Performance Optimization of the Evaporative Condenser Design

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***Abstract*— With the increasing demand of air conditioning system worldwide power consumption has been also increase. Evaporative cooling has been used successfully throughout history to provide cooling and is especially effective in hot-dry climates. The use of evaporative processes to improve cooling efficiency is an important vehicle for reducing energy use and peak demand in hot-dry climates. Direct space cooling through evaporative cooling does not provide the same quality of comfort as compressor-based processes in that for most technologies moisture is added rather than removed from the air. While this may be acceptable in dry climates it is not in humid climates where air conditioning is re-lied upon not only for sensible cooling but for dehumidification. Evaporative condensers utilize the high efficiency of evaporative cooling at the condensing unit, while also providing dehumidification identical to a conventional air conditioning system. Evaporative condenser may play key role in reducing power consumption in present air conditioning system.**

I. INTRODUCTION

Now a day's, energy consumption is more in refrigeration and air-conditioning field all over the world. Air conditioning systems have been incresely common all over the world.

One way of reducing power consumption in compressor-based cooling system is to use a evaporative condenser in place of water cooled condenser and cooling tower. The main advantage of evaporative condenser use is less area required for construction and more efficiency than the cooling tower and condenser.

II. EVAPORATIVE CONDENSER

The term evaporative condenser is defined as comprising a coil in which the refrigerant is flowing and condensing inside, and its out surface is wetted with water and exposed to stream of air to which heat is rejected principally by evaporation of water. The coils are generally made of copper steel in multiple circuits and passes. The external surfaces are sometimes finned to increase heat transfer surface. The coil should have arrangements for cleaning under fouling water condition. Evaporative condenser is a combination of the condenser and cooling tower. Evaporative condenser is working on combined principal of the condenser and cooling tower.[1]

Evaporative Condenser= Condenser + Cooling tower

A. Principal of Evaporative Condenser:

The vapour to be condensed is circulated through a condensing coil, which is continually wetted on the outside by a recirculating water system. Air is pulled or pushed over the coil, causing a small portion of the recirculating water to evaporate. The evaporation removes heat from the vapour in the coil, causing it to condense.

B. Function of Evaporative Condenser:

Condenser in refrigeration system is to de-super heat and condense the compressor discharge vapour and frequently to sub cool the resultant liquid while introducing the minimum pressure drop. It is a heat rejection component in the refrigeration cycle.

Condenser is to transfer heat that has been absorbed by the system to air or water. In an air-cooled condenser the outside air passing over the condenser surface dissipates the heat to the atmosphere. In water cooled condenser the water is pumped to a cooling tower where the heat is transferred to the atmosphere by means of evaporation.

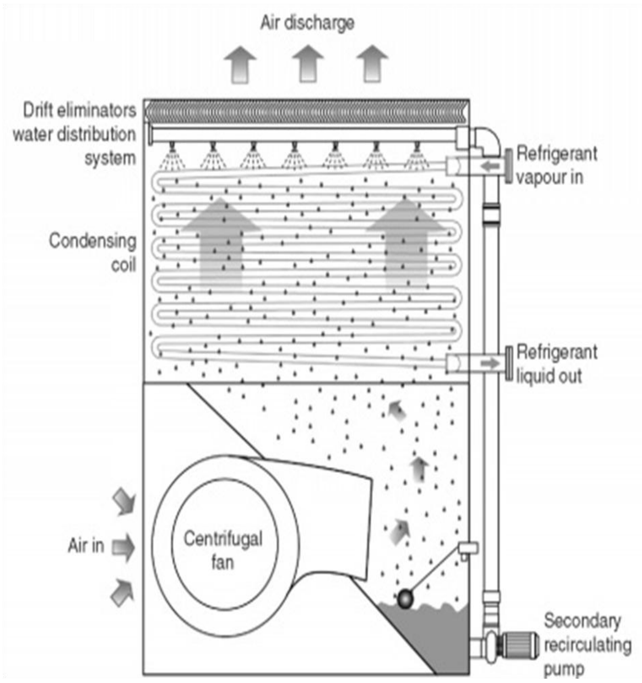

Fig.1- Evaporative Condenser

The wetting of coil is done by re-circulating system comprising water pan, a pump and water distribution system. The water distribution system mainly comprises nozzles for spray of atomized water on the coils. The pan catches the drainage of all coils. There is a float valve to admit make up water and maintain the correct level in the pan. Centrifugal pumps of moderate head are necessary. Such pumps are not affected much by extraneous matter found in such open recirculating systems. Most evaporative condensers employ forced circulation of air with a fan to either blow or to draw air through the unit. Effective elimination of moisture from the leaving air stream by eliminators is essential to prevent projection of mist which can deposit moisture on the surrounding surfaces. The eliminator plates work on the simple principle of abrupt changes in flow direction. Moisture particles being heavier get deposited on these eliminator plates and get drained back to the sump or the pan.[1]

C. Advantages of Evaporative Condenser:

(1) Lower energy consumption.
(2) Saving of investment cost.
(3) Smaller plan area.
(4) Smaller driving power for compressors.
(5) Evaporative condensers reduce the water pumping and chemical treatment requirements associated with cooling tower / refrigerant condenser system.
(6) In addition they require substantially less fan power than the air cooled condenser of comparable capacity.
(7) The evaporative condenser can operate at a lower condensing temperature than the air cooled condenser.
(8) Compared to Shell & Tube Condensers and cooling tower, about 15% electrical consumption can be saved due to low pressure condensation of refrigerant.

D. Disadvantages of Evaporative Condenser:

(1) The water may freeze at low operating temperatures.
(2) Impurities in the vapours may cause corrosion.
(3) Cost of water consumption and water treatment method the saving on total cost may not be significant.
(4) Spread of Legionnaires disease. Precautionary measures needed.
(5) Air intakes of ventilation and air conditioning system Away from them due to water mist and noise's emission.
(6) A small amount of the cooling water must be continually purged to prevent the build-up of contaminants.

III. EVAPORATIVE CONDENSER DESIGN

CASE STUDY:

Evaporative condenser is considered for condensation of ammonia vapours. Cooling water falls over the condenser tubes at a required rate at a constant temperature of 6°C above the design wet bulb temperature and Dry bulb temperature is 43°C. The design wet bulb temperature is taken as 28°C. Suction temperature = -10°C Ammonia enters the condenser at 98°C and condenses at 38°C (means 4°C higher than cooling water inlet temp). Circulation rate of ammonia is 0.18 kg/s. The geometric parameters are assumed as: Tube outer diameter (Do) = 17.2 mm, Tube inner diameter (Di) = 13.8 mm, Tube length (L) = 2800 mm, Pitch (P) =30 mm.

DESIGN:

Using KC3 Compressor table (Kirloskar brother pvt. Ltd.)[2] We get the total heat rejection 253.32 KW. From mass flow rate of refrigerant we find number of tube required 18 tubes. We calculate the mass of air and mass of water required 554.4 Kg/min(16317 CFM) and 414 Kg/min(109 GPM) considering 90 % saturation efficiency and From literature review it has been found that water to air ratio is 1 GPM per 150 CFM flow of air.[3] Power of the fan and pump we get from company manual for optimization.[4][5].when the DBT and WBT changes at that time fan power and pump power changes.

IV. PERFORMANCE OPTIMIZATION

Performance of evaporative condenser changes with the outside weather condition and mainly it depends upon WBT of outside air. There is rise in condenser capacity take place with reduction in WBT temperature. So it possible to optimize the condenser capacity by reducing condenser pressure and by varying air flow rate and water flow rate.

So here we optimize the performance using two ways:

(1) Reducing condenser pressure

(2) Using VFD for fan and pump

CASE.1- Reducing Condenser Pressure

Here we take DBT and WBT data throughout the year. When change in DBT and WBT at that time change in condenser pressure and condensing temperature.

Month	DBT(°C)	WBT(°C)	Condensing temperature (°C)
January	18	10	25.1
February	22	12	26.2
March	24	11	25.4
April	36	25	35.1
May	43	28	38
June	39	26	35.4
July	37	28	34
August	32	26	34.7
September	34	30	36.9
October	28	24	36.2
November	25	13	26.6
December	20	10	23.1

Table.1- Month & Condensing temperature

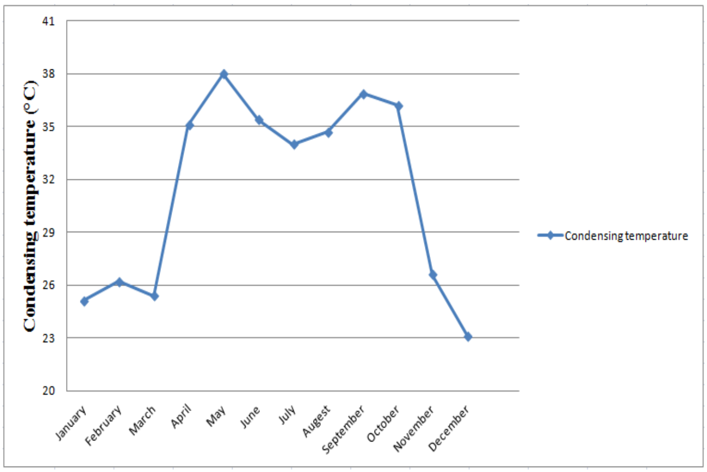

Fig.2-Month vs Condensing temperature

As shown in table.-1 we discuss how much change in condensing temperature with respect to month. Using table.-1 we plot graph month vs condensing temperature in fig. - 2.

Month	Condensing temperature (°C)	W_c (kW)	Re (kW)	$[(Wc+P_{fan}+P_{pump})/Re]$ (kW/kW))
January	25.1	44.6	208.72	0.227
February	26.2	45.8	207.52	0.234
March	25.4	44.85	208.47	0.228
April	35.1	53.7	199.62	0.283
May	38	55.96	197.36	0.297
June	35.4	53.9	199.42	0.284
July	34	52.76	200.56	0.277
August	34.7	53.35	199.97	0.280
September	36.9	55.1	198.22	0.292
October	36.2	54.6	198.72	0.288
November	26.6	45.9	207.42	0.234
December	23.1	42.74	210.58	0.216

Table.2- Month & Specific power consumption

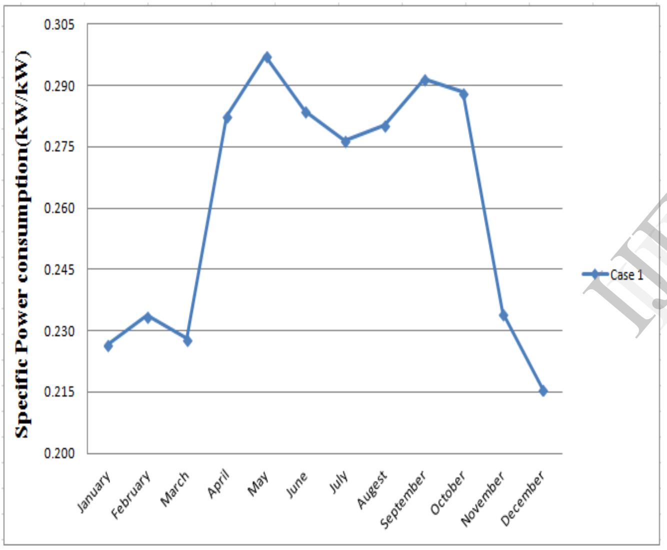

Fig.3- Month vs Specific power consumption

As shown in table 2 we discuss change in specific power consumption with respect to month. Here take one example shown in table 2 for May month condensing temperature 38°C and specific power consumption 0.297 kW/kW . Calculating specific power consumption compressor power, fan power, pump power and refrigerating effect required. We get compressor power and refrigerating effect from KC3 compressor table and take fan power, pump power constant as per our design. Here pump power and fan power constant so only change compressor power and refrigerating effect with respect to condensing temperature which we discuss in table 2. Here pump power and fan power taking constant because in first case reducing condenser pressure do not change in fan power and pump power only changes occur at condenser temperature.

Case.2- Using VFD For Pump and Fan

Month	DBT(°C)	WBT(°C)	Mass of air (Kg/min)
January	18	10	193.62
February	22	12	206.79
March	24	11	201.31
April	36	25	430.57
May	43	28	562.93
June	39	26	498.33
July	37	28	633.3
August	32	26	515.23
September	34	30	506.64
October	28	24	391.73
November	25	13	216.20
December	20	10	193.62

Table.3- Month & Mass of air

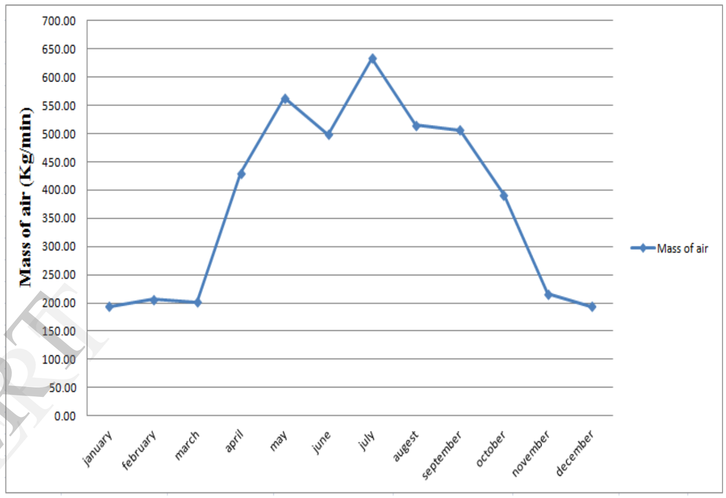

Fig.4- Month vs Mass of air

As shown in table.3 we discuss the change in mass flow of air with respect to month. We get mass of air in May 562.93 kg/min. Here we take the total heat rejection 253.32 kW constant for every month. Taking 90 % saturation the enthalpy at inlet air 89 kJ/kg and outlet air 116 kJ/kg of the evaporative condenser as per our rated design condition 43°C DBT & 28°C WBT. Enthalpy of inlet and outlet air change for every month with change in DBT and WBT. Using these values we find mass of air for every month which we tabulated in table 3. From table 3 we plotted fig. 4 Month vs Mass of air.

Month	DBT(°C)	WBT(°C)	Mass of water (Kg/min)
January	18	10	143.98
February	22	12	153.77
March	24	11	149.70
April	36	25	320.18
May	43	28	418.60
June	39	26	370.57
July	37	28	470.93
August	32	26	383.13
September	34	30	376.74
October	28	24	219.30
November	25	13	160.77
December	20	10	143.98

Table.4-Month & Mass of water

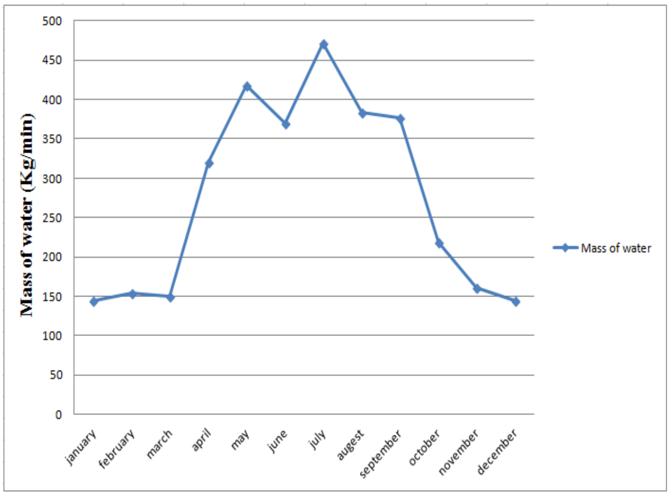

Fig.5- Month vs Mass of water

As shown in table .4 we discuss the change in mass flow of water with respect to month. Here we get the mass of water for may 418.60 kg/min. We get mass of water using mass of air taking 150 CFM = 1 GPM air-water ratio from BAC company manual. As we calculated mass of water for all the months which tabulated in table 4. Using this table we plotted fig. 5 month vs mass of water.

Month	Mass of air (Kg/min)	Mass of water (Kg/min)	Fan power (kW)	Pump power (kW)	$[(W_c+P_{fan}+P_{pump})/R_e]$ (kW/kW)
January	193.62	143.98	1.25	1.11	0.296
February	206.79	153.77	1.4	1.2	0.297
March	201.31	149.70	1.3	1.11	0.296
April	430.57	320.18	1.65	1.5	0.300
May	562.93	418.60	3.6	2	0.312
June	498.33	370.57	2.25	1.8	0.304
July	633.3	470.93	4.5	2.5	0.319
August	515.23	383.13	3.3	2.2	0.311
September	506.64	376.74	2.25	1.8	0.304
October	391.73	219.30	1.65	1.3	0.298
November	216.20	160.77	1.4	1.2	0.297
December	193.62	143.98	1.25	1.11	0.296

Table.5- Month & Specific power consumption

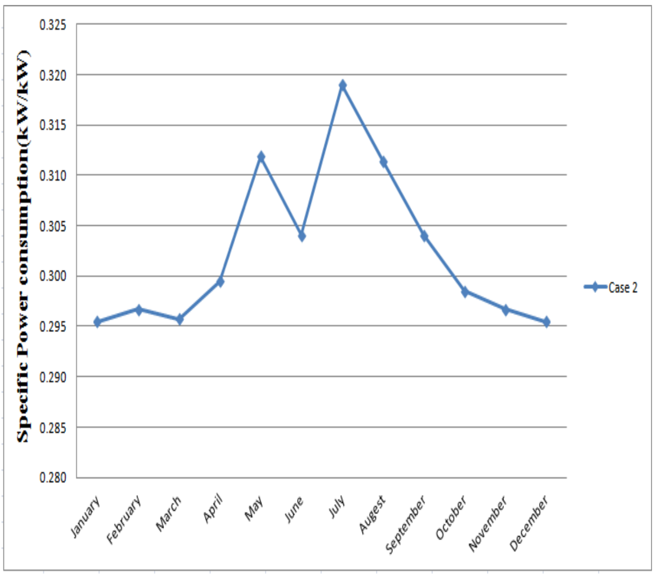

Fig.6- Month vs Specific power consumption

As shown in table 5 we discuss change in specific power consumption with respect to month. Here take one example shown in table 5 for May month condensing temperature 38 °C and specific power consumption 0.312 kW/kW .Calculating specific power consumption compressor power, fan power, pump power and refrigerating effect required. We get pump power and fan power from pump and fan selection characteristic chart as per the calculating mass of water mass of air considering head loss in pump and air pressure drop across the coil and take compressor power, refrigerating effect constant as per our design. Here compressor power and refrigerating effect constant so only change pump power and fan power with respect to condensing temperature which we discuss in table 5. Here compressor power and refrigerating effect taking constant because in second case we use VFD for pump and fan do not change in compressor power and refrigerating effect only changes occur at mass of water and mass of air.

Case.2- Comparison of case 1 and case 2

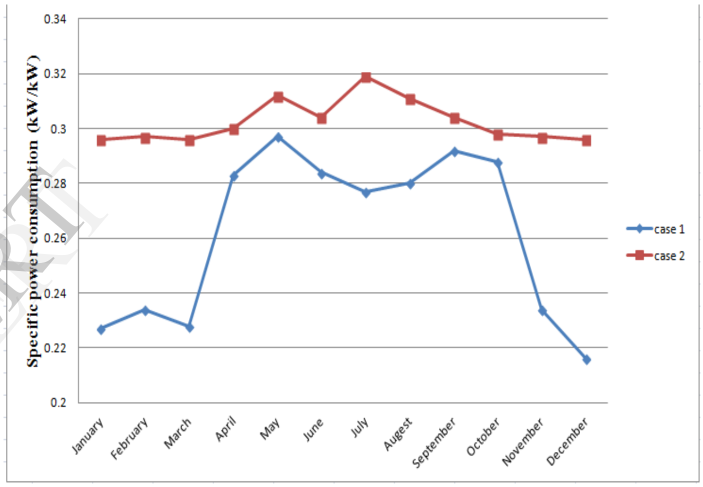

Fig.7- Comparison of two cases

As shown in fig.7 here we compare first and second case. From fig.7 we says that Specific power consumption in case 1 is less than the case 2. So finally we says that in case 1 we can get less specific power consumption compare in to case 2. From fig.7 we conclude that first case is more preferable compare to second case for Performance optimization of the evaporative condenser deign.

V. CONCLUSIONS

(1) Evaporative condenser results higher COP compare to conventional air-cooled and water cooled condenser. Also evaporative condenser is compact compare to conventional air-cooled and water cooled condenser due to high overall heat transfer coefficient.
(2) Evaporative condensers can also achieve lower condensing temperature than the air cooled and water cooled condensers.
(3) Water flow rate in evaporative condenser is about one-third that of the flow circulated between the water-cooled condenser.

(4) Evaporative condensers required less water compare to water cooled condenser, which reduces the water pumping and chemical treatment costs.
(5)Evaporative condenser performance change with the weather condition, at lower DBT and WBT its heat rejection capacity increases.
(6) It has been found that for same heat rejection capacity, total specific power consumption is less for an optimum reduction in condenser pressure compare to Evaporative condenser provided with VFD for pump and fan.
(7) All these features make evaporative condensers a better option for condensation. They can be used in industrial refrigeration, air-conditioning, cold storage and breweries.

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