Waste Heat Utilization of Vapor Compression Cycle for Operation of Vapor Absorption System

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***Abstract*- There are two types of energy i.e. high grade energy and low grade energy. Majority of the processes require high grade energy which is depleting day by day. Hence, it has become a matter of great concern to use the non conventional source of energy or to recover the waste heat liberated from the processes. This paper studies theoretical approach to recover the waste heat liberated from vapour compression cycle, which is used to run vapour absorption cycle. The required heat has been given by solar energy. The work evaluated the performance of combined cooling cycle.**

***Index Terms*- combined cooling cycle, waste heat recovery, Vapour compression cycle, vapour absorption cycle, solar heat**

I. INTRODUCTION:-Energy is the driving force of civilization and it measure prosperity of the nation. Now a day, per capita energy consumption is directly related with per capita income of the people. All developed and developing countries are using conventional energy rapidly. Due to high rate of consumption of energy, sources available in earth surface will exhaust after some period. Therefore, engineers and scientists are trying to see new possibilities to use sources efficiently and utilize waste heat. Waste heat is the heat which gets untapped and directly released into the atmosphere. It is released in the form of streams of gases and liquids which leaves the system at a temperature higher than the surrounding.

In present work combined cooling has been carried out. In this combined cycle, vapour compression cycle (VCC) is topping cycle and vapour absorption cycle (VAC) is bottoming cycle. The exhaust of topping cycle is utilized by bottoming cycle. Combined cycle performance is far better than single running cycle. Present work deals in improving the performance of a combined cooling cycle i.e vapour compression cycle and vapour absorption cycle. The exhaust of VCR is utilized to drive VAC with the help of solar energy.

In the present work two cooling cycle run parallel to each other. One is topping cycle and the other is bottoming cycle. Topping cycle is VCC and the bottoming cycle is VAC. It can be clearly observed from the combined diagram that the waste heat liberated from the condenser section of the vapour compression cycle is transferred to the generator section of the vapour absorption cycle, but this alone may or may not be sufficient to drive the bottoming cycle. Hence, some amount of heat energy is also taken from a non conventional source of energy i.e solar energy which is abundantly available. Solar heat is utilized by using a flat plate collector. The solar collector generates required heat at generator section of VAR. The main purpose of adding solar heat is to raise the temperature inside the generator which would be sufficient enough to convert liquid ammonia to vapour form.

There a possible way to utilise this waste heat i.e waste heat powered ejector refrigeration system. The waste heat obtained from the vapour compression refrigeration system could be used to phase change of the refrigerant in generator of the ejector system. In this way it might be possible to improve the co-efficient of performance of a vapour compression system by combining it with simple ejector system, which would be operated by this waste heat, obtaining from compression cycle. The two refrigeration systems i.e one is high grade energy operated and other one is low grade energy operated system could be joined together to form a combined refrigeration system so that improve the COP of the plant. Here we propose a theoretical approach to operate an Ejector refrigeration plant by the waste heat from the condenser of a vapour compression refrigeration plant. In this way an additional cooling effect is obtained without giving any additional energy or heat.

There are two refrigeration plants (as shown in figure) one is simple vapour compression plant (a-b-c-d-a) and other one is Simple ejector system (1-2-3-4-5-6-1) **[6]** join together to form a combined refrigeration system. As we can see from block diagram as well as T-s diagram that heat required to operate the ejector cycle is coming from condenser of the vapour compression cycle. In vapour compression cycle process a-b is condensation, vapour refrigerant reject its latent heat and convert in liquid form, process b-c is expansion, obtain low pressure liquid refrigerant, process c-d is evaporation of refrigerant, producing cooling effect by absorbing heat from surrounding, process d-a is compression, obtain high pressure vapour refrigerant; and cycle repeats its path. On other hand, Referring to the basic ejector refrigeration cycle in Figure ,the system consists of two loops, the power loop and the refrigeration loop. In the power loop, low-grade heat, QG, (obtaining from condenser of vapour compression system) is used in a generator to evaporate high pressure liquid refrigerant (process 6-1). The high pressure vapour generated, known as the primary fluid, flows through the ejector where it accelerates through the nozzle. The reduction in pressure that occurs induces vapour from the evaporator, known as the secondary fluid, at point 2. The two fluids mix in the mixing chamber before entering the diffuser section where the flow decelerates and pressure recovery occurs. The mixed fluid then flows to the condenser where it is condensed rejecting heat to the environment, Qc.

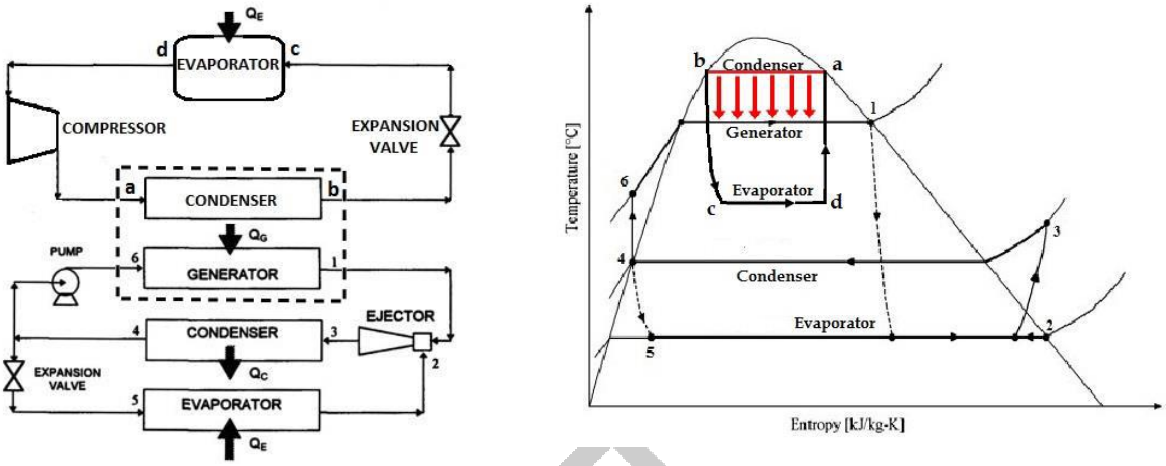

Fig. 1. Combined Vapour compression and absorption System

II. LITERATURE REVIEW:-

Mahto & Pal(1) reported the utilization of exhust gas of topping cycle(gas turbine) to run bottoming cycle (Rankine cycle). In their work they used exhaust of gas turbine cycle to run the Rankine cycle. Maurya and Avasthi(2) evaluated the waste heat from vapour compression cycle and utilized it using an ejector. They studied at a generator temp. 64°C, condenser temp. 44°C and evaporator temp. 10°C and plant capacity 7tons and there refrigerant was F12. . They found that the cop of the plant increased by 50% if the waste heat was utilized using an ejector.

Renjith and Joshi (3) concluded in their work that ammonia water as a refrigerant for vapour absorption cycle is the most suitable pair. They also show that this pair of refrigerant eliminates dependency on fossil fuels and advantageous in ozone layer depletion. Dipak Jagdhane (4) elaborated double cooling effect with the waste heat liberated from the engine surface. They utilized exhaust heat of engine surface to heat the aqueous ammonia solution in the generator section of the vapour absorption cycle. They found an additional cop of 0.4.

Kaushik and Singh(5) reported the analytical study of vapour absorption refrigeration cycle by applying energy and mass balance in each section of the absorption system. They designed lithium bromide-water (LiBr-H2O) absorption refrigeration system with capacity of 5.25 kW and the cop of the system was found 0.881.

Nguyen *et al.* (2001) developed a pump-less ejector refrigeration system driven by solar thermal energy. Water was used as refrigerant in the system, which goes back to the generator from the condenser by means of the gravity force. A prototype was constructed and the experiments were done with the system. The results showed that the COP can be up to 0.32 with the operation condition: generation temperature of 76.6 , evaporation temperature of 1.5 , condensation temperature of 26.82 , and the cooling capacity of 5.09 kW. The minimum vertical separation of the condenser to the generator was 7 m mentioned in the paper; the large height of the system restricted the use of such system in some circumstances. **[1]** On other way, combined vapour compression and ejector refrigeration system is other method to maximize the co-efficient of performance of vapour compression system by using heat recovery phenomenon.

III. ANALYSIS OF VAPOUR COMPRESSION CYCLE

Let us consider an R134a vapour compression refrigeration plant of refrigeration capacity 2 TR working under following conditions:

Table 1: Vapour compression Refrigeration System description

Suction Pressure of compressor	22PSI = 1.51 bar
Discharge Pressure of compressor	127 PSI= 8.75 bar
Evaporator temperature	7^0C
Condenser temperature	56^0C
Power I/P	240V, 50Hz supply

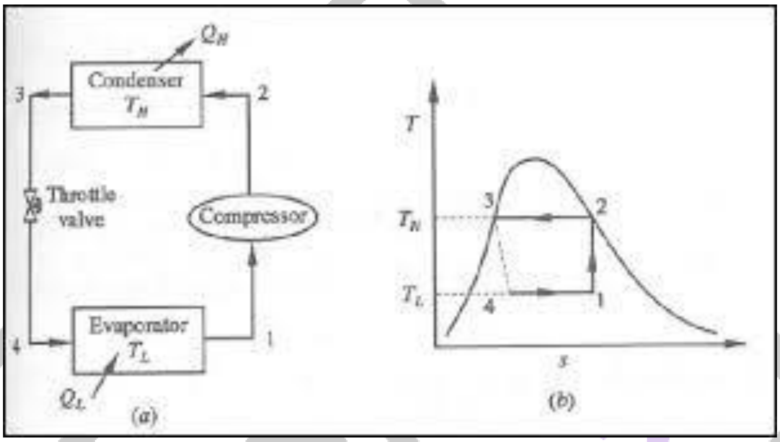

Fig. 2. T- s Plot of Vapour compression Refrigeration System

From P-H Diagram of R134a Chart h_1= 430 kj/kg
h_2= 445 kj/kg
h3= h_4 = 260 kj/kg

Mass Flow Rate of Refrigerant= (2*3.5)/(h1-h4) = (2*3.5)/(430-260) = 0.04 kg/sec
Rejected heat through condenser = mr (h2 – h3) = 7.6035 kw
COP = $\frac{(h1-h4)}{(h2-h1)}$= **11.33**

IV. ANALYSIS OF VAPOUR ABSORPTION CYCLE

Let us consider a aqua ammonia(NH_3-$H_2$0) vapour absorpsion plant working under the following considerations.

Table 2: Vapour Absorption Refrigeration System description

Model Of VAR	RH440LD
Volume	14ltr
I/p Voltage	220-240V AC. 50-60Hz

Refrigerant	H_20 14gm/$NH_3$100gm
Insulation Gas	C_5H_{10}

From the h-c chart we find the enthalpies at various points and consequently the heat energy associated with each section of the vapour absorption cycle.

h1 =1600 kJ/kg

h8 = 380 kJ/kg

h2 = h3 =500 kJ/kg

ha = 90 kJ/kg

h4 = 1650 kJ/kg

h9 = h10 =100 kJ/kg

h5 = h6 = 50 kJ/kg

h11 = 1720 kJ/kg

h7 = 310 kJ/kg

h12 = 1870 kJ/kg

Heat given to generator is 78% of heat supplied by vapour compression cycle

i.e. considering 22% losses. Therefore, Qg = 31 kW

Qe = mr (h4 – h3) = 16.877 kW

Qc = mr (h1 – h2) = 16.923 kW

Qa = mr (h4 - ha) = 23.01 kW

Cop = 0.62

Therefore in order to achieve the heat requirement the condenser of capacity 7.5 kw & 24 kw of heat from a solar collector will be required to the VAR system.

V. CONCLUSION: - By utilizing the waste heat released from vapour compression cycle to vapour absorption cycle we have increased the coefficient of performance by 10.5 %. As load on the evaporator section of the vapour compression cycle increases, more heat is released in the condenser section. Thus performance of the combined cooling cycle increases with increased loads in the topping cycle.

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