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Design, Experimentation and analysis of Photovoltaic Operated Instantaneous Water Cooler

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Abstract— In today's world use of non-renewable energy resources brought us plethora of problems like anthropogenic pollution, accelerated global warming and so on. This caused us to look for a sustainable and viable solution, renewable energy resources. As we all known solar energy is never ending source of energy, it is being professes by the international community for its sustainable and clean energy.Two known approaches of using solar energy to provide refrigeration includes vapour compression cycle and vapourabsorption cycle. In this project, we are going to discuss about the water cooler based on VCR cycle which consist of tube-in-tube type of evaporator coil and the manufacturing of instantaneous water cooler. Our main objective is to make an effective refrigeration system by making use of solar energy in order to cool water quickly and to decrease power consumption.

Index Terms—Instantaneous Water Cooler, Non-renewable Energy, Quick Water Cooling, Refrigeration System, Solar Energy, Tube-in-tube Evaporator Coil, Vapour Compression Cycle.

1. INTRODUCTION

Solar energy is radiant light and heat from the sun that is harnessed using a range of ever evolving technologies, such as solar heating, photovoltaic and solar thermal energy. Besides heating water and other fluids, solar thermal technology can reduce air-conditioning and water cooling costs.Solar cooling systems use concentrating solar collectors and absorption chillers to drive the cooling process. These systems are ideal for cooling hotels, office buildings, data centers and other large commercial buildings. The solar refrigeration can be very useful in far off remote places, where there is no continuous supply of electricity. PV operated cycle rely on VCR cycle whereas, absorption refrigeration uses thermal energy as input to the cycle. Among these PV system is most viable and appropriate for instantaneous water cooling. Solar PV system consists of an arrangements of several components including solar panels (absorb and convert sunlight into electricity), a solar inverter (change the electric current from DC to AC), as well as mounting and cabling and other electrical accessories (battery, electric meter, circuit breaker switch, etc.) to set up the working system.PV system range from small, rooftop-mounted or building integrated systemswith capacity,which ranges between watts, kilowatts or megawatts. Operating silently and without any moving parts or environmental emission. Rooftop systems recoup the invested energy for its manufacturing and installation within 0.7 to 2.0 years and at produces about, 95% of net clean renewable energy over 30-years' service.

All the water coolers available in the market today are of storage types. Storage type water coolers take more time for cooling. This is because; it has to cool entire volume of storage tank. Thus, conventional water cooler cools the water equal to storage capacity of the tank. Hence, it consumes more electricity. "Instantaneous Water Cooler"

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operates only after the operator switch on electric supply and within few seconds, cold water is obtained. (I.e. continuous electric supply to the compressor is not needed.)

2 Literature Review

An evaluative report of information found in the literature related to our research papers is discussed. It should give the theoretical base for the research and determine the nature of the research.

An overview of the experimental and numerical studies on performance enhancement of solar photo Voltaic cells by using effective cooling methods. [2]

The recent advances in solar photovoltaic systems for emerging trends and advanced applications and performance analysis of the solar photovoltaic systems. The recent developments in the research on different applications such as water pumping, home lighting, space technology, building integrated PV systems, concentrated PV, desalination and photovoltaic thermal have been studied. [1]

3 Procedure

3.1 Fabrication

The manufacturing process of instantaneous water cooler is explained below. It took couples of weeks to fabricate the model.

Initially, all the components required for the system were gathered. Then welding of mild steel frame was done in the welding workshop. To check the proper working of compressor, various test were performed on it, like NO2 flushing and cleaning etc. Pressure test and vacuum test was conducted for both, compressor and condenser. After conducting all tests compressor and condenser were mounted on a wooden plate which was situated on the bottom of steel frame. Side by side, process of bending and then inserting tube-in-tube type of evaporator coil was done.

Fig. 1- Compressor and condenser

Fig. 2-Experimental setup

As all major components were ready to installed, they were connected with copper tubes in order to make leak proof system. Copper tubes were bent and brazed to the major components of the system. Then the pressure gauges, digital temperature sensors, thermostat, electrical components and water tank were flared and mounted on the refrigeration system one after another. After the

VCR system is ready tests like leak test, pressure test and vacuum test were conducted on system. Finally, charging of refrigerant (R134a) in the copper tubes was compassed. Conclusively, the manufacturing of refrigerating system was accomplished. Following are the illustrations of fabrication process

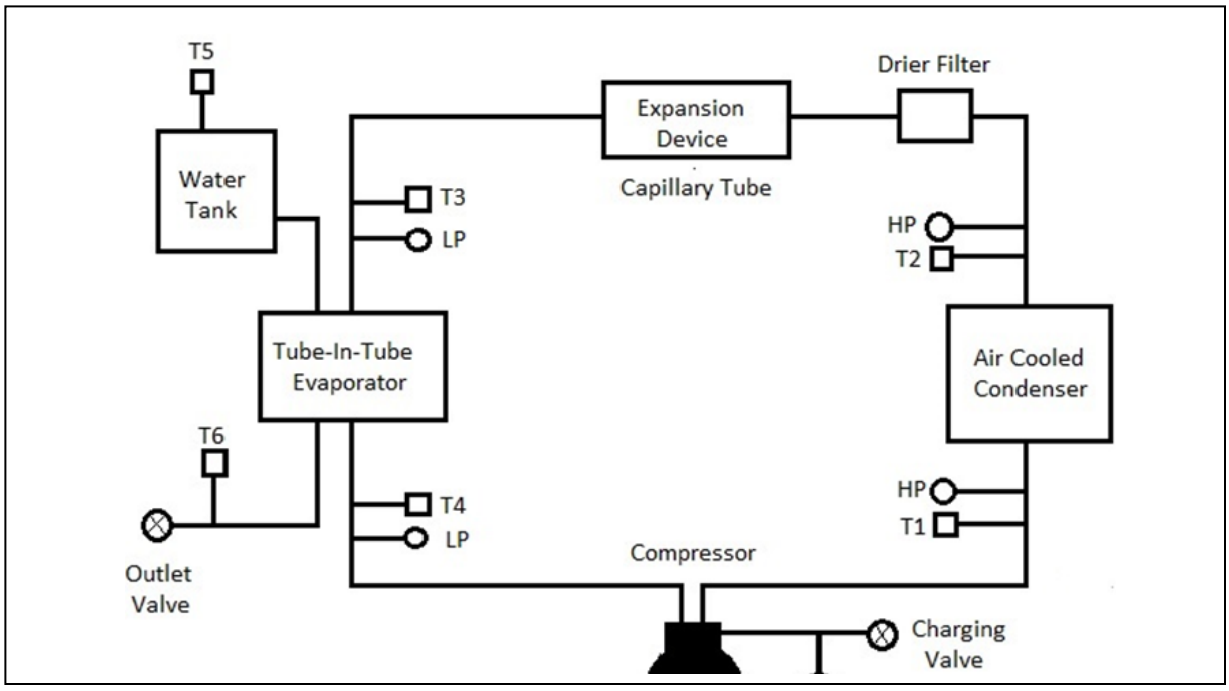
3.2 Experimentation

Instantaneous water cooler can run on solar PV supply, as well grid power supply. The working of a solar PV system is given below:

Photovoltaic (PV) converts the raysof sun, into electricity, using semiconducting materials that exhibit the photovoltaic effect (phenomenon studied in physics, photochemistry and electrochemistry). A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power.

Firstly, the photoelectric effect followed by an electrochemical process where crystallized atoms, ionized in a series, generate an electric current. PV Installations may be ground-mounted, rooftop mounted or wall mounted.Solar PV generates no pollution. The direct conversion ofsunlight to electricity occurs without any moving parts. Hence, the less components are needed which indirectly decreases the cost of installation.

The diagrams below show the components of a vapor-compression refrigeration cycle: compressor, condenser, tube-in-tube type expansion valve, and evaporator. A low pressure, low temperature liquid is converted to vapor in the evaporator, thus, absorbing the heat from the water and keeping it cool. The fluid is driven around the cycle by the compressor, which compresses the low temperature, low pressure vapor leaving the evaporator to high pressure, high temperature vapor respectively. Then the vapor is condensed to liquid in the condenser, thus giving off heat at a high temperature to the surrounding environment. Finally, the high pressure, high temperature liquid leaving the condenser is cooled and reduced in pressure by passing it through an expansion valve. This provides the input to the evaporator. Thus, the cycle keeps on repeating and the water cools instantly.



In conventional water coolers, refrigerant flows through evaporator coil which is wounded around water tank. But in our model we have manufactured tube-in-tube type evaporator coil which is used as heat exchanger. Water flows through inner copper tube and refrigerant through outer coil, which help us to remove more heat in less time. Thus quick cooling is obtained using tube-in-tube type of evaporator. The diagram of tube-in-tube type evaporator is shown below

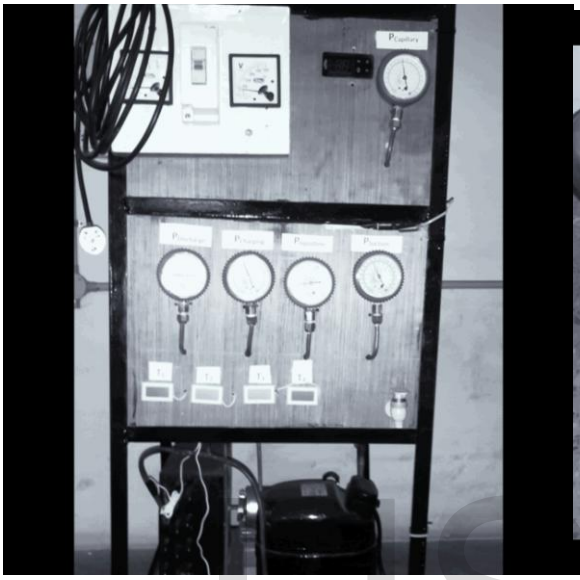


Fig. 3- Experimental Setup (front view)

Fig. 4- Tube-In-Tube Evaporator Coil

4 RESULT

4.1 For Water Cooler:

In order to obtain results, various experiments are conducted on the model for particular amount of time, keeping discharge or time period constant.

Following are specifications and formulas to find the COP, power required and refrigerating effect:

Table.1- Water Cooler Specification Table

Compressor	0.5 TR
Condenser(forced)	Fan Type
Evaporator Coil Dia.	127mm & 635mm
Capillary	0.050mm
Refrigerant (R134a)	1000ml
Storage Tank	10,000ml
Pressure Gauges	3LP & 2HP
Thermostat	Digital Control
Refrigerant Oil	1000ml

(1.) COP = RE ÷ Work

(2.) RE = Heat Removed(Q) ÷ Time(t)

(3.) Power Req. = Voltage x Current

Where, COP-Coefficient of performance
RE-Refrigeration effect

Sample Calculation:
Given-
Mass = 0.25 kg
Sp. Heat (Cp) = 4.17 kJ
T (in) = 27° C
T (out) = 20 °C
Time = 15 sec

Solution-
RE = (M x Cp x T) ÷ t
RE = [0.25 x 4.17 x (27-20)] ÷15= 486.5W
P = V x I
P = 230 x 2.6= 598W
COP = RE ÷ P
COP = 486.5 ÷ 598= 0.81

4.2 For Solar Panels:

As we install our experimental setup and conduct the experiment in Lonavla(latitude- 18.7546° N, longitude- 73.4062° E), Maharashtra, India.the annual direct normal irradiation (DNI) is 5.23520019531.

With the help of DNI and power required, to run the applications, we can estimate the number of solar panels required.Link for analysis of DNI values of various areas in India, according to latitude and longitude is mentioned in reference.

Since, 'Instantaneous Solar Water Cooler" needs around 600W of power. We will need 6 solar panels, according to above specifications

Following are the estimations for selection of solar panels

Table.2- Solar Panel Specification Table

Brand	GREENENERGY
Power	100W
Maxi. Peak Voltage	18V
Maxi. Peak Current	5.5A
Temperature Range	-40°c to 80°C
Frame	Aluminum
Glass Thickness(mm)	3.2
Size(mm)	1189 x543 x35
Cost (approx.)	Rs. 7,500

Table.3- Result Table

C(IN) T°C	C(OUT) T°C	E(IN) T°C	E(OUT) T°C	WATER (IN) T°C	WATER (OUT)T°C	TIME SEC	W(MASS) (ML)	COP
33.3	27.9	24.9	22	27	21	15	250	0.69
35.1	29.1	23.9	22	27	20	15	250	0.81
35.1	29.6	24.0	23	27	20	15	250	0.81
37.2	30.3	24.3	22	27	20.3	20	250	0.58
38.1	31.4	22.8	22	27	19.9	20	250	0.61
8.3	31.5	23.3	22	27	20	20	250	0.60

5 CONCLUSION

Hence, an issue of pollution and global warming is resolved to some extent. The research contributes in using non-conventional energy source. Use of solar energy to generate electricity, helps in adopting environmental friendly resources. Therefore, solar energy is used for generation of electric energy, to run a refrigeration system. The water cooling system based on VCR cycle is effective and convenient as compared to other water cooling system. All in all, in this paper, aninstantaneous water cooler is manufactured, which runs using electrical energy produced by solar energy as well as grid electrical energy. The COP obtained is 0.68.Thus, COP of system can be increase by making some changes in manufacturing of water cooler prototype. Capacity of compressor and length of evaporator coil can be varied according to the application.

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