

**24AG301- APPLIED THERMODYNAMICS AND THERMAL
SYSTEMS IN AGRICULTURAL ENGINEERING**

**UNIT 4 PSYCHROMETRICS AND CONTROLLED
ATMOSPHERE APPLICATIONS**

HANDLED BY

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An air conditioning system is designed under the following conditions:

Outdoor conditions 15°C DBT and 10°C WBT

Required conditions 20°C DBT and 50% RH

Amount of free air circulated $0.25\text{m}^3/\text{min}$ person.

Seating capacity - 50 persons

The required condition is achieved first by heating and then by adiabatic humidifying. Determine the following

1. Capacity of heating coil in kW

2. Capacity of humidifier

Given data:

Out door conditions:

Dry bulb temperature, $t_{d1} = 15^{\circ}\text{C}$

Wet bulb temperature, $t_{w1} = 10^{\circ}\text{C}$

Required Indoor conditions:

Dry bulb temperature, $t_{d2} = 20^{\circ}\text{C}$

Relative humidity, $\phi_2 = 50\%$

Amount a free air circulated = $0.25\text{m}^3/\text{min}/\text{person}$

$v = 4.17 \times 10^{-3} \text{m}^3/\text{s}/\text{person}$

Seating capacity = 50 persons

So, Amount of free air circulated, $V = 4.17 \times 10^{-3} \times 50 = 0.21\text{m}^3/\text{s}$

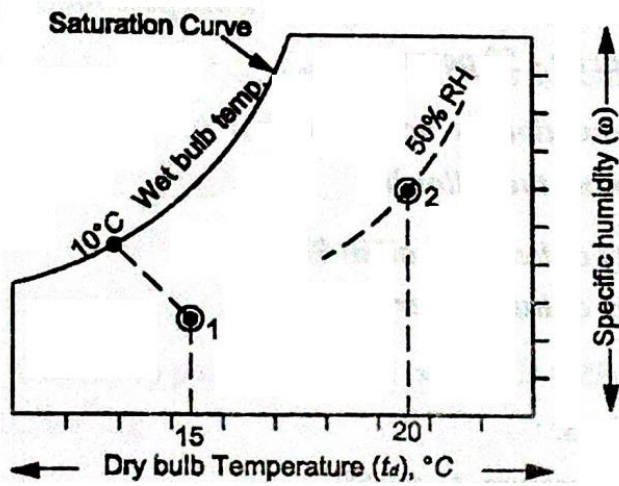
⊙ Solution:

Step 1:

Outdoor conditions of air i.e. 15°C dry bulb temperature 10°C wet bulb temperature are marked on the psychrometric chart at point 1. The required indoor conditions of air 20°C dry bulb temperature and 50% relative humidity is marked on the psychrometric chart at point 2.

Step 2:

Draw an inclined line through point 2 along constant wet bulb temperature line till it cuts total enthalpy line. Draw a horizontal line from point 2 both the lines intersect at point 3



Step 3:

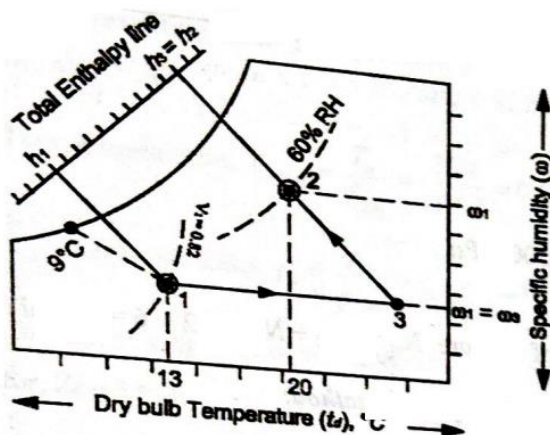
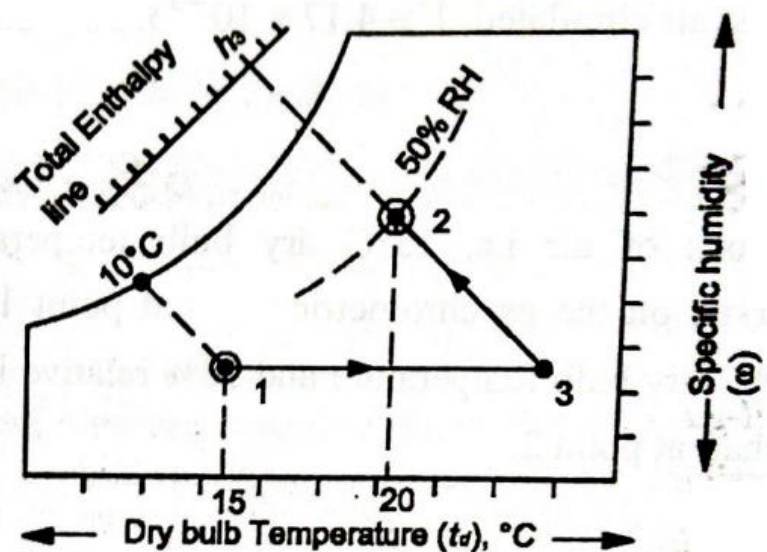
From psychrometric chart,

$$h_1 = 30 \text{ kJ/kg}$$

$$h_2 = h_3 = 40 \text{ kJ/kg}$$

$$\omega_1 = \omega_3 = 0.0055 \text{ kg/kg of dry air}$$

$$\omega_2 = 0.0075 \text{ kg/kg of dry air}$$



Specific volume passing through point 1 is $0.835 \text{ m}^3/\text{kg}$

$$\text{i.e. } v_1 = 0.835 \text{ m}^3/\text{kg}$$

$$m_a = \frac{V_1}{v_1} = \frac{0.21}{0.835} = 0.25 \text{ kg/s}$$

$$\text{Heating coil capacity} = m_a (h_3 - h_1)$$

($\because$ 1-3 line, dry bulb temp increases)

$$= 0.25 (40 - 30) = 2.5 \text{ kW}$$

Ans. ∞

$$\text{Capacity of the humidifier} = m_a (\omega_2 - \omega_1)$$

$$= 0.25 (0.0075 - 0.0055) = 5 \times 10^{-4} \text{ kg/s} \quad \text{Ans. } \infty$$

Sensible heating : 90 m^3 of air per minute at 20°C and 75% R.H. is heated until its temperature becomes 30°C . Calculate :

(i) R.H. of the heated air.

(ii) Heat added to air per minute.

Solution. For air at 20°C and 75% R.H. :

$$p_{vs} = 0.0234 \text{ bar (from steam tables, at } 20^\circ\text{C)}$$

$$p_v = \phi \times p_{vs} = 0.75 \times 0.0234 = 0.01755 \text{ bar}$$

$$t_{dp} = 15 + (16 - 15) \frac{(0.01755 - 0.017)}{(0.0182 - 0.017)} \approx 15.5^\circ\text{C}$$

$$W_1 = \frac{0.622 p_v}{p_t - p_v} = \frac{0.622 \times 0.01755}{1.0132 - 0.01755}$$

$$= 0.0109 \text{ kg/kg of dry air}$$

$$\begin{aligned} \text{Enthalpy, } h_1 &= c_p t_{db} + W h_{\text{vapour}} \\ &= 1.005 \times 20 + 0.0109 [h_g + 1.88 (t_{db} - t_{dp})] \\ &= 1.005 \times 20 + 0.0109 [2538.1 \\ &\quad + 1.88(20 - 15.5)] \end{aligned}$$

$$= 47.85 \text{ kJ/kg of dry air}$$

(i) **Relative humidity of heated air :**

For air at 30°C DBT :

Since the saturation pressure of water vapour at 30°C is higher than the saturation pressure of water vapour at 20°C so it is *sensible heating*, where p_v is same after heating.

Relative humidity, ϕ

$$= \frac{p_v}{p_{vs}} = \frac{0.01755}{0.0425} = 0.412 \text{ or } 41.2\%$$

$$(p_{vs} = 0.0425 \text{ bar, corresponding to } 30^\circ\text{C})$$

i.e., Relative humidity of heated air = **41.2%**. (Ans.)

($p_{vs} = 0.0425$ bar, corresponding to 30°C)

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(ii) **Heat added to air per minute :**

$$\begin{aligned}\text{Enthalpy, } h_2 &= c_p t_{db} + W h_{\text{vapour}} \\ &= 1.005 \times 30 + 0.0109 \times [h_g + 1.88 (t_{db} - t_{dp})] \\ &= 1.005 \times 30 + 0.0109 [2556.3 \\ &\quad + 1.88 (30 - 15.5)] \\ &= 58.31 \text{ kJ/kg of dry air}\end{aligned}$$

Mass of dry air in 90 m^3 of air supplied

$$\begin{aligned}m_a &= \frac{pV}{RT} = \frac{(p_t - p_v)V}{RT} \\ &= \frac{(1.0132 - 0.01755) \times 10^5 \times 90}{287 \times (273 + 20)} \\ &= 106.5 \text{ kg/min.}\end{aligned}$$

Amount of heat added per minute

$$\begin{aligned}&= 106.5 (h_2 - h_1) \\ &= 106.5 (58.31 - 47.85) = \mathbf{1114 \text{ kJ.}} \text{ (Ans.)}\end{aligned}$$

An air-water vapour mixture enters an air-conditioning unit at a pressure of 1.0 bar, 38°C DBT, and a relative humidity of 75%. The mass of dry air entering is 1 kg/s. The air-vapour mixture leaves the air-conditioning unit at 1.0 bar, 18°C , 85% relative humidity. The moisture condensed leaves at 18°C . Determine the heat transfer rate for the process.

Solution.

$$t_{db_1} = 38^\circ\text{C, R.H., } \phi_1 = 75\%$$

$$t_{db_2} = 18^\circ\text{C, R.H., } \phi_2 = 85\%$$

The flow diagram and the process are shown in

At 38°C :

From steam tables :

$$p_{vs} = 0.0663 \text{ bar, } h_{g1} = 2570.7 \text{ kJ/kg}$$

$$p_v = \phi \times p_{vs} = 0.75 \times 0.0663 = 0.0497 \text{ bar}$$

$$W_1 = \frac{0.622 \times 0.0497}{1.0 - 0.0497} = 0.0325 \text{ kg/kg of dry air}$$

At 18°C:

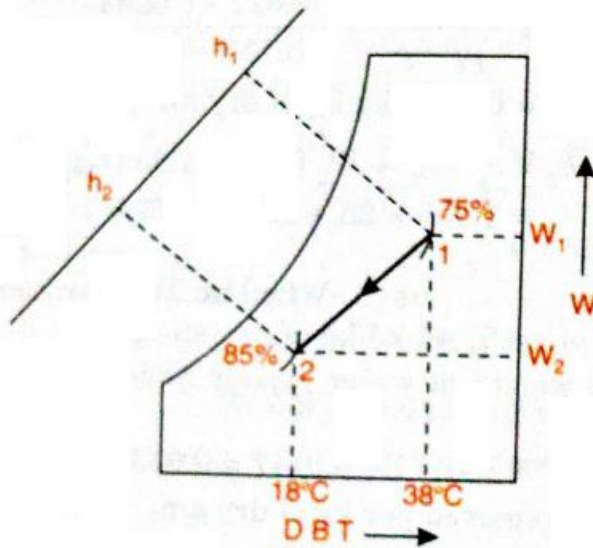
From steam tables :

$$p_{vs} = 0.0206 \text{ bar. } h_{g2} = 2534.4 \text{ kJ/kg}$$

$$h_{f2} = 75.6 \text{ kJ/kg}$$

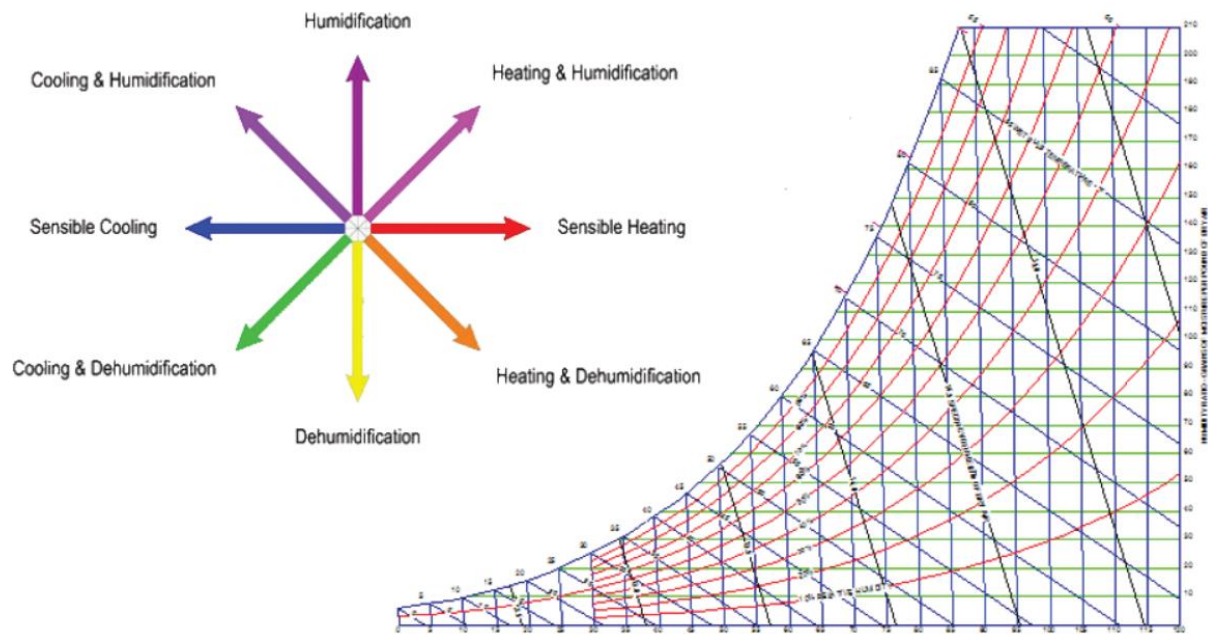
$$p_v = 0.85 \times 0.0206 = 0.01751 \text{ bar}$$

$$W_2 = \frac{0.622 \times 0.01751}{1 - 0.01751} = 0.01108 \text{ kg/kg of dry air}$$



Heat transfer rate,

$$\begin{aligned} q &= (W_2 h_{g2} - W_1 h_{g1}) + c_p (t_{db2} - t_{db1}) \\ &\quad + (W_1 - W_2) h_{f2} \\ &= (0.01108 \times 2534.4 - 0.0325 \times 2570.7) \\ &\quad + 1.005 (18 - 38) + (0.0325 - 0.01108) \times 75.6 \\ &= -55.46 - 20.1 + 1.62 \\ &= -73.94 \text{ kJ/kg of dry air.} \end{aligned}$$



A psychrometric chart is a graphical representation of the thermodynamic properties of moist air. It is a valuable tool in agricultural systems for managing air temperature, humidity, and moisture content—critical factors in crop production, post-harvest processing, and livestock care.

Applications of Psychrometric Charts in Agriculture

1. Grain Drying and Storage

Psychrometric charts help determine the optimal air conditions for drying grains like paddy, maize, and wheat. By plotting dry-bulb and wet-bulb temperatures, one can assess relative humidity and enthalpy, ensuring efficient moisture removal while minimizing energy consumption. This is crucial for preventing spoilage and maintaining grain quality during storage.

2. Greenhouse Climate Control

In greenhouses, maintaining appropriate humidity and temperature levels is vital for plant health. Psychrometric charts assist in visualizing how air properties change with heating, cooling, humidification, or dehumidification. For instance, understanding that warmer air holds more moisture can guide decisions on heating to reduce relative humidity and prevent fungal diseases.

3. Livestock Housing

Proper ventilation in livestock buildings is essential to ensure animal comfort and health. Psychrometric charts aid in designing ventilation systems by illustrating how air temperature and humidity interact. This helps in preventing heat stress and respiratory issues in animals.

4. Frost Protection

Understanding the dew point and relative humidity through psychrometric charts enables farmers to predict frost conditions. This information is critical for timing frost protection measures, such as activating irrigation systems to prevent crop damage.

Humidity control in cold storage and drying chambers

Humidity control is essential in both **cold storage** and **drying chambers** to maintain product quality, prevent spoilage, ensure energy efficiency, and facilitate controlled processes, although the target humidity levels and methods differ significantly. Controlling humidity in cold storage and drying chambers is crucial for product quality, shelf life, energy efficiency, and preventing spoilage.

or damage. Below are principles, methods, and practical considerations for managing humidity in both contexts, with examples.

Key Principles of Humidity Control

First, some definitions and basic relationships:

- **Relative Humidity (RH):** The amount of moisture in air relative to the maximum it can hold at that temperature. Cold air holds less moisture, so cooling tends to reduce RH unless moisture is added.
- **Dew Point:** The temperature at which air becomes saturated and water starts condensing. If surfaces in a cold room are below dew point, condensation or frost will form.
- **Moisture Loss and Product Respiration:** Fresh produce loses moisture; respiration (for fruits/veggies) produces moisture. These affect internal humidity.
- **Latent vs Sensible Heat:** Changing moisture (latent heat) vs changing just temperature (sensible heat) affect system loads.

Cold Storage

Why control humidity in cold storage?

- Prevent **weight loss** in produce due to moisture evaporation from product surfaces. Low RH draws moisture from products.
- Retain **turgidity, appearance** (texture, firmness, visual quality).
- Reduce **spoilage, shrivelling**, maintain shelf life.
- Avoid formation of **ice or frost** on equipment, surfaces, or stored product — that can damage surfaces, reduce heat transfer efficiency, increase defrost cycle

Typical humidity targets

- For many fresh fruits, vegetables, flowers: RH around **90-95%** when temperature is just above freezing.
- For warmer storage (non-freezing): RH of $\approx 75\%$ may be sufficient/optimal depending on product.
- For seed storage or products needing low humidity: much lower RH to avoid mould, ageing.

Control Methods

Humidification: To raise RH and prevent dehydration, systems like **spray humidifiers** or **ultrasonic foggers** introduce fine water mist directly into the cold room air.

Dehumidification/Ice Prevention: To remove excess moisture, especially from infiltrating air:

- **Desiccant Dehumidifiers:** These units use moisture-absorbing materials (like silica gel on a rotating wheel) to dry the air. They are highly effective in **low-temperature environments** (freezers) where traditional refrigeration dehumidifiers struggle. Often, they condition the air in an airlock or before it enters the main cold store.
- **Refrigeration-Based Dehumidifiers:** These draw air over a cold coil, causing moisture to condense and drain away. They are more common in **chilled storage areas** (above freezing).
- **Airflow Management:** Proper air circulation is vital to distribute humidity evenly and prevent stagnant zones where condensation or high moisture pockets can form.
- **Infiltration Control:** Minimizing the entry of warm, moist outside air using **high-speed doors, air curtains, vestibules (airlocks)**, and well-sealed building envelopes is the most effective first step

Methods / technologies for control

Drying Chambers

Drying chambers have different goals: you want to remove moisture from the product (e.g., grains, spices, medicinal plants) under controlled conditions, without damage to product (e.g. color loss, case hardening, nutrient losses). Humidity control is thus central, along with temperature and airflow.

Key considerations

- **Humidity must be low enough** to remove moisture from the product, but not so low (or temperature so high) that it damages or overdries or causes case hardening (surface dries too fast, trapping moisture inside).
- **Airflow** is important, to carry away moist air, replace with drier air; avoid stagnation.
- **Temperature control:** since drying rate depends both on temperature and RH. Too high temperature may degrade product quality.
- **Moisture content of product** at different stages; drying curves often have “constant rate period” then “falling rate period” etc. Humidity control helps manage the falling-rate period effectively.
- Query successful

Effective control of **humidity in drying chambers** is critical for product quality, energy efficiency, and process speed. The methods and technologies employed largely depend on the required humidity level, temperature, chamber size, and application (e.g., food, pharmaceuticals, industrial materials).

Methods / technologies for controlling humidity in drying chambers

- Query successful

Try again without apps

Effective control of **humidity in drying chambers** is critical for product quality, energy efficiency, and process speed. The methods and technologies employed largely depend on the required humidity level, temperature, chamber size, and application (e.g., food, pharmaceuticals, industrial materials).

The primary technologies for controlling humidity are:

1. Desiccant Dehumidification Systems

These systems use a **hygroscopic material** (a desiccant) to remove moisture directly from the air through adsorption or absorption. They are particularly effective for achieving **very low humidity** levels (down to 1% RH or lower) and can operate well at low temperatures where refrigeration methods become impractical (below freezing dew points).

- **Rotary (Wheel) Desiccant Systems:**
 - A rotating wheel, impregnated with a solid desiccant like **silica gel** or **zeolites**, passes through two separate airstreams.
 - **Process Air:** The moist air from the drying chamber passes through a section of the wheel, and the desiccant **adsorbs** the moisture, returning dry air to the chamber.
 - **Regeneration Air:** A separate, heated airstream passes through the saturated section of the wheel, driving off the collected moisture and venting it outside. This reactivates the desiccant.
- **Liquid Desiccant Systems:**
 - These use a liquid sorbent, often a salt solution like **lithium chloride**, to absorb moisture.