National Journal of Advanced Research
Online ISSN: 2455-216X; Impact Factor: RJIF 5.12
www.allnationaljournal.com
Volume 2; Issue 6; November 2016; Page No. 32-34

Optimal design and performance vapour absorption refirgeration system

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Abstract

Absorption cooling systems have become increasingly popular in recent years from the viewpoints of energy and environment. Despite the lower coefficient of performance (COP) as compared to that of vapor compression cycle, absorption refrigeration systems are attractive for using inexpensive waste heat, solar, geothermal or biomass energy sources for which the cost of supply is negligible in many cases. In addition absorption refrigeration use natural substances, which do not cause any ozone layer depletion.

Here will be a considerable amount of waste heat from any power plant. The heat can be utilized in various ways for different purposes. Perennial problem with waste heat is the capital cost of plant, required to make its utilization justifiable. A good example of this is the use of waste heat to power absorption refrigerators. Similarly, here the waste heat from the power plant is used for running a vapor absorption refrigeration system. The aim of this paper is to arrive at with an optimum design of a vapor absorption refrigeration system (VARS) driven by any waste heat available. This involves a mathematical modeling of the vapor absorption system to produce the maximum tons of refrigeration (TR) for a given heat load. The design parameters and factors that are affecting the performance of the VARS are studied. Also a cost analysis of the system was performed. The designed system is then thermo-economically evaluated to identify the effects of design variables on costs. Thereby values of new design variables that would make the overall system cost-effective with better performance are suggested.

Keywords: Optimization; Simulation; Vapour Absorption Refrigeration System

1. Introduction

In the present energy scenario the continuous increase in the cost and demand for energy has led to more research and development to utilize available energy resources efficiently by minimizing waste energy. In recent years, there are a great deal of waste heats being released into environment, such as exhaust gas from turbines and engines, and waste heat from industrial plant, which lead to serious environmental pollution. In addition, there are also abundant geothermal resources and solar energy available in the world. Therefore, it is very important to focus on utilizing these waste heats and renewable energy for their potential in reducing fossil fuel consumption and alleviating environmental problems

The vapor-absorption refrigeration cycle is more than 100 years old. Today the technology developments have made of the absorption refrigeration an economic and effective alternative to the vapor compression cooling cycle. In recent years, theoretical and experimental researches on the vapor absorption refrigeration system (VARS) have increased, because these systems harness inexpensive energy sources (like waste heat from gas and steam turbines, solar, geothermal, biomass) in comparison to vapor compression systems. Besides, VARS cause no ecological dangers, such as depletion of ozone layer and global warming, and hence they are environment-friendly. The increase of electricity cost and environmental problems has made this heat-operated cycle more attractive for both residential and industrial applications. Absorption chillers are widely used in the air-conditioning industry, in part because they can be activated by hot water, steam and direct fired natural gas, among others, instead of electricity.

1.1 Vapor Absorption Refrigeration System (VARS)

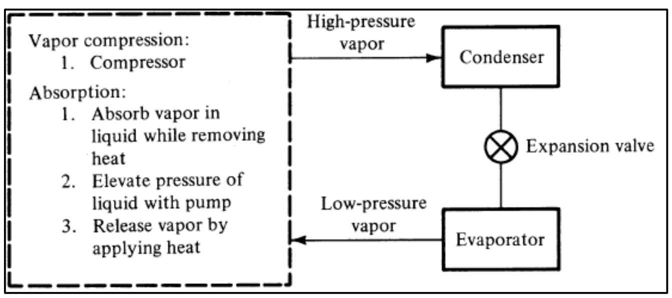

Fig 1: Comparison of VARS with Vapor compression refrigeration system

Absorption refrigeration cycle is similar to the vapor compression cycle in that it employs a volatile refrigerant, usually either ammonia or water, which alternatively vaporizes under low pressure in the evaporator by absorbing the latent heat from the material being cooled and condenses under high pressure in the condenser by surrendering the latent heat to the condensing medium. The principle difference in the absorption and vapor-compression cycles is the motivating force that circulates the refrigerant through the system and provides the necessary pressure differential between the vaporizing and condensing processes. In the absorption cycle, the vapor compressor employed the vapor compression cycle is replaced by an absorber and generator which perform all the functions performed by the compressor in the vapor compression cycle. In addition whereas the energy input required by the vapor compression cycle is supplied by the mechanical work of the compressor, the energy input in the absorption cycle is in the form of heat supplied directly to the generator.

2. Thermodynamic Modeling and simulation of Vars

The behaviour of a component or a system can be modelled by applying the conservation and applicable auxiliary laws. Modelling of the system involves in design and development of the system. This involves in the methodology of fixing the operation variables and various other factors of the system based on thermodynamic principles. The design variables and operating parameters of the system will be calculated based on mass, material and energy balances. A step by step approach is used to calculate the parameters of the system. The established correlations obtained from literature were used for calculation of thermodynamic properties.

Mass balance

$$\sum m = 0 \tag{1}$$

Material balance

$$\sum m\, x = 0 \tag{2}$$

Energy balance

$$\sum Q = 0 \tag{3}$$

2.1 Modeling and Simulation of a Double Effect Aqua-Ammonia VARS

Here for a double effect aqua-ammonia VARS has been considered for simulation. The system operates identical to that of a single effect system but, the principle difference comes in the generator. The double effect system contains an additional generator called as low pressure generator. This low pressure generator as the name indicates pressure compared to that of the high pressure generator. The refrigerant from high pressure generator which holds considerable amount of energy is made to pass through low pressure generator. This low pressure generator receives weak solution from high pressure generator, from this weak solution further more refrigerant is evolved. The system contains high pressure generator, low pressure generator, absorber, evaporator, condenser, two pressure reduction valves, an expansion valve and two heat exchangers (solution heat exchanger). The suitable correlations obtained from the literature will be used for calculating the state points of the system. The area of the components will be calculated based on which the cost of the system is calculated. The schematic diagram representing the double effect aqua-ammonia VARS is shown in Fig. 2.

Assumptions

The following assumptions are made for simplification of the simulation of double effect aqua-ammonia VARS

1. The liquid leaving the condenser is saturated at the condenser temperature
2. The strong solution leaving the absorber is saturated at the absorber temperature
3. The weak solution leaving the generator is saturated at the generator temperature
4. The strong solution is heated only up to the saturation temperature.
5. Assume that refrigerant at the exit of generator is to be 100% pure.
6. Neglect the pressure drop in the various pipe segments.
7. The effectiveness of the heat exchangers is considered to be 1.
8. The pressure in the low pressure generator is assumed to be 0.65*pressure of high pressure generator.

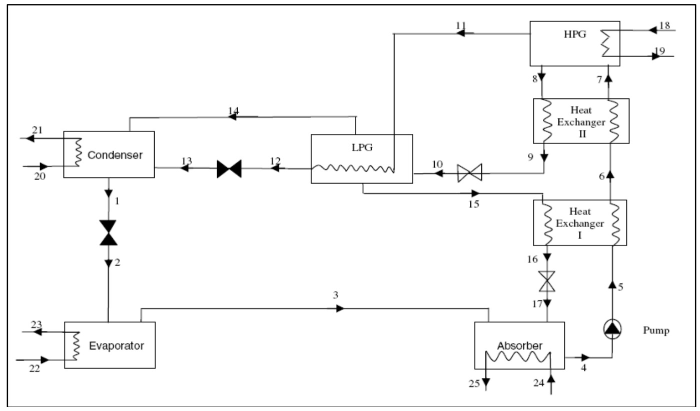

Fig 2: Schematic diagram of a double effect aqua-ammonia VARS

3.0 Results and discussions

3.1 Single Effect LiBr-H_2O VARS

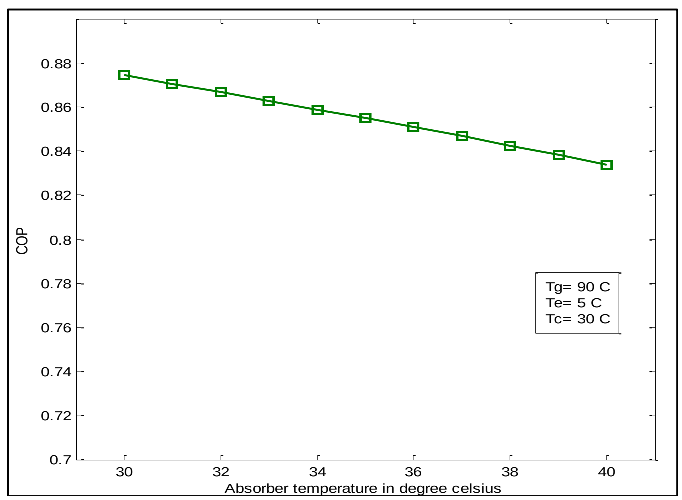

Fig 3: Variation of COP with increase in absorber temperature (single effect LiBr-H_2O VARS)

4. Double Effect NH_3-H_2O VARS

Variation of COP with Change in System Parameters

The system shows some different characters compared to single effect system. From Fig 4. It is evident that with increase in generator temperature there is decrease in COP of the system. This can be attributed to the fact that more amount of refrigerant get evolved in low pressure generator when operated at lower generator temperatures which contributes to increase in COP.

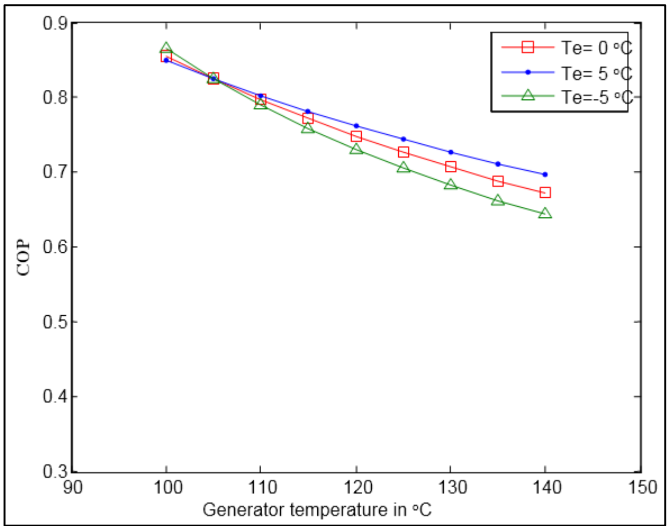

Fig 4: Variation of COP with increase in temperature of high pressure generator

5. Optimization Results

The optimization of the system is done based on the GA program. The results of optimization are obtained. The program is run for several times and average of the temperatures has been taken and the best operating temperatures are found. Atypical results obtained with respect to this are given below for the 20 tonne refrigeration capacity. The program is run for several times and the average of the results was taken. The trial results of the program were shown in table 1. The programs for simulation and optimization were given in annexure.

Evaporator temperature=3 ^{0}C;
Generator temperature =108 ^{0}C;
Condenser temperature= 35.5 ^{0}C;
Absorber temperature = 35 ^{0}C;
COP = 0.4224;
Total cost of the system= 7.77 Lakhs.

5. Conclusions

Vapor absorption refrigeration proves to be a best alternative for the utilization of waste heat. The simulation results show that a single effect LiBr-H_2O VARS has higher COP compared to that of single effect aqua-ammonia VARS. The results show that a vapor absorption refrigeration system performs best at high generator temperature and evaporator temperatures and at low absorber and condenser temperatures. The absorber in the system is most influential in both performance and cost ways. Also the simulation results show that double effect system are better when compared to the single effect systems, without much variation in the cost of the system. The optimization results show the best operating parameters with respect to COP to cost ratio of the system as T_e= 3 ^{0}C, T_g =108 ^{0}C, T_c= 35.5 ^{0}C, T_a= 36 ^{0}C.

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