

# Refrigeration System Based- Dehumidifier.pdf

*by*

---

**Submission date:** 09-May-2023 04:47AM (UTC+0700)

**Submission ID:** 2087960679

**File name:** Refrigeration System Based-Dehumidifier.pdf (1.08M)

**Word count:** 2579

**Character count:** 13286

PAPER · OPEN ACCESS

## Refrigeration system based-dehumidifier

6  
To cite this article: D Ariwibowo *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **845** 012039

6  
View the [article online](#) for updates and enhancements.

### You may also like

- 5  
[YOUNG COCONUT WASTE AS GREENER DESICCANT ALTERNATIVE IN DESICCANT DEHUMIDIFIER](#)  
N. Idris, I.M. Saadon, M.F. Kamarulzaman et al.
- [Tribocorrosion behaviors of TiSiCN nanocomposite coatings deposited by high power impulse magnetron sputtering](#)  
Haoqi Wang, Yixiang Ou, Xu Zhang et al.
- 7  
[Performance of dehumidifier drying machine for soybean seeds drying](#)  
B Susilo, M B Hermanto, R Damayanti et al.



The Electrochemical Society  
Advancing solid state & electrochemical science & technology

243rd Meeting with SOFC-XVIII  
Boston, MA • May 28 – June 2, 2023  
Accelerate scientific discovery!

Learn More & Register

11

This content was downloaded from IP address 182.255.4.125 on 27/04/2023 at 05:59

## Refrigeration system based-dehumidifier

D Ariwibowo<sup>1\*</sup>, Indartono<sup>1</sup> and S Darmanto<sup>1</sup>

Mechanical Engineering Dept. Vocational School, Diponegoro University. Semarang, Indonesia

E-mail: didik.ariwibowo@live.undip.ac.id

**Abstract.** This research aimed to develop a dehumidifier prototype based on R-404C vapor compression refrigeration system and observed its performance. Condenser and evaporator became a unit to condense the moisture content of the air and heat it to an elevated temperature. Condenser and evaporator were arranged in line with airflow to be treated. The air velocity drawn through the unit of condenser-evaporator arrangement was set at 4.5, 5.0, 5.5 m/s by fan current input controller. Evaporator and condenser are a fin-tube type with areas of 0.6 m<sup>2</sup>. Refrigerant inlet temperature to evaporator was set at -20 °C. Temperature and Relative humidity (RH) of air at the inlet and outlet of the unit were measured by thermohygrometer. The humidifier performance was indicated by a ratio between moisture condensed (kg) and system energy input (kW). The heat released in the cooling and condensation process was 10.1 kW and 17.8 kW, whereas heat consumed in the heating process was 24.8 kW. The best performance of the dehumidifier was 16.7 kg/kWh at air velocity, outlet temperature and RH were 5 m/s, 42 °C and 17 %, subsequently.

### 1. Introduction

In the food industry, drying process development for heat sensitive raw materials becomes crucial. Drying atmosphere affects to properties and qualities of dried product. Air at elevated temperature and lower relative humidity (RH) is needed to dry a temperature-sensitive product, such as herbal-based product. The drying temperature for the product is in the range of 30 °C – 40 °C [1;2]. The temperature not only avoids nutritional damage but also case hardening of the product [3].

At room temperature, water diffusion in herb-fiber is drawn slower to achieve product surface so that the drying process becomes longer. An effort to solve the problem is to expose the product in a lower air relative humidity. In this environment, the drying process will be faster [4;5]. The dehumidification process can lower relative humidity. One of the dehumidification process methods is by lowering air temperature until its dew point. At dew point, a part of moisture content in the air will be condensed. The rest portion will be as dried-air with lower relative humidity.

One of the dehumidification process methods is by lowering air temperature until its dew point. At dew point, a part of moisture content in the air will be condensed. The rest portion will be as dried-air with lower relative humidity.

The equipment to utilize the dehumidification process namely <sup>12</sup> Conditioning (AC) unit. The evaporator in AC unit will condense air drawing through it. But, the temperature of the air is relatively low. To increase the air temperature, the heater is installed [6;7]. In this scheme of dehumidification process, air flowing out from the equipment about 30 °C – 57 °C [8] with relatively low RH .

<sup>2</sup>  
\* To whom any correspondence should be addressed.



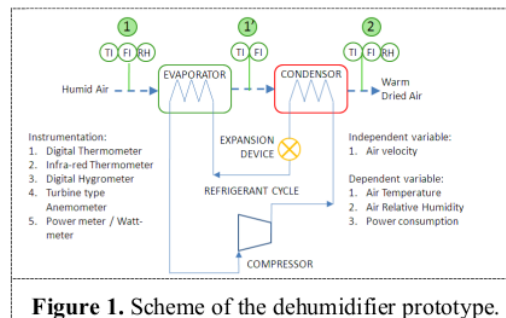
Dehumidifier using AC and heater affects to higher operational cost, because AC is designed for room conditioning, not for obtaining dried-air. Therefore, modification of evaporator-condenser arrangement and their size could be a prospect design.

Modification of the evaporator-condenser arrangement and their size in a refrigeration system will affect the vapor compression system cycle balance [9]. For this preliminary research, the evaporator and condenser were in the same size. The cycle balance and air flowing out from the equipment were observed.

## 2. Literature review

The extraction rate of moisture takes into account an observation of a dehumidifier system. The drying load will decrease as the product dries out, affect the property of the process air. The change in air property will disturb the refrigeration cycle. The air property, together with an inter-dependence of the air and refrigerant, results in the dynamic behavior of the dehumidifier system. This leads to different behavior in each period of the dehumidification process. During all differing dehumidification periods, adjustment to the main influencing parameters will achieve an optimal performance of the dehumidifier. The parameter includes compressor power and the air flow rate. The regulation for a batch-type dehumidifying process is therefore difficult. Steady-state operation of dehumidifier by using a refrigeration system or sorption systems to be a better choice, if the process dynamics are avoided.

The aim of dehumidifier design is how to use energy efficiently [9]. Evaporator and condenser take a role in the amount of internal heat loss effects. Most refrigeration system based-dehumidifier perform far away from efficient points. The varies design condition of the dehumidifier will lead to varies optimum points. Inappropriate dimensioning of the heat exchanger component leads to this inefficient design conditions. Heat exchanger components size and arrangement will be one of the most critical challenges of a refrigeration based-dehumidifier design.



**Figure 1.** Scheme of the dehumidifier prototype.

The capacity of refrigeration or evaporation is proportional to the specific enthalpy difference of air. And this enthalpy difference is proportional to the temperature difference of the evaporator's inlet and surface temperature, with considering of slope of the saturation line. It is possible to calculate the optimum temperature difference, with a given relative humidity (RH) in a continuous process and given dehumidifying air temperature. This optimum temperature difference is for a minimum evaporation capacity.

At this point, a certain amount of water will be discharged. On the other hand, it is possible to calculate the optimum temperature difference related to the influence-parameters mentioned above to achieve a maximum moisture extraction. There is no correspondence between maximum moisture extraction and the minimum evaporation capacity. This is due to the fact that there are different optimal enthalpy differences.

### 3. Materials and methods

Equipment used in this research were the dehumidifier prototype built from modified refrigeration equipment. The observed parameter was measured using thermohygrometer, power meter and pressure gauge. Data collected from the measurement were analyzed and shown as graphs.

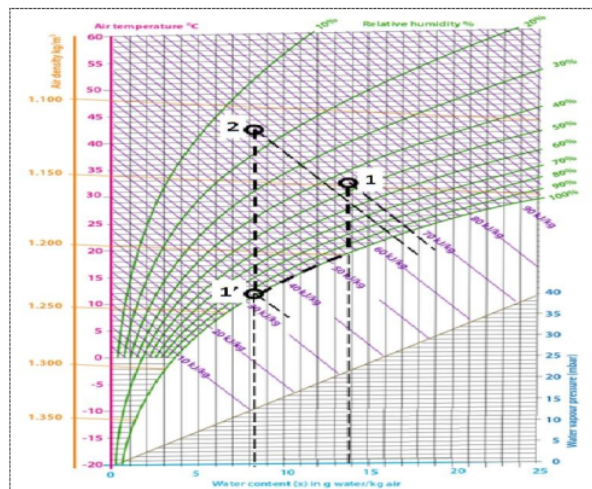
#### 3.1. Equipment

The dehumidifier prototype was built based on the scheme shown in Fig. 1. There were two elements of the prototype. Element 1 consists of the main equipment of the refrigeration system; those are a compressor, condenser, expansion device, and evaporator. Whereas element 2 consists of a duct and fan that draws air through evaporator and condenser arrangement. Evaporator and condenser were arranged in line with airflow so that air experiences cooling and heating processes. The Condenser placed immediately downstream of the evaporator.

Kulthorn WJ 2450ZK-Pyang was the compressor for the refrigeration system. Evaporator and condenser have a heat transfer area of 0.6 square meters (m<sup>2</sup>), whereas the fan used were LTF3E-300-50, 80 watts, 1380 revolution per minute. The refrigerant used in the refrigeration system was R-404C.

#### 3.2. Data analysis

The parameter measured in this research were air velocity (m/s), air temperature (°C), air relative humidity (RH), power input to the refrigeration system and fan (Watt).



**Figure 2.** Cooling, condensation, and heating processes of air flowing through evaporator-condenser arrangement.

The temperature was measured at inlet (1), intermediate (1'), and outlet point (2) of the dehumidifier. Data collected from the measurement were analyzed. The performance of the dehumidifier was calculated as the ratio between moisture condensed and system energy input (kg/kWh). The air velocity was varied at 5.5 m/s, 5 m/s, 4.5 m/s.

### 4. Results and discussion

Air that experienced cooling, condensation, and heating processes when flowing through the evaporator-condenser arrangement was described in Mollier chart shown in Fig. 2. Air, from initial

temperature 30 °C and 50% RH (point 1), was drawn into the dehumidifier, and indicated at point 2 when out from dehumidifier.

The temperature of air out from evaporator (point 1') was 12 °C, whereas air out from condenser (point 2) had temperature and relative humidity of 42 °C and 17% RH. Fig. 2 shows that moisture decreasing was about 5.8 g/kg air.

At the best point, the air mass flow rate was 2,800 kg/h. This condition would condense moisture from the air about

$$\dot{w} = 2,800 \frac{\text{kg}}{\text{h}} \times 5.8 \frac{\text{g}}{\text{kg}} = 16.24 \text{ kg/h}$$

The total power input to the system was 0.97 kW. Therefore, the ratio between moisture condensed and power input was

$$\text{Moisture to power input ratio} = \frac{16.24 \text{ kg/h}}{0.97 \text{ kW}} = 16.7 \text{ kg/kWh}$$

The air experienced a cooling and condensation processes when contacted with the evaporator surface. At this time, there was an amount of heat released in the form of sensible heat and latent heat. The sensible heat is the heat released from the entry point of the evaporator to the dew point (cooling process), whereas latent heat is the heat released when condensation occurs. The amount of the heat was calculated by specific enthalpy and mass flow rate of air.

**Table 1.** Enthalpy, Temperatur and RH at inlet, intermediate, and outlet point.

Air velocity, Vair (m/s)	13	Inlet (Ti)	Intermediate (Tint)	Outlet (To)
5.5	T (°C)	30	21	35
	RH (%)	50		34
5	T (°C)	30	12	42
	RH (%)	50		17
4.5	T (°C)	30	9	42
	RH (%)	50		11

Refer to Figure 2, specific enthalpy at the entry point of the evaporator was 68 kJ/kg. The specific enthalpy at dew point and out from evaporator was 55 kJ/kg and 32 kJ/kg, subsequently. Therefore, the sensible heat and latent heat were determined by the following calculation.

$$\text{Sensible heat} = \frac{2,800 \frac{\text{kg}}{\text{h}} \times (68 \frac{\text{kJ}}{\text{kg}} - 55 \frac{\text{kJ}}{\text{kg}})}{3,600}$$

$$= 10.1 \text{ kW}$$

$$\text{Latent heat} = \frac{2,800 \frac{\text{kg}}{\text{h}} \times (55 \frac{\text{kJ}}{\text{kg}} - 32 \frac{\text{kJ}}{\text{kg}})}{3,600}$$

$$= 17.8 \text{ kW}$$

The heat consumed in heating process determined by the following calculation.

$$\text{Heating} = \frac{2,800 \frac{\text{kg}}{\text{h}} \times (64 \frac{\text{kJ}}{\text{kg}} - 32 \frac{\text{kJ}}{\text{kg}})}{3,600}$$

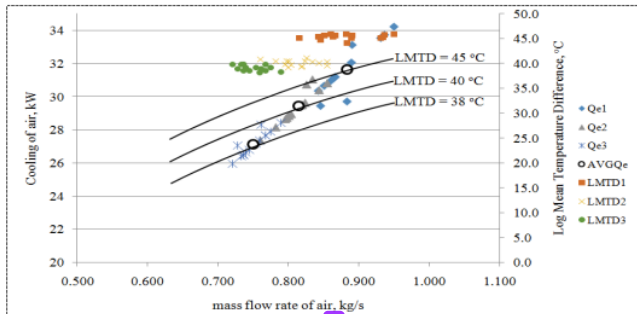
$$= 24.8 \text{ kW}$$

The temperature measured at inlet, intermediate, and outlet points for the various velocity of air is shown in Table 1. Table 1 shows that the intermediate temperature of the air was decreased as air velocity decreased. It is reasonable that the lower air velocity affects heat transfer contact time longer, so that tends to decrease the final temperature with decreasing of air velocity. This longer contact time also affects to heating process at the condenser.



The ratio between air heating effect at the condenser and air cooling effect at evaporator at air velocity 5.5 m/s, 5 m/s, and 4.5 m/s were 1.5, 1.44, 1.47, subsequently. This ratio depends on the pressure ratio of the compressor.

The cooling process of air flowing through evaporator released a amount of heat termed as the heat of air, in kilowatt (kW) unit. The relation between the heat of air, the mass flow rate of air and log mean temperature difference (LMTD) was figured at Fig. 3. This LMTD was the temperature difference between air temperature flowing through the evaporator and surface temperature of the evaporator (Tse). The surface temperature of the evaporator was constant from inlet to outlet, and closed to refrigerant temperature (Te) of -20 °C.



**Figure 3.** Cooling of air with a mass flow rate of air and LMTD evaporator.

The cooling of air was obtained from this equation,

$$Q_{air,e} = \dot{w}_{air} \times C_{p_{air}} \times (T_{int} - T_i) \text{ kW} \tag{1}$$

whereas LMTD was calculated from this equation

$$LMTD = \frac{(T_i - T_{se}) - (T_o - T_{se})}{\ln\left(\frac{T_i - T_{se}}{T_o - T_{se}}\right)} \tag{2}$$

Figure 3 shows that the cooling of air was increased when air mass flow rate and LMTD increased. Similar to the evaporator performance described by Stoecker [10], this description of Fig. 3 is a rationale. It could be said in other terms that the air side heat transfer coefficient  $h_{air}$  increases as the airflow rate increases as a result, the overall heat transfer coefficient of the evaporator increases.

The observation was done to the whole system when operated. There was an abnormality of the compressor when air velocity was lower than 4.5 m/s. In this condition, the temperature of the compressor increased, and the compressor current was rising close to its upper limit. Until the upper limit was reached, the system was turned off. It was caused that air cooling capacity to condenser was lower. This lower cooling capacity affected to increase the temperature of the refrigerant flowing in condenser and evaporator tube.

There was not frozen condensate on the evaporator tube surface. It was indicated that the evaporator was operated at normal condition.

The best performance of the dehumidifier was 79.77 at air velocity, outlet temperature and RH were 5 m/s, 37 °C and 17 %, subsequently. At the best performance, the enthalpy change of air flow through the evaporator and condenser.

## 5. Conclusion

The evaporator-condenser arrangement in the refrigeration system could be a prospect design for dehumidification. The design could lower the relative humidity of air from 50% to 17% with air velocity of 5 m/s. The outlet temperature was 42 °C, the suggested temperature for heat sensitive products.

14

## Acknowledgment

This research was supported by Vocational School Diponegoro University. We thank our colleagues from Mechanical engineering who provided insight and expertise that greatly assisted the research.

8

## References

- [1] Qing-guo H, Min Z, Mujumdar A S, Wei-hua D and Jin-cai S 2006 *Dry. Technol.* **24** 1025
- [2] Kuntjoko A 1989 Paripurna, Jakarta
- [3] D Ariwibowo and M E Yulianto 2013 *Majalah Gema Teknologi* **22** 31
- [4] Hawlader M N A, Perera C O and Tian M 2006 *J. Food Eng.* **74** 392
- [5] D Ariwibowo and Yulianto M E 2012 *METANA* **6** 7
- [6] Perera C O and Rahman M S 1997 *Trends Food Sci Tech.* **8** 75
- [7] Minea V 2015 *Dry. Technol.* **33** 515
- [8] Strumillo C 2006 *Dry. Technol.* **24** 1059
- [9] Kumar R and Sharma K K 2018 *Natl J. Multidiscip. Res. Dev.* **3** 491



# Refrigeration System Based-Dehumidifier.pdf

## ORIGINALITY REPORT

16%

SIMILARITY INDEX

14%

INTERNET SOURCES

10%

PUBLICATIONS

10%

STUDENT PAPERS

## PRIMARY SOURCES

1	Submitted to Universitas Sebelas Maret Student Paper	5%
2	eprints.keele.ac.uk Internet Source	2%
3	www.scribd.com Internet Source	2%
4	iopscience.iop.org Internet Source	1%
5	B Susilo, M B Hermanto, R Damayanti, E D E Putri. "Performance of dehumidifier drying machine for soybean seeds drying", IOP Conference Series: Earth and Environmental Science, 2022 Publication	1%
6	myresearchspace.uws.ac.uk Internet Source	1%
7	P Setyadi, N G Yoga, R Anggrainy, O F Hidayat, Y F N Syamsy. "Energy Saving on Spray Drying Process by Modifying the Hot Air Flow", Journal of Physics: Conference Series, 2022	1%

---

8	<a href="http://psjfas.jfas.info">psjfas.jfas.info</a> Internet Source	1 %
9	Submitted to British University In Dubai Student Paper	1 %
10	Submitted to Far Eastern University Student Paper	1 %
11	<a href="http://faculty.uobasrah.edu.iq">faculty.uobasrah.edu.iq</a> Internet Source	<1 %
12	Prabir Basu, Cen Kefa, Louis Jestin. "Chapter 7 Convective Heating Surfaces", Springer Science and Business Media LLC, 2000 Publication	<1 %
13	<a href="http://core.ac.uk">core.ac.uk</a> Internet Source	<1 %
14	<a href="http://ejournal2.undip.ac.id">ejournal2.undip.ac.id</a> Internet Source	<1 %
15	<a href="http://eprints.utm.my">eprints.utm.my</a> Internet Source	<1 %
16	Eric Golliher, Andy Hong, Greg Pace, Barbara Sakowski, Dan Gotti, Jay Owens. "Evaporative Heat Transfer Mechanisms within a Heat Melt Compactor", 43rd International Conference on Environmental Systems, 2013 Publication	<1 %

---

---

Exclude quotes      On

Exclude matches      Off

Exclude bibliography      On

# Refrigeration System Based-Dehumidifier.pdf

GRADEMARK REPORT

FINAL GRADE

**/0**

GENERAL COMMENTS

**Instructor**

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7