Performance Evaluation of Waste Heat Assisted Vapor Absorption Refrigeration System

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Objective

Generally, VAM is applied to utilize waste heat energy from different unit operations of dairy plant. The study was taken up with following objectives:

1. To evaluate Performance of major components such as generator, evaporator, absorber, condenser and heat exchanger of water-lithium bromide vapor absorption refrigeration system.
2. To carry out thermal analysis of various components of waste heat assisted water-lithium bromide vapor absorption refrigeration system.
3. To carry out cost analysis of the refrigeration system and to minimize, and to examine the suitability of VAM in dairy industry.
4. To study the effect of operational time and environment conditions.

The data collected and study conducted will be useful to make efficient utilization of waste energy from different sources of dairy plant operations using vapor absorption refrigeration system. It will also help to optimize different operating parameters of major components of vapor absorption system based on its possible applications of different dairy plant operations.

Methodology

The commercial Water-LiBr plant having installed capacities of 350 TR was selected for the study. The commercial Water-LiBR chilling system uses the exhaust heat of the power plant for supply of thermal energy at the generator of system. The power plant produces flue gases at a temperature of in the range of 400-450 °C. The waste heat assisted refrigeration plant consists of generator, evaporator, absorber, condenser and heat exchangers. The system has PLC based control system in order to regulate the flow rate of chilled water, flue gases, concentration of LiBr solution etc. The performance evaluation of the plant was carried out by collecting the operating data of temperature, power as well as other data obtained by various calculations adopting heat and mass transfer relations. The properties table and chart of water-LiBr solution were used for the determination of coefficient of performance and energy analysis of major components of the VARS.

The work was planned to carry out performance evaluation of the water-LiBr vapour absorption refrigeration plant in term of coefficient of performance (COP) as well as energy analysis of major components of the plant. The energy analysis carried out for the various components such as generator, condenser, absorber, evaporator and cooling tower of the commercial plant. Performance evaluation of various components of VAM and efficiency of plant and plant component like low temperature heat exchanger, high temperature heat exchanger, cooling tower and coefficient of performance of the plant were studied.

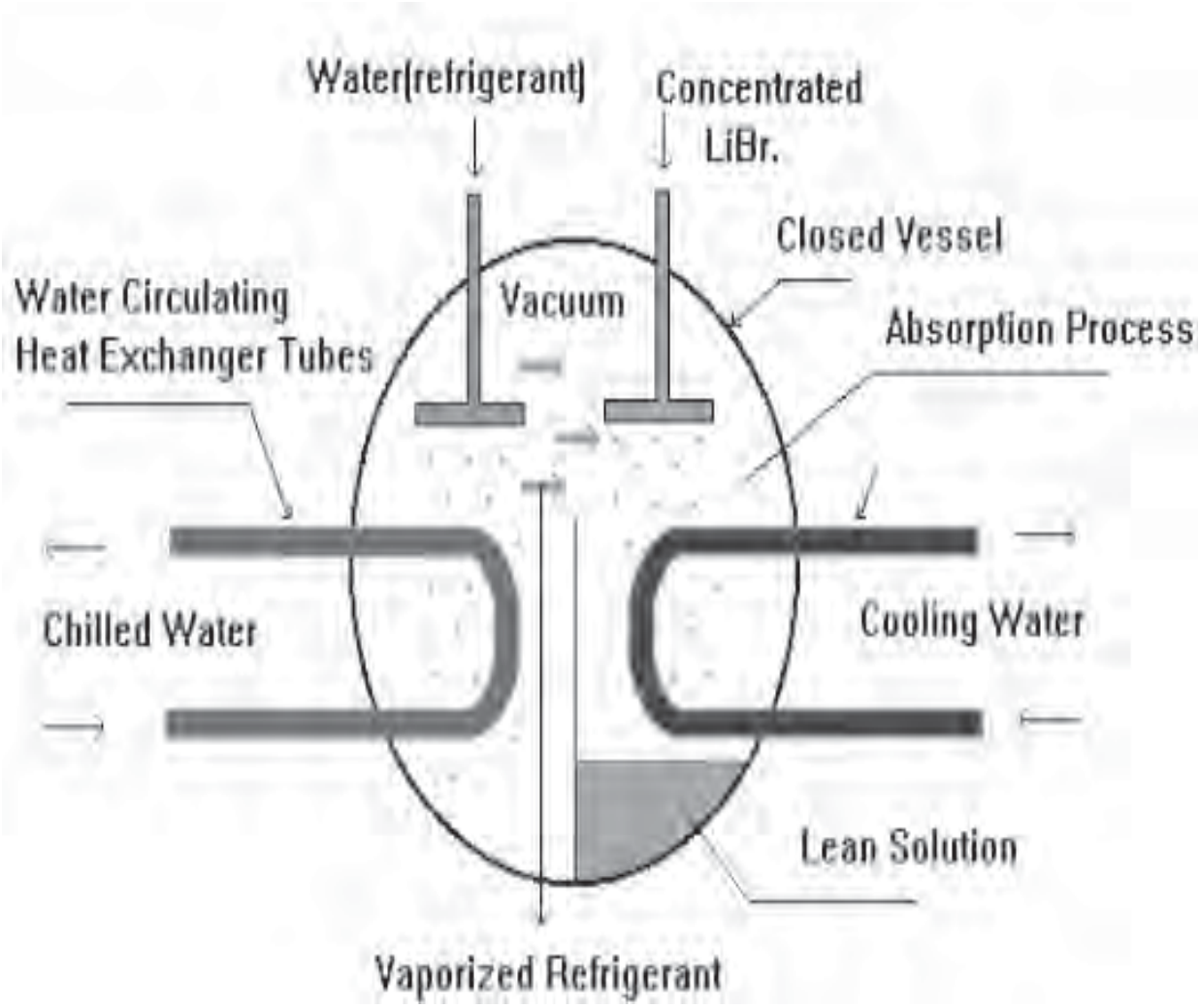

FIG: Absorption system of commercial VAM

Result & Discussion

The performance evaluation of water-LiBr waste heat assisted vapor absorption refrigeration system was carried out in the month of February, March and April, 2013. The VARS of commercial dairy plant having installed capacities of 350 TR was selected for the study. Water-LiBR chilling system of commercial dairy plant uses the exhaust heat of the thermal power plant for supply of thermal energy at the generator of system. The waste heat assisted refrigeration plant consists of generator, evaporator, absorber, condenser and heat exchangers. The system has PLC based control system in order to regulate the flow rate of chilled water, flue gases, concentration of LiBr solution etc. The inlet chilled water temperature of the chiller ranged from 7.1 to 10.1° C during the entire study period. The chilling capacity of the VARS ranged from 243 kW (69.43 TR) to 455 kW (126.57 TR) during operation of the plant. The chilling capacity showed variation depending on the temperature of incoming chilled water, generator temperature as well as the temperature of cooling medium used at the condenser. The variation in the condensing temperature during operation of the VARS was very narrow ranging from 26.7 to 31.0 ^{o}C during the entire period of the study as the water cooled in the cooling tower first passes through absorber of the plant before being used at the condenser. It is observed that lower condensing temperature increased the refrigerating capacity of the VARS. The temperature of generator was regulated by PLC based temperature controller in order to

regulate the damper position which regulates the flow rate of flue gases. The generator temperature were vary from 121.9 to 131.6 °C during the operation of the VARS.

The values of theoretical COP calculated based on the operating temperatures of the VARS range from 1.97 to 2.64 during the entire period of study based on the variation of condensers and generator temperatures. The values of actual COP calculated based on actual chilling effect produced by the chiller and thermal energy required in the generator of the VARS ranged from 0.78 to 0.98 during the entire period of study. It has been noticed that as the efficiency of cooling tower increased, the COP of the plant also showed an increasing trend.

The values of efficiency of Low temperature heat exchanger (LTHE) was observed between the ranged of 43 % to 53 %. It is noticed higher efficiency of LTHE gave higher COP of VARS and vice versa. The higher efficiency of LTHE gave higher temperature of the weak LiBr solution resulting into the lower thermal energy requirement in the generators. The value of efficiency High temperature heat exchanger (HTHE) was observed between ranged of 70 % to 80 %. It is also noticed that higher efficiency of HTHE gave higher COP during the entire period of study.

The cost calculations revealed that operating cost of VARS on natural gas comes to ` 1876792 per month and it is uneconomical. The VARS of commercial Dairy operates on waste heat of thermal power plant and hence the operating cost of the system was ` 29700 per month as electrical energy cost. The operating cost of equal capacity vapour compression refrigeration system (VCRS) comes to ` 540540 per month which is very high as compared to waste heat assisted VARS.

Conclusion

The values of theoretical COP calculated based on the operating temperatures of the VARS range from 1.97 to 2.64 during the entire period of study based on the variation of condensers and generator temperatures. The values of actual COP calculated based on actual chilling effect produced by the chiller and thermal energy required in the generator of the VARS ranged from 0.78 to 0.98 during the entire period of study. The energy analysis of the VARS indicated that the average refrigerating effect produced, generator work and heat rejected at the condenser were 340 kW, 380 kW and 730 kW respectively. It is suggested to evaluate the performance of VARs when the system is operated at rated capacity by increasing the energy input at the generator, increasing the flow rate of LiBr solution and the chilled water flow rate in the chiller. It is suggested to improve the performance of the condenser by supplying cooling water directly from the cooling tower to the condenser. At present, the water from the cooling tower first passes through the absorber and then goes to the condenser. The water required for the absorber can be supplied separately either from a separate cooling tower or by increasing the capacity of the existing cooling tower.