8 Spray drying

Spray dryers are continous direct convective heat transfer dryers. They are used to remove a fluid phase (usually water) from suspensions, aerosols or slurries containing solid particles that cannot be mechanically dried, that are heat-sensitive and cannot be exposed to high temperatures for a long time or even fluid phases containing ultrafine particles that could melt and agglomerate if dried under different conditions.

Spray dryers are indeed suitable for food and pharma products due to the short residence time in the hot zone of the unit and due to the protection from very high temperatures ensured by the liquid film over the particles. This liquid film causes the steady state operating temperature to be equal to the wet bulb temperature of the drying air. Moreover, spray dryers are suitable for color pigments whose size needs to be the same as the original solid particles one or for slurries with very fine dispersed particles and non-newtonian behaviour even with very low moisture content, such as clays.

Spray dryers consist of a large cylindrical or conical chamber in which the material to be processed is atomized and sprayed by mean of nozzles. Liquid drops containing the solid particles are mixed with a gas flow hot enough to provide the required heat to let the whole liquid phase evaporate. After this operation, the gas is cooled down and separated from solid particles; the air-solid separation is partially obtained at the bottom of the chamber thanks to gravity. For smaller particles, cyclones or more effective processes are used, such as sleeves filters or electrostatic separator.

Drying chambers are typically big empty equipment: they should be high enough to ensure the contacting time required to obtain the desired residual moisture; the diameter needs to be large enough to avoid contact between particles and wall, with resulting precipitation and decantation.

8.1 Spray dryer design for powdered milk production

Powdered milk should be produced by mean of a spray dryer whose nozzle atomizes 0.2 mm diameter drops with an initial velocity $v_P^0 = 0.3\,m/s$.

Milk and air physical properties are listed in Table 8.1.

Given an equipment diameter equal to 5.5 m, the calculation of the equipment height for a final moisture equal to 0.005 kg/kg is requested.

Milk	**Value**	**Unit**
Q_{milk}	1 750	kg/h
T_P^0	303	K
fat	4.76	$\%\,(kg/kg)$
ρ_P	1000	kg/m^3
c_P^m	1	$kcal/(kg \cdot K)$
ΔH_{ev}	540	$kcal/kg$
Antoine		$mmHg\,vs\,K$
A	18.3036	
B	3816.44	
C	-46.13	

Air	**Value**	**Unit**
G_{dry}	72 000	kg/h
T_g^0	403	K
P	1	atm
μ	$2.3 \cdot 10^{-5}$	$kg/(m \cdot s)$
c_P^g	0.25	$kcal/(kg \cdot K)$
D_{va}	$1.8 \cdot 10^{-5}$	m^2/s
k	$8 \cdot 10^{-6}$	$kcal/(m \cdot s \cdot K)$

Table 8.1: Milk and air properties