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Waste heat Utilization of vapour compression cycle

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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.

List of symbols

COP	Coefficient of performance
VCC	Vapour compression cycle
VAC	Vapour absorption cycle
Q	Heat energy (kW)
h	Enthalpy (kJ/kg)
s	Entropy (kJ/kgK)
x	Quality of steam
Subscripts	
g	Generator
c	Condenser
a	Absorber
e	Evaporator

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.

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.

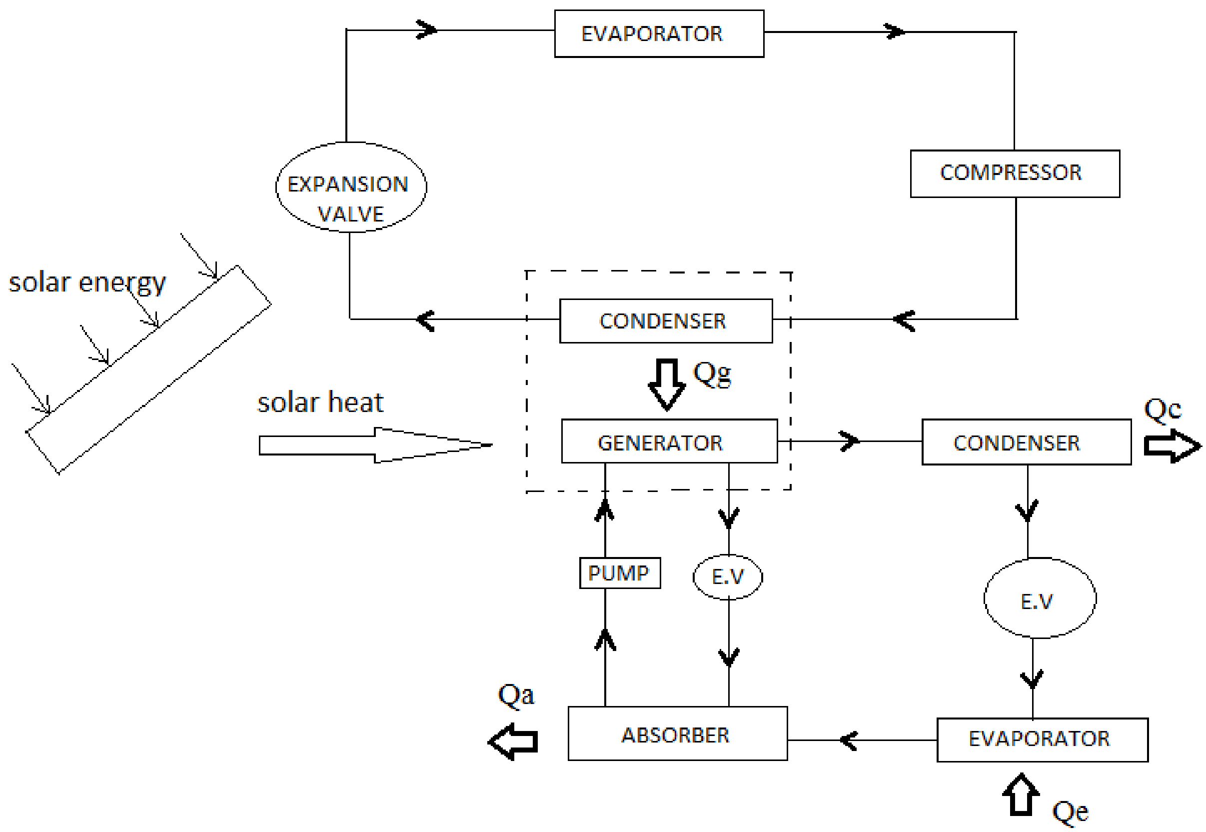
Dipak Jagdhane (4) elaborated double cooling effect with the waste heat liberated from the engine surface. They utilized exhaust heat of engine surface to heat the aqueous ammonia solution in the generator section of the vapour absorption cycle. They found an additional cop of 0.4.

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-H_2O) absorption refrigeration system with capacity of 5.25 kW and the cop of the system was found 0.881.

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.

II. THEORY

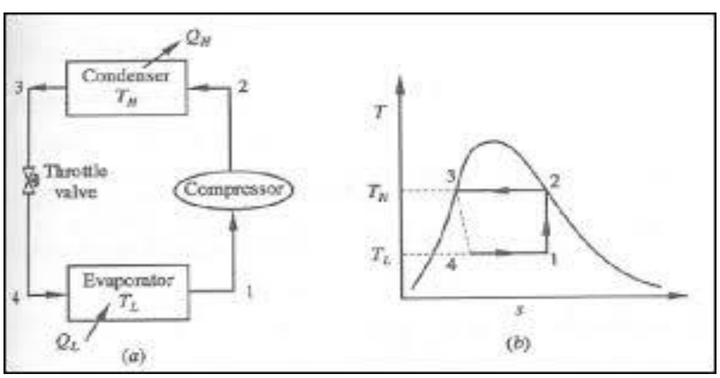
In the present work two cooling cycle run parallel to each other. One is topping cycle and the other is bottoming cycle. Topping cycle is VCC and the bottoming cycle is VAC. It can be clearly observed from the combined diagram that the waste heat liberated from the condenser section of the vapour compression 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.



III. ANALYSIS OF VAPOUR COMPRESSION CYCLE

Considering a F-12 vapour compression refrigeration(Topping cycle) plant of refrigeration capacity 10 TR working under following conditions.

Temp (°C)	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kgK)	s_g (kJ/kgK)
30	64.56	199.62	0.2398	0.6853
-15	22.32	180.955	0.09045	0.7053



$h_3 = h_4 = 64.56$ KJ/kg

$h_2 = 199.62$ KJ/kg

$s_1 = s_2$

$s_1 = s_f + x(s_g - s_f)$

$s_2 = 0.6853$ kJ/K

Therefore, $0.09045 + x\,(0.7053 - 0.09045) = 0.6853$

$x = 0.9674$

Therefore, $h_1 = h_f + x(h_g - h_f)$

$h_1 = 22.32 + 0.9674\,(180.955 - 22.32)$

$h_1 = 175.783$ kJ/kg

m_r = refrigerant flow rate = $\frac{10*3.5}{(h1-h4)} = \frac{10*3.5}{175.783-64.56}$ =0. 3146 Kg/s

Rejected heat through condenser = $m_r (h_3 - h_4)$

= 0.3146 (199.62 – 64.56) = 42.5kW

COP = $\frac{h1-h4}{h2-h1} = \frac{175.783-64.56}{199.62-175.783} = 4.666$

IV. ANALYSIS OF VAPOUR ABSORPTION CYCLE

Let us consider a aqua ammonia(NH3-H20) vapour absorpsion plant working under the following considerations.

Concentration of strong solution	0.4
Concentration of weak solution	0.3
Condenser pressure	14 bar

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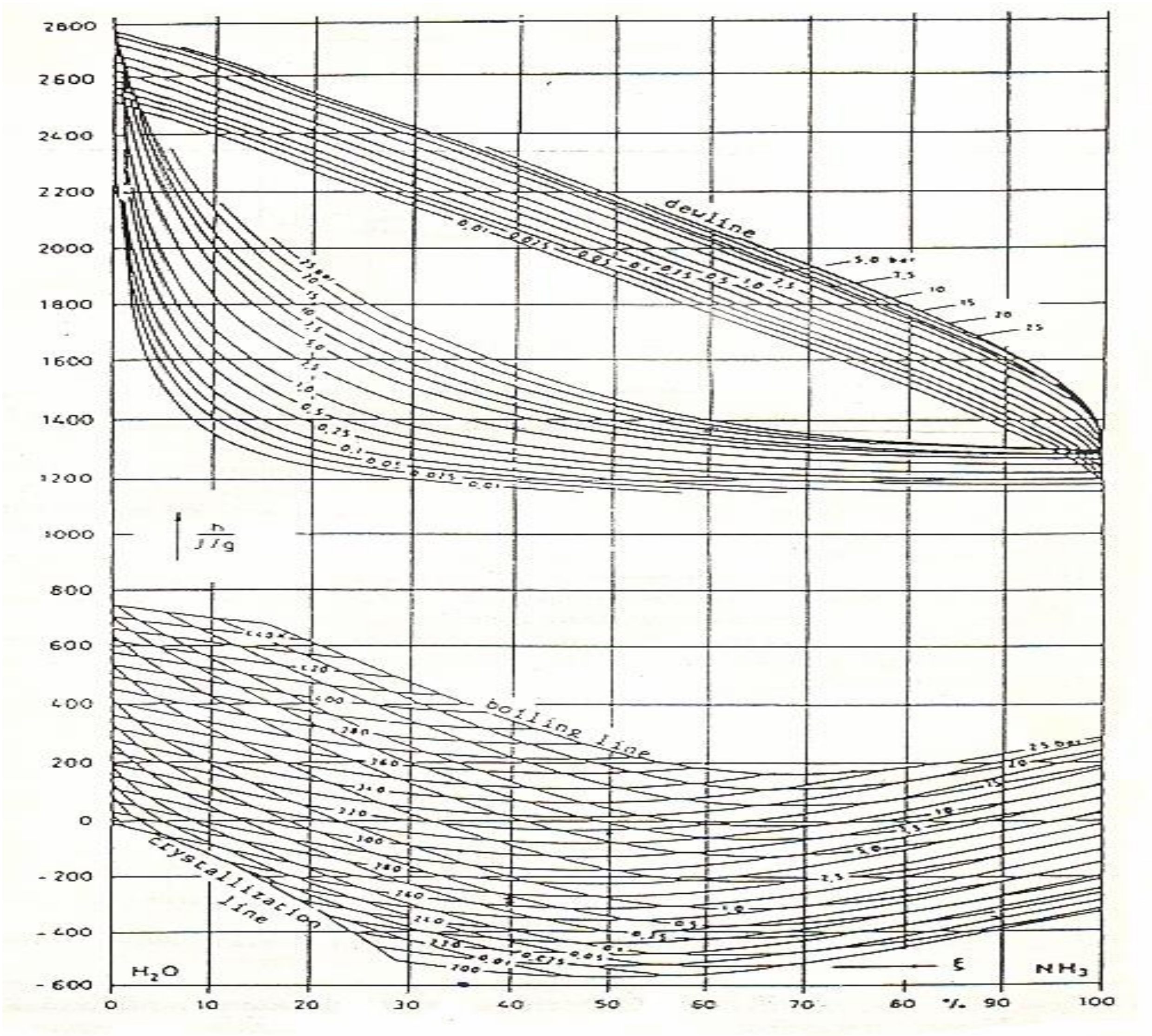
Evaporator pressure	2 bar

h-c chart



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 =1620 kJ/kg	h8 = 400 kJ/kg
h2 = h3 =510 kJ/kg	ha = 100 kJ/kg
h4 = 1600 kJ/kg	h9 = h10 =100 kJ/kg
h5 = h6 = 50 kJ/kg	h11 = 1750 kJ/kg
h7 = 300 kJ/kg	h12 = 1850 kJ/kg

Heat given to generator is 80% of heat supplied by vapour compression cycle
i.e. considering 20% losses.

Therefore, $Q_{g} = 34$ kW

Refrigerant flow rate = $m_r = \frac{34}{h12-ha} = 0.0153\ kg/s$

Therefore,

$Q_e = m_r\,(h4 - h3) = 16.677$ kW
$Q_c = m_r\,(h1 - h2) = 16.983$ kW
$Q_a = m_r\,(h4 - ha) = 26.01$ kW
Cop = $\frac{Qe}{Qg} = 0.49$

V. RESULTS

In this paper a vapour compression cycle is proposed which is working under the temperature limits of -15°C to 30°C i.e. evaporator temp is -15°C and the condenser temp is 30°C . The refrigerant is F-12 and the system is designed for a capacity of 10 TR .The waste heat liberated from the condenser is utilized in a vapour absorption cycle working under the pressure limits of

14 bar and 2 bar . The refrigerant is ammonia and the absorbent is water and the concentration of the strong and weak solution is taken as 0.4 and 0.3 respectively. Analysis of work found an additional cop of 0.49.

VI. 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.

REFERENCES

[1] D. Mahto, S. pal "Thermodynamics and thermo-economic analysis of simple combined cycle with inlet fogging", Applied Thermal Engineering, 51 (2013) 413-424

[2] Satish. K. Maurya, Saurav Avasthi, " Waste Heat Recovery : An Analytical Study of Combined Ejector and Vapour Compression Refrigeration System", International Journal of Engineering Sciences and Research Technology , March 2014

[3] V.R.Renjith, P.J.Joshi, " Vapour absorption refrigeration system using low grade energy- an ecofriendly approach" First international seminar SAFE 99,on safety and fire engineering,Cochin,India ,November 24-26, 1999

[4] Dipak Jagdhane, " Automobile Double Cooling Effect" , International Journal of Mechanical and Industrial Techology Vol 1,Issue 1,pp (40 - 47) , Month: (oct 2013-march 2014)

[5] Sachin Kaushik , S Singh, "Thermodynamic Analysis of Vapour Absorption Refrigeration System and Calculation of COP", International Journal for Research in Applied Science and Engineering Technology Vol 2 , Issue 2, Feb 2014

[6] Arora and Domkundwar, " A course in Refrigeration and Air conditioning" chapter(4 & 7)

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