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BIOMASS STORAGE: FIRE SUPPRESSION USING NITROGEN INERTING

A silo fire can be devastating and expensive, leading not only to the complete loss of stored material, but also to an extended production loss by the plant. Nitrogen inerting is an effective solution to mitigate risk.

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Biomass is a preferred fuel for renewable, carbon-neutral electricity generation by power plants. The U.S. is the largest global exporter of densified biomass, predominantly to the European Union. These wood pellets are stored in very large silos, both after production and prior to export, leaving them prone to unique operational and fire safety challenges.

One of the main safety issues with wood pellet storage is the potential for a silo fire. A silo fire usually initiates deep inside the center of the silo and is not easily detected until it has engulfed most of the biomass inside. Once a silo fire has started, most options to control the fire while saving the structure and material within are futile.

Methods for Detecting and Preventing Silo Fires

Biomass fires often begin with smoldering due to the biological and chemical activities that produce combustible gases, such as methane and carbon monoxide (CO). These gases build up in concentration and ignite in the presence of air, producing heat. The local temperature rise further increases the chemical oxidation, with rapid generation of combustible gases spreading the smoldering fire throughout the interior of the silo. Depending on the porosity of biomass and the air ingress into the silo, the combustible gases slowly rise to the headspace, creating an explosive atmosphere at the silo's top. The potential for exposure to a high concentration of CO and the explosive mix of gases precludes firefighters from fighting a silo fire from the top.

The typical method for detecting an incipient fire in a storage vessel is by monitoring the combustible gas concentration in the headspace. In the case of biomass silo fires, this approach may not be very effective due to the slow rise of combustible gases through the biomass. Depending on the height of biomass in the silo, it could take days before a concentration rise is detected in the headspace. By this time, the chemical and biological oxidation has spread to cover a significantly larger volume inside the silo (Persson, H., 2013, "Silo Fires: Fire Extinguishing and Preventive and Preparatory Measures," Swedish Civil Contingencies Agency).

One approach to suppressing a silo fire

is the application of water or foam from the top of the silo. However, this method is potentially hazardous due to the buildup of combustible gases in the headspace. Additionally, the use of water leads to swelling and bridging of the biomass, which can result in silo collapse without effectively extinguishing the fire in the interior of the silo.

Preventing, Suppressing Silo Fires Using Nitrogen

One approach to suppressing a silo fire is by injecting an inert gas, such as nitrogen, into the silo. However, large volumes of nitrogen are not always readily available or near the silo. Although nitrogen can be delivered in bulk quantities by tanker from their production plants located nearby, some infrastructure is required for injecting nitrogen into a silo, such as piping, injection point location and orientation that needs to be built into the silo itself.

Sufficient nitrogen delivery could take days, and depending on the fire intensity and the silo size, it could take weeks to months to extinguish a fire onsite. A silo fire can be devastating and expensive, leading not only to the complete loss of stored material, but also an extended production loss by the plant.

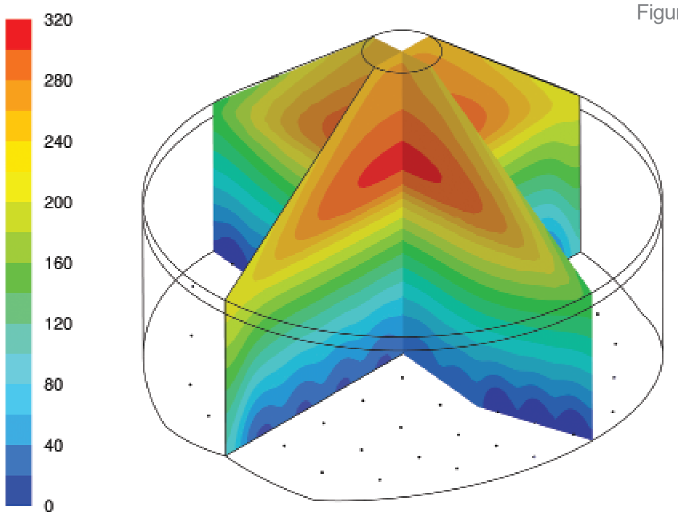
Given the extreme challenge of fighting a silo fire once it has begun, preventative approaches like proactively inerting storage silos with dry nitrogen are the best option. As the oxygen concentration in the storage area is lowered by displacement with nitrogen, the energy required to start a fire becomes significantly higher. Furthermore, combustion cannot be sustained below the limiting oxygen concentration of the biomass, therefore protecting the silo and its contents. The purging with an inert gas during the filling and emptying steps can also be a penetrative approach.

Dry nitrogen gas can also reduce moisture on the surface of the biomass, helping curtail biological activity while cooling the biomass to lower the chemical oxidation rate. Providing a continuous purge of dry nitrogen gas into the silo creates a lower oxygen concentration in the headspace, and reduces the risk of an explosive atmosphere forming in the headspace.

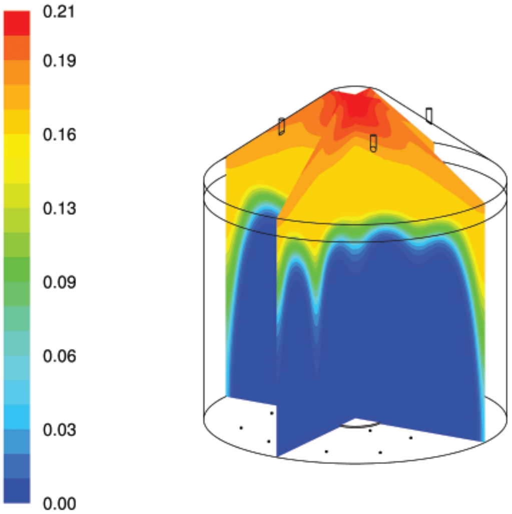
Proactive inerting is recommended both at the receiving facility and at the biomass production facility where material is stored in large silos prior to shipment.
PHOTO: BIOMASS MAGAZINE

Designing a Nitrogen Inerting System for Biomass Storage

Proactive inerting is recommended both at the receiving facility (i.e., power plant) and at the biomass production facility where material is stored in large silos prior to shipment. A cost-effective silo inerting process can be designed utilizing computational modeling of gas flow within the silo, and requires the



The formation of volatile gases, such as methane, and their concentration distribution can be simulated through computational modeling. This illustration shows the methane distribution in a silo with continuous nitrogen inerting.



Computational modeling can be used to design an efficient inert gas delivery system. This illustration shows the transient oxygen distribution as nitrogen is injected into the silo at a fixed flow rate.

installation of plug-free nitrogen injection nozzles. To ensure uniform nitrogen gas dispersion with optimal nitrogen gas usage, the number and placement of gas injection nozzles are critical to the design.

Computational Fluid Dynamics can be used to simulate the spatial distribution and generation of combustible gases within a silo, using standard or material-specific reaction models. Inefficient nozzle design and placement can lead to pockets of high oxygen and combustible gas concentration in the silo, thereby creating unsafe conditions. CFD can also be used to create oxygen and combustible gas concentration profiles under both transient conditions, for example, during startup or a nitrogen injection surge, as well as for steady-state operation in a specific silo. The inerting system can be designed to control to a maximum combustible gas concentration in the silo, to a maximum oxygen concentration in the silo, or both. Along with this prevention approach, the capability of injecting a large volume of nitrogen in the event of a fire can also be built into the design. On-site nitrogen storage or generation equipment can be specified to meet a steady inerting requirement, as well as to achieve a surge flow during an emergency event.

Figures 1 and 2 are examples of CFD modeling results used to design fire prevention and suppression systems for biomass silos at both a biomass power station and a biomass production and storage facility. In one case, a coal-fired power station made the decision to convert its primary fuel source to wood. To store the biomass safely, a nitrogen injection and delivery system was designed to prevent the buildup of methane and other flammable gases, thus mitigating the risk of a silo fire. Extensive CFD simulations were performed, based on the specific geometry of the silos to minimize methane concentration and optimize nozzle placement within the silo to ensure the most cost-effective gas distribution (see Figure 1). In addition, a nitrogen gas delivery system including nitrogen flow controls linked to gas and heat sensors, as well as proprietary injection nozzles designed to alleviate plugging with dust particles, were added.

In another case, a storage facility had experienced a silo fire that resulted in months of smoldering wood pellets and eventual silo collapse. When rebuilding the facility, for both fire prevention and mitigation, the silos were designed to be inerted with nitrogen below the limiting oxygen concentration of the wood pellets when filled to capacity. CFD studies were used to evaluate the nitrogen injection system design and validate the number and placement of the injection nozzles (see Figure 2). Transient simulations performed showed not only the propagation of an inert atmosphere, but also the time required to dispel oxygen from the silo geometry at a given flow rate. This enabled the operation team to fine tune their operating strategy, validate their design and ensure adequate nitrogen was available on-site to reduce the oxygen concentration in a silo at any given time.

The examples in Figures 1 and 2 demonstrate that a range of solutions exists for fire suppression and inerting biomass silos. These solutions can be designed and engineered to the specifications of a storage project and can include consultation on the approach to fire mitigation, CFD studies to validate a design based on simulation results, and the addition of specific flow control systems or plug-free nozzles, along with nitrogen supply. Given the immense risk posed by fire in a biomass silo, implementing a fire suppression system optimized for a specific operation is vitally important to ensuring a safe and profitable operation.

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