5.4. MEASUREMENT OF AIR HUMIDITY BY ASSMANN PSYCHROMETER

Purpose of experiment

Determine various parameters of the air in the room

Tasks of experiment

- Determine absolute and relative air humidity.
- Evaluate the effective temperature in a room and set the dew point.
- Conclude whether the indoor conditions are optimal.

Theoretical topics

- Liquid evaporation and condensation.
- Saturated and unsaturated water vapor.
- Psychrometry. Local microclimate.
- Thermoregulation in the human body.

Equipment and materials

ASSMANN psychrometer, pipette, water, stand.

Theoretical part

Air is a mixture of nitrogen, oxygen, and small amounts of some other gases. Air in the atmosphere normally contains some water vapor (or moisture) and is referred to as atmospheric air. By contrast, air that contains no water vapor is called dry air. It is often convenient to treat air as a mixture of water vapor and dry air since the composition of dry air remains relatively constant, but the amount of water vapor changes as a result of condensation and evaporation from oceans, lakes, rivers, showers, and even the human body. Although the amount of water vapor in the air is small, it plays a major role in human comfort.

The amount of moisture in the air can be described by absolute and relative humidity. Absolute humidity is the mass of water vapour divided by a unit volume of air or simpler it can be called the mass of water vapour which exists in 1 m$^3$ of air. Absolute humidity can be determined from the Clausius-Clapeyron equation:

$$
\rho = \frac{\mu p}{RT}.
$$

(5.4.1)

here $\mu$ – mass of one air mole, $p$ – partial pressure of water vapour in the air, $R$ – ideal gas constant, $T$ – absolute temperature (it is the room temperature during your experiment).

The humidity has a definite effect on how comfortable we feel in an environment. However, the comfort level depends more on the amount of moisture the air holds ($m_v$) relative to the
maximum amount of moisture the air can hold at the same temperature \((m_s)\). The ratio of these two quantities is called the relative humidity \(r\):

\[
r = \frac{m_s}{m_v} \cdot 100\% = \frac{p_v \cdot V / RT}{p \cdot V / RT} \cdot 100\% = \frac{p_v}{p} \cdot 100\%
\]

(5.4.2)

where \(p_v\) is the saturated water vapour pressure and \(p_v\) partial pressure of water vapour.

The relative humidity ranges from 0\% for dry air to 100\% for saturated with water air. Note that the amount of moisture air can hold depends on its temperature. Therefore, the relative humidity of air changes with temperature even when its specific humidity remains constant.

Effective temperature is not an actual temperature in the sense that it can be measured by a thermometer. It is an experimentally determined index of the various combinations of dry-bulb temperature (the normal temperature that an ordinary thermometer reads), humidity, radiant conditions, and air movement that induce the same thermal sensation. Those combinations that induce the same feeling of warmth or cold are called thermo-equivalent conditions.

If you live in a humid area, you are probably used to waking up most summer mornings and finding the grass wet. You know it did not rain the night before. So what happened? Well, the excess moisture in the air simply condensed on the cool surfaces, forming what we call dew. In summer, a considerable amount of water vaporizes during the day. As the temperature falls during the night, so does the “moisture capacity” of air, which is the maximum amount of moisture air can hold. After a while, the moisture capacity of air equals its moisture content. At this point, air is saturated, and its relative humidity is 100 percent. Any further drop in temperature results in the condensation of some of the moisture, and this is the beginning of dew formation.

The dew-point temperature \(T_{dp}\) is defined as the temperature at which condensation begins when the air is cooled at constant pressure. In other words, \(T_{dp}\) is the saturation temperature of water corresponding to the vapor pressure: \(T_{dp} = T_{sat}\).

As the air cools at constant pressure, the partial water vapour pressure \(p_v\) remains constant. Therefore, the vapour in the air undergoes a constant-pressure cooling process until it strikes the saturated vapour line. The temperature at this point is \(T_{dp}\), and if the temperature drops any further, some vapour condenses out. As a result, the amount of vapour in the air decreases, which results in a decrease in \(p_v\). The air remains saturated during the condensation process and thus follows a path of 100\% relative humidity (the saturated vapour line). The ordinary temperature and the dew-point temperature of saturated air are identical.

**Methodology**

Air humidity is determined with an ASSMANN psychrometer. The psychrometer consists of two thermometers \((t_1\) and \(t_2\)) (Figure 5.4.1). The sensor ball of thermometer \((t_2)\) is wrapped in linen, or other absorbent cloth, moistened with water. Only water molecules of the highest kinetic energy can escape from the moistened linen, thus decreasing the temperature of the linen and of the thermometer \((t_2)\) ball. To avoid increasing the vapour concentration close to the wet bulb, turn on the fan \((F)\), which blows away excess vapour. Thus, during the whole measurement process, the two thermometers remain in an atmosphere with the same water vapour concentration.

The temperature of the wet thermometer (wet-bulb temperature) decreases until the processes of heat loss due to water evaporation and heat accession due to conduction and convection stops at equilibrium.
When the wet bulb temperature ceases to fall, the dry ($t_1$) and wet ($t_2$) thermometers show different temperatures $t_1$ and $t_2$. Evaporation is more effective, and hence the temperature difference between the two thermometers is higher when the air is dry than when the air is saturated with water vapour, and its partial pressure $p_v$ is less than the saturated water vapour pressure $p_s$ saturating the air in a room. The temperature difference $t_1 - t_2$ is inversely proportional to the coefficient $k$, which depends on air (wind) speed: 

$$ t_1 - t_2 = \frac{1}{k} \frac{p_s(t_2) - p_v}{P}; $$

(5.4.3)

where $P$ - atmospheric pressure.

Then

$$ p_v = p_s(t_2) - kP(t_1 - t_2). $$

(5.4.4)

To find the relative humidity $r$, the water vapour partial pressure $p_v$ value calculated from (5.4.3) is inserted into the formula:

$$ r = \frac{p_v}{p_s(t_1)} \cdot 100\%. $$

(5.4.5)

From the psychrometric chart (nomogram in Figure 5.4.2) find the effective (feeling) temperature in the room, given the room temperature, relative humidity and air circulation speed. People feel comfortable when the effective temperature in summer (lightly dressed) is between 17.7 °C and 21.2°C; and in winter (dressed appropriately) between 15.5 °C and 23.2 °C.

**Procedures**

1. Hang the psychrometer on a rack with no contact with other objects and let the air circulate freely. Put a few drops of water on the material wrapping the thermometer $t_2$. Switch on the psychrometer fan.
2. Observe both thermometers until steady temperatures of $t_1$ and $t_2$ settles. Record the temperature readings $t_1$ and $t_2$.
3. Record the atmospheric pressure $P$ (mm Hg) readings shown on the room barometer.
4. From the hygrometric table (see Annex I of the textbook Physics Table 14) find the saturated water vapour pressure $p_s(t_1)$ (mm Hg) and $p_s(t_2)$ corresponding to the temperatures $t_1$ and $t_2$.
5. Insert $p_s(t_2)$ and $P$ values into the formula (5.4.4), calculate the water vapour partial pressure $p_v$.
6. Calculate absolute air humidity (5.4.1 formula).
7. Having obtained the absolute humidity from Table 14 (see Annex I of the Physics textbook) find the dew-point temperature.
8. Insert $p_s(t_1)$ and calculate the relative humidity $r$ (5.4.5 formula).
9. Determine the effective temperature (Fig. 5.4.2) and assess the local air conditions.
10. All measurements are repeated 3 times. Enter the instruments’ readings and calculated results into Table 1.
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Table 1

<table>
<thead>
<tr>
<th>$t_1$, °C</th>
<th>$t_2$, °C</th>
<th>$P$, mm Hg</th>
<th>$k$, K$^{-1}$</th>
<th>$p_s(t_1)$, mm Hg</th>
<th>$p_s(t_2)$, mm Hg</th>
<th>$p_v$, mm Hg</th>
<th>$\rho$, g/m$^3$</th>
<th>$r$, %</th>
<th>$T_{ef}$, °C</th>
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References:


