International Journal of Scientific & Engineering Research, Volume 8, Issue 3, March-2017
ISSN 2229-5518



# A Review of Absorption Refrigeration in Vehicles using Waste Exhaust Heat

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**Abstract:** This paper provides a literature review on absorption refrigeration system. The study shows energy from the exhaust gas of an internal combustion engine is used to power an absorption refrigeration system to air-condition an ordinary passenger car. In vapor absorption refrigeration system, a physicochemical process replaces the mechanical process of vapor compression refrigeration system. Aqua-ammonia is the best combination of absorbent-refrigerant having no adverse effect on environment. The average coefficient of performance of absorption refrigeration system is low about 0.1-0.3. The low COP value is an indication that improvements to the cycle are necessary.

**Key words:** car air-conditioning, absorption refrigeration, aqua-ammonia, COP.



## INTRODUCTION

The vapor absorption refrigeration is a heat operated system. This is older than the vapor compression system. In the early 1900's, refrigeration with this system using kerosene burner was popular. When CFC's were introduced and electric power was cheap, compression system having better COP got popular. With increase in the electricity charges and the phase out of the CFC's, the absorption system is again becoming popular in large capacities. In both the system we have the evaporator and the condenser. The process of evaporation and condensation takes place at two different pressure levels in both the systems. They also differ in the manner in which the evaporator is circulated in the system. In contrast to the vapor compression system which utilises a mechanical compressor; the absorption type makes benefit from a 'absorber' and a 'generator'. A solution called the absorbent that has an affinity for the refrigerant is used. The absorbent in the absorber draws or sucks the refrigerant vapor formed from the evaporator thus maintaining low pressure in the evaporator to enable the refrigerant to evaporate at low pressure. In the generator the absorbent is heated to release the refrigerant vapor as a high pressure vapor, to be condensed in the condenser [8].

Due to the international attempt to find alternative energies, absorption refrigeration has become a prime system for many cooling applications. Where thermal energy is available the absorption refrigerator can very well substitute the vapor compression system. Even for a relative small car-engine, such as for the Nissan1400, 15 kW of heat energy can be utilized from the exhaust gas. This heat is enough to power an absorption refrigeration system to produce a refrigeration capacity of 5KW [5].

**Table 1:** Environmental impact [5]

| Ozone Depleting and Global Warming Potentials | | | |
|---|---|---|---|
| Chemical | ODP | GWP | Estimated atmospheric life (years) |
| CFC-12 | 0.93 | 3700 | 122 |
| HCFC-22 | 0.05 | 510 | 18 |
| HFC-134a | 0 | 400 | 18 |
| Carbon dioxide | 0 | 10 | 230 |
| Ammonia | 0 | 0 | - |
| Water | 0 | 0 | - |

The standard working fluids for absorption refrigeration plants are water and ammonia, Lithium-Bromide and water, and Tetra-Ethylene Glycol Dimethyl-Ether (TEG-DME) and R-22. Of these combinations, water and ammonia is no threat to the environment and is preferable for this application. 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 its alloys when it has been hydrated. Therefore, all components are made from mild steel or stainless steel. In order to circumvent the toxicity problem, water or glycol is used as a secondary fluid to transfer the heat from the passenger space to the evaporator. In this manner, the chance of ammonia contact with the passengers is minimized [5].

## PRINCIPLE OF OPERATION

Absorption cycles produce cooling and/or heating with thermal input and minimal electric input, by using heat and mass exchangers, pumps and valves. The absorption cycle is based on the principle that absorbing ammonia in water causes the vapor pressure to decrease [13].

The basic operation of an ammonia-water absorption cycle is as follows. Heat is applied to the generator, which contains a solution of ammonia water, rich in ammonia. The heat causes high pressure ammonia vapor to desorb the solution. Heat can either be from combustion of a fuel such

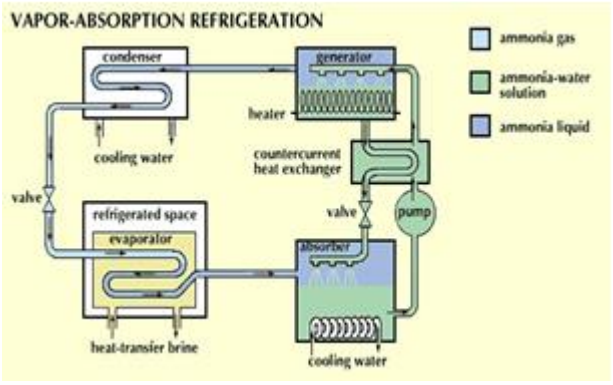


**Fig 1:** Aqua-ammonia absorption cycle [13]

as clean-burning natural gas, or waste heat from engine exhaust, other industrial processes, solar heat, or any other heat source. The high pressure ammonia vapor flows to a condenser, typically cooled by outdoor air. The ammonia vapor condenses into a high pressure liquid, releasing heat which can be used for product heat, such as space heating. The high pressure ammonia liquid goes through a restriction, to the low pressure side of the cycle. This liquid, at low pressures, boils or evaporates in the evaporator. This provides the cooling or refrigeration product. The low pressure vapor flows to the absorber, which contains a water-rich solution obtained from the generator. This solution absorbs the ammonia while releasing the heat of absorption. This heat can be used as product heat or for internal heat recovery in other parts of the cycle, thus unloading the burner and increasing cycle efficiency. The solution in the absorber, now once again rich in ammonia, is pumped to the generator, where it is ready to repeat the cycle [13].

## LITERATURE REVIEW

Li-Ting Chen, 1988, Modified ejector-absorber absorption refrigeration cycle is presented and analyzed. From the results it is observed that a considerable improvement in COP is obtained with the present cycle when compared with that of the conventional cycle [1].

George Vicatos, 1995, The author studied the absorption refrigeration system and Heat and Mass correlation and simulate the system and then designed the system. This study has developed a methodology which could be adopted in designing an absorption refrigeration plant, given a refrigeration requirement [2].

Shiyi Wang, 1996, In this thesis S Wang designed the system, simulated it at different loads, manufactured it, carried out bench test and road test. In the exhaust gases of motor vehicles, there is enough heat energy which can be utilized to power an air-conditioning system "free" from any energy requirements [3].

P. Srikhirin et al., 2001, This paper provided a literature review on absorption refrigeration technology. A double-effect absorption systems using lithium bromide/water seem to be the only high performance system which is available commercially [4].

J Gryzagoridis et al.,2008, The theoretical design is verified by a unit that is tested under both laboratory and road-test conditions. The evaluation of the COP, with and without the heat exchanger also proves that unless there is a high purity refrigerant, the effect of the heat exchanger to the generator's heat is small [5].

Andre Aleixo Manzela et al., 2010, This work presented an experimental study of an ammonia-water absorption refrigeration system using the exhaust of an internal combustion engine as energy source. Overall, carbon monoxide emission was decreased when the absorption refrigerator was installed in the exhaust gas, while hydrocarbon emissions increased [6].

Khaled S. AlQdah, 2011, This work presented an experimental study of an aqua-ammonia absorption system used for automobile air conditioning system. It is evident that COP strongly depends on working conditions such as generator, absorber, condenser and evaporating temperature [7].

Isaac Mathew Pavoodath, 2012, In this paper study of absorption refrigeration is done. Such a system would vastly help take of the compressor load of the vehicle engine and would prove a great percentile of power saving for small capacity engines [8].

Christy V Vazhappilly et al., 2013, A breadboard prototype of an absorption system for refrigeration using heat from the exhaust-gases is to be designed, built and tested. The heating coil generator system of absorption refrigeration system has been replaced by plate frame type heat exchanger, there by utilizing the exhaust gases of the IC engine [9].

Janardhanan.k et al., 2014, This work presented a theoretical study of an aqua-ammonia absorption system used for automobile air conditioning system. Using a vapor absorption refrigeration system within an automobile as an air conditioner will not only reduce the fuel consumption of the vehicle while working but will also reduce the environmental pollution [11].

S. Manoj prabhakar et al., 2014, This work presented an experimental study refrigeration system, using vapor absorption system. The coefficient of performance of the system is low, that means that the system is expected to use a lot of energy with respect to the cooling it offers [12].

J.P. Yadav et al., 2014, In this paper study of an experimental set up is designed and fabricated. Using heat exchangers, analyzer, and pre-heater the COP of the system further improves. Even by using two evaporators the effectiveness of the system can be increased [14].

Paul Cedric Agra et al., 2014, This paper simulated the performance of the system using waste heat, a Bunsen burner was used which was attached to a propane tank via a rubber hose with a regulator. The small scale model with maximum COP 0.3685 at evaporator temperature 28 degree Celsius was achieved. In order to improve the performance of the system it is suggested to use high concentration of aqua ammonia solution [10].

S. Thanga mohan raja et al., 2015, In this paper study of ab- sorption refrigeration is done. The waste heat energy available in exhaust gas is directly proportional to the engine speed and exhaust gas flow rate [16].

Tambe. Y.D et al., 2015, In this paper the more focus was given to the design and manufacturing of the system with 80 cc internal combustion petrol engine. The experiments conducted on the system, prove that the concept is feasible and could be used for refrigeration in traction and non-

traction application of engine [19].

K L Rixon et al., 2015, In this paper study, design and fabrication of absorption refrigeration is done and result are obtained accordingly. Using a vapor 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 [18].

N. Chandana reddy et al., 2015, In this paper, an overview of utilization of waste heat with a brief literature of the current related research is studied. A maximum power consumption of 42.38 percent is saved using proposed system compared to existing system [17].

Atishey Mittal et al., 2015, In this paper study of comparison of absorption refrigeration and compression refrigeration sys- tem is done. Waste heat recovery system is the best way to recover waste heat and saving the fuel [15].

Dinesh Chandrakar et al., 2016, In this paper designing of absorption refrigeration is done and results are obtained. As power output increase, the heat recovered from exhaust gas also increase difficulty may occur when the vehicles at rest or in very slow moving traffic conditions [20].

An extensive literature study on the subject of absorption refrigeration had revealed that exhaust of vehicles has enough energy that can be utilized to power an air-conditioning system. Absorption refrigeration system has low COP and it's an indication to improve it.

## CONCLUSION

In the exhaust gases of motor vehicles, there is enough heat energy that can be utilized to power an air-conditioning system [5]. Using a vapor 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 [18]. The low COP value is an indication that improvements to the cycle are necessary. Once a secondary fluid such as water or glycol is used, the aqua-ammonia combination appears to be a good candidate as a working fluid for an absorption car air-conditioning system. This minimizes any potential hazard to the passengers [5].

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