Increase of Cooling Performance in Refrigeration System using Flue Gas Waste Heat with Cascade Refrigeration System

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Abstract— In this the waste heat sent to the atmosphere is utilized by the waste heat recovery system. Here the heat is utilized for the purpose of vapourizing the refrigerant mixture in Vapour Absorption System. For that the heat from the flue gas of coal burning industries is utilized. The temperature of flue gas be normally above 220 °C, which is enough for the generator work. A Compression-Absorption Cascade Refrigeration System is used here. Normally compression systems are cascaded for getting higher effect than produced by single system. But the power requirement for this is more. Absorption system requires less heat input for its operation which can be supplied by renewable energy sources. In this system the generator temperature of VARS system is about 90 °C. By using cascading system for 5 °C sub-cooling which cause increase in COP of 16.05%. With that the power used for the purpose of refrigeration system in the same industry can be reduced.

Key words: Flue Gas, Cascade Refrigeration System

I. INTRODUCTION

Waste heat is a kind of thermal (heat) energy that is sent out to the atmosphere in different means without being put to practical use. Waste heat includes hot combustion discharged gases and heated products sent out from industries as waste. While some waste heat losses from industries are not reusable. For such situation new technology can be implemented to reduce the heat loss.

The use of compression-absorption cooling system provides electricity saving compared to vapour compression cooling system. The structure of the system is additional advanced however they use the benefits of each compression and absorption cooling system. The cascade system provides usage of electricity and heat energy along at constant time for obtaining refrigeration result. Furthermore, non-conventional energy sources like solar, geothermal, and waste heat in industries can be equipped to the absorption section of the cascade system.

A. Need for Performance Improvement

With the increase in cooling performance the required cooling effect can be achieved by using the same power input. At the same time the power required for compressor also reduced.

B. Performance Improvement Techniques

– Cascade refrigeration system
– Combined refrigeration system

In cascade refrigeration system, the vapour compression and absorption systems are connected in serial manner.

In the combined refrigeration system, the vapour compression and the vapour absorption systems have the same compression rate and this rate is equal to the total compression rate on the combined refrigeration system.

II. EXPERIMENTAL SETUP

Coal is an important energy source for human kind. Direct coal combustion is used for industrial and domestic purposes because of large scale storage and low cost. After the coal combustion flue gas is emitted from that. It carries out large amount of heat in it. These flue gases are sent out to the atmosphere through chimney. In that flue gas passage water tubes are placed as heat exchangers. Figure 1.0

Those tubes absorb the heat from the flue gas and it is carried out to the VARS system generator. There the heat is given to the solution for vapourizing. After the heat rejection the water is again circulated through the tubes for the same process.

Fig. 1: Shows the Schematic diagram of the Cascade Compression–Absorption Refrigeration System

(a) Compressor, (b) Evaporator 2 Cum Condenser 1, (c) Expansion Valve 1, (d) Evaporator 1, (e) Generator, (f) Water Separator, (g) Condenser, (h) Expansion Valve 2, (i) Absorber, (j) Pump, (k) Heat Exchanger, (l) Chimney, (m) Flue Gas In, (n) Flue Gas Out

A. Sub-Cooling

Figure 2, shows the process of sub-cooling area

Fig. 2: the process of sub-cooling area

Sub-cooling is a method implemented in refrigeration to reduce the condenser temperature with the use of some other cooling resources.
III. EXPERIMENTAL PROCEDURE

1) LiBr₂·H₂O was used in the absorption section and R134a is used in the vapour compression section of this sample cycle.
2) The heat that is absorbed by the water tubes are given to the generator.
3) With that heat supplied the refrigerant get vapourized and flows through the separator.
4) The cooling effect of absorption system is given to the condenser of the compression system.
5) It helps in reducing the condenser temperature further the normal.

IV. THEORETICAL ANALYSIS

The following are the obtained result values in compression system using the properties of R134a with condenser temperature as 40 °C and evaporator temperature as -10 °C.

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>h2 (kJ/kg)</th>
<th>h1 (kJ/kg)</th>
<th>h3 (kJ/kg)</th>
<th>Gr (%)</th>
<th>M (kg/s)</th>
<th>Cop</th>
<th>Pr</th>
<th>Vcc (kJ/min)</th>
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</thead>
<tbody>
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<td>40</td>
<td>426.353</td>
<td>392.7</td>
<td>256.4</td>
<td>0.902187</td>
<td>0.1474</td>
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<td>5.07</td>
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<td>392.7</td>
<td>249</td>
<td>0.916879</td>
<td>0.24356</td>
<td>4.708976</td>
<td>5.41038</td>
<td>1325.508</td>
</tr>
</tbody>
</table>

Table 1: Result Values

V. RESULTS AND DISCUSSION

After the process of sub-cooling of 5 °C the following result values are obtained

<table>
<thead>
<tr>
<th>T3 (°C)</th>
<th>T1 (°C)</th>
<th>h2 (kJ/kg)</th>
<th>h1 (kJ/kg)</th>
<th>h3 (kJ/kg)</th>
<th>Gr (%)</th>
<th>M (kg/s)</th>
<th>Cop</th>
<th>Pr</th>
<th>Vcc (kJ/min)</th>
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<td>423.2162</td>
<td>392.7</td>
<td>256.4</td>
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<td>0.24356</td>
<td>4.708976</td>
<td>5.41038</td>
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<td>30</td>
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<td>420.609</td>
<td>392.7</td>
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<td>0.93028</td>
<td>0.23179</td>
<td>5.41038</td>
<td>3.83948</td>
<td>1413.198</td>
</tr>
</tbody>
</table>

Table 2: Result Values
Figure 7, shows that with reduced condenser temperature the volumetric cooling capacity rate increases.

VI. RESULTS AND DISCUSSION

If vapour absorption system is used separately the cooling effect from the vars system is lower than the VCRS system. So both are combined to form a single system called cascade refrigeration system. The waste heat sent to the atmosphere through the flue gas is utilized to vaporize the refrigerant mixture in vars system. With that the actual COP that is obtained in a vapour compression refrigeration system without sub-cooling with the evaporator temperature as -10°C and condenser temperature as 40°C is 4.05. If sub-cooling attachment is proposed the COP obtained is 4.27 with a 3°C sub-cooling temperature. Therefore the percentage rise in COP is 5.43% with the same input power. The waste heat in many other industries are not utilized properly. Large amount of heat is sent to the atmosphere without reusing.

VII. FUTURE SCOPE

In this paper the future scope is that with special arrangements the flue gas can be used directly for heating. Further for getting higher cop the newly developing material such as phase change material can be used in evaporator or in condenser for the higher performance.

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I sincerely thanks to my parents and my staffs who supported me to come out with a great work

VIII. CONCLUSION

In this paper the waste heat sent to the atmosphere is utilized in a recovery unit and further it is used for the refrigeration system for vaporising the refrigerant mixture in vapour absorption refrigeration system. For getting a higher cooling effect in vapour compression system the cascaded system is introduced here, where both the absorption and compression system are combined in a single system. By using the absorption system directly it takes more time to achieve the required cooling effect. In most of the industries vapour compression system is used for refrigeration and air-conditioning purposes. This cascade system can be installed with that unit and with the same power higher performance can be achieved.

REFERENCE