DESIGN 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 In the present work, the heating coil generator system has been replaced by the frame plate type heat exchanger.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 IC-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 recovered energy of the exhaust gases is to be analyzed for representative Internal Combustion Engine.

Keywords— Absorption System; Exhaust Gas; Internal Combustion Engine; Ammonia-Water

1. 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 focused 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.

2. 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 work. In 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. 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.

3. 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

<table>
<thead>
<tr>
<th>TABLE – 1 IC ENGINE SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ENGINE MAKE</td>
</tr>
<tr>
<td>2 ENGINE TYPE</td>
</tr>
<tr>
<td>3 POWER</td>
</tr>
<tr>
<td>4 SPEED</td>
</tr>
<tr>
<td>5 BORE DIAMETER</td>
</tr>
<tr>
<td>6 STROKE LENGTH</td>
</tr>
<tr>
<td>7 ROOM TEMPERATURE</td>
</tr>
<tr>
<td>8 EXHAUST GAS TEMPERATURE RANGE</td>
</tr>
</tbody>
</table>

4. DESIGN OF GENERATOR IN VAPOUR ABSORPTION SYSTEM

Following table is indicating 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.

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 (Qd) 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-1 The essential components of the air-cooled absorption system

Figure-2 Ammonium-water vapour absorption system

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.

### TABLE – 2 OBSERVATION OF REFRIGERATION SYSTEM

<table>
<thead>
<tr>
<th>STAT E POINT</th>
<th>P, BAR</th>
<th>T, ºC</th>
<th>CONCENTRATION(X), Kg OF NH3/Kg OF SOLUTION</th>
<th>ENTHALPHY, Kj/Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.04</td>
<td>13.9</td>
<td>0.996</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.04</td>
<td>26.1</td>
<td>0.408</td>
<td>-58.2</td>
</tr>
<tr>
<td>3</td>
<td>13.61</td>
<td>26.1</td>
<td>0.408</td>
<td>-56.8</td>
</tr>
<tr>
<td>4</td>
<td>13.61</td>
<td>93.3</td>
<td>0.408</td>
<td>253.6</td>
</tr>
<tr>
<td>6</td>
<td>13.61</td>
<td>115.6</td>
<td>0.298</td>
<td>369.9</td>
</tr>
<tr>
<td>7</td>
<td>13.61</td>
<td>36.1</td>
<td>0.298</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>2.04</td>
<td>36.1</td>
<td>0.298</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>13.61</td>
<td>54.4</td>
<td>0.996</td>
<td>1512.1</td>
</tr>
<tr>
<td>11</td>
<td>13.61</td>
<td>36.1</td>
<td>0.996</td>
<td>344.3</td>
</tr>
<tr>
<td>12</td>
<td>13.61</td>
<td>30.0</td>
<td>0.996</td>
<td>318.7</td>
</tr>
<tr>
<td>13</td>
<td>2.04</td>
<td>-17.8</td>
<td>0.996</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>2.04</td>
<td>4.4</td>
<td>0.996</td>
<td>1442.3</td>
</tr>
</tbody>
</table>

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 a kirlosker engine.

### 5. SELECTION OF HEAT EXCHANGER

For above table indicate 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. for above information to calculating the diameter, area, length of heat exchanger. Over all heat transfer co-efficient ($U$) =800 w/m² C

### TABLE -3 CALCULATION OF HEAT EXCHANGER

<table>
<thead>
<tr>
<th>Hot Gas</th>
<th>Ammonia-Water Mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet and Outlet temp (ºC)</td>
<td>160 &amp; 87.5</td>
</tr>
<tr>
<td>Specific heat (kj/kgºC)</td>
<td>1.15</td>
</tr>
<tr>
<td>Mass flow rate (Kg/s)</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Heat transfer rate ($Q$) = $mhch(Th1-Th2)+mccc(Tc2-Tc1)$

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

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

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

### 6. PLATE SPECIFICATION

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

![Figure-4 Plate frame heat exchanger](www.ijmtes.com)

- GUIDING BARS IN STAINLESS STEEL
- SUPPORT COLUMNS IN ALUMINIUM OR PAINTED CARBON STEEL
- CARRYINGS BAR IN ALUMINIUM OR PAINTED CARBON STEEL
7. PLATE GEOMETRY

![Figure- 5 Plate geometry]

8. PLATE MATERIALS

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

9. CONCLUSION

The heating coil generator system of absorption refrigeration system has been replaced by plate frame type heat exchanger, thereby 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.

REFERENCES