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Best Practices for Fighting and Preventing a Fire in a Wood Pellet Storage Dome or Silo

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This white paper is about fires in wood pellet storage systems and the lessons learned from several decades of experience. The author of this paper has over four decades of hands-on experience with wood pellet manufacturing. The experience and wisdom that he and others have gained is the basis for the best practices that are described below.

This white paper not only discusses best practice but also recounts how they were used to successfully resolve a major silo fire. The silo fire was at the Pacific BioEnergy (PacBio) 350,000 tonne per year pellet plant in Prince George, BC[1] in August of 2017. The tactics used to combat the fire resulted in a successful outcome. This is in contrast to a long history of silo and dome fires resulting in the complete loss of the structures, major damage to surrounding infrastructure, and injury and loss of life.

Smoke from smoldering wood pellets inside a PacBio silo containing 3,500 tonnes was first noticed on the evening of Wednesday August 23rd (on the left in the photo below).

[1] The original pellet mill of the company that became Pacific BioEnergy in Prince George, BC was built by the author of this white paper, John Swaan, in 1994.

Over a period of 7 days, the fire was controlled, extinguished, the silo was saved, and there was no injury or loss of life. Pellets worth over $500,000 were damaged, but millions of dollars of pellet plant infrastructure was no damaged. Unfortunately, although the silo did not collapse and there no explosions or fires that damaged the pellet mill or caused injury, the silo will be demolished because of uncertainty regarding its structural integrity.

Credit for this successful outcome belongs to the Pacific BioEnergy management and operations team, and the first responders from the Prince George fire department; all of whom followed a carefully crafted plan for controlling and extinguishing the fire. PacBio CEO Don Steele and VP of Operations Shawn Bells and his operations team, along with vital guidance and support from the author of this white paper, John Swaan, applied industry best practices to their tactical planning. They thought carefully before they acted and used information developed from years of experience. They proceeded carefully but deliberately with a primary objective of keeping everybody safe.

What not to do!

Historically, the industry has examples of "not so successful" outcomes of silo or dome fires. This has been due to the lack of knowledge about the characteristics of wood pellets (often by both pellet plant operators and first responders) and incorrect and self-defeating tactics.

The following incorrect tactics have been the cause of loss of buildings and other assets, pellets, injuries, and worst of all, in several incidents, loss of life.

- Although water may help with controlling the flames of an out of control silo fire incident, deluging or spraying water on top of the pellets in a silo, dome, or flat storage will never aide in extinguishing a smouldering mass of wood pellets. The wood pellets on the top of the pile will absorb the water and swell, creating a blanket of material restricting the ability of water to penetrate anywhere near the core of the smouldering pellets which are located somewhere within the centre of the pile of pellets. Water contacting hot pyrolyzed wood pellets will generate CO and hydrogen which adds to the seriousness of the conflagration and is not helpful for extinguishing a silo fire. Water may also create pinnacles and/or columns within the silo which may become a problem when trying to remove the product.

- To Immediately begin removing the wood pellets from the silo, dome, or flat storage pile before the pyrolysis activity within the core of the pile has been extinguished is a recipe for disaster. The gases being released by the pyrolysis activity are nasty and dangerous, especially the methane, CO, and other life threating gases. The ignition point of methane released from wood pellets is very low and will ignite when it encounters the smouldering core and the supply of oxygen from the open air. In other words, when removing the pellets down to the level where the pellets are exposed to both the smouldering core and atmospheric air, chances of an explosion and/or a rapidly spreading fire are very high.

Best Practices

Lesson Learned # 1 – Have a plan based on best practices, and train the local fire department.

This kind of incident has the potential for major injury and loss of life. Money can replace material assets, but not life. Safety of all personnel on site and the surrounding area is priority one. In the PacBio fire, each deliberate step taken to mitigate the incident by the PacBio team and all support resources was focused on safety first.

The PacBio operations team also maintained control of all actions taken, including those by the first responders. The typical reaction by a fire department is to deluge a fire with water. By having actions controlled by the PacBio team, that "what not to do" action was avoided. The Prince George fire department had trained at the site and understood that a silo fire is not a typical incident. The response required direct communications with the fire department but with control by the pellet plant operations team.

Taking time to research information resources, craft a plan, and work with the local fire fighters is the major reason that the PacBio incident has a successful conclusion. Drawing on the experiences of other incidents successful or not, helped in the decision making of steps taken.

Lesson Learned #2 – Inert gas injection significantly lowers the probability of negative outcomes.

The danger of a gas and/or dust explosion causing serious injury, and extensive property damage is very possible.

Nitrogen is most effective for minimize these risks and provides a low risk pathway to gain control of the smoldering pyrolysis inside the pile while emptying the material.

Nitrogen injection is recognized as the better solution as an inert gas for mitigating silo fire incidents: it is more readily available in large quantities, is easier to vaporize, and is more economical than CO_2. The use of nitrogen gas was a key part of the tactics that were used to control and extinguish the PacBio fire.

We recommend a review of the report published in 2013 by Henry Persson of SP Technical Research Institute of Sweden titled, "Silo Fires – Fire extinguishing and prevention and preparatory measures". This report should be a standard reference for every pellet plant and for every fire department that may respond to a pellet silo or dome fire.

The PacBio team, with the guidance of the author of this paper, referenced the report's recommended nitrogen injection flow rate[2]. Calculations for the size of the silo where made, and very quickly a call to the local gas supplier Praxair was made.

A mobile nitrogen vaporizer and tank unit along other tankers to follow where mobilized from Edmonton, Alberta (the gas and oil industry utilize this type equipment regularly). An engineer from Solid Industrial Solutions was also dispatched to provide onsite assistance with the setup of the nitrogen distribution system and control the nitrogen injection of the flow rate.

Based on the needed flows and volumes of nitrogen, the PacBio team specified how to fabricate the lances to be driven into the side of the 80-foot (~24 meter) diameter silo. Four lances of ¾ inch (~2 centimeters) steel pipes approximately 20 feet long (~6 meters) with ¼ inch (~6.5 millimeters) holes drilled every 2 inches (~5 centimeters) where fabricated at the machine shop and installed around the bottom of the silo.

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2 As referenced in the report under "Summary of measures in the event of a silo fire" – Chapter 1 – page 13. "The injection rate of nitrogen gas is based on the silos cross section area and should be at least 5 kg/m2 per hour, which gives an average vertical gas filling velocity of about 8 m/h (based on 50% porosity of the bulk material). The total required gas should be estimated based on the silo's gross volume (empty silo) and a total gas requirement of 5–15 kg/m3 could be expected.

Within 24 hours of the call to mobilize the nitrogen; the vaporizing unit was set onsite, injection lances where in place, nitrogen distribution system connected, and the nitrogen injection began to flow.

Several attempts were made to foam the top of the silo, however regardless of the foam densities, the deluge system originally installed for water was not adequate for dispersing foam evenly over the top of the pellets to create an effective proper seal.

Emptying the silo commenced within 48 hours of nitrogen injection after the oxygen level measures within the head space of the silo dropped below 10%.

The PacBio team safely handled and evacuated the removed material. The first responders equipped with respiration equipment kept all personnel safe and out of harm's way. Wood pellets and the carbonized clumps coming from the silo were conveyed safely without incident to a flat area away from the plant. Even when meeting atmospheric air there were no issues.

It took approximately 7 days to evacuate the 3500 tons of aborted material, and each truckload was safely moved to a secure area away from other fibre residue stockpiles and deluged with water as they were dumped to make sure there were no residual hot spots.

Lesson Learned #3 – Be prepared to detect and control silo/dome fires

Monitoring, detection, and suppression systems must be installed and maintained in good working order.

A properly installed and operating heat monitoring system will assist with discovering the location of a developing hot spot within the pellet silo or dome. Early warnings of an incident will be detected and alarmed when temperature monitors inside the silo are operating correctly. Early warning, before smoke is observed, will significantly lower the loss of product and the likelihood of a much more serious incident.

Carbon monoxide and oxygen monitors installed on the top of the silo providing constant measurement will also assist with early incident detection. Once the nitrogen was being injected into the PacBio silo, obtaining readings without sampling equipment already installed at the top of the silo made it more challenging to determine the gas levels required for removing the material from the silo material safely.

Testing and maintaining these systems must be part the weekly PM (preventive maintenance) program.

A permanent and properly sized and installed nitrogen injection system within the silo or dome complete with a manifold in a safe location with a convenient hookup is critical[3]. If there are no nearby suppliers of nitrogen and evaporators, the plant should strongly consider having that equipment on site. The quickly rigged manifold shown in the photo above used at the PacBio plant was not optimal for controlling flow to the lances. Managing an even flow rate properly distributed into the silo would have been more effective and may have controlled the pyrolyzing core quicker.

Silo or dome ventilation systems control are critical when managing a silo fire incident.

- The system should have the ability to shut down and seal off bottom asperation fans.
- The system should have the ability to control the top ventilation of the silo. This is very beneficial to minimize the exhausting gas flow and improve nitrogen penetration and to reduce the total volume of nitrogen required.

Installing a proper permanent deluge system that can accommodate both water and distribute foam properly over the top of the entire pile of pellets would be very effective. Not having the ability to seal off the material at the top of the silo or dome allows the injected of nitrogen to escape more readily which lowers the ability to control and stop the pyrolysis. The PacBio incident may have been controlled with less nitrogen and quicker if a foam cap had been applied.

[3] Report by Henry Persson referenced above. Chapter 7 Preventive and preparatory measures – pages 96 – 110

Summary of key lessons learned

- Do not react without a plan; safety-first and stay in control of mitigating the incident.
- Be informed of best practices and move forward deliberately with a plan of action.
- Gain the trust and cooperation of everyone and the support services involved with mitigating the incident. Communicate, keep everyone onsite informed.
- Nitrogen injection lowers the oxygen level in the silo or dome reducing the risk of a gas or dust explosion and/or subsequent out of control fire.
- Controlling silo ventilation systems are critical.
- A Properly installed foaming system to evenly distribute foam over the top of the pile optimizes the inert gas systems.
- A permanent nitrogen injection system with some on site nitrogen storage for immediate use can very advantageous.

Key causes of fires inside wood pellet silos, domes, or flat storage buildings.

In most cases it's suspected that the ignition which sets off the pyrolysis activity is due to some foreign hot debris. This could be from failed pellet mill roller bearings, conveyor system roller and/or belt failure, or molten steel from hot maintenance work. All of the above have been the causes of incidents.

Because wood pellets are a biogenic product, self-heating can also be the cause of silo fire incidents[4]. This may be due to microbiological activity, chemical oxidation processes, moisture migration, moisture absorption, or a combination of these. This process usually occurs within a temperature range up to 45–75 ˚C since microbes die at higher temperatures. Microbial activity primarily generates carbon dioxide (CO_2) and may be detected by measuring the carbon dioxide concentration in the silo headspace. At higher temperatures, self-heating is derived from chemical oxidation processes. In wood pellets, the cause is usually a chemical oxidation process since the pellets are more or less "sterilized" during the production process. Practical experience shows that this oxidation process is especially likely in newly produced pellets, in part due to the oxidation of different resins contained in the wood material.

[4] Report by Henry Persson referenced above. Chapter 5 Possible Silo Fire Scenario's – pages 65 - 67

Call to Action

Every wood pellet industry stakeholder across the globe, from producers to end-users, must share the learnings of this incident and adopt the protocols and technology for mitigating and hopefully eradicating silo fire incidents.

This call to action includes all wood pellet industry associations and institutions, wood pellet plants, shipping terminals, and power plant owners. It is essential for both safety and reliability that these best practices be understood and adopted by wood pellet plant operations management and personnel, local and regional first responders and fire brigades, first responder training academies, governmental work place safety institutions, fire protection equipment providers, wood pellet handling providers (silos, domes, conveyors), rail and shipping companies, and wood pellet project developers, engineers, and EPC contractors.

Any entity in the supply chain that has pellet storage in silos or domes must be encouraged to assess their current wood pellet storage systems for their ability to detect and control fire incidents and, if deficient, install protection technology and equipment (including ventilation controls, foaming equipment, and nitrogen injection). Wood pellet plants, and wood pellet storage and shipping terminals should identify and develop a relationship with a nitrogen supply and gas engineering service nearest to their respective plant location. Within a 10 to 12-hour transport radius would offer a sufficient response time. Any farther away, an onsite nitrogen generation system should be considered.

Any entity in the supply chain that has pellet storage in silos or domes must be encouraged to develop a fire incident mitigation and training plan. They must insure that all operations personnel and the fire fighters that will be called to the site understand the characteristics of wood pellets within a silo or dome and how to fight the fire with maximum effectiveness and minimum danger and damage. All personnel should be acquainted with the dangers of the gasses contained within the smoke being released.

The statement, "it is not IF there is a fire, but WHEN" should never be allowed to influence stakeholders into a state of complacency. Every stakeholder within wood pellet industry must strive to ensure that the "IF" does not instill a sense of acceptance with business-as-usual, and that the chances of "WHEN" are close to zero.

However, should there be a "WHEN", all stakeholders must be fully informed on how to deal with an incident and fully prepared to deal with it safely and effectively.