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Design Of Air Cooled Water Chiller

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ABSTRACT

A chiller is a device which cools a fluid by removing heat from it, either through a vapour compression or absorption refrigeration cycle with the key components being the compressor, condenser, evaporator and expansion device.. This paper emphasizes on studying the design procedure followed in the industries and performance evaluation of different configurations of chilling plant. Chillers are widely used for cooling buildings in the subtropical regions at the expense of considerable energy this emphasizes on studying the design procedure followed in the industries and performance evaluation of two different configurations of 5 ton based chilling plant. The two such configurations studied are scroll compressor and plate heat evaporator and scroll compressor and shell and tube evaporator with R404A refrigerant. The results on basis of this experiment shows that the configuration scroll compressor and plate heat evaporator can give better results as compared to the configuration scroll compressor and shell and tube evaporator, The attempt is also made to reduce the refrigerant requirement & life of condenser by replacing the copper tube with fin condenser by aluminium micro channel condenser.

Keywords— **COP, WORK DONE**

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INTRODUCTION

Water chiller is a broad term describing an overall package which includes refrigeration plant, water chiller and air or water cooled condenser. This name infers that the compressor, condenser and chiller with internal piping and controls are combined into a single unit. Water chiller plant may range in size from small capacity reciprocating compressor units with air or water cooled condensers up to large units incorporating centrifugal or screw compressors. Although the entire chiller package is more complex, the basic components required for mechanical refrigeration are the compressor, evaporator, condenser and thermostatic expansion valve. This so called chillers are largely used for air conditioning, which includes comfort and controlled process applications. Typical comfort air conditioning applications are in larger buildings where the capacities are bigger such as office buildings, shopping centers, hospitals, universities and schools says. Wisdom. Process air conditioning is where close control of temperature and humidity is required. These sometimes require simultaneous cooling and reheat; and include laboratories computer rooms, operating theatres and critical manufacturing environments. Process cooling applications also include any manufacturing process where heat generated needs to be rejected. These typically include plastics, food and many other manufacturing processes For Chilling Plant applications,

We calculate the required capacity of the chilling plant by using the following formula:

$Q = M \times Cp \times \Delta T/3024$

Where

Q = Quantity of heat exchanged (TR/Hr)

W = Flow rate of fluid (LPH)

C = Specific heat of fluid (°C)

ΔT = Temperature change of fluid (°C)

M= mass of the product per hr. COP=Q/W

Q= heat exchanged in condenser (condenser)

W= net work done by the system (compressor)

When selecting water chillers it is essential that the following be carefully considered

Performance characteristics at both maximum and part load operation. To achieve efficient operation it is necessary that the water chiller be able to reduce the refrigeration capacity as the cooling load of the building decreases.
Selection of the type of water chiller must also take into account the minimum load that the chiller may be required to operate down to. As an example, reciprocating compressors can unload to between 12– 15%, centrifugal chillers down to 20–25% and screw compressors down to 10–15%. Should this turn down ratio be insufficient to meet the minimum cooling requirement on the building, then multiple chillers will be necessary in order to achieve energy efficient operation. The chilled water temperature should be maintained as high as possible to reduce the energy consumption of the compressor. Typically, a 1°C increase in chilled water temperature can reduce the compressor energy input by approximately 2%.
The temperature differentials across both the condenser and chiller heat exchangers should optimized to be as high as possible. High temperature differentials will result in lower water flow rate with a consequential reduction of pumping energy

II.LITERATURE REVIEW

details of literature review are as under

2.1 M.W Browne etal.2000 : This paper presents an overview of various simulation techniques that may be useful for predicting the in-situ (dynamic) performance of vapour-compression liquid chillers over a wide range of operating conditions. Four models were considered namely steady-state and transient physical models, and steady-state and transient neural network models. It was found that the steady-state models can give excellent results (to within ±5%) during quasi-static operation. However under more dynamic conditions discrepancies of up to ±20% can occur. They also have the obvious limitations during the shutdown process where they will either drastically overestimate the work input or under predict the cooling capacity depending on the choice of the convergence variable[1]

2.2 PK.Bansal etal. 2000: presents a steady-state moel or predicting the performance of vapour-compression liquid chillers over a wide range of operating conditions.. In particular, it employs an elemental NTU-e methodology to model both the shell-and-tube condenser and evaporator. The approach allows the change in heat transfer coefficients throughout the heat exchangers to be accounted for, thereby improving both physical realism and the accuracy of the simulation model. The model predicts the electrical work input to the compressor, and the coefficient of performance (COP), and the condenser capacity to within ±10% for the majority of operating conditions for both chillers. The model is also able to predict the refrigerant temperatures in the condenser and the evaporator to within ±1% for the majority of operating conditions.[2]

2.3 Sheng kaiwang: In condensers of large air-cooled chillers chillers, VV-shaped finned-tube condenser coils are usually configured with the upper fan, often resulting in unevenly distributed flow and varying wind speed. This first part of the study attempted to investigate the effects of various configurations of condensing coils, three types of variant fin configuration (VFC) and four types of variant row configuration (VRC). Using CFD airflow simulation and heat transfer analysis, the results of this study showed that VRC-designed condensers improve airflow distribution and enhance

2.4 Jin chang jiang etal.2012: The second part of this study (Part II) used full-scale experimentation to investigate the manner in which how two condenser coil configurations (VRC and CRC) influence the performance (energy efficiency) of the system and individual components of air-cooled chillers. The results showed that, for both DX and FL evaporator configurations, the chillers with VRC condensers had a greater cooling capacity (an increase of 4.5% and 4.0%, respectively), refrigeration capacity (an increase of 6.5% and 5.6%, respectively), and COP (an increase of 7.3% and 6.7%, respectively), compared to chillers using CRC condensers. This demonstrates that VRC-designed condensers can effectively improve heat transfer performance and enhance the energy efficiency of refrigeration systems without increasing material costs or the number of tubes and fans. The

2.5 Outcome of the literature review : Depending on the load conditions, the chiller COP could increase by 1.7–84.8% when variable speed condenser fans and the optimum set point of condensing temperature are applied to existing air-cooled screw chillers. Also the chiller's COP can be maximized by adjusting the set point based on any given chiller load and wet-bulb temperature of the outdoor air. A 5.6–113.4% increase in chiller COP can be achieved from the new condenser design and condenser fan. Operation. Out of the three VFC designs were unable to improve the airflow distribution in the VV-shaped configuration the four VRC innovative designs all effectively improved the airflow distribution problem in VV-shaped configurations, increasing the average air velocity and heat transfer rate in the coils. The results showed that, for both DX and FL evaporator configurations, the chillers with VRC condensers had a greater cooling capacity (an increase of 4.5% and 4.0%, respectively), refrigeration capacity (an increase of 6.5% and 5.6%, respectively), and COP (an increase of 7.3% and 6.7%, respectively), compared to chillers using CRC condensers

2. 6 :Objective of the present work : 1. To study the basics of water chiller used in industries 2.To study the design procedure followed in the industries. 3. To find out the best configuration for 5 ton based chilling plant from the two configuration using R404A refrigerant

III.DESIGN PROCEDURE

The design procedure followed in the industries includes customer probing for temperature difference (Temperature required) to be maintained in the evaporator or for water and flow rate of water. Refrigerant to be used is generally decided by the company but in rare cases it is considered according to the customer. Then capacity of chilling plant is calculated then capacity of compressor ,capacity of condenser and capacity of evaporator is calculated. After deciding the capacities of all equipments, all the equipments are either designed at home industries or import from other industries .In medium scale and small scale industries 5 ton based chilling plant equipments are import from other vendors and are assembled .After assembling the machine, the machine is tested for performance check ,.5-10ºc temperature is maintained and then it is dispatched to customer. If any problem is detected the machine is send to production department for solution.

3.1 Design calculation[1.4] : Analysis of VCR cycle In this design R-404A is used as a refrigerant For design purpose considering condenser temperature 40 ^{o}c and evaporator temperature 5 ^{o}c and. The VCR cycle is dry saturated
From P-h chart for R-404A following values are obtained:
H1 = 361 KJ/Kg ,
H2' = 380 KJ/Kg, h3 = 264 KJ/Kg= h4 ,
S2'=1.65 KJ/Kg^{0}K,
S2= 1.59 KJ/Kg^{0}K, S2 = S2' + 2.3 ×CP ×log (T2/ T2') ,
1.65=1.59 + 2.3×1.5 ×log (T2/ 313)=318.49K
H2= h2'+ CP (T2− T2'), h2=380+ 1.5 (318.49− 313)= h2=388.8 KJ/Kg
Work Done by Compressor, WC :
Wc = h2 - h1
= 388.23-361= 27.2 KJ/Kg

Mass Flow rate of refrigerant, M:
M= REFRIGERANT CAPACITY OF SYSTEM / REFRIGERANT EFFECT OF REFRIGERANT
= 16.7 /(h1 – h4) = 16.7/ (361-260) = .165kg/s
Compressor Capacity, P: P = M (h2 - h1) = 0.165 x (388.2-361) =4.44KW
Condenser capacity, CC: CC = M (h2 –h3) = 0.165 x (388.2-260)=21.1KW Refrigeration Effect, Q41: Q41 = h1 - h4 = 361-260 =101KJ/Kg
Evaporator Capacity, CE: CE = M Q41 = 0.165 x 15 = 16.66KW
Coefficient of Performance, COP: COP = (h1-h4)/(h2-h1) = 101/27.1=3.72

IV.EQUIPMENT SELECTION

A selection of equipment consist of mainly four parts, selection of compressor, condenser ,evaporator and expansion valve. Based on the compressor capacity calculated compressor is selected on the basis of performance data sheet available to the industries. Two types of compressors used for 5 ton based chilling plant according to the data provided from the industries are scroll and hermetic compressors. Same selection is applied to condenser selection and evaporator selection. Evaporator used for 5 ton based chilling plant is a heat exchanger which is sometimes selected according to customer information, two types of evaporators are mostly used which are Shell and tube type type and plate heat exchanger. For 5 ton based air cooled condenser there is no change in types, the same type condenser is used in all cases of 5 ton chilling plant. Expansion valve used is TEX -2 which depends upon the nominal cooling capacity required, and the difference of pressure required to be maintained. Which is selected on basis of performance data sheet available to the industries

V.EXPERIMENTAL TESTING

A The testing procedure and testing setup of how 5 ton air cooled chiller is explained. For the analysis purpose same water is circulated in the chiller, after attaching the temperature sensor through tape at required points performance is conducted and readings are noted at every 5 min interval .based on this performance theoretical work done, theoretical COP and actual COP and actual work done is calculated for all the readings of each configuration of 5 ton air cooled chiller .for the analysis purpose two different compressors, hermetic and scroll compressor is used. Two different evaporator, shell and tube and plate heat exchanger are used. The condenser used for all the configuration is same and the expansion valve too (TEX-2)

5.1 TESTING SETUP
Digital temp Sensor of range -50 TO 99
Digital thermometer of range -50º c to 99 º c
Pressure range : Think and mica pressure gauge
Suction range 0-250psi Discharge range (-30)-350psi

5.2 PROCEDURE FOR TESTING
Temperature sensor are attached through tape at liquid line, evaporator outlet, expansion valve and one sensor is permanently installed in the tank
Pressure guages are connected to suction and discharge line.
Temp and pressure readings are note down for every 5 min interval.
In the above experiment same water is circulated from the tank without the addition of application water, which is added or subtracted continuously at constant rate depending upon the type of application.
5.3 Performance Calculation:
Performance calculation of 5 ton based air cooled chiller is shown. Work done and COP calculation for configuration is shown with the result table and charts, and are shown below

5.4 Result and discussion : Result table 5.1: For the configuration scroll compressor and plate heat evaporator

NO OF READINGS	COP_{TH}	COP_{ACT}	COP_{CAR}	WD_{TH} (KW)	WD_{ACT} (KW)
1	4.003	1.11	6.09	4.39	8.85
2	4.23	1.092	6.21	4.1	8.93
3	4.32	1.07	6.36	3.99	8.7
4	4.18	1.06	5.6	4.05	8.42
5	4.2	1.01	5.31	4.035	7.57

R404A refrigerant.

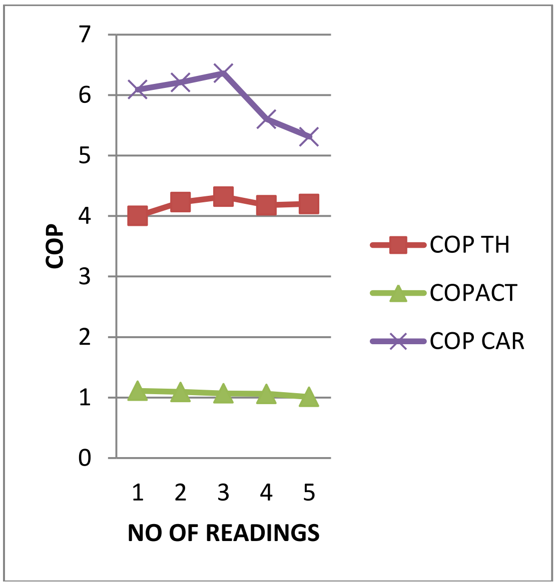

FIG 5.1:cop comparison chart for the configuration scroll compressor and plate heat exchanger as evaporator with r 404A refrigerant

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