

# Waste heat energy utilization in refrigeration and air-conditioning

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**Abstract.** This paper represents the utilization of wastage of heat energy from Refrigeration and air-conditioning, thereby saving energy. Generally in refrigeration system waste heat available at condenser unit, so we have used that available waste heat for heating of water. For making this system multifunctional, flexible and economical Condensing coil is immersed in water to be heated and a part of cooling coil 1<sup>st</sup> passed through filled water tank in which water is to be cooled and then remaining coil is utilized for cooling of air so that desired space to be cooled. Hence here cooling of air, water and heating of water all the three process is done simultaneously in a single unit. For this an experimental setup is designed and fabricated in the hydraulic machine lab of BIT sindri, Dhanbad and various measuring parameter were recorded through different instruments. The COP of system, Capacity of water heater and cooling capacity of room air cooler here calculated is 4.03, 1.51, 3.0034 TR respectively, which is within permissible range.

## 1. Introduction

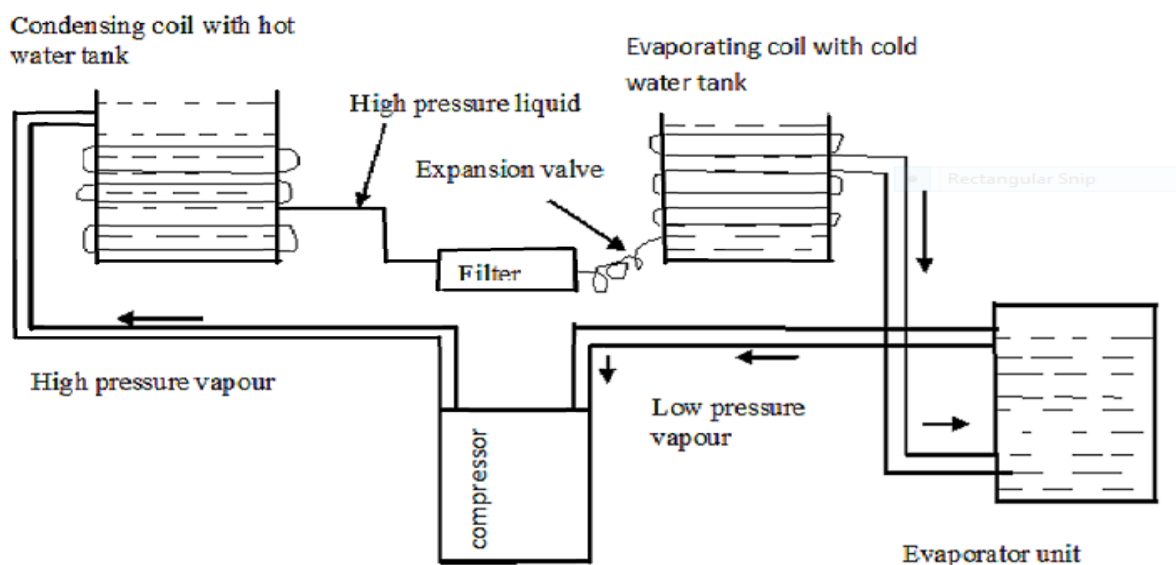
This project is to fulfill the needs of people and new technological advancements to work as an economic utility at all places to provide comfort conditions to the people. In comparison to previous systems of obtaining hot water through heat pumps, this proposed unit provides utilization in multi – purpose ways throughout year with better performance. We have used R134a (Tetra fluoro ethane) as a refrigerant in this project since Due to absence of chlorine atom in its molecular formula its ozone depletion potential is zero and hence it is ecofriendly. Technique employed here is only modification of simple vapor compression cycle.

Jatinder gill et al.,[1] Investigated by taking LPG and R134a as mixture of refrigerant in the weight ratio 28:72 . And concluded that this mixture can be better substitute of R134a refrigerant in VCRS, on the basis of better COP, lower pull down times and discharge temperature of compressor with respect to R134a. Devesh chugh et al.,[2] Presented results on experimental basis related to hybrid system which saves energy for utilizing in heating of water released in the process of dehumidification .They have utilized ionic liquid to eliminates corrosion and crystallisation issues. K.Harby et al.,[3] Proposed technique of heat pump coupled cooling system in residents by using evaporative condensers .They found by using this technique COP can be improved by approximately 113.4% and energy usages can be diminished up to 58% with system cooling capacity up to 3-3000 KW. Calin sebachievici et al.,[4] Presented device based on operation of energy for heat pump system which is coupled with ground, tested performance in different operating modes of proposed system.



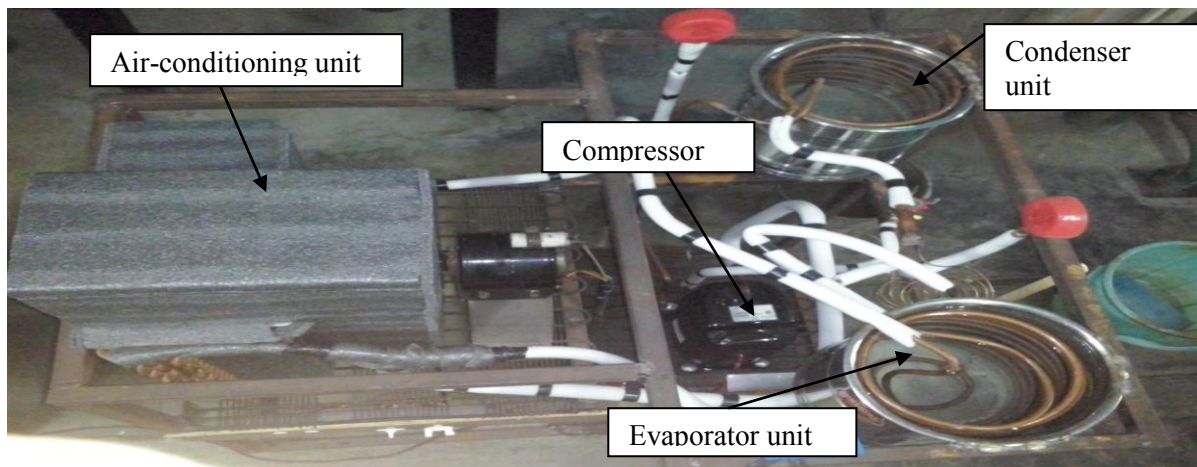
They also found simulations using transient systems simulation software in good bond with expected data. Alexandros arsalis et al.,[5] Studied and fabricated a model of cooling and heating unit based on solar energy. They also did parametric study for design parameters performance, found proposed system is better than heat pump based on electrical energy in terms of cost. This system is more favourable for the place having long summer like climates. G.Lychnos et al.,[6] Investigated performance of binary source driven hybrid refrigeration system, which in turn systems flexibility and efficiency improves due to the use of heat and electricity as binary sources. Overall COP ranges from 0.24 to 0.76. Pradeep bansal et al.,[7] Presented different technology which can replace conventional vapour compression refrigeration system, provide energy savings and can be ecofriendly. Among various technologies thermoelectric and magnetic refrigeration technologies seems to be most promising. M.Mohanraj et al., [8] Studied and concluded that artificial neural networks (ANN) can be applied successfully with permissible accuracy in the area of heat pump coupled with refrigeration and air-conditioning systems. Z.Tamainot et al .,[9] Designed and investigated a prototype based on plate heat exchanger concept .Average COP obtained from prototype of sorption generator is 0.22. Zhenjun Xu et al., [10] Proposed a unit which displaces requirements of heating based on electrical energy and thereby saving energy. Objective of this unit is to enhance performance by utilizing wastage of heat from gas engine.

## 2. Experimental Setup



**Figure 1.** Designed layout of the experimental setup.

Water is used as the condensing or cooling medium & being heated due to the heat exchange from the hot vapor refrigerant. Cooling of water is obtained from the evaporator unit due to the heat transfer of water to the refrigerant. Air cooling is obtained due to the fact of heat exchange between hot air & cold refrigerant. In this system Condensing coil is immersed in water to be heated and a part of cooling coil 1st passed through filled water tank in which water is to cooled and then remaining coil is utilized for cooling air so that desired space to be cooled.



**Figure 2.** Top view of fabricated model.

### 3.Results and discussion

#### 3.1. First run(15<sup>th</sup> may 2015)

The analysis of the designed and fabricated system has been started from 15<sup>th</sup> May 2015. for this purpose experimental readings have been taken using pressure gauge and thermometer under the climate conditions of BIT Sindri ,Dhanbad in hydraulic machine lab.

**Reading:** Evaporator temperature= 10°C, Condenser temperature=60°C, Compressor outlet temperature=64.79°C, Evaporator pressure = 4.25 bar, compressor outlet pressure = 16.8 bar after 10 min of run of machine.

**Table 1.** Enthalpy and entropy chart of R134a refrigerant corresponding to reading.

Saturation temperature (°c)	Pressure in( bar)	Enthalpy (kJ/kg)		Entropy(kJ/kg K)	
		Liquid	vapour	Liquid	vapour
10	4.2	213.53	404.40	1.0483	1.7224
60	16.8	287.49	426.86	1.2847	1.7031

By the analysis of temperature-entropy and pressure-enthalpy diagram of VCRS (vapor compression refrigeration system) theoretical cycle with vapor after compression in superheated region, coefficient of performance of system has been calculated which is 4.03 and is within permissible range.

#### 3.2 Second run (18<sup>th</sup> may 2015)

On this day we have taken reading for calculating cooling capacity of room air cooler. For this calculation we have used psychrometric chart for getting value of enthalpy corresponding to recorded value of D.B.T and W.B.T. For 1<sup>st</sup> state of dry bulb temperature we have recorded temperature of ambient air by thermometer when it is not affected by moisture present in air. And corresponding wet bulb temperature by recording temperature of air when bulb of thermometer is surrounded by a wet cloth exposed to the air. And after 10 min of run of machine D.B.T and W.B.T for state2.

**Table 2.** Enthalpy chart corresponding to dry bulb temperature and wet bulb temperature recorded.

State	D.B.T	W.BT	Enthalpy(kJ/kg)
1	37°c	22°C	65
2	26°c	16°C	45

After calculation Cooling capacity of room air cooler is coming 3.0034 TR which is also within permissible range.

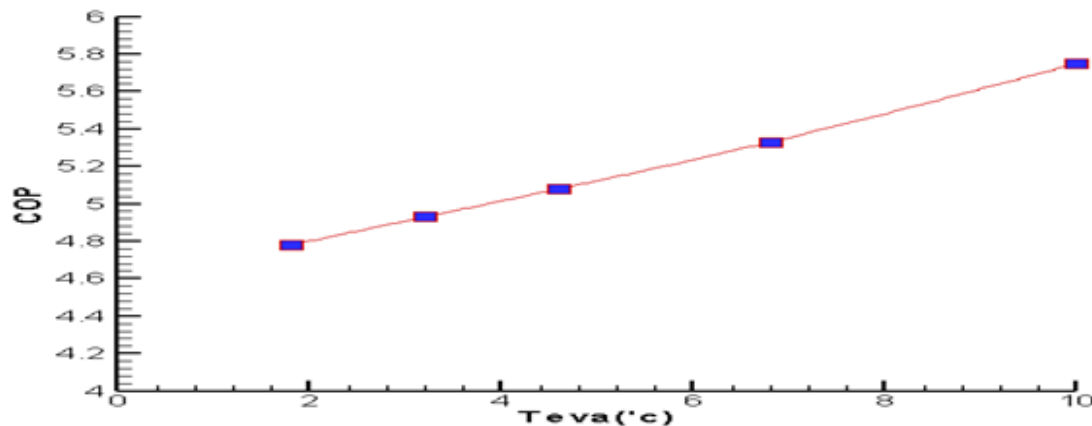
### 3.3 Third run (25<sup>th</sup> may 2015)

On this day we have taken reading for the purpose of showing graph between evaporator temperature Vs coefficient of performance. For this 50 min of run of machine has performed and after every interval of 10 min reading of evaporator temperature has taken. And since in my designed project it is required to continuous change of water in heating tank for continuous run of machine .So for this analysis purpose after reaching of **condenser temperature at 59.21°c** we have started feeding of normal water in heating tank so that this temperature can be kept constant .And for this variation of graph we have calculated COP by considering this machine as a reversible system. And we have used formula for calculating  $COP = \frac{T_L}{(T_H - T_L)}$

**Table 3.** Chart of evaporator temperature recorded and corresponding value of coefficient of performance.

Evaporator temperature(Teva°C)	Coefficient of performance
10	5.75
6.8	5.33
4.6	5.08
3.2	4.93
1.8	4.78

In figure 3 graph has been plotted between evaporator temperature taken on abscissa and coefficient of performance on ordinate. From graph we can see that as evaporator temperature decreases value of COP also decreases and as evaporator temperature increases value of COP also increases, hence nature of curve is straight line



**Figure 3.** Graph of  $T_{eva}(^{\circ}\text{C})$  vs COP for R134a refrigerant.

**Table 4.** Variation of evaporator temperature with refrigerating effect.

Condenser temp ( $^{\circ}\text{C}$ )	Evaporator temp ( $^{\circ}\text{C}$ )	$h_1=h_g(\text{KJ/kg})$	$h_4=h_{f3}(\text{KJ/Kg})$	Refrigerating effect= ( $h_1-h_4$ )in KJ/Kg
60	10	404.40	287.49	116.91
62	6.8	402.54	290.77	111.77
65.38	4.6	401.39	295.76	105.63
69.5	3.2	400.64	302.56	98.08
70.3	1.8	399.26	305.42	93.84

### 3.4 Calculation for capacity of water heater

Radius of tank = 11cm=0.11 m, Height of tank =25cm=0.25 m

Hence volume of cylindrical tank=  $\pi r^2 h = 3.14 \times (0.11)^2 \times 0.25 = 9.49 \times (10)^{-3} \text{ m}^3$

Hence mass of water =  $M_w = \rho_w \times V_w = 1000 \times 9.49 \times (10)^{-3} = 9.49 \text{ kg}$

$(C)_w = 4.2 \text{ kJ/kg K}$

$T_1$  = Normal water temperature =  $25^{\circ}\text{C}$

$T_2$  = Temperature of hot water =  $65^{\circ}\text{C}$

$T'$  = Time period of run of machine = 5 min

Heat lost by condensing coil or refrigerant = Heat gained by water

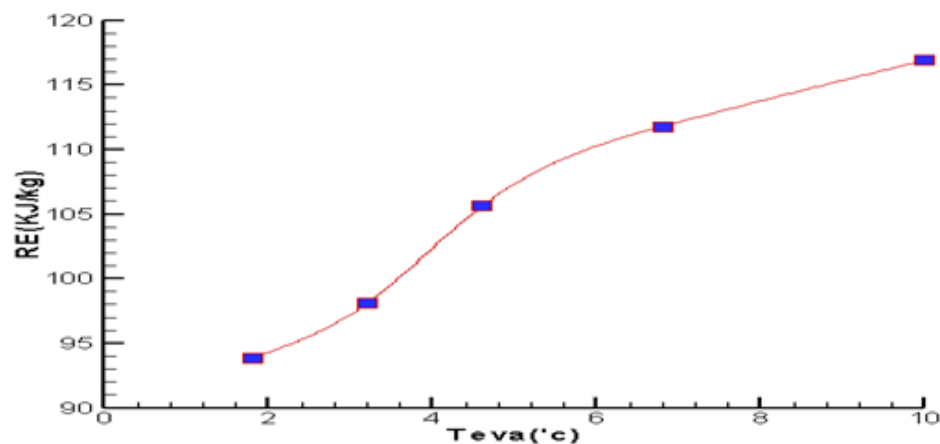
$$= Q = M_w \times C_w \times \delta T$$

$$= 9.5 \times 4.187 \times (65 - 25) = 1591.06 \text{ KJ}$$

Since 1 ton of refrigeration unit = 210 KJ/min

$$\text{Capacity of water heater} = 1591.06 / (210 \times 5) = 1.51$$

In figure 4 graph has been plotted between evaporator temperature in  $^{\circ}\text{C}$  on abscissa and refrigerating effect on ordinate. From graph we can see that as evaporator temperature increases refrigerating effect also increases but in starting rate of increasing is somewhat greater than after certain temperature. That is graph is of increasing nature but not uniformly increasing.



**Figure 4.** Graph of evaporator temperature Vs refrigerating effect for R143a refrigerant.

#### 4. Conclusions

This project is one of the reusable and an eco- friendly project which can be implemented in our day to day life for the effective management of power consumption factor. The heating unit in the system utilizes heat lost through the condenser and thereby saving energy, by the utilization of wastage of heat energy performance of the system has improved significantly. This system can be utilized throughout the year according to need and finally a simple working model of the system is fabricated and tested.

#### 5. References

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