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Modeling And Experimental Analysis Of Generator In Vapour Absorption Refrigeration System

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Abstract
A breadboard prototype of an absorption system for refrigeration using heat from the exhaust-gases is to be designed, built and tested. In the commercial vapour absorption refrigeration system a heating coil generator system has been employed to vaporize the ammonia refrigerant. In the present work, the heating coil generator system has been replaced by the frame plate type heat exchanger. The exhaust gases from the IC engine have been utilized to vaporize the ammonia refrigerant. The available heat in the exhaust gases has to be estimated based on actual I.C-Engine driving cycles. The frame plate type heat exchanger has to be modeled and flow analysis inside the heat exchanger has to be analyzed. In addition, the recoverable energy of the exhaust gases is to be analyzed for representative Internal Combustion Engine.
Keywords – Absorption system, Ammonia-water, Exhaust gas, Internal combustion engine, Plate frame heat exchanger

I. INTRODUCTION

A considerable portion of the total energy consumption of the western world is centered in the transport sector (Mei et al. [1] estimate a value of about 25 percent for the United States). Automobiles and trucks alone account for approximately 80 percent of all transportation energy expenditures. These internal combustion engines typically have a thermal efficiency of 40 percent. The remaining energy is rejected to the atmosphere in the form of hot exhaust gases or as energy convected from the radiator and the engine. Much work now in progress is directed to the improvement of the thermal efficiency by achieving better consumption of the fuel. Some effort has been devoted to the utilization of the vast amount of waste energy dissipated in the exhaust gases. Unfortunately, few have focussed on using the waste heat for air-conditioning and refrigeration. Trucks used for the transport of perishable foodstuffs must be equipped with refrigeration systems (Perishable foodstuffs, such as milk, vegetables, fruits, and meat, deteriorate fairly rapidly at ambient temperature).

There are three major categories of truck refrigeration. The most widely used system utilizes a vapor compression machine powered by the vehicle engine via pulley and belt or by an APU (auxiliary power unit). Some trucks use a eutectic solution plate refrigeration storage system. Still others use expendable liquid nitrogen or carbon dioxide spray systems. All of these systems consume precious fuel or electricity to achieve refrigeration. One alternative to the vapor compression cycle which has been increasingly discussed in recent years is the absorption refrigeration cycle, which, for example, employs ammonia as refrigerant and water as absorbent. Ammonia contains no halogen atoms at all, and even its gradual leakage into the atmosphere poses negligible environmental or atmospheric risks. By employing waste heat discharged from a vehicle's internal combustion engine to drive an absorption refrigeration system, the engine shaft can be relieved of the load required by the compressor of a conventional vapor-compression system, and considerable fuel can be saved. Another attractive feature is that an absorption refrigeration system is almost noise-free and virtually maintenance-free.

II. VAPOUR ABSORPTION REFRIGERATION SYSTEM

The vapor-absorption cycle is similar to the better known vapor-compression cycle in that it employs a volatile refrigerant, e.g. ammonia, which alternately condenses under high pressure in the condenser by surrendering heat to the environment and vaporizes under low pressure in the evaporator by absorbing heat from the medium being cooled. The principal difference between the absorption and the vapor-compression cycles is the mechanism for circulating the refrigerant through the system and providing the necessary pressure difference between the vaporizing and condensing processes. The vapor compressor employed in the vapor-compression cycle is replaced in the absorption cycle by an absorber and a generator or boiler, which compress the vapor as required. The energy input required by the vapor-compression cycle is supplied to the compressor in the form of mechanical workIn the absorption cycle, the energy input is mostly in the form of heat supplied to the generator. In the present case the heat source is the exhaust heat of an internal combustion engine.

In truck refrigeration system exhaust gas volume flow rate and the gas temperature could be varied continuously in order to simulate the various operating conditions of an actual truck engine. In the generator a mixture of ammonia and water is heated. The boiling point of ammonia is lower than that of water, so it vaporizes, separating the refrigerant from the absorbent. Since the vapor is not a pure ammonia gas, it must be purified as it flows through a stripping and rectification column. The heat exchangers of the generator rectification system were designed as compact plate-fin heat exchangers and the column was filled with stainless steel Pall rings.

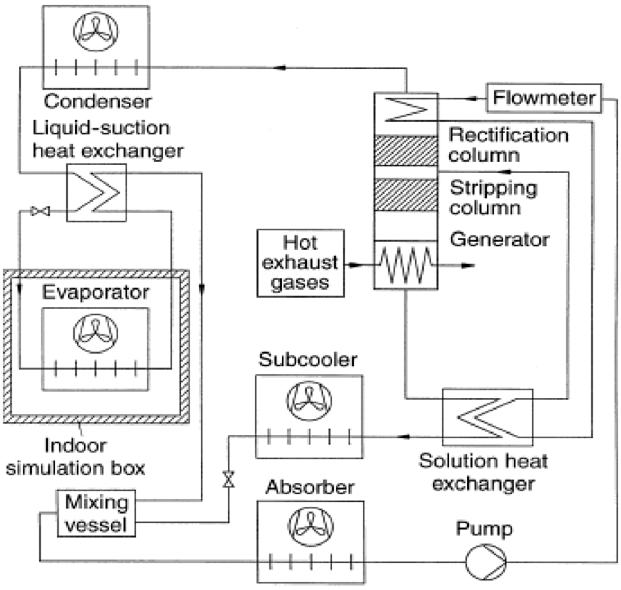

Figure 1 The essential components of the air-cooled absorption system.

The almost pure ammonia vapor flows from the top of the column to the condenser as a high-temperature, high pressure mixture. As ambient air passes over the condenser, it removes heat from the gas-mixture and the vapor condenses to a liquid. Since the boiling point of water is higher than that of ammonia, the trace water condenses first, resulting in liquid with a considerably higher water concentration at the start of the condensation process. At several locations concentrations of the binary mixture were determined by titration. The volume flow rate of the strong solution was measured by a magnetic flow meter. The generator heat flow rate was determined by measuring the exhaust gas volume flow rate and the gas-side temperature drop across the generator. The gas volume flow rate was measured using a total pressure grid.

III. EXHAUST GAS

In Vapour absorption refrigeration system, generator portion is designed for utilizing exhaust gas from internal combustion engine. Type of engine and also details of engine parameters are given below. Temperature of an exhaust gas in kirloskar engine by an heat balance on engine by using electrical loading. Fuel used in engine is high speed diesel. Exhaust gas temperature range is varied depends upon the type and also amount load acting on the engine

1	ENGINE MAKE	KIRLOSKAR
2	ENGINE TYPE	SINGLE CYLINDER FOUR STROKE
3	POWER	3.7 KW
4	SPEED	1500 rpm
5	BORE DIAMETER	80 mm
6	STROKE LENGTH	110 mm
7	ROOM TEMPERATURE	29ºC
8	EXHAUST GAS TEMPERATURE RANGE	125ºC to 260ºC

Table 1 IC Engine specification

IV. DESIGN OF GENERATOR IN VAPOUR ABSORPTION SYSTEM

Following table is indicate the one type on vapour absorption refrigeration system using heating coil. It is used to generate the vapour refrigerant in generator outlet. ammonium-water refrigerant is used in refrigerant and absorber.

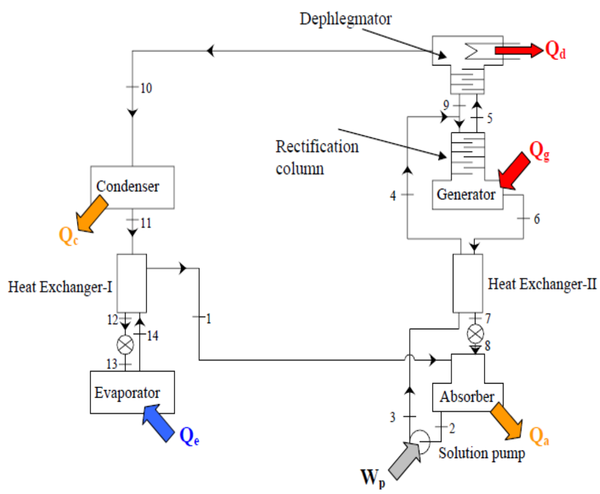

Figure 2 Ammonium-water vapour absorption system.

A vapour absorption refrigeration system based on ammonia-water has refrigeration capacity of **100 TR**. The various state properties of the system shown below are given in the table. Taking the heat rejection rate in the reflux condenser (Q_d) as **88 kW**, find a) The mass flow rates of solution through the evaporator, strong solution and weak solution; b) Enthalpy values not specified in the table and c) Heat transfer rates at condenser, absorber and generator and solution pump work d) System COP.

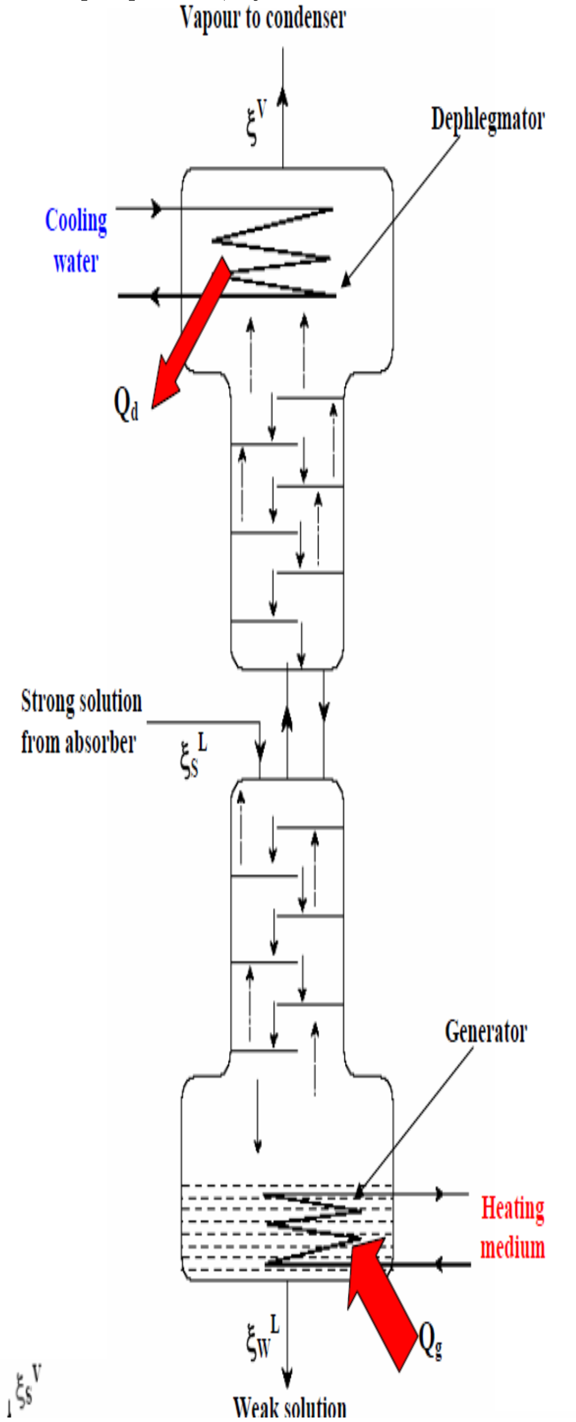

Figure 3 Generator

Figure 3 shows the schematic of the rectification system consisting of the generator, rectifying column and dephlegmator. As shown in the figure, strong solution from absorber enters at the rectification column, vapour rich in ammonia leaves at the top of the dephlegmator and weak solution leaves from the bottom of the generator. A heating medium supplies the required heat input Q_g to the generator and heat Q_d is rejected to the cooling water in the dephlegmator.

It can be seen that compared to heat input to the system at the generator, the work input to the system is almost negligible (less than 0.5 percent) The system COP is reduced as the required heat input to the generator increases due to heat rejection at dephlegmator. However, this cannot be avoided as rectification of the vapour is required. However, it is possible to analyze the rectification process to minimize the heat rejection at the dephlegmator.

STATE POINT	PRESSURE (P) BAR	TEMPERATURE (T) °C	CONCENTRATION(X) Kg OF NH_3/Kg OF SOLUTION	ENTHALPHY Kj/Kg
1	2.04	13.9	0.996	--
2	2.04	26.1	0.408	-58.2
3	13.61	26.1	0.408	-56.8
4	13.61	93.3	0.408	253.6
6	13.61	115.6	0.298	369.9
7	13.61	36.1	0.298	--
8	2.04	36.1	0.298	--
10	13.61	54.4	0.996	1512.1
11	13.61	36.1	0.996	344.3
12	13.61	30.0	0.996	318.7
13	2.04	-17.8	0.996	--
14	2.04	4.4	0.996	1442.3

Table 2 Observation of refrigeration system

For using above information we have calculating the mass flow rate of evaporator, mass flow rate of weak solution, mass flow rate of strong solution, energy balance across the heat exchangers, and also heat transfer rate at condenser, absorber, generator ,power input to the pump. Finally we have calculating the cop of the system.

In this vapour absorption system is modified in generator part to introducing the heat exchanger to transforming the ammonium-water liquid in to ammonium vapor in the usage of exhaust gas from an kirlosker engine.

V. SELECTION OF HEAT EXCHANGER

The table indicates the required data for calculating the design of heat exchanger. It is taken from the existing vapour absorption system and internal combustion engine for single cylinder four stroke diesel engine.

	HOT GAS	AMMONIA-WATER MIXTURE
Inlet and Outlet temp. (°C)	160 & 87.5	25 & 54
Specific heat (kj/kg°c)	1.15	2.138
Mass flow rate (Kg/s)	0.2	0.5

Table 3 Calculation of heat exchanger

For above information to calculating the diameter, area, length of heat exchanger

Over all heat transfer co-efficient (U) =800 w/m^{2o} C

Heat transfer rate (Q) $=m_h c_h (T_{h1}-T_{h2})=m_c c_c (T_{c2}-T_{c1})$

$(\Phi_{LMTD}) = (\Phi_1 - \Phi_2)/\ln(\Phi_1/\Phi_2)$

Area (A) $= Q/(u\ \Phi_{LMTD})$

Diameter (D) $=A / \pi L$

VI. PLATE GEOMENTRY

There are basically six different types of plate patterns. The geometry of different types of plate patterns are given below

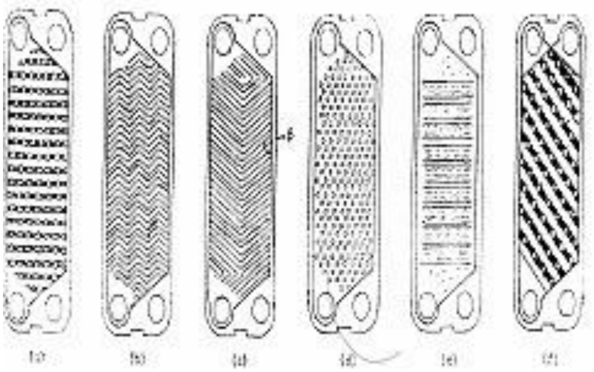

Figure 4 Plate Patterns

VII. PLATE SPECIFICATION

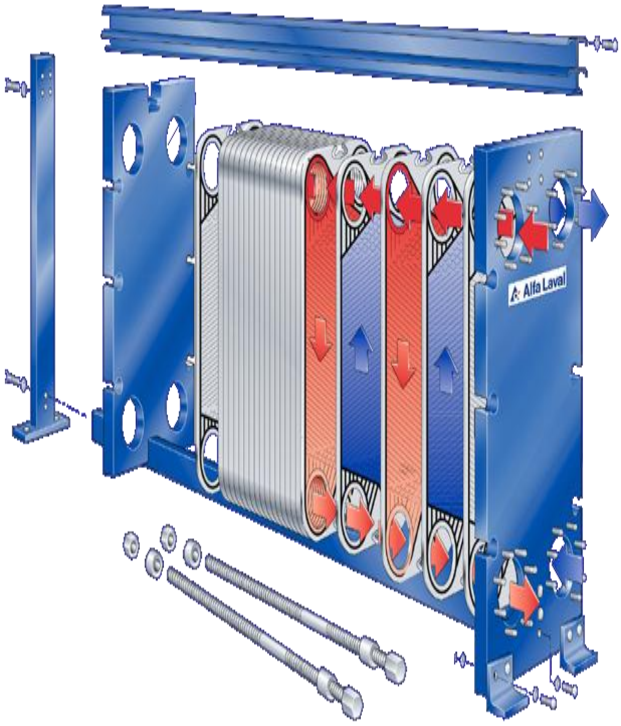

Figure 5 Plate frame heat exchanger

Number of plates =120
Material of plates =Stainless steel
Thickness of the plate =0.015m
Hole Diameter =0.05m

a. Guiding bars in stainless steel
b. Support columns in aluminium or painted carbon steel
c. Carryings bar in Aluminium or painted Carbon Steel

VIII. PLATE MATERIALS

- Standard materials and thicknesses
  - **a.** AISI 304 (stainless steel)
    - Usually 0.4 or 0.5 mm thickness
    - Cheapest possible solution
    - Some with thicker plates (high-pressure applications)
  - **b.** AISI 316 (stainless steel)
    - Always 0.5 and 0.6 mm
  - **c.** 254 SMO (high-alloy stainless steel)
    - Usually in 0.6 mm to allow stock-keeping
  - **d.** Titanium
    - Always 0.5 and 0.6 mm
    - Some with thicker plates (high-pressure applications)
    - Some PHEs with 0.4 mm (low-pressure applications)
  - **e.** Alloy C-276 (Nickel alloy)
    - Usually in 0.6 mm to allow stock-keeping
    -

IX. CONCLUSION

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. Furthermore, the available heat in the exhaust gases has to be estimated based on actual I.C-Engine driving cycles. The work cycle has to be simulated, and a detailed model to calculate the two-phase binary flow of the condenser and absorber has to be developed and verified.

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