16 Pneumatic and Flash Drying

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16.1 INTRODUCTION

Drying is a separation process that converts a wet solid, semisolid, or liquid feedstock into a solid product by evaporation of the liquid into a vapor phase with the application of heat. Essential features of the drying process are phase change and production of a solid.

Thermal drying is one of the most important unit operations in most industrial sectors. Indeed, it is hard to find a product in daily use that has not undergone drying as a stage of its manufacture.

Drying is an essential operation in the chemical, agricultural, biotechnology, food, polymer, ceramic, pharmaceutical, pulp and paper, and wood processing industries. Drying is extremely energy-intensive and in many cases has important implications as the thermal energy needed for drying is obtained by combustion of fossil fuels, leading to emission of carbon dioxide. Well-designed modern drying equipment with high thermal efficiencies is becoming increasingly important.

One of the most widely used drying systems is flash drying and is also known as pneumatic drying. Flash dryers are most commonly direct drying units and are also known as convective dryers. Pneumatic or flash dryers may be classified as gas solid transport systems that are characterized by continuous convective heat and mass transfer processes. Hot air produced by indirect heating or direct firing is the most common drying medium in these systems. In direct flash dryers, the gas stream transports the solid particles through the system, and makes direct contact with the material to be dried. This gas stream (drying medium) also supplies the heat required for drying and carries away the evaporated moisture. Superheated steam can also be used as drying medium yielding sometimes to higher efficiencies and often to higher product quality.

The large surface area for heat and mass transfer and the high convective heat and mass transfer coefficients, which take place at these units, result in high drying rates and as a result, high drying capacity. The size of particulates to be dried is usually in the range of 10 500 μm. One of the features of these types of dryers is the relatively short contact time between the hot air and the particulate materials (0.5 10 s) at the drying section. Because of this the material temperature stays always low in the drying process.

16.2 BASIC OPERATION PRINCIPLE AND APPLICATIONS OF FLASH DRYERS

Figure 16.1 shows a simple pneumatic flash drying system in which particulate solids are dried during transport in a hot gas stream (usually air or combustion gases). The simple flash drying system includes six basic components: the gas heater, the wet material feeder, the drying duct, the separator, exhaust fan, and a dried product collector. The wet particles are fed into the hot gas stream sometimes with special mixing devices. The stream flows up the drying tube. The gas velocity must be greater than the free fall velocity of the largest particle to be dried. The gas velocity in relation to the particle velocity is high. Thermal contact between the conveying air and the solids as mentioned above is usually very short and therefore flash dryers are most suitable for removal of external moisture (surface moisture) and are less suitable for removal of internal moisture. At the end of the drying process a dust separation arrangement is installed. It must comply with the regulations for pollution control. For this purpose cyclone dust separators, fabric filters, electrostatic precipitators, wet scrubbers, and fabric filters are used.

High rates of evaporation in flash dryers are leading to low temperatures of the dried material and indicate that flash dryers are particularly useful for drying granular, crystalline, pasty, and powdery products, etc. Flash dryers are used in various branches of the chemical, pharmaceutical, ceramic, gypsum, wood, and mining industries. Flash dryers are simple in construction and have low capital cost and they are almost trouble free.

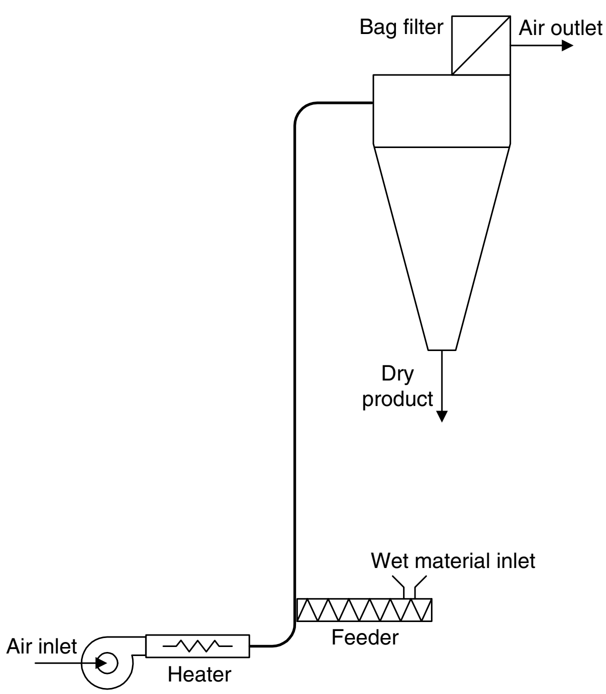

FIGURE 16.1 Simple flash drying system.

Vertical type of construction, which facilitates installation in existing buildings, is advantageous for the flash drying systems. The tube of most flash dryers is of circular and uniform cross section. In some cases, the tube may diverge and converge and may have sudden expansions and contractions. The tube may be heated through the wall to keep up the temperature of the gas.

In order to shorten the drying time, recirculation of the material is used. In this case the number of cycles of different particles may be different and as a result the residence time of the particles will not be the same. In conclusion the advantages of flash dryers are the following:

- Short contact time and parallel flow make possible to dry thermolabile materials.
- The dryer needs only a very small area and can be installed outside a building. However, the gas cleaning system should be located inside the building in order to avoid moisture and dust deposition.
- The dryer is easy to control. The low material content in the dryer enables equilibrium conditions to be reached very quickly.
- Due to small number of moving parts the maintenance cost is low.
- The capital costs are low in comparison with other types of dryers.
- Simultaneous drying and transportation is useful for materials handling process.

The disadvantages of flash dryers are as follows:

- High efficiency of gas cleaning system is required.
- Because of powder emission, the dryer cannot be used for toxic materials.
- In some cases this disadvantage can be avoided using superheated steam as a drying agent.
- For lumped materials difficult to disperse, drying is impossible to carry out in this apparatus.
- There is a risk of fire and explosion, so care must be taken to avoid flammability limits in the dryer.
- In general, especially when recirculation is applied, not all material particles have the same residence time in the dryer [1].

In order to achieve efficient pneumatic drying process, the air velocity should be as low as possible to achieve materials transport, the mass flow rate of the gas should be the minimum necessary to achieve the specified drying rate, the temperature of the hot gas should be as high as possible without exceeding limits imposed by the thermal sensitivity of the solids or safety considerations, and the construction of the dryer should allow to achieve thermal equilibrium between the gas and the solid [2].

16.3 DESIGN OF FLASH DRYERS

The materials dried in flash dryers have different properties and each product requires specific design solutions. It depends on the initial and final required moisture, temperature sensitivity, size and shape of the particles, etc. Finally, each product to be dried requires an optimum solution of the problems involved (efficiency and product quality).

Design procedure of dryers has to find:

- Dimensions of flash dryer
- Choose the type and amount of drying agent
- Requirement of energy supply
- Inlet and outlet parameters for the drying agent and material to be dried (temperature, moisture content, velocity, etc.)

Basically, the design consists of execution of the following steps:

- Heat balance
- Mass balance
- Momentum balance
- Determination of heat and mass transfer coefficients

By design of the whole drying system, care must be taken of the gas-heating unit, the material feed section, the particle separation section, and the product collection system.

The feed system has to be carefully chosen and designed in order to supply the wet material into the dryer at the required rate. Typical feed systems are shown in Figure 16.2 [3]. Metering and feed elements, sometimes with mixing devices arranged upstream lead the wet product into the flash dryer. For free-flowing powdery solids, a screw feeder or a rotary valve may be used effectively. Pasty or sticky materials need to be preconditioned by blending them with dried product using single- or twin-shaft paddle blender and then dispersed mechanically using a kicker mill or one of the several other designs of rotating disperser [4].

The selection of gas solid separators is based mainly on the material characteristics, required degree of separation, concentration of solids, moisture content of solids, environmental regulations, and cost. In utilization are mainly: gravity separators; different types of cyclones with different efficiencies; fabric filters, and wet scrubbers. Usually a combination of separation units is applied.

There are different possibilities of modifications of simple flash dryers. For instance in a simple flash dryer a rapid decrease of drying force along the tube takes place. The design of a dryer with internal pipe through which hot drying agent is flowing leads to an increase of the driving force. Another possibility to increase the drying force is to heat up the tube of the dryer through the wall.

In order to decrease the dryer height and increase the drying time, the material is recirculated. In Figure 16.3 a two-stage system is presented [3]. The solid particles, after passing through the first stage, which has the form of a vertical tube, are separated in the upper part of the dryer, fall down, and are directed to the second stage. Wet material is supplied to the first stage by a special feeding system. Each drying stage in the system is equipped with its own heat generator. The drying agent from the second drying stage is fed

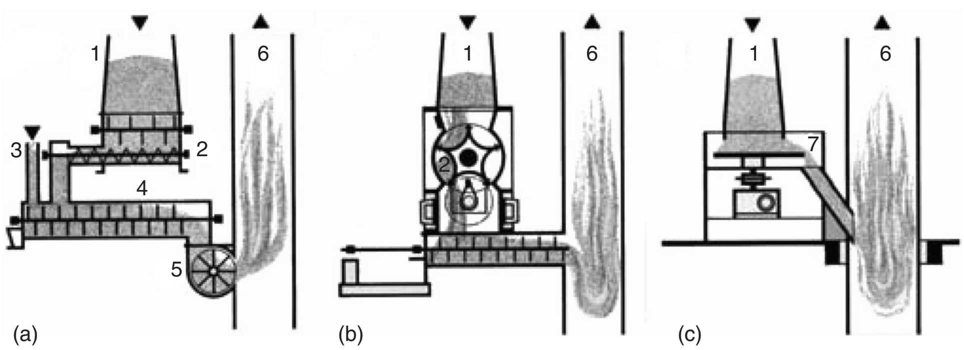

FIGURE 16.2 Typical feed systems for pneumatic flash dryers. 1, Wet product bin; 2, metering; 3, recirculated product; 4, mixer; 5, sling; 6, flash dryer tube; 7, disc feeder. (From *Flash Dryer*, Deutsche Babcock, Babcock BSH GMBH, 1998. With permission.)

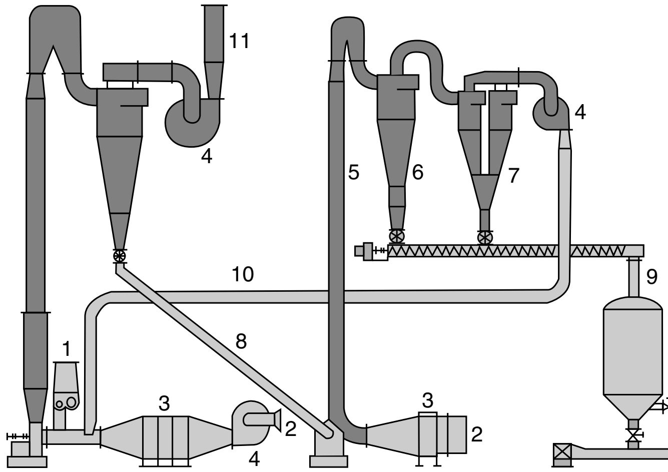

FIGURE 16.3 Two stage pneumatic dryer with vapor utilization. 1, Wet product; 2, primary air inlet; 3, heat generator; 4, fan; 5, dryer tube; 6, cyclones; 7, cyclone separator; 8, predried product discharge; 9, dried product discharge; 10, vapor return line; 11, waste gas stack. (From *Flash Dryer*, Deutsche Babcock, Babcock BSH GMBH, 1998. With permission.)

back to the first drying stage. This system is particularly efficient if the drying agent is superheated steam. Separation is by means of cyclone separators.

A second drying stage can also be used as a cooling stage. Two-stage flash dryers can be used for products difficult to dry, e.g., for methylcellulose. The number of cycles of different particles in two-stage systems may be different and as a result the resistance time of the particles will not be the same.

For longer resistance times the duct can be formed into a continuous loop (ring dryers). In these systems the material is recirculated until it is dried to the required humidity. For instance high-temperature short-time ring dryers are used in the food industry to expand the starch cell structure in potatoes or carrots to give a rigid porous structure, which enhances conventional drying rates [5].

Figure 16.4 presents a spin-flash dryer that can be utilized for some special applications. As described in Ref. [4] the spin-flash dryer is basically a mechanically agitated fluidized bed device for very short residence times. Hence it is targeted for surface moisture

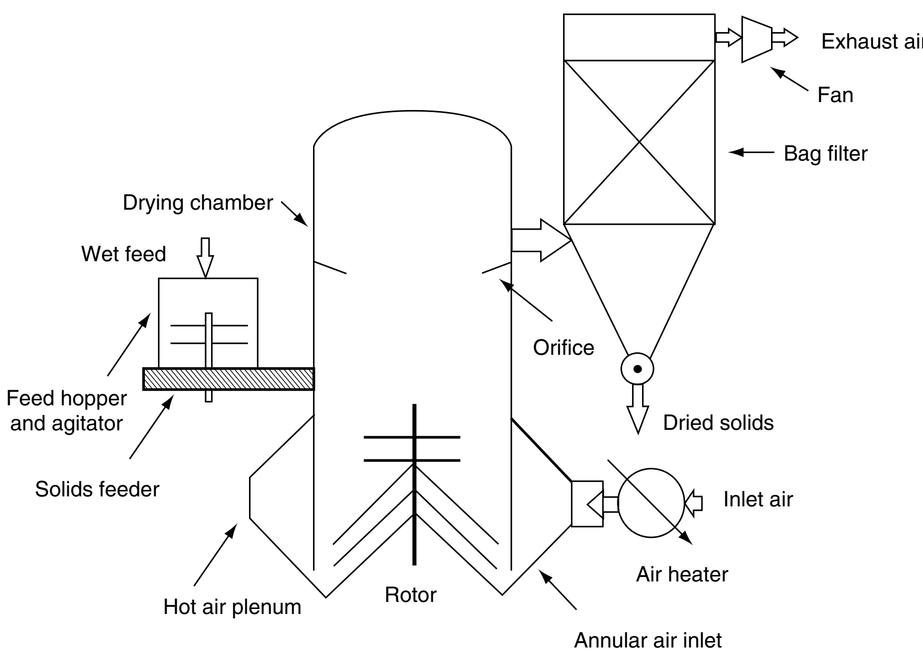

FIGURE 16.4 Spin flash dryer. (From Devahastin, S. (Ed.), *Mujumdar's Practical Guide To Industrial Drying Principles, Equipment And New Developments*, Exergex Corporation, Montreal, Canada, 2000. With permission.)