DESIGN AND FABRICATION OF VAPOUR COMPRESSION REFRIGERATION CYCLE AND WATER GENERATOR

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ABSTRACT

Affordable access to potable water is a global issue, as approximately 844 million people around the world lack access to clean water. Water extraction from air, based on vapor compression refrigeration cycle system, is becoming a technology more and more diffused on various models of air to water generators that atmospheric water generators are emerging, and claiming the best efficiency. Atmospheric water generation can address this issue by generating potable water from the water vapor present in air. The current work is an indicator to standardise the Atmospheric Water Generator (AWG) efficiency evaluation and It is called Water Energy Transformation (WET). It generates water production from the AWG machine and calculated its energy performance with an approach similar to COP (Coefficient of Performance) and EER (Energy Efficiency Ratio) evaluation. The concept was developed expressly to overcome issues that affect the existing evaluation parameter, like specific energy consumption (SEC). Water Energy Transformation indicator is meant to be a normalised tool that permits comparing on our Atmospheric Water Generator (AWG) machine, Our project is to generate water from Atmospheric water generator machine by using Water Energy Transformation equation, with a discussion about involved terms, a set of calculations.

Key words: Vapour Compression Refrigeration Cycle, Water Energy Transformation

INTRODUCTION

In the last few years water extraction from air, based on a vapour compression refrigeration cycle, is becoming a solution for different world areas where traditional water sources are scarce, or too polluted to be safely employed. The market of such a solution is growing and several atmospheric water generator (AWG) systems, all claiming the best effectiveness, can be found on the market. The principle of water extraction from air is common to all the techniques, vapour compression refrigeration cycle based or not and it consists in forcing the condensation process of the air vapour content . In particular, AWGs, based on compression reverse cycle, force such a condensation by cooling air under its dew point. A representative scheme of the thermodynamic cycle is reported in Figure 1. The scheme shows that the environmental airflow (wet warm air, in the left side) is blown into heat exchanger 1, where it yields heat to the refrigerant, with a consequent partial condensation of its vapour content. Then, the condensate is collected and delivered to a treatment unit or simply to a storage unit. Then, the refrigerant passes through heat exchanger 2 where the subtracted heat is yielded to external environmental air or to another thermal vector. It should be noted that a whole AWG machine, beside such apparatus, may contain also other parts, such as fans, pumps, electronic components and so on, but their configuration strongly varies based on the particular design choices.

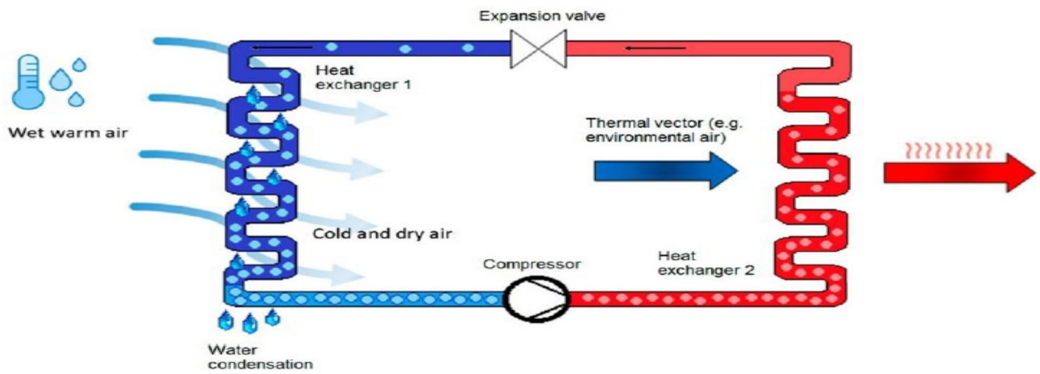


Figure 1 : Representative Reverse Thermodynamic cycle.

1.1 CONVENTIONAL R-134A SYSTEM MODEL

This section is divided into four parts corresponding to detailed descriptions of the key components of a conventional single-stage R-134a cycle. In Section below the model of a single-stage centrifugal compressor model is described. In the falling film indirect-contact, R-134a-to-water condenser model is presented. Section describes the indirect-contact, R-134a-to-water flooded evaporator model. This describes the models of the chilled water and condenser water pumps.

Compressor Model The operating conditions characterizing large chillers lead to the use of centrifugal compressors in industry today. Other compressor designs are not able to meet 61 the efficiency targets and consequently they are not economically competitive. The compressor model described in this section is a single-stage centrifugal compressor.

1.2 PERFORMANCE OF COMPRESSOR

The centrifugal compressor model is developed using the software so that it can easily be integrated with a single-stage R-134a refrigeration cycle model. The compressor model is used to estimate the performance, size, and cost of an R-134a compressor. The model builds upon simple relations for the performance of the sub-components that make up the centrifugal compressor, the nozzle, impeller, vaneless space, vaned diffuser, and the collector, in order to predict the static and stagnation states that the refrigerant experiences along a mean-line path between the compressor inlet and the exit. the various parameters that are used in the model to capture the characteristics of the centrifugal compressor.

2.1 LITERATURE SURVEY

Chandler,D. et.al.[1] studied about the Severe water shortages affect many factors in the world growth and global warming. In most components of the earth mostly in the driest places, water attracts wet objects directly from moisture. The use of fog in some countries has to be 100% quantitative because the use of fog is highly valued in some countrys like Chile and Morocco, and it requires heavily humid air. The way to convert water in dry areas is to collect dew. This method cools the surface and condenses the water. but "consumes considerable energy."

M.Yaghi et.al.[2] analyzed about the Crystalline organometallic structures (MOFs) are created by a lattice synthesis method that establishes durable bonds between inorganic and natural units. Radical excess frame crystal with excessive thermal and chemical stability. These homes create an opportunity for a garage, a fuel separated from the chemical fuel phosphorus, and the MOF ability to have catalysis. The precision and simple topology commonly used in chemical formulations is that the force to expand the index exists over the entire range of various solids. MOFs often alternately repeat the chemical composition and type of the building blocks of the selected form several times, but they already exist and create synergistic materials.

Joshi.V et.al.[3] developed and experimentally investigate a thermoelectric fresh water generator (TFWG) based on the fundamental of Thermoelectric Cooling Effect by condensing the moisture from the ambient moist air. It can be made useful to the people in coastal and humid regions with relative humidity above 60 % having scarcity of drinking water and concluded that the quantity of water generated is directly proportional to all the three parameters in the domain of experimentation they are Electric current, air mass flow rate and humidity of moist air. Bortolini.M et.al.[4] designed an equipment for extracting water from atmospheric vapor and then experimentally studied under a small inlet air flow rate. The impact of operating conditions on surface temperatures of cold/hot sides and water yield are investigated, including the air flow rate and humidity. Concluded that Air flow optimization can make increase drinking water production through air dehumidification.

Zeghmati.B et.al.[5] their research was aimed at conducting an experimental investigation to study the heat sink performance of a new rectangular fins array. And developed a small scale prototype of thermoelectric Dehumidifier (TED). It was composed of two thermoelectric (TE) cooling modules and concluded a good performance of the hot heat sink design for the intended thermoelectric application and developed a new Design Optimization of a New Hot Heat Sink with a Rectangular Fin Array for Thermoelectric Dehumidifiers. A.E.Kabeel et.al.[6] conducted the experiment on the effect of using sandy bed solar collector system for extraction of water from air has been demonstrated. The sandy bed used to simulation of the Arab country desert condition. In project titled “Application of sandy bed solar collector system for extraction of water from air. Astrain.D et.al.[7] developed a design of device for the dissipation of the heat from the hot side of Peltier pellets in thermoelectric refrigeration, based on the principle of a thermosyphon with phase change and concluded that Increase of COP in the thermoelectric refrigeration by the optimization of heat dissipation in the system.

Esam Elsarrag et.al [8] concluded that atmosphere is the endless source of water, contains a large quantity of water in the form of vapour in varying amounts especially in Gulf coastal region. which is one of the most arid regions in the world. The lack of water is considered as the most important problem. Annual rainfall is slight and erratic, with an annual average of 81 millimetres in Doha. As a result, renewable ground water resources are extremely limited and, in addition, there are problems with groundwater salinity. Alexander Bolonkin et.al.[9] suggested a method that is fundamentally dictinct from all existing methods that extract freshwater from air. He discovered a new, cheap method for the extraction of freshwater from the Earth’s atmosphere. All other industrial methods extract water from a saline water source (in most cases from seawater.

M. Hamed et.al.[10]. Experimentally investigated the theoretical cycle for absorption of water vapour from air with subsequent regeneration. A theoretical limit for the maximum possible amount of water which can be collected from air using the desiccant through the absorption regeneration cycle at certain operating conditions of ambient parameters, heat to be added to the desiccant during regeneration and maximum available heating temperature could be evaluated through the analysis of this cycle.

V. V. Tygarinov et.al.[11] published a theory as “An Equipment for Collecting Water from Air,” in Russia, 1947 . An apparatus consisting of a system of vertical and inclined channels in the earth to collect water from atmospheric air by cooling moist air to a temperature lower than its dew point has been proposed.

Zhaoand Guihua Yu et.al.[12] Conducted an experiment from this perspective AWH ,they first illustrated the sorption mechanism, including absorption and adsorption for moisture–harvesting materials and summarize fundamental requirements ,as well as design principles of moisture harvesters . Recent progress on material and structural designs of moisture harvesters for AWH is critically discussed. We conclude with prospective directions for next-generation moisture harvesters to promote AWH from scientific research to partial application. Klemm et.al.[13] studied and aims to design and improve AWG. The collector will be used for rehabilitating the dry land and affected ecosystem due to water scarcity. In recent decades, as a result of climate change and mismanagement, water scarcity and drought has become more frequent, affecting both the humans and the biodiversity drastically. As a result of such phenomena, more research has been done to find an alternative sustainable way of obtaining fresh water for afforestation and drinking water for human and animal consumption.

Xiaowei Zhang et.al.[14]. Explained about The interfacial solar absorbers with an ionic-liquid-based sorbent, an atmospheric water generator with a simultaneous adsorption–desorption process is generated. Here by combining tailored interfacial solar absorbers with an ionic-liquid-based sorbent, an atmospheric water generator with a simultaneous adsorption–desorption process is generated. It is expected that this interfacial Solar-driven atmospheric water generator, based on the liquid sorbent with a simultaneous adsorption– desorption process opens up a promising pathway to effectively harvest water from air.

Jarimi H et.al.[15]. Experiments conducted on different types of sustainable water harvesting methods from the atmospheric fogs and dew. they reported upon the water collection performance of various fog collectors around the world. they also taken technical aspects of fog collector feasibility studies and the efficiency improvements. Modern fog harvesting innovations are often bioinspired technology. The dew water collection systems is divided into three categories: i) dew water harvesting using radiative cooling surface, ii) solar-regenerated desiccant system and iii) active condensation technology. The created new approaches in the development of an atmospheric water collector that can produce water regardless of the humidity level, geographical location, low in cost and can be made using local materials

Uttam paul.C et.al.[16] Conducted an experiment on a hydrophilic and self-floating photothermal foam that can generate potable water from sea water and atmospheric moisture via solar-driven evaporation at its interface. The foam can also be repeatedly used in multiple hydration-dehydration cycles, consisting of moisture absorption or water collection followed by solar-driven evaporation; in each cycle ,1g of the foam can harvest 250-1770 mg of water. To the best of our knowledge, this is the first report of a material that integrates all the desirable properties for solar evaporation, water collection, and atmospheric-water harvesting. The light weight and versatility of the foam suggest that the developed foams can be a potent solution for water efficiency, especially for off-grid situations.

R Ziatdinov et.al.[17].Proposed the concept a dew collection device with a helicoidal structure in order to increase its surface area, and we suggest taking into account Frenkel's mathematical model of sliding drops on an inclined surface as the fundamental idea in designing dew collection devices. he also believe that in the future this mathematical model can be used to investigate the possibility of condensing liquid drops within other planets' atmospheres that contain hydrogen and oxygen. Finally, he represented a new concept as a three-dimensional Rhino model.

Matthew Salazar et.al.[18] Performed an experiment on the native dipole moment of water molecule results in the nucleation of liquid phase on carriers of electrical charge due to the suppressed evaporation. Nevertheless, the practical implementation of electrostatic water nucleation (EWN) is still in the stage of laboratory demonstrations. This conclude the theoretical background of the phenomenon and past experimental data, presents further experimental results and new data from practical implementation of EWN.

Chang, W et.al.[19] they created a new MGA (modified genetic algorithm) together with a solution strategy for a group of nonlinear equations is proposed to obtain optimal set point under different operating conditions in a vapor compression refrigeration cycle and compared the proposed method with traditional on–off control strategy to evaluate its performance lucia cattani et.al.[20] derived a new proposal for a new indicator to compare air water generators efficieny by using a new parameter called water energy tansformation to over come the isuuses that affect the only exisiting evalution parameter , a sort of energy consumption

Devotta Padalkar et.al.[21] made R 407 c as a substitute to R 22 . R-407C has 2.1% lower cooling capacity for the lower outdoor conditions and 7.93% lower for the higher outdoor conditions compared to R-22. The cooling efficiency for R-407C is 7.9% lower for the lower outdoor conditions and 13.47% lower for the higher outdoor conditions. The discharge pressures measured for R-407C were higher in the range 11-13% than for R-22.

PoachaiyapoomLeardkun et.al.[22] experimented Using R134a with electronics cooling technique. and concluded The highest COP gained is 9.069 at a compressor speed of 3000RPM and a heating power of 200W, which yields the heater surface temperature of 73.3°C. The proposed system is not suitable for electronics cooling at a heating power of 100W and 150W, because the heater surface temperature is less than 40°C.

The project is based on dew point dehumidification technique on the principles of refrigeration which will overcome the disadvantages of the liquid desiccants and peltier device. It is made cost-effective and portable, making it easy to install at any location. The aim is to generate water by using Atmospheric water generator (AWG) machine with the WET (WATER ENERGY TANSFORMATION) indicator and testing the efficient working conditions of atmospheric water generator phenomena of vapour compression refrigeration cycle by using refrigerant R-134a.

3. METHODOLOGY

A typical refrigerant used in common refrigeration cycles is R-134a, which is a hydrofluorocarbon (HFC). HFC's generally have high global warming and ozone depletion potential, which is not ideal or in keeping with the purpose of delivering clean water in a sustainable way. As a result we researched a more sustainable and less harmful refrigerant alternative with similar thermodynamic properties as R-134a. We obtained a new generation of refrigerants known as hydrofluoroolefin (HFO) refrigerants that exhibit much lower global warming and ozone depletion potential as compared with their HFC counterparts. Accordingly, we obtained R290 ,it is a natural hydrocarbon refrigerant that can be obtained directly from liquified petroleum gas and its doesnot have a destructive effect on ozone layer. For example, R-134a has a moderate boiling point, operating pressure, and low GWP.

3.1 Instrumentation & Assembly

In order to verify that the actual system is performing to the calculated standards, temperature, pressure, and mass flow rate readings must be taken. This is done using thermocouples, pressure transmitters, and a flow meter. The piping and instrumentation diagram (P&ID) can be seen in Figure 3 below, which outlines all the necessary equipment for experimental setup.

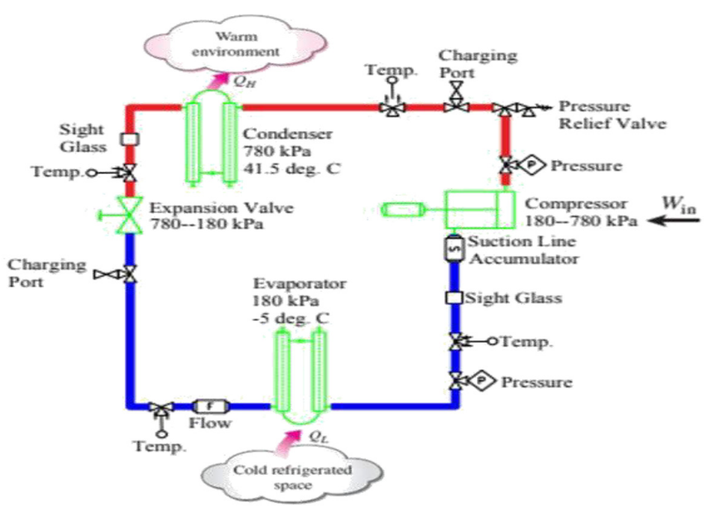


Figure 2: P&ID of experimental VCC

Every piece of equipment, with exception to the inline flowmeter and sight glasses, is connected to the system via a copper tee that is brazed to the copper tubing. Similarly, sight glasses at the entrance of the compressor and exit of the condenser will allow for verification that the refrigerant undergoes a full phase change in both heat exchangers, as the refrigerant should exit the evaporator as a vapor and exit the condenser as a liquid.

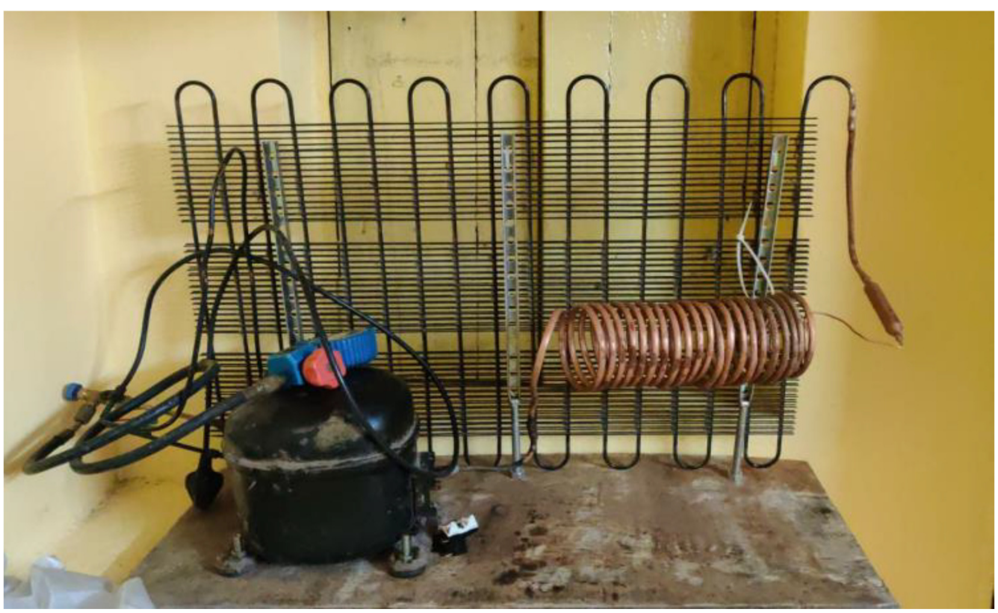
3.2 Heat Exchanger Fabrication

In order to save table space, it was decided to orient both heat exchangers in the vertical direction. Using the lengths from the Design section as a guideline, the evaporator and condenser were cut from a ten foot stock of copper tubing. The actual cut length was slightly greater than the calculated length to leave extra room on either side of the condenser and evaporator to account for any slight measurement errors. Next, the tubes had to be bent into the desired shape using a hand-held tube bender shown.

Figure 3: Tube Bending Device

3.3 Experimental Setup

After the final leak test was performed, the exit of the evaporator and entrance to the condenser was brazed to the compressor, along with the suction line accumulator, as seen in figure below.



Figue 4 : Fully assembled VCRC

The final step before fully running the system was to clean the inside of the tubing of any debris and dirt so that it would not affect the system performance and damage the equipment. To do this, the system was first vacuumed to about 150 microns to remove all the air so that it does not mix with the refrigerant. The refrigerant canister was then connected to a manifold that leads to one of the binary valves in the system and a refrigerant recovery unit. The manifold controls whether refrigerant flows from the canister to the system or from the system to the recovery unit. Once loaded with refrigerant, the equipment was rotated and moved around so that refrigerant flowed through every part of the system. It was then flushed out through the recovery unit and the system was ready for testing.

Although the VCRC was designed to operate in ambient indoor conditions, as specified in the Design section, extra equipment was added to better simulate greenhouse conditions and ensure full phase change in both heat exchangers. Since the evaporator and condenser were sized based on ambient conditions, it is assumed that greater heat transfer will occur given the experimental setup, thus increasing the effectivity of the system and yielding better results. It was decided to use a commercial humidifier and aim it at the evaporator in order to better simulate humid greenhouse conditions. This will increase the amount of water condensed on the surface of the evaporator. In order to increase the heat rejected at the condenser, and therefore the rate of refrigerant condensation, the condenser was placed in an ice bath to provide a greater temperature differential. Although ecological adaptations will not mimic this setup, it will provide better results for our experiment by providing only liquid to the entrance of the evaporator. Furthermore, a fan was used over the evaporator to increase the rate of heat exchange from forced convection. A collection tray was used under the evaporator to weigh the total amount of condensed water during the tests.

RESULTS AND DISCUSSIONS

In, several different conditions are assumed to depict some representative climatic conditions, but most of them are suitable for the tested technology

In order to avoid the same issue and to provide something more adherent to the existing design praxis, the authors studied the ranges and design conditions of more than one hundred machine models for external and internal use, which are characterised by different sizes and propose four couples of conditions

Two of them are extreme conditions, in order to depict an AWG machine behaviour at the average limits of operation. The other two are nominal conditions, one representative of the most diffused declared ones, the other representative of more temperate weather zones.

Analysing the AWGs data sheet it is possible to observe that, when declared, nominal conditions are expressed by a dry bulb temperature and relative humidity values, which are usually rounded to ten. The most diffused, for both types of AWG machines (internal and external), are two couples:

Analysing average values, it is possible to find a first piece of interesting information: nominal conditions for internal and external machines are almost the same. Such a result can be justified, in part, from the observation mentioned above: some models of internal machines take air (from which water is extracted) from the external environment. Another explanation is that, generally, the concept of an AWG system for internal use comes from a miniaturization of the first idea of an AWG machine studied for outdoor environment; thus, the design parameters are almost the same.

Another important statement comes from the comparison of the four points reported the best candidate to be representative of the most diffused AWGs nominal conditions is the point at 30 ◦C and 70% RH. In effect, its specific enthalpy differs at maximum 2.1 kJ/kg from the averages and its specific humidity differs from them only 1 g/kg, while the point at 30 ◦C and 80% RH presents more marked differences.

The above nominal conditions are representative of humid and hot climates. In order to give indications of machine behaviour in more temperate zones, a further set of temperature and RH could be also added, e.g., 25 ◦C and 50%, which is the mild condition obtained.

Analysing the above table it is possible to determine that extreme conditions differ considerably for internal and external machines. Such a result was expected because the working range for a miniaturised AWG internal machine cannot be as wide as the working range of a bigger system, which, for example, has enough space to house special reinforced equipment, as enlarged heat coils are expressively studied for very dry conditions.

In this case, the authors propose two couples of standard extreme conditions: one intended for external machines and the other intended for the internal ones. In addition, in this case, found average values were rounded, in compliance to technical practice.

The vapour compression cycle energy efficiency and the coefficient of performance water energy transformation indicator is compared. By calculating the water energy transformation rate. We obtained a 0.89% of latent heat of condensation for our atmospheric water generator for all 12 months in Hyderabad region with our experimental setup by comparing with theoretical values, where the best output of water from the vapour compression refrigeration cycle is obtained from July to October months. The actual greenhouse conditions is necessary for testing the applicability of VCRC in large scale ecological systems, this project demonstrates that atmospheric water generation using VCRC is achievable for AWG machines and it has been calculated. This WET (Water Energy Transformation), has been formulated with the same approach of EER and COP, and has been designed in order to be applied for AWG machines . The parameter is used in technical practices and it is affected by a lack of any standardization for its calculation and inhomogeneity in measurement units. On the basis of existing AWG machines, these water energy transformation indicator values is set of unified nominal and extreme conditions is presented for WET calculation to obtain comparable results. The indicator was applied to an existing outdoor AWG machine, and results were arranged in summary and monthly WET results for different climates were presented.

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