International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

REFRIGERATION EFFECT FROM WASTE HEAT FROM IC ENGINE ABSORPTION REFRIGERATION SYSTEM

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Abstract

With the rapid changing in environmental changes and the atmospheric depravation, including the factors such as excessive energy loss and cost factors, the emission from the exhaust of a vehicle is emphasized on heavily. Out of all the available sources, the internal combustion engines are the major consumers of fossil fuel around the globe. Carbon dioxide coming out of every car's tailpipe is a greenhouse gas [1]. Recently, the total heat energy supplied to the engine in the form of combustible fuel, approximately, 35% to 40% is converted into productive mechanical work; the remaining energy in the form of heat is expelled by the exhaust gases and engine cooling systems, resulting in the rise of entropy and serious environmental pollution, thus there is a demand to utilize this waste heat from the vehicle into useful work output. The refrigerating units which are being currently employed in the vehicle are of Vapor Compression Refrigeration system (VCRS). The main drawback of this system is that it uses power directly from the engine shaft to power and run the drive of the compressor of the refrigeration system; hence the engine has to produce extra power to run the compressor of the unit, thus utilizing fuel. The energy loss from the vehicle can be utilized to operate the Vapour Absorption Refrigeration System (VARS), hence reducing the excessive work done by the engine. Keeping this in mind, this paper explores the possibilities of utilizing the VAC in moving vehicles.

KEYWORDS: I.C Engine, Refrigeration, VARS, VCRS, Waste Heat.

I. INTRODUCTION

Refrigeration is the process of removing heat from an enclosed or controlled space or from a substance and moving it to a place where it is unobjectionable. The primary purpose of refrigeration is lowering the temperature of the enclosed space or substance and then maintaining that lower temperature as compared to the surroundings. The basic objective of developing a Vapour absorption refrigerant system for cars is to cool the space inside the car by utilizing waste heat and exhaust gases from engine. The air conditioning system of cars in today's world uses "Vapour Compression Refrigerant System" (VCRS) which absorbs and removes heat from the interior of the car which is the space to be cooled and further rejects the heat to be elsewhere. Now to increase an efficiency of car beyond a certain limit vapour compression refrigerant system resists it as it cannot make use of the exhaust gases from the engine. In vapour compression refrigerant system, the system utilizes power from engine shaft as the input power to drive the compressor of the refrigerant system. Hence the engine has to produce extra work to run the compressor of the refrigeration system thus utilizing extra amount of fuel. This loss of power of the vehicle for refrigeration can be neglected by implementing this type of refrigeration system.

The basic objective of developing a vapor absorption refrigerant system for automobiles is to lower the temperature of a small space inside the vehicle by utilizing waste heat and exhaust gases from engine. It is a well known factor that an IC engine has an efficiency of about 35%-40%, which means that only one-third of the energy produced by the combustion of the fuel is converted into useful work done i.e. into mechanical output and about 60-65% of the energy in the form of heat is lost to environment. In which about 28%-30% is lost by coolant and lubrication losses, around 30%-32% is lost thorough exhaust gases from the exhaust pipes and remainder of the energy is lost by radiation and convection. In a Vapor Absorption Refrigerant System, the heat required for running the system can be obtained from that which is wasted into the atmosphere from IC engine. Hence to utilize the exhaust gases and waste heat from an engine the vapor absorption refrigerant system can be put into practice which increases the overall efficiency of Automobiles.

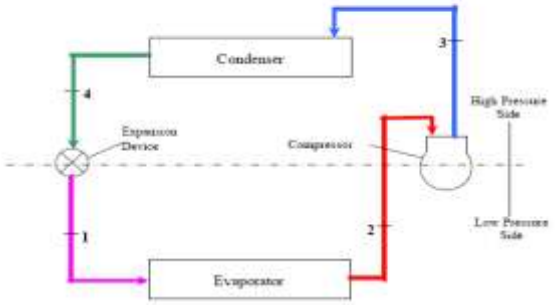
II. BACKGROUND INFORMATION

SCOPE OF THE WORK:

The engine waste heat can be recovered by using radiator water as source /generator for VARS. The arrangement of various components of air conditioning system is also a challenge because of the fixed size of vehicles. In the proposed model condenser and evaporator will be arranged same as the conventional unit.

COMPARISON OF DIFFERENT REFRIGERATION SYSTEMS

Vapor Compression System Vapor-compression refrigeration cycle is the popular refrigeration cycle in today's life. This is due to the factors like relatively efficient, inexpensive and compact. A system is composed of four major components namely: a compressor, condenser, thermal expansion valve and an evaporator. A liquid refrigerant circulates through the system, absorbing and releasing heat producing a cooling effect in a confined space. The refrigerant enters the compressor as a saturated vapor at point (1) in figure 1. As the refrigerant is compressed it increases in temperature and leaves the compressor as a superheated vapor. The superheated vapor enters the condenser, at point (2), which is generally a coiled or finned tube cooled by air or water. At this point the refrigerant releases heat to the surroundings through convection and changes phase from a superheated vapor to a saturated liquid as the refrigerant cools to below its saturation temperature. The liquid is then funneled through the expansion valve, as indicated by point (3), where the sudden drop in pressure causes flash evaporation of the saturated liquid to a saturated vapor resulting in a temperature drop of the refrigerant which occurs because the drop in pressure across the expansion valve simultaneously lowers the refrigerant's saturation temperature. This change in temperature corresponds to the enthalpy of vaporization of the given refrigerant. The refrigerant only partially evaporates because the cooling produced from initial evaporation lowers the refrigerant temperature back to below its saturation temperature. The cold liquid-vapor mixture continues on to the evaporator, point (4), where it absorbs heat and fully vaporizes. This is the final stage, which accounts for the cooling in the refrigeration cycle. The vapor then enters the compressor, completing the cycle. Common household cycles run at efficiencies of roughly 50% of Carnot's theoretical limit, which is about five times more efficient than the other refrigeration cycles (Jernqvist, 1993). Because a small amount of refrigerant liquid can produce a large amount of cooling, the system can be compact and still be efficient. This allows it to be both space saving and inexpensive. Despite all of the advantages, the vapor-compression refrigeration process still has few disadvantages i.e. the system uses hydro chlorofluorocarbon (HCFC) refrigerants. These refrigerants contribute to the depletion of the o-zone layer and adversely affect the environment. Most systems that don't use HCFC refrigerants use hydro fluorocarbon (HFC) refrigerants. HFCs contribute to global warming and are generally lessefficient



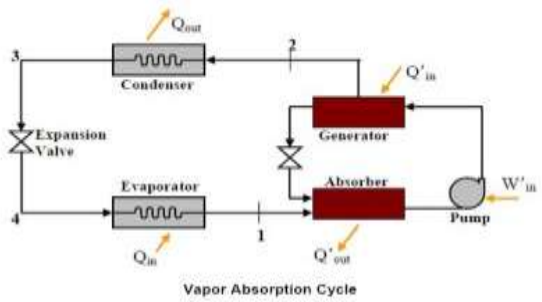


Fig 1 - Vapor Compression Cycle

Fig 2 - Vapor Absorption System

Vapor Absorption System Absorption is the process of attracting and holding moisture by substances called desiccants. Desiccants are sorbents, i.e., materials that have an ability to attract and hold other gases or liquids, which have a particular affinity for water. During absorption the desiccant undergoes a chemical change as it takes on moisture, as for example the table salt, which changes from a solid to a liquid as it absorbs moisture. The characteristic of the binding of desiccants to moisture makes the desiccants very useful in chemical separation processes. Ammonia-Water combination possesses most of the desirable qualities which are listed below: 1m3 of water absorbs 800m3 of ammonia (NH3).• Latent heat of ammonia at -15⁰ C = 1314 kJ/kg.• Critical temperature of NH3 = 132.6⁰ C.• Boiling point at atmospheric pressure = -33.3⁰ C• The NH3-H2O system requires generator temperatures in the range of 125°C to 170°C with air-cooled absorber and condenser and 80°C to 120°C when water-cooling is used. Ammonia is highly soluble in water and this ensures low solution circulation rates. Both constituents are obtainable at minimal cost. The choice of Ammonia-water combination is not made without considering certain disadvantages: ammonia attacks copper and normally water boils at 100°C. However, for every pound of pressure increase, the boiling point increases by 3°F. The temperature of the coolant can sometimes reach 250 to 275° F (121 to 135° C). Even with ethylene glycol added, these temperatures would boil the coolant, so something additional must be done to raise its boiling point. Typical radiator cap pressure is 12 to 16 psi. This raises the boiling point of the engine coolant to about 250°F to 260°F. Many surfaces inside the water jackets can be above 212°F.

SL NO	VAPOUR ABSORPTION SYSTEM	VAPOURCOMPRESSOR 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 pressure also without affecting the COP.	The COP decreases considerably with decrease in evaporator pressure.

Table 1 – Comparison of VARS and VCRS

III. MAIN RESULT

WORKING PRINCIPLE

The unit consists of four main parts - the boiler, condenser, evaporator and the absorber. The unit can be run on waste exhaust gas heat. When the unit operates on the exhaust gas, the heat is supplied by the exhaust gas which is fitted underneath the central tube and when the unit operates on electricity the heat is supplied by a heating element inserted in the pocket. The unit charge consists of a quantity of ammonia, water and hydrogen at a sufficient pressure to condense ammonia at the room temperature for which the unit is designed.When heat is supplied to the boiler system, bubbles of ammonia gas are produced which rise and carry with them quantities of weak ammonia solution through the siphon pump. This weak solution passes into the tube, whilst the ammonia vapour passes into the vapour pipe and on to the water separator. Here the water vapor is condensed and runs back into the boiler system leaving the dry ammonia vapour to pass to the condenser.Air circulating over the fins of the condenser removes the heat from the ammonia vapour to cause it to condense into liquid ammonia which flows into the evaporator. The evaporator is supplied with hydrogen. The hydrogen passes across the surface of the ammonia and lowers the ammonia vapour pressure sufficiently to allow the liquid ammonia to evaporate.
The mixture of the ammonia and the hydrogen vapour passes from the evaporator to the absorber. Entering the upper portion of the absorber is a continuous trickle of weak ammonia solution fed by gravity from the tube. This weak solution, flowing down through the absorber comes into contact with the mixed ammonia and hydrogen gases which readily absorbs the ammonia from the mixture, leaving the hydrogen free to rise through the absorber coil and to return to the evaporator. The hydrogen thus circulates continuously between the absorber and the evaporator. The strong ammonia solution produced in the absorber which flows down to the absorber vessel

and then to the boiler system, thus completing the full cycle of operation. The liquid circulation of the unit is purely gravitational. Heat is generated in the absorber by the process of absorption.This heat must be dissipated into the surrounding air. Heat must also be dissipated fromthe condenser in order to cool the ammonia vapour sufficiently for it to liquefy. Free air circulation is therefore necessary over the absorber and the condenser. The whole unit operates by the heat applied to the boiler system and it is of paramount importance that this heat is kept within the necessary limits and is properly applied.A liquid seal is required at the end of the condenser to prevent the entry of hydrogen gas into the condenser. Commercial Platen-Munters systems are made of all steel with welded joints. Additives are added to minimize corrosion and rust formation and also to improve absorption.

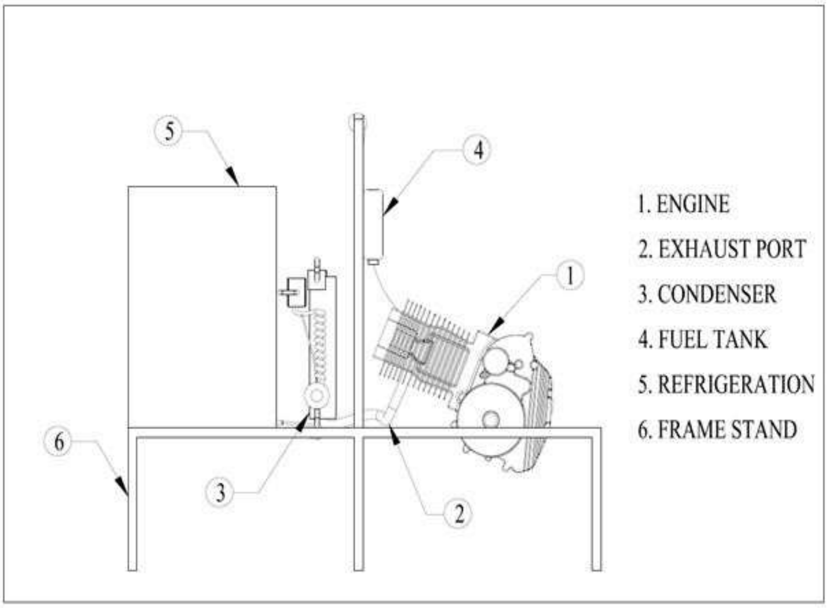


Fig 3 2D MODEL

POTENTIAL OF HEAT RECOVERY FROM THE ENGINE OF THE VEHICLE

Waste heat, which is generated by fuel combustion in the engine, and is then dissipated into the environment even though it could still be reused for some useful and economic purpose. This heat depends on the temperature of the waste heat gases and mass flow rate of exhaust gas. Waste heat losses arise both from equipment inefficiencies and from thermodynamic limitations on equipment. Considering the internal combustion engine approximately 35% to 40% of heat energy is converted into useful mechanical work. The remaining heat from the engine is expelled into the atmosphere by exhaust gases and engine cooling systems [6]. It means approximately 60%-65 % energy losses as a waste heat through exhaust. Exhaust gases immediately leaving the engine can have temperatures as high as 842- 1112°F [450-600°C]. Thus the high content of heat from the exhaust can easily be redirected and reused to provide useful work.

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SL NO	Engine Type	Power Output (kW)	Waste Heat
1	Small air cooled diesel engine	35	30-40 % of energy
2	Water air cooled engine	35-150	30-40 % of energy
3	Trucks and road engines	220	30-40 % of energy
4	Marine applications	150-220	30-40 % of energy

Table 2 – Waste Heat according to the Engine Type

POSSIBLE WAY OF USING HEAT RECOVERY SYSTEM

The modern day vehicles run generally on IC engines, i.e. Internal Combustion engines. The majority of vehicles are still powered by either spark ignition (SI) or compression ignition (CI) engines. Small air-cooled diesel engines up to 35 kW output are used for irrigation purpose, small agricultural tractors and construction machines whereas large farms employ tractors of up to 150 kW output. Water or air-cooled engines are used for a range of 35-150 kW and unless strictly air cooled engine is required, water-cooled engines are preferred for higher power ranges. Earth moving machinery uses engines with an output of up to 520 kW or even higher, up to 740 kW. Trucks and road engines usually use high speed diesel engines with 220 kW output or more.

REFRIGERANT USED FOR THE ABSORPTION REFRIGERATION SYSTEMS

The properties of the refrigerant combination are that, in liquid phase, they must have a margin of miscibility within the operating temperature range of the cycle. The mixture should also be chemically stable, non-toxic, and no explosive. In addition to these requirements, the following are desirable [8-9]: a. Refrigerant should have high heat of vaporization and high concentration within the absorbent in order to maintain low circulation rate between the generator and the absorber per unit of the cooling capacity. b. Transport properties that influence heat and mass transfer, e.g., viscosity, thermal conductivity, and diffusion coefficient should be favorable. c. Both refrigerant and absorbent should be non-corrosive, environmental friendly, and economical. There are some 40 refrigerant compounds and 200 absorbent compounds available. However, the most common working fluids are water/ammonia and LiBr/water. Since the invention of absorption refrigeration systems, water/ammonia has been widely used for both cooling and heating purposes. The main properties are: a. Ammonia (refrigerant) and water (absorbent) are highly stable for a wide range of operating temperature and pressure. b. Ammonia has a high latent heat of vaporization, which is necessary for efficient performance of the system. Its latent heat of vaporization at -15℃ is 1315kJ/Kg. c. Its boiling point at atmospheric pressure is -33.3 ℃ & freezing point is -77 ℃. d. It has highest refrigerating effect per Kg of refrigerant. The leakage of this refrigerant may be quickly & easily detected by the use of burning sulphur candle which in the presence of ammonia will form white fumes of ammonium sulphite.. It is environmental friendly.

IV. RESULTS METHODOLOGY

Absorption refrigeration systems use a heat source instead of conventional means of power to provide the energy needed to produce cooling. In this system the use of condenser is omitted and an absorber is used instead of the condenser. The key processes in an absorption refrigeration system are the absorption and desorption of the refrigerant. A simple absorption system has five main components: the generator, the condenser, the evaporator, the absorber, and the solution heat exchanger The Figure (4) shows the schematic diagram of the VARS with the flow of the refrigerant though the different components. In this system the NH3 is used as a refrigerant and the water is used as an absorbent. The ammonia and water combination is used in this system because of the following desirable qualities: 1m3 of water absorbs 800m3 of ammonia (NH3).• Latent heat of ammonia at -15o C = 1314 kJ/kg.• Critical temperature of NH3 = 132.6o C.• Boiling point at atmospheric pressure = -33.3o C• In this system the low pressure ammonia vapor refrigerant leaving the evaporator enters the absorber, where it is absorbed by the water at lower temperature in the absorber. The water has an ability to absorb a very large quantity of ammonia vapor. The absorption of ammonia vapor in water lowers the pressure in the absorber which in turn draws more ammonia vapor from the evaporator and thus raises the temperature of the solution. Cooling arrangement is employed in the absorber to remove the heat of solution emitted, this is necessary to increase the absorption capacity of water, because the temperature of water is inversely proportional to the absorbing ability of water for ammonia vapor. This results in the formation of a strong solution in the absorber. This solution is then stored in the generator. The generator is the heating unit, where the heat is supplied to the ammonia solution. The generator requires the temperatures in the range of 125°C to 170°C with air cooled absorber/condenser and 80°C to 120°C when water cooling is used in the system. In this case, the generator unit is placed near the exhaust pipe and the heat from the exhaust is utilized to raise the temperature of the mixture in the generator. During the heating process ammonia vapors are separated from the solution at high pressure and leaves behind the weak solution in the generator. The weak ammonia solution flows back to the absorber at low pressure. The high pressure ammonia vapor moves from the generator and is condensed in the condenser to high pressure forming liquid ammonia. The third fluid is used in the system to regulate the pressure. The H2 is the selected fluid due to its certain properties which flows from the absorber to the evaporator. Conditions in a VARS:- 1. At point 1, 4 and 8 there is only Saturated Liquid. 2. At point 10, there is only Saturated Vapor. 3. The weak ammonia solution is present at state 1, 2 and 3. 4. The strong ammonia solution is present at state 4, 5 and 6. 5. The Temperatures in different units: For Generator, Inlet Temperature of Water = 100°C Outlet Temperature of Water = 90°C For condenser, Inlet Temperature of Water = 20°C Outlet Temperature of Water = 24°C For Absorber, Inlet Temperature of Water = 20°C Outlet Temperature of Water = 24°C For Evaporator, Inlet Temperature of Water = 20°C Outlet Temperature of Water = 12°C

V. CONCLUSION

The use of a Vapor Absorption Refrigeration System in the vehicles used on roads. Transport vehicles have the following advantages: 1. No dedicated IC engine is required for the working of the refrigerating unit. 2 No refrigerant compressor is required. 3. No extra work is required for the working of the refrigerating unit 4. Reduction in capital cost. 5. Reduction in fuel cost. 6. Reduced atmospheric pollution. 7. Reduced maintenance. 8. Reduced noise pollution. The possibility to design a refrigeration unit inside an automobile using the waste heat from the engine of the vehicle based on Vapor Absorption Refrigeration System is realistic. Also keeping in mind the Environmental safety view, this system is Eco-friendly as it involves the use of Ammonia (a natural gas) as a refrigerant and is not responsible for Green House effect and OZONE layer depletion. In this way we can conclude, that out of the total heat supplied to the engine in the form of fuel combustion, approximately, 35% to 40% is converted into useful mechanical work; the remaining heat is categorized under the waste heat and expelled out of the system, resulting in the rise of entropy, so it is required to utilize this waste heat into useful work. Possible methods to recover the waste heat from internal combustion engine through the study on the performance and emissions of the internal combustion engine are discussed upon and can be designed. Waste heat recovery system is the best way to recover waste heat and saving the Fuel.

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