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Effect of Condenser Length on Performance of Water Cooling Refrigeration System Cum Air Cooler

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Abstract: ***Now a days Air conditioning system has become a need for everyone to feel comfort in hot and humid condition and everyone feels comfortable to drink chilled water for quenching the thirst of the people. According to American Society of Heating, Refrigerating and Air conditioning Engineers in short ASHRAE Human comfort is defined as the condition of mind which expresses satisfaction with surrounding air.***

In this project, we developed the water cooling refrigerator and air cooling system by combining both the systems through which water is chilled by an eco-friendly refrigerant R-134a and then the air is cooled by this chilled water. Performance analysis of the water cooling refrigeration system was done and analyzed with varying condenser length. By combining these both systems we can reduce the compressor work, cost, save the electrical energy and environment too.

Keywords: ***Water cooling refrigeration system, Air cooler, Refrigerant, Vapour Compression System(VCS)***

I. INTRODUCTION

Refrigeration is the process of maintaining the temperature lower than the surroundings. William Cullen at the University of Glasgow invented the basis for modern refrigeration in 1748. However he never used his discovery for the practical purposes. Later Oliver Evans, an American inventor in 1805, described a closed vapour compression refrigeration cycle for producing ice. Jacob Jenkins in 1834 developed first hand operated compressor machine. James Harrison in 1857 invented first ice making machine which is used for practical food purpose. In 1859, same idea was prepared for more complicated applications by Ferdinand. In 1927, the first domestic refrigeration widely used for general electronics.

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The development of refrigeration was slow at the beginning stage because steam engines were the only prime movers to run the compressors. With the advance of electric motors and increases in higher speeds of compressors, the scope of application is increased. Presently there are many types of refrigeration systems were developed due to vast environment conditions and based on applications, in recent years the use of chlorofluorocarbons (CFC) as refrigerants are using in refrigeration system. These chlorine atoms create environment problems like ozone depletion, global warming etc. by the year 1987 Montreal protocol tells that CFC are harmful impact on ozone layer. Therefore to protect the environment, these refrigerants are replaced by ecofriendly refrigerants. The high global warning and ozone depletion potential were due to R12 emissions from domestic refrigerators. Many studies were conducted in order to replace the harmful refrigerants with eco-friendly refrigerants in the refrigeration system. The hydrocarbon (HC) as refrigerant has several positive characteristics such as zero ozone depletion potential, very low global warming potential, low toxicity, miscibility with lubricant, good compatibility is used in refrigeration system. Hydro fluids such as R134a refrigerant provide alternative to these many CFC refrigerants in order to their zero ozone layer depletion. Since hydrocarbons have no chlorine content but the thing is the hydrocarbons are selected based on the flammability.

Bolaji B.O, Akintunde M. A [1] has applied experimental investigations on 3 ozone friendly Hydro-fluoro-carbon (HFC) refrigerants such as R134a, R152a and R12 and focussed on performance analysis. R. Cabello et al [2] analyzed the performance using three different working fluids like R22, R134a and R407c of a vapour compression refrigeration system. The operating parameters are the condensing pressure, degree of superheating and evaporating pressure at inlet of the compressor. He concluded that the consumption of power decreases when CR increases with R22 when compared to other working fluids usage. Vinay Vishwanath, Rohan Jikarare[3] done the project on water dispenser system using air conditioner the main aim is to develop the multifunctional unit to provide hot water and cold water at a time and makes it more economical by providing both air and water cycle. The hot water is gained is 47 degrees at three hours' time and the cold water is at 18 degrees at three hours' time. Dr. U. V. Kongre, A. R. Chiddarwar [4] has done testing and performance analysis on air conditioner cum water Dispenser. M. James Calm [5] premeditated about emission and ecological impacts of R134a, R123 and R11 due to outflow from centrifugal chiller system.

He inspected the whole impact in appearance of TEWI and variation in system performance or efficiency due to loss in charge. The author also reviewed the techniques to diminish the losses in refrigerant by the system design modifications,

lubricant & servicing changing, preventive safeguarding measures improvement, usage of purge-system for refrigerant vapour resurgence.

Bolaji. B.O. et al [6] proposed the process of selecting environmentally friendly refrigerants which has low global warming potential and zero ozone exhaustion potential. Methane derivatives are R32 and R23 & ethane derivatives are R134a, R152a, R125 and R143a from the emerging refrigerants which have low flammability, non toxic and environmentally friendly. To examine their performance in the system, those refrigerants are used theoretically and experimentally. Ahmed B & Samira B.D. [7-8] demonstrated the usage of halogenated-refrigerants which are damaging for environment and the usage of natural refrigerants suit a credible solution. So normal refrigerants are used as an substitute solution in place of halogenated refrigerants. The refrigerants should be like that, which should not contain no chlorine and no fluorine. The researchers concentrated to reduce the emissions which will produce bad effects on our atmosphere. Their main concentration towards the involvement to the lessening of greenhouse gases with substitute of the polluting cooling fluids(HCFC). Satish M, Vishal Nathile, Faizan Q et al [9] were conducted the experiment on design and fabrication of refrigerator cum air cooler. In this project the aim is to reduce the cost of the refrigeration system and power consumption and to be useful for all economically background people in order reduce the cost. E.Granryd [10] has listed the dissimilar hydrocarbons as operational medium in refrigeration-system. He deliberated the various safety principles associated to refrigerants. He proved the characteristics of hydrocarbons that put together them for fascinating refrigerating alternatives for efficient in energy and environmental friendly. But safety precautions due to flammability must be seriously taken into account.

Lee. S Y et al [11] have observed the performance of VCR Systems with isobutene & contrast the outcomes with R22 and R12. The researchers used R600a about 150g and maintain the refrigeration temps about -10 °C and 4 °C to keep up the condition of cold storages and freezing applications. They maintained capillary tube with internal diameter of 0.7mm and length of 4m to 4.5m for cold storage applications and internal diameter of 0.6 mm & 4.5m to 5m for freezing applications. They concluded that the COP lies between 0.8-3.5 in freezing applications & 1.2-4.5 in cold storage applications. Their main observations for getting better performance, they use two capillary tubes in parallel in cold storages and AC applications, and in freezing applications a single tube is most suitable. P. Preethiban [12] conducted the experiment on design of water cooler cum air conditioner the purpose of this project is combining the both the systems the refrigerant is used in the refrigeration only not in air cooling system.The aim is reduce the cost the project doing it economically and temperature is gained nearer to the actual air conditioner. P. Sarat Babu, Prof. N. HariBabu [13] are conducted the experimental study of domestic refrigerator using variable condenser length in this project the optimum length of the condenser is five meters length, in this project for five meters length condenser the theoretical cop is 3.1 and Actual COP for five meters condenser length the cop is 2.96. The basic refrigeration system working principle is given in fig. 1.

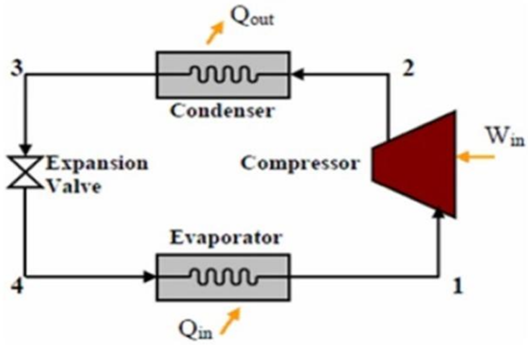

Fig. 1. Basic refrigeration system

In this work, the actual refrigeration system is extended to by combining the air cooling system. After the working of actual refrigeration cycle the water is cooled to required temperature then the cooled water is circulated through the condenser which is connected to the system by placing the fan in front of condenser. Then the fan drags the cooled air through the condenser and one more parameter is by varying the condenser length we can achieve the optimum cop.

II. EXPERIMENTAL SETUP AND METHODOLOGY OF REFRIGERATION CUM AIR COOLER

In this experimental setup, the compressor and motors are run with the use of electrical power. Tests are to be conducted on the refrigeration system by varying the condenser lengths in order to compare the performance parameters of the system. The instruments like thermocouples, presser gauges, volt meter and ammeter are used in order to take the readings during experiment. Digital thermocouple sensors are used which gives direct values of temperatures at different stages. Initially the refrigeration is charged with R134a refrigerant. The condenser is connected which have four meters length and experiment is conducted and readings are taken later the condenser is replaced which have five meters and three meters length. The experiment readings taken and analysis part are to be analyzed. The schematic diagram of water cooling refrigerator cum air cooler is shown in fig. 2. The experiment is to be done in order to find the cop of refrigeration system. Fig.3 shows experimental setup of refrigeration cum air cooling. Compressor, the forced convection air cooled condenser, expansion value and evaporator and additional condenser is shown for the cooling water circulation are the components of domestic refrigerator are shown in the fig. 3. Temperature indicators are used in order to take the various temperatures like condenser inlet and outlet temperatures, evaporator inlet and outlet temperatures.

A. Construction of Refrigerator cum Air Cooling System

In this system the normal refrigeration cycle is used to construct the water cooling and this chilled water is used to cool the air circulating the cool water through the copper coil and placing a fan in front of the copper coil. The components present in the complete system are the compressor, condenser, capillary tube, evaporator, water tank, cool water flowing condenser and a fan.

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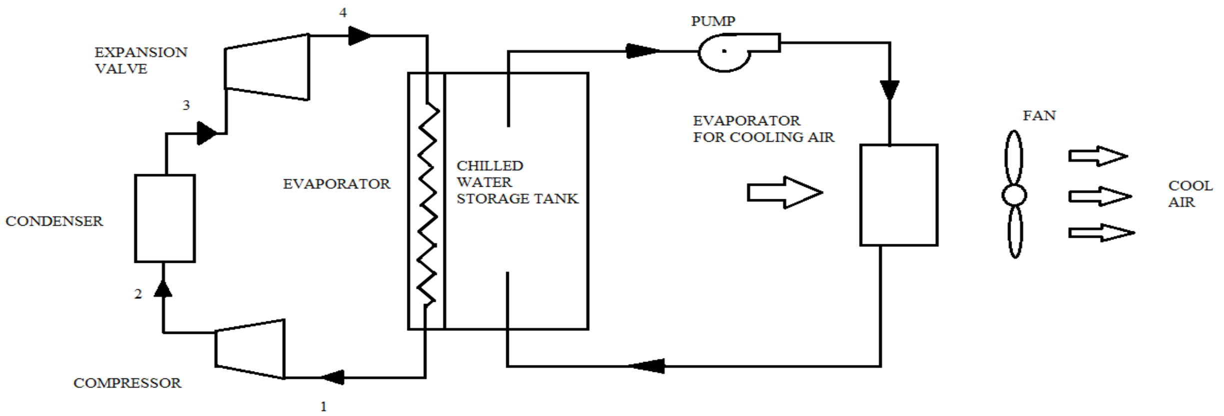

Fig. 2.Schematic diagram of water cooling refrigerator cum air cooler

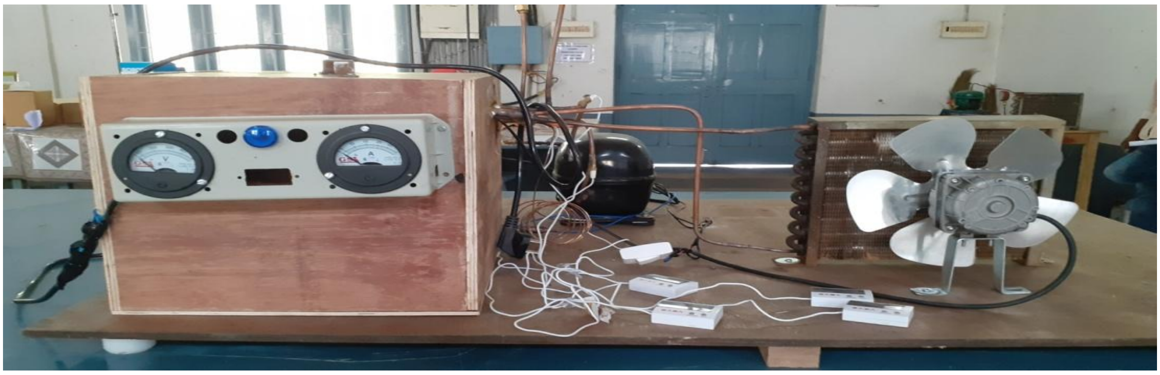

Fig. 3. Air cooler cum water cooling refrigeration system

In this experimental work a domestic VCS has been used. In any compression-refrigeration-system, there may be two various pressure conditions. One is low pressure side (evaporator), and another one is high pressure side (condenser), heat is absorbed in low pressure side and suction line which is entrance to the compressor-suction valve is on low pressure side. From the refrigerant, heat is released in high pressure side of the condenser. Expansion device connects both pressure sides and it is designing such that the end goal that no fluid refrigerant will move through it until and except if the pressure in the evaporator is lessened by running of the compressor. Refrigerant is splashed into the evaporator because of low pressure; it boils quickly and retains absorbs heat. The vaporized refrigerant moves back to compressor through the suction line and it compressed to high pressure side as superheated vapour. While through the air cooled condenser it is cooled, gives up heat that absorbed in the evaporator and comes back to fluid then flows into fluid receiver prepared to repeat the cycle of system.

III. EXPERIMENTAL STUDY

By varying condenser length, the parameters like COP, circulating rate, heat rejection rate and compression ratio has been calculated by using the appropriate formulae in sections III-A,B and C.

A. Condenser Length =3m

Compressor suction pressure (P1)=0.57 bar=0.057MPa
Compressor discharge pressure(P2) =7.73bar=0.77MPa
h1 =205KJ/Kg, h2 =265KJ/Kg
h3 =h4= 76KJ/Kg
T1=30.8°c, T2=38.3°c, T3=36.4°c and T4=8.9°c
Theoretical COP =[(h1-h4)/(h2-h1)]
=205-76 / 265-205=2.15
Circulating rate to obtain one tonne of refrigeration (mR) =210/RE
RE=(h1-h4)= 205-76=130 KJ/Kg
mR =210/130 =1.55Kg/min
Heat of compression = (h2-h1)= 265-205 = 60 KJ/Kg
Heat rejected in condenser =(h2-h3)= 265-76 = 190 KJ/Kg
Actual COP =Refrigeration effect/Compressor work
For 0.5 ton of Refrigeration effect = 3.5×0.5=1.75KW
Compressor work = V×I=210×4 =0.84 KW
Actual COP = 1.75/0.84 = 2.04
Heat rejection rate =(210/130) 190= 306.92 KJ/Kg
Heat rejection factor = 306.92 /210= 1.46
Compression Ratio =(Pd/Ps)=7.73 /0.57 =13.56

B. Condenser length =4m

Compressor suction pressure (P1)=0.6 bar=0.06MPa
Compressor discharge pressure(P2) =7.94bar=0.79MPa
h1 =225KJ/Kg, h2 =280KJ/Kg, h3 =h4 =80KJ/Kg
T1=31.4°c, T2=40.3°c, T3=34.6°c and T4=8°c
Theoretical COP =[(h1-h4)/(h2-h1)]
=225-80/280-225=2.65
Circulating rate to obtain one tonne of refrigeration (mR) =210/RE
RE =(h1-h4)=225-80=145KJ/Kg
mR =210/145=1.45Kg/min

Heat of compression = (h2-h1)=280-225 =55KJ/Kg

Heat rejected in condenser =(h2-h3)=280-80
=200KJ/Kg

Actual COP =Refrigeration effect/Compressor work

For 0.5 ton of Refrigeration effect = 3.5×0.5
=1.75KW

Compressor work = V×I=220×3 =0.66 KW

Actual COP = 1.75/0.66=2.64

Heat rejection rate =(210/145)200=289.65KJ/Kg

Heat rejection factor =289.65/210=1.38

Compression Ratio =(Pd/Ps)=7.94/0.6=13.23

C. Condenser Length = 5m

Compressor suction pressure=0.63 bar=0.063MPa

Compressor Discharge Pressure=8.15 bar= 0.815MPa

h1 =245 KJ/Kg, h2 =295 KJ/Kg, h3=h4=90 KJ/Kg

T1 =32^{0}C, T2=42.3^{0}C, T3=32.8^{0}C and T4=7.1^{0}C

Theoretical COP= (h1-h4) / (h2-h3)
= (245-90)/(295-245) = 3.1

Circulating rate to obtain one tonne of Refrigeration, mR=210/R.E

R.E=h1-h4=245-90=155

mR=210/155=1.35Kg/min

Heat of Compression =h2-h1=295-245=50KJ/Kg

Heat rejected in Condenser=h2-h3=295-90
=205KJ/Kg

Actual COP=Refrigeration effect/Compressor work

For 0.5 ton, Refrigeration effect=3.5*0.5=1.75KW

Compressor work=V*I
=230*2.6=598W=0.59KW

Actual COP = (1.75/0.59)=2.96

Heat rejection rate = (210/155)205 =277.74KJ/Kg

Heat rejection factor=277.74/210=1.32

Compression ratio=Pd / Ps=8.15/0.63=12.93

Air temperature from the air cooler = 21^{0}c

IV. RESULTS AND DISCUSSIONS

In this project, fabricated water cooling refrigeration cum air cooler and evaluated the performance parameters such as COP, circulating rate, heat rejection factor and compression ratio by varying condenser length.

The analysis done by varying the condenser length of the refrigeration cycle for finding the variation of the COP that is to find weather it is useful or not and finally obtained the better results shown in table I.

Table I: Results

Condenser length (m)	3	4	5
Actual COP	2.04	2.64	2.96
Theoretical COP	2.15	2.65	3.1
Circulating Rate	1.55	1.45	1.35
Heat Rejection Rate	303.33	289.65	277.74
Compression Ratio	13.56	13.23	12.93

Within the increase of the condenser length the COP is increasing and within the decrease of the condenser length the COP is decreasing and with the increase of the condenser length the mass flow rate or circulating rate of the refrigerant is decreasing and with the decrease it is increasing and coming to heat rejection rate with increase in condenser length it is decreasing and with decrease it is increasing and finally the compression ratio is decreasing with increasing condenser length and increasing with the decrease in the condenser length.

From the condenser length of 4m, the obtained COP is 2.64 and mass flow rate of refrigerant of 1.45, heat rejection rate is 289.65 and compression ratio is 13.23. And next analysis has been done for condenser length of 5m that is increasing in condenser length, then COP increases and reduced circulating rate and heat rejection rate and compression ratio. And next condenser length is changed to 3m then COP decreases and increases the circulating rate, heat rejection rate and compression ratio. For condenser length of 5m, maximum COP of 2.96 is achieved. The COP variation w.r.to condenser length is represented in fig 4. The remaining parameters circulating rate, heat rejection factor and compression ratio w.r.to varying condenser length are shown in figs 5-7.

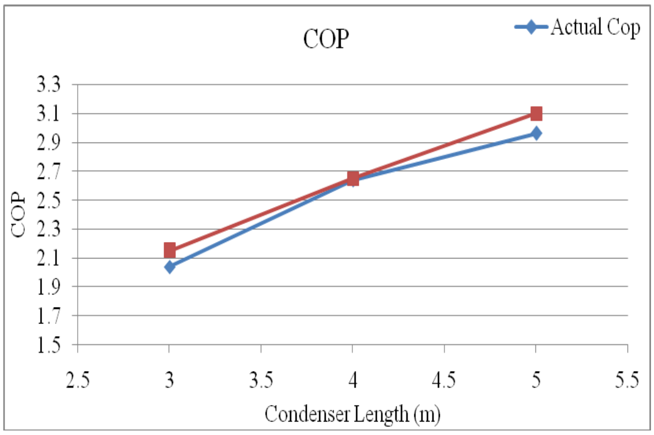

Fig. 4.Graph between Condenser Length and COP

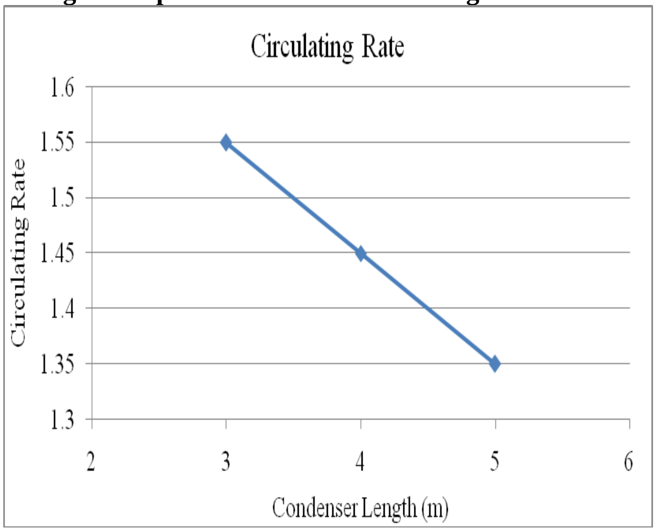

Fig. 5.Graph between Condenser Length and Circulating Rate

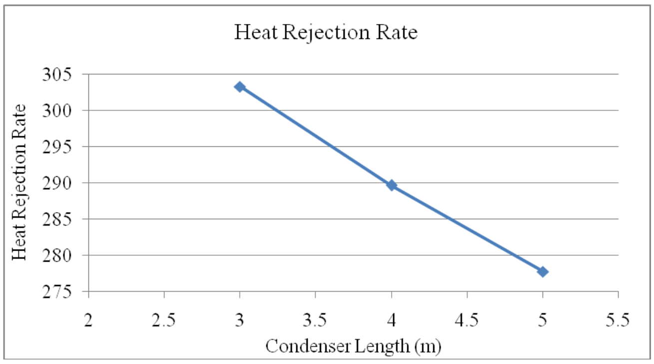

Fig. 6.Graph between Condenser Length and Heat rejection rate

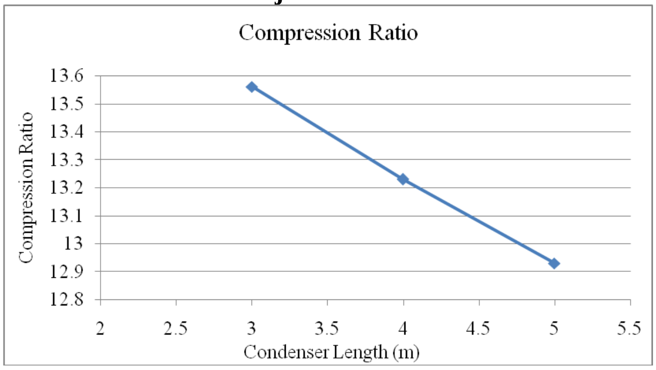

Fig. 7.Graph between Condenser Length and Compression Ratio

V. CONCLUSIONS

In this paper, the water cooling refrigeration system cum air cooler was developed and observed the performance factors by varying condenser length. The performance characteristics like COP, circulating rate, heat rejection factor and compression ratio are calculated for three different condenser lengths 3m, 4m and 5m. As the condenser length increases from 3m to 5m, the COP is also increases and the remaining factors circulating rate, heat rejection factor and compression ratio are decreases.

From the performance characteristics, the water cooling refrigeration system cum air cooler provides more cooling effect by reducing the compressor work and the cost. And also it helps to reduce the usage of electricity.

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