engine.

Piston:

A piston is a component of reciprocating engines. It is located in a cylinder and is made gas-tight by piston rings. Its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston also acts a valve by covering and uncovering ports in the cylinder wall.

Propelling nozzle:

For jet engine forms of internal combustion engines, a propelling nozzle is present. This takes the high temperature, high pressure exhaust and expands and cools it. The exhaust leaves the nozzle going at much higher speed and provides thrust, as well as constricting the flow from the engine and raising the pressure in the rest of the engine, giving thrust for the exhaust mass that exists.

Crankshaft:

Most reciprocating internal combustion engines end up turning a shaft. This means that the linear motion of a piston must be converted into rotation. This is typically achieved by a crankshaft.

Flywheels:

The flywheel is a disk or wheel attached to the crank, forming an internal mass that stores rotational energy. In engines with only a single cylinder the flywheel is essential to carry energy over from the power stroke into a subsequent compression stroke. Flywheels are present in most reciprocating engines to smooth out the power deliver engines to smooth out the power delivery over each rotation of the crank and in most automotive engines also mount a gear ring for a starter. The rotational inertia of the flywheel also allows a much slower minimum unloaded speed and also improves the smoothness at idle. The flywheel may also perform a part of the balancing for the flywheel, enabling it to be balanced in a separate operation. The flywheel is also used as mounting for the clutch or a torque converter in most automotive application.

Starter system:

All internal combustion engines requires some form of system to get them into operation. Most piston engines use a starter system powered by the same battery as runs the rest of the electric systems. Large jet engines and gas turbines are started with a compressed motor that is geared to one of the engine's drive shafts. Compressed air can be supplied from another engine are often started by pull cords. Motor cycles of all sizes were traditionally kick-started, though all but smallest are now electric-start. Large stationary and marine engines may be started by the timed injection of compressed air into the cylinders or occasionally with cartridges. Jump starting refers to assistance from another battery (typically when the fitted battery id discharged), while bump staring refers to an alternative method of starting by the application of some external force, e.g. rolling down a hill.

Heat shielding systems:

These systems often work in combination with engine cooling and exhaust systems. Heat shielding is necessary to prevent engine heat from damaging heat sensitive components. The majority of old cars use simple steel heat shielding to reduce thermal radiation and convection. It is now common for modern cars are to use aluminum heat shielding which has lower density, can be easily formed and does not corrode in the same way as steel. Higher performance vehicles are beginning to use ceramic heat shielding as this can withstand far higher temperatures as well as further reductions in heat transfer.

Lubrication systems:

Internal combustion engines require lubrication in operation that moving parts slide smoothly over each other. Insufficient lubrication subjects the parts of the engine to metal-to-metal contact, friction, heat build-up, rapid wear often culminating in parts becoming friction welded together e.g. piston in their cylinders. Big ends bearings seizing up will sometimes lead to a connecting rod breaking and poking out through the crankcase.

Several different types if lubrication systems are used. Simple two-stroke engines are lubricated by oil mixed into the fuel or injected into the induction steam as a spray. Early slow-speed stationary and marine engines were lubricated by gravity from small chambers similar to those used on steam engines at the time with an engine tender refilling these as needed. As engines were adapted for automotive and aircraft use, the need for a high power-to-weight ratio led to increase speeds, higher temperatures, and greater pressure on bearings which in turn required pressure lubrication for crank bearings and connecting-rodjournals. This was provided either by a direct lubrication from a pump, or indirectly by a jet of oil directed at pickup cups on the connecting rod ends which had the advantage of higher pressure as the engine speed increased.

1.4 REFRIGERATION

Refrigeration is a process of removing heat from a low-temperature reservoir and transferring it to a high-temperature reservoir. The work of heat transfer is traditionally driven by mechanical means, but can also be driven by heat, magnetism, electricity, laser, or other means. Refrigeration has many applications, including, but not limited to: household refrigerators, industrial freezers, cryogenics, and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to air conditioning units.

1.4.1 NON-CYCLIC REFRIGERATION

This refrigeration method cools a contained area by melting ice, or by sublimating dry ice. Perhaps the simplest example of this is a portable cooler, where items are put in it, then ice is poured over the top. Regular ice can maintain temperatures near, but not below the freezing point, unless salt is used to cool the ice down further (as in traditional ice maker). Dry ice can reliably bring the temperature well below freezing.

1.4.2 CYCLIC REFRIGERATION

This consists of a refrigeration cycle, where heat is removed from a low-temperature space or source and rejected to a high-temperature sink with the help of external work.

A refrigeration cycle describes the changes that take place in the refrigerant as it alternately absorbs and rejects heat as it circulates through a refrigerator. It is also applied to heating, ventilation, and air conditioning HAVC work,

Heat naturally flows from hot to cold, work is applied to cool a living space or storage volume by pumping heat from a lower temperature heat source into a higher temperature heat sink. insulation is used to reduce the work and energy needed to achieve and maintain a lower temperature in the cooled space. The operating principle of the refrigeration cycle was described mathematically by sadicarnot in 1824 as a heat engine.

The most common types of refrigeration systems use the reverse-Rankinevapour refrigeration compression cycle, although absorption heat pumps are used in a minority of applications.

Cyclic refrigeration can be classified as:

1. Vapour cycle, and
2. Gas cycle

Vapour cycle refrigeration can further be classified as:

1. Vapour-compression refrigeration
2. Vapour-absorption refrigeration

1.5 VAPOUR-COMPRESSION CYCLE

The vapour-compression cycle is used in most household refrigerators as well as in many large commercial and industrial refrigeration systems.

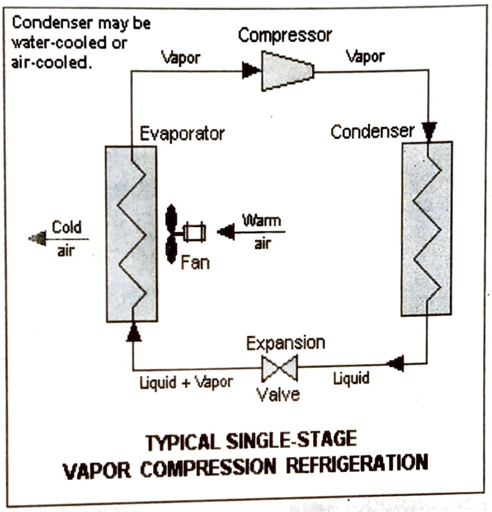

Fig 1.3 Vapour compression refrigeration system

1.6 VAPOUR ABSORPTION CYCLE:

In the early years of the twentieth century, the vapour absorption cycle using water-ammonia systems was popular and widely used. After the development of the vapour compression cycle, the vapour absorption cycle lost much of its importance because of its low coefficient ofperformance (about one fifth of that of the vapour compression cycle). Today, the vapour absorption cycle is used mainly where fuel for heating is available but electricity is not, such as in recreational vehicles that carry LP gas. It is also used in industrial environments where plentiful waste heat overcomes its inefficiency.

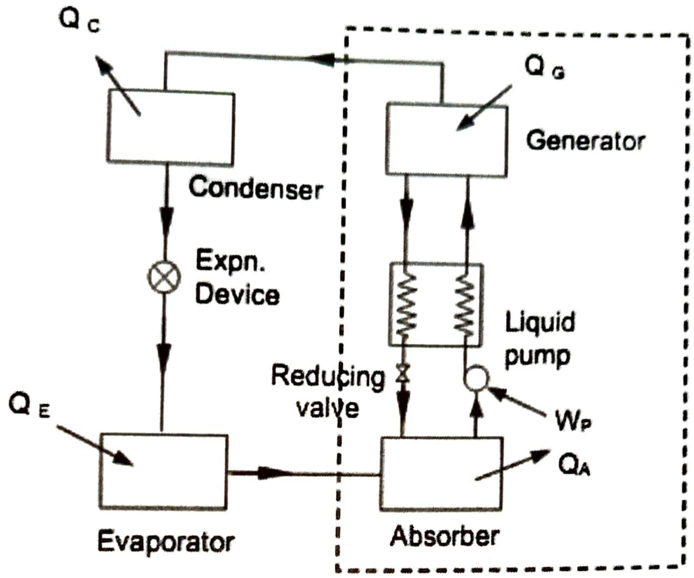

Fig 1.4 Vapour absorption refrigeration system.

The absorption cycle is similar to the compression cycle, except for the method of raising the pressure of the refrigerant vapor. In the absorption system, the compressor is replaced by an absorber which dissolves the refrigerant in a suitable liquid, a liquid pump which raises the pressure and a generator which, on heat addition, drives off the refrigerant vapor from the high-pressure liquid. Some work is needed by the liquid pump but, for a given quantity of refrigerant, it is much smaller than needed by the compressor in the vapor compression cycle. In an absorption refrigerator, a suitable combination of refrigerant and absorbent is used. The most common combinations are ammonia (refrigerant) with water (absorbent), and water (refrigerant) with lithium bromide (absorbent).

1.7MAJOR COMPONENTS OF AN ABSORPTION CYCLE:

There are five major components of an absorption cycle the evaporator, condenser, generator, absorber and heat exchanger; and other components such as solution and water pumps, air purge system, etc.

Evaporator

Refrigerant supplied from condenser evaporates under vacuum conditions which absorbs heat of process water flowing on the other side of the heat exchanger. Because water is used as a refrigerant, evaporation temperature cannot be lower than about 5-6oC which is a main drawback for LiBr-H_2O systems. However hybrid systems overcome this defect.

Condenser

High pressure superheated vapour supplied from the generator rejects heat to the ambient and condenses in the condenser and becomes ready for evaporation.

Generator

Diluted solution supplied from the absorber by a solution pump is heated by a heat source in the generator. The solution is concentrated in terms of LiBr by the boiling of water which is continuously supplied to the condenser. The concentrated solution goes to the absorber to be diluted by the vapour supplied from the evaporator.

Absorber

Concentrated solution supplied from the generator absorbs vapour and is diluted in the absorber, it is then collected and pumped to the generator to be concentrated and extract high pressure vapour again. Absorber can be considered as the heart of the system, however it is usually the least efficient component of an absorption machine ,hence absorption rates can be considered as a direct measurement for overall system performance.

Falling film absorbers are the most commonly used absorbers, because absorption surface is very large compared to the solution volume and rejection of heat of absorption to the ambient is easier. Heat of absorption is released at the absorption surface and presence of this heat decreases absorption performance, hence it should be removed from the system to enhance absorption performance. Bubble absorption, in which vapour is supplied from bottom of a pool, which is filled of solution, is not practical, because pressure of vapoursupplied from the evaporator is very low (about 0.01 bar). Absorber performance is affected by large number of parameters such as :

a. Presence of non-condensable.

As the absorbers operate under vacuum conditions, there should not be presence of any gases other than refrigerant vapour. However corrosion and passivation generate non-condensable gases which cause resistance to mass flow. These non-condensables are removed from the system by the purge system.

b. Solution Distribution.

Because the solution is usually sprayed over tubes arranged vertically or horizontally, instabilities, which prevents uniform film flow, can arise. However, these instabilities usually improve absorption performance.

c. Heat of Absorption.

Heat, generated during absorption process, must be removed, otherwise absorption performance falls; hence, lowering solution temperature increases absorption rates unless solubility limit for Li-Br is not reached. If temperature increases over a critical value, vapour desorption instead of absorption occurs.

The released heat of absorption is generally removed by water for large-scale applications, which completes its cycle by flowing through the condenser and consequently rejecting its heat in a cooling tower. However, air cooled systems are preferred for middle and low-scale residential and commercial applications, to be more economical. Commonly, there are two types of falling film absorbers:

- Vertical tubular absorber
- Horizontal tube bundle absorber

Vertical absorber is made of a number of vertical tubes, where the rich solution is supplied from the top of the vertical tubes, and flows down in the form of thin falling film. Vapour is supplied from the evaporator and is absorbed by the solution while the solution is flowing down. Heat of absorption is rejected to cooling water, which is flowing inside the tube. However for air-cooled small scale applications, the solution flows down inside the tube (so also the vapour is supplied from inside of the tube) and cooling air flows outside the finned tube.

Horizontal absorber is made of a number of horizontal tubes arranged vertically. The rich solution is sprayed over the top of the top tubes, and flows down in the form of thin falling film on the tubes. Similar to the vertical absorber, vapor is supplied from the evaporator and is absorbed by the solution while the solution is flowing down. Heat of absorption is rejected to cooling water, which is flowing inside the tube

CHAPTER 2
LITERATURE REVIEW

LITERATURE REVIEW

Nadaf and Gangavati [1] "A Review on Waste Heat Recovery and Utilization from Diesel Engine". This paper provides that finding more efficient technologies have the great reasons for the investigation of waste heat recovery techniques and focuses on the different waste heat recovery technologies based on current developments.

About 70% of the energy produced by the fuel is lost, of which mostly it is in the form of heat. 25-30% of the energy is dissipated from the engine in the form of heat. There are several methods of waste heat recovery like thermal electric conversion, direct heat applications (refrigeration, air conditioning, desalination). It provides there advantages and disadvantages and the conditions in which they can be applied.

Satyam and Anand [2] "A review paper on thermodynamics analysis of vapour absorption system driven by low grade energy"In this paper provides a review on various vapour absorption refrigeration technologies and study on different working fluids used in VARS and improvements in the system are discussed. The effect of various parameters on C.O.P of Li-Br water vapour absorption system also discussed and analyzed with reference to its use in automobiles for air conditioning. This review paper also illustrates various advantages of using VARS by means of waste/low grade heat. Finally it concludes , for better working of VARS the crystallization phenomenon should be carefully studied.

S SMothapati et.al [3] "A study of automobile air conditioning system based on absorption system using Exhaust heat of a vehicle"In this paper theoretical evaluation of Li-Br water based absorption refrigeration system is presented. Mathematical modeling of using EES software is done. Also, effects on C.O.P of with in different parameters has been studied. As per the calculations of heat load and heat availability obtained from a vehicle of 2KW is feasible to provide air conditioning in a vehicle. From system analysis it is seen that C.O.P of system increases with increases in generator temperature and evaporator temperature but it reduces with increase in condenser and absorber temperature. There is optimum value of generator temperature above which C.O.P reduces. Also C.O.P increases with increase in mass flow rate.

Dinesh kumar [4]"Performance evaluation of water Li-Br vapour absorption refrigeration system" In this paper use of VARS system for cooling of milk and milk products are discussed using waste heat instead of VCRS which helps in reduction in consumption of electric grid supply.

The inlet chilled water temperature of the chiller ranged from 7.1°C to 10.1°C during the entire study period. The chilling capacity of the VARS ranged from 243KW to 455KW during the operation of the plant. The chilling capacity showed variations depending on the temperature of incoming chilled water, generator temperature as well as the temperature of cooling medium used at the condenser.

Aziz et.al [5] "Design and Fabrication of vapour absorption refrigeration system" In this paper a simple VARS system is designed and fabricated to analyze the performance of the system. Heat of 500 watt capacity is for a pressure of 32.5 mBar is supplied through electric grid. It is found to have a C.O.P of 0.698. The C.O.P can be further be increased by using a heat exchanger b/w the absorber and generator as well as b/w the condenser and pressure reducing valve.

N ChandanReddy[6] "Performance analysis of VARS using exhaust gas heat of C.I Engine"In this paper by using waste heat energy the C.O.P is increased by 23% and the energy consumption of 220 KJ/K is saved than the existing system. So, it is estimated that recovery of waste heat reduces heat loss, improves performance of system, saves the fuel, reduces the emission of exhaust gas and is economically feasible. Also the area from which heat is lost to the surroundings decreases. By using waste heat input in the form of heat at the generator pipe, the maximum C.O.P of the system is obtained as 2.41.

AbhisheikandPrashant [7] "Thermodynamic Analysis of Lithium Bromide-water (LiBr-H2O) vapour Absorption Refrigeration System based on Solar Energy" In this paper analytical approach to the study of the VARS, by the application of First and second law of thermodynamics is done. By analytical calculations the C.O.P was found to be 0.876. It was ascertained that the solar collector efficiency and clearness of sky play a vital role in the overall efficiency of the system.

Babu and Marutiparasad [8]"Performance Analysis of Li-Br water Absorption Refrigeration System Using Waste Heat of Boiler Flue Gases" In this paper analysis on VARS system is done to find influence of operating temperatures on thermal load components and their C.O.P. It is found that the operating temperatures of condenser and absorber has to be maintained less than 40°C, evaporator temperature has to be more than 10°C and the generator temperature not exceeding 85°C, so as to run the absorption system efficiently.

From the literature review it is observed that there is a lot of scope for research in the area of vapour absorption refrigeration system utilizing waste heat. If the source of waste heat is considered as exhaust gases of an internal combustion engine, there will be an improvement in the fuel economy. Using vapour absorption refrigeration system as a substitute to vapour compression refrigeration system in automobiles can be a long term solution for the depletion of fuels. Hence the problem considered for analysis is partly experimental and partly analytical, where in the quantity of waste heat is measured by the operation of a diesel engine and these values are used as input for vapour absorption refrigeration system.

Hence a practical diesel engine system and theoretical vapour absorption system are combined for analysis to evaluate the overall performance. Waste heat recovery from the exhaust gases is the prime objective of the present study.

CHAPTER 3

THERMODYNAMIC ANALYSIS

THERMODYNAMIC ANALYSIS

3.1 PROBLEM STATEMENT:

To conduct load test on a four stroke diesel engine, to evaluate its power output and obtain the heat of exhaust gases. This is followed by an analytical evaluation of Vapour absorption refrigeration system using the waste heat of exhaust gases to obtain the overall performance of combined diesel engine and vapour absorption refrigeration system.

3.2 EXPERIMENTAL SETUP:

The engine used in this experiment is dual cylinder four stroke engine which is hand cranked. It is fitted withexhaust gas calorimeter so as to measure the heat available from the exhaust engine. Its specifications

ENGINE MAKE	M/S KIRLOSKAR
CYLINDER POSITION	VERTICAL
BRAKE POWER	10 H.P
SPEED	1500 R.P.M
BORE	80 mm
STROKE	110 mm
COMPRESSION RATIO	17:1
ORIFICE DIAMETER	25 mm
COOLING	WATER COOLED
STARTING	HAND CRANKING
DYNAMOMETER	A.C GENERATOR

Table 3.1 engine specifications

3.3ASSUMPTIONS:

- Specific heat of water and specific gravity of the fuel are assumed constant.
- The solution leaving the absorber is saturated at the evaporator pressure.
- The solution entering and leaving the generator are saturated at the evaporator pressure.
- There is no undercooling in the condenser and the vapour leaving the evaporator is assumed to be dry saturated.
- The enthalpy of superheated steam at low pressure is assumed equal to the saturated value at the same temperature.
- pump work is neglected.
- Pressuredrops and heat losses from the ducting in VARS is neglected.

3.4EXPERIMENTALPROCEDURE:

The Dual cylinder four stroke diesel engine is started by handcranking after checking the fuel in the tank, lubricating oil levels in the sump and cooling water supply. The Load is applied by an electrical dynamometer on the engine and allowed to attain a steady state. Then the following observations are noted.a) time foe 10 cc of fuel consumption b) temperatures at all salient locations c) voltmeter and ammeter readings d) flow rates of water through engine and exhaust gas calorimeter. The procedure is repeated atdifferent loads.

3.5DIESEL ENGINE PARAMETERS:

Applying energy balance to the exhaust gas calorimeter

$m_g.c_{pg}(T_4\text{-}T_5)= W_1.c_p*(T_3\text{-}T_1)$

Heat carried away by exhaust gases, $H_g=m_g.c_{pg}.(T_4\text{-}T_a)$

Mass flow rate of fuel $m_{f1}=\frac{10}{t}*\frac{3600*sp.gr}{1000}$

Heat supplied to the engine $Q=m_{f1}*c.v$

Brake power of the engine, B.P= $\frac{\sqrt{3}*vicos\theta}{1000}$

Brake thermal Efficiency, $\eta = \frac{B.P}{Q}$

3.6 VAPOUR ABSORPTION REFRIGERATION SYSTEM PARAMETERS:

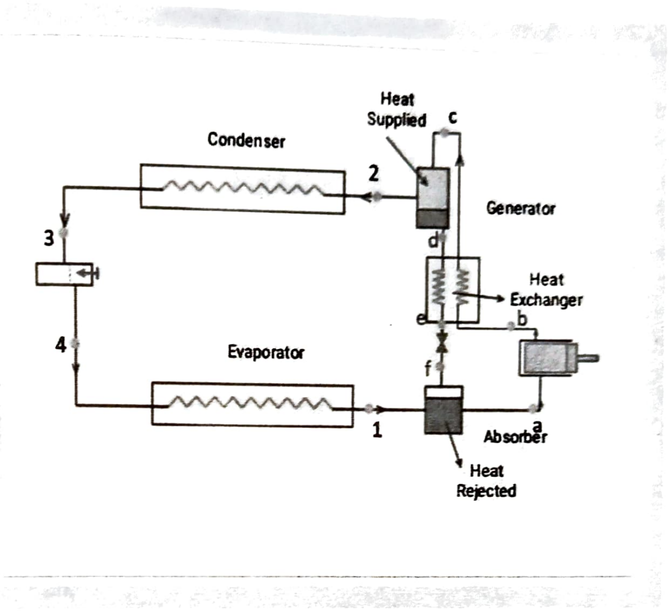

Fig 3.1 vapour absorption refrigeration system

1-represents the state of refrigerant after leaving the Evaporator.

2-represents the state of refrigerant before entering the Condenser.

3-represents the state of refrigerant before entering the Throttle valve.

4-represents the state of refrigerant after leaving the Throttle valve.

a-represents the state of refrigerant-absorbent solution after leaving the Absorber.

c-representsthe state of refrigerant-absorbent solution before entering the Generator.

d-represents the state of absorbent after leaving the Generator.

f-represents the state of absorbent before entering the Absorber.

Mass flow rate of water, $m_1 = \frac{REFRIGERATION\ CAPACITY}{REFRIGERATION\ EFFECT}$

a) ABSORBER

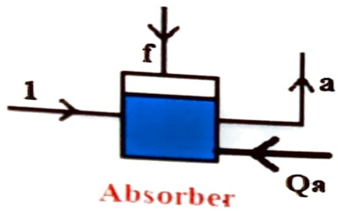

Fig 3.2 absorber

Applying total mass balance to the absorber

$$m_1 = m_a - m_f$$

$$m_a = m_1 + m_f$$

From lithium bromide mass balance

$$x_1 m_1 = x_a m_a - x_f m_f$$

b) GENERATOR

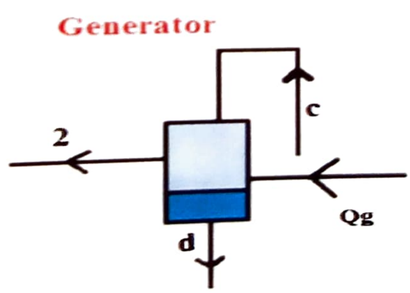

Fig 3.3 generator

Applying an energy balance to the generator

$$Q_g + m_c h_c = m_2 h_2 + m_d h_d$$

c) CONDENSER

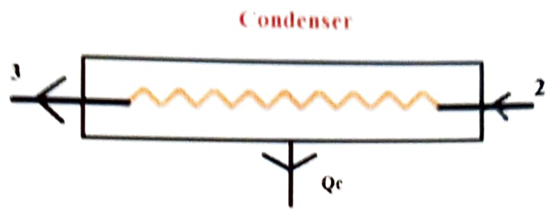

Fig 3.4 condenser

Applying an energy balance to the condenser

$$Q_c = -m_1(h_2 - h_3)$$

Applying an energy balance to the complete system,

$$Q_g + Q_e + Q_c + Q_a = 0$$

$$COP_{ref} = \frac{\text{REFRIGERATION CAPACITY}}{\text{HEAT SUPPLIED}}$$

d) EVAPORATOR

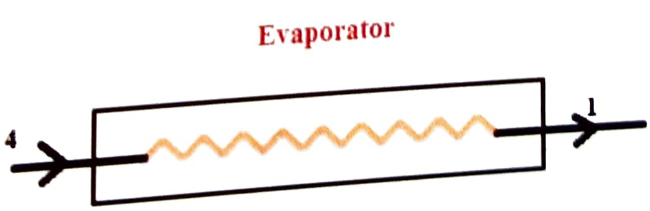

Fig 3.5 Evaporator

Refrigeration effect = $h_1 - h_4$

CHAPTER 4

RESULTS

AND DICUSSIONS

RESULTS AND DICUSSIONS

4.1 OPERATING PARAMETERS:

DIESEL ENGINE:

- The engine is loaded by using electrical dynamometer, which can apply a maximum load of 7.5 kW.
- The maximum loading capacity on the engine is 7.4 kW.
- Specific heat of the water is constant, 4.18 kJ/KgK.
- Specific gravity of the fuel remains constant, 0.87
- Calorific value of the fuel is 45,000 kJ/Kg.

VAPOUR ABSORPTION REFRIGERATION SYSTEM:

- The condenser and evaporator saturation temperatures are $34^{O}C$ and $3^{O}C$ respectively.
- The generator is maintained at $85^{o}C$ using supply of waste heat from hot gases and the absorber is at $25^{o}C$.
- The condenser and evaporator pressures are 5.38 kN/m^2 and 0.7575 kN/m^2.

4.2 OBSERVATIONS:

Table 4.1 experimental observations

S.NO	LOAD (kW)	VOLTAGE (V)				AMPFRAGF (A)				TIME FOR 10CC OF FUEL CONSU-MPTION(sec)	TEMPERATURE (°C)					W1 (cc/sec)
		RY	YB	BR	AVG	R	Y	B	AVG		T_1	T_2	T_3	T_4	T_5	
1.	NO LOAD	393	391	34.14	392.33	45	0.1	0.1	0.1	34.14	28	29	31	147	123	45
2.	1.5	402	403	27.51	402.67	45	1.3	1.0	1.25	27.51	28	30	31	183	153	45
3.	3	416	419	19	417.33	60	3.2	2.6	2.9	19	28	29	31	223	181	60
4.	4.5	417	410	16	412.3	70	4.9	3.7	4.63	16	20	30	32	279	227	70
5	6	407	409	14	408	80	7.0	5.6	6.47	14	28	31	33	327	263	80

4.3 MODEL CALCULATIONS:

a) Diesel Engine:

At a load of 4.5KW

Rate of flow of water through calorimeter, W_1=70CC/sec

=288Kg/hr

Specific heat of water at constant pressure, C_p-4.18 kJ/KgK

$m_g.c_{pg}\ (T_4-T_5) = W_1.c_p*(T_3-T_1)$

$$m_g.c_{pg} = \frac{288*4.18*(32-28)}{279-227}$$

=81.027kJ/hr.K

Heat carried away by exhaust gases, $H_g=m_g.c_{pg}.(T_4-T_a)$

=20986.17KJ/hr

=5.83kW

Mass flow rate of fuel, $m_{f1} = \frac{10}{t} * \frac{3600*sp.gr}{1000}$

$$= \frac{10}{16} * \frac{3600*0.87}{1000}$$

=1.96Kg/hr

Heat supplied, $Q=m_{f1}$*c.v

=1.96*45000

=88200kJ/hr

=24.5kW

Brake power of the engine, B.P= $\frac{\sqrt{3}*vicos\theta}{1000}$

$$=\frac{\sqrt{3}*418.5*4.63*1}{1000}$$

=3.32kW

Brake thermal Efficiency, $\eta=\frac{B.P}{Q}$=0.1355

b) <u>Vapour Absorption Refrigeration System:</u>

From concentration-enthalpy chart of Lithium Bromide-Water Solution (Appendix):

1) At T=80°C, P=5.38kN/m^2

x_d=0.6, h_d=-88kJ/Kg

2) At T=25°C, P=0.7575kN/m^2

x_a=0.51, h_a=-185kJ/Kg

Solution entering at c must have the same concentration as that leaving the Absorber.

i.e, $x_c=x_a$

3) At x_c=0.51, P=5.38kN/m^2

h_c=-104kJ/Kg

Refrigeration effect=h_1-h_4

=2506.4-142.4

=2363.8kJ/Kg

Mass flow rate of water, $m_1=\frac{REFIGERATION\ CAPACITY}{REFRIGERATION\ EFFECT}$

ABSORBER:

Applying total mass balance to the absorber

$m_l=m_a-m_f$

$m_a=m_l+m_f$

From lithium bromide mass balance

$x_l m_l=x_a m_a-x_f m_f$

$0.51m_a=0.6m_f$(since $x_l=0$)

$0.51(m_l+m_f)=0.6m_f$

$m_f=5.55m_l$

$m_a=6.53m_l$

GENERATOR:

$m_2=m_l$

$m_c=m_b=m_a=6.53m_l$

$h_2=h_g$ at 80 °C =2643.2kJ/Kg, from steam tables.

Applying an energy balance to the generator

$Q_g+m_c h_c=m_2 h_2+m_d h_d$

Heat supplied for Generator $Q_g=m_l*2833.92$

Heat supplied for Generator $Q_g=m_l*2833.92$

$5.83=m_l*2833.92$

$m_l=0.00206$Kg/s

Mass flow rate of water, $m_l=\frac{REFRIGERATION\ CAPACITY}{REFRIGERATION\ EFFECT}$

m_1=kW /2363.8

Refrigerating capacity=4.87kW

CONDENSER:

Heat rejected from Condenser $Q_c=m_1*(h_2-h_3)$

$= 0.00105*(2643.2-142.4)$

$= 5.15kW$

Applying energy balance for system

Heat rejected from Absorber Q_a=5.55kW

$$COP=\frac{\text{REFRIGERATION CAPACITY}}{\text{HEAT SUPPLIED}}$$

COP = 4.87/5.83

=0.8353

Brake power/Refrigeration capacity (B.P/R.C) = 0.682

Effectiveness of the combined system, $\varepsilon=\frac{B.P+R.C}{Q}$

=0.3342

4.4 PARAMETRIC ANALYSIS

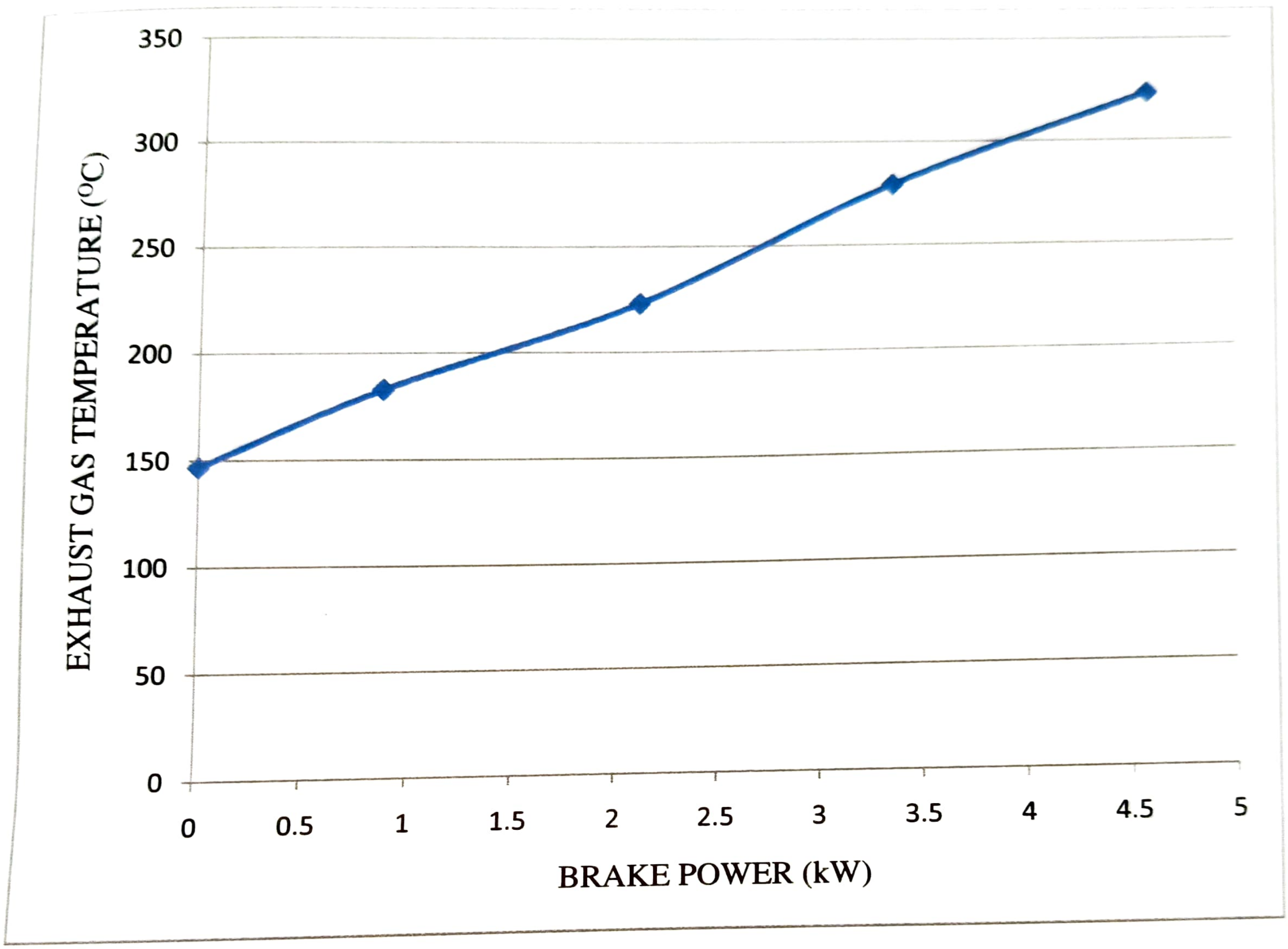

Fig 4.1 Brake PowervsExhaust Gas Temperature

From the plot of brake power and exhaust gas temperature. It is observed that as the brake power on the engine is increased there is an increase in the mass rate of the fuel into the engine cylinder. As a result of which temperature inside the cylinder increased, due to which there is an increase in the exhaust gas temperature.

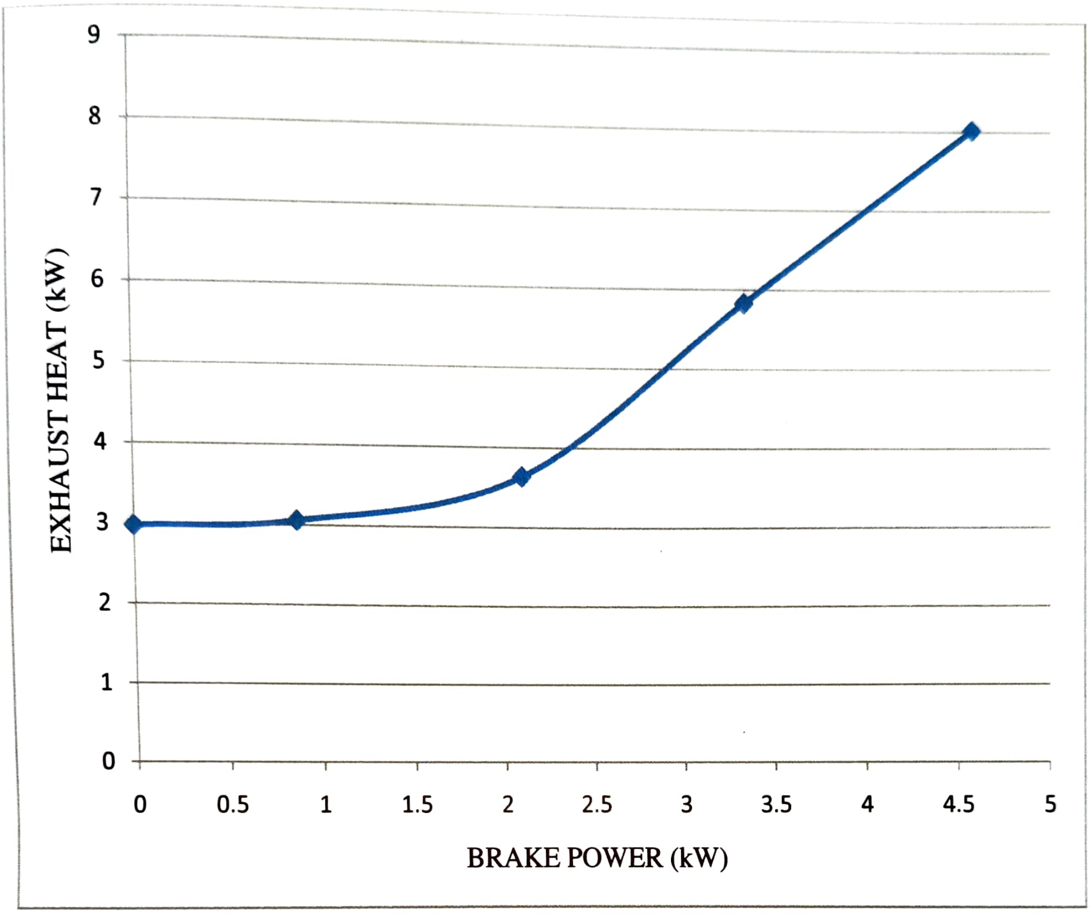

Fig 4.2 Brake PowervsExhaust Heat

From the plot of brake power andexhaust heat,It is observed that the increase in heat loss to exhaust gases is very slight for the range of brake power from 0 to 2.096 kW. However the rate of exhaust heat loss is linear and increases at a rapid rate with further increase in brake power from 2.096 to 4.57 kW.

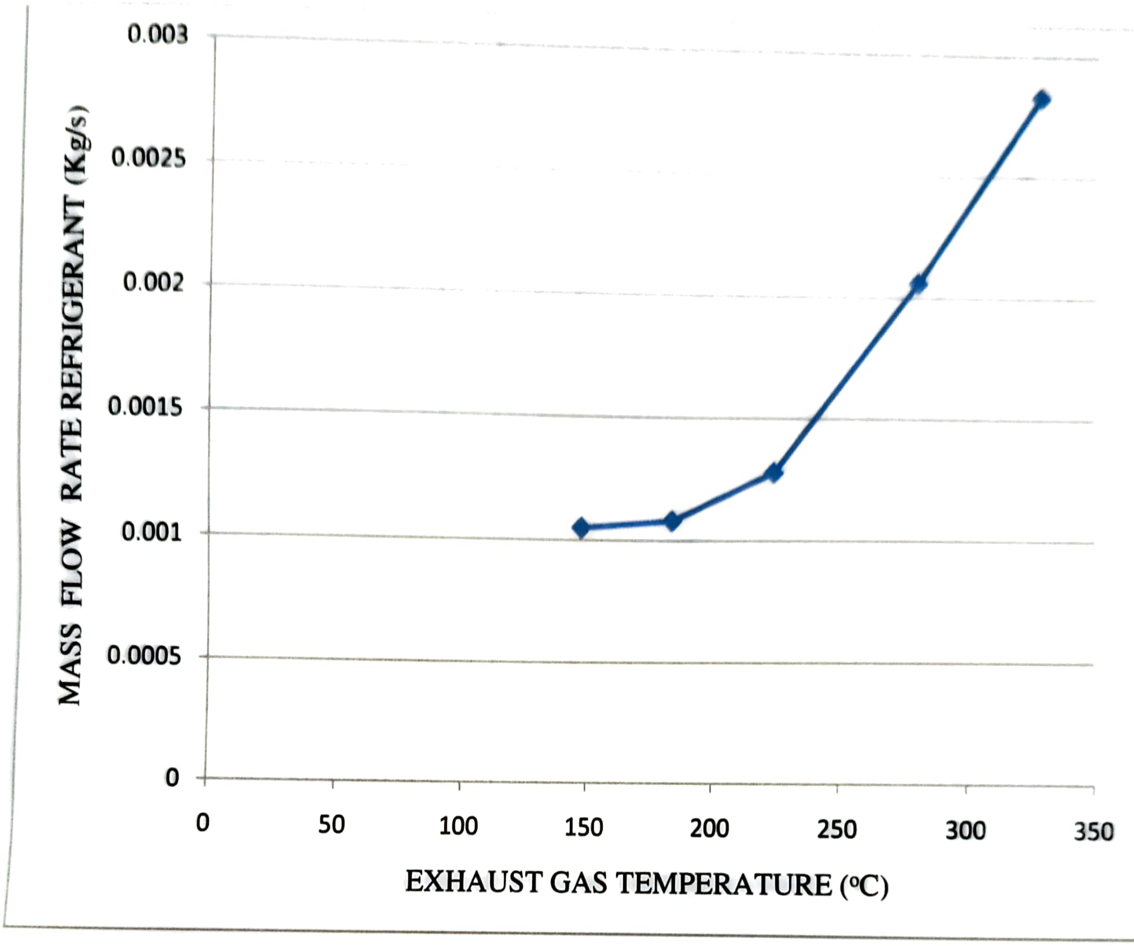

Fig 4.3Exhaust Gas Temperature vsMass Flow Rate of Refrigerant

From the plot of exhaust gas temperatureand mass flow rate, it is observed thatas the capacity parameters of the absorption refrigeration system are maintained constant, hence the refrigeration effect of the evaporator is also constant. Hence there is an increase in mass flow rate of the refrigerant with the increase in quantity of exhaust gases heat input rate in the generator.

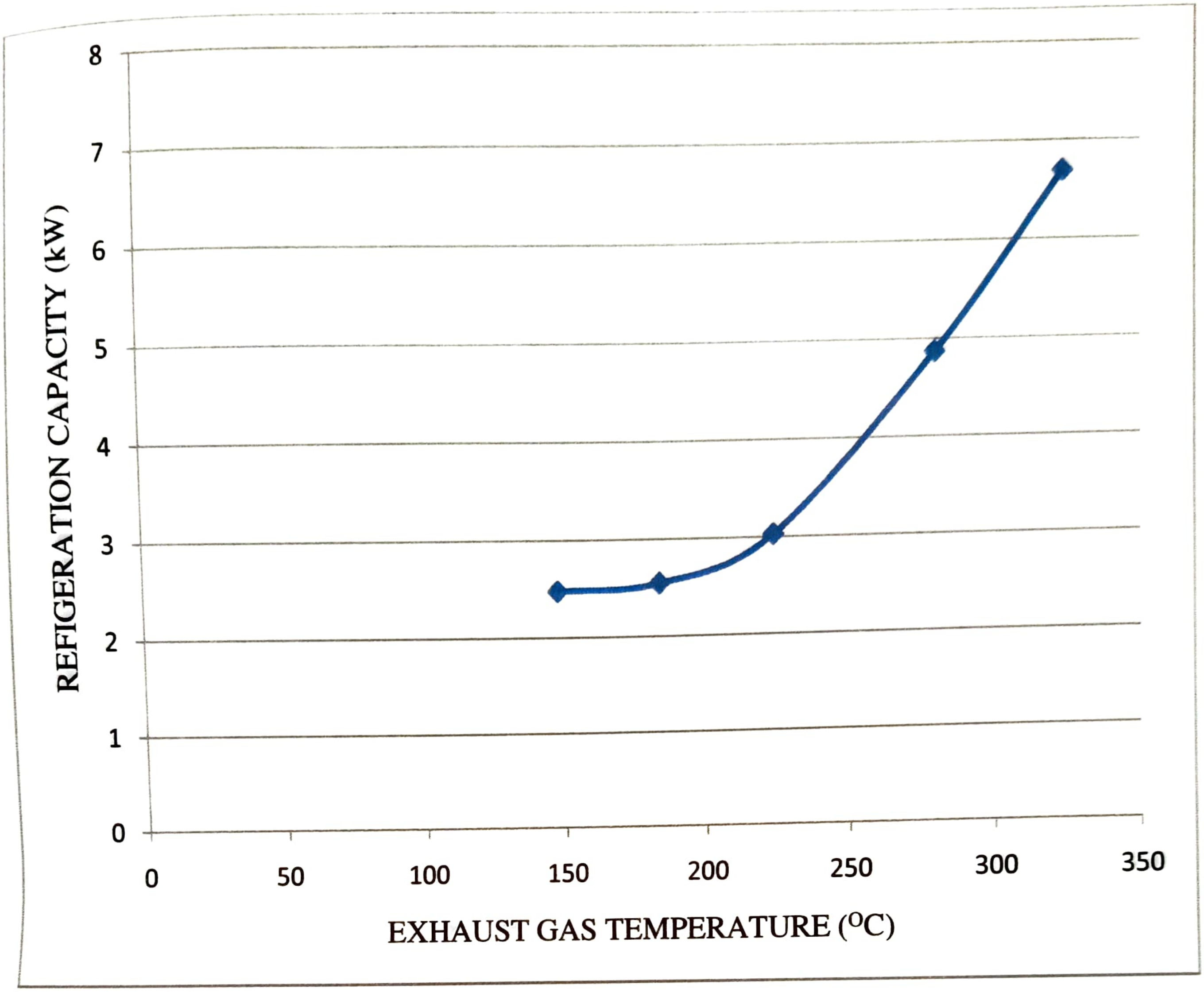

Fig 4.4Exhaust Gas Temperature vsRefrigeration Capacity

From the plot of exhaust gas temperature and refrigeration capacity.It is observed that there is an increase in refrigeration capacity with the increase in exhaust gas temperature. The rate of increase in refrigeration capacity is low as rate of increase in mass flow rate is low from 147 to 223°C. The rate of increase in refrigeration capacity is high from 223 to 327°C as the increase in mass flow rate is high.

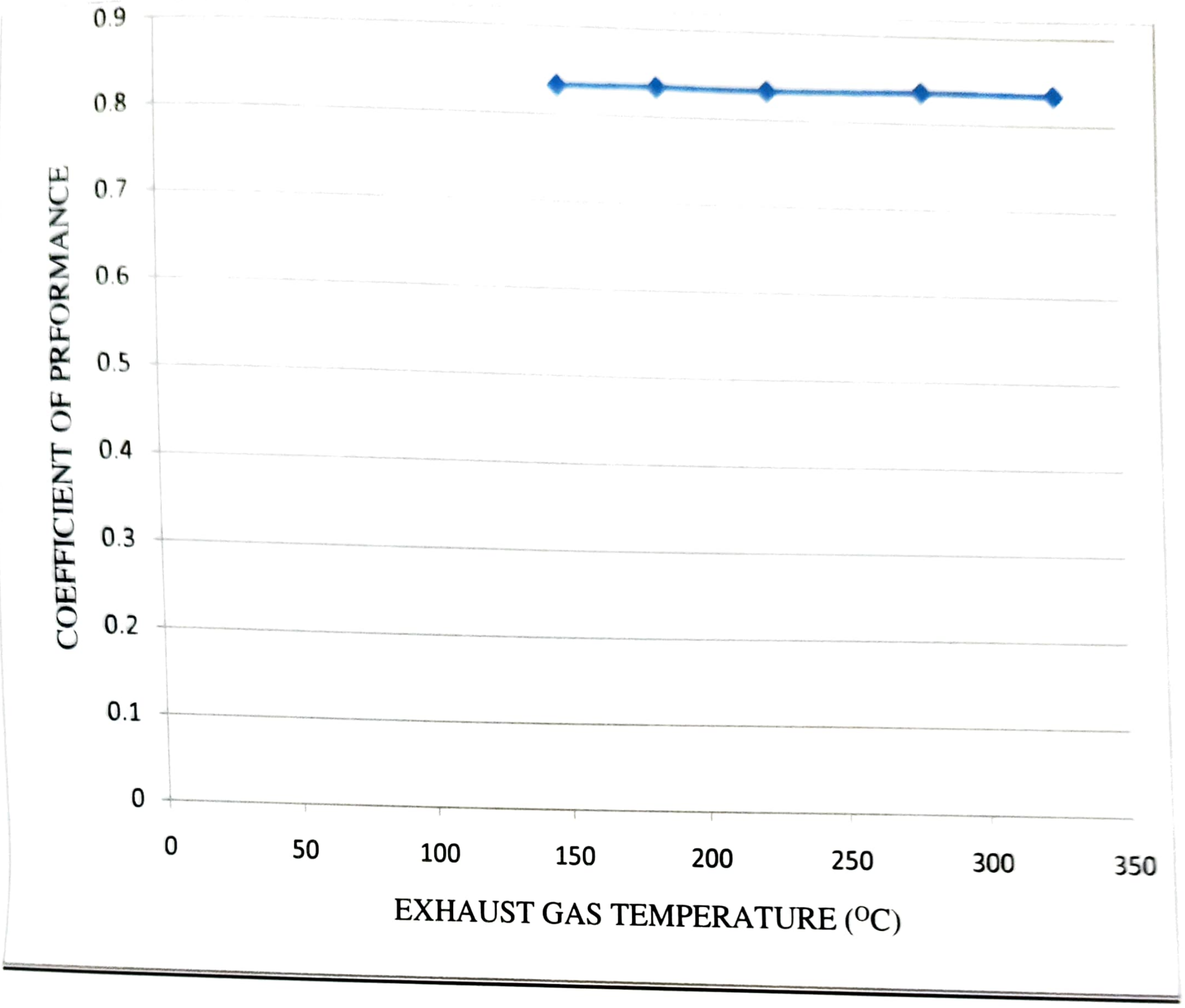

Fig 4.5Exhaust Gas Temperature vsCoefficient of Performance

From the plot of Exhaust gas temperatureand C.O.P.It is observed that the Coefficient of performance of the absorption refrigeration system is invariable with exhaust gas temperature as the above plot suggests. This is due to the fact that the refrigeration capacity varies proportionally with the heat input to the system.

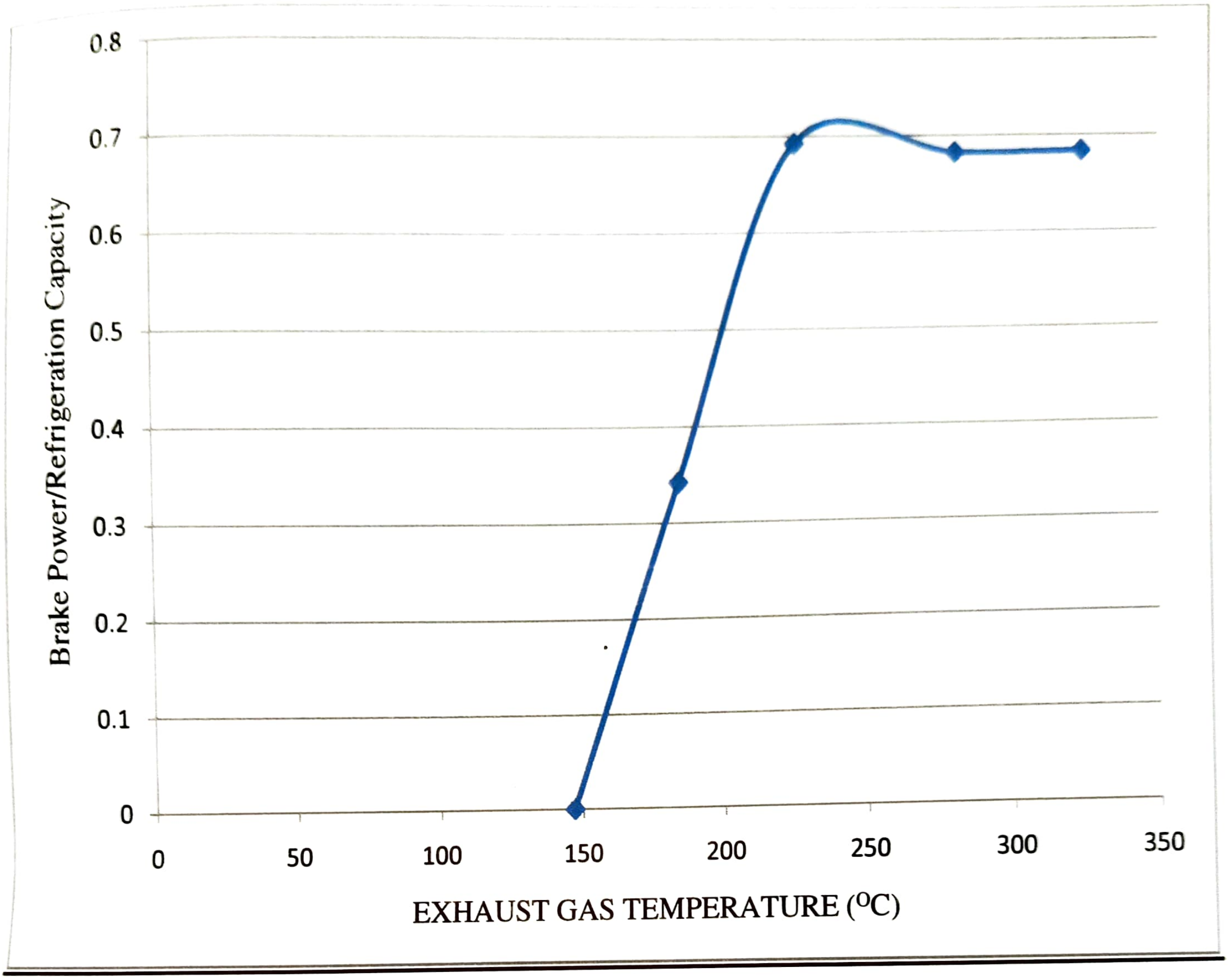

Fig 4.6 Exhaust Gas Temperature vs Brake power/refrigeration capacity

To evaluate the relative performance of diesel engine and vapour absorption refrigeration system, the ratio of brake power to refrigeration capacity is plotted with respect to exhaust gas temperature. The exhaust gas temperature is a function of the load or brake power of the engine. It is also observed that the refrigeration capacity increases with the load. A plot of the ratio of the two outputs of the combined system exhibits an interesting trend. It is observed that the refrigeration capacity is always greater than the power output. With the increase in the load the ratio increases and reaches an asymptotatic value of 0.68, which reflects that brake power and refrigeration capacity increases at the same rate.

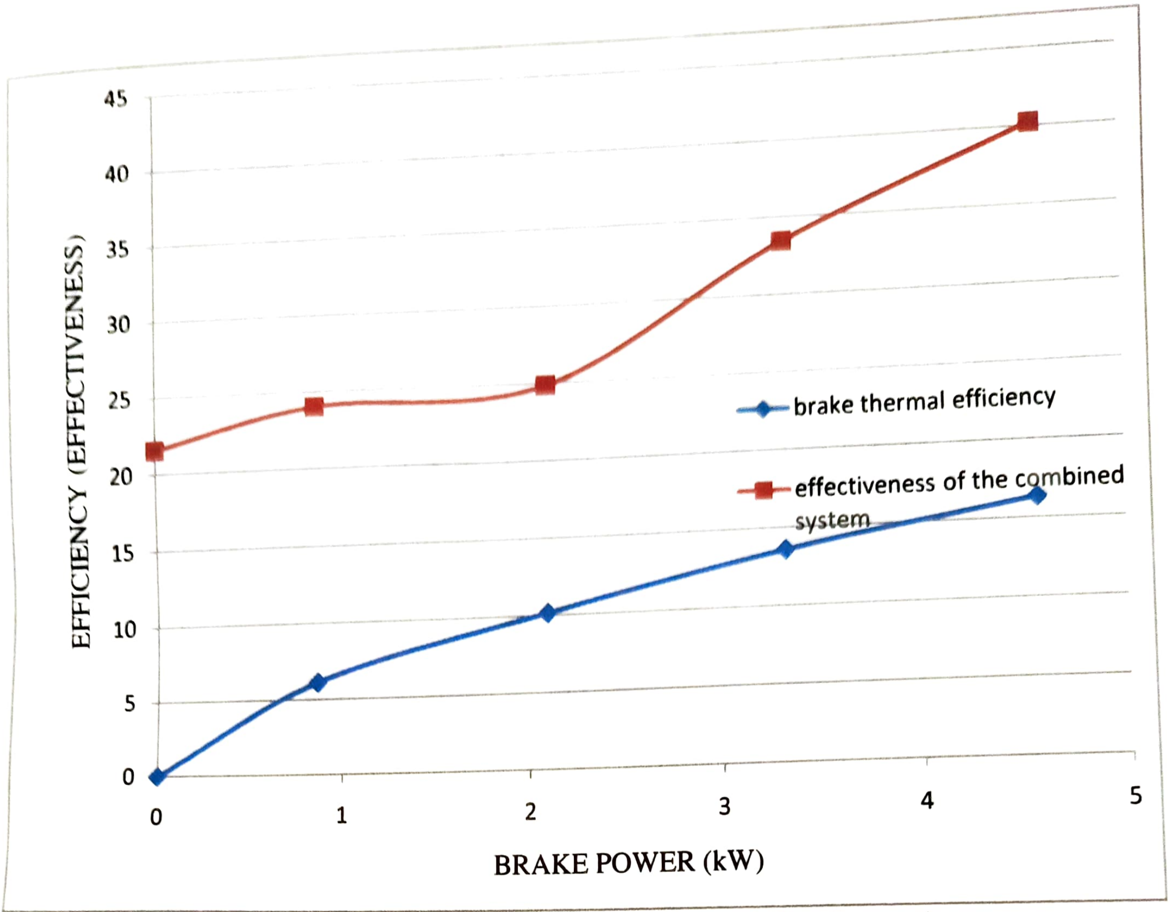

Fig 4.7 brake powervs efficiency (effectiveness)

A graph is drawn between brake power and efficiency (effectiveness).It is observed thatas the engine is more than decade old there is a significant drop in the brake thermal efficiency as compared to normal diesel engine. The efficiency of the engine varied from 0 to 16%. The effectiveness of the combined system ranged from 21 to 40%, which implies an increase in efficiency from 21 to 24% as compared to brake thermal efficiency.

CHAPTER 5

CONCLUSIONS

CONCLUSIONS

- The refrigeration capacity of the system increases with the increase in load/ brake power of the system.
- The Refrigeration capacity is dependent on the rate of heat loss from the engine.
- The increase in refrigeration capacity with exhaust gas temperature is marginal in the lower power range (0 to 2.09 kW). The refrigeration capacity increases abruptly with the increase in the output, this variation in refrigeration capacity with the power output indicates that the system (diesel engine and VARS) suggested here is a viable alternative to VCRS being currently used in automobiles.
- The ratio brake power and refrigeration capacity increases with load and reaches an asymptotatic value of 0.68
- The brake thermal efficiency of the engine is in the range from 0-16% for the load range considered. However the performance of the combined system stands at 21% at no load and increases upto 40% at the maximum load of 6 kW. The increase in effectiveness of the combined system is almost constant at 24%.
- C.O.P of the system remained constant at 0.83.
- By recovering the waste heat of the gases to run Vapour Absorption Refrigeration System, the fuel consumption can be economized.

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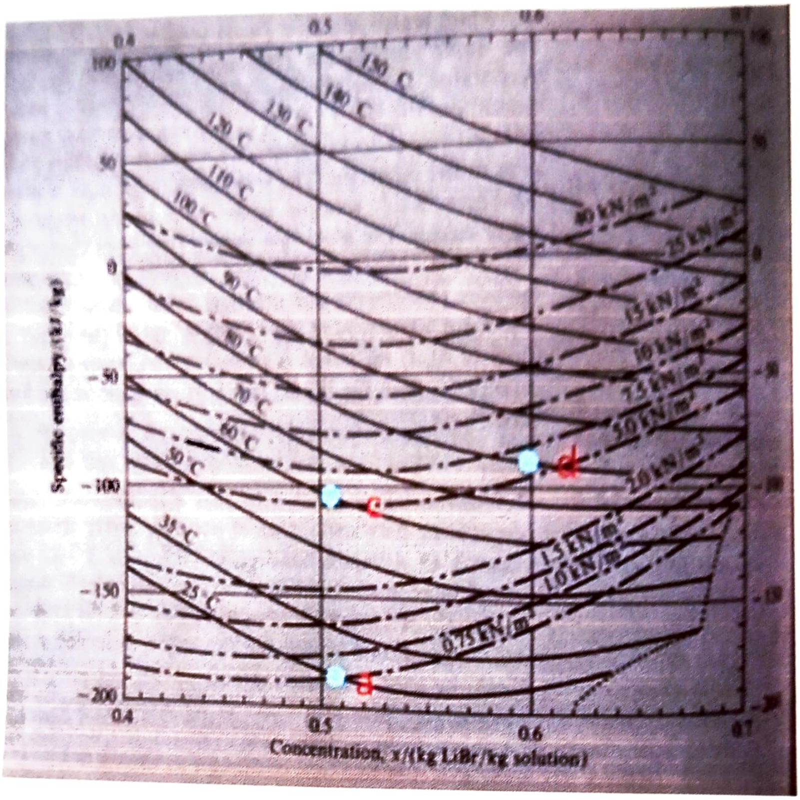
APPENDIX



a-represents the state of refrigerant-absorbent solution just after leaving the Absorber.

c-represents the state of refrigerant-absorbent solution just before entering the Generator.

d-represents the state of absorbent just after leaving the Generator.

f-represents the state of absorbent just before entering the Absorber.