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DESIGN AND DEVELOPMENT OF HEAT RECOVERY SYSTEM IN WATER COOLER

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ABSTRACT
More than 15% of total energy consumption of the world is for the cooling and airconditioning application. Beign the huge contributor in consumption of electricity, these systems have the scope of developments in terms of optimum utilization of the resources. The cooling systems are improved over the years by means of design, use of different cooling mediums and th performance. The conventional water coolers are less energy efficient and the wastage of water is also the issue to be addressed. Authors have presented the improved design in terms of energy efficiency and the waste water utilization in this paper. The design fo the system components in Solid Works software is presented in the paper along with the parameter calcutions. Water and electricity are important aspects to be saved. Optimal utlistion of the electricity and water results in saving the environment, cost, and environmental hazards.

Keywords: Water Cooler, Heat Recovery System, Cooling System, Energy Conservation, etc.

INTRODUCTION
Energy efficient systems are the future of electrical devices and mechanical systems in coming decade. The energy and water conservation are the most important aspects while designing the systems associated with it. Conventional water coolers are not designed with consideration of energy efficiency.
With increase in tepmrature and change in the living styles of human being over last decades, water cooler and commonly installed in many commercial places such as colleges, universities, shopping malls, industries and many more. With this extensive use, it has become mandatory to think over, effective design in terms of energy and water saving for water coolers.
Generally, when a person drinking water from water cooler, it is observed that, a significant part of the water is wasted because of improper use. The cooling system is designed such that, there is not proper

utilisation of the resources. It results in to the higher energy consumption. The conventional cooling cycle is as shown if figure below.

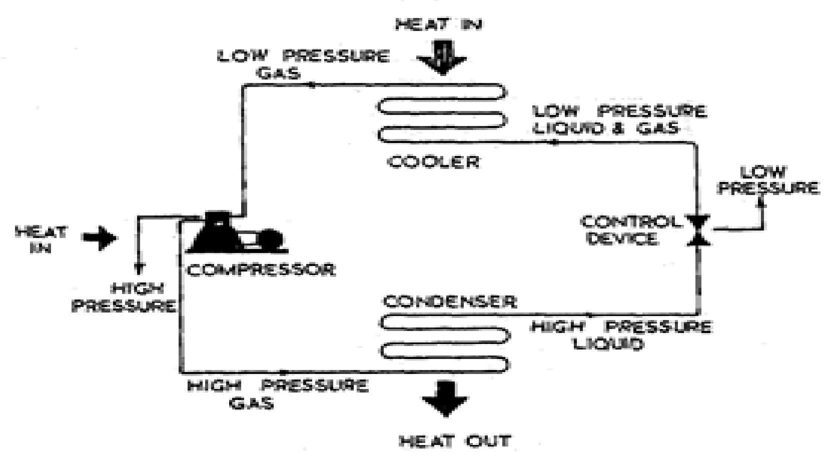

Fig.1: Basic Refrigeration Cycle

The refrigerent is compressed at compressor as shown in above figure. The pressurised gas is then passes through the condenser and gets converted to pressurised liquid. This liquid passes through the cooler in order to cool the water. Authors have proposed the use of heat exchanger in the the water cooler for better utilisation of the cooling system.

Whenever the water from the tap of the cooler is dispensed, some of the water is wasted. Authors have proposed to collect the waste water and use it for the cooling of the coolent in the heat exchanger.

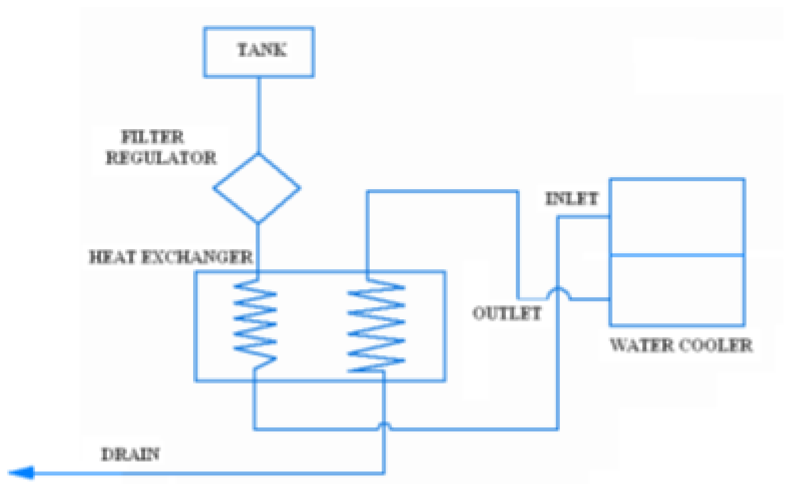

Fig.2: Water Cooler with Heat Exchanger

The hot refrigerent, before coming out from the compressor is proposed to be cooled in the heat exchanger using the drain water of the water cooler. Introduction of heat exchanger in the cooling cycle will help to improve the efficiency of the system. The heat exchanger adds the advantage of saving the energy on cooling of the water along with use of the drain water.

OBJECTIVES OF THE WORK

The work is carried out to achive the following objectives:

- Designing the water cooler with improved efficiency.
- Improving the cooling performance of water cooler.
- Utilising the drain water of water cooler for cooling.

System Modelling:

The modelling is done using solid works software. The developed solide meodel 3D images are as shown below.

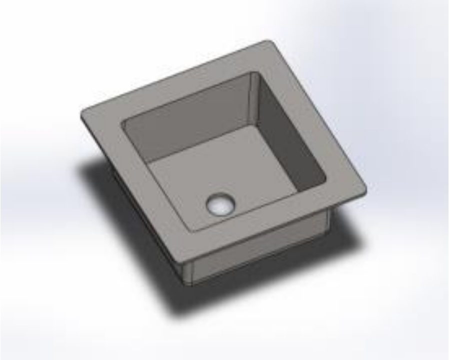

Fig.3: Basin Model

Fig.4: Condenser Assembly

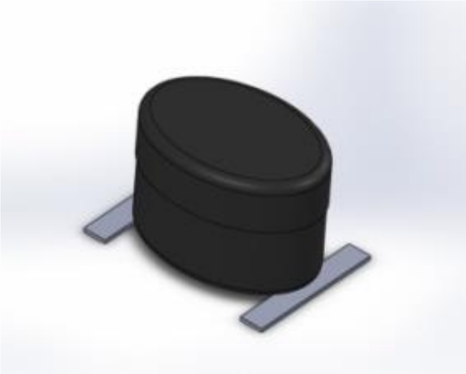

Fig.5: Compressor Model

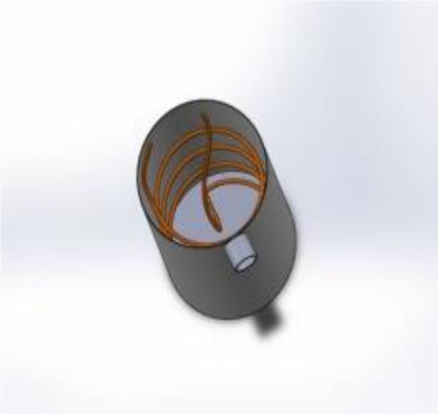

Fig. 6: Heat exchanger

Fig. 7: Assembly of the Water Cooler

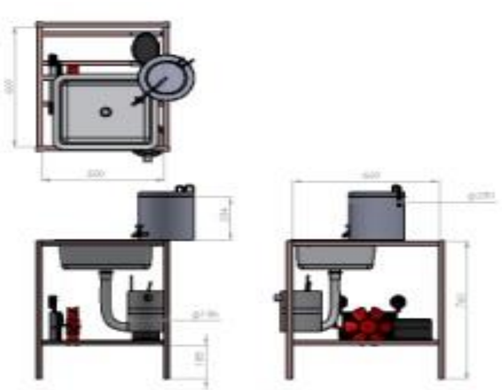

Fig. 8: Drafting

System Design

The design of the proposed system is presented in this section.

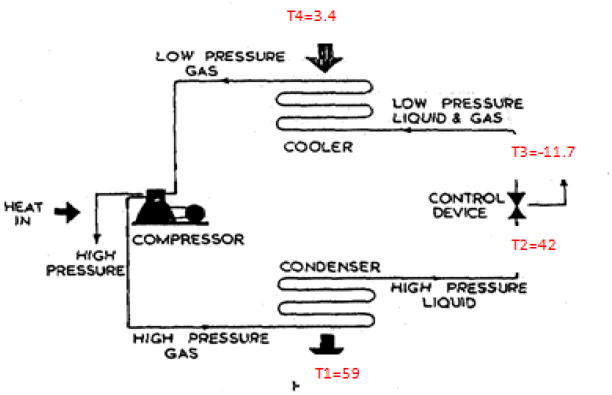

Fig.9: The Proposed System Model

Observations Table No- 01:-

Water filled in top vessel = 1 liter

Final temp of water = 13^{0} C

Reading at energy meter =

Voltage = 230 V

Current = 1.4 amp

Wattage = V x A = 230 x 1.4 = 125 watt

Theoretical cop = 0.5 (from HMT design data book for 125 compressor pg no…13.5)

Heat removed = 62.5 watt

Table 1: Observation without filling water in heat exchanger 30 minutes after starting cycle
Stage 1:-

Sr No.	Condenser inlet ºC	Condenser Outlet ºC	Evaporator entry ºC	Evaporator exit ºC
1	43.2	30.5	11.9	20
2	41.8	32.9	11.6	20.2
3	44	31.6	11	20.3
4	40.3	32.2	11.9	20.5
5	42.3	33.1	11.8	20.6

Calculations:
Stage 1:-
Reading no 1

$$COP = \frac{(T_{evap\ exit} - T_{evap\ entry})}{(T_{condenser\ inlet} - T_{evap\ exit})}$$

$$Cop = \frac{(20 - 11.9)}{(43.2-20)} = 0.34$$

Reading no 2

$$COP = = \frac{(20.2-11.6)}{(41.8-20.2)} = 0.398$$

Reading no 3

$$COP = \frac{(20.3-11)}{(44-20.3)} = 0.392$$

mean cop = 0.376

Observations table no- 02:-
Water filled in top vessel = 1 liter
Final temp of water = 13^0 C
Reading at energy meter =
Voltage = 230 V
Current = 1.4 amp
Wattage = V x A = 230 x 1.4 = 125 watt
Theoretical cop = 0.5 (from HMT design data book for 125 compressor pg no…13.5)

Heat removed = 62.5 watt

Table 2: Observation without filling water in heat exchanger 30 minutes after starting cycle
Stage 1:-

Sr No.	Condenser inlet ºC	Condenser Outlet ºC	Evaporator entry ºC	Evaporator exit ºC
1	37.5	29.5	10.1	19
2	36.6	30.9	11.9	19.2
3	37.1	31.6	12.2	20.3
4	35.4	30	12.9	22.5
5	36.5	29.9	9.8	18.6

Calculations:-

Stage 1:-

Reading no 1

$$COP = \frac{(T_{evap\ exit} - T_{evap\ entry})}{(T_{condenser\ inlet} - T_{evap\ exit})}$$

$$Cop = \frac{(19-10.1)}{(37.5-19)} = 0.48$$

Reading no 2

$$COP = = \frac{(19.2-11.9)}{(36.6-19.2)} = 0.419$$

Reading no 3

$$COP = \frac{(20.3-11)}{(44-20.3)} = 0.482$$

mean cop = 0.46

Design of Condenser

Power of compressor =125watt

20% of compressor power add due to friction

Heat required to remove from condenser = 1.2 * Power of Compresser

=1.2 * 125

=150 watt

Notation :- T_1 = Temp. at inlet of Condenser tube = 59^0 C

T_2 = Temp. at outlet of Condenser tube = 42^0 C

T_{atm} = Temp. of atmosphere =30^0 C

We know that,

$$Q = U * A * \Delta T$$

where U =Overall heat transfer

Then , $\Delta T = ((\Theta i - \Theta o)/(\ln (\Theta i / \Theta o)))$

Θi = T1 - Tatm

= 59-30

=29^0 C

Θo = T2 - Tatm

=42-30

=12^0 C

Put in above equation,we get,

ΔT=(29-12)/ ln(29/12)

=19.26^0 C

Taking U=28 $w/m^{2\,0}C$ will be the best selection (from Heat &Mass transfer handbook)

Now we are try to create such a box which have temperature above atmospheric .That means overall heat transfer increases for 10%

U = u * 1.1
= 28*1.1
=31$w/m^{2\,0}C$

Therefore Q = U * A * ΔT

150 = 31*A * 19.26

:.Acontact = 0.2512 m^2

Now,

Acontact = Π * Dtube * Ltube

Take diameter of tube = 6.25 mm

0.2512 =Π*6.25* 10^{-3} * Ltube

:. Ltube =12.79 m

For design purpose,

:. Ltube=13 m

Now since,Ltube=Perimeter * number of tubes

We know,

Box size = 230 x 340

Perimeter = (340 + 230) x 2 =570 mm

13= 570 * 10^{-3} * Number of turns

Number of turns =22.8

Number of turns=23

Design Of Evaporator

Notation :- T_3 = Temp. at inlet of evaporator =-11.7^0 c
T_4 = Temp. at outlet of evaporator =3.4^0 C
T_{atm} = temp. of atmosphere =30^0 C

Now,

Ɵi = Tatm-T_3
= 30-(-11.7)
=41.7^0 C

Ɵo = Tatm - 3.4
= 30 - 3.4
=26.6^0 c

Then,

ΔT= ((Ɵi - Ɵo)/(ln (Ɵi / Ɵo)))

=41.7-26.6/(ln (41.7/26.6))

=33.58^0 C

Therefore ,

Q= U * A *ΔT

Taking U=16 $w/m^{2\,0}C$ will be the best selection (from Heat &Mass transfer handbook)

Now we are try to create such a box which have temperature above atmospheric .That means overall heat transfer increases for 10%

U= 16 * 1.1

= 18 w/m$^{2\,0}$C

Therefore

Q = U * A * ΔT

150 =18*A*33.58

:. Acontact = 0.2481 m^2

Now,

Acontact = Π * Dtube * Ltube

0.2481 =Π * 9.25* 10^{-3} * Ltube

:. Ltube =8.53 m

:.Ltube=Perimeter * number of tubes

We know,

Box size = 230 x 340

Perimeter = (340 + 230) x 2 =570 mm

8.53= 570 * 10^{-3} * Number of turns

Number of turns =14.96

Number of turns=15

RESULT AND DISSCUSION

Table 3: Result Table for unit

Sr. No.	Parameter	Cooler without heat exchanger	Cooler with heat exchanger
1.	Energy Consumption (Unit)	1.4	1.1714
2.	Time (minutes)	100	82

Therefore in 1 hr 0.03855 unit energy saved and in one day water cooler runs for 10 hr so 0.3855 unit energy saves per day. Then in one month (30 days) 11.565 unit energy saved. The total energy saved in year is **138.78 units**.

Coefficient of performance of Water Cooler:

1. Before heat exchanger

COP = ―――――――― = ――――

= 14 / (31- 14)

= 0.8235

2. After heat exchanger

COP = ―――――――― ――――

= 18 / (28.4 - 18)

= 1.7307

3. Now, Net COP = COP After heat exchanger - COP After heat exchanger

= 1.7307– 0.8235

= 0.9072

Therefore, the **COP is increased by 0.9072.**

Table 4: Result for Temperature

Sr. No.	Time	Temperature without heat exchanger	Temperature with heat exchanger
1	0	31	28.4
2	5	30.3	27.5
3	10	29.4	26.8
4	15	28.7	25.4
5	20	28.0	24.1
6	25	27.1	23.1
7	30	26.2	22.6
8	35	25.4	21.3
9	40	23.7	19.9
10	45	22.9	19.0
11	50	21.4	18.3
12	55	19.5	17.5
13	60	18.7	16.7
14	65	17.9	15.9
15	70	17.2	15.3
16	75	16.8	14.8
17	80	16.2	14.3
18	85	15.8	-
19	90	15.0	-
20	95	14.6	-
21	100	14.0	-

CONCLUSION

Authors have presented the design and development of the heat exchanger based water cooler in this paper. The design calculations and 3D design models developed using Solid Works softwares. The proposed design is found suitable for electricity saving and uses the drain water for cooling purpose. The design is found suitable for the commercial water cooler development. The result achieved after completion of project where highly appreciable in terms of knowledge, quality and with cost reduction. The project has certainly helped us to know the gap between our theoretical and practical knowledge. It enabled us to see how the knowledge gained through textbooks is implemented in practice.

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