Increasing your dryer’s production capacity

One of the most common questions clients ask me is, “How can I increase my operation’s drying capacity?” The obvious answer is to install another dryer. But adding an additional independent dryer line to increase your drying capacity is expensive and may not be practical.

Before spending the money to add a new dryer line, it may be worthwhile to examine whether you can increase your existing dryer’s production capacity. Conduct a process-performance audit of your existing dryer operation, develop drying curves from bench-scale tests, determine your material’s temperature sensitivity, and define process design limitations for your existing gas-handling equipment, including blowers, fans, heaters, cyclones, scrubbers, and filters. This will give you the information you need to maximize the capacity and performance of your existing drying equipment.

In this column, I’ll provide practical methods for increasing your existing dryer’s capacity,1 but first, it’s important to review some drying basics.

Drying basics
In bulk solids drying, heat is transferred from a heat source to a wet bulk material. Dryers use one of three methods to transfer heat: convection, conduction, or radiation. In a convection dryer (including flash, hopper, rotary, spray, tunnel, fluid-bed, and other dryers) the heat source (hot gas) directly contacts the wet material and carries away the evaporated moisture. In a conduction dryer (including drum/flaker, paddle, disc, thermal-screw, steam-tube rotary, and other dryers) a metal wall separates the heat source (hot gas, steam, hot water, or hot oil) from the wet material, so that the heat source indirectly contacts the material. The heat is transferred (conducted) to the material through the wall, and a gas stream (not the heat source) sweeps away the vaporized moisture. A radiation dryer uses infrared, radio-frequency, or microwave energy to create heat within the wet material, resulting in moisture diffusion within the solids and surface evaporation. As in a conduction dryer, a gas stream or vacuum carries away the vaporized moisture.

The drying process has two principal zones, called the constant-rate zone and the falling-rate zone. The constant-rate zone ends at the critical moisture level, when the drying rate slows and the falling-rate zone begins.

Drying in the constant-rate zone is heat-transfer-controlled. That is, moisture evaporation occurs as rapidly as heat can be supplied to the wet material. Surface moisture is evaporated, as well as internal moisture, so long as the particle’s internal moisture-diffusion rate is greater than or equal to the surface-evaporation rate. As long as the drying gas doesn’t become saturated, the gas’s relative humidity (dew point) isn’t a significant factor during constant-rate drying.

At the critical moisture level, the surface moisture has mostly evaporated, but internal moisture
remains and must be removed during falling-rate drying, which is **diffusion-rate limited**. As the material temperature increases, the moisture-diffusion rate within the particle increases, thereby reducing the necessary residence time in the dryer. The driving force for drying during this stage is the partial pressure differential — that is, the difference between the particle’s internal moisture vapor pressure and the partial pressure of the moisture in the surrounding drying gas. In this stage, the drying gas’s relative humidity can become a significant factor, affecting the final moisture content you can achieve.

Using data from laboratory bench-scale tests, the two zones and the critical moisture level can be plotted, as shown the drying curve in Figure 1. In the figure, the blue line (the drying curve) plots the material’s changing moisture content (pounds of moisture per pound of dry solids) over the drying time. The red line plots the material temperature during the same period.

Typically, during constant-rate drying, the blue line will be nearly straight, descending from the material’s initial moisture level down to the critical moisture level. This is because the particle surfaces are moisture-saturated, so the drying proceeds at a constant rate. After the material reaches the critical moisture level, the particles no longer have a saturated surface, so the drying rate now depends on moisture diffusion to the surface for further evaporation. That’s why the drying curve’s slope is no longer a straight line; it shows a continuously decreasing drying rate during falling-rate drying.

During constant-rate drying, the material temperature remains nearly constant at the wet bulb temperature of the drying gas. As falling-rate drying progresses, the material temperature increases toward the heating-source temperature.

Now, let’s look at some ways to improve your dryer’s production capacity.

### Increasing capacity during constant-rate drying

Since temperature differential (between the heat source and the material) is the driving force for heat transfer in the constant-rate zone, consider using a higher heat-source temperature. **Caution:** Keep in mind your material’s temperature limitations — if it gets too hot, will it case-harden, soften, stick, melt, or degrade?

Once you’ve maximized the heat-source temperature, the next step is to decrease heat-transfer-resistance factors. In a convection dryer, you can reduce heat-transfer resistance by increasing the contact efficiency between the gas and the wet material. Gas flow through the material bed is more effective than a gas sweep across the material bed’s surface. If you can also increase the relative velocity between the gas and the material, you’ll further reduce the resistance.

The relative velocity also reduces heat-transfer resistance in a conduction dryer. The greater the relative velocity across the heat-transfer surface, the lower the heat-transfer resistance at the heating surface. In addition, the greater the mixing turbulence in the material bed, the less the resistance to heat transfer from particles migrating from the heat-transfer surface into the bulk mass of material.

Consider using auxiliary heating devices. You can install indirect-contact heat-transfer plates or tubes to supplement the heating gas in a fluid-bed or hopper convection dryer. Another possibility for both convection and conduction dryers is using radiation as a supplemental energy source, although this can be very expensive.

### Increasing capacity during falling-rate drying

By increasing the diffusion rate you can reduce the residence time...
needed to achieve your desired final product moisture. You can increase the diffusion rate in several ways:

- Increase the material temperature. This will increase the moisture vapor pressure within the particles, increasing the moisture’s diffusion rate.
- Use a low-dew-point drying gas in intimate contact with the moist material to increase the partial pressure driving force.
- Use vacuum drying. This will increase the partial pressure driving force while maintaining a low temperature for a temperature-sensitive material.

Just as there are heat-transfer-resistance factors in the constant-rate zone, there are moisture-diffusion-resistance factors in the falling-rate zone. By reducing the diffusion resistance, you can improve drying capacity. One way to do this is to reduce the diffusion path’s length within each particle by changing the particle size or shape. The smaller the particle diameter, the greater the surface-area-to-volume ratio and the shorter the diffusion path. Similarly, needle- or flake-shaped particles often have short diffusion paths.

Creating drying zones

You may be able to increase your dryer’s production capacity by segregating the two drying zones in the drying chamber. Fluid-bed dryers, belt-conveyor dryers, and hopper dryers (to some extent) can often be zoned. If you zone your drying chamber, you can increase the constant-rate evaporation capacity by using a higher inlet gas temperature without necessarily increasing the drying gas flowrate. Then, in the subsequent falling-rate zone, you may be able to use a smaller quantity of low-dew-point drying gas. By chamber-zoning, you can shift the bulk of the evaporative load to the constant-rate zone and gain additional residence time at a higher material temperature in the falling-rate zone, which will also speed diffusion drying.

Using multistage drying

If your dryer doesn’t readily lend itself to chamber-zoning, you can follow the same principle by using a separate predryer or postdryer stage. A predryer with a 0.5- to 5.0-minute residence time can provide constant-rate drying, allowing you to use a less expensive first-stage dryer (predryer) that uses a higher heating temperature to minimize the drying gas flowrate. A flash dryer can often be used as a predryer.

A postdryer is better suited to diffusion-rate drying. It usually has limited heat-transfer capabilities but provides inexpensive residence time for material to contact a dry, heated atmosphere. Examples are a vertical hopper dryer, which can be designed for 1- to 12-hour residence times, and a horizontal purge vessel, which is a cylindrical- or U-shaped tub with a slowly moving horizontal rotor-agitator that typically provides up to 60 minutes of residence time under atmospheric or vacuum conditions. Consider adding one of these inexpensive postdryers if, after modifying your existing dryer to improve its evaporation capacity, you’ve lost available diffusion-limited residence time with your increase in material throughput.

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References

1. The information presented here is adapted from a previous “Drying Desk” column.

For further reading

For more information on this topic, see previous “Drying Desk” columns and articles listed under “Drying” in Powder and Bulk Engineering’s Article Archive at www.powderbulk.com. All articles listed in the archive are available for free download to registered users.

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