EXAMPLE 1. Heat energy in air drying

A food containing 80% water is to be dried at 100oC down to moisture content of 10%. If the initial temperature of the food is 21oC, calculate the quantity of heat energy required per unit weight of the original material, for drying under atmospheric pressure. The latent heat of vaporization of water at 100oC and at standard atmospheric pressure is 2257kJ/kg. The specific heat capacity of the food is 3.8kJ/kg/oC and of water is 4.186kJ/kg/oC. Find also, the energy requirement/kg water removed.

Calculating for 1kg food
Initial moisture = 80%
800g moisture are associated with 200g dry matter

Final moisture = 10%
100g moisture are associated with 900g dry matter

Therefore, 100/900 X 200g = 22.2g moisture are associated with 200g dry matter
1kg of original matter must loose (800 – 22)g moisture = 778g = 0.778kg moisture

Heat energy required for 1kg original material =
heat energy to raise temperature to 100oC + latent heat to remove water =
mct + ml = (1 x3.8 x (100 - 21) + 0.778 x 2257
= 300.2 + 1755.9 = 2056kJ

Energy/kg water removed, as 2056kJ is required to remove 0.778 kg of water = 2056/0.778 = 2543kJ

EXAMPLE 2. Heat energy in vacuum drying

Using the same material as in Example 7.1, if vacuum drying is to be carried out at 60°C under the corresponding saturation pressure of 20 kPa abs. (or a vacuum of 81.4 kPa), calculate the heat energy required to remove the moisture per unit weight of raw material.

Heat energy required per kg raw material
= heat energy to raise temperature to 60°C + latent heat of vaporization at 20 kPa abs.
= (60 - 21) x 3.8 + 0.778 x 2358

= 148.2 + 1834.5
= 1983 kJ.

In freeze drying the latent heat of sublimation must be supplied. Pressure has little effect on the latent heat of sublimation, which can be taken as 2838 kJ kg-1.

EXAMPLE 3. Heat energy in freeze drying
If the foodstuff in the two previous examples were to be freeze dried at 0°C, how much energy would be required per kg of raw material, starting from frozen food at 0°C?

Heat energy required per kilogram of raw material= latent heat of sublimation
= 0.778 x 2838
= 2208 kJ.

Constant rate and falling rate in drying

Constant rate drying occurs at the beginning of drying of a wet product in which the rate of moisture removal is constant.

$$\frac{dM}{dt} = F_v A(P_s - P_a) = \frac{K_f A}{h}(T_a - T_s)$$

Falling rate drying is the process in which the rate of moisture removal decreases with time. This occurs after the constant rate and the moisture content at which the constant rate changes to falling rate is known as critical moisture content

$$\frac{dM}{dt} = \acute{\alpha}\,(M - M_e)$$

EXAMPLE
1. If the wet-bulb temperature in a particular room is measured and found to be 20°C in air whose dry-bulb temperature is 25°C (that is the wet-bulb depression is 5°C) estimate the relative humidity, the enthalpy and the specific volume of the air in the room using the Psychometric chart in Figure 1