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Study of Vapour Absorption System Using Waste Heat in Sugar Industry

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Abstract: - *Most of the energies are utilized by the industries due to depletion of fossile fuels and increasing the fuel price to exploit the maximum presented energy from the waste heat source. The sugar industry steam turbine exhausts carry a considerable amount of thermal energy. This energy can be set in to positive use as a heat source for vapour absorption system to serves as cooling system. This paper illustrates the thermal and fiscal advantages of using single effect lithium bromide water absorption by means of waste heat. The objective of this work is to hypothetical design of lithium bromide water absorption Refrigeration system using waste heat from sugar industry steam turbine exhaust. The various parts of the vapour absorption system are absorber, solution heat exchanger, evaporator, condenser and generator. The hypothetical design based on the cooling effect required for DC thyrist motor in a sugar industry. Energy consumption and energy savings in terms of energy and fuels are calculated. The Overall heat transfer coefficient, effectiveness and COP of the heat exchanger are measured.*

Keywords: - *DC thyrist motor, effectiveness, steam, vapour absorption system, waste heat and lithium bromide.*

I. INTRODUCTION

The energy and global warming crises have drawn rehabilitated benefit to thermally driven cooling systems from the air conditioning and process cooling fraternities. The lithium bromide-water absorption chiller is one of the favorites due to the following specific reasons: (i) it can be thermally driven by gas, solar energy, and geothermal energy as well as waste heat, which help to substantially reduce Carbon dioxide emission; (ii) its use of water as a refrigerant; (iii) it is quiet, durable and cheap to maintain, being nearly void of high speed moving parts; (iv) its vacuumed operation renders it amenable to scale up applications. LiBr-H2O absorption chillers enjoy cooling capacities ranging from small residential to large scale commercial or even industrial cooling needs. The coefficient of performance (COP) varies to a small extent (0.65-0.75) with the heat source and the cooling water temperatures. Single effect chillers can operate with hot water temperature ranging from about 80^0C 120^0C when water is pressurized.

[1] The paper describes about increasing nature of the refrigerant and tried different type of salt. [2] It provides a literature review on absorption refrigeration technology [3] Design and Construction of a Lithium Bromide Water Absorption with a nominal capacity of 1 kW. [4] This paper presents a thermodynamic modeling study of the utilization of an existing high potential geothermal low-temperature heat source (114 kg/s and 73º C). [5]Solar Energy to Drive Half-Effect Absorption Cooling System. Most of the papers are express upgrading of the technology so for concentrating the thermal energy recovery system.

Quality of steam in steam turbine exhaust:
Mass flow rate = 3.76 T/hr.
Inlet temperature of water =109 ^{0}C.
Inlet pressure of steam =0.6 kg/cm^2
For this availability the single effect lithium bromide vapour absorption system adopted so this paper illustrate about the hypothetical design of the system according to requirement of the industry.

II. ENERGY RECOVERY

Available energy in the steam turbine exhaust:
Q = ms × Cps × (tout-tin), Where, h = Cps × (tout-tin),hsup= [hs+ Cps × (tsup-tsat)],hsup = 2699.3 kJ/kg.
Total heat energy available = ms × hsup, = 2811.81 kJ/sec.
Vapour compression system for producing the cooling effect to the thyrest DC motor drives, Specification of air conditioned room Area of the space to be cooled: 15 m^2, Volume of the room: 152 m^2 Total number of machine: 3TR/each, Compressor input power: 4kW, Company: blue star, Total refrigeration capacity: 12TR.

Energy required for operating the vapour Compression system
P = 4 kW/machine = 4 × 2/3 × 24,= 64 kW/day/machine, Total number of machine is 4 so,= 4 × 64,P = 256 kW/day.
256 kW of energy required for operating the vapour compression system for producing the cooling effect to thyrest DC motor drive for a day. The plant operated 180 days for the year.

Energy required for vapour compression System
= 46080 units/year.
Energy required for operating vapour absorption System
= 2% of VCR
Energy required for vapour absorption system
= 921.6 units/year.
Energy recovery = (Energy required for vapour Compression system) – (Energy required for vapour absorption system)
= 45158.4 units/year.

Energy saving in terms of fuel:

Calorific value of bagasse	= 2500 kcal / kg.
	= 10465 kJ/kg.
Total amount of electricity saved per year	= 45158.4 units
Mass of steam required	= 45158.4 × 5.5
	= 251671.2 kg of steam.
Enthalpy of super heated steam	= hs + Cps (tout-tin).
	= 2634.25 kJ/kg.

$$\text{Efficiency Of the boiler} = \frac{\text{Energy available}}{\text{Energy supplied by the coal.}}$$

Mass of fuel saved **= 74.53021 tons of fuel.**

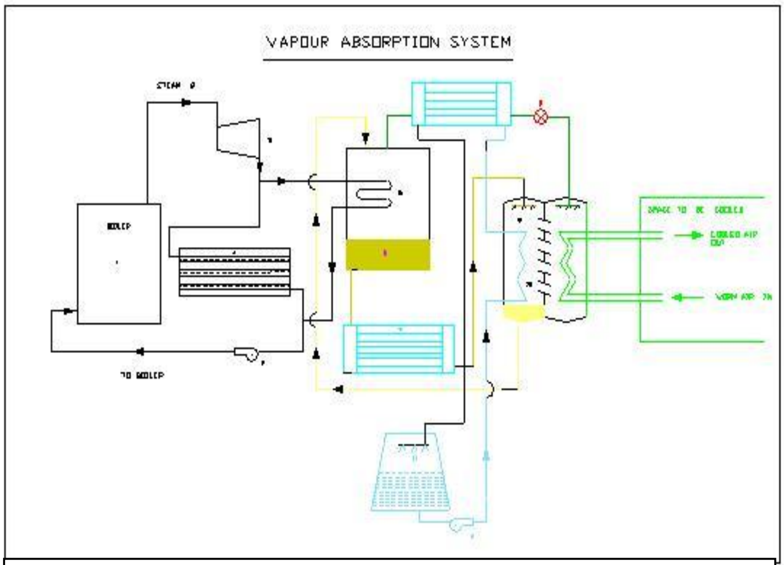
III. THEORETICAL DESIGN OF VAPOUR ABSORPTION SYSTEM

Assumptions

Generator and condenser as well as evaporator and absorber are under same pressure, Refrigerant vapor leaving the evaporator is saturated pure water, Liquid refrigerant leaving the condenser is saturated, Strong solution leaving the generator is boiling, Refrigerant vapor leaving the generator has the equilibrium temperature of the weak , solution at generator pressure Weak solution leaving the absorber is saturated ,No liquid carryover from evaporator, Flow restrictors are adiabatic , Pump is isentropic, No jacket heat losses.

Crystallization of lithium bromide:

The Crystallization of lithium bromide is the major dilemma while in operating because pure water as refrigerant so should not able to operate below 4^0C.If operated then the refrigerant will be in solid form after that system get collapsed. Primarily lithium bromide and water solution are mixed in 60% ratio because 60% provide better than other ratios [2]. The generator predominantly used for boost the pressure and temperature of the solution after increasing the temperature solution will be separated like lithium bromide and water after completing the process again mixed with desired ratio then only can continue the process so for according to the temperature of the refrigerant should fix the temperature of the solution for that the crystallization chart plays a major role for finalizing temperature of the absorber and evaporator.



1. Boiler	5.Generator	09. Expansion device
2. Steam	6.Li-Br 60% Solution	10.Water inlet 3.
3. Turbine	7. Solution heat exchanger	11. Cooling tower
4. Condenser	8.absorber	12.Space to be cooled

Fig No: 1 Layout of vapour absorption Refrigeration system

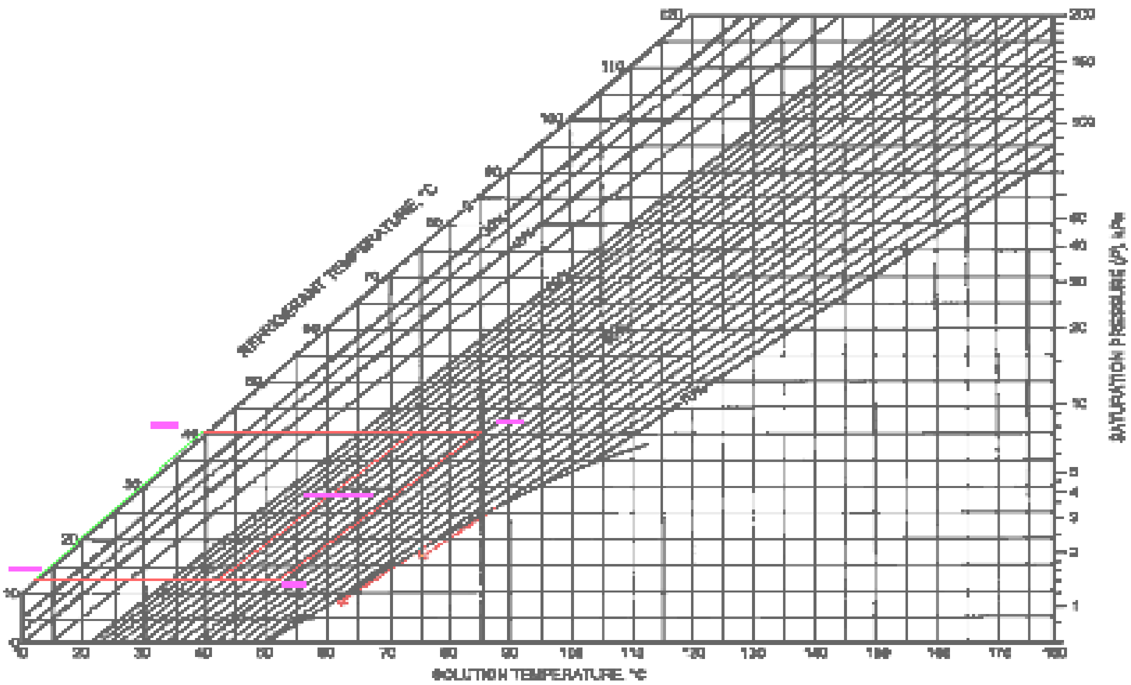


Fig No: 2 crystallization of lithium bromide

Table No: 1 Significance of Parts of Vapour Absorption System

S.No.	Parameters	Unit	Evaporator	Condenser	Solution	Absorber	Generator
1.	Inlet temperature	°C	11	85	85	62	109
2.	Outlet temperature	°C	22	40	62	45	89
3.	Inlet temperature of coolant	°C	40	72	45	33	55
4.	Outlet temperature of coolant	°C	26	33	55	72	85
5.	Mass flow rate of Refrigerant	Kg/sec	0.03769	0.03769	0.01492	0.01442	0.01492
6.	Mass flow rate of coolant	Kg/sec	0.12627	0.01042	0.053	0.01043	0.053
7.	Average heat transfer coefficient	$\frac{W}{m^2k}$	3135.29	5768.16	1598.4	1192.7	8318.2
8.	Overall heat transfer coefficient	$\frac{W}{m^2k}$	613.30	2193.73	496.03	1992.8	703.62
9	Average heat transfer coefficient for air	$\frac{W}{m^2k}$	2597.5	655.12	2420.09	423.63	2426.02
10.	Inner diameter of the tube	mm	8.0962	8.0962	8.0962	8.0962	8.0962
11.	Outer diameter of the tube	mm	9.525	9.525	9.525	9.525	9.525
12.	Length of the tube	m	1	1	1	1	1
13.	Area of the heat transfer	m^2	0.06433	0.06433	0.1525	0.0383	0.2516
14.	Evaporator load	KW	1.76309	1.7004	1.114	0.4521	3.002
15.	Number of tube required		5	3	6	2	9
16.	Effectiveness of heat exchanger	%	50.04	86.5	82.6	29.25	55.55
17.	Number of transfer unit		0.8	1.094	3.5	0.4	1
18.	Logarithmic Mean temperature difference		15.99	41.19	14.28	17.312	15.99

IV. DESIGN OF PUMP

Coolant Pump Design

Mass how rate of solution $\dot{m}_{sl55}$ = $0.01043 \frac{lit}{sec}$

Assume, Suction head h_s = 8 m

Delivery head h_d = 10 m

Q_{act} = $1.738 \times 10^{-5} \frac{m^3}{sec}$

C_d = 0.6

d = 0.058 m

L = 0.076 m

P = 3.066 W

Solution Pump Design

Q_{act} = $0.0530 \times 10^{-3} \frac{m^3}{sec}$

Q_{th} = $8.883 \times 10^{-5} \frac{m^3}{sec}$

Assume, Suction head h_s = 1m

Delivery head h_d = 2m

d = 0.058 m

L = 0.076 m

P = 12.99 W

CONCLUSION

The theoretical design of vapour absorption refrigeration system is done and each parts of the machine are adjusted to the requirements of the output. From that above design the following conclusions are made.

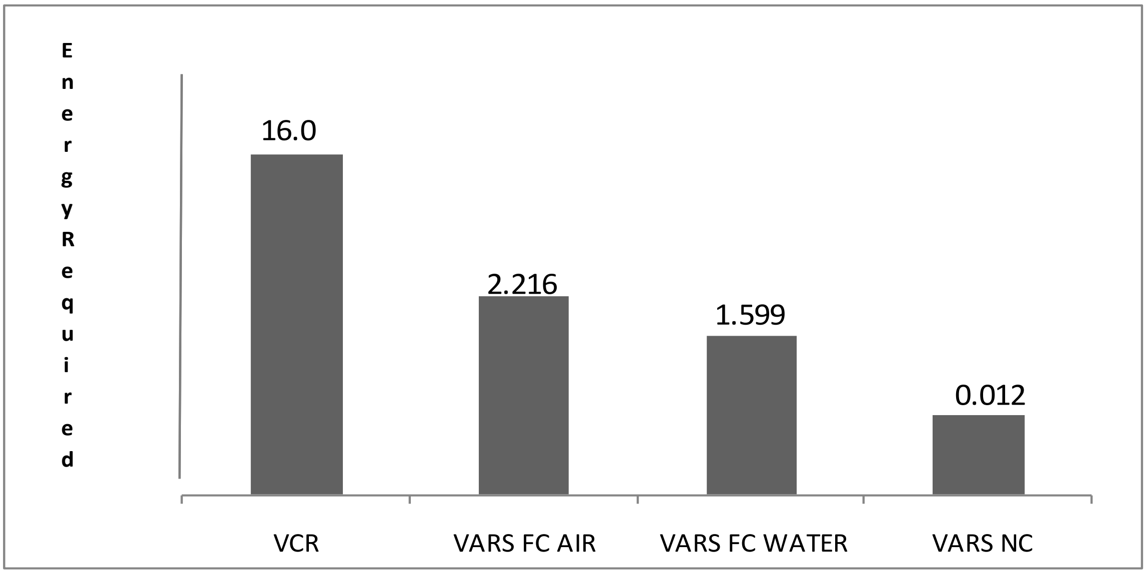
Energy required for operating vapour compression system = 16 kW/hr.
Energy required for operating 55% solution pump = 0.012 kW/hr.
Energy required for operating for forced convection using water = 1.599 kW/hr.

Fig No: 3 comparisons of vapour compression system and vapour absorption system

If using natural convection for cooling the condenser then can save 1.599 kW and can eliminate the compressor or pump. The cost of the installation will be reduced.

Total energy saved using vapour absorption system = 15.988 kW/hr.
Total energy recovery = 45158.4 kW/year
Annual cost saving = Rs 158056/year.

The reduction of ozone layer caused by the refrigerant which used in vapour compression system but the vapour absorption system offer better environment.



ABBRIVATION

ms = Mass of steam Kg.
Cpw = Specific heat of water KJ/Kg k.
Cps = Specific heat of steam KJ/Kg k.
hs = Enthalpy of steam KJ/Kg .
hsup = Enthalpy of super heated steam KJ/Kg.
Tout = Outlet temperature.
Tin = Inlet temperature.
P = Power.
P_a- Atmospheric pressure = 1.01325 bar
V_a- Volume of air in m^3
R- Gas constant = 0.287$\frac{kJ}{Kg.k}$
T_a- Atmospheric temperature=31ºc
M_a- Mass of Air in kg
$\dot{m}_a$- Mass flow rate of Air in $\frac{kg}{sec}$.
$\dot{m}_r$- Mass flow rate of Refrigerant in $\frac{kg}{sec}$.
C_{Pr}- Specific heat of Refrigerant = 4.134 $\frac{kJ}{Kg.k}$
C_{PA}- Specific heat of Air =1.005 $\frac{kJ}{Kg.k}$
T_1- Inlet temperature of refrigerant in ºC
T_2- Outlet temperature of refrigerant in ºC
T_3- Inlet temperature of Air in ºC
T_4- Outlet temperature of Air in ºC
Q_e- Evaporator load in kW
T_{mf} - Mean flim temperature in ºC
ρ- Density in $\frac{kg}{m^3}$
μ- absolute viscosity in m $\frac{NS}{m^3}$
γ- Kinematic viscosity in $\frac{m^2}{sec}$
K- Thermal conductivity in $\frac{W}{mk}$
A - Area in m^2
V- Velocity in $\frac{m}{sec}$
Re- Reynolds Number
Nu- Nusselt Number
h_i- Average heat transfer coefficient for hot fluid $\frac{W}{m^2k}$
h_o- Average heat transfer coefficient for hot fluid in $\frac{W}{m^2k}$
U- over all heat transfer coefficient in $\frac{W}{m^2k}$
p_r- Prandcl Number
LMTD- logarithmic mean temperature difference
N- Number of tube
l- Length of the tube
e_g- Effective ness of the heat exchanger for generator
C_{min} - $m_h C_{ph}$ (or) $M_c C_{pc}$
NTU- Number of Transfer unit
D_i- Inner diameter of the tube =8.09×10^{-3}m
D_0- Outer diameter of the tube =9.525×10^{-3}m

Acknowledgment

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