

## Exhaust Gas Heat Utilization for Air Conditioning

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**Abstract** - This work presents a Vapor absorption refrigeration system using the exhaust gas heat of any prime source (like Boiler, IC engine or Chimney) as low grade energy source. In this project the system runs on the heat supply from the waste heat gases. Vapour compression refrigeration system is replaced by the Vapour absorption refrigeration system. In any type of prime heat source almost 30% of heat is wasted in the form of exhaust gas to the surrounding atmosphere. So, this waste heat is used for the system to provide as energy source to Generator in system. Temperature of this exhaust gas should be more than 100 °C and it should be provided in temperature range of 80-130 °C to Generator. Ammonia-water mixture is used as refrigerant in this system. All the remaining parts of the system i.e. condenser, expansion device and evaporator will be same as that of simple vapour compression refrigeration system. This system of ammonia-water refrigerant can provide up to -5 °C temperature but we can achieve nearly 5-6 °C temperature range because of some losses. In this project our aim is to achieve the sufficient temperature range for the human comfort. Concentration of this project is to utilize the exhaust gas heat which is wasted to the surrounding and lead to the rise in temperature of atmosphere.

**Key Words:** waste heat, exhaust heat, vapour absorption refrigeration, Vapour compression, ammonia-water refrigerant etc.

### 1. INTRODUCTION

The diversity of energy sources is one of the prime motivations for technological development. The increasing demand for energy involves the search for new sources of Energy or new processes to save more. Internal combustion engines (ICE), mostly based on fossil fuels, are one of the most mature and widespread thermal engines. One of the Challenges of these engines is to reduce their emissions of greenhouse gases and to increase their efficiency. Indeed, only one third of the energy supplied to the IC Engine is transformed into mechanical work, the rest is lost through the cooling and exhaust systems. Thus, the development of absorption machines becomes important for both air Conditioning and preservation applications. Schulden[1] analyzed that engine exhaust gas considered as potential power source for absorption refrigeration system. Installation of vapour absorption system in exhaust gas

system significantly decrease the temperature of exhaust gas, which shown that decrease in carbon monoxide emission with an increase of hydrocarbon emission. Qin F, Chen J, Lu m[2] developed an exhaust gas automobile air conditioning system which works on hydride pair. This review paper shows that COP of the system increase with minimum temperature decrease in exhaust gas. It show that the reactors have satisfied mass transfer performance, both system cooling power and COP increase with the growth of heat source temperature. Jinzhou S, Wang RZ, Lu YZ[3] presented an absorption air conditioning system used in internal engine locomotive driver cabin, which consist of an absorber and cold storage evaporator driven by engine exhaust gas waste heat. This review paper assess that system seems to be simple in structure, reliable and feasible to apply driver cabin space cooling. This systems have many fundamental advantages besides environmentally friendly refrigerants and electricity saving. Yiji Lu, Anthony Paul Roskilly, Chi Ma [4] presented a case study on a waste heat recovery and economic analysis using heat driven absorption system. This paper review that thermodynamic simulation model has been developed and built to evaluate the performance of a single effect LiBrH<sub>2</sub>O absorption chiller under various operational conditions. This absorption refrigerator can be used as alternative refrigeration system in the place, where huge amount of heat is available, and can save the operational cost of using electricity driven refrigerator.

### 1.1 VAPOUR ABSORPTION SYSTEM

The vapour absorption system uses heat energy as an input source to the generator instead of mechanical energy as in vapour compression systems, to change the conditions of the refrigerant required for the operation of the refrigeration cycle. The function of a compressor in a vapour compression system is to take the vapour refrigerant from the evaporator. It then raises its temperature and pressure higher than the cooling medium in the condenser so that the higher pressure vapours can reject heat in the condenser. The liquid refrigerant leaving the condenser is expanding in the evaporator.

This system consists of all the components similar to that of vapour compression system except the generator. In this system compressor is replaced by various component such as generator, absorber, pump, heat exchanger etc. The process of working of this refrigeration system is that a

mixture of refrigerant and an absorber that is strong solution is pumped from the absorber using a small pump to the generator. The generator is the main unit of the whole refrigeration system. The generator is where heat is supplied to the strong solution. Due to the supplied heat to the strong solution in the generator the refrigerant is separated from the strong solution and forms vapour. The remaining weak solution flows back through a heat exchanger in to the absorber. The refrigerant is then passed through a condenser where the heat of the vapour is extracted and the refrigerant temperature is cooled to the room temperature. This cooled refrigerant is then passed through an expansion device where during expansion the temperature of the refrigerant falls below the atmospheric temperature. The cold refrigerant is then passed through the evaporator, where the heat is extracted and refrigerant effect is produced. Then the weak refrigerant from generator mixes with refrigerant from the evaporator due to high affinity between two liquids, then again passed to the generator and cycle is repeated.

### 1.2 Generator

Generator is simply a type of heat exchanger in which heat is being transferred from exhaust gas to vaporize the ammonia from strong aqua-solution. During the heating process, the vapour is formed in the generator at high pressure and temperature. This vapour ammonia formed is supplied to the generator. The weak solution flows back to the absorber at low pressure after passing through the pressure reducing valve. The high pressure ammonia vapour from the generator is condensed in the condenser to the high pressure liquid ammonia. This liquid ammonia is passed to the evaporator through expansion valve

### 1.3 Absorber

In the absorber the low pressure ammonia vapour refrigerant leaving the evaporator which enter the absorber and is absorbed by the water which has the strong affinity. Water has the ability to absorb very large ammonia vapour and the solution thus formed, is known as aqua-ammonia solution. Because of absorption capacity of water which lowers the pressure in the absorber and hence more ammonia refrigerant comes inside the absorber. In the absorber, rich solution of aqua-ammonia is formed and which being supplied to the generator through heat exchanger which raises the temperature of the refrigerant.

### 1.4 Condenser

The fin type condenser consist of coils of pipe in which high pressure and temperature vapour refrigerant is being cooled and condensed into liquid form. The refrigerant while passing through the condenser rejects its latent heat to the surrounding medium such as air or water. In the condenser the super heated vapour is formed into saturation temperature of refrigerant. The

liquid refrigerant is passed to expansion valve to decrease the temperature of the refrigerant.

### 1.5 Expansion valve

It is also called as throttle valve. The high pressure and temperature of liquid refrigerant is being transformed from the expansion valve. Which allow the refrigerant to pass through the small coil which reduces the pressure and temperature of the refrigerant.

### 1.6 Evaporator

Evaporator is simple a cooling chamber which consists of a coil of pipe in which the liquid vapour at low pressure and temperature is evaporated and change into vapour refrigerant at low pressure and temperature in the evaporator. In this liquid vapour refrigerant absorbs its latent heat of from the medium such as air, liquid brine etc.

### 1.7 Pump

Pump converts the mechanical energy from motor to the energy of a moving fluid. Some energy goes into the kinetic energy of fluid motion and some goes into fluid motion. Aqua-ammonia solution pumped at high pressure to the generator.

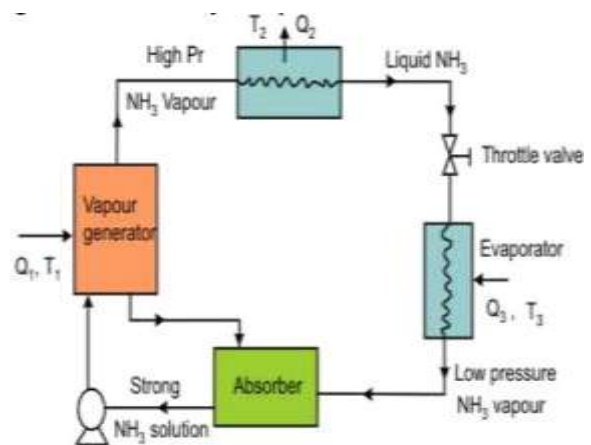


Fig: Vapour absorption system

## 2. EXPERIMENTAL SETUP

### 2.1 Electrolux system

The main purpose of this system is to eliminate the pump in order to make the machine noiseless in the absence of moving parts. This system is often called Munters Platen system. Ammonia is used as a refrigerant. The ammonia vapor in the condenser is condensed to liquid and flows to evaporator by gravity. The whole plant is charged to a pressure of about 15 bars. The liquid ammonia meets hydrogen at about 12

bars in the evaporator. Thus the partial pressure of ammonia falls to about 3 bar, keeping the same total pressure, and the temperature falls to about - 10°C. Ammonia vaporizes at this temperature hence producing refrigeration. Water is used as a solvent for ammonia. It absorbs ammonia readily. If liquid ammonia is introduced at the top of the system it passes on to the evaporator and vaporizes. Hydrogen flows upwards in the evaporator counter - flows to liquid ammonia that falls from the top. The ammonia vapor and hydrogen leave the top of the evaporator and flow through the gas heat exchange getting warmed by the warmer hydrogen flowing through the evaporator. Both the gases flow to the absorber. Weak aqua ammonia solution enters at the top of the absorber and absorbs ammonia gas as it passes counter flow through the absorber. The hydrogen does not mix in weak aqua ammonia solution and gets separated and then flows through the heat exchanger right up to the evaporator. Strong aqua ammonia solution reaches the generator after leaving from the bottom of the absorber.

Heat is supplied to the generator from external source by gas burner etc., expelling ammonia vapor out from the strong solution. Here the problem is to raise the elevation of weak solution of ammonia also so that it can pass to the separator and flow back to the absorber. Principle of bubble pump is used here. The

delivery tube from the generator is immersed below liquid level in the generator. Thus as ammonia vaporizes in the tube, they carry slugs of weak solution vessel, hence cycle is completed.

### 2.2 Setup Diagram

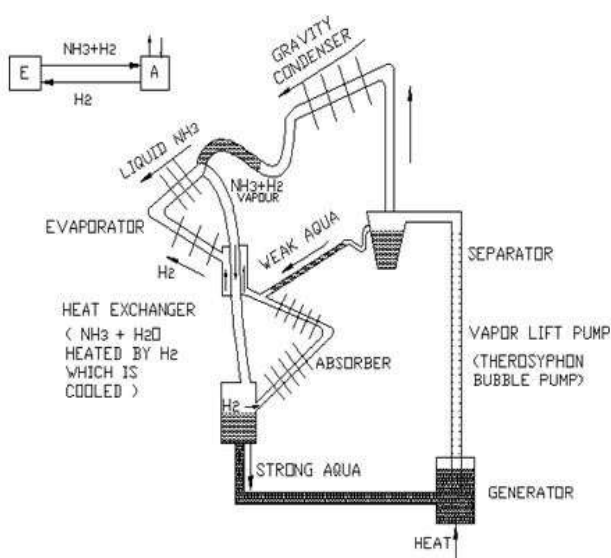


Fig: Electrolux System

### 2.3 Working

1. This type of refrigerator is known as three fluid refrigeration system in which refrigerant is ammonia, solution used as aqua ammonia and third fluid is hydrogen.
2. Circulation of system is achieved by providing high pressure condenser and generator and low pressure in the evaporator.
3. The liquid ammonia flows under gravity into evaporator.
4. The heavy mixture of vapor and hydrogen vapor coming out of evaporator is passed to evaporator.
5. The strong solution of aqua ammonia from the absorber again enters into generator through heat exchanger.
6. The strong aqua ammonia solution is heated by the generator by exhaust gas.
7. The advantage of Electrolux refrigerator is that it has no moving parts.

### 3. READINGS AND CALCULATION

Assuming various temperature in the system

Generator temperature =  $T_g = 90^\circ\text{C}$

Condenser temperature =  $T_c = 40^\circ\text{C}$

Evaporator temperature =  $T_e = 15^\circ\text{C}$

$$\text{Theoretical COP} = \left( \frac{T_e}{T_c - T_e} \right) * \left( \frac{T_g - T_c}{T_g} \right)$$

$$= \left( \frac{15}{40 - 15} \right) * \left( \frac{90 - 40}{90} \right)$$

$$\text{COP} = 1.5$$

If we assume to design air conditioning system with evaporator capacity of 1 Ton that is 3.5 KW

$$\text{COP} = \frac{\text{heat to be absorbed at evaporator}}{\text{heat to be supplied at generator}}$$

$$1.5 = \frac{3.5}{h_s}$$

$$h_s = 2.33 \text{ kW}$$

So, theoretical heat to be supplied at the generator

$$h_s = 2.33 \text{ kW}$$

So from the above theoretical calculation, we can conclude that if we supply exhaust gas at temperature of 90 C with exhaust heat of more than 2.33 KW and the condenser cooling temperature of 40 C then we achieve temperature of 15 C at evaporator for 1 Ton capacity.

If we vary the exhaust gas temperature or exhaust gas mass flow rate then we could be able to achieve various temperatures at the evaporator.

So to calculate the interrelation between generator temperature and the evaporator temperature, we assume various evaporator temperatures and will try to find out exhaust gas temperature and exhaust heat supplied to the generator.

Reading number	T <sub>e</sub> (°C)	T <sub>c</sub> (°C)	T <sub>e</sub> (°C)	COP	h <sub>g</sub> (kW)	h <sub>c</sub> (kW)
1	90	40	10	1.3	3.5	2.69
2	90	40	15	1.5	3.5	2.33
3	90	40	20	2.02	3.5	1.73

From the theoretical calculation we can conclude that, as the evaporator temperature goes on increasing then the heat supplied at generator is required goes on decreasing.

So, to utilize the exhaust gas heat to more extent we should design a system which works at low temperature at evaporator.

If exhaust gas is of IC engine then 25-30% of heat is exhausted. That amount of heat could be approximately 5-6 KW for single cylinder 4-stroke engine. If we use this heat as low grade heat energy source for generation in our project then we can save up to 2-3 KW heat power for generation of evaporating effect of 1 Ton.

## CONCLUSION

From this we conclude that, applying vapor absorption system for utilization of exhaust gas heat will result in economic operation. It will use the waste heat of exhaust gas and will decrease the temperature of exhaust gases. It will also reduce the electricity bill of the running plant. It will give the COP of nearly 0.43.

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