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Air Cooling Inside Vehicles using Vapour Absorption Refrigeration System

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***Abstract*—Vapour Compression Refrigeration system (VCRS) is the currently used refrigerating system in road transport vehicles. The input power for the compressor of the refrigeration system is a part of the power produced by the engine, hence extra work to run the compressor of the refrigerating unit has to be generated by the engine. This loss can be neglected by replacing the conventional system by another refrigeration system ie. a Vapour Absorption Refrigeration System (VARS). It is well known that the efficiency of an IC engine is about 35-40%, and about 60-65% is wasted to environment. In which around 30-32% is lost in the form of exhaust gases, about 28-30% is lost by cooling water and lubrication losses, and remainder by radiation, etc. In a Vapour Absorption Refrigeration System, the mechanical process of the Vapour Compression Refrigeration System is replaced by a physicochemical process using heat energy rather than mechanical work. The heat required for running the Vapour Absorption Refrigeration System can be obtained from the exhaust gases which is wasted into the atmosphere from the engine.**

Keywords— Refrigeration, exhaust, generator

I. INTRODUCTION

It is well known that the efficiency of an IC engine is about 35-40%, and about 60-65% is wasted to environment. In which around 30-32% is lost in the form of exhaust gases, about 28-30% is lost by cooling water and lubrication losses, and remaining by radiation etc. In a Vapour Absorption Refrigeration System, the mechanical process of the Vapour Compression Refrigeration System is replaced by a physicochemical process using heat energy rather than mechanical work. The heat energy required for the Vapour Absorption Refrigeration System can be obtained from the exhaust gases which is wasted into the atmosphere from the engine.

Hence using a Vapour Absorption Refrigeration System will not only produce refrigeration using exhaust from the engine which is low grade energy but will also prevent the loss of power from the vehicles engine. By using a Vapour Absorption Refrigeration System the amount of fuel burned is reduced thereby reducing pollution.

II. VAPOUR ABSORPTION REFRIGERATION SYSTEM

The vapour absorption refrigeration method is one of the oldest methods of refrigeration. The principle of vapour absorption was discovered in 1824 by Michael Faraday while performing a set of experiments to liquefy certain gases. In 1860 a French scientist Ferdinand Carre developed the first vapour absorption refrigeration machine. The, commonly used refrigerant is ammonia.

To change the conditions of the refrigerant required for the operation of the refrigeration cycle, the vapour absorption system uses heat energy, instead of mechanical energy as in vapour compression systems. The purpose of compressor, in this system, is to withdraw the refrigerant from the evaporator which will be vapour form. Then the compressor increases its temperature and pressure to a value higher than the cooling agent inside the condenser so that the high pressure vapour can reject heat in the condenser. The liquid refrigerant leaving the condenser is now ready to expand to the evaporator again. VARS consists of a condenser, an expansion valve and an evaporator similar to a VCRS, but the compressor is replaced by a generator, a small pump and an absorber. A vapour absorption refrigeration system utilizes two or more fluids one is the refrigerant and the other is the absorbent which has high affinity towards each other.

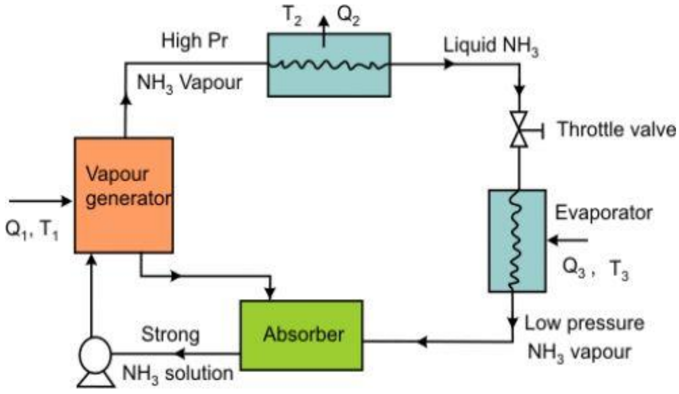

Figure II.i: VARS Schematic Diagram

The process of working of this refrigeration system is that a mixture of refrigerant and an absorber (ie. strong solution) is pumped from the absorber using a small pump to the generator. The generator is the vital part of the whole refrigeration system where heat is supplied to the strong solution. Due to the supplied heat, from the mixture in the generator the refrigerant is separated from the strong solution and forms vapour. The remaining solution which will be weak flows back to the absorber through a restrictor. The refrigerant is then allowed to pass through a condenser where the heat of the vapour is extracted and the refrigerant temperature is brought to the room temperature. The refrigerant at room temperature will then pass through an expansion valve where the temperature is reduced to a value below the atmospheric temperature. This cold refrigerant is then passed through an evaporator from where it absorbs heat and produces the required refrigerating effect. The hot refrigerant coming from the evaporator is then passed to the absorber. The weak solution coming from the generator and the refrigerant coming from the evaporator gets mixed in the absorber due to high affinity towards each other, hence forming a strong solution. The resulting strong solution is again pumped to the generator and the cycle repeats.

III. EXPERIMENTAL SETUP

A. *Working Diagram*

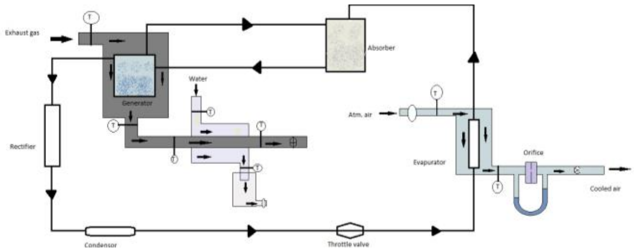

Figure III.i: Working Diagram

B. *Materials/Experiments Used*

- Vapour absorption system – Which was removed from a Vapour absorption refrigerator
- GI Pipe 3 inch diameter, 45 cm long - 1Nos.
- GI Pipe 1.5 inch diameter, 90 cm long – 2 Nos.
- M.S. Plate (2.5x4 inch) used for making flange.
- Aluminium Channel
- Steel sheet for making orifice.
- PVC Pipes and joints for making Heat exchanger
- DC Blower
- DC Power supply
- Thermocouples. -7 Nos
- Temp. display unit
- Selecting knob
- U-Tube manometer
- Aluminium Foil
- Asbestos Rope
- Shellac
- M-seal.
- Pipe clamps 3 inch dia.
- Nuts & Bolts
- Workshop machines & Equipment.

C. *Specification of IC Engine Used*

The IC engine based on which the calculations are done is
Brake power = 6 HP
Speed = 650 rpm
No: of Cylinders = 1
Bore = 114.3 mm
Stroke = 139.7 mm
Orifice Diameter = 17 mm
Diameter of rope = 13 mm
Diameter of drum = 45.7 mm

Figure III.ii: IC Engine Used

IV. FABRICATION

- First of all the VARS system was taken from a absorption Refrigerator and Heating coil was dismantled from it.
- A 3 inch pipe is cut into 2 equal section. 2 holes are drilled on the 3 inch pipe sections to accommodate 1.5 inch pipes on it. Then the pipes are welded keeping them correctly aligned and is checked for holes & leakages.
- MS plate is used to make a flange which connects the Heat exchanger with exhaust manifold of engine. First the plate is drilled with 1.5 inch hole and holes for bolt are drilled.
- Flat is welded into inlet pipe of heat exchanger.
- Aluminium foil is attached to evaporator tube of the system and Aluminium channel is attached to it.
- A DC blower is attached to one end of channel, in such a way that blower blows air into channel where it makes contact with foil connected & maintained at same temperature of evaporator. Other end of channel is connected to the space required to be cooled.
- A mild steel Frame is fabricated to hold the entire setup.
- A PVC Heat exchanger is made to make heat exchange between water and Exhaust gas.

- The thermocouples are placed at required positions.
- An orifice of 30 x30 mm size is made to accommodate in Aluminium channel.
- U tube manometer is partially filled with water and connected at 2 sides of orifice by means of hose collar and rubber tube.
- Required electrical connections are made for displaying temperature.
- Now the heat exchanger is connected to generator side of system by means of pipe clamps
- For prevention of leakages, M seal is used in entire system.
- Similarly for preventing temperature losses we used asbestos rope and shellac.
- The exhaust manifold from engine is connected to inlet side of heat exchanger.
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Figure IV.i: VARS Connected to Engine

V. WORKING OF THE SYSTEM

When engine is running, the exhaust air is at about 50-400ºC (which changes according to speed and load of engine). This hot air is fed into the heat exchanger where heat is transferred from air to working fluid of vapour absorption system. With this input heat energy the system maintains the evaporator tube at low temperature. When blower is connected with power supply, it takes air from atmosphere and blows it to the channel where it comes in contact with Aluminium sheet. Aluminium sheet extracts heat from air and cooled air is blows to the cabin.

Thus the heat from engine exhaust, which is lost to atmosphere is utilized to produce cold air which can be used for air conditioning. The temperature up to which the refrigerator space can be cooled or maintained depends on the temperature of exhaust air, COP of heat exchanger system and leakage in system ducts.

A. Experimental procedure

- Start engine at no load with required procedures.
- Switch on power supply to blower and temperature display unit.
- Turn on water supply to heat exchanger.
- Maintain constant head in collecting tank.
- Take required readings, different position temp., manometer readings, Tine for 10 cc fuel consumption
- Repeat experiment with different loads.
- Calculations are done and required graphs are plotted

B. Observations and Calculations

TABLE I. OBSERVATIONS

Weight (Kg)	0	3	5
T_1 (ºC)	98	152	180
T_2 (ºC)	91	143	170
T_3 (ºC)	80	133	159
T_4 (ºC)	28	28	29
T_5 (ºC)	30	31	31
T_6 (ºC)	33	36	41
T_7 (ºC)	30	32	34
Head in Tank, H (cm)	10	10	10
Manometric Head, h (cm)	1.2	1.3	1.2
COP	0.062	0.1066	0.1409

T_1= inlet temperature of exhaust gas in the heat exchanger in ^{0}c

T_2= outlet temperature of exhaust gas from the heat exchanger in ^{0}c

T_3= temperature of the exhaust gas leaving to atmosphere in ^{0}c

T_4= water inlet temperature to the heat exchanger in ^{0}c

T_5= water outlet temperature from the heat exchanger in ^{0}c

T_6= inlet temperature of air in to the system in ^{0}c

T_7=outlet temperature of air from system in ^{0}c

C. Formulation

Heat Extracted

$Q_E = m_a \times c_p \times \Delta t$

m_a = mass flow rate of air in kg/m^3

c_p = specific heat of air = 1.005 kJ/kg K

$\Delta t = T_{ai} - T_{ao}$

Where,

T_{ai} = inlet temperature of air in K

T_{ao} = outlet temperature of air in K

Heat Input

From heat exchanger:

Heat absorbed by water = heat loss to the exhaust gas

$m_w*c_{pw}*\Delta t_w = m_e*c_{pg}*\Delta t_g$

Where,

m_w = mass flow rate of water in kg/m^3

c_{pw}= specific heat of water in kJ/kgK

$\Delta t_w = T_{wo} - T_{wi}$

T_{wi} = inlet temperature of water in K

T_{wo} = outlet temperature of water in K

m_e = mass flow rate of exhaust gas in kg/m^3

$\Delta t_g = T_{gi} - T_{go}$

T_{gi} = inlet temperature of exhaust gas in heat exchanger in K

T_{go}= outlet temperature of exhaust gas in heat exchanger in K

Heat input to the system, $Q_s = m_e*c_{pg}*\Delta t_e$

$\Delta t_e = T_{ei} - T_{eo}$

T_{ei} = inlet temperature of exhaust gas to system in K
T_{eo}= outlet temperature of exhaust gas from system in K

Work done
Blower work:
$W_b = V*I$
Where,
V = Voltage in V
I= Current in A

Coefficient of Performance
COP = heat extracted / (heat input + work done)

VI. RESULT

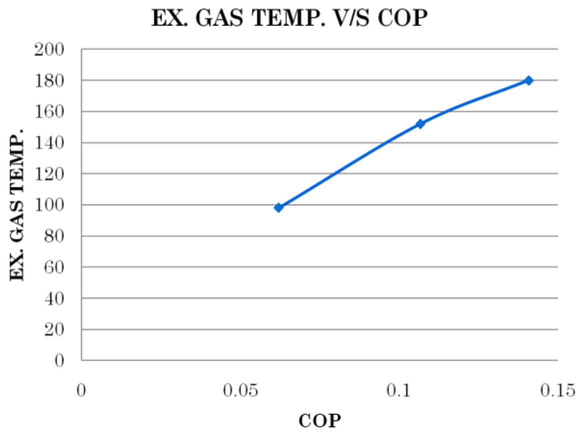

Figure VI.i: Exhaust Gas temperature vs COP

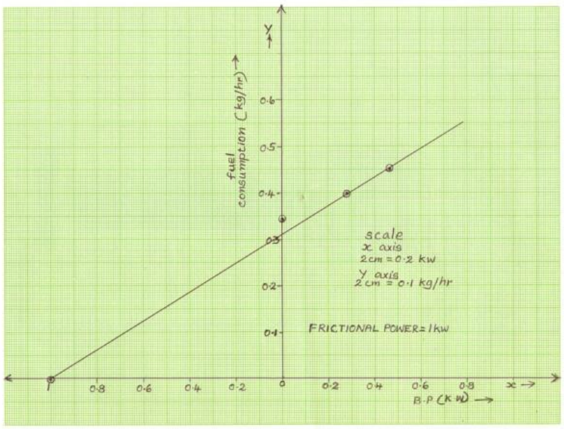

Figure VI.ii: Fuel Consumption vs Brake Power

VII. CONCLUSION

With all the components it is possible to install a vapour absorption refrigeration system utilizing the wasted heat energy of the vehicle's engine exhaust gases to produce refrigerating effect inside the automobile's cabin. Using a vapour absorption refrigeration system within an automobile as an air conditioner will not only reduce the fuel consumption of the vehicle but will also provide many other advantages like the efficiency of the engine is not decreased considerably.

In the present world, fuel crisis is high. So the mileage of vehicles has an important role. Sure, this project was a tool to improve our creativity in the field of refrigeration systems. And in the social point of view, it is a new idea to implement in the present vehicles & results in better fuel efficiency. Hope, the physical effort behind this will extend our knowledge in practicability.

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