Biosolids Heat Drying: Safety in Design & Owner Operation

Hari Santha, Kenny Blanton, Webster Hoener, and Gary Shimp

Particular Hazards Associated with Biosolids Heat Drying

Dried biosolids are a combustible material which, if present with air and an ignition source, will burn. As a result, safety measures commonly applied to combustible material should also be applied to the design and operation of biosolids drying facilities.

In addition to the typical hazards associated with combustible material, heat drying of biosolids can create some unique hazards, including overheating caused by auto-oxidation of the dried material and unstable operating conditions caused by fluctuations in the moisture content of the feed solids from dewatering.

Combustible dust is produced with material handling of the dried product. Dust accumulation can occur if there is excessive dust production because of solids that are too dry or if there is inadequate removal of dust from equipment. Combustible dust can be an explosive hazard if it is suspended in air in sufficient concentrations when an ignition source is present.

Dried biosolids contain biological material which can undergo auto-oxidation if it is rewetted from condensation in storage bins or if too much moisture remains in the product after drying. The auto-oxidation process generates heat which, if not dissipated, could result in a smoldering fire and, if left unattended, an uncontrolled fire.

In addition to the hazards associated with the fire itself, the fire can provide an ignition source for explosion of nearby combustible dust. Smoldering material can produce carbon monoxide, which is a combustible gas—although opinions are divided as to whether explosive levels would ever be produced in a drying system.

Publicly owned treatment works (POTWs) have only limited control over the constituents contained in the influent wastewater and in the solids processed for ultimate disposal. Excessive fiber or grease in the influent can end up in the solids and create problems when the solids are heat dried. High levels of fiber in the feed can produce buildup of fiber within air filters, screens, and product coolers, resulting in blockages, and can also result in poor granule formation, leading to high dust production.

Large amounts of grease can volatize during the drying process, producing combustible vapors. Grease in excessive amounts can also deposit on the inside of equipment and create blockages and a source of combustible material.

Designing Safe Drying Systems

Design of safe drying systems includes provisions for adequate fire and explosion protection systems, as well as features which facilitate successful operating conditions.

<u>Fire Explosion Protection Systems</u>

The basis for fire and explosion protection systems should include industry standards and system supplier experience. The specific means of protection should be applicable to the risks associated with biosolids drying.

Industry Standards. There are many national, state, and local regulations, codes, and standards applicable to the design and operation of biosolids heat drying facilities. Here are the standards and guides of particular interest relative to the fire and explosion risks associated with drying biosolids:

- *NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids.* This standard applies to all phases of the manufacturing, processing, pneumatic conveying, and handling of materials containing or consisting of combustible particulate solids that present a fire or explosion hazard. The standard includes requirements for facilities, overall systems, and individual equipment components. Protection requirements, including prevention and mitigation measures, are specified for different types of equipment. Facility and system protection requirements are also included, as well as training, inspection, and maintenance requirements. Depending on local building codes, this standard may be enforceable for systems producing combustible dust.
- *NFPA 69, Standard on Explosion Prevention Systems.* This standard provides requirements for systems which prevent explosions of gas and combustible dust. Systems covered include prevention systems, such as oxidant concentration reduction and combustible concentration reduction, and prevention and limitation of damage systems, such as spark extinguishing, deflagration suppression, isolation methods, and deflagration pressure containment (deflagrations are reactions similar to explosions, but which propagate at less than the speed of sound). Also included are requirements for submittals to local code authorities and testing for explosion prevention systems.
- *NFPA 68, Guide for Venting of Deflagrations.* This guide provides criteria for the design of venting gas or combustible dust deflagrations. Typically, deflagration venting is provided for drying system components that are at risk of dust explosions and that are not adequately protected by explosion prevention systems.
- *British Health and Safety Executive HSE 847/9, Control of Health and Safety Risks at Sewage Sludge Drying Plants.* This document provides background information on the biosolids drying process and guidance for risk assessments to establish an adequate basis of plant safety. As a British standard, it is not enforceable in the United States, but provides much information related to specific risks and design considerations associated with biosolids drying facilities. The American standards specify effective protection requirements for equipment and systems, but they are lacking information regarding specific risks associated with biosolids drying. Instead, standards are established for systems processing any type of combustible material which creates explosion hazards.

System Supplier Experience. In addition to adhering to applicable standards, it is important to select a drying system supplier that has adequate experience with drying municipal biosolids and has improved its system based on that experience to ensure that sufficient protection systems are provided.

Continued on page 16

Hari Santha is a process engineer in the Kansas City, Mo., office of the engineering, consulting, and construction company Black & Veatch. Kenny Blanton is a project manager in the company's Jacksonville office, Webster Hoener is an engineering manager in the company's Houston office, and Gary Shimp is a senior project manager and biosolids practice leader in the company's Chicago office. This article was presented as a technical paper at the 2007 Florida Water Resources Conference in April.

Continued from page 14

The importance of this is stipulated in NFPA 654, Paragraph 2.1, which states, "Systems that handle combustible particulate solids shall be designed by and installed under the supervision of qualified engineers who are knowledgeable of these systems and their associated hazards. The design of systems and facilities that handle combustible particulate solids shall consider the physical and chemical properties and hazardous characteristics of the materials being conveyed."

Because of the unique characteristics of municipal biosolids, it is imperative that the designer has sufficient experience with this material to ensure that the system is designed to handle the material without serious safety, operability, or maintenance problems.

As a practical matter, many safety systems are incorporated into equipment in response to a particular problem that occurred previously. More experienced system suppliers have had greater opportunity to incorporate safety systems into their equipment that address the hazards specific to municipal biosolids. Of course, neither the length of experience record nor the number of installations is a guarantee that a supplier has been effective in enhancing the safety of its drying system based on the lessons learned from previous projects.

Prevention and Mitigation Systems. Specific means of protection for drying systems include both prevention and mitigation systems. Some of the more important prevention systems include:

- Inerting. The drying area of most drying systems is typically inerted with evaporative steam during operation to ensure that the oxygen level stays below the lower explosive limit—the level of oxygen concentration that would sustain a dust deflagration. Various means can be used to inert the drying area during startup and shutdown: steam created by water injection sprays, exhaust gases created by the combustion process in direct fired dryers, or nitrogen gas supplied from a nitrogen purge system. Product storage areas are typically blanketed with inert nitrogen gas, in some cases on a continuous basis and in other cases in response to indications of incipient fire conditions. Finally, some drying suppliers inert all or a portion of product material handling systems.
- Most drying systems have deluge water systems to drench material in the drying area if monitoring indicates that incipient fire conditions, such as elevated temperature, are present.
- All drying systems have some means of temperature control for the drying area to ensure that temperatures do not rise to unsafe levels and material does not become too dry, which would create excessive dust. Temperature monitoring also ensures that other preventive systems are activated in case of elevated temperatures. Product storage areas are typically monitored with respect to both temperature and carbon monoxide (combustion byproduct gas) to alarm unsafe conditions and activate inerting systems.
- Most recently manufactured drying systems cool the final product before storage to reduce the potential for auto-oxidation of dried material. Some drying systems cool all dried material to reduce temperatures throughout the dried material handling systems.
- Ventilation of dried material handling equipment is often provided to keep the dust concentration below the lower explosive limit and to remove moisture that could lead to build-up of material on the inside of equipment.
- Some drying systems are provided with spark detection devices to detect glowing or burning material at key transition areas, such as the discharge of the dryer or gas/product separator, and activate deluge systems as required.

Some of the more important mitigation systems for biosolids drying systems include:

- Explosion venting is provided for the product storage areas of drying systems to minimize hazards from a deflagration. Often, explosion venting is also provided for higher-risk dried material handling equipment, such as bucket elevators.
- Isolation is provided between components of drying systems to ensure that a deflagration will not spread to other areas that store significant amount of dried material, such as recycle bins or storage silos, or to areas of high dust concentrations, such as baghouses.

<u>Design of Operable Systems</u>

Features should be incorporated into the design of drying systems to ensure that the systems can be effectively operated.

Instrumentation. Adequate instrumentation is important in providing operators with sufficient information regarding the state of dryer operation and alerting them to upset conditions. Some of the more important components of the instrumentation systems include:

- Temperature monitoring is important for controlling the drying process and ensuring that safe conditions are maintained. Temperature monitoring should include 1) dryer product or process gas discharge to control the drying process, 2) product cooler discharge to verify adequate cooling before storage, 3) storage areas to monitor for reheating of the product, 4) furnace or heat exchanger outlets to verify operation within acceptable limits, 5) water into and out of the cooler to monitor heat exchanger performance, 6) process gas to monitor drying conditions, and 7) scrubber water discharge to monitor scrubber performance.
- Gas monitoring is important for ensuring that oxygen levels in drying areas are below levels that can sustain a deflagration and for detecting elevated carbon monoxide levels which, as a byproduct of biosolids combustion, can provide indication of a fire.
- System pressures, whether indicated locally or electronically, also provide important operating information. Pressure monitoring throughout process gas systems can indicate blockages in equipment, including ductwork and mist eliminators. Pressures in water supplies can ensure that sufficient water is available for proper operation of equipment, as well as indicate when water sprays have become partially blocked.

Control of Material. Drying systems should be designed to provide flexibility in handling material under non-standard operating conditions. Systems should include provisions for removing dried product from the dryer or recycle bin, to address "off-spec" product or empty storage systems for prolonged shutdown periods.

For drying systems operated with centrifuges, provisions should also be provided for diverting excessively wet material from the drying system. Sloppy material can present significant operation issues once in the drying system, including clumping of material, buildup of material inside equipment, and moisture to initiate auto-oxidation of material.

Safe Drying System Operation

The unique hazards identified with biosolids drying—combustible dust accumulation, auto-oxidation of material, and poor feed material—can not be prevented by the design of protection systems. These conditions can be minimized or eliminated only by proper operation of the drying system, which underscores the importance of sound operating practices for avoiding unsafe conditions.

The primary criteria for safe drying operation entails operating the system under steady state conditions with the moisture content within optimum limits for the wet feed to the drying system, the mixed wet feed and recycle material (if recycle system is provided), and the dried material.

When a drying system that includes back-mixing and product recycle is operated within optimum moisture limits, a cohesive pellet or granulate is produced. Almost all of the material is encapsulated in the pellet, and build up of material—whether as dust or sticky cake—inside the equipment is mini-

Continued on page 18

Continued from page 16
mized. The final product is dry enough to retard auto-oxidation and cohesive enough to prevent the granules from breaking apart and producing dust.

If moisture content is outside of acceptable ranges, the following problems can result:

- In a drying system that has a back-mixer and product recycle, when the moisture content of the dewatered cake to the mixer is too low, the cake will not adhere to and properly coat the dry recycle material to produce a pellet with a dry core and a wet outer layer. Wet material not bound to the pellets can adhere to dryer walls and plug process equipment. If the moisture content of the dewatered cake is too high, large clumps of wet material may form, which can lead to smoldering material and plugging throughout the drying system.
- With a recycle system, if the mixed material sent to the dryer is too wet, it can overload the dryer as well as plug components.
- If the moisture content of the dried material is too low at the discharge of the dryer, then excessive dust may be produced, requiring cleaning of the drying system and dust accumulation. If the moisture content of the dried material is too high, reheating of the product can occur.

Certain periods and situations of dryer operation pose higher-than-normal risks, including startup and shutdown and opening of baghouses or other equipment when smoldering conditions are present.

Startup of dryers can be especially risky if the unit was shut down with too-wet material left in it. This material can smolder during shutdown, producing small fires, and restart of the unit with its fans can introduce large volumes of oxygen, which can increase the intensity of the combustion.

The startup of fans can also suspend accumulated dust to provide an explosive mixture for which the smoldering material can provide an ignition source. The startup of material handling equipment can cause smoldering material to be transferred to other areas, including areas that may have accumulated dust, and spread the areas of fire.

Clean-out of baghouses to address smoldering material should be addressed carefully because opening the unit to atmosphere will provide oxygen for the fire, which may have been significantly retarded by an oxygen-reduced atmosphere.

Considerations for Achieving Safe Operation

Considerations for achieving safe drying system operation include systematic optimization procedures, adequate training, maintaining a core group of dryer operators, a strong safety program, and modifications to plant operation if needed to address specific conditions.

Optimization Procedures. As previously noted, operating a drying system with material outside of acceptable moisture level ranges can result in serious operational and safety problems. Systematic optimization procedures can be effective for determining acceptable moisture levels and monitoring to ensure acceptable levels are maintained. Such optimization procedures can be especially useful during the initial operating period, when operators have little experience with the system and have not yet developed an intuitive understanding of what feed and final product material characteristics and dryer operating parameters will avoid unsafe conditions.

The optimization process should include a systematic set of procedures to monitor moisture concentration of the feed solids to the dryer and at several internal dryer locations. Statistical analysis should be performed to correlate the moisture concentrations data with process malfunctions and then establish acceptable operating ranges for each of the locations monitored. Finally, moisture content should be routinely monitored to quickly identify when material moisture content is approaching limits which increase the risk of dryer malfunction, and operating procedures should be established to direct material moisture content back to acceptable levels.

Adequate Training. Drying systems are complex, with many different types of equipment and subsystems, and the operation of each subsystem will have significant impact on interrelated subsystems. Because of this complexity, adequate training of dryer operators is important—especially during the initial startup of the system. Training material and information from the initial training, as well as lessons learned from operating experience, should be passed on to new operators. There are several key issues to ensure that initial start up training is effective:

- Initial training by the system supplier should include sufficient classroom and hands-on training. At least a week of initial formal training is recommended for each of the operations shifts and for maintenance personnel, both mechanical and instrumentation and control. Follow-up training is also recommended several months after startup to provide an opportunity for the owner's personnel to review specific problems and issues they have encountered during operation and maintenance with the system supplier's personnel, who may know of similar issues at other plants.
- Training should cover all components of the drying system, including instructions on startup, shutdown, normal operating procedures, safety precautions, emergency conditions and procedures, and use of the control system. The training should include a site inspection of all the components of the drying system, during which the function, operation, safety precautions, and emergency conditions and procedures should be reviewed.
- The owner's personnel should have access to the dryer facility during the system supplier's commissioning to observe problems encountered with dryer operation and appropriate responses. Part of the formal training should include hands-on activities at the equipment, and the instructors should be able to communicate effectively with the operators in terms that are directly applicable to operating situations.
- Training and operations and maintenance instructions should not only address individual equipment components but also include descriptions of the overall drying system and how different components and subsystems interact and impact each other. Overall system information should include appropriate operating parameters, such as temperatures and pressures, for each of the subsystems. Training should also address how to recognize abnormal operating conditions and systematic approaches to either re-establishing operation within acceptable limits or initiating appropriate shutdown procedures.
- All written operation and maintenance instruction should be tailored to the specific plant equipment and operations. All drying facilities are different, so standard "cookbook" or manufacturer catalog data used for all dryer projects may leave the operators short of necessary information.

Procedures should be established by the owner to capture the information provided by the initial training and make sure it is available for new dryer operators. One approach would be to tape the training sessions for review. Programs should also be established to encourage the transfer of lessons learned from experienced operators to new operators.

Core Group of Operators. As indicated, drying systems are complex to operate and maintain because of the many types of equipment; the different process streams of solids, gas, and water; the impact that a particular subsystem will have on other subsystems; and the change in material characteristics under different operating conditions. To address the complexity of operation, it is important that owners utilize a core group of operators who develop sufficient experience to acquire adequate knowledge of operating issues. Not having operators who specialize in drying systems can result in not retaining lessons learned from dealing with specific problems.

Safety Program. Adequate drying system safety depends on a strong overall plant safety program that creates a culture emphasizing consideration of safety in all decisions and procedures. Included in such a program are adequate security roles established for control systems and lockout/tagout procedures.

Security roles should be implemented to ensure that only qualified personnel are able to modify safety controls. This will make sure that alarm conditions and interlocks are not modified without adequate review and understanding of potential impacts. Adequate lockout/tagout procedures are critical for drying systems because many equipment safety interlocks are dependent on the electronic control system.

Modifications to Operations. Modifications to plant operations may be required to address safety concerns. If the plant accepts septage or other material with high quantities of grease or oil and digestion is not used at the plant, then the amount of grease accepted may need to be reduced. Grease and oil can volatize at high temperatures, which in turn can produce high levels of combustible vapors within the drying process or result in the grease condensing out in the material handling system, plugging equipment.

Different strategies should be considered if high levels of fiber have the potential to lead to excess build-up of fiber inside equipment, resulting in blockages or poor pellet formation, creating dust accumulations. Screen presses have been effective at some plants in removing fiber from the sludge processed by drying systems. Digestion has also been demonstrated at several facilities to reduce the problems associated with fiber. If the source of fiber is associated with a particular industry, then pretreatment to remove the fiber should be reviewed.

Conclusions

There are unique hazards associated with the drying of biosolids, including accumulation of combustible dust, auto-oxidation of dried solids, and problems caused by poor feed material. These hazards should be addressed during the design and operation of drying facilities.

Design provisions should include adequate fire and explosion protection systems, based on industry standards and supplier experience, as well as operability features, including instrumentation and material handling flexibility. Operation provisions should include use of optimization procedures, adequate training, a core group of operators, strong plant safety program, and process modifications if needed.