Effect of using Cooling Tower Exit Air on the Air –Cooled Chillers for Air-Conditioning Applications

Sharad Chaudhary
Institute of Engineering & Technology, Devi Ahilya Vishwavidyalaya, Indore

Abstract— Air cooled chillers, one of the most widely used chillers for air-conditioning applications, are restricted to areas where the ambient temperatures are below 40oC. The compressor requires excess power and the refrigerating effect is also reduced thereby reducing the Coefficient of Performance (COP). One of the ways to lower the condenser temperature in such a chiller if blowing cooler air over the condenser coils. This could be achieved by using the cooled and humid air out of the cooling tower exit. The paper provides the estimation to enhance the performance of air-cooled chiller by blowing the cooling tower exhaust air to the condenser coils by a proposed ducting arrangement. The performance of the chillers was increased by 16% in addition to other benefit as regards to maintenance.

Key words: Air Cooled Chiller, Vapour compression Cycle, Ducting Arrangement, Coefficient of Performance (COP)

I. Introduction

Chiller is a heart of any refrigerating & air conditioning system that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. This liquid can be circulated through a heat exchanger to cool the air or equipment as required. The refrigerant media absorb the heat from evaporator and are exhausted to ambient by condenser and cooling tower. Chillers are of many types but screw chillers have found their way into wide range of applications. This paper lays the fundamentals of achieving power saving from a screw chiller by reducing condenser temperature by applying cooling tower discharge air on screw chiller condenser during typical regional summer. Such a screw chiller has performance issues due to high ambient summer temperatures. A class of screw chillers are based on Head Pressure Controls (HPC) under which the condenser temperature floats around a high set point temperature of around 50o C based on ambient temperature of 35 ℃. Condenser works between 50oC to below as per ambient conditions and different chiller loads on weather conditions.

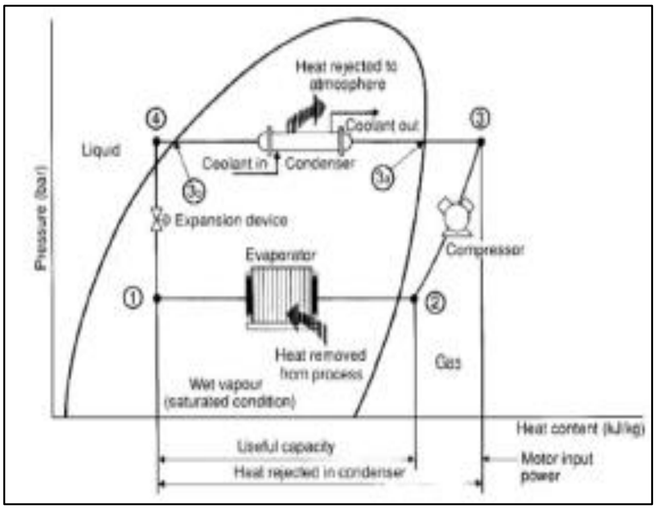

Fig. 1: Schematic of Vapour compression cycle

II. Background

It is evident that lower condensing temperature can save lot of energy in the form of electrical energy by using variable condensing temperature CTC (condenser temperature controls). It is an alternative of HPC to lower the condensing temperature and change the See the attached diagram below which outlines the key components of the chiller system. COP = enthalpy point 1-2/enthalpy point 2-3. COP indirectly related to power. If COP is more than compressor power is less for given ambient temperature conditions and variable load conditions. As a consequence of change in condensing temperature the performance if affected. When condensing temperature (Tc) increases, condenser pressure (Pc) also increases, and (Mr) mass flow rate of refrigerant decreases, (□v) volumetric efficiency decreases. As a result volume of refrigerant increased and hence coefficient of Performance (COP) is decreased. Current vapour-compression chiller technology is based on the "reverse-Carnot" cycle known as vapour-compression cycle.

From chart it clear seen that process 1-2-3-4 is high condenser temperature and pressure this is without cooling tower exhaust air , but process 1-2'-3'-4' this is with cooling tower exhaust air have less condenser pressure means Pcd. Pcd is more than Pcd'. Compressor power 1-2 is more than 1-2'and refrigeration effect is 4-1 is less than 4'-1. So it is clear from above chart COP is more than previous cycle 1-2-3-4.

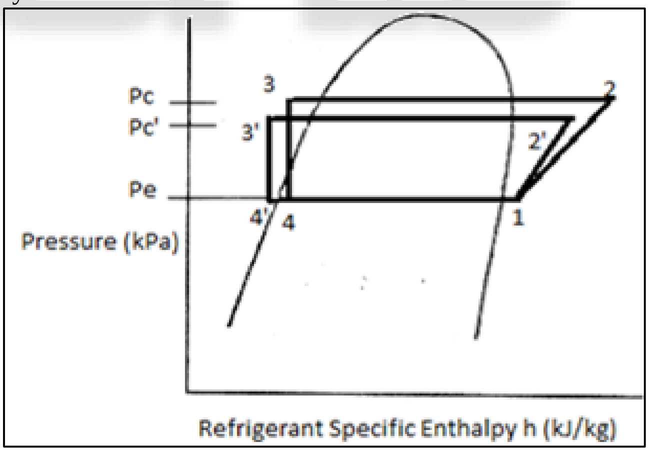

Fig. 2: Effect on Condenser Temperature on P-H Chart

III. Objectives

The research intents to fulfil the following objectives:

1) Study the Air-cooled screw chiller, with regards to capacity and operation
2) To study the effect of various operational parameters on performance of air cooled screw chiller
3) To investigate to effects of using the cooling tower exhaust air to reduce the condensing temperature
4) To find the behaviour of the system in summer and winter seasons

IV. LITERATURE REVIEW

Yu F [1] from the Hong Kong Polytechnic University Hong Kong found the efficiency Improvements of Air-Cooled Chillers equipped With High Static Condenser Fans. Jai Yang et al [2] investigated the chiller efficiency can be improved by using water mist to pre- cool ambient air entering the condenser to decrease the compressor power Wu-Chieh Wu, et al [3] carried research based on energy and exergy analysis for improving the energy performance for air cooled screw chiller by different – Coil configuration. They investigated the potential for enhancement in performance efficiency in air cooled chillers and energy conservation of each component, by changing the angle configuration of condenser coil and hence chiller performance. I S. Nagar, et al [4] have done experimental investigation of energy saving in refrigeration system. In this paper they have state that when condenser rejects the heat in atmosphere water droplets is sprayed reduces the ambient. Yu and Chan [6] prove that performance of air cooled screw chiller can be improved by using variable speed condenser fan

V. METHODOLOGY

The following methodology was adopted for the study

Reading of the various psychrometric and refrigerant properties of the existing arrangement in the months of summer as well as winter

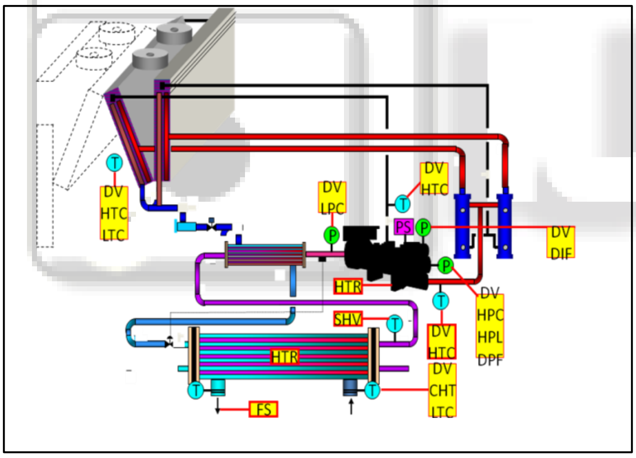

Fig. 3: Schematic of Air-Cooled Chiller for Air-Conditioning

CHT	Chilled liquid temperature
COP	coefficient of performance
DIF	Differential pressure cut-out
DP	discharge pressure
DPF	Discharge pressure fan control
DST	discharge saturation temp
DT	discharge temp
DV	Display value
FS	Flow switch
h_2-h_1	Refrigeration effect
h_3	enthalpy in discharge of (compressor) side
h_3-h_2	Compressor work
HPL	High pressure load limiting
HTC	High temperature cut-out
HTR	Heater
LPC	Low pressure cut-out
LTC	Low temperature cut-out
PS	Pressure switch
SHV	Superheat value
SP	suction pressure
SST	suction saturation temperature
ST	suction temp

Table 1: Nomenclature

The laying down of the duct arrangement as proposed and then again recording the various psychometric and Refrigerant properties. A ducting arrangement was fabricated as proposed. The duct was responsible for transmitting air from cooling tower exhaust to air cooled condenser on screw chiller. The exhaust air is at low dry bulb and wet bulb temperature (less than ambient), but have high humidity. The estimated cost of the work is Rs 6, 60, 759. 00 with supports to hang the ducting system near air cooled screw chiller conditioner in whole length aprox. 11 meter in both sides of chiller for both units. A study was done to check all parameter after ducting was installed

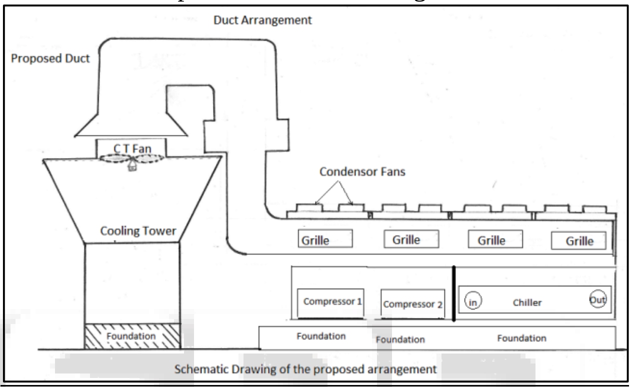

Fig. 4: Schematic Drawing of the proposed ducting arrangement

Estimating the change in the performance of the screw-chiller under investigation. The following table (Table 2) shows the system specifications that were used for study.

Chiller Type	Air cooled chiller
Capacity	300 TR or 1000 kW each capacity .(02 unit)
Refrigerant	407 C
Compressor Nos.	08 with 25000 CFM each in a unit
Condenser fans Nos.	04 nos.(90 & 60 TR) in each unit
Condenser fan electric consumption	2 HP
Exhaust air capacity of cooling tower	100000 CFM

Table 2: System Specifications

VI. DATA COLLECTION

The data were collected for the months of May –Jun and Dec –Jan under the following categories

Data collection (without cooling tower air). The following psychrometric properties were recorded through the day in the month of May: (1) Dry bulb (2) Wet Bulb (3) Relative Humidity while the refrigerant properties which were recorded were (1) Enthalpies at state points (2) Pressure and temperature of evaporator and condenser. (3) SST, DST. While the following system performance parameters were estimated (1) Load (2) Current (3) COP. The following chart shows the recorded readings. The condition of sudden halting of the compressor is evident with current drawn exceeding the set value.

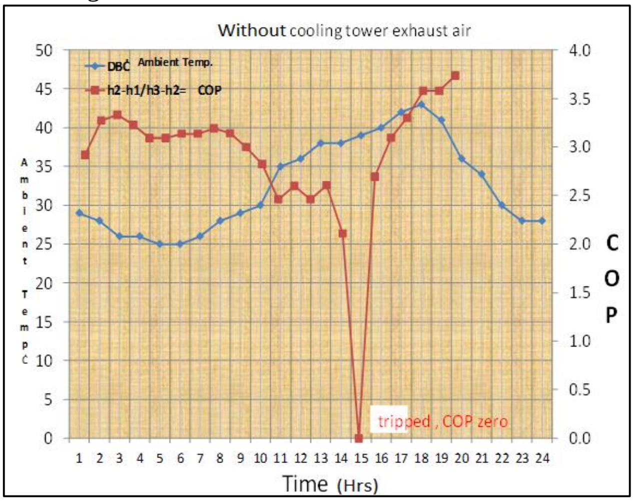

Fig. 5: The values of Dry bulb temperature and COP without cooling tower exhaust

Data Collection with cooling tower exhaust air on: The Coefficient of Performance (COP), Refrigeration Effect (RE) and Dry Bulb Temperature (DBT) recorded with the cooling tower air supplied to the condenser of the chiller. The following table shows the reading recorded after the installation of the ducting arrangement.

The following relevant fundamental equations were employed in the analysis.

$$RE = \dot{m}\Delta h_e \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$W_c = \dot{m}\Delta h_c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$COP = {RE}/{W_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

$$COP = \frac{(h_2 - h_1)}{(h_3 - h_2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

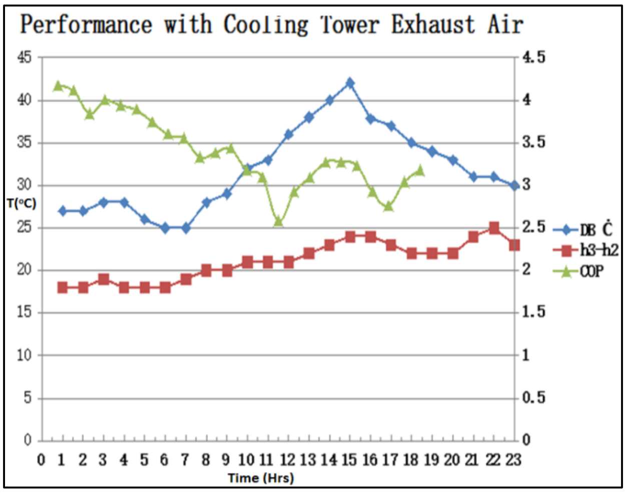

Fig. 6: The values of Dry bulb temperature and COP with cooling tower exhaust

VII. Results and Discussion

After recording the data under two arrangements, one without the cooling tower exhaust on condenser and with cooling tower exhaust on to the condenser. The following result were obtained

The following table shows the values of the parameters for each unit of compressor with and without cooling tower exhaust air on to the chiller condenser.

S. No	Property/ Parameter	Value (Units)
Without Cooling tower Exhaust		
1	Ambient temperature	42°C
2	Work of compressor	7.9 x10^{-3} kWh
3	Current drawn	194 A
With Cooling tower Exhaust		
1	Ambient temperature	40 °C
2	Work of compressor	7.0 x10^{-3} kWh
3	Current drawn	188 A
Difference in the parameters		
1	Change in Current drawn	6A
2	Difference in condenser temperature	2°C
3	Difference in compressor work	0.9 x10^{-3} kWh

Table 3: Comparison of performance parameters with and without use of cooling tower exhaust

The saving in the compressor work and the current drawn can be scaled up for the entire plant involving 4 compressors with rate of electricity 6.5 /kWh as under With 04 Nos. compressors in each unit, total power saving: 24 Amp.

The power P= √3VxI cos ∅ (for three phase power supply)

cos ∅ is power factor take 0.90

P= √3(420x24)/1000 , = 17.45 unit /hr

Rate of unit is Rs. 6.50

Total saving 17.45 x6.50=114.00 / hr

If system working in twenty four hours in a day and working thirty days the amount save is Rs 114 x 24 x30=82080 per month in summer season

Total power saving consider power factor 0.9 is Rs. 73872.00 for each month.

Averaged COP for complete duration of investigation with cooling tower exhaust: 3.39

Averaged COP for complete duration of investigation without cooling tower exhaust: 2.91

The percentage increase in COP: 16 %

VIII. Conclusions

The following conclusions have been drawn with the study under-taken.

- The air cooled screw chillers are not very good option when the actual value of the condenser exceeds the designed value.
- The work done required by the compressor is increased when the condenser temperature is higher
- The electric power consumption is increased thereby reducing the value of performance parameters
- Coefficient of Performance of chiller may be improved reducing condenser temperature
- The air supplied to the condenser is clean and washed and is dirt free reducing the cost involved in maintenance

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