Moist air and wet walls in buildings: mass transfer, psychrometrics, basic calculations, and detection

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Wet walls in buildings have a range of causes, among them condensation due to insufficient ventilation; condensation as a result of thermal bridges; and water penetration from the outside. To identify these areas, thermal imaging can provide a valid remedy when combined with thermodynamic knowledge. Accordingly, it is necessary to understand moist air and gain a quantitative measurement thereof. In this regard, moist air can be considered as an ideal mixture of dry air and water, where water vapor has the partial pressure $p_{W(T)}$. If the amount of water increases and the air is saturated with moisture, the water vapor reaches the partial pressure of saturation ($p_{WS(T)}$). The water can then appear either as water vapor or in a condensed state, as liquid water or ice. Consequently, there are four areas of moist air, namely (1) unsaturated moist air with water as vapor, (2) saturated moist air with liquid water, (3) saturated moist air with ice, and (4) saturated moist air under triple point conditions (contains saturated water vapor and liquid water and ice).

From a thermodynamic point of view, water can be transported in capillary-porous structures, such as wood and masonry, by diffusion or by capillary transport. The discharge of water from wet surfaces into the surrounding air occurs by convective mass transfer. The evaporation of water is an endothermal process resulting in the cooling of the surface. Here the mass transfer is superposed by convective heat transfer to the surface, radiation exchange, and heat conduction.

The wet bulb temperature or adiabatic saturation temperature is the lowest obtainable temperature to which moist air—depending on its initial state—can cool down to during the adiabatic evaporation of water. Accordingly, one can detect surface moisture by the means of infrared imaging. This is further facilitated by knowing the adiabatic saturation temperature.

There are simple correlation equations for the calculation of the temperature-dependent saturation pressure of water ($p_{WS(T)}$). However, the consideration of condensation on surfaces as a result of insufficient ventilation or of thermal bridges requires the calculation of the dew point temperature of the moist air. Its method of computation will be detailed in the presentation, and can be effortlessly entered in spreadsheet applications, such as Microsoft Excel.

In addition, during the presentation, we will measure the surface temperature of a moistened surface of a capillary-porous structure with the help of infrared imaging. Based on the measurement of relative humidity and the temperature of the ambient air, we will then calculate the temperatures of the dew point and the adiabatic saturation temperature and further properties of the ambient air in order to solve the above problem.

Keywords

adiabatic saturation temperature, condensation, dew point temperature, heat transfer, mass transfer, moist air, psychrometric temperature difference, relative humidity, saturated air, thermal bridge, vapor pressure, water vapor, wet bulb temperature, wet walls

