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Performance Assessment of Atmospheric Water Generator Integrated with Water Cooler Through Experimental Approach.

***Aniket V. Deshmukh[1], Rucha R. Kolhekar[2], Ankur S. Sakhare[3]**

*Aniket V. Deshmukh[1], Rucha R. Kolhekar[2], Ankur S. Sakhare[3]
[1,2,3] Department of Mechanical Engineering, Prof. Ram Meghe Institute of Technology and Research, Badnera, India.
* aniket.deshmukh11292@gmail.com , https://orcid.org/0000-0001-7980-667X

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ABSTRACT
This research project aims to create a water cooler-AWG as hy-brid product. Water Cooler becomes able to extract water from moist air. Air, the second most abundant source of water, may be distilled. This product is useful when there is enough of moisture but not enough clean drinking water like coastal areas. This work is supported by ex-perimental investigation, CFD analysis and regression analysis but, this article only talks about experimental data. The experimental setup has two VCR cycles. VCR cycles with Water Cooler and AWG condensa-tion. The amount of water collected each day is a critical output pa-rameter for assessing the system. It produces 17 litres/day for the speci-fied value (Ta = 250C V air = 9 m/s and RH = 60%), and 30 litres/day for Ta = 300C V air = 11 m/s and RH = 80%. In Case-I, COP of water cooler enhanced by 26.67%, while in Case-II, it increased by 24.04%. To assure the economic feasibility of the system, in this article the com-puted cost of water generation per unit of water generated by conden-sation is found around 2.04 Rs/litre (0.025 $/litre) for Ta = 300C, Vair = 11 m/s and RH = 80%.***Keywords:*** *Innovation Management, Creativity, Organizational Culture, Leadership, Employee Engagement*

Keywords - Atmospheric Water Gen-erator (AWG); AWG integrated with Water Cooler; Experimental Investi-gation of AWG; Performance Analysis of AWG

Introduction

Ample amount of moisture and water vapour is present in atmosphere [1], as it is a second largest source of water [2]. This water can be extracted with the help of Atmospheric water generator. In the market, well developed AWG is available in various size and water extraction capacity. This device absorbs the latent heat of vaporisation from moisture present in air, to convert moisture into liquid water [3]. Dew point temperature is the limit, below this temperature condensation process occurs [3,7]. The regions like coastal areas, rain forest areas, flooded areas, hilly areas, ships in sea are those cases where amount of temperature and moisture present is more and are suitable for AWG [4]. In last few years many researchers have studied and performed experimentation on it [5].

This study is related to modifications done in Water Cooler, so that Water Cooler will additionally work like AWG [6]. As Water Cooler is a vary commonly used product in Indian schools and offices, a facility can be given of water generation with it by adding few costs [7]. AWG in market costs around one lack and above, which is expensive to buy and maintain in offices. This research is about developing a system which will work like both Water Cooler and AWG. This paper discusses the experimental investigation conducted on system mentioned here and its performance is studied by studying the output parameters like mass of water collected (Mw), Coefficient of performance (COP) of AWG and Water cooler and cost of water generation per litre. This system makes use of the vapour compression refrigeration cycle to work [8]. A heat exchanger is designed to carry the condensation process and cool down air below dew point temperature. Further that cold air is circulated over the condensers of the Water Cooler and AWG. Use of AWG in integration with Water Cooler improvs the COP of Water Cooler [9].

The output of AWG depends on the ambient air temperature and relative humidity. More the air temperature more will be moisture carrying capacity of air and more relative humidity means more presence of moisture available to get condensed.

1. Literature Review

AWH has grown in popularity in recent years as a result of growing worries about water scarcity, strained water infrastructure, public water system issues, and natural disasters [10]. The United Nations developed Sustainable Development Goal 6 in 2015 to tackle the rising problem of water shortage, with the goal of "ensuring availability and sustainable management of water and sanitation for all" [11] In order to make considerable progress toward sustainable development, the United Nations declared the Water Action Decade 2018-2028 in 2018 [12]. Because the amount of fresh water on Earth is only 2.5%, compared to the 96.54% of salty water in oceans, seas, and bays, there have been concentrated efforts to collect water from cloud or fog cover or atmospheric water vapor, particularly in arid regions [13]. Water can be extracted from the atmosphere using either passive or active atmospheric water generators [14]. Water accumulation can occur passively, without the expenditure of additional energy, by taking advantage of temperature changes in the surroundings [14-16]. The most common passive technique is a fog catcher, which can generate a significant amount of water [17]. They can, however, only be used in certain climates and regions [18], such as those with high humidity [19]. Furthermore, the approach for collecting fog water has a small impact on water scarcity [18-20].

2. METHODOLOGY

In this study experimentation as per variables and their levels selected. Data collection instrument is designed in two steps. In first step as per customer requirement for 20 litre/day capacity, to cooldown air below its dew point temperature (DPT) mass flow rate of refrigerant is identified around 8.34 cc/revolution. To match the requirement compressor of 8.8 cc/revolution is selected. Further in second step the components of VCR cycle use in AWG are designed for selected compressor. After fabrication experimentation starts with the design of experiment, data collection sample is decided here along with cases (combination of system like working Water Cooler and AWG), variables and their levels for experimentation. Three variables are considered here like ambient air temperature T_a (^{0}C), relative humidity RH (%) and velocity of air flow in heat exchanger V_{air} (m/s). For total study with all possible chances of study is segregated in three cases are as mentioned below.

Case-I: AWG and Water Cooler Both are ON

Table 1:*(Variables and Their Levels for Case-I)*

Levels / Parameter	Level A	Level B	Level C
V_{air} (m/s)	7	9	11
RH (%)	40	60	80
T_a (^{0}C)	20	25	30

Case-II: AWG is OFF and Water Cooler is ON

Table 2:*(Variables and Their Levels for Case-II)*

Levels / Parameter	Level A	Level B	Level C	Level D
V_{air} (m/s)	0	7	9	11
T_a (^{0}C)	20	25	30	-

Case-III: Study of simple domestic Water Cooler

Table 3: *(Variables and Their Levels for Case-III)*

Levels / Parameter	Level A	Level B	Level C
T_a (^0C)	20	25	30

Full factorial (all combinations) is considered for experimentation, therefore 27 experiments in Case-I, 12 experiments for Case-II and 3 experiments for Case-III are performed i.e. total 42 experiments are performed.

Experimental Setup.

In this setup two VCR systems are used, one is with Water Cooler (by default present in it) and second is for the AWG to extract water, inside heat exchanger. Heat exchanger is consisting of evaporator to cool down air and extract water. Fig 1 shows the path of flow of air in light brown colour arrow, air enters into heat exchanger and come in contact with the evaporator and get cooled below DPT. Below DPT moisture get separated from air and convert into water, and cold dry air moves towards the second section of heat exchanger, where condenser tubes are present. Cold air with some velocity (for example V_{air} = 9m/s) comes in contact with condenser tube and carry rejected heat and dry hot air leaves the heat exchanger. So that cold air utilization will be effective. Water separated in first section of heat exchanger collected at the bottom of heat exchanger.

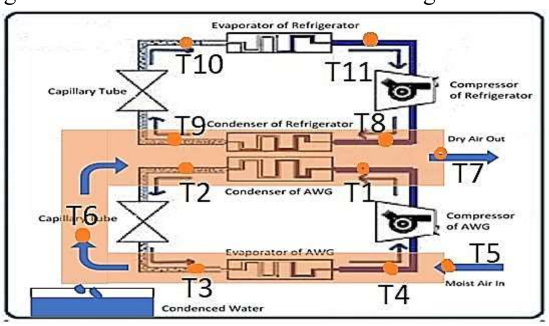

Fig. 1 Final Layout of system designed with Temperatures.

During experimentation various data collection instruments were used like Temperature sensor to measure temperature of air, thermo-anemometer for air velocity measurement, hygrometer for dry bulb and wet bulb temperature measurement, water measuring jar, energy meter for electricity measurement, U-tube manometer to identify pressure drop in heat exchanger. Along with these measuring instruments a controlled environment was maintained in a room of small size. As ambient air temperature and air temperature vary with respect to time, air conditioner and room heater is used to maintain the controlled environment for experimentation.

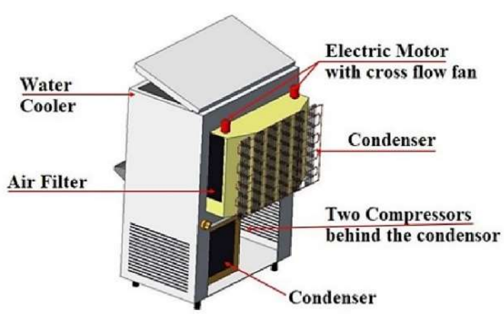

Fig. 2 Experimental Setup (Ornamental representation of setup.)

Overall presentation of experimental invistigation is showen in fig. 2, the AWG is installed at the back wall of water storage tank of water cooler. The detail of the AWG setup is shown in fig. 3.

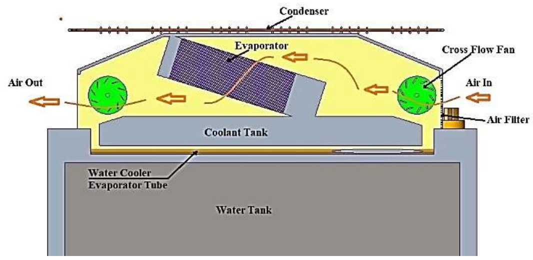

Fig. 3. AWG Setup (Cross section of heat egchanger section)

In fig. 3 setup can be seen, cross flow fans are used as a source of air in heat exchanger, water can be collected from bottom of heat exchanger and material used for the heat exchanger wall is steel and evaporator of copper tubes. The mass flow rate of refrigerant and surface area of tubes to exchange heat was kept constant thought study.

For calculating output parameters like COP of Water Cooler & AWG standard temperature-based formulas are used and few output parameters like mass of water collected (Mw) was observed and recorded directly by measuring equipment.

3. RESULT R & DISCUSSION

Data collection from data collection instrument in experimental investigation is analysed on the basis of various output parameters. Like COP of AWG, COP of Water Cooler in various cases, mass of water collection per day. To support and validate the outcomes of the experimentation, analysis using CFD and regression analysis is done but not discussed in this article.

3.1 Mass of Water Collected (M_w)

The main objective of this research is to extract the mass of water present in the air. The system is designed for variable Ta = 26^0C in level taken as 25^0C, V_{air} = 9m/s and RH = 60%. Just to observe and study the effects of change in variables on the output of system, variables are considered one level up and one level down as mentioned in methodology. Mass of water collected is directly proportional to the Temperature, RH and velocity of air.

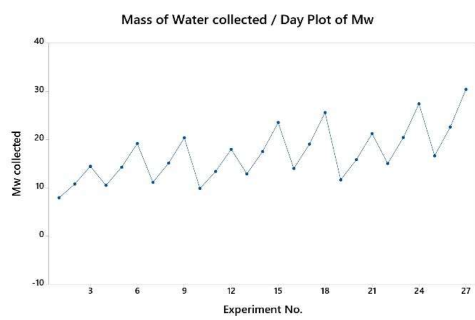

Fig. 4 Graphical representation of Experiment number Vs. Mw Collected

In the graph above blue line indicates the mass of water collected per day with respect to each case. But increase in output requires more compressor input in the form of electrical energy. 14^{th} case is for designed values and 17.508 Kg/day is the mass of water collected as an output. AWG was designed for 20 Kg of water/day. Highest value achieved in the experiment is of 30.370 Kg/day for 27^{th} case.

3.2 COP of VCR Cycles.

The experimental setup consists of two VCR cycles, one is used for the AWG heat exchanger and another VCR cycle is in Water Cooler. The performance measure for VCR cycle is coefficient of performance which is a ratio of temperature differences. Here AWG is used in case-I only, but Water Cooler study is done in the all three cases.

3.2.1 COP of AWG

VCR cycle used in heat exchanger of AWG, in this heat exchanger is getting fresh air every time at the inlet of evaporator section. Due to this temperature of evaporator remain nearly constant and COP of system drops.

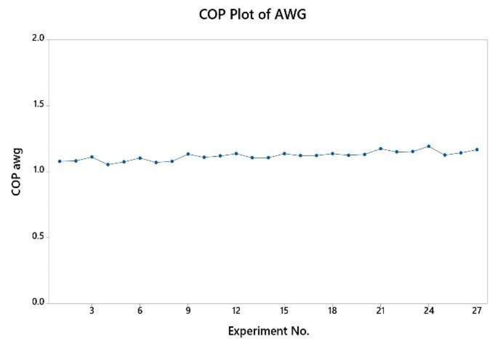

Fig. 5 Graphical representation of Experiment number Vs. COP of AWG

In the graph above, COP of AWG is presented for respective cases. Here COP varies in the range of 1.053 to 1.19. With respect to velocity of air COP is increasing. Because, more the velocity of air mare will be amount of heat transfer.

3.2.2 COP of Water Cooler

In the experimental study, VCR cycle of Water Cooler is used in all three cases. First case is when Water Cooler and AWG both are running and Condenser of Water Cooler in inside heat exchanger, second case is when AWG is not running but Condenser of Water Cooler in inside heat exchanger and air is flowing and the for last case standard household Water Cooler is considered.

First case is of 27 number of experiments, second case is of 9 number of experiments and in third case is of 3 experiments only. here results of second and third cases are repeated with respect to parameters for the better appearance during comparison.

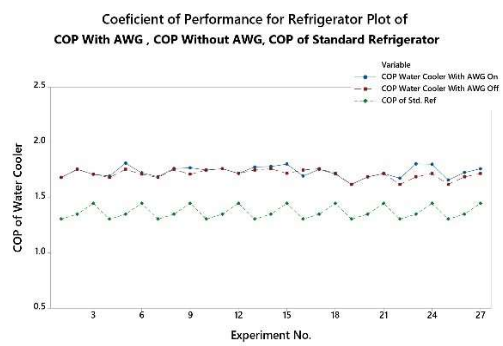

Fig. 6 Graphical representation of Experiment number Vs. COP of Water Cooler

In the graph above 3 COP's of Water Cooler are shown where, blue colour indicates the COP of Water Cooler with AWG is On, brown colour indicates the COP of Water Cooler with AWG is OFF or COP of Water Cooler without AWG and green colour indicates the COP of Standard Water Cooler. It can be clearly seen that COP of standard Water Cooler is less than other two cases. Average COP of Standard Water Cooler 1.36, where the average COP of first case is 1.73. On an average COP of standard Water Cooler is less by 27.2 % of first case. COP of first and second cases are nearly same but better for first case most of the time.

Other parameters like efficiency of heat exchanger is observed inversely proportional with the input parameters Relative humidity and velocity of air. Cost of water generation observed in the range of 2.04 Rs/Litre (0.025 $/litre) to 7.34 Rs/Litre (0.084 $/litre).

4. CONCLUSION

In this research, processes inside AWG and Water Cooler are observed and output parameters evaluated with the help of experimental investigation. Its validation is done with the help of mathematical model generated by regression analysis, but not discussed here in this article.

Mass of water collected per day is the main output parameter, as per parameters considered for design (Ta = 25 ^{0}C V air = 9 m/s and RH = 60 %) mass of water generation is 17.5 litres/day. Highest amount of output is provided for Ta = 30 ^{0}C V air = 11 m/s and RH = 80 % equal to 30.370 litres/day. This output is totally dependent on the RH and Temperature of Air.

As at the outlet of AWG, air become cold and dry. Its use at condenser of Water Cooler enhance heat transfer and ultimately COP of Water Cooler. Average COP of AWG is found 1.12, average COP of standard Water Cooler is found 1.368. But when Water Cooler used with the AWG heat exchanger, Water Cooler's COP improves by 24.04 % in Case-II (AWG: Off & Water Cooler: On) and it improves by 26.67 % in Case-I (AWG: On & Water Cooler: On).

System work and collect the water in well manner, its performance changes with respect to weather conditions. Its use is desirable in coastal areas.

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