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Exploring the Water Potential of an Atmospheric Water Generator System Using R22 Refrigerant

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ABSTRACT

The availability of clean water remains a challenge in various regions of Indonesia, creating a need for alternative sources besides groundwater and surface water. The Atmospheric Water Generator (AWG) offers a solution by condensing water vapor from the ambient air into water through the vapor compression cycle principle, as used in refrigeration systems. This study aims to design and test a refrigeration system for an AWG using a 1.5 PK R22 hermetic rotary compressor. The method used was an experimental design, beginning with the creation of a block diagram, the design of the refrigeration cycle using CoolPack software, simulation of the condensation process using DWSIM, determination of component specifications, assembly of the apparatus, and finally testing and collection of actual data over a 24-hour period. The results of the cycle design using CoolPack yielded a Coefficient of Performance (COP) value of 5.18 with a design water flow rate of 1.346 L/h. Actual testing showed that the calculated COP values ranged from 5.58 to 8.50 (average 6.97) and the COP values from the software simulation ranged from 6.43 to 8.77 (average 7.95), both of which were above the design values. However, the average actual water production was only 0.90 L/h (21.58 L/day), lower than the design values (1.029–1.340 L/h), although it briefly reached a peak of 1.450 L/h in the early morning. These results indicate that the efficiency of the AWG refrigeration cycle consistently exceeded the design target, but the volume of water produced.

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1. INTODUCTION

Water is one of humanity's basic needs for drinking, cooking, washing, bathing, and various daily activities, and it is also required by the industrial, agricultural, health, and commercial sectors (THUFA'IL, 2023). Efforts by the government and the public to address the scarcity of clean water such as infrastructure development and the construction of community wells have not yet fully resolved the issue quickly, making it necessary to adopt more innovative alternative approaches.

One alternative water source that can be utilized is the ambient air (atmosphere), which, according to previous research, contains large amounts of water vapor, nearly 35% of which is wasted (THUFA'IL, 2023). An Atmospheric Water Generator (AWG) is a device that utilizes atmospheric air and condenses it into water through a working principle similar to that of refrigerators and air conditioners (Vidiyanto et al., 2019), namely the vapor compression cycle which involves a compressor, condenser, expansion valve, and evaporator as its main components. On a commercial scale, AWG units are reported to be capable of producing up to 3,500 gallons of drinking water per day for commercial use and approximately 10 gallons per day for average household needs (Pontious et al., 2016).

The effectiveness of AWGs is greatly influenced by environmental conditions. The rate of water production depends on relative humidity, ambient air temperature, and compressor size; in general, refrigerant condensation generators operate less efficiently when the temperature is below 18.3°C or relative humidity is below 30% (Tripathi et al., 2016). This indicates that the design of AWG systems must take into account variations in weather conditions and operating times to optimize water production.

Based on the above description, this study aims to:

(1). design a refrigeration system for an Atmospheric Water Generator

(2). determine the specifications of the system's main components including the compressor, evaporator, condenser, and expansion device in accordance with the system's requirements

(3). calculate the effectiveness of the Atmospheric Water Generator based on the Coefficient of Performance (COP) and the volume of water produced. This study is limited to the design of a refrigeration system using R22 refrigerant without discussing the details of the water filtration system,

2. RESEARCH METHODS

This study employs a design-based experimental method, beginning with the creation of a block diagram as the initial system concept, followed by implementation into a physical circuit, component assembly, and testing through direct measurements. The designed system consists of five main functional parts, namely panel/compressor protection, refrigeration cycle controller, AWG system design, device assembly, and data acquisition testing.

I. Design Cycle and Simulation

The refrigeration cycle design was performed using CoolPack software version 1.50 to validate the compressor power and COP values based on the parameters of low-pressure, high-pressure, superheat, and subcooling. Next, the process of condensing water vapor from humid air into water was simulated using DWSIM software with the CoolProp property model, which models multicomponent systems using thermodynamic equations of state such as the Peng-Robinson equation (Alpi, 2025). The mass flow rate of air calculated manually was converted to kg/h as input for the inlet air stream component, and the separator output in DWSIM was then used to estimate the volume of condensed water.

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II. Specifications Components

The main components of the AWG system consist of a hermetic R22 rotary compressor with a capacity of 1.5 PK (voltage 220–240 V, operating pressure 10–15 psi), a finned-tube condenser and evaporator made of copper tubing and , an expansion valve in the form of a copper capillary tube with a diameter of 0.54 mm and a length of 1.8 m, a filter dryer, a condenser axial fan, a shaded-pole centrifugal blower motor (60 W, 1500 RPM), and a structural frame made of food-grade 304 stainless steel with dimensions of 120 cm x 50 cm x 50 cm. The temperature and humidity monitoring system uses an ESP32-WROOM-32 microcontroller connected to an SSD1306 OLED display, two DHT22 sensors for measuring the inlet and outlet air temperature and humidity at the evaporator, and two DS18B20 sensors for monitoring the refrigerant pipe temperature. Condensate is collected in a 25-liter SS304 stainless steel tank.

Table 1. Component Specifications

Component	Specifications
Compressor	Panasonic, hermetic rotary type, 1,5 PK, tegangan 220–240 V, R22 refrigerant
Condenser	Copper pipe with aluminum fins, 360 mm straight tube length, equipped with a 10–12 inch
Expansion valve	axial fan Copper capillary tube, 0.54 mm diameter, 1.8 m length
Evaporator	Finned-tube type, copper pipe with aluminum fins, fin dimensions 350.3 mm × 110 mm
Evaporator Blower	Shaded-pole motor, centrifugal fan, 220–240 V AC, 60 W, 1500 RPM
frame	304 stainless steel, dimensions 50 cm × 50 cm × 120 cm, food-grade
Water tank	SS304 stainless steel, 25-liter capacity, enclosed with filtered ventilation
Monitoring system	ESP32-WROOM-32 microcontroller, DHT22 and DS18B20 sensors, SSD1306 OLED display

III. Assembly and Testing

The unit was assembled by constructing the main frame from 30x30 mm angle iron, installing the compressor, condenser, expansion valve, and evaporator in accordance with the refrigerant flow sequence, connecting the piping using copper tubing via brazing, and installing a 220 V AC electrical system for the compressor, blower motor, and a 12 V DC adapter for the condenser fan. Testing was conducted in three stages: a no-load functional test, a 30-minute no-load test at four measurement points (low pressure, high pressure, condenser temperature, and evaporator temperature), and a leak test using soapy water on each pipe joint.

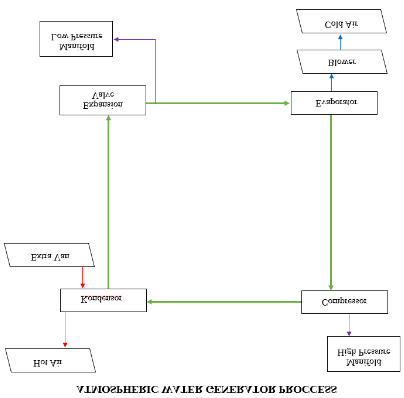

Figure 1. How the Atmospheric Water Generator Works

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IV.Data Collection and Data Analysis

After a 15-minute vacuum process and charging the system with R22 refrigerant to 5 bar, the system was allowed to stabilize for 60 minutes before data collection. Temperature data was measured at six points using thermocouples: before and after the compressor, condenser, expansion valve, and evaporator. Data collection was conducted over 24 hours at one-hour intervals. The data obtained was then used to calculate the cross-sectional area, air flow rate, mass flow of air and refrigerant, moisture content, water condensation rate, compressor work, and Coefficient of Performance (COP), which were subsequently compared with the results of the initial design from the CoolPack and DWSIM simulations.

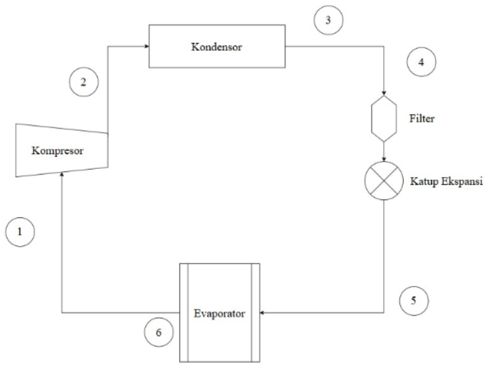

Figure 2. Data Collection Points

3. RESULT AND DISCUSSION

I. Design Data

The design parameters for the refrigeration cycle using CoolPack are shown in Table 1. These parameters serve as a benchmark for comparison with the actual test results in the next stage.

Table 2. AWG Cicle Design Data

In Evap (°C)	Out Evap (°C)	Out Konden (°C)	Out Komp (°C)	RH In (%)	RH Out (%)	Low P (bar)	High P (bar)	COP	Air (L/jam)
7,19	7,69	38,01	76,04	74,00	92,03	4,6	20	5,18	1,346

II. Comparison of COP Values

A comparison of the COP values from the design (fixed values), calculations based on hourly experimental data, and software simulation results over a 24-hour data collection period is presented in Table 2 (data are shown every 3 hours for readability; complete hourly data are available in the research document).

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Table 3. Comparison of COP Values from Design, Calculations, and Software (Samples taken every 3 hours)

Hours	COP Design	COP Calculation	COP Software
06.00	5,18	8,50	8,59
09.00	7,71	7,20	8,42
12.00	4,50	6,88	6,43
15.00	4,90	5,58	8,42
18.00	9,96	6,53	8,58
21.00	8,53	6,97	8,77
00.00	8,30	6,83	6,43
03.00	10,50	7,55	8,75
03.00	10,50	7,55	8,75

The COP values calculated from the experimental data range from 5.58 to 8.50, with an average of 6.97, while the COP values from the software simulation range from 6.43 to 8.77, with an average of 7.95. Both average values are consistently higher than the design COP design value of 5.18, being approximately 34.6% and 53.5% higher, respectively. During the day (12:00–15:00), the calculated COP values fall within the lowest range because the refrigerant's condensing pressure and temperature increase due to hot ambient temperatures, causing the compressor to work harder. Conversely, from evening through early morning, condensing pressure decreases as the air temperature drops, making it easier to release heat in the condenser and causing the COP to rise to 8.00 at 05:00. The COP values generated by the software tend to be higher and more stable because the simulation assumes ideal operating conditions without accounting for pressure losses in the actual system.

III. Comparison of the Volume of Water Produced

A comparison of the design water volume (results of manual calculations and software simulations, which are fixed) with the water volume obtained from calculations and experimental measurements is presented in Table 4 (samples taken every 3 hours).

Table 4. Comparison of Design and Experimental Water Volumes (L/hour, samples taken every 3 hours)

Hours	Design Flow (Calculated)	Design Flow (Software)	Experimental Flow (Calculated)	Experimental Water (Software)	Actual Measured Water
06.00	1,029	1,340	1,692	1,243	1,100
09.00	1,029	1,340	1,141	1,225	0,700
12.00	1,029	1,340	1,198	0,252	0,600
15.00	1,029	1,340	0,900	1,953	0,420
18.00	1,029	1,340	0,831	1,811	0,700
21.00	1,029	1,340	1,170	2,018	1,000
00.00	1,029	1,340	1,328	1,960	1,450
03.00	1,029	1,340	1,227	1,885	1,400

The calculated water volume remains constant because it is derived from initial design parameters that do not change (1.029 L/h for manual calculations and 1.340 L/h for software simulations), whereas the experimentally determined water volume and the actual measured

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water volume fluctuate quite significantly in response to changes in refrigerant and ambient air conditions. Water production peaked from night through the early morning, reaching 1.450 L/h at 12:00 a.m., as the refrigerant's evaporation temperature became lower, allowing the water vapor condensation process in the evaporator to proceed more optimally. Conversely, from noon through the afternoon, the water volume drops sharply to 0.370 L/h at 14:00, even though the refrigerant continues to absorb heat according to its cycle, because low air humidity results in very little water vapor available for condensation.

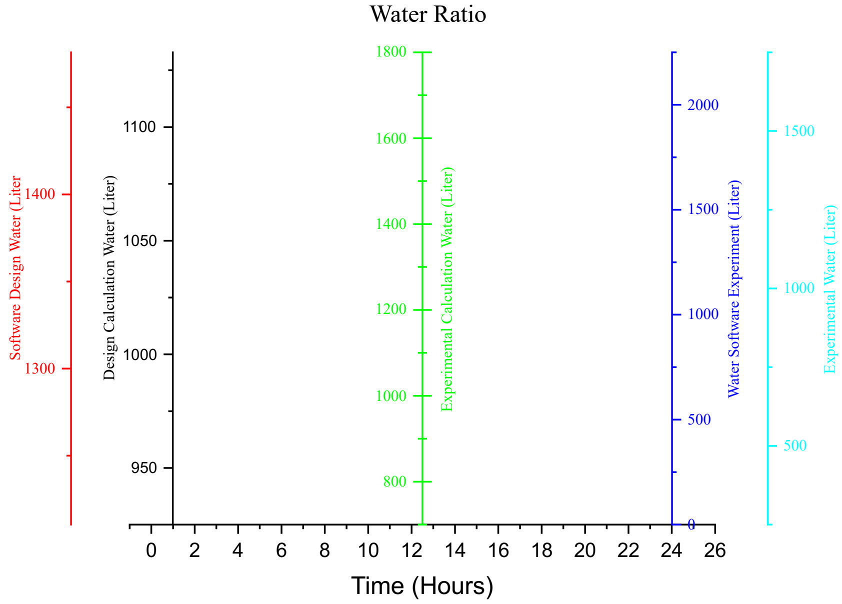

Figure 3. Water Comparison Chart

The graph shows that the experimental water volume and the water volume from the experiment exhibit much greater fluctuations compared to the design water line and the software-calculated water volume, which are relatively constant. The highest water production tends to occur from night through the early morning, in line with the conditions of R22 Freon in the evaporator, which operates at lower evaporation pressure and temperature due to a drop in ambient air temperature, allowing the Freon to absorb heat from the air more effectively and accelerating the condensation of water vapor. Conversely, during the day, the actual water curve drops sharply even though the of the Freon in the evaporator remain stable and operate according to the refrigeration cycle, because the decrease in ambient air humidity during the day reduces the amount of water vapor available for condensation. This graph reinforces the conclusion that AWG water production performance is not only determined by the conditions of the Freon within the system, but is also significantly influenced by the relative humidity and temperature of the ambient air at the time the test is conducted.

IV. Analysis

Overall, the performance of the AWG, which was designed using a 1.5 PK R22 compressor, showed good results in terms of refrigeration cycle efficiency, with actual COP values consistently exceeding the design target. However, in terms of water production, the average actual water volume during the 24-hour during the test was only 0.90 L/hour (equivalent to 21.58 L/day), which remains below the design values derived from both manual calculations

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(1.029 L/hour) and software simulations (1.340 L/hour), although during hours of high humidity the experimental water volume did exceed the design value. This indicates that the water production performance of the AWG is not only determined by the efficiency of the refrigeration cycle but is also significantly influenced by the relative humidity and ambient air temperature at the time of testing, consistent with the findings (Tripathi et al., 2016) that the effectiveness of the AWG decreases significantly under conditions of low temperature and humidity.

4. CONCLUSION

Based on the results of the design, testing, and analysis conducted on the refrigeration system of the Atmospheric Water Generator using a 1.5 PK R22 compressor, it can be concluded that:

(1) the AWG refrigeration system has been successfully designed using a standard vapor compression cycle with R22 refrigerant, with a design COP of 5.18 and a design water flow rate of 1.346 L/h, and the enthalpy diagrams from the experimental test results and the CoolPack design results show that the system operates in accordance with the planned vapor compression cycle principle

(2) The specifications of the AWG's main components have been successfully determined according to system requirements, and all components have been assembled into a single unit proven capable of continuous operation during a 24-hour test

(3) The effectiveness of the AWG shows differing results in two aspects—operating efficiency of the refrigeration cycle (average COP of 6.97 in experiments and 7.95 in simulations) consistently exceeded the design value of 5.18, while average water production (0.90 L/hour) remained below the design target due to the significant influence of relative humidity and ambient air temperature on the condensation process.

For further research, it is recommended that the AWG's operating hours be optimized to the nighttime through early morning hours when relative humidity is higher, that tests be conducted on the use of more environmentally friendly alternative refrigerants as a replacement for R22, and that tests be conducted over a longer duration and under different weather conditions so that the data on AWG effectiveness is more representative of various environmental conditions in Indonesia.

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