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Smart Atmospheric Water Generator AWG

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Report will be printed on A4 paper (21.0 cm x 29.7 cm). The margins will be 3.0 cm left and 2.5 cm right, please take this into consideration.

Abstract: Egypt has faced a series of exhausting grand challenges in recent centuries that have slowed its march forward. Among all of these issues, the problem of water scarcity has reached a tipping point since the increasing population. It necessitates a fast and comprehensive response. Finally, Egypt has its own plans for desert reclamation. Unfortunately, these plans have run into a series of challenges, including a lack of adequate facilities and overcrowding. The purpose of study is to develop a new approach for enhancing clean water resources. Considering all of the benefits and drawbacks of the prior solutions, it was clear that the chosen solution, the atmospheric water generator, was the right approach. The refrigeration system is effective method for achieving the desired goals. The prototype was developed with precise measurable design requirements, which are producing drinkable water and satisfying human needs. The major finding is the prototype was hardy work with less efficiency in the low humidity regions and times. By comprehensively testing the prototype, the result preferable than expected as it confirmed that the project fulfilled its design requirements and is ready to be impactful if put into action.

***Keywords* (12 Bold):** *Humidity, Compressor, Arduino, Dew point, Minerals*

1. INTRODUCTION

One of the most significant bits of evidence on Egypt's suffering was a 50 percent increase in the price of drinking water since June 3, 2018. The scarcity of water resources has an impact on Egypt's economy and other facets of Egyptian life, including public health, daily living, citizens' income, and agriculture quality and quantity, all of which have exacerbated the crisis on other Egypt's grand challenges. Such a water crisis must be resolved, from public health issues to economic depression and the failure to restore desert regions. As illustrated in figure (1), 55.5 billion

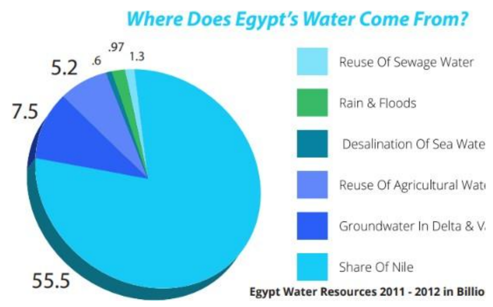

Figure (1) shows Egypt water resources in 2011.

cubic meters of water were primarily derived from the Nile River. This stress causes urban congestion along the Nile River. Consequently, arid areas in Egypt reach more than 93%, which causes pollution from CO2, other hazardous industrial, and sewer wastes. According to studies, Egypt's water sustainability requires 110 cubic meters of water per year in 2019. Many other countries and businesses have attempted to overcome this problem in recent years. Some were successful, while others faltered. In India, for example, the Nemmeli atmospheric water generator system provides water in streets for public consumption. Nemmeli is producing a relatively tiny amount of freshwater daily due to its small scale, although supplying healthy and freshwater to people in public spaces at a relatively high cost. As a result, the objectives of this project were not met. Drupps, which is a Swedish project, met its primary goal of providing more than 150 cubic meters of water each day. Drupps, on the other hand, was successful as it provided this massive amount of industrial water considered its point of strength. However, it is quite expensive. In light of this, it was agreed and decided to develop a project that would produce more water in less time. The chosen project involved creating an atmospheric water generator, producing water from water vapor in air. To achieve this solution, water vapor condenses on the surface of stainless-steel revolutions at a surface temperature of -15 degrees Celsius. Thus, water vapor changes to ice. Therefore, an extraction fan is used to melt ice into liquid distilled water. It is unhealthy to drink distilled water. As a consequence, mineralizing the water was necessary. The project's features allowed it to meet the design criteria of efficiency and drinkable water parameters. The prototype was tested to prove its validity after the scientific calculations were considered. Furthermore, the prototype was completed and the results exceeded the expectations. Consequently, the project met the design criteria and would be successful in the real world if implemented.

2. **Analysis**

The scientific base of the prototype (constructing and designing) is one of the most important steps that had to be made to accomplish the design requirements. Aiming for decreasing the surface area's temperature to condense the water over it is the idea of the prototype. The water is collected beneath the evaporator. This water contains fewer Hydrogen moles, making it a less acidic.

2.1 **Dew Point**

The temperature of the water condenses (changes its state from gas (vapor) to liquid) on a surface area called DEW Point. The dew point depends on two different variables (At the sea-level pressure). It depends on the air temperature and saturation mixing ratio as shown in figure (2). The dew point is the temperature at which the water vapor pressure equals the saturated water pressure, so the water has to be in vapor equilibrium. Below this temperature, the water begins to condense and changes to the dew. The condensed water begins to increase and is collected in a tank.

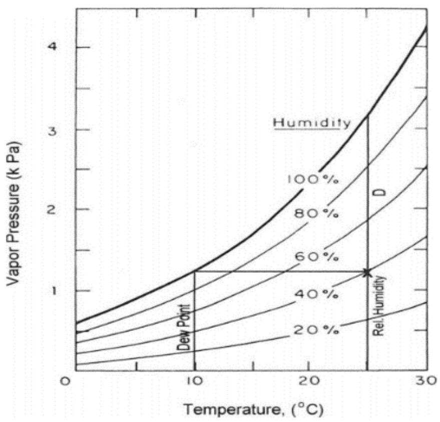

Figure (2) shows the relation between vapor pressure and temperature.

2.2 **Refrigeration System**

A refrigeration system is required to make a surface area approximately continuously cold for condensing the water on its surface. As explained in physics, the performance of any refrigeration circuit is calculated by $\frac{Qc}{Win}$ where QC refers to the heat removed from the refrigerant, and the Win represents the amount of heat that has to be added, keeping the circuit in 0 net. Consequently, a closed enthalpy circuit is used to condense water.
A compressor and an evaporator are used to increase the refrigerant fluid's temperature, and a condenser and capillary tube are used to decrease its temperature.
In brief, the compressor compresses the fluid. Then, it moves through the condenser by using the temperature of the surrounding place. For instance, it moves through the capillary to decrease its temperature below the dew point by decreasing the fluid's pressure.
Finally, it goes through the evaporator and decreases the temperature of the surrounding air. The next step taken must be explained is how each component works and contributes in the outcome of the project.

2.3 **Refrigerant**

The refrigerant can decrease and increase its temperature by only changing the pressure. The refrigerant R134a (1,1,1,2 Tetrafluoroethene) has its thermodynamics properties as shown in figure (2). The R134a reaches 67.5 C after the compressing then reaches 32 C after the condensing phase since it is all before the capillary tube. The capillary reaches the refrigerant to 15 C. Finally, it returns to the compressor for re-execute the circuit.

Pressure	Temperature	Specific volume (m^3/kg)		Enthalpy (kJ/kg)		Entropy (kJ/kg.K)	
kPa	°C	Sat Liq vf	Sat Vap vg	Sat Liq hf	Sat Vap hg	Sat Liq sf	Sat Vap sg
1200	46.3	0.0008935	0.0167	117.8	273.9	0.4245	0.9131
1400	52.4	0.0009167	0.0141	127.3	276.2	0.4533	0.9106
1600	57.9	0.0009401	0.0121	136.0	277.9	0.4792	0.9080
1800	62.9	0.0009640	0.0106	144.1	279.2	0.5031	0.9051
2000	67.5	0.0009888	0.0093	151.8	280.1	0.5252	0.9020
2500	77.6	0.0010569	0.0069	169.7	280.9	0.5755	0.8925
3000	86.2	0.0011413	0.0053	186.6	279.2	0.6215	0.8792

Figure (3) shows the thermodynamic properties of R134a.

2.4 **Compressor**

A refrigeration circuit is needed to keep the collecting surface (Evaporator) cold. In order to achieve this, there are some components needed the thermodynamic properties of R134a. Starting with the compressor as shown in figure (4).
The compressor is used to compress the refrigerant, increasing its pressure and temperature (known by Win) by using the piston part. The piston part compresses the air by changing the cross-sectional area. First, the air enters the cylinder (facing the piston), and by pulling the piston, there must be an alternative air filling the vacuum created by the piston. Then the air inlet with the high cross-sectional area closes, and the air outlet with the low cross- sectional area closes.

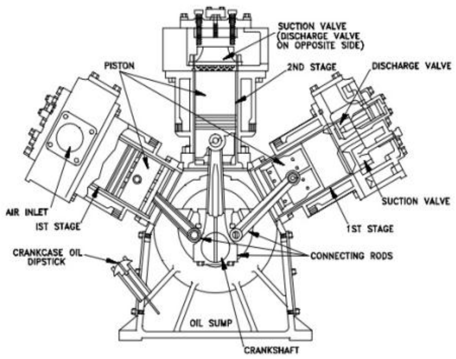

Figure (4) shows: the inner components of the compressor.

As mentioned in the physics concepts, using the continuity equation:
$A_1V_1 = A_2V_2$ (A for area, V for velocity, 1&2 for comparison), it is found that by changing the area, the velocity must increase, and unavoidable the pressure and temperature increases by increasing the velocity.
The compressor used is ADW57 1/6 HP. Consequently, it uses 136 W (before saving energy) to proceed means it used 136 joules per second.

2.5 **Condenser**
After the compressor stage, the refrigerant goes through a condenser. The condenser in the refrigeration system removes the heat in the refrigerant, decreasing its pressure. It converts the refrigerant to the gaseous state with a much low temperature.
The condenser capacity (Qk) can be formulated as follows: $Q_k = Qo + N - Q_h$ (kcal/h)
where,

Q_0 = Evaporator capacity + increase of enthalpy up to the cylinder
N = Compression work in kcal/h
Q_h = Heat emission from compressor pot

Therefore, the refrigerant moves through the filter drier to get out of all the impurities it took from the condenser. For instance, the refrigerant shifts through the capillary tube after the condensing phase to downturn both its temperature and pressure.

2.6 **Capillary tube**
When the refrigerant leaves the condenser and enters the capillary tube, its pressure drops down suddenly due to the very small diameter of the capillary, and this is the main rule of the capillary since two factors.

1. The refrigerant has to deal with the friction between the refrigerant and the tubes' wall.
2. The refrigerant decreases to vapor pressure as its pressure reduces.

Consequently, the saturation pressure, when the vapor pressure equals its liquid, decreases mean the vapor pressure is decreased and the refrigeration temperature also decreases. The capillary tube is a non-adjustable device which means it is designed to pursue a specific condition. This project used a 1/6 H.P compressor which needs 0.78 with 5 feet long to achieve -10 C for the evaporator as shown in Table (5). That will change the refrigerant from a liquid state into a gaseous state with low temperature.

REF	hp	-10 LOW	+20 MED	+45 HIGH
R134A / R401A	1/8 hp	121" # 5	92" #5	53" # 5
R401B/R406A	1/6 hp	78" # 5	106" #1	79" # 1
R409A/R500	1/5 hp	59" # 1	39" #1	26" # 1
	1/4 hp	47" # 1	99" #2	66" # 2
	1/3 hp	102" # 2	79" #2	39" # 2
	1/2 hp	105" # 3	52" # 3	99" # 4
	3/4 hp	66" # 3	101" #4	79" # 4
	1 hp	39" # 3	92" #4	59" # 4
	1-1/2 hp	92" # 4	66" #4	47" # 4
	2 hp	61" # 4	44" #4	29" # 4

Figure (5) shows the capillary tubes sizes for some gases.

2.7 **Evaporator**

The evaporator is a surface made from the stainless-steel, so it doesn't affect the water chemically. Stainless steel, a mixture of Iron (Fe), Chromium (Cr), and Carbon (C). Besides these, it also contains Nickel (Ni), which does contribute to transferring temperature from its entire area to the surrounding one. Since the project was designed on a small scale, the evaporator was designed for 17 revolutions.
To calculate the surface area, illustrate the evaporator as it is a cylinder. Therefore, its lateral area is equal to $2\pi r_1 h$.

$r_1 = the\ radius\ of\ the\ evaporator's\ tube = 4\ e^{-1}\ cm$

$r_2 = the\ radius\ of\ the\ revolution = 8.5\ cm$

$h = 17\ r_2\ (as\ there's 17\ revolution\ of\ the\ Evaporator)$

Then the overall calculation is equaled $2\pi \times 0.4 \times 17\ (8.5) \approx 363.17\ cm2 = 3.6317\ e^{-2}\ m^2$
Moreover, colliding the water with the cold surface area causes it to be collected into a tank. However, the water needs to be modified chemically before drinking.

2.8

Tables:

Table (1): Prices of Materials

No.	Item	Price
1	Compressor	
2	R134a gas	
3	Condenser	
4	Filter of refrigerator	
5	Capillary tube	
6	Evaporator	
7	Bio Ceramic filter	
8	Arduino UNO	
9	Relay module	
10	DHT 11 Sensor	

3. CONCLUSIONS

The results of the designed prototype were positive as it was able to achieve the selected design requirements which are the expected effectiveness and the water parameters. In addition, the solution is reliable and the prototype can satisfy the usage of an individual person daily and more by collecting 2.124 liters per day. Finally, the prototype was implemented and the plan went as anticipated.

4. Recommendations

It is clear to use the prototype's recommendation in both the real project and the prototype:

Prototype recommendations:

4.1 **R600a:**

R600a (Isobutane) is the recommended refrigerant instead of R134a. It has the same Ozone Depletion Potential as R134 a. However, R134a has a global warming potential of 1430, which is higher than isobutane (R600A), which has a global warming potential of just 3.

4.2 **DHT22 sensor:**
The DHT22 sensor is recommended to be used instead of DHT11 as it is more accurate, but it is 5 times the DHT11's price.

4.3 **The tropical compressor** is recommended as it can provide continuous work and is environmentally friendly. But it wasn't be used as its high price.

4.4 **Using contractor** instead of relay in the Arduino because contractors have its own special property that can turn the current off if there is any overload.

Real-life Recommendation:
4.5 **Enlarging scale**
Egypt's homes have an average size of 3.59 persons in 2021. Our prototype has a rate of 2.124 L/day and the average water usage per person is 2 L/person, the real-life application must provide 7.625 per day. Therefore, the surface for the real project can be calculated by it and the surface of the evaporator to be 0.125 m^2.

4.6 **Location:**
The recommended region is North coast or Mahalla Elkobra as they have the greatest humidity percentages in Egypt as shown in figure (6) and that will increase the rate of collection. In addition, putting it in an arid area to save the required money for transferring drinking water.

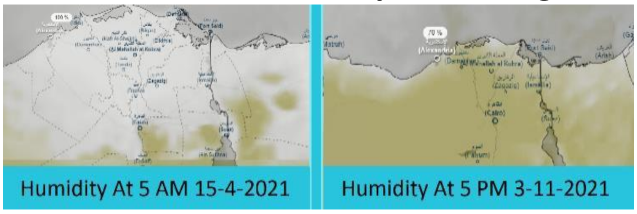

Figure (6) shows the capillary tubes sizes for some gases.

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Symbols and Abbreviations

Q_C refers to the heat removed from the refrigerant, and the Win represents the amount of heat that has to be added, keeping the circuit in 0 net.

$A_1V_1 = A_2V_2$ (A for area, V for velocity 1&2 for comparison).

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