Research Inventy: International Journal of Engineering And Science
Vol.13, Issue 5 (May. 2023), PP 40-47
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Design and Performance Analysis of 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 two different configruatons 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 configruation scroll compressor and plate heat evaporator can give better results as compared to the configruation scroll compressor and shell and tube evaporator.

Keywords: *cop, work done,*

Date of Submission: 05-05-2023 Date of Acceptance: 16-05-2023

I. 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 compressorsr. 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 centres, hospitals, universities and schools says. Wisdom.Process air conditioning is where close control of temperature andhumidity 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

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 underpredict the cooling capacity depending on the choice of the convergence variable[1]

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]

K.T Chan etal.2001: This paper reports how the coefficient of performance (COP) of air-cooled chillers can be improved by adopting variable condensing setpoint temperature control and using mist evaporation to pre-cool ambient air entering the condensers to trigger a lower condensing temperature. Chiller models without and with water mist system were established, and the former was validated by using measured operating data of an installed screw chiller. The baseline refers to an air- cooled chiller operated under HPC with variable speed fans. The chiller COP could increase by -0.29- 12.2% and 3.1-71.9% from the baseline when the chillers operated under the traditional HPC but adding water mist and under the new CTC, When the chiller operated under CTC with water mist, the energy performance could be further improved, and the chiller COP could increase by 7.1-72.9% from the baseline.[3]

K.A Manske, 2001 : This paper is a result of a research project, which focused on optimization of an existing industrial refrigeration system for a large two-temperature level cold storage distribution facility located near Milwaukee, Wisconsin. This system utilized a combination of single-screw and reciprocating compressors (each operating under single-stage compression), an evaporative condenser, and a combination of liquid overfeed and direct expansion evaporators., Simulation results for the annual performance of the refrigeration system investigated in this project show a reduction in annual energy consumption by 11% as a result of the recommended design and control change.[4]

J.D Tedford ,2001 : This paper presents a system simulation model of an oil-injected screw chiller. The refrigerant (shell and tube) heat exchangers are modeled, using a three-zone approach, to study the effects of the operational parameters on the fractional area allocated to each phase within the heat exchangers. With a PLR greater than 0.5, the subcooled region in the condenser accounts for less than 2%, the two-phase region accounts for up to 73% and the superheated region occupies about 25% of the total area of the condenser.[5]

Rhett david graves 2003: This paper presents a thermodynamic model for a screw chiller and cooling tower system for the purpose of developing an optimized control algorithm for the chiller plant. The thermodynamic chiller model is drawn from the thermodynamic models developed by Gordon and Ng (1996).. The models are coupled to form a chiller plant model which can be used to determine the optimal performance. Two correlations are then required to optimize the system: a wet-bulb/setpoint correlation and a fan speed/pump speed correlation. Using these correlations, a “quasi-optimal” operation can be achieved which will save 17% of the energy consumed by the chiller plant.[6]

Fu wing U etal. 2005.This paper describes how the COP of these chillers can be improved by a new condenser design, using evaporative pre-coolers and variable-speed fans. A thermodynamic model for an air-cooled screw-chiller was developed.It is found that the chiller 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.[6]

Ho Yin chun 2006 : This paper presents a simulation study on how to increase the coefficient of performance (COP) of an air-cooled screw chiller equipped with high static condenser fans. A thermodynamic chiller model was developed and validated using the operating data and specifications of the chiller. The simulation results show that reducing the condensing temperature as low as possible is incapable of maximizing the chiller COP when the rated condenser fan power is high by up to 77 W per kW cooling capacity. 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.[7]

Zhang Xiosong etal. 2006 novel method was put forward for improving the energy efficiency of air-cooled water chiller plant operating on part load conditions. The conventional multiple-chiller plant was proposed to be integrated into one refrigeration cycle, by connecting those separate compressors, Both the simulative and experimental results indicated that applying this novel energy-saving method, the air-cooled chiller plant could get a significant performance improvement on various part load ratio (PLR) conditions, due to the apparent decrease of condensing temperature and some increase of evaporating temperature. Under the same outdoor temperature of 35 °C, when the PLR decreased from 100% to 50%, the COP increased by about 16.2% in simulation and 9.5% in experiment.[8]

RAHMAN SAIDUR 2009 In this paper, energy consumption by chillers has been estimated using data collected by walkthrough energy audit for Malaysian office buildings. It has been found that chillers use about 42,285MWh and 84,569MWh of electric energy for 50% and 100% loadings in an institutional buildings.so this study shows that It has been found that 90MWh-896MWh of energy can be saved for using energy efficient chillers for different percentage of loadings. Along with energy savings, US$57,314 as a bill savings can be achieved for high efficient chillers for 50% chillers loading.this study also shows suggest that 35,975 MWh energy and US$2,302,431 bill can be saved for 60% of speed reductions using VSD.

Madhur behl, 2012: This paper presents a green scheduling approach with chilling plants to reduce their peak power demands. A green scheduling approach means the use of thermal energy storage with vcr system,this thermal energy storage stores the energy in peak hours and uses that power in the time of need.whem main system is shut off for any reason. Using this system it is found that a green scheduling approach has a potential to save average monthly electricit. bill by 17 % as compared to system without thermal energy storage**.**

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 heat transfer performance

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

Gregor p henze 2013 : This article describes a field study conducted on two university campuses in Massachusetts and Colorado during the cooling season of 2011. The purpose of this experimental study was to alleviate AT degradation problems on both campuses through the use of intelligent pressure-independent control valves, and to quantify the improvements achieved. The MA field results revealed that the intelligent control valves when coupled with a AT management strategy have allowed the campus to serve additional cooling load on its campus with the same distribution and central plant system.

Oucome of the literature riview: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

2.16 :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. Referegerant 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 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 wendors 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.

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 ºC and evaporator temperature 5 ºC and. The VCR cycle is dry saturated
From P-h chart for R-404A following values are obtained:
$h_1 = 361$ KJ/Kg , $h_2' = 380$ KJ/Kg,
$h_3 = 264$ KJ/Kg= h_4 ,$S_2' =1.65$ KJ/KgK, $S_2 = 1.59$ KJ/KgK,
$S_2 = S_2' + 2.3 \times C_P \times \log (T_2/ T_2')$,
$1.65=1.59 + 2.3\times1.5 \times\log (T_2/ 313)=318.49K$ $h_2 = h_2' + C_P (T_2 - T_2')$,
$h_2=380+ 1.5 (318.49-313)$= $h_2=388.8$ KJ/Kg
Work Done by Compressor, W_C :
$W_c = h_2 - h_1$
= 388.23-361= 27.2 KJ/Kg
Mass Flow rate of refrigerant, M:

$$M= \frac{refrigeration\ capacity\ of\ system}{refrigeration\ effect\ of\ refrigerant}$$

= 16.7 /($h_1 - h_4$)
= 16.7/ (361-260)
= .165kg/s
Compressor Capacity, P:
$P = M (h_2 - h_1)$
= 0.165 x (388.2-361)
=4.44KW
Condenser capacity, C_C:
$C_C = M (h_2 - h_3)$
= 0.165 x (388.2-260)=21.1KW
Refrigeration Effect, Q41: $Q_{41} = h_1 - h_4$
= 361-260
=101KJ/Kg

Evaporator Capacity, CE:
C_E = M Q41
= 0.165 x 15
= 16.66KW
Coefficient of Performance, COP: COP = $(h_1-h_4)/(h_2-h_1)$
= 101/27.1=3.72

IV. EQUIPMENT SELECTION

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 compresors. Same selection is apllied 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

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, theorectical 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)

TESTING SETUP

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

PROCEDURE FOR TESTING

1 temperature sensor are attatched through tape at liquid line, evaporator outlet, expansion valve and one sensor is permanently installed in the tank
2 Pressure guages are connected to suction and discharge line.
3 Temp and pressure readings are note down for every 5 min interval.
4 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 Two different combination are tested which includes.
1 scroll compressor and shell and plate heat exchanger as evaporator R404A as refrigerant
2: scroll compressor and shell and tube heat exchanger as evaporator r 404a as refrigerant

Performance Calculation: performance calculation of 5 ton based air cooled chiller is shown. Work done and COP calculation for every configuration is shown with the result table and charts, and are shown below for all the configurations.
Two different configurations which are tested are as under with r400A refrigerant

VI. Result and discussion :

Result table 5.1: For the configuration scroll compressor and plate heat evaporator R404A refrigerant.

FIG 5.1: this fig shows the variation in theoretical cop, actul cop and carnot cop for the configruation scroll comressor and shell and tube evaporator with r 404a refrigerant

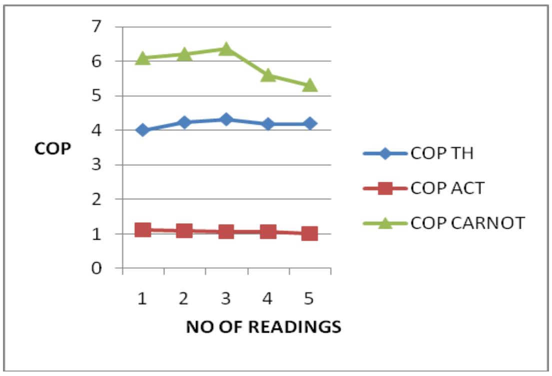

FIG 5.1:cop comparison chart for the configuration scroll compressor and plate heat exchanger as evaporator with r 404A refrigerant**.**

FIG5.2:This fig shows the variation in theoretical work done and actual work done for the configruation scroll comressor and shell and tube evaporator with R404A refrigerant.

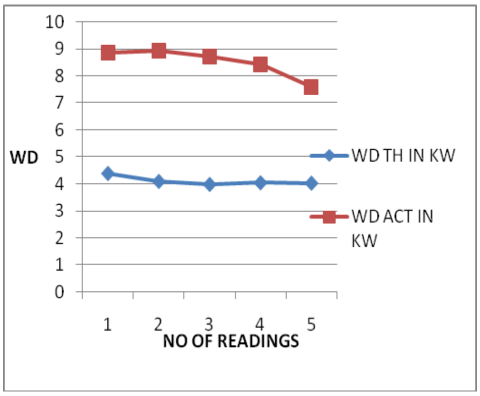

FIG 5.2: Work done comparison chart for the configuration scroll compressor and plate heat exchanger with R404A refrigerant.

S.R NO of readings	COP TH	COP ACT	COP CAR	WD_{TH} (KW)	WDACT (KW)
1	4.48	1.32 4	4.5	3.9	7.55
2	4.77	1.12	5.01	3.70	7.5
3	4.70	1.10	4.8	3.66	7.75
4	4.4	1.06	4.5	3.60	7.6
5	4.48	1.03	4.61	3.9	7.45
6	4.42	1.02 5	4.75	3.68	7.4
7	3.7	1.03	4.75	3.5	7.3

Result table 5.2: Result table for the configuration scroll compressor and shell and tube evaporator with R404A refrigerant.

FIG 5.3: This fig shows the variation in theoretical cop, actul cop and carnot cop for the configruation scroll compressor and shell and tube evaporator with R404A refrigerant

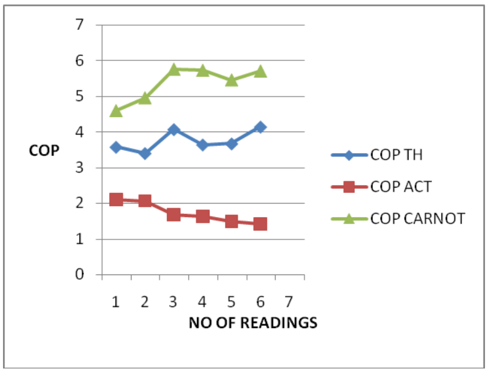

FIG 5.3:Cop comparison chart for the configruation scroll compressor and shell and tube evaporator with R404A refrigerant

FIG 5.4:This fig shows the variation in theoretical work done and actual work done for the configruation scroll compressor and shell and tube evaporator with R404A refrigerant.

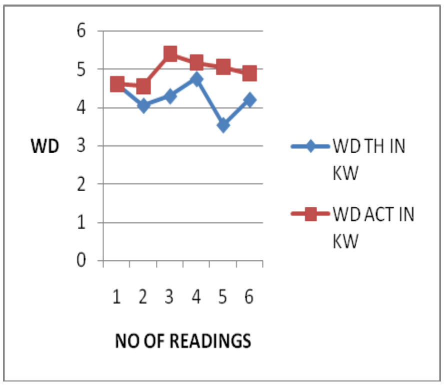

FIG 5.4:Theoretical work done comparison chart the configruation scroll compressor and shell and tube evaporator with R404a refrigerant.

FIG5.5: The fig shows the variation between theoretical work done and actual work done between the configurations scroll comnpressor and plate heat evaporator and scroll compressor and shell and tube heat evaporator with R404A refrigerant.

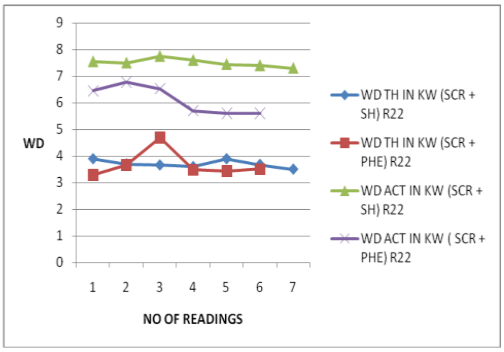

FIG5.5:Work done comparison chart between the configurations scroll compressor and plate heat evaporator and scroll compressor and shell and tube evaporator with R404 refrigerant.

FIG 5.6 :This fig shows the variation of cop between the configurations scroll compressor and plate heat evaporator and scroll compressor and shell and tube evaporator with R404 refrigerant.

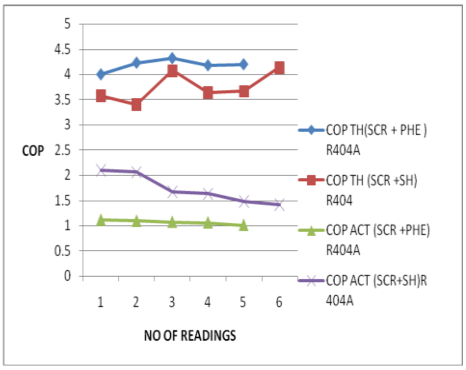

FIG5.6:Cop comparison chart between the configurations scroll compressor and plate heat evaporator and scroll compressor and shell and tube evaporator with R404 refrigerant.

VII. CONCLUSSSION

1. The chart in the fig 5.5 shows that the actual and theoretical work done in the configruation scroll compressor and shell and tube heat evaporator is more than the configruation scroll compressor and plate heat evaporator.

2. The chart in the fig 5.6 shows that the actual cop for the configruaton scroll compressor and plate heat evaporator is less than the configruation scroll compressor and shell and tube evaporator. and theoretical cop for the configruation is more than the confogruation scroll compressor and shell an tube evaporator.

3. Also the in the plate heat configruation actual cop decreased gradually as compared to shell and tube configruation in which actual cop decreased drastically in initiall phase . so the plate heat configruation could give the better results on based of above comparison.

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