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Effect of inlet air velocity on air-water harvester machines using one and two evaporator with 1.5 PK compressor power

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ABSTRACT

During the dry season, clean water crisis often occurs in various parts of Indonesia. As a result, clean potable water is difficult to obtain. Therefore, this research uses an air-water harvester machine, because this machine can be used anywhere as long as there is a source of electricity at that location. This study aims to determine the effect of inlet air velocity on air-water harvester machines using one and two evaporators with 1.5 PK rotary compressor power on water mass and total heat transfer rate. The method used in this research is the experimental method, with variations in inlet air velocity of 0 m/s, 1.5 m/s and 3 m/s, using one and two split AC fin type evaporators each with a capacity of 0.5 PK, with a pipe diameter of 7.65 mm. The refrigerant used is R32. The study was conducted from 09:00 to 16:00, for 18 days, 7 hours per day. The results showed that the higher the air velocity used and the increase in the number of evaporators, can increase the mass of water and the heat transfer rate obtained. The highest mass of water and heat transfer rate obtained in this study is in the air velocity variation of 3 m/s using two evaporators, which is 4.073 kg of water mass for 7 hours and a total heat transfer rate of 1375.09 W.

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1. INTRODUCTION

During the dry season, clean water crises frequently occur in various regions of Indonesia. Clean water plays a crucial role as a fundamental necessity for living beings. To meet this need, several efforts are undertaken by the community, such as traveling long distances solely to obtain clean water, only to find murky and unclean water instead. The provision of clean water in this context refers to water intended for consumption (drinking water).

There are several methods for obtaining clean water, one of which is capturing water from the air. This method has various types, including the use of wind turbines designed to extract water from the air. However, this approach has certain limitations, such as requiring specific height conditions, high installation costs, and a location with strong wind speeds. Additionally, it is highly dependent on weather conditions, although it can produce a significant amount of water. Another method involves fog-harvesting nets, which also have

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drawbacks, as they rely heavily on foggy locations and are highly weather-dependent. Therefore, the most practical and straightforward method is the use of an air-water harvester machine. This machine can be employed in any location to extract water from the air, provided there is an available electricity source. It operates using a vapor compression system in a refrigeration unit, where an evaporator serves as the medium for condensing water vapor from the air to generate water (Mirmanto et al. 2021).

Research on air-water harvester machines has been widely conducted; however, these machines still produce a relatively small mass of water. Some of these studies have been conducted by Winata (2021), Faroni (2022), Prasetya (2022), and Azari (2022), however, the studies conducted so far have not been able to produce water in large quantities. Winata (2021) produced 0.5043 kg of water in his study, while the studies conducted by Faroni (2022), Prasetya (2022), and Azari (2022) only yielded 0.369 kg, 0.438 kg, and 0.44 kg, respectively, within the same duration. However, Winata's (2021) results were comparatively higher. Therefore, further research on air-water harvester machines is crucial to enhance water production efficiency.

Mirmanto et al. (2023) conducted a study on an air-water harvester machine using a natural convection method, without the assistance of an airflow fan on the evaporator coil. However, the obtained water mass and heat transfer rate were 527 g and 75.47 W, respectively, which were lower compared to the use of forced convection. Mirmanto et al. (2024a) investigated an air-water harvester machine utilizing forced convection with two evaporator coils of 6.35 mm diameter, varying the inlet air velocity at the evaporator. The results showed that an air velocity of 6 m/s increased the total heat transfer rate to 240 W. However, freshwater production reached 1,457 g at an inlet air velocity of 5 m/s. In another study, Mirmanto et.al (2024b) examined the effect of inlet air velocity variation using three evaporator coils with a 6.35 mm diameter and a 1 PK compressor. However, the impact of air velocity on machine performance remained unclear. The highest recorded water mass production was 1.72 kg, with a maximum total heat transfer rate of 582 W at an inlet air velocity of 5 m/s. Irhami (2023) investigated an evaporator pipe arranged in parallel with a 1.7 mm diameter and a fan on the inlet side, resulting in a water mass of 1.241 kg and a heat transfer rate of 208.21 W at a velocity of 5 m/s. Mar'i (2024) conducted a study using a 0.5 PK air conditioning component with an evaporator pipe diameter of 7.65 mm. By implementing a forced convection system, the achieved water mass was 3.73 kg, with a total heat transfer rate of 1,238.22 W at an air velocity of 3 m/s. Therefore, this study will employ a forced convection system while increasing the number of evaporators, as higher water mass production has been observed with this approach.

Several factors influence the amount of water mass produced, including the relative humidity (RH) of the incoming air, the temperature of the incoming air, the evaporator surface area, the evaporator pipe diameter, and the inlet air velocity. Considering these factors, this study utilizes variations of one and two finned evaporators from a split-type air conditioner (AC), each with a capacity of 0.5 PK and a 1.5 PK compressor, which is available in the laboratory. The selection of finned evaporators from a split AC system is based on their larger surface area and pipe diameter compared to the evaporator coils used in previous studies, which is expected to enhance water mass production and heat transfer rates. Additionally, a forced convection method is employed, with inlet air velocity variations of 0 m/s, 1.5 m/s, and 3 m/s. The objective of this study is to analyze the effect of varying inlet air velocities (0 m/s, 1.5 m/s, and 3 m/s) using one and two finned evaporators from a split AC system, with a 1.5 PK compressor in an air-water harvester machine, on heat transfer rates and the amount of water mass produced.

2. RESEARCH METHODS

The dependent variable is the variable that cannot be controlled or determined. In this study, the dependent variables are mass of water resulting from condensation, temperature of air leaving the evaporator, RH of air leaving the evaporator and rate of heat transfer absorbed by the evaporator from the air.

The independent variable is the variable that can be controlled and determined. In this study, the independent variable is the inlet air velocity, which is set at 0 m/s, 1.5 m/s, and 3 m/s. The study utilizes one and two finned evaporators from a split-type air conditioner (AC), each with a capacity of 0.5 PK. Data collection for each independent variable is repeated three times.

The method used in this study is the experimental method, conducted from 09:00 to 16:00 for a duration of 18 days. The schematic of the equipment used in this study is shown in Figure 1, which consists of several components of a refrigeration system.

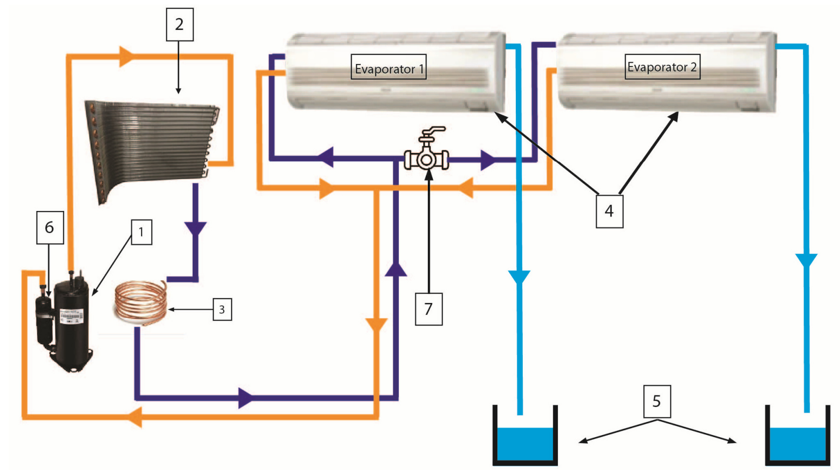

Figure 1. Experimental apparatus: 1. compressor, 2. condenser using fan in one unit, 3. capillary tube, 4. evaporators connected in parallel and blower in a single unit, 5. condensate water collection tank, 6. accumulaor, 7. valve.

Figure 1 illustrates the components used in this study. The objective of this research is to analyze only the heat transfer and the mass of water produced by the condensation unit (4); therefore, the refrigerant flow is not examined. The exterior of the condensation unit (4) is insulated using aluminum foil, while the input pipes leading to evaporator 1 and evaporator 2 (4) are insulated with sponge pipe wrap. The length of each input pipe is set to 186 cm, and the output pipes are 197 cm, adjusted to match the experimental setup. The working principle of the system shown in figure 1 is as follows. The compressor (1) compresses the refrigerant in its vapor phase, directing it to the condenser (2). This process increases the refrigerant's pressure and temperature. The refrigerant then flows from the condenser (2) to the capillary tube (3), where sensible heat is released, causing a decrease in refrigerant temperature, and latent heat is discharged, leading to a phase change from vapor to liquid. Next, the refrigerant moves from the capillary tube (3) to the evaporator (4). Here, the refrigerant passes through small pipes (3), which result in a pressure and temperature drop. Before reaching the evaporator (4), the refrigerant first flows through the valve (7). When the valve is closed, the refrigerant flows only to evaporator 1, whereas when the valve is open, it flows to both evaporator 1 and evaporator 2 with a series of parallel pipes (4). During this process, latent heat is absorbed from the surrounding air, causing the water vapor in the air to reach its dew point and condense. The resulting condensate is collected in the water storage tank (5). In the final stage, the refrigerant, now in vapor form after absorbing heat, flows to the accumulator (6) to ensure it is entirely in the vapor phase before being re-circulated by the compressor (1).

Table 1. Specification of tools and materials

Name	Specification
Outdoor compressor unit, condenser, capillary pipe	AC Sharp 1,5 PK (968 W)
Two Indoor evaporator units	AC Taco split fin type 0.5 PK, pipe diameter 7.65 mm, evaporator area 0.168 m^2
Anemometer	Air velocity measurement range: 0 – 45 m/s (± 3%)
Monitor temperature	Digital thermometer and thermocouple
Data logger	Applent AT45-24 channels
Refrigerant	R32
Air	The condition of the room is not maintained
RH	The condition of the room is not maintained
Inlet air velocity	0 m/s, 1.5 m/s, 3 m/s.
Dimension of intake air area	0,06 m × 0,3 m = 0,018 m^2
Temperature	Measured with a K-type thermocouple with error ± 0,5 °C

The variable sought in this study is the heat transfer rate. The following equation is derived from Mirmanto et al. (2024c). The first variables calculated are the mass flow rate of condensate, the mass flow rate of water vapor, and the mass flow rate of dry air. The mass flow rate of condensate can be determined using the following equation (1).

$$\dot{m}_w = \frac{m_w}{t} \tag{1}$$

$\dot{m}_w$ is the flow rate of dew or condensed water (kg/s), m_w is the mass of dew or water produced (kg), t is the duration of the trial (s).

$$\dot{m}_v = w_1 \times \dot{m}_d \tag{2}$$

$\dot{m}_v$ is the water vapour flow rate (kg/s), w_1 is the section of water vapour at the time of entering the evaporator obtained through the online psychrometric chart at http://www.hvac-calculator.net/index.php?v=2 based on evaporator inlet air temperature and RH. $\dot{m}_d$ is the dry air mass flow rate (kg/s) which is obtained through equations (3) and (4).

$$\dot{m}_d = \frac{\dot{m}_t}{w_1 + 1} \tag{3}$$

$$\dot{m}_d = \frac{\dot{m}_w}{w} \tag{4}$$

Equation (3) is used for the calculation of forced convection systems namely at an inlet air speed of 1.5 m/s and 3 m/s, while equation (4) is for natural convection systems namely at an inlet air speed of 0 m/s. $\dot{m}_t$ is the total mass flow rate (kg/s) which can be obtained through equations (6) and (7). While w is the portion of water vapour that is condensed, which can be obtained using equation (5).

$$w = w_1 - w_2 \tag{5}$$

w_2 is the share of water vapour at the exit of the evaporator, which can be obtained through the online psychrometric chart at http://www.hvac-calculator.net/index.php?v=2 based on the temperature and RH of the evaporator outlet air.

$$\dot{m}_t = \dot{m}_v + \dot{m}_d \tag{6}$$

$$\dot{m}_t = \rho \times A \times v \tag{7}$$

ρ is the density of air (kg/m^3) which can be obtained from the atmospheric pressure table Cengel (2002), based on the evaporator inlet air temperature. A is the inlet air area (m^2), and v expresses the inlet air velocity (m/s). After the mass flow rate is obtained, the heat transfer rate can be calculated using the following equation:

$$\dot{Q}_w = \dot{m}_w \times h_{fg} \tag{8}$$

$\dot{Q}_w$ is the heat transfer rate of dew or water produced (W). h_{fg} is either evaporation or condensation (J/kg) obtained from the table of vapour or saturated water properties Padang (2019), based on T_{avg} is the average air temperature entering and leaving the evaporator (°C).

$$T_{avg} = (T_{in} + T_{out})/2 \tag{9}$$

T_{in} is the evaporator inlet air temperature (°C) and T_{out} is the evaporator exit air temperature (°C).

$$\dot{Q}_v = \dot{m}_v \times (h_{g\,in} - h_{g\,out}) \tag{10}$$

$\dot{Q}_v$ is the heat rate of the cooled vapour (W). hg_{in} is the enthalpy of saturated vapour entering the evaporator (J/kg) and hg_{out} is the enthalpy of saturated vapour exiting the evaporator. hg_{in} obtained based on the inlet air temperature and hg_{out} obtained based on the exit air temperature of the vapour table or saturated water properties Padang (2019).

$$\dot{Q}_d = \dot{m}_d \times (h_{in} - h_{out}) \tag{11}$$

$\dot{Q}_d$ is the heat rate of dry air (W). h_{in} is the enthalpy of air entering the evaporator (J/kg) and h_{out} is the enthalpy of air leaving the evaporator. h_{in} obtained through online psychrometric charts at http://www.hvac-calculator.net/index.php?v=2 based on evaporator inlet air temperature and RH. h_{out} obtained through online psychrometric charts at http://www.hvac-calculator.net/index.php?v=2 based on the temperature and RH of the evaporator outlet air.

$$\dot{Q}_{total} = \dot{Q}_w + \dot{Q}_v + \dot{Q}_d \tag{12}$$

$\dot{Q}_{total}$ is the total heat transfer rate (W).

3. RESULTS AND DISCUSSION

From the calculations that have been carried out, the discussion will be divided into two according to the research objectives of the effect of inlet air velocity with one and two evaporators on the mass of water and the resulting displacement rate.

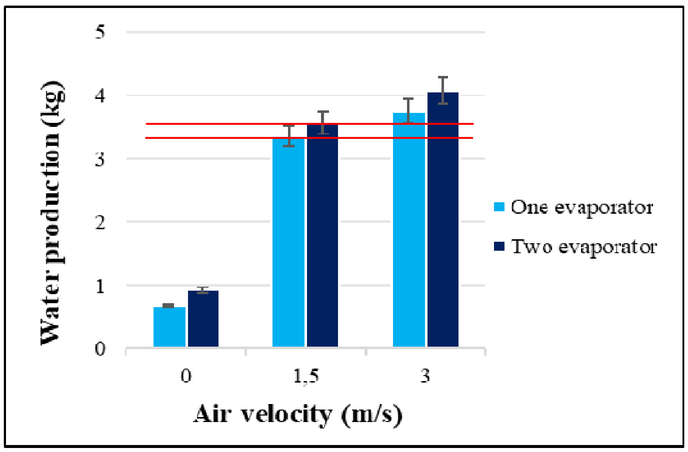

Figure 2. The effect of inlet air velocity using one and two evaporators on the mass of water produced.

Based on Figure 2, it can be observed that the differences in the water mass produced across the six variations are significant, as indicated by the fact that the error bar legs do not intersect the horizontal line. An increase in the inlet air velocity and the number of evaporators enhances the mass of water generated. The highest water mass, 4.073 kg, was achieved at an air velocity of 3 m/s using two evaporators. This outcome is attributed to the increased amount of water vapor entering the condensation unit per unit time with higher air velocities. However, higher air velocity also reduces the contact time between the water vapor and the evaporator surface, leading to greater vapor outflow and a relative humidity at the outlet RH_{out} higher than at the inlet RH_{in}. Condensation occurs due to the heat transfer from the air to the evaporator wall, where the wall temperature is lower than the dew point, causing the water vapor in the air to condense. Therefore, when the air velocity decreases, the amount of vapor entering the evaporator is reduced; however, a greater proportion of this vapor condenses due to the longer contact time, resulting in a lower amount of collected condensate but a lower RH_{out} compared to RH_{in}. The lowest water mass production, 0.673 kg, was recorded at 0 m/s using a single evaporator.

When comparing the mass of water obtained using one and two evaporators, a higher mass of water is produced when using two evaporators. This is because the use of two evaporators increases the heat absorption area, leading to greater water condensation. Mirmanto et al. (2021) conducted a study on the effect of increasing the number of evaporators on the mass of water produced, demonstrating that a higher number of evaporators results in an increased amount of water obtained. In this study, a similar trend was observed, where the mass of water increased as the number of evaporators increased. However, in this study, when using two evaporators arranged in parallel, the mass of water obtained per evaporator was lower than when using a single evaporator.

This is because, in a parallel configuration, the refrigerant mass flow is divided into two, reducing the effectiveness of the condensation process. Furthermore, during the experiment, there was no addition or reduction of refrigerant mass, ensuring that the refrigerant mass remained constant across all variations.

In this study, similar to the research conducted by Muslimin (2025), a single AC evaporator with a capacity of 0.5 PK, a compressor power of 1.5 PK, and an inlet air velocity of 3 m/s was used. However, the results of this study yielded a water mass of 3.753 kg over 7 hours, whereas Muslimin (2025) achieved a higher water mass of 5.837 kg over the same duration. This difference is attributed to the larger evaporator surface area and inlet air area used in Muslimin (2025) study, which were 0.207 m² and 0.03 m², respectively. The larger surface area allowed for greater heat absorption, resulting in a higher amount of water vapor entering and condensing. In contrast, this study utilized an evaporator surface area of 0.168 m² and an inlet air area of 0.018 m², leading to a lower amount of water vapor entering and condensing due to the smaller heat absorption area. This comparison further confirms that both the evaporator surface area and the inlet air area significantly influence the amount of water produced. Consequently, the water mass obtained in Muslimin (2025) study remains higher than in this study.

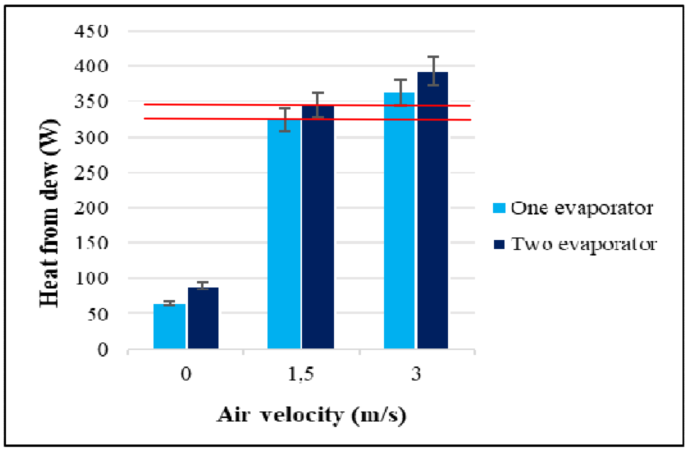

Figure 3. The effect of inlet air velocity using one and two evaporators on heat transfer from water or condensation.

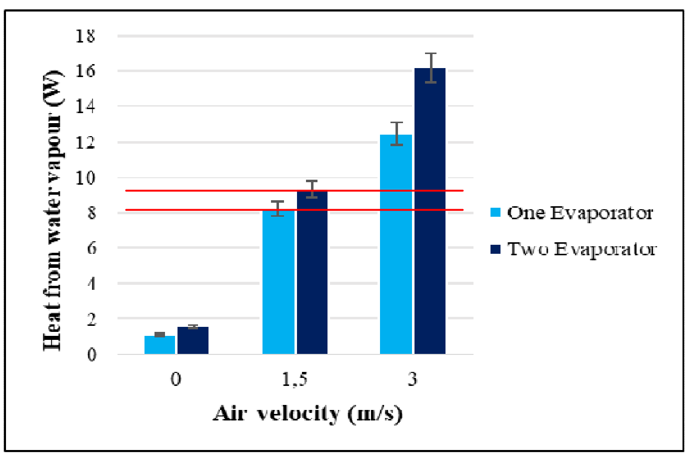

Figure 4. The effect of inlet air velocity using one and two evaporators on heat transfer from water vapor.

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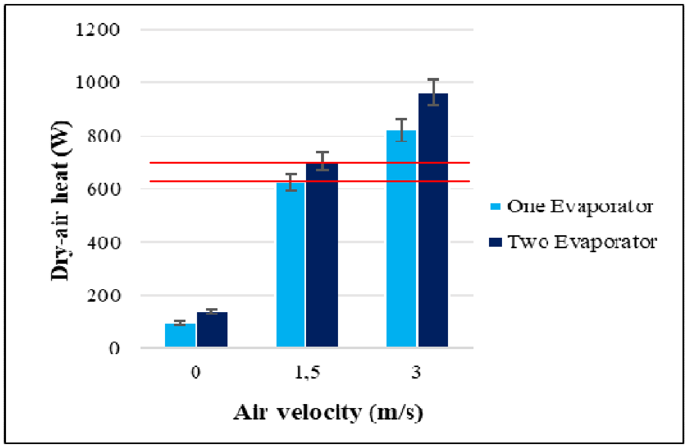

Figure 5. The effect of inlet air velocity using one and two evaporators on heat transfer from dry air.

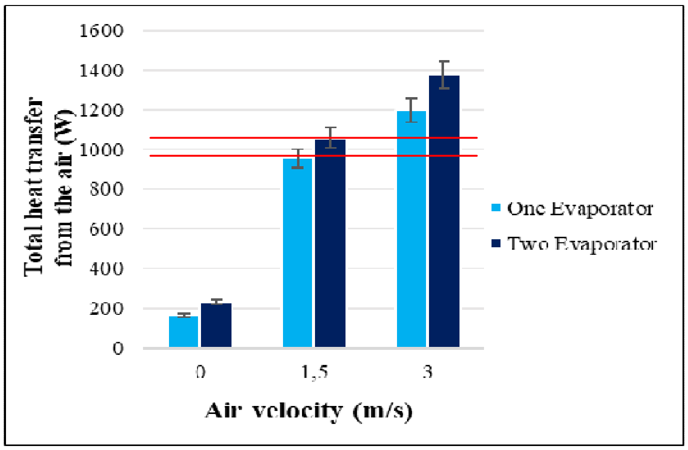

Figure 6. The effect of inlet air velocity using one and two evaporators on total heat transfer.

Based on figure 6, the total heat transfer consists of heat transfer from condensate (figure 3), water vapor (figure 4), and dry air (figure 5). The differences observed in each variation are significant, as the error bar margins do not intersect the horizontal line. The results exhibit an increasing trend similar to the other heat transfer processes. The lowest total heat transfer is obtained at an air velocity of 0 m/s using a single evaporator, amounting to 162.99 W. This low result is due to the 0 m/s velocity corresponding to natural convection heat transfer. In contrast, the highest total heat transfer is achieved at an air velocity of 3 m/s using two evaporators, reaching 1375.09 W. The increasing heat transfer is attributed to the rise in mass flow rate with increasing air velocity, which significantly affects the calculated heat transfer rate, resulting in higher total heat transfer at 3 m/s. The use of two evaporators enhances heat transfer due to the larger heat exchange surface area. However, when using two evaporators, the heat transfer per individual evaporator is lower than that of a single evaporator. This occurs because, in a parallel configuration, the temperature drop is distributed across both evaporators, leading to a less significant temperature decrease per evaporator compared to a single evaporator setup.

This study resulted in a total heat transfer of 1196.56 W using a single evaporator at an air velocity of 3 m/s, utilizing the same equipment as in the study by Muslimin (2025). The obtained result is lower than that of Muslimin (2025), which reported a total heat transfer of 3030.78 W. This discrepancy is attributed to the larger air inlet area and evaporator surface area used in Muslimin (2025) study, allowing a greater amount of water vapor to pass through the evaporator. Additionally, a larger evaporator surface area and air inlet area contribute to higher heat transfer, resulting in a greater total heat transfer. Consequently, this study yielded a lower total heat transfer compared to Muslimin (2025).

4. CONCLUSION

Based on the research findings and analysis conducted on the effect of air inlet velocity using one and two evaporators on the produced water mass and total heat transfer rate, the following conclusions were obtained:

1. The highest water mass was achieved at an air inlet velocity of 3 m/s using two evaporators, with an average water mass of 4.073 kg over 7 hours.
2. The highest total heat transfer rate was obtained at an air inlet velocity of 3 m/s using two evaporators, with an average total heat transfer rate of 1375.09 W..

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NOMENCLATURE

$\dot{m}_w$	: flow rate of dew or condensed water (kg/s)
m_w	: mass of dew or water produced (kg)
t	: trial duration (s)
w	: large fraction of condensed water vapour (kg/kg $_{\text{dry air}}$)
w_1	: large fraction of condensed water vapour (kg/kg $_{\text{dry air}}$)
w_2	: large fraction of condensed water vapour (kg/kg $_{\text{dry air}}$)
RH_{in}	: relative humidity entering the evaporator (%)
RH_{out}	: evaporator exit relative humidity (%)
$\dot{m}_d$	: dry air mass flow rate (kg/s)
$\dot{m}_v$	: water vapour mass flow rate (kg/s)
$\dot{m}_t$	: total mass flow rate (kg/s)
ρ	: density of air (kg/m^3)
A	: cross-sectional area of inlet air duct (m^2)
v	: intake air velocity (m/s)
h_{fg}	: enthalpy of evaporation or condensation (latent energy) (J/kg)
$h_{g\,in}$	: enthalpy of saturated vapour entering the evaporator (J/kg)
$h_{g\,out}$	: enthalpy of saturated vapour exiting the evaporator (J/kg)
h_{in}	: enthalpy of air entering the evaporator (J/kg)
h_{out}	: enthalpy of air leaving the evaporator (J/kg)
T_{in}	: evaporator inlet air temperature (°C)
T_{out}	: evaporator exit air temperature (°C)
T_{avg}	: average air temperature (°C)
$\dot{Q}_w$	: heat flow rate of dew or water produced (W)
$\dot{Q}_v$	: heat flow rate of cooled vapour (W)
$\dot{Q}_d$	: dry air heat flow rate (W)
$\dot{Q}_{total}$	: total heat transfer rate (W)

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