

## Saving energy in your drying process

With light crude oil now well over \$100 per barrel, it's a good time to expand on my previous column "How to reduce drying energy costs" (January 2005).

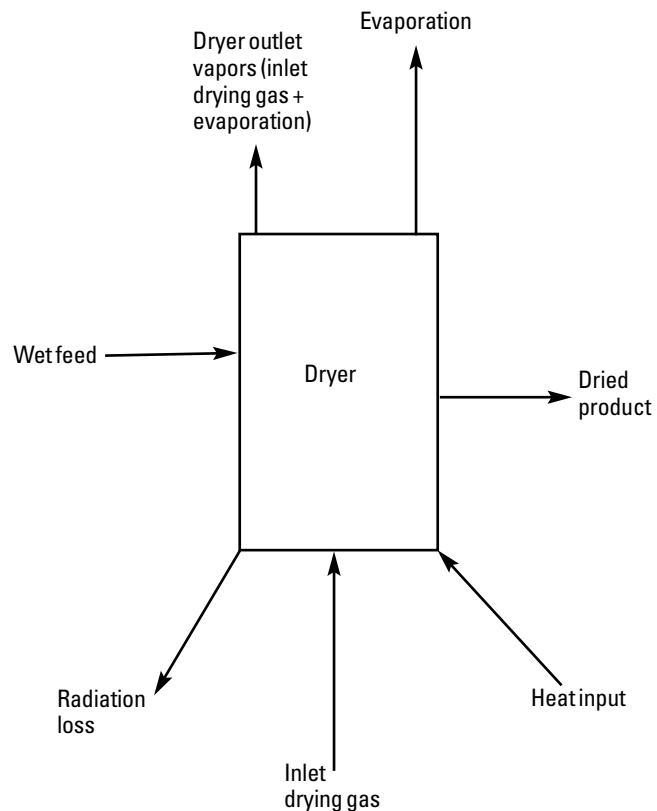
First, a rule of thumb: It's usually more economical to remove moisture by mechanical means, followed by thermal drying if necessary, than to remove the same moisture by thermal drying only. (For more information on mechanical dewatering, see the January 2008 column.)

### Thermal drying basics

Let's recap some of the main points from the January 2005 column. Figure 1 is a generalized dryer schematic and can be used to analyze both types of thermal drying: *direct-contact convection drying*, in which heat (thermal energy) is put into the dryer via heated inlet gas, and *indirect-contact conduction drying*, in which heat is put into the dryer via the dryer's heated walls.

Figure 1

### Basic drying schematic



Drying heat distribution can be expressed as

$$Q = q_1 + q_2 + q_3 + R$$

where  $Q$  is the heat input,  $q_1$  is the drying gas's sensible heat duty<sup>1</sup> (outlet heat content – inlet heat content),  $q_2$  is the dried product's sensible heat duty (outlet heat content of the solids and residual moisture),  $q_3$  is evaporation heat duty, and  $R$  is radiation loss.

Keep this basic information in mind as you read the following summary of three key energy-saving techniques discussed in January 2005 and two new techniques just coming into use in the dry bulk solids industries. The following discussion relates only to continuous drying, not batch drying.

### Three key energy-saving techniques

1. *Reducing the outlet drying gas's sensible heat duty ( $q_1$ ).* You can accomplish this by minimizing or eliminating the inlet drying gas flow, minimizing the outlet drying gas temperature, or both. With indirect-contact conduction dryers, the inlet drying gas flowrate is very minimal; it's used only to sweep away the vaporized moisture and not as the heat source. Hence, 1,200 to 1,400 Btu/lb of evaporation isn't an uncommon heat requirement for these dryers. With direct-contact convection dryers, the inlet drying gas is heated to supply the thermal energy for moisture evaporation. The higher the heated inlet gas temperature and the lower the dryer's outlet gas temperature, the lower the drying gas flowrate needed to supply the heat duty. Typical heat requirements for convection dryers are in the range of 2,000 to 6,000 Btu/lb of evaporation.

2. *Reducing the dried product's sensible heat duty ( $q_2$ ).* Drying at a low material temperature is one way to reduce this heat duty. However, this may not be practical because of the strong correlation between the required final product moisture content and the material temperature during drying within a suitably defined residence time. For another way to reduce

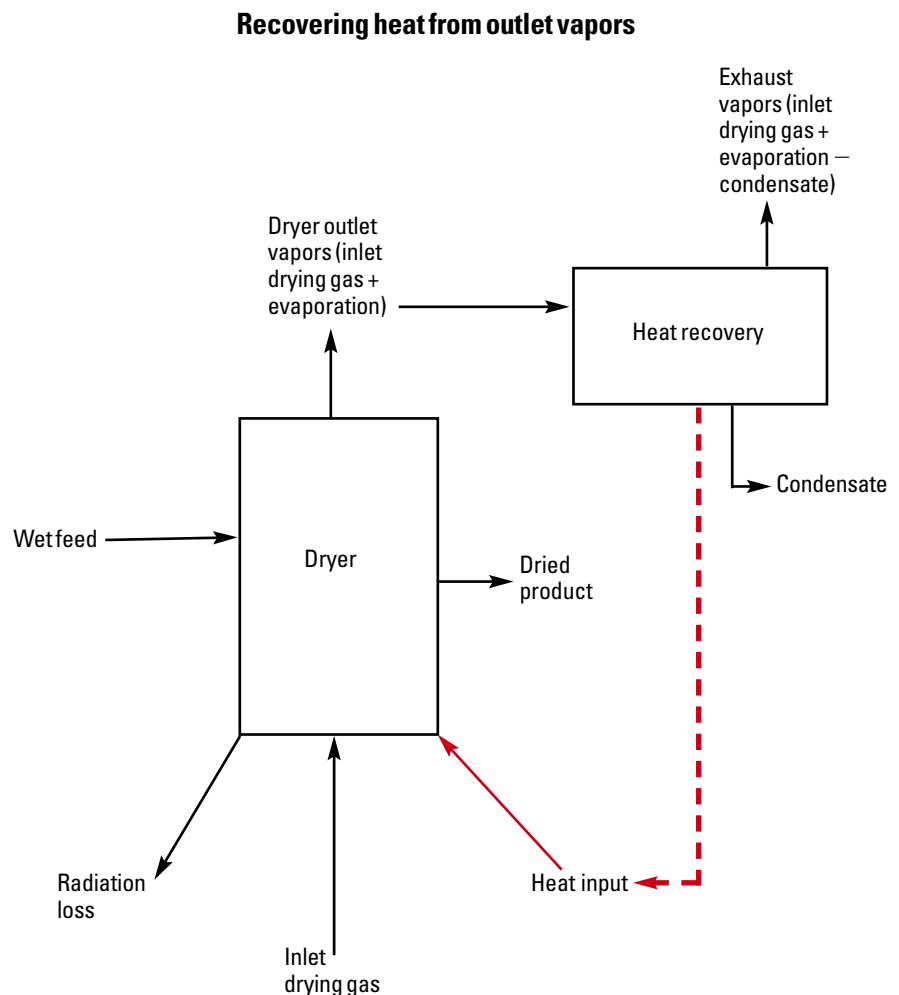
the product's sensible heat duty, see item 4 in the following section.

3. *Reducing the evaporation heat duty ( $q_3$ ).* This is typically the drying operation's largest heat duty and where predrying by mechanical dewatering can play an important role. However, even when you've dewatered the material, the evaporation load can still represent the largest heat demand in drying. Now is the time for heat recovery from the dryer's outlet vapors. Figure 2 illustrates this concept. The dryer's outlet vapors are cooled down in a heat recovery unit to condense evaporated moisture, releasing heat that will be transferred back to the drying operation to preheat the inlet drying gas, the wet feed, or both. The lower the temperature of the exhaust vapors, the greater the release of latent heat by condensation of the evaporated moisture.

### New techniques to try

4. *Recovering heat by cooling the product.* Adding product cooling to the process goes one step further in saving energy. You can recover heat not only from the dryer's outlet vapors, but also from the dried product. I've recently found an interesting drying technique that promises to do this effectively. Figure 3 illustrates the technique, developed by Steve Shivvers, former chief engineer of Shivvers Manufacturing, Corydon, Iowa. The technique employs iterative stages of heating without evaporation, followed by evaporative cooling, with heat recovery from the dryer's outlet vapors as well as from the dried product. The net result is in an overall thermal requirement of only 500 to 700 Btu/lb of evaporation. This patent-pending technique appears to be compatible with various types of direct-contact convection dry-

Figure 2



ers as well as indirect-contact conduction dryers. I hope to discuss this technique in much more detail in a future column.

**5. Using superheated steam.** This method (Figure 4) uses superheated steam as the drying gas in a form of closed-cycle drying (see the September 2007 column). Typically, the recirculating loop of superheated steam is indirectly heated via heat exchange with the combustion gas from a direct-fired burner. You must control the superheated steam inlet temperature and flowrate to balance the evaporative load's latent heat plus the discharged dried product's sensible heat duty, while still maintaining the steam in the vapor state at the dryer's outlet. In other words, you don't allow steam condensation to occur in the drying circuit.

As moisture evaporation continues, the pressure in the closed-cycle loop begins to increase. Pressure control equipment allows evaporated moisture to bleed off in the form of exhaust steam. At this point, the superheated steam dryer's thermal energy requirement approaches that of an indirect-contact conduction dryer — 1,200 to 1,400 Btu/lb of evaporation. However, when you can use the exhaust steam heat content in another thermal operation in your plant, you can reduce the effective thermal requirement for the drying operation to less than 1,000 Btu/lb of evaporation. (Mechanical vapor recompression outside the drying circuit can raise the exhaust steam pressure to a more usable condition for subsequent heating applications.)

In addition to thermal energy savings, the superheated steam dryer provides

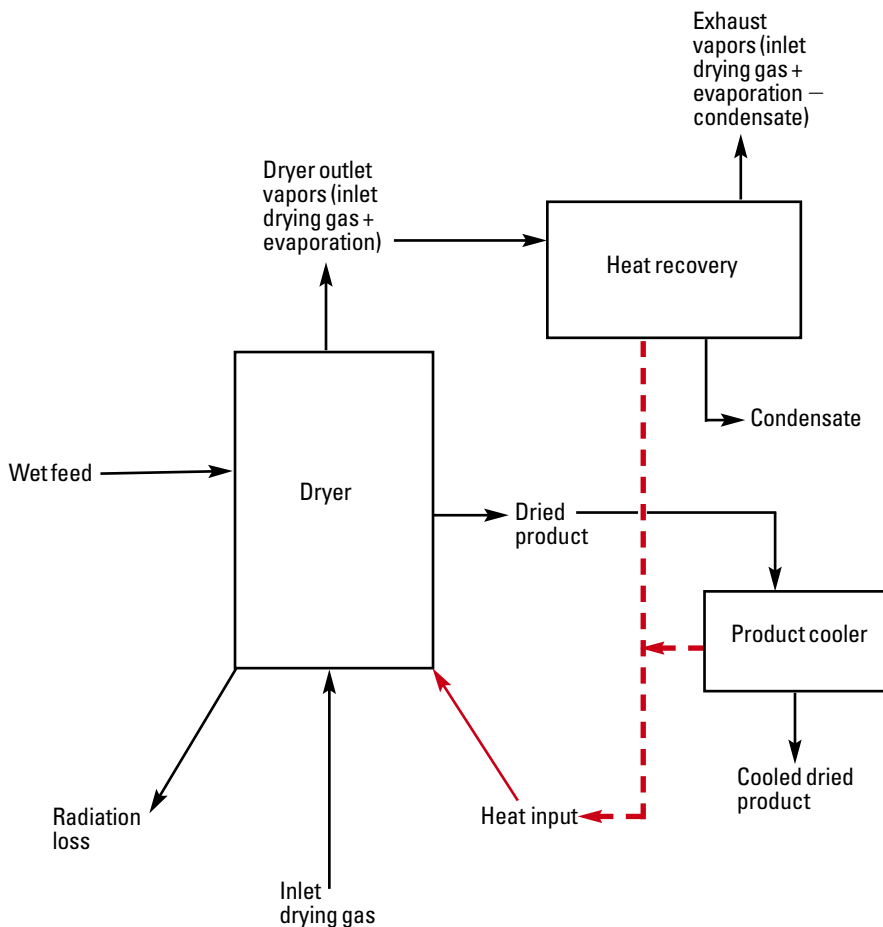
an oxygen-free environment. This reduces the potential for fires developing within the drying circuit when you're drying organic materials that tend to adhere to metal surfaces and then become overdried, baked-on accumulations susceptible to spontaneous combustion. In other words, the superheated steam dryer can achieve the same non-combustible condition as a closed-cycle dryer that recirculates nitrogen as the drying gas — but without the expense of costly nitrogen make-up.

Unfortunately, thermal degradation of the product (for example, in color, protein content, and nutritional value) can occur during superheated steam drying because of the steam's high temperature as it enters the dryer. The temperature difference (inlet superheated steam versus dryer outlet steam) determines the superheated steam flowrate needed for drying. The larger this temperature difference, the lower the flowrate requirement and the less expensive the steam circuit equipment (such as fans, cyclones, and heat exchangers). Thus, it's not uncommon to see inlet superheated steam temperatures in the range of 800°F to 1,200°F.

Another issue in superheated steam drying is the potential of "steam collapse" and the creation of a vacuum condition within the drying circuit. Since superheated steam dryers are essentially direct-contact convection dryers, the ancillary equipment and ductwork in the closed-cycle circuit are typically constructed of sheet metal with external stiffeners. (In contrast, indirect-contact conduction dryers are constructed of plate metal as pressure vessels.) The sheet metal construction may not be able to withstand a full-vacuum condition. Unfortunately, installing vacuum-relief devices to allow air in-leakage when the system senses the development of a vacuum condition may compromise the superheated steam circuit's oxygen-free environment, possibly resulting in spontaneous combustion of organic materials within the drying circuit. Some choice — implosion or fire! However, I'm confident that reliable dryer manufacturers will be able to implement tech-

**Figure 3**

**Recovering heat from outlet vapors and dried product**



niques to engineer a safe solution to this steam collapse issue. **PBE**

*dustrial drying at the Center for Professional Advancement, New Brunswick, N.J., and Amsterdam, The Netherlands.*

## Reference

1. *Sensible heat* is the amount of heat put into a material to raise its temperature without causing a phase change. *Heat duty* is the difference between a material's inlet heat content and its outlet heat content, or the amount of heat needed to perform the drying process.

**John J. Walsh, PE**, has a BE in chemical engineering from The City College of New York and has worked in the field of solids thermal processing more than 30 years. He holds several process and equipment patents and has written numerous technical articles. He has been an instructor on in-

The author will answer your questions in future issues. Direct questions to him at American Drying Consultants, 5174 Lexington Avenue, St. Paul, MN 55126-1358; 651-263-3697, fax 651-481-0980 (jjwalshpe@ameridrycon.com, www.ameridrycon.com) or to Editor, *Powder and Bulk Engineering*, 1155 Northland Drive, St. Paul, MN 55120 (fax 651-287-5650; toneill@cscpub.com).

**Figure 4**

### Superheated steam drying

