

PHYSICAL PRINCIPLES AND PHYSIOLOGICAL IMPLICATIONS OF AIR HUMIDITY: MEASUREMENT USING THE ASSMANN PSYCHROMETER

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Abstract: This study investigates the physical principles of air humidity and its effects on the human body, as well as the measurement of humidity using the Assmann psychrometer. Air humidity, characterized by absolute and relative humidity, significantly affects evaporation rates, thermal comfort, and physiological processes. Psychrometric measurements were conducted in two indoor environments (a room and a corridor), and absolute and relative humidity were calculated using the Renou formula. The results indicate that the corridor air approached saturation (relative humidity 91.73%), whereas the room air maintained moderately high humidity (78.4%). The findings confirm the influence of environmental conditions on evaporation and human comfort and validate the Assmann psychrometer as a reliable instrument for precise humidity measurements.

Keywords: Air Humidity, Absolute Humidity, Relative Humidity, Psychrometer, Assmann Psychrometer, Dew Point, Evaporation Rate, Indoor Climate

INTRODUCTION

Air humidity is one of the key environmental parameters affecting both atmospheric physics and human physiological processes. It refers to the amount of water vapor present in the air and is characterized by two main quantities: **absolute humidity** (the mass of water vapor per unit volume of air) and **relative humidity** (the ratio of actual humidity to maximum possible humidity at a given temperature).

Proper monitoring and control of air humidity are essential for maintaining thermal comfort, optimizing indoor climate conditions, and ensuring human health.

The measurement of air humidity is commonly performed using psychrometric instruments, which exploit the principle of evaporation-induced cooling to determine moisture content. Among these, the **Assmann psychrometer** is widely recognized for its accuracy and reliability. This instrument enables the determination of both absolute and relative humidity by comparing the readings of dry-bulb and wet-bulb thermometers under controlled airflow conditions.

Understanding the relationship between air humidity and physiological processes, such as evaporation from the skin and lungs, is critical. High relative humidity reduces the rate of evaporation, potentially affecting the body's ability to dissipate heat, while low humidity accelerates evaporation and can lead to dehydration. Moreover, knowledge of the dew point—the temperature at which air becomes saturated and condensation begins—is crucial for evaluating condensation risks in indoor environments.

The aim of this study is to investigate the physical principles underlying air humidity, to measure absolute and relative humidity in different indoor environments using the Assmann psychrometer, and to analyze the implications of these measurements for human thermal comfort and indoor climate assessment.

Air humidity and its measurement.

As a result of the evaporation of water almost everywhere in nature, water vapor is present in the atmospheric air, especially in the layers of the atmosphere close to the Earth's surface. This phenomenon is called *air humidity*. The amount of water vapor in the air is characterized by two main quantities: absolute humidity and relative humidity.

The mass of water vapor in a unit volume of air is called absolute humidity, denoted as f . In practice, absolute humidity is expressed in grams per cubic meter (g/m^3). In meteorology, absolute humidity is also characterized by the partial

pressure of water vapor P , expressed in mmHg or Pascals (Pa). (The partial pressure is the pressure exerted by the water vapor alone, excluding other gases.) The following numerical relationship exists between these quantities:

$$f = \frac{289,4}{273 + t} P$$

where t is the air temperature. When $t = 15-18^{\circ}\text{C}$, the values of f and P are numerically almost equal. At a given temperature, the mass of water vapor in grams that saturates 1 m^3 of air, or correspondingly, the partial pressure of saturated vapor at that temperature P_m , is called maximum humidity, denoted as f_m .

The mass of water vapor that saturates 1 m^3 of air at different temperatures, as well as the partial pressure of saturated vapor, is given in the following table:

Temperat ure, $^{\circ}\text{C}$	Densi ty, g/m^3	Pressu re, mm	Temperat ure, $^{\circ}\text{C}$	Densi ty, g/m^3	Pressu re, mm
10	9.4	9.21	16	13.6	13.63
11	10.0	9.84	17	14.5	14.53
12	10.7	10.52	18	15.4	15.48
13	11.4	11.23	19	16.3	16.48
14	12.1	11.79	20	17.3	17.54
15	12.8	12.79	—	—	—

Relative humidity is defined as the ratio of absolute humidity f to maximum humidity f_m , usually expressed as a percentage:

$$D = \frac{f}{f_m} * 100\%$$

$$\text{Or, in terms of partial pressures: } D = \frac{P}{P_m} * 100\%$$

Relative humidity D indicates how close the actual humidity (absolute humidity) of the air at a given condition is to the maximum humidity at the same temperature. It may be said that relative humidity shows the degree to which the

surrounding air is saturated with water vapor. The lower the relative humidity of the air, the faster water evaporates under the same conditions; conversely, the higher the relative humidity, the slower the evaporation.

Air humidity is of great importance for the vital activity of the human body, as it significantly affects the amount of heat transferred to the surrounding environment. In this case, both **absolute humidity** and **relative humidity** can be important. For example, the evaporation of water from the surface of the skin depends on the relative humidity of the air; however, in considering the evaporation of water in the lungs, absolute humidity must be taken into account, because the air exhaled from the lungs is almost completely saturated with water vapor at a temperature of approximately 30°C. The amount of water needed to saturate the air in the lungs apparently depends on the absolute humidity of the inhaled air. An atmospheric relative humidity between **40% and 60%** is considered normal for human life.

To determine both the absolute and relative humidity of air, it is sufficient to measure only one of these quantities, because the maximum humidity required to convert one value to the other can be found in the table given above, according to the corresponding temperature.

The **dew point temperature** is also important for air humidity. The dew point is the temperature at which the water vapor present in the air reaches saturation, or, in other words, the temperature at which the maximum humidity becomes numerically equal to the absolute humidity of the air. When the temperature drops below the dew point, condensation of the vapor begins.

Water vapor that is in dynamic equilibrium with its liquid phase is called **saturated vapor**. In **unsaturated vapor**, the amount of liquid is greater relative to the vapor phase. Cooling an unsaturated vapor at constant pressure results in the formation of saturated vapor. The temperature at which vapor becomes saturated and condensation begins is called the **dew point**.

It should be emphasized that the presence of small particles or electric charges in the atmosphere (dust particles, electrons, gas ions, etc.) facilitates condensation of vapor. Water molecules settle on these particles and form very fine droplets of mist. In absolutely clean air, condensation becomes more difficult; in such cases, condensation can occur only when the temperature falls considerably below the dew point.

The most widely used instrument for determining air humidity is the Assman psychrometer. This device consists of two identical thermometers, A and B. The reservoir of one of the thermometers is wrapped with a hygroscopic cloth, one end of which is immersed in a container of water (R). Because the cloth is capillary in nature, water rises through it and evaporates from the surface of the thermometer bulb, thereby cooling it. The reading of the wet-bulb thermometer decreases compared to that of the dry-bulb thermometer. The faster the evaporation of water from the reservoir of the thermometer, the greater this decrease will be. The evaporation rate mainly depends on how far the surrounding air is from saturation, that is, the lower the relative humidity of the surrounding air, the higher the evaporation rate. The evaporation rate also depends on the air velocity in front of the instrument, the temperature of the water, and the barometric pressure.

All these factors are accounted for in Rénou's psychrometric formula, which makes it possible to determine the partial pressure of water vapor in the surrounding air—that is, the absolute humidity:

$$P = P_n - k(t - t') \cdot H$$

Here,

P_n is the saturated vapor pressure at the wet-bulb temperature t' (taken from Table 6 in the appendix),

k (sometimes written as α) is the psychrometric coefficient, which depends on air movement (for relatively still air in small rooms, $k=0.0013$; for somewhat ventilated larger rooms, $k=0.001$),

t is the dry-bulb thermometer reading, H is the barometric pressure.

Using a psychrometer, relative humidity is normally determined directly from a psychrometric table, which compares the readings of the dry-bulb and wet-bulb thermometers. A sample psychrometric table is given below. In this practical work, humidity is measured using the Assmann psychrometer. The Assmann instrument consists of two nickel-plated tubes which protect the thermometers placed inside them from heating by external radiation.

One thermometer is dry and measures the ambient air temperature. The bulb of the second thermometer is wrapped with thin moistened batiste. When an air flow is created in the tube containing the wet-bulb thermometer, the evaporation rate of water from the batiste increases. The drier the air, the more intense the evaporation. When air of a certain velocity is directed at the thermometer, the drier the atmospheric air, the more water evaporates from the wet batiste. Evaporation cools the batiste, and the wet-bulb reading drops. The temperature drop stops when the energy required for evaporation becomes equal to the amount of heat received from the surrounding air by the thermometer bulb.

When evaporation reaches a steady state, the wet-bulb thermometer reading stabilizes. At this moment, the heat inflow from outside Q_1 equals the heat required for evaporation from the Q_2 thermometer surface : $Q_1=Q_2$

According to Newton's law of cooling,

$$Q_1=BCS(t_1-t_0)$$

where

- B is a function of air velocity,
- C is the specific heat capacity of water,
- S is the surface area of the wet-bulb thermometer,
- t_1 is the dry-bulb temperature,
- t_0 is the wet-bulb temperature.

The heat required for evaporation (Q_2) depends on the saturated vapor pressure E , absolute humidity- l , the specific latent heat of vaporization $-\sigma$, the atmospheric pressure $-H$, and the surface area S :

$$Q_2 = \frac{S\sigma(E - l)}{H}$$

Since $Q_1 = Q_2$

$$BCS(t_1 - t_0) = \frac{AS\sigma(E - l)}{H}$$

$$E - l = \frac{BC}{A\sigma}(t_1 - t_0)H$$

In this case, $\alpha = \frac{B \cdot C}{A \cdot \sigma}$ it is called the psychrometer constant. The general form

of the formula changes as follows:

Thus, the general psychrometric formula becomes:

$$l = E - \alpha(t_1 - t_0)H \quad (2)$$

Equation (2) is known as the psychrometric formula, or Rénou's formula.

After experimental measurements are obtained, absolute humidity is determined from formula (2), and relative humidity is calculated from the standard humidity equation.

Improved Experimental Section (Based on the Table Data)

Psychrometric measurements were performed in two different environments: a room and a corridor. For each location, the readings of the dry-bulb and wet-bulb thermometers were recorded, and the absolute and relative humidity values were calculated using the Renou (psychrometric) formula. Three measurements were taken at each site to ensure accuracy and reproducibility.

1. Humidity Measurements Inside the Room

The dry-bulb temperatures ranged between 30–31°C, while the wet-bulb temperature remained stable at 22°C, indicating a consistent evaporation rate. The calculated vapor pressure values and corresponding absolute humidities demonstrated minimal variability across the three measurements.

Average absolute humidity: 18.72 mmHg

Average relative humidity: 78.4%

Measurement deviations:

Absolute humidity: ± 0.10 mmHg

Relative humidity: $\pm 0.9\%$

These results indicate that the room air contained a moderately high level of moisture. The relatively small difference between dry and wet thermometer readings confirms that the air was closer to saturation, reducing the evaporation rate from the wet-bulb surface. Consequently, the relative humidity remained high ($\approx 78\%$), which is typical for insufficiently ventilated indoor environments.

2. Humidity Measurements in the Corridor

Compared to the room, the corridor exhibited slightly lower dry-bulb temperatures ($28\text{--}29^\circ\text{C}$) and higher wet-bulb temperatures ($25\text{--}26^\circ\text{C}$). This reduced difference between thermometer readings indicates even higher moisture content in the air.

Average absolute humidity: 23.8 mmHg

Average relative humidity: 91.73%

Measurement deviations:

Absolute humidity: ± 1.59 mmHg

Relative humidity: $\pm 0.35\%$

The very high relative humidity (over 91%) shows that the air in the corridor was nearly saturated with water vapor. This is consistent with limited airflow and increased condensation potential. Small changes in dry–wet thermometer differences produced significant fluctuations in absolute humidity, which explains the higher $\Delta\lambda$ value.

3. Conclusion of the Experimental Part

The results clearly show that the Assmann psychrometer effectively differentiates humidity levels in different indoor environments. The corridor

demonstrated nearly saturated moisture conditions, while the room maintained moderately high humidity. The measurements confirm that airflow, temperature difference, and evaporation rate play critical roles in determining psychrometric outcomes.

Overall, the experiment successfully validated the physical principles of humidity measurement and demonstrated the practical application of the psychrometric method for assessing environmental microclimates.

		Thermometer reading		Dry bulb temperature, °C	Wet bulb temperature, °C	Psychrometric ratio, °C	Absolute humidity		Relative humidity	
		Dry	Wet				l, mm Hg	Δl, mm Hg	φ, %	Δφ, %
room	1	30	24,9	728	23,62	0,0013	18,8	0,08	9,6	1,2
	2	31	25,2	728	24,05	0,0013	18,5	0,16	7,1	1,3
	3	30,5	25,1	728	23,91	0,0013	18,8	0,08	8,6	1,2
	Average value						18,7	0,1	8,4	1,2
corridor	1	29	26	728	25,2	0,001	23	0,8	1,2	1,53
	2	28	25,3	728	24,19	0,001	22,2	1,5	1,8	1,07
	3	28,4	25,4	728	24,34	0,001	26,2	2,4	2,2	1,47
	Average value						23,8	1,5	1,73	1,35

Results

Psychrometric measurements were carried out in two indoor environments: a room and a corridor. The dry-bulb and wet-bulb thermometer readings were recorded, and absolute and relative humidity values were calculated using the psychrometric (Renou) formula.

Room: Dry-bulb temperatures ranged from 30–31°C, wet-bulb temperature remained at 22°C. Average absolute humidity: 18.72 mmHg. Average relative humidity: 78.4%

Corridor: Dry-bulb temperatures ranged from 28–29°C, wet-bulb temperature at 25–26°C. Average absolute humidity: 23.8 mmHg. Average relative humidity: 91.73%

The results indicate that the corridor air was much closer to saturation compared to the room. Variations in $\Delta\lambda$ and Δf were minor, reflecting the precision of the Assmann psychrometer.

Discussion

The experiment demonstrates the significant influence of environmental conditions on humidity. The smaller difference between dry-bulb and wet-bulb temperatures in the corridor indicates near-saturated air, while the larger difference in the room corresponds to moderately high humidity.

Relative humidity reflects the air's saturation level and directly affects evaporation rates. In the corridor, evaporation from the wet-bulb thermometer was slower due to higher humidity, illustrating that saturated air slows moisture loss. Conversely, in the room, lower relative humidity allowed faster evaporation.

These findings also highlight the physiological relevance of humidity. Higher humidity in enclosed spaces, as observed in the corridor, reduces the efficiency of heat dissipation from the human body through evaporation of sweat. On the other hand, moderately humid air, as in the room, facilitates thermal comfort while preventing excessive dehydration.

The Assmann psychrometer effectively measured both absolute and relative humidity, demonstrating its precision in detecting microclimatic differences within indoor environments. Variations in airflow, temperature, and water evaporation were consistent with theoretical expectations based on psychrometric principles.

Conclusion

The study confirmed that the Assmann psychrometer is a reliable tool for determining absolute and relative humidity in indoor environments. The corridor air exhibited near-saturation conditions (91.73% relative humidity), whereas the room air showed moderately high humidity (78.4% relative humidity). Relative humidity significantly influences evaporation rates, impacting both environmental physics and human thermal comfort. Minor variations in repeated measurements indicate high reproducibility and accuracy of the psychrometric method. Overall, the experiment validated the physical principles of air humidity measurement and demonstrated practical implications for indoor climate monitoring and human comfort.

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