If drying a powder is part of your manufacturing process, you should know that this operation can be hazardous. To make drying safer, you need to identify the hazards associated with powder decomposition, fire, and explosion during drying. This article outlines an approach for designing a safer drying operation based on understanding the probability and magnitude of a fire or explosion so you can choose the right safeguards for your process.

Drying powders is an essential unit operation in the manufacture of many chemicals, foods, pharmaceuticals, agricultural products, explosives, and other products. Yet this operation can be hazardous. One study of major chemical manufacturers indicates that powder drying operations may have contributed to 37 percent of all plant accidents in a 16-year period.1 These accidents — including fires, explosions, or both — can be devastating, potentially resulting in worker injuries or even deaths. A dryer shutdown after such an event can cause serious production losses, as well.

To prevent a dryer fire or explosion and protect your workers and equipment from the consequences of such an event, it’s critical to identify fire and explosion hazards in your powder drying operation during process development, before you select full-scale drying equipment. This includes testing your wet feed powder for potential fire and explosion risks and performing a process hazard analysis to identify such risks in your process. Once your drying operation is running, you should periodically review the process hazard analysis and update your testing results to current standards, as needed. This strategy will allow you to quantify your drying operation’s risks for an adverse event, such as powder decomposition, fire, explosion, and dryer malfunction. But most important, the strategy will allow you to design and implement adequate safeguards to protect your workers, equipment, and plant in case of such an event.

Unless your company is very large, you probably don’t have the in-house facilities or expertise to test your powder’s drying hazards or develop a strategy for safely handling these hazards. In this case, you can contract any of several independent dust explosion testing labs around the US. Consultants in these labs have experience testing thousands of powders and understand how the test results can be used to design effective explosion safety systems in bulk solids plants. The consultant you work with will not only help you conduct the appropriate tests on your powder samples, but will discuss your safety concerns, your powder, and your drying operation and come up with a customized strategy for mitigating your powder’s fire and explosion hazards.

Powder testing
The strategy starts with conducting screening tests on samples of your wet feed powder (commonly called wet cake in the chemical and pharmaceutical industries) to determine whether heating in a dryer can cause the material to undergo exothermic or endothermic decomposition and create a potential explosion hazard.

If the powder can undergo *exothermic decomposition*, in which heat is released by the powder as it decomposes — typically in a sudden explosion that releases energy or...
gases (or both) — you also need to determine whether this is because the powder is thermally unstable, is sensitive to shock or friction (or both), is prone to self-accelerating decomposition, or can propagate explosively or be detonated. Some materials prone to explosions caused by exothermic decomposition include aluminum powder, silicon powder, cocoa, coffee, corn starch, milk sugar, and polystyrene.

The powder will also pose an explosion hazard if it can undergo endothermic decomposition, in which the powder decomposes as it absorbs heat. This form of decomposition typically occurs at higher-than-expected process temperatures and can result in a dryer explosion because of the excessive pressure and rate of pressure rise created by this reaction’s rapid generation of fixed gases — most commonly carbon dioxide. (A fixed gas isn’t typically compressible in chemical processes.) For example, an explosion hazard resulting from endothermic decomposition can occur when a wet organic carbonate chemical is heated to remove water: Removing the water probably requires reaching a dryer temperature of 212°F (100°C) at some point or using a vacuum system such as lyophilization (freeze-drying) to drive off the water at a lower temperature. But if the dryer control system malfunctions and the dryer temperature soars to 302°F (150°C), the molecules could decarboxylize, very suddenly releasing a large amount of carbon dioxide and potentially resulting in a significant pressure rise that damages the dryer or even injures workers.

Conduct a literature search to determine if this or a similar powder has been involved in a dryer explosion.

Screening tests. The screening tests of the wet powder feed are typically conducted in the following sequence. [Editor’s note: For details about the test equipment and procedures, contact the author or see “For further reading” at the article’s end.]

1. Examine the powder’s molecular structure, based on the powder’s chemical formula, to determine if the powder contains any chemical functional groups (that is, groups of reactants that facilitate and control organic reactions) that are considered unstable or explosive or can generate gas when heated.

2. As part of the hazard evaluation process for synthesizing a new or existing chemical powder, use ASTM International’s CHETAH software program to predict the potential for deflagration or detonation of a pure chemical contained in the powder.

3. Use a differential scanning calorimeter with high-pressure crucibles (sample containers) to conduct small-scale powder heating tests that can identify exothermic and endothermic events over a broad temperature range, such as 75°F to 750°F (25°C to 400°C).

4. Use an advanced reactive screening tool, accelerating-rate calorimeter, or similar instrument to conduct a small-scale test that characterizes the powder’s time-pressure profile and rate of temperature-pressure rise.

5. Dry the powder in a lab oven under air to observe whether its color changes during drying, which indicates the powder has the potential for an air oxidation reaction that can result in a fire and, in a confined space, an explosion.
6. Conduct a literature search to determine if this or a similar powder has been involved in a dryer explosion. (But be aware that a search that doesn’t yield such an incident isn’t a basis for considering your powder to be safe from drying hazards.)

Additional tests. If any information from the screening test sequence indicates that your powder is potentially hazardous during drying, work with your testing lab consultant to determine whether one or more of these additional tests is required:

1. Use the BAM (German Federal Institute for Testing Materials) fall-hammer technique to run a shock-sensitivity test on the powder, which will determine whether it can detonate when shocked or impacted, and use a BAM friction tester to determine whether friction can ignite the powder. If either test is positive, work with your consultant to interpret the results, determine whether more tests are required to further characterize the powder, and determine which safeguards can mitigate these hazards during drying.

2. If the powder appears to be prone to oxidation, consider running some form of aeration test, such as the bulk cell test, aerated cell test, or layer cell test (also called the air-over-layer test), to determine the minimum oxygen level that will prevent oxidization during drying. The test results will help you set the dryer’s automatic controls to maintain a safe oxygen level.

3. Run a go/no-go test (a simple, fast combustibility screening test) to determine if the powder generates a combustible dust cloud. If the test is positive, consider running an explosion severity test (also called the KSt test because it determines explosion overpressures and rates of pressure rise, from which the dust’s KSt value is derived). Then work with the consultant to interpret the results, determine whether you need to run more dust combustibility tests (listed in the next item) to further characterize the powder, and select safeguards that can mitigate these hazards during drying. [Editor’s note: Find information on safely handling combustible dusts in these National Fire Protection Association [NFPA] standards: NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids (2006) and NFPA 61: Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities. (2008).]

4. If the go/no-go test result is positive, you may need to run additional tests, including the minimum ignition energy (MIE), minimum ignition temperature (MIT), and minimum oxygen concentration (MOC) tests. Based on the results, work with your consultant to decide whether your powder requires drying equipment with an inert atmosphere, electrical equipment that meets the hazardous electrical classification for your operating area (as described in NFPA 70: National Electrical Code [2011]), or other safety measures.

Process hazard analysis and quantitative risk assessment

Once your powder has been tested, the testing lab consultant will typically use the test results along with other process safety information to help you facilitate a process hazard analysis. This analysis — required by OSHA’s Process Safety Management regulation 29 CFR 1910.119 (appendices A, B, C, and D) — will assess your drying process’s potential hazards and provide information to help you make the process safer by reducing the likelihood of a fire or explosion and reducing the consequences of such an event to acceptable levels. OSHA requires that you review the completed analysis every 5 years to ensure that it’s still current; when the analysis becomes outdated, you must update it either as a good manufacturing practice or under OSHA’s Process Safety Management regulation.

In the process hazard analysis, you’ll evaluate potential causes and consequences of fires, explosions, and other adverse events in your entire drying process, focusing on equipment, instrumentation, utilities, human actions, and external factors that might create or increase these process hazards. Various methods for conducting the analysis are available, and your consultant can help you select one based on your drying process’s complexity, how long the process has been in operation, and whether the process is common or unique.

Once the process hazard analysis has identified your drying process’s fire and explosion risks, you may also need to conduct some form of quantitative risk assessment to meet your company’s safety standards. This assessment validates and more precisely predicts these risks to help you choose the best means of controlling or eliminating them. One practical way to accomplish this is to run a layers of protection analysis on the steps in your drying process that present fire and explosion hazards. This analysis will make a realistic determination of how frequently a fire or explosion can occur and how well your safeguards will protect your workers, equipment, and plant in case of such an event.

Safeguarding your drying process

Dryers are available in several types, including spray, fluid bed, pneumatic conveying, vacuum, rotary, and others. While the fire and explosion safeguards appropriate for your drying process will depend on your dryer type, most dryers can be equipped with an inert gas (such as nitrogen or argon) purging system, one of the most common drying safeguards. When properly designed, such a system can reduce the risk of a fire or explosion in the headspace above the powder in the dryer.
An additional safety measure is required if your wet feed powder contains a flammable solvent. In this case, the dryer control system must maintain the drying airstream’s oxygen level below the critical oxygen concentration to prevent the flammable dust-solvent mixture (the hybrid system) from exploding. Find more information on these requirements in NFPA 30: Flammable and Combustible Liquids Code (2012), NFPA 329: Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases (2010), NFPA 497: Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas (2008), and NFPA 499: Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas (2008).

If your final dried powder is a combustible dust hazard or can generate off-gases when heated, you must also use explosion venting on the dryer and calculate each vent’s required size based on your dust test results and the entire drying system’s pressure rating. These requirements are explained in NFPA 68: Standard on Explosion Protection by Deflagration Venting (2007) and NFPA 69: Standard on Explosion Prevention Systems (2008).

Additional ways to safeguard your drying process include using a total containment system (that is, designing the dryer and related components without explosion vents that could release flames or hot gases into the plant and ensuring that the equipment can withstand explosion pressures), an explosion suppression system, flame-arresting devices, and similar explosion safety components along with explosion isolation devices to prevent flame from propagating from the dryer to the rest of the system. [Editor’s note: For more information on explosion protection equipment, see the later section “For further reading.”]

Also make sure that all equipment in your drying process is bonded and grounded according to NFPA 77: Recommended Practice on Static Electricity (2007), NFPA 70: National Electrical Code (2011), and NFPA 499: Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas (2008).

References
3. These NFPA standards and others mentioned in this article are available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471; 800-244-3555, fax 617-770-0700 (www.nfpa.org).

For further reading
Find background information on explosion testing and safely drying powders in these resources:


Find additional information on this topic in articles listed under “Drying” and “Safety” in Powder and Bulk Engineering’s comprehensive article index (in the December 2011 issue and at PBE’s website, www.powderbulk.com) and in books available on the website at the PBE Bookstore. You can also purchase copies of past PBE articles at www.powderbulk.com.

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